

AI Sensors &
Transducers
2025
Conference

The 2nd International Conference on AI Sensors and Transducers

29 July – 03 August 2025 | Kuala Lumpur, Malaysia



Program and Abstract Book

Notice

Delegates will receive a name-badge at the Information Desk upon registration. The badge must be worn prominently in order to gain access to the conference lecture halls and meals during the event. Admission will be refused to anyone not in possession of an appropriate badge.

Wi-Fi

1. Connect to the "AIS2025" wireless network;
 2. Enter the Wi-Fi PIN that is provided below.
- PIN: mkl8888

Conference Photo



Please scan the QR code to check the conference photos.

Latest Program



Please scan the QR code to check the latest program.

Shuttle Bus Schedule

Time: 1 August 2025

For Chairs, Symposium Chairs, Plenary, Keynote, and Invited Speakers:

Time	Pick-Up Location	Destination	Trip Type
15:00	Melia	Islamic Arts Museum	One Way
18:00	Museum	Ritzy KL (Appreciation Dinner)	One Way
20:30	Ritzy KL	Melia	One Way

For All Attendees

Time	Pick-Up Location	Destination	Trip Type
15:00	Melia	Islamic Arts Museum	One Way
18:00	Museum	Melia	One Way

If you prefer to return on your own:

Walk 12 mins to Jabatan Warisan Negara bus stop **Take Bus 750** → Alight at Central Market (2 stops) **Walk 9 mins** to Hub Lebuhr Pudu **Take Bus 580** → Alight at Swiss Garden Hotel (2 stops)

Walk 8 mins to Melia Hotel

Total time: approx. 30 mins.

Venue

Main Conference Hall

Alhambra I, Alhambra II, Alhambra III, Alhambra IV

Meeting Rooms for Symposia

Alhambra I, Alhambra II, Alhambra III, Alhambra IV, and Andalus 1



General Information

CONFERENCE VENUE

Melia Kuala Lumpur

Address: 16, Jln Imbi, Bukit Bintang, 55100 Kuala Lumpur, Federal Territory of Kuala Lumpur, Malaysia

The conference will take place at Meliá Kuala Lumpur, ideally situated in the heart of the city's Golden Triangle. The hotel is located directly opposite Berjaya Times Square and steps from Imbi Monorail Station, providing excellent connectivity to major attractions such as the Petronas Twin Towers and Pavilion Kuala Lumpur. The hotel features spacious rooms and exclusive "The Level" suites, offering private lounge access, all-day refreshments, and more—ensuring a comfortable stay for business and leisure travelers alike.



REFRESHMENTS

A light dinner will be provided on 29 July 2025 between 15:00 and 18:00.

CONFERENCE BANQUET (for all participants)

Venue: Berjaya Times Square Hotel

Address: Berjaya Times Square, 1, Jalan Imbi, Hotel, Bukit Bintang, 55100 Kuala Lumpur, Wilayah Persekutuan Kuala Lumpur, Malaysia

Date and Time: Thursday, 31 July 2025, 18:30



We are excited to invite you to our Banquet Dinner, the cost of which is included in your conference registration fee.

The dinner will be held at the Berjaya Times Square Hotel, a fantastic venue conveniently located within the iconic Berjaya Times Square complex. This places you right in the heart of Kuala Lumpur, surrounded by shopping, entertainment, and dining options. The dinner will provide an ideal opportunity to relax and network after a day of engaging sessions.

Directions from Melia:

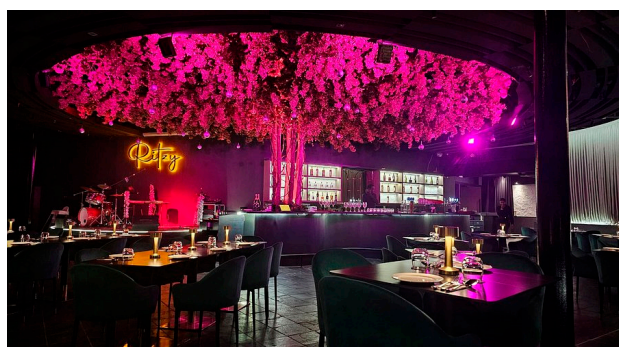
The walk from Meliá Kuala Lumpur to Berjaya Times Square Hotel is very short, taking 5 minutes (300 meters). You may simply cross Jalan Imbi, as the hotels are directly opposite each other, by means of a pedestrian connection or stairs near the Imbi Monorail Station that lead to Berjaya Times Square.

APPRECIATION DINNER (for Chairs, Symposium Chairs, Plenary, Keynote, and Invited Speakers only)

Venue: Ritzy KL

Address: Sky Level, First Ave, Bandar Utama, 47400 Petaling Jaya, Selangor, Malaysia

Date and Time: Friday, 1 August 2025, 18:30



The Appreciation Dinner will be held at Ritzy KL, a fantastic venue offering a sophisticated and chic atmosphere. Located in a prime spot in Kuala Lumpur, it provides an exquisite setting in which to relax, network, and enjoy fine dining after a day of engaging sessions. Its central location also offers easy access to the city's vibrant attractions and entertainment.

The Appreciation Dinner will take place after the social activity and we will be provided shuttle buses from the museum to Ritzy KL venue—please refer to the schedule below for details. If you wish to go on your own, please make sure to **arrive by 18:30**.

SOCIAL ACTIVITIES (for all participants)

Attraction: Islamic Arts Museum Malaysia

Address: Islamic Arts Museum Malaysia, Jalan Lembah, Tasik Perdana, 50480 Kuala Lumpur, Wilayah Persekutuan Kuala Lumpur, Malaysia.

Date and Time: Friday, 1 August 2025, 15:00

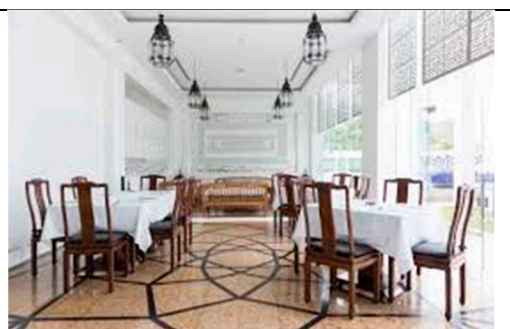


Recommended Nearby Restaurants (after the tour)

Please note that the conference will not provide dinner for regular attendees on 1 August after the visit to the Islamic Arts Museum Malaysia. If you are looking for a place to dine following the tour, we are pleased to recommend the following restaurants in the museum area. These options include both elegant venues for a more refined experience and popular local eateries offering authentic Malaysian street food.

1. Moza Restaurant

Address: Islamic Arts Museum Malaysia,
Jalan Lembah, Tasik Perdana, 50480 Kuala
Lumpur
Distance: On-site at the Museum Ground
Floor
Opening hours: 10:00–17:00



This cozy, Middle Eastern-inspired restaurant is located conveniently within the museum itself. It offers a calm and elegant ambiance, suitable for a light meal or refreshment after the tour.

2. Petaling Street (Chinatown)

Address: Jalan Petaling, City Centre, 50000 Kuala Lumpur, Wilayah Persekutuan Kuala Lumpur

Distance: About a 10–15-minute walk from the museum (via Pasar Seni)

Opening hours: 17:00 until midnight or later



Petaling Street is well known for its night market and traditional Chinese Malaysian dishes, such as Hokkien mee, claypot rice, and asam laksa. The area is also home to historic architecture and lively market stalls.

3. Hadramawt Restaurant

Address: 226 Jalan Ampang, Kuala Lumpur 50450 Malaysia

Distance: Approx. 10–15 minutes by taxi from the museum

Opening hours: 12pm – 12am



Offering authentic Yemeni cuisine, Hadramawt is well known for its flavorful Mandi rice with lamb or chicken, served in a clean and welcoming environment.

Certificate of Attendance

Event participants will be able to download an electronic Certificate of Attendance by accessing their dashboard on Sciforum.net once the event is concluded. The certificate will be found under the “My certificates” category.

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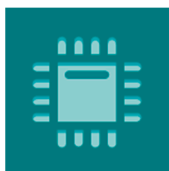


AI Tools Network

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sensors

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Sensors (ISSN 1424-8220) provides an advanced forum for the science and technology of sensor and its applications. It publishes comprehensive reviews, regular research papers and data descriptor. Our aim is to encourage scientists to publish their experimental and theoretical results in as much detail as possible. The full experimental details must be provided so that the results can be reproduced. There are, in addition, three unique features of this journal:

- Manuscripts regarding research proposals and research ideas are particularly welcome.
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Impact Factor: 3.4 (2023); 5-Year Impact Factor: 3.7 (2023)



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chemosensors

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- Manuscripts regarding research proposals and research ideas are particularly welcomed.
- Electronic files and software regarding the full details of the calculation and experimental procedure, if unable to be published in a normal way, can be deposited as supplementary material.
- We also accept manuscripts communicating to a broader audience on research projects financed with public funds.

Impact Factor: 3.7 (2024); 5-Year Impact Factor: 3.8 (2024)



robotics

an Open Access Journal by MDPI

Robotics (ISSN 2218-6581) aims to provide an international forum with which to report the latest developments on robotic systems in theory, design, and applications with special attention to autonomous behaviors, multi-sensor fusion, learning algorithms, system modelling, control software, smart actuators, service applications, and human-machine interaction. There is no restriction on the maximum length of the papers.

Special emphasis is given to technological innovations and real-world applications.

Impact Factor: 3.3 (2024); 5-Year Impact Factor: 3.8 (2024)



AI sensors

an Open Access Journal by MDPI

The rapid evolution of artificial intelligence (AI) has ushered in an era of unprecedented innovation across various industries. As AI continues to transform our world, the integration of AI sensors is becoming increasingly essential. *AI Sensors* (ISSN 3042-5999) aims to provide a platform for researchers, engineers, and innovators to explore and share their cutting-edge developments, insights, and breakthroughs in the field of AI sensing technologies, with a particular focus on edge computing and AIoT (AI and Internet of Things) sensing.

The field of AI sensors encompasses a wide range of technologies that enable machines to perceive, interpret, and interact with the world around them. With the rise of edge computing, these sensors are increasingly being deployed in decentralized environments, where data processing and decision making occur closer to the source of data. This paradigm shift is particularly relevant in the context of AIoT, where the convergence of AI and IoT is driving the development of smart, connected systems. *AI Sensors* aims to bridge the gap between the AI, IoT, and sensor communities, fostering collaboration and knowledge exchange to accelerate innovation in edge computing and AIoT sensing technologies.

The 2nd International Conference on AI Sensors and Transducers

29 July–3 August 2025 | Kuala Lumpur, Malaysia



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Welcome from the Chairs

Dear Colleagues,

Welcome to the 2nd International Conference on AI Sensors and Transducers in **Kuala Lumpur, Malaysia!**

The 1st International Conference on AI Sensors and 10th International Symposium on Sensor Science in Singapore were held at the National University of Singapore with great success. The event attracted 400 attendees, bringing together researchers and industry experts from China, Singapore, Japan, Korea, Italy, UK, USA, India, and other countries to share their latest findings.

We are delighted to invite you to this premier gathering of innovators, researchers, and experts at the forefront of sensors, sensing technology, AI sensors and AI-enhanced sensing systems, and transducers and AI-enhanced transducers. Building on the success of our previous conference in Singapore, this event promises to be an exciting platform for exploring cutting-edge advances and fostering collaboration in the rapidly evolving field of AI, Sensors, and Transducers.

Key areas of focus for this conference include, but are not limited to, the following:

- Sensing Systems Enhanced by AI;
- Computer Vision;
- AI Sensors Based on Vision and Voice Data;
- Data Fusion and Processing with Sensor Applications;
- Sensor Modality/Sensing System Enhanced by Multi-Modality Deep Learning;
- Data Mining for Sensor Applications;
- Edge Computing Technologies;
- Neuromorphic Computing;
- Computing in Memory;
- In Sensor Computing;
- MEMS Sensors Enhanced by Edge Computing;
- CMOS MEMS/NEMS and AI Sensors;
- Hardware for Enabling Artificial Intelligence of Things (AIoT) Systems;
- Heterogeneous Integration for AIoT Systems;
- Chiplet and System-in-Package (SiP) for AIoT-on-a-Chip;
- Autonomous AIoT Systems;
- Cutting-Edge AI Sensor Technologies;
- Generative AI Technologies;
- Photonics AI Accelerator;
- Innovative AI Sensor Applications Across Industries;
- Physical Sensors and MEMS;
- Chemical Sensors;
- Medical Sensors;
- Gas Sensors;
- Ultrasound Sensors;
- Optical Sensors, CMOS Image Sensors, and IR Focal Plane Array;
- Magnetic Sensors and Spintronics;
- Biosensors and Bioelectronics;
- Wearable Sensors;
- Implantable Sensors, Neural Interfaces and Electroceuticals;
- Sensors for Intelligent Robots;
- Sensors for Drones;
- Self-powered Sensors;

- Zero-biased Sensors and Science;
- Nanomaterials, Nanosensors and NEMS;
- Si Photonics (SiPh) for Sensing;
- Nanophotonics and metalenses for Sensing;
- Metasurface and Mid-IR Sensing;
- Metamaterials and THz Sensing;
- Spectroscopy and Sensing Technology;
- Internet of Things (IoT) and Sensor Networks;
- Energy Harvesting for IoT Sensors;
- Remote Sensors, Data Acquisition, and Processing;
- Integration of Actuators with Sensors for Smart Systems.

We look forward to welcoming you to **Kuala Lumpur** for this exciting event, where you will have the opportunity to engage with leading experts, present your research, and contribute to shaping the future of AI sensors and transducers.

Join us as we explore the fascinating intersection of artificial intelligence and sensing technology, paving the way for groundbreaking innovations that will transform industries and improve lives.



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Conference Chair

The University of Tokyo



Prof. Sang-Woo Kim
Conference Chair

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Prof. Chengkuo Lee
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Prof. Zhou Li
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Prof. Xinge Yu
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National Taiwan University of Science and Technology;
Yushan Fellow, Ministry of Education



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Korea National University of Transportation



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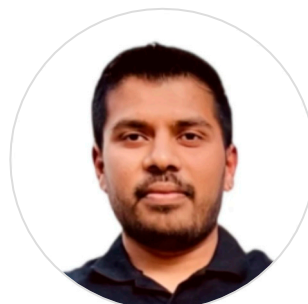
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Prof. David Tsai



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Prof. Linda Shao
Shanghai University



Prof. Long Liu
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Prof. Luming Zhao
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Prof. Mang Gao
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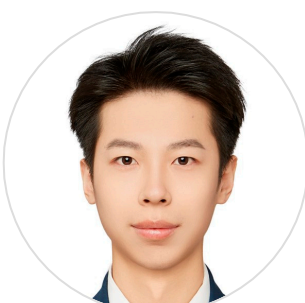
Prof. Mengwei Wu
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Prof. Mingfa Peng
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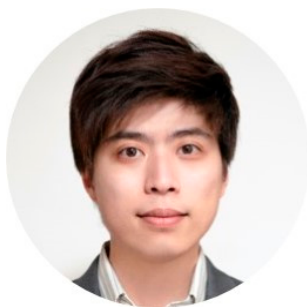


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Prof. Zhengjin Weng
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Prof. Zhihui Lai
Shenzhen University



Prof. Zhiqiang Mu

Chinese Academy of Sciences Shanghai Jiao Tong University



Prof. Zhiran Yi



Prof. Zhuang Zhang

Fudan University



Prof. Zingway Pei

National Chung Hsing
University

AIS 2025 Abridged Program

29 July 2025 (Tuesday)	DAY 1 30 July 2025 (Wednesday)	DAY 2 31 July 2025 (Thursday)	DAY 3 1 August 2025 (Friday)	DAY 4 2 August 2025 (Saturday)	3 August 2025 (Sunday)
	Registration				
	Opening Ceremony	Plenary Speech 3	Symposium	Symposium	
	Plenary Speech 1	Plenary Speech 4			
	Plenary Speech 2				
		Coffee Break			
	Symposium	Symposium	Symposium	Symposium	
		Lunch Break			Free Activities
	Symposium	Symposium	Symposium	Symposium	
	Coffee break		Coffee break		
Registration	Symposium	Poster Session & Coffee break	Social Activity	Award Ceremony	
		Banquet Dinner			

AIS 2025 Detailed Program

Alhambra 1

	DAY 1 30 July 2025 (Wednesday)	DAY 2 31 July 2025 (Thursday)	DAY 3 1 August 2025 (Friday)	DAY 4 2 August 2025 (Saturday)
8:30–10:00	Registration Opening Ceremony Plenary Speech 1 Plenary Speech 2	Plenary Speech 3 Plenary Speech 4	SYM 1	SYM 12
10:00–10:30		Coffee Break		
10:30–12:00	SYM 2	SYM 1	SYM 1	SYM 12
12:00–13:30		Lunch Break		
13:30–15:30	SYM 2	SYM 2	SYM 1	SYM 5
15:30–16:00		Coffee break		
16:00–18:30	SYM 2	/	/	Award Ceremony

Alhambra 2

	DAY 1 30 July 2025 (Wednesday)	DAY 2 31 July 2025 (Thursday)	DAY 3 1 August 2025 (Friday)	DAY 4 2 August 2025 (Saturday)
8:30–10:00	/	/	SYM 13, 14	SYM 17
10:00–10:30		Coffee Break		
10:30–12:00	SYM 4	SYM 24	SYM 13, 14	SYM 17
12:00–13:30		Lunch Break		
13:30–15:30	SYM 4	SYM 4	SYM 13, 14	SYM 17
15:30–16:00		Coffee break		
16:00–18:30	SYM 4	/	/	/

Alhambra 3

	DAY 1 30 July 2025 (Wednesday)	DAY 2 31 July 2025 (Thursday)	DAY 3 1 August 2025 (Friday)	DAY 4 2 August 2025 (Saturday)
8:30–10:00	/	/	SYM 22	SYM 15
10:00–10:30		Coffee Break		
10:30–12:00	SYM 16	SYM 16	/	SYM 15
12:00–13:30		Lunch Break		
13:30–15:30	SYM 16	SYM 21	SYM 19	SYM 15
15:30–16:00		Coffee break		
16:00–18:30	SYM 16	/	/	/

Alhambra 4

	DAY 1 30 July 2025 (Wednesday)	DAY 2 31 July 2025 (Thursday)	DAY 3 1 August 2025 (Friday)	DAY 4 2 August 2025 (Saturday)
8:30–10:00	/	/	SYM 20	SYM 26
10:00–10:30		Coffee Break		
10:30–12:00	SYM 6, 7, 8, 9	SYM 3	SYM 20	SYM 26
12:00–13:30		Lunch Break		
13:30–15:30	SYM 6, 7, 8, 9	SYM 3	SYM 3	SYM 26, 27
15:30–16:00		Coffee break		
16:00–18:30	SYM 6, 7, 8, 9	/	/	/

AI Andalus 1				
	DAY 1 30 July 2025 (Wednesday)	DAY 2 31 July 2025 (Thursday)	DAY 3 1 August 2025 (Friday)	DAY 4 2 August 2025 (Saturday)
8:30–10:00	/	/	SYM 18	SYM 18
10:00–10:30		Coffee Break		
10:30–12:00	SYM 10	SYM 25	SYM 18	SYM 18
12:00–13:30		Lunch Break		
13:30–15:30	SYM 10	SYM 11	SYM 18	SYM 18
15:30–16:00		Coffee break		
16:00–18:30	SYM 23	/	/	/

Opening Ceremony And Plenary Speeches

Day 1 (30 July 2025, Wednesday)

Alhambra 1

Chaired By: Prof. Chengkuo Lee

8:30–8:45	Opening Ceremony	
8:45–9:25	Plenary Speech 1	Optical Nanomaterials As Frequency Converters For Imaging And Sensing Xiaogang Liu (National University Of Singapore)
9:25–10:05	Plenary Speech 2	AI Empowered Wearable Ultrasound Technology Sheng Xu (University Of California San Diego)

Day 2 (31 July 2025, Thursday)

Alhambra 1

Chaired By: Prof. Chengkuo Lee

8:30–9:10	Plenary Speech 3	Triboelectric energy harvesting for self-sustained healthcare technologies Sang-Woo Kim (Yonsei University)
9:15–9:55	Plenary Speech 4	Intelligent Soft Electronics For Healthcare Monitoring And Vr Xinge Yu (City University Of Hong Kong)

S1. Lab-on-a-chip (LoC) and MicroTAS

Day 2 (31 July 2025, Thursday)

Alhambra 1

Chaired By: Prof. Kai Chen

10:30–10:50	Invited Speaker	Yong Wang	Flexible and multi-mode acoustofluidics enabled by thin-film acoustic waves
10:50–11:10	Invited Speaker	Yan Xu	Pioneering nanofluidics for next-generation chemical and biological sensing
11:10–11:30	Invited Speaker	Hyoungsoo Kim	Improving lipid vesicle stability via controlled solvent evaporation in microfluidic double emulsions
11:30–11:45	Oral Presenter	Yuya Ishii	Extracellular potential analysis of neuromuscular system using a microelectrode array
11:45–12:00	Oral Presenter	Chaoshan Zhao	A multifunctional microfluidic chip based on single nanoparticle scattering for psa detection

Day 3 (1 August 2025, Friday)

Alhambra 1

Chaired By: Prof. Hiroaki Onoe

8:30–9:00	Keynote Speaker	Chia-Hung Chen	Rare Immune Effector Cell Isolation for Precision Immunotherapy via Microfluidic LISA
9:00–9:20	Invited Speaker	Daisuke Yoshino	Design of an organoid chip that mimics the structure of human placenta
9:20–9:40	Invited Speaker	Moeto Nagai	Programmable Optical Toolbox for Single-Cell Manipulation: Enabling Spatial, Temporal, and Functional Versatility
9:40–10:00	Invited Speaker	Yong Lin Kong	Addressing unmet clinical needs with additive manufacturing of bioelectronics
10:00–10:15	Oral Presenter	Daiki Miyashita	Measurement of extracellular potentials using electrode anchors for skeletal muscle tissue

S1. Lab-on-a-chip (LoC) and MicroTAS

Day 3 (1 August 2025, Friday)

Alhambra 1

Chaired By: Prof. Chia-Hung Chen

10:30–10:50	Invited Speaker	Kenichi Funamoto	Investigation on aerokinesis and aerotaxis of human breast cancer cells by using microfluidic devices
10:50–11:10	Invited Speaker	Yoshikazu Hirai	Microfluidics-guided assembly of fluorescent nanodiamonds for high-sensitivity thermometry
11:10–11:30	Invited Speaker	Yuya Morimoto	Biohybrid system integrating cultured tissues and devices for evaluation of physiological function
11:30–11:50	Invited Speaker	Kento Yamagishi	On-skin bioelectronic systems with liquid metal microchannels for electrophysiological signal monitoring
11:50–12:05	Oral Presenter	Mami Akaike	Microfluidic sensor for direct measurement of micro-pressures in micro-tissues in vivo
12:05–12:20	Oral Presenter	Partha Pratim Sarkar	High-throughput and efficient intracellular delivery via parallel-periodic mechanoporation with viscoelastic fluids

Chaired By: Prof. Michinao Hashimoto

13:30–14:00	Keynote Speaker	Hiroaki Onoe	In vitro tube-shaped intestinal model with crypt-like inner surface for bacterial co-culture
14:00–14:20	Invited Speaker	Chenjie Xu	Development of cryomicroneedles for the transdermal delivery of biologics
14:20–14:40	Invited Speaker	Ye Ai	Acoustic Microfluidics For Biomedical Applications
14:40–14:55	Oral Presenter	Haixia Zhao	High-throughput sers-droplet system for label-free, real-time microbial metabolite profiling
14:55–15:10	Oral Presenter	Yuanhao Xie	Machine learning-enabled analysis of reaction processes in microdroplet reactors

S2. Biosensors and Biomedical Devices

Day 1 (30 July 2025, Wednesday)

Alhambra 1

Chaired By: Prof. Tamiya Eiichi

10:30–11:00	Keynote Speaker	Jian Chen	Single-cell detection and microsenors
11:00–11:20	Invited Speaker	Wataru Iwasaki	Flow control in microfluidic paper-based analytical devices with valve using thermoresponsive polymer
11:20–11:40	Invited Speaker	Piyasak Chaumpluk	Utilization of plant microstructure as a straightforward lab -on-a-chip for rabies virus detection
11:40–11:55	Oral Presenter	Zhaojie Xu	Dual-modal ptnps/pedot-rgo microelectrode arrays reveals synergistic encoding of social-related neurons and dopamine

Chaired By: Prof. Tamiya Eiichi

13:30–13:50	Invited Speaker	David Tsai	Cmos implants for at-scale brain machine interfaces
13:50–14:10	Invited Speaker	Luming Zhao	Enhancing sensitivity of schottky contact biosensor by modulating interface property
14:10–14:30	Invited Speaker	Hongcheng Xu	A fully-integrated stretchable device platform for swallowing disorder
14:30–14:50	Invited Speaker	Jingbin Zeng	Multi-modal and multi-channel sensing platform for rapid, multiplexed pathogen detection
14:50–15:05	Oral Presenter	Jinping Luo	Label-free electrochemical aptasensor for sensitive detection of estradiol
15:05–15:20	Oral Presenter	Xinyi Liang	Multifunctional trimer nanoparticles synthesized based on lattice mismatch for multi-mode identification of multiple bacteria
15:20–15:35	Oral Presenter	Xin Wang	Revolutionizing point-of-care diagnostics: a daylight-driven zero-background phosphorescent lateral flow assay enabled by solid silica-encapsulated carbon dots

S2. Biosensors and Biomedical Devices

Day 1 (30 July 2025, Wednesday)

Alhambra 1

Chaired By: Prof. Arakawa Takahiro

16:00–16:30	Keynote Speaker	Chang-Po Chao	Predicting blood pressures for pregnant women by ppg and personalized deep learning
16:30–16:50	Invited Speaker	Nur Syakimah Ismail	Development of electrochemiluminescence-based biosensor using nitrogen-doped carbon dots for bisphenol a detection
16:50–17:10	Invited Speaker	Monica Florescu	Enhancing the sensitivity, selectivity, and sustainability of nanotechnology-driven biosensors
17:10–17:25	Oral Presenter	Guohao Xi	Conical nanopores for enhanced sensing applications engineered via surface modification
17:25–17:40	Oral Presenter	Qingyu Xu	A fluorescent probe for in situ imaging of hydrogen peroxide and sulfur dioxide in biological oxidative stress models
17:40–17:55	Oral Presenter	Nuha Alekhmimi	Mmp-9 and il-6 biomarkers are detected using a biosensor based on au-ides for the quick diagnosis of sepsis

S2. Biosensors and Biomedical Devices

Day 2 (31 July 2025, Thursday)

Alhambra 1

Chaired By: Prof. Arakawa Takahiro

13:30–14:00	Keynote Speaker	Tamiya Eiichi	Electrochemiluminescent Biosensors Using Printed Electrodes and Mobile Diagnostic Devices and Their Biomedical Applications
14:00–14:30	Keynote Speaker	Zhiwei Huang	Stimulated raman scattering tomography for label-free dynamic and functional imaging of live cells and tissue
14:30–14:50	Invited Speaker	Kenta Iitani	Enzyme-based fluorometry for gas-imaging applications
14:50–15:10	Invited Speaker	Hsiang-chieh Lee	High speed optical tomographic imaging for biomedical applications based on MEMS technology
15:10–15:25	Oral Presenter	Juntao Liu	Automatic localization of seizure onset zone using directed transfer function on EEG
15:25–15:40	Oral Presenter	Arifah Syahirah	Optical Characterization of Lignocaine-impregnated Maltose-based Dissolvable Microneedles

S3. In-body IoT Sensing Technology, Electroceuticals and Neural Interfaces

Day 2 (31 July 2025, Thursday)

Alhambra 4

Chaired By: Prof. Sanghoon Lee

10:30–10:50	Invited Speaker	Yiyuan Yang	Wireless implantable optogenetics: revolutionizing neuroscience behavior studies and treatment of neuro-disorders
10:50–11:10	Invited Speaker	Donghee Son	Self-healing and stretchable bioelectronic devices for stable neuroprosthesis
11:10–11:30	Invited Speaker	Hanmin Peng	Controlled drug release method combined with ultrasonic sensing and therapy
11:30–11:45	Oral Presenter	Shiya Lv	Multimodal biofeedback-guided closed-loop electrical stimulation for cognitive rehabilitation in alzheimer's disease
11:45–12:00	Oral Presenter	Qianli Jia	Tracking of dopamine dynamics and cellular-level electrophysiological activity during different sleep stages

Chaired By: Prof. Yiyuan Yang

13:30–14:00	Keynote Speaker	Sanghoon Lee	Advanced neuromuscular interface for application in bionic limbs
14:00–14:20	Invited Speaker	Bowen Ji	Minimally invasive implantable flexible brain-computer interface sensors
14:20–14:40	Invited Speaker	Seongjun Park	Next-generation biomedical and neural interfaces using multifunctional thermally drawn fibers with soft materials
14:40–15:00	Invited Speaker	Sukho Song	Minimally invasive soft bioelectronic interfaces enabled by soft robotic technologies
15:00–15:15	Oral Presenter	Jaeu Park	Peripheral nerve coil interface for enhancement of axial direction induced magnetic field gradient
15:15–15:30	Oral Presenter	Yu Wang	Chronic flexible probe reveals epileptic spatial coding deficits
15:30–15:45	Oral Presenter	Jong-Hwan Kim	A robust ai gesture classification system for unexpected situations in smart manufacturing using decision transformer

S3. In-body IoT Sensing Technology, Electroceuticals and Neural Interfaces

Day 3 (1 August 2025, Friday)

Alhambra 4

Chaired By: Prof. Yiyuan Yang

13:30–14:00	Keynote Speaker	Yilin Song	Advanced Electro-Chemical Neural Interfaces for Brain Health and Cognition
14:00–14:20	Invited Speaker	Joonsoo Jeong	Enhancing microelectronic neural interfaces by versatile 3d structuring, multi-modality, and substrate-electrode materials
14:20–14:35	Oral Presenter	Mixia Wang	An intelligent precision brain function localization system for non-human primates based on microelectrode array
14:35–14:50	Oral Presenter	Jian Miao	High-Stability Microelectrode Arrays for Precise Neural Electrophysiological Monitoring During Sleep–Wake Cycle

S4. Nanophotonics and Metasurface

Day 1 (30 July 2025, Wednesday)

Alhambra 2

Chaired By: Prof. Jing Hua Teng

10:30–11:00	Keynote Speaker	Guangya Zhou	Single-pixel imaging for advanced spectroscopy and lidar sensor applications
11:00–11:20	Invited Speaker	Qingfeng Yan	Micro phase retarder based on bottom-up grown quasi-1d fibrous red phosphorus flake
11:20–11:40	Invited Speaker	Yanjun Liu	Fabrication and applications of ultrathin suspended chiral metasurfaces
11:40–12:00	Invited Speaker	Tao Wang	Mechanical tunable mid-infrared plasmonic resonance

Chaired By: Prof. Guangya Zhou

13:30–13:50	Invited Speaker	Ting Mei	Light-controlled antimony sulfide phase change for reconfigurable photonic devices
13:50–14:10	Invited Speaker	Haiyang Zou	Carrier transport modulation via surface and interfacial engineering
14:10–14:30	Invited Speaker	Kai Chen	Hybrid plasmonic antenna arrays for the detection of volatile organic compounds
14:30–14:45	Oral Presenter	Hao Dai	Chalcogenide visible metasurfaces: a new platform for high-performance optical devices
14:45–15:00	Oral Presenter	Xinyuan Hu	Experimental realization of convolution processing in photonic synthetic dimensions
15:00–15:15	Oral Presenter	Dongxiao Li	Mid-infrared metasurface with grating-enhanced plasmon resonance for spectral imaging

Chaired By: Prof. Ting Mei

16:00–16:30	Keynote Speaker	Jing Hua Teng	Tunable optics using phase change and van der waals materials for sensing and imaging
16:30–17:00	Keynote Speaker	Xin Zhang	Custom-tuned Materials
17:00–17:20	Invited Speaker	Bingsheng Li	MOCVD Growth of β -Ga ₂ O ₃ Based Heterojunctions for Solar Blind Deep UV Photodetector
17:20–17:40	Invited Speaker	Hong Liu	Printable photonic materials

S4. Nanophotonics and Metasurface

Day 2 (31 July 2025, Thursday)

Alhambra 2

Chaired By: Prof. Hong Liu and Prof. Yanjun Liu

13:30–13:50	Invited Speaker	Guixin Li	Title: to be announced
13:50–14:10	Invited Speaker	Yungui Ma	Precision beam steering and optical metrology enabled by micro-meta-lens array
14:10–14:30	Invited Speaker	Bing Wang	Light control with synthetic temporal presenter interfaces
14:30–14:50	Invited Speaker	Kun Huang	Nanowire metasurfaces with continuous superconfined modes for ultrabroadband and wide-angle meta-optics
14:50–15:10	Invited Speaker	Qiong He	Light manipulation via near-field coupling control in plasmonic metasurface
15:10–15:25	Oral Presenter	Cheng Xu	Cmos enabled mid-infrared chiroptic platform for polarization-wavelength multiplexed imaging
15:25–15:40	Oral Presenter	Chenyu Liu	Chaos-based communication in synthetic temporal presenter lattices
15:40–15:55	Oral Presenter	Yu Kee Ooi	Nanosphere lithography of iii-nitride nanowires

S5. Acoustic, RF, THz Metamaterials and AI-Enabled Metamaterials

Day 4 (2 August 2025, Saturday)

Alhambra 1

Chaired By: Prof. Nan Wang

13:30–14:00	Keynote Speaker	Sang-Seok Lee	MEMS device fabrication based on printing technology
14:00–14:30	Keynote Speaker	Yao Zhu	Accelerating PiezoMEMS Innovation and Commercialisation
14:30–14:50	Invited Speaker	Linda Shao	Multi-channel metasurface for full-polarization modulation of electromagnetic wavefronts
14:50–15:10	Invited Speaker	Qian Li	Epsilon-near-zero photonics: infinite potentials
15:10–15:30	Invited Speaker	Hongyan Fu	Metamaterial-enabled integrated photonic devices for advanced spectral-scanning lidar systems
15:30–15:45	Oral Presenter	Yinpeng Wang	Active learning enabled designs for near-field enhanced THz metamaterial biosensors

S6. Neuromorphic Computing, In-Memory Computing and Applications
 S7. Photonics Integrated Circuits (PIC) and Novel Materials
 S8. Enabling Technology for Photonic Neural Networks (PNN) and Applications
 S9. In-Sensor Computing and Enabling Technology for Edge Computing

Day 1 (30 July 2025, Wednesday)

Alhambra 4

Chaired By: Prof. Aaron Danner

10:30–11:00	Keynote Speaker	Kah Wee Ang	Scalable 2d-cmos heterointegration for energy-efficient compute-in-memory ai hardware
11:00–11:20	Invited Speaker	Zhengjin Weng	High-performance memristors based on two-dimensional transition metal phosphorus trichalcogenides for neuromorphic computing
11:20–11:40	Invited Speaker	Yiming Ma	Denoising-autoencoder-facilitated MEMS computational spectrometer with high performance
11:40–11:55	Oral Presenter	Zian Xiao	Artificial Intelligence-Integrated Near-Infrared Photonic Multi-Modality All-optical Edge Computing Platform for Spectroscopic Sensing

Chaired By: Prof. Kah Wee Ang

13:30–14:00	Keynote Speaker	Aaron Danner	Chip-based photonics in barium titanate
14:00–14:20	Invited Speaker	Xingyan Zhao	Integrated photonic devices on thin-film alscn platform
14:20–14:40	Invited Speaker	Akihiko Kasukawa	High power, high efficiency gainasp/inp single mode lasers
14:40–15:00	Invited Speaker	Binbin Wang	All-solid-state beam steering based on the electro-optical effect of thin-film lithium niobate
15:00–15:15	Oral Presenter	Yu-Hsuan Chiang	S-fddft: a few-shot learning framework for real-time motion detection using flexible sensors on edge ai devices
15:15–15:30	Oral Presenter	Yangyang Zhuge	Photonic Bayesian neural network for robust and uncertainty-aware computing

Chaired By: Prof. Yiming Ma

16:00–16:30	Keynote Speaker	Vittorio Passaro	High-performance optical sensing by non-hermitian photonics
16:30–16:50	Invited Speaker	Sanghoon Chae	Novel 2d materials integrated sin waveguides for chip-based photonic processing
16:50–17:10	Invited Speaker	Xudong Zou	Micro-nano mechanical resonant sensors with in-sensor neuromorphic computing capability
17:10–17:25	Oral Presenter	Koshi Fujimoto	Randomized 2-Dimensional LSPR Gas Sensor using Fluorescent-dyes - Au/Ag NPs coupling
17:25–17:40	Oral Presenter	Yao Wang	Quick and High-Sensitive Gas Detection Using LSPR-SERS Dual-Mode Sensor

S10. MEMS/NEMS Sensors

Day 1 (30 July 2025, Wednesday)

AI Andalus 1

Chaired By: Prof. Jian Zhou and Prof. Chun- Wei Tsai

10:30–11:00	Keynote Speaker	Jong Baeg Kim	Transferred carbon nanotubes for sensors and actuators
11:00–11:20	Invited Speaker	Jingui Qian	Acoustofluidic particle localization on piezoelectric resonators for liquid-phase mass sensing
11:20–11:40	Invited Speaker	Jian Zhou	High-frequency surface acoustic wave sensors and their applications
11:40–11:55	Oral Presenter	Wei Guo	Quantum magnetometry based on ensemble nv-centers in integrated MEMS
11:55–12:10	Oral Presenter	Daojiang Yu	Uniform Metal-assisted Chemical Etching for High-Aspect-Ratio Microstructures Fabrication with Low Cost

Chaired By: Prof. Jin Xie

13:30–14:00	Keynote Speaker	Qing-An Huang	Parity-time symmetry for silicon micromechanical resonators
14:00–14:20	Invited Speaker	Mingzhi Yu	Research on MEMS alkali metal atomic vapor cell and miniature atomic magnetometer
14:20–14:40	Invited Speaker	Hong Zhou	Electrically reconfigurable photonic quasi-bound states in the continuum (bic) platform via MEMS actuation
14:40–15:00	Invited Speaker	Zhaojun Liu	Wide-temperature-range flexible thin-film temperature sensor
15:00–15:20	Invited Speaker	Qian Zhang	Flexible sensors and soft robotics

S11. Semiconductor Sensors, Photodetectors and CMOS MEMS

Day 2 (31 July 2025, Thursday)

AI Andalus 1

Chaired By: Prof. Swee Tiam Tan and Prof. Po-Liang Liu

13:30–14:00	Keynote Speaker	Qijie Wang	Mid-infrared detection and spectroscopy with 2d materials
14:00–14:20	Invited Speaker	Wanfeng Xie	Tailoring mxene thickness and functionalization for enhanced room-temperature trace no2 sensing
14:20–14:40	Invited Speaker	Jicong Zhao	Van der waals mid-wave infrared photodetector linear array
14:40–15:00	Invited Speaker	Wei-Sea Chang	Induced sensing via ferroelectric and piezoelectric
15:00–15:20	Invited Speaker	Muhamad Ramdzan Buyong	Dielectrophoresis Technology and Application
15:20–15:40	Invited Speaker	Azrul Azlan Hamzah	Ultrasonic Transducer for Flow Rate, Occlusion and Bubble Detection in Portable Peritoneal Dialysis System
15:40–16:00	Invited Speaker	Chun-Wei Tsai	Electrostatic MEMS-Driven Silicon Photonics Switch with Zero Static Power Consumption
16:00–16:15	Oral Presenter	Saravanan Adhimoorthy	SnS2 nanosheets-Niobium diselenide@C60 hybrid materials-based self-power broadband photodetectors for advanced neuromorphic AI vision systems
16:15–16:30	Oral Presenter	Muhammad Ahsan Iqbal	Redefining Limits: Advanced Organic Infrared Photodetectors for Next-Gen Optoelectronics

S12. Piezoelectric MEMS And Resonators – FBAR, SAW, pMUT

Day 4 (2 August 2025, Saturday)

Alhambra 1

Chaired By: Prof. Yao Zhu

8:30–8:50	Invited Speaker	Zhiqiang Mu	Polarity-inverted aluminum scandium nitride resonators and ferroelectric modulations
8:50–9:10	Invited Speaker	Yansong Yang	MEMS transducers empower ultrasonic and rf applications
9:10–9:30	Invited Speaker	Zhiran Yi	Piezoelectric MEMS cooler
9:30–9:50	Invited Speaker	Qinghua Ren	Strain engineering for regulating the behavior of nitrogen vacancies in Al _{1-x} Sc _x N film

Chaired By: Prof. Aron Woldeghiorgis

10:30–11:00	Keynote Speaker	Nan Wang	A Hybrid Design Method of Lamb Wave Mode Filter Based on Machine Learning and COM Model
11:00–11:30	Keynote Speaker	Siddhartha Ghosh	Design and Fabrication of Phononic Integrated Circuits in Scandium Aluminum Nitride
11:30–11:50	Invited Speaker	Daniel Chen	AI-enhanced quantification of abnormally oriented grains in scaln thin films for in-line process monitoring
11:50–12:10	Invited Speaker	Qilin Hua	Submersible soft robotics with ultrasonic echolocation capabilities
12:10–12:25	Oral Presenter	Hong Zhang	High-Accuracy Simulation Model for Temperature-Frequency Characteristics of Single-Port SAW Resonators Based on Asymptotic Waveform Evaluation

S13. Piezoelectric Transducers and Energy Harvesters

S14. Ferroelectric / Perovskite / 2D Materials Thin Film and Applications

Day 3 (1 August 2025, Friday)

Alhambra2

Chaired By: Prof. Huicong Liu

8:30–9:00	Keynote Speaker	Junwen Zhong	Flexible dual-directional electromechanical transducers for human-machine interactive applications
9:00–9:20	Invited Speaker	Fengru Fan	Efficient catalytic conversion of gas molecules based on novel charged interfaces
9:20–9:40	Invited Speaker	Pengcheng Jiao	AI-informed mechanical piezo-metamaterials for self-powered sensing
9:40–9:55	Oral Presenter	Hangrui Cui	An Intelligent Cube-Designed Piezoelectric Node (iCUPE) with Simultaneous Sensing and Energy Harvesting Capabilities
9:55–10:10	Oral Presenter	Fong-Zhi Chen	NCIR's WS2 2D Material R&D Collaboration and Its Application In Gas Sensors

Chaired By: Prof. Ying-Hao Chu and Prof. Wee Chen Gan

10:30–11:00	Keynote Speaker	Huicong Liu	MEMS energy harvesting and sensing techniques for health monitoring and fault diagnosis
11:00–11:20	Invited Speaker	Tao Wu	AlN/AlScN piezoelectric thin film transducers
11:20–11:40	Invited Speaker	Jia Lu	Electret-based self-powered flexible vibration sensor with high sensitivity and durability
11:40–12:00	Invited Speaker	Shimpei Ono	The advanced functionalities of ions

Chaired By: Prof. Junwen Zhong

13:30–14:00	Keynote Speaker	Ying-Hao Chu	Flexible high entropy nonlinear dielectrics with superior performance
14:00–14:20	Invited Speaker	Sagnik Ghosh	ScalN-based piezoelectric micromachined ultrasound transducers as a multipurpose lead-free solution
14:20–14:40	Invited Speaker	Takashi Nakajima	Vibration energy harvesting for sustainable iot: advances in piezoelectric polymer materials

S15. Gas Sensors and Chemosensors

Day 4 (2 August 2025, Saturday)

Alhambra3

Chaired By: Prof. Fei Wang

8:30–9:00	Keynote Speaker	J. Andrew Yeh	Predicting liver function from breath vocs via machine learning with support for isfet sensor integration
9:00–9:30	Keynote Speaker	Kun-Lin Yang	Applications of polymer network-liquid crystals (pnlc) as chemical and gas sensors
9:30–9:50	Invited Speaker	Yanbai Shen	High response and selectivity hydrogen sensors based on sandwich-structured msnx-rgo-sno2 composites
9:50–10:10	Invited Speaker	Arakawa Takahiro	Non-invasive human volatiles detection via a wearable biochemical gas sensor

Chaired By: Prof. Fei Wang

10:30–11:00	Keynote Speaker	Xiaojing Mu	Applications of Surface-Enhanced Infrared Absorption Spectroscopy in Molecular Sensing
11:00–11:30	Keynote Speaker	Sang Sub Kim	Surface functionalization of metal oxide semiconductors for enhanced chemiresistive gas sensing
11:30–11:50	Invited Speaker	Sikai Zhao	Sno2 functionalized mos2 nanostructures for high-performance nh3 sensing
11:50–12:05	Oral Presenter	Zhao Rao	A high-sensitivity gas sensor for simultaneous detection of methane and ethane in urban gas networks

Chaired By: Prof. Inkyu Park and Prof. Dae-Sik Lee

13:30–14:00	Keynote Speaker	Fei Wang	MEMS gas sensors with wafer level fabrication and testing techniques
14:00–14:30	Keynote Speaker	Xuhui Sun	Artificial olfaction platform based on MEMS gas sensor array
14:30–14:50	Invited Speaker	Fang Xu	Study of alcohol selectivity of a room temperature operated gas sensor based on tio2
14:50–15:10	Invited Speaker	Dae-Sik Lee	Nano-chemical sensors technology for diet-monitoring/cancer-screening systems using exhaled breath
15:10–15:25	Oral Presenter	Tianshu Chu	Space confinement strategy and nano sensing performance of mxene materials

S16. Triboelectric Nanogenerators and Self-powered Sensors

Day 1 (30 July 2025, Wednesday)

Alhambra3

Chaired By: Prof. Ying-Chih Lai

10:30–11:00	Keynote Speaker	Yunlong Zi	Tribo-photonics: an emerging field toward fully-self-powered wireless sensing
11:00–11:30	Keynote Speaker	Chenguo Hu	Achieving high output performance and efficient energy utilization of TENG
11:30–11:50	Invited Speaker	Jicang Si	A self-powered gas sensing system based on triboelectric vibration energy harvesting for highly sensitive and selective nh3 detection in engine rooms of ammonia-powered ships
11:50–12:10	Invited Speaker	Yi Xi	Study on interface electrical properties of tribodielectric materials

Chaired By: Prof. Minyi Xu

13:30–14:00	Keynote Speaker	Zhen Wen	Triboelectric tactile sensors
14:00–14:30	Keynote Speaker	Kean C. Aw	Harvesting energy with electromagnetic, piezoelectric, and triboelectric technologies
14:30–14:50	Invited Speaker	Xuelian Wei	Sensory Evolution of Intelligent Robots: Innovative Exploration of Triboelectric Sensing for Object Identification
14:50–15:10	Invited Speaker	Mengwei Wu	Stretchable Rope-Shaped Triboelectric Sensor for Multi-Scenario Monitoring
15:10–15:25	Oral Presenter	Xinge Guo	Biocompatible Ionic Hydrogel with Stable Energy Harvesting and Self-Powered Leaf Health Monitoring for Future Smart Farming

S16. Triboelectric Nanogenerators and Self-powered Sensors

Day 1 (30 July 2025, Wednesday)

Alhambra3

Chaired By: Prof. Yina Liu and Prof. Xinkai Xie

16:00–16:30	Keynote Speaker	Ying-Chih Lai	Untethered, autonomously self-healable, and self-powered actively-perceiving and energy-harvesting triboelectric skins and their applications in soft robotics
16:30–16:50	Invited Speaker	Yina Liu	An Ultrasensitive Triboelectric Pressure Sensor for Multimodal Healthcare Applications
16:50–17:10	Invited Speaker	Min-Hsin Yeh	Enhancing self-induced polarization of pvdf-based triboelectric film by introducing functional g-c3n4 layers for ultrasensitive triboelectric pressure sensors
17:10–17:30	Invited Speaker	Mang Gao	Abrasive wear detection for metal-polymer plain bearing based on triboelectric effect under dry and boundary working condition
17:30–17:50	Invited Speaker	Xinkai Xie	Self-powered triboelectric neuromorphic devices for bioinspired tactile perception
17:50–18:05	Oral Presenter	Delong Han	An antifreeze gel as strain sensors and machine learning assisted intelligent motion monitoring of triboelectric nanogenerators in extreme environments

Day 2 (31 July 2025, Thursday)

Alhambra3

Chaired By: Prof. Zhen Wen

10:30–11:00	Keynote Speaker	Minyi Xu	Deep-learning-assisted triboelectric whisker for near field perception and online state estimation of underwater vehicle
11:00–11:20	Invited Speaker	Po-Kang Yang	Recent advances in functional wearable design using layered nanomaterials
11:20–11:40	Invited Speaker	Chen-Kuei Chung	Laser processing and molding of flexible polymer for unique triboelectric nanogenerator and self-powered sensor application
11:40–11:55	Oral Presenter	Moldir Issabek	Implementation of Triboelectric nanogenerator-based wearable sensors for Muscle Activity Monitoring
11:55–12:10	Oral Presenter	Sabyrzhan Oralkhan	Smart Gripper with Triboelectric Sensors and Data-Driven Machine Learning for Object Classification

S17. Energy Harvesting Technology and Applications

Day 4 (2 August 2025, Saturday)

Alhambra2

Chaired By: Prof. Xuhui Sun

8:30–9:00	Invited Speaker	Cailiang Zhang	Dynamics analysis of a hybrid piezoelectric-dielectric harvester
9:00–9:20	Invited Speaker	Zhihui Lai	Research on a self-powered rolling bearing fault diagnosis method with vibration energy harvesters for self-sensing
9:20–9:40	Invited Speaker	Junlei Wang	Energy concentration pipe based on passive jet control for enhancing flow-induced vibration energy harvesting
9:40–9:55	Oral Presenter	Shuang Xiao	Reactive crystallization of halide perovskites for high-performance solar cells

Chaired By: Prof. Xuhui Sun

10:30–11:00	Keynote Speaker	Shengxi Zhou	Mechanical energy harvesters for powering wireless sensors in rail transit infrastructure
11:00–11:20	Invited Speaker	Yang Kuang	Track-borne magnetic field energy harvesters for electrified railways

Chaired By: Prof. Shengxi Zhou

14:00–14:20	Invited Speaker	Hiroko Yamada	Development of microbial fuel cells using waste cutting fluids
14:20–14:40	Invited Speaker	Dongmei Huang	Design and analysis of galloping energy harvesters
14:40–15:10	Invited Speaker	Guobiao Hu	Equivalent circuit modeling methods and their applications in vibration energy harvesting and control
15:10–15:20	Invited Speaker	Guozhi Zhang	Ultrasonic and rf pulse sensing multimodal sensing technology for partial discharge of power equipment

S18. Flexible, Stretchable and Wearable Sensors

Day 3 (1 August 2025, Friday)

AI Andalus 1

Chaired By: Prof. Jae Yeong Park and Prof. Jungil Choi

8:30–9:00	Keynote Speaker	Michinao Hashimoto	Title: to be announced
9:00–9:20	Invited Speaker	Jungwook Choi	Design, manufacturing, and applications of carbon nanomaterial-based physical sensors
9:20–9:40	Invited Speaker	Xianjie Pu	Wearable triboelectric sensor and its output enhancement
9:40–10:00	Invited Speaker	Wei Zhai	Tough and strong soft materials for flexible electronics

Chaired By: Prof. Bingpu Zhou and Prof. Jungil Choi

10:30–11:00	Keynote Speaker	Jae Yeong Park	Wearable biosensor patches for digital healthcare and medical applications
11:00–11:20	Invited Speaker	Bingpu Zhou	Flexible and wearable magnetized interface
11:20–11:40	Invited Speaker	Jungil Choi	Soft, skin-conformal multifunctional microfluidic platforms for precise monitoring of sweat biomarkers and temperature
11:40–12:00	Invited Speaker	Yan Wang	Electronic skins for continuous health monitoring
12:00–12:15	Oral Presenter	Wenlong Xu	Machine learning assisted gel-based flexible sensors and human-machine interaction

Chaired By: Prof. Tomoyuki Yokota and To be announced

13:30–14:00	Keynote Speaker	Tomoyuki Yokota	Sheet-type image sensor
14:00–14:20	Invited Speaker	Junseong Ahn	All-inorganic nanoribbon yarns for wearable transducers
14:20–14:40	Invited Speaker	Da Wan Kim	Multilayered bio-adhesive architectures for sensor interfaces: reversible skin attachment and structured suction layers
14:40–14:55	Oral Presenter	Rawat Jaisutti	Textile-Based Temperature Sensing for Smart Wearable Heating Systems

S18. Flexible, Stretchable and Wearable Sensors

Day 4 (2 August 2025, Saturday)

AI Andalus 1

Chaired By: Prof. Wei Zhai

8:30–9:00	Keynote Speaker	Chuanfei Guo	Artificial skin for accurate measurement of pressure and vibration
9:00–9:20	Invited Speaker	Min-Ho Seo	Three synchronized, miniaturized, wireless imu sensors for automated gait and balance analysis system
9:20–9:40	Invited Speaker	Shipeng Zhang	Ultra-thin stretchable multifunctional wearable sensor for on-skin smart healthcare monitoring
9:40–9:55	Oral Presenter	Heng Zhang	Jellyfish-like gold nanowires as flexosensors for sweat analysis
9:55–10:10	Oral Presenter	Min Xu	Elastic nanoparticle-reinforced, conductive structural color hydrogel with super stretchability, self-adhesion, self-healing as electrical/optical dual-responsive visual electronic skins

Chaired By: Prof. Chuanfei Guo

10:30–11:00	Keynote Speaker	Jianyong Ouyang	Flexible sensors for food processing and food digestion monitoring
11:00–11:20	Invited Speaker	Kai Wu	Deformation/fracture behavior and electromechanical response of metal films
11:20–11:40	Invited Speaker	Tian Li	Biohybrid system integrating cultured tissues and devices for evaluation of physiological function
11:40–12:00	Invited Speaker	Junlong Yang	Synergistic interface integration in multi-layered systems for a resilient and adaptive electronic skin
12:00–12:15	Oral Presenter	Tian-run Lv	Harnessing built-in electric fields for enhanced electron transfer in biosensor for precise digital health assessment
12:15–12:30	Oral Presenter	Myrto Patagia Bakaraki	AI-Enhanced Wearable Sensor Systems for Monitoring and Optimizing Neurorehabilitation in Post-Stroke Patients

S18. Flexible, Stretchable and Wearable Sensors

Day 4 (2 August 2025, Saturday)

AI Andalus 1

Chaired By: Prof. Tian Li and Prof. Junlong Yang

13:30–14:00	Keynote Speaker	Inkyu Park	Micro/nano-enabled wearable/flexible sensors for smart healthcare and medical applications
14:00–14:30	Keynote Speaker	Ting Zhang	Wearable flexible sensing devices and applications
14:30–14:50	Invited Speaker	Sunghoon Lee	Skin-attachable next-generation wearable electronics
14:50–15:10	Invited Speaker	Yanhao Yu	Soft electronic packaging
15:10–15:25	Oral Presenter	Dengke Song	Regulating anti-freezing properties of gels by adjusting polymer monomer ratios for object recognition via flexible sensors
15:25–15:40	Oral Presenter	Bismark Asiedu Asante	Wand v2: seamless indoor and outdoor navigation using gps and imu data fusion
15:40–15:55	Oral Presenter	Gangsheng Chen	Shear force enabled liquid metal circuits with hierarchical embedded structure for paper electronics

S19. Wearable AI Sensors

Day 3 (1 August 2025, Friday)

Alhambra3

Chaired By: Prof. Ting Zhang

13:30–13:50	Invited Speaker	Kai Xiao	Neuromorphic iontronic devices for brain-machine hybrid intelligence
13:50–14:05	Oral Presenter	Shengxin Xiang	A stretchable, self-assembled janus structured electronic skin for gesture recognition in deep learning
14:05–14:20	Oral Presenter	Xiao Wei	Fiber-based tactile sensor for intelligent human-machine interaction
14:20–14:35	Oral Presenter	Zixuan Zhang	Transfer learning enhanced lip language interface for silent speech recognition
14:35–14:50	Oral Presenter	Huiyun Zhang	A Strain-Insensitive and Multifunctional Triboelectric Fiber Based on Liquid Metal and Silver Nanowires Synergic Network

S20. AI-enhanced Tactile Sensors and e-Skin

Day 3 (1 August 2025, Friday)

Alhambra4

Chaired By: Prof. Po-Liang Liu

8:30–9:00	Keynote Speaker	Jun Wu	Flexible tactile devices and intelligent systems
9:00–9:30	Keynote Speaker	Haoyong Yu	Bio-inspired tactile sensor integrated with dexterous robotic hand for object grasping
9:30–9:50	Invited Speaker	Yan Wang	Deep learning-assisted triboelectric smart mats for personnel comprehensive monitoring toward maritime safety
9:50–10:10	Invited Speaker	Cheol Song	Optical force sensing for precision epidural injections

Chaired By: Prof. Jun Wu

10:30–11:00	Keynote Speaker	Po-Liang Liu	First-principles investigation of work function modulations induced by co-adsorption of no, no ₂ , co, co ₂ , h ₂ s, and o ₃ on znGa ₂ O ₄ (111) for gas sensing
11:00–11:20	Invited Speaker	Yang Li	Hybrid wearable device based on integrated pressure sensing and visualization
11:20–11:35	Oral Presenter	Jingfeng Xu	Edge-ai enhanced multimodal tactile glove with in-sensor computing

S21. Haptic Technology and Applications

Day 2 (31 July 2025, Thursday)

Alhambra3

Chaired By: Prof. Xinge Yu

13:30–13:50	Invited Speaker	Dengfeng Li	Wearable robotic haptic feedback technologies
13:50–14:10	Invited Speaker	Zhuang Zhang	Origami-based structures for multimodal soft actuation and high-fidelity haptics
14:10–14:30	Invited Speaker	Yitian Shao	Wide bandwidth tactile sensing of human and embodied intelligence
14:30–14:50	Invited Speaker	Yuan Ma	Developing advanced human-machine mechanical interfaces
14:50–15:05	Oral Presenter	Lei Shi	A Machine Learning-Based Knee Brace System for Walking Gait Analysis
15:05–15:20	Oral Presenter	Luwei Wang	Metaverse-Enabled Yoga Coach Avatar Using Multimodal Insole Sensing System

S22. Advanced Sensors for Robots and Autonomous Systems

Day 3 (1 August 2025, Friday)

Alhambra3

Chaired By: Prof. Minglu Zhu

8:30–9:00	Keynote Speaker	Chee Kong Chui	Cyber-physical systems with edge computing for robotic automation in chemical development
9:00–9:20	Invited Speaker	Dongsheng Li	Perception and interaction for minimally invasive surgical robots
9:20–9:35	Oral Presenter	Juan Augusto Heins Herrera Ollachica	Human presence detection for rescue applications by using ultra-wideband radar and deep neural network: a framework for drone integration
9:35–9:50	Oral Presenter	Sungho Son	Analyzing camera recognition under simulated visual contamination with real-world validation
9:50–10:05	Oral Presenter	Xichen Hu	Magnetically-gated mechanosensing with adaptive sensitivity enabled by machine learning
10:05–10:20	Oral Presenter	Ketan Sahu	A neuro-adaptive multi-pack grey wolf optimizer for resilient multi-rover path-planning in lunar-style terrains

S23. Intelligent Sensors and AI-Enhanced Humanoids

Day 1 (30 July 2025, Wednesday)

AI Andalus 1

Chaired By: Prof. Qiongfang Shi

16:00–16:30	Keynote Speaker	Qiongfang Shi	Intelligent tactile sensors for multimodal perception and robotic e-skins
16:30–16:50	Invited Speaker	Long Liu	Self-powered human-robot interaction sensing system as a dexterous teaching platform for embodied artificial intelligence learning
16:50–17:10	Invited Speaker	Huimin Hao	A High-Sensitivity Trace Sebum Gas Sensor for Ultra-Early Diagnosis of Parkinson's Disease
17:10–17:30	Invited Speaker	Jianxiong Zhu	AI-augmented wearable triboelectric human-machine interface in motion identification
17:30–17:45	Oral Presenter	Ya Tang Yang	Optical flow based obstacle avoidance of autonomous nano quadcopter using on board computing

S24. Enabling Technology for Digital Twin, Metaverse, and Smart Sensing Systems

Day 2 (31 July 2025, Thursday)

Alhambra2

Chaired By: Prof. Cong Yang

10:30–11:00	Keynote Speaker	Minglu Zhu	Sensing and feedback fusion for mutual perception in metaverse and robotics
11:00–11:20	Invited Speaker	Cong Yang	From Human-Computer Interaction to Human-Robot Manipulation
11:20–11:35	Oral Presenter	Cheng-Lun Kan	In-situ measurement of residual stress and parameter optimization in laser drilling
11:35–11:50	Oral Presenter	Priyanshu Srivastava	AIoT-Driven Natural Language Communication for Smart Device Interaction and Maintenance

S25. AIoT Technology and Applications

Day 2 (31 July 2025, Thursday)

AI Andalus 1

Chaired By: Prof. Yang Kuang

10:30–10:45	Oral Presenter	Syafar Hidayat	Integration of IoT, LoRa, and Machine Learning for Temperature and Humidity Monitoring in Hydroponic Greenhouse Farming.
10:45–11:00	Oral Presenter	Zixuan Zhong	Diffraction-Integrated AOM-Based Φ -OTDR Achieves 1.5 m Spatial Resolution for Distributed Acoustic Sensing over a 50 km range
11:00–11:15	Oral Presenter	Fan-Jie Kung	Enhancing Speech Localization and Separation with Convolutional Neural Network -Based Voice Activity Detection in Noisy Acoustic Scenarios
11:15–11:30	Oral Presenter	Uzair Hussain Bhatti	An Integrated AIoT and Generative AI Framework for Predictive Maintenance and Automated Resource Planning

S26. Sensors for Applications in Agriculture, Aquaculture, Food Technology (A2FT) and Harsh Environment

Day 4 (2 August 2025, Saturday)

Alhambra4

Chaired By: Prof. Sang-Seok Lee

8:30–9:00	Keynote Speaker	Toshihiro Itoh	Wearable bioacoustic devices for animal health monitoring
9:00–9:20	Invited Speaker	Xuming Zhang	Fiber-optic marine sensors for dual-parameter measurement of salinity and temperature
9:20–9:40	Invited Speaker	Michitaka Yamamoto	Development of molecular weight measurement method using whistle acoustic signals for remote sensing of cattle-emitted gases
9:40–9:55	Oral Presenter	Md Shokor Rahaman	A Multi-Branch Hybrid Convolution-Transformer Architecture for Intelligent Microseismic Event Detection

Chaired By: Prof. Sang-Seok Lee

10:30–11:00	Keynote Speaker	Xiaoxing Zhang	Insulation monitoring of power equipment and green electrical technology
11:00–11:20	Invited Speaker	Naoki Shiraishi	Weight-detectable resonant sensors for monitoring volatile fatty acids (vfas) in the rumen of cows
11:20–11:40	Invited Speaker	Noriko Tsuruoka	Microperfusion needle for minimally invasive monitoring of biological components of individual plants

S26. Sensors for Applications in Agriculture, Aquaculture, Food Technology (A2FT) and Harsh Environment

S27. Industry Forum and Commercialization of Sensors and Transducers

Day 4 (2 August 2025, Saturday)

Alhambra 4

Chaired By: Prof. Chun-Wei Tsai

14:00-14:20	Invited Speaker	Tadao Matsunaga	Automatic light environment measurement system for plant cultivation utilizing fine-cut optic fiber-optic
14:20-14:40	Invited Speaker	Tomoaki Kageyama	Development of maintenance-friendly water quality sensing devices: approaches using isfet and wifi-csi
14:40-14:55	Oral Presenter	Miheung Choe	Marine Environment Observation using an Acoustic Tomography System with Multi-Channel Acoustic Sensors and an Efficient Phase Correlation Signal Processing Algorithm
14:55-15:10	Oral Presenter	Sarika Yadav	Enhanced taste and quality analysis of soft drinks and milk samples using a single-channel hybrid e-tongue with an unsupervised machine learning approach
15:10-15:25	Oral Presenter	Shih-Yi Yeh	Integrated Micro-LED Light Module and MEMS Mirror on a Chip for Visible Light Communication Application

Poster List

1.	Azrul Hamzah	Engineering High Signal-to-Noise Performance in TiO ₂ /rGO FET Biosensors through Precise Control of Annealing and rGO Content
2.	Christakis Damianou	MR compatible sensors for a focused ultrasound robotic system for brain cancer.
3.	Minwoo Kim	Nanovesicle-based ultrasensitive biosensor for Drug discovery of CB1 receptor
4.	Ryun Kang	Non-Contact Colorimetric Sensor for Rapid Pre-Screening of Urinary Tract Infection
5.	Solpa Lee	On-Site Screening of Salmonella in Food Using a Polydopamine-Based Lipopolysaccharide Imprinted Polymer
6.	Arifah Abdul Rahman	Process Optimization of Maltose-Based Microneedles for Anesthetic Delivery Using Taguchi Design
7.	Miral Sabry	Using rational in silico design to develop peptide-based sensors for detection of bacteria
8.	Yilin Song	PEDOT:DSS-Modified Microelectrode Arrays for Simultaneous Recording of Neural Activity in Dual Brain Regions
9.	Siqiang Zhao	Lithium Niobate Metasurface for Flexible Color Sensor Application
10.	Ouslimani Habiba	Activation of Millimeter-Wave Sensors Based On Surface Currents On 3D Periodic Gratings
11.	Tingwei Wang	Electromagnetically Induced Transparency in Reconfigurable K-Architecture Metamaterials: Toward Multifunctional Optoelectronic Logic and Biochemical Sensing
12.	Wenqing Zheng	Multifunctional electrically tunable split-ring resonator for dynamic modulation applications
13.	Wenwen Yang	Split-Disk Terahertz Metamaterial with Ultra-High Polarization Ratio for Reconfigurable All-Optical Logic
14.	Yan Gong	Thin-Film Lithium Niobate Spatial Light Modulator Based on High-Q Guided Mode Resonance
15.	Aron Michael	2D Wide-Angle Beam Steering with a MEMS Diffraction Mirror for High-Resolution Scanning LiDAR
16.	Tongtian Zhang	A Micromechanical Wide-Range Stiffness-Tuning Mechanism for MEMS Applications
17.	Shih-Yi Yeh	Design and Manufacture of Suspended MEMS-Based Infrared Sensors with 3D Stacking Technology
18.	Chun-Wei Tsai	Efficiency Enhancement and Performance Analysis of Temperature-Responsive Silicon-Based Grating Coupler
19.	Dong Wook Kim	Preliminary test for MEMS-based wearable respiratory self-training system
20.	Jie Liu	Simulation Analysis of MEMS Scanning-Grating-Micromirror-Integrated Quantum Cascade Laser External Cavity Systems
21.	Po-Liang Liu	First-Principles Study of NO Co-adsorbed with Multiple Gases on SnO ₂ (110): Work Function Modulation and Sensing Potential
22.	Danyu Mu	Extract Temperature Coefficients of LGS for High-Temperature Applications Based on the Finite Element Method
23.	Yang Xue	Weakened phonon scattering in Schottky junction of large-area black phosphorus/PtSe ₂ films for high operating temperature broadband photodetectors
24.	Fei Wang	Anti-interference acetone gas detection system for exhaled breath monitoring
25.	Anshu Kashyap	DMPA-GWO++: A Neuro-Adaptive Multi-Pack Grey Wolf Optimizer for Intelligent IoT Sensor Deployment in Smart Agriculture
26.	Leandro Sacco	From single-element to multicomponent materials: A rapid high-throughput screening method to develop gas-sensing layers based on an automated dry printing technology
27.	Akihiro Yoshifuku	High-dimensional Localized Surface Plasmon Resonance gas sensor with subpixel structure
28.	Ginji Akinaga	Identification of mixed VOC gas species Using Surface-Enhanced Raman Scattering Sensor
29.	Shih-Min Huang	A Portable and Recyclable Biomechanical Sensor Design based on Triboelectrification
30.	Jian Qiu	Cylinder bluff body modified with counter-flow fin-shape rods for enhanced wind-induced vibration energy harvester
31.	Shi Hyeong Kim	Integrated Electrostimulation Cell Culture System Powered by Chemically Modified Twistron Harvesters

32.	Chia-Hung Chang	A wearable non-contact radar sensor with DC offset canceling for vital-sign sensing
33.	Ming-Jong Tsai	Additive Manufacturing of Porous Structure for Flexible Sensors and Multi-objective Optimization using Taguchi-based GRA
34.	Jia Lu	Electret-based Wearable Pressure Sensor for Human Pulse and Blood Pressure Monitoring
35.	Dan Fang	Revisiting the “Stick-slip”; Process via Magnetism-coupled Flexible Sensors with Bio-inspired Ridge Architecture
36.	WENXUE DAI	Self-Adhesive Electronic Skin with Bio-inspired 3D Architecture for Mechanical Stimuli Monitoring and Human-machine Interactions
37.	Shi Hyeong Kim	Self-Powered Flexible Sensors Based on Chemo-Mechanical Energy Harvesting for Organ Motion Monitoring
38.	Ting Zhu	Topological Gradients for Metal Film-Based Strain Sensors
39.	Quanyi Cheng	Capacitive Tactile Sensors: Morphological Engineering and Applications
40.	Kyoung Su Park	Advanced Sensing Algorithm for Slewing Bearings Using Multi-Feature Extraction and Self-Attention
41.	Changmin Pyo	Application of AI-Based Surrogate Models Utilizing FEA Data in Advanced Sensors for Unmanned Robots
42.	Changmin Pyo	Sensors for Predicting Structural Failure in Support Arms for Autonomous Welding Robots with a Deep Learning Surrogate Model
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45.	Seong-Cho Hong	A Study Validating an IoT-based Drug Pills Feature Point Extracting Algorithm
46.	Alessandro Leone	An Adaptive IoT-Based Platform for CO ₂ Forecasting Using Generative Adversarial Networks: Enhancing Indoor Air-Quality Management with Minimal Data
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51.	Sang-Seok Lee	Integration of pH and DO sensor based on ISFET
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Session 1. Lab-on-a-Chip (LoC) and MicroTAS

sciforum-120504: Improving Lipid Vesicle Stability via Controlled Solvent Evaporation in Microfluidic Double Emulsions

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Lipid vesicles, synthetic capsules composed of lipid bilayers similar to cellular membranes, have emerged as crucial model systems for cellular biology studies and highly promising vehicles for targeted drug delivery due to their biocompatibility and structural properties. Microfluidics technology enables efficient, controlled, and high-throughput generation of lipid vesicles, typically through the formation of water-in-oil-in-water (W/O/W) double emulsions. Despite these advantages, a persistent challenge remains the instability encountered during solvent evaporation from the intermediate oil phase. Rapid or uncontrolled solvent evaporation frequently leads to structural rupture and low yields of stable vesicles.

In this study, we systematically investigated the mechanism of vesicle instability by directly observing solvent distribution and the dewetting behavior of the oil phase within microfluidic double emulsions using confocal microscopy combined with fluorescent imaging. Our experiments revealed that residual dichloromethane within the thin oil layers significantly reduces the lipid bilayer's adhesion energy, precipitating vesicle rupture. By carefully modulating the evaporation rates of solvents through the use of controlled mixtures of dichloromethane and pentane, we were able to substantially increase the lipid bilayer adhesion energy. This method effectively suppressed vesicle rupture, enhancing the stability and uniformity of the resulting lipid vesicles.

Our findings provide a deeper understanding of the physical processes underpinning lipid vesicle formation and present a practical strategy to optimize solvent evaporation rates in microfluidic systems. The controlled approach demonstrated here significantly improves vesicle formation efficiency, facilitating rapid and reliable synthesis. This advancement holds significant promise for practical applications in drug delivery, synthetic biology, and biophysical research, paving the way for more efficient and scalable fabrication of lipid vesicles.



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sciforum-122086: Biohybrid system integrating cultured tissues and devices for evaluation of physiological function

Yuya Morimoto

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Our main research interest is the development of biohybrid systems that integrate cultured tissue with microdevices, enabling the quantitative and reproducible evaluation of tissue functions within artificial platforms. These biohybrid systems hold great potential for applications such as providing alternatives to animal models in drug testing and the preclinical evaluation of drug efficacy and side effects.

By engineering appropriate culture environments using microdevices, we have succeeded in constructing functional cultured tissue. For instance, we developed contractile skeletal muscle tissues by culturing myoblast-laden hydrogel blocks under mechanical tension. Furthermore, we established a method to integrate sensors with cultured tissues, leading to the development of organ-on-a-chip systems capable of the in vitro monitoring of tissue function. Using this approach, we have quantitatively measured dynamic changes in tissue activity, including the fatigue and recovery of human skeletal muscle tissue during repeated contractions, as well as the human iPS cell-derived neuronal firing activity. We have also successfully evaluated tissue responses to pharmacological agents. For example, we successfully investigated changes in the contractility of human iPS cell-derived cardiomyocytes in response to the administration of clinically relevant drugs.

We believe that these organ-on-a-chip models, based on biohybrid technology, offer a promising platform for the application of cultured tissues across various scientific and industrial domains.



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sciforum-121856: Investigation of aerokinesis and aerotaxis in human breast cancer cells using microfluidic devices

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Cancer cells migrate and proliferate in an extracellular matrix (ECM), resulting in cancer metastasis. Heterogeneous oxygen conditions in the ECM reportedly affect cancer cell behaviors, but the details of oxygen-dependent active movement (aerokinesis) and the directed migration of cancer cells toward oxygen (aerotaxis) are still unclear. The author's group has developed microfluidic devices that can control oxygen concentration by gas exchange between media/gel channels for cell culture, and gas channels for gas supply. Here, the aerokinesis and aerotaxis of the human breast cancer cell line (MDA-MB-231 cells) were investigated under various oxygen conditions with different oxygen levels and gradients. MDA-MB-231 cells were mixed with type I collagen solution (1.5 mg/mL, pH 7.4) at a final cell density of 2.0×10^5 to 4.0×10^5 /mL, and three-dimensionally distributed in the gel channel. After placing the device in an incubator overnight and replacing the cell culture medium in the media channel, the device was subsequently placed in a stage incubator mounted on a microscope. Then, either a uniform normoxic or hypoxic condition, or an oxygen concentration gradient was generated in the device by supplying gas mixtures at predefined oxygen concentrations to the gas channels. Twenty-four-hour observations of MDA-MB-231 cells showed that the cell proliferation and aerokinesis were enhanced under hypoxic conditions, leading to further changes in cell distribution. In addition, tracking the individual cells under various oxygen concentration gradients revealed different aerotactic behaviors at specific oxygen concentrations, i.e., the aerotaxis directed the migration of MDA-MB-231 cells toward higher oxygen concentrations under 2–6% O₂ and lower oxygen concentrations under 7–12% O₂. Consequently, although cell proliferation was the main factor, aerokinesis and aerotaxis of MDA-MB-231 cells also contributed to changes in cell distribution.



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sciforum-123895: Programmable Optical Toolbox for Single-Cell Manipulation: Enabling Spatial, Temporal, and Functional Versatility

Moeto Nagai

Toyohashi University of Technology

Introduction

Fundamental biological research and biomedical applications require single-cell manipulation capabilities. While various working principles exist, optical approaches offer unique advantages through non-contact control with high spatial and temporal resolutions. Here, we present light-based techniques for single-cell manipulation that establish the core methodologies. Each approach utilizes tailored light sources, optical systems, and target cells optimized for specific applications.

Methods

Our optical methods include the following: **(1) Optoporation:** A nanosecond pulse laser (532nm) coupled with a galvanometric scanner delivers targeted photomechanical stimulation for membrane permeabilization and molecular delivery. **(2) Biological Actuation:** A digital micromirror device (DMD) projects patterned blue light (470nm) to guide phototactic *Euglena gracilis* microorganisms for cargo transport in microfluidic channels. **(3) Single Cell Screening:** The same DMD system projects 405nm patterns to selectively polymerize gelatin methacrylate (GelMA), creating protected regions for capturing and analyzing individual cells.

Results

Each technique demonstrated specific capabilities: **(1)** Galvanometric scanner-guided optoporation achieved efficient molecular delivery while maintaining high cell viability across multiple cell types. **(2)** DMD-controlled *Euglena* demonstrated precise positioning with micron-level accuracy, enabling controlled manipulation of microscale cargo. **(3)** DMD-patterned GelMA encapsulation formed within seconds, enabling parallel analysis of multiple single cells. After analysis, cells of interest were selectively recovered by dissolving the GelMA using trypsin treatment, allowing for further downstream processing and analysis.

Conclusions

The ability to deploy these techniques independently or in sequence provides versatile options for addressing diverse cellular manipulation challenges. This work establishes three complementary light-based strategies employing galvanometric scanning and DMD projection for high-throughput single-cell manipulation. These optical approaches provide methods for building customized experimental protocols for applications in biology, drug screening, and tissue engineering.



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sciforum-121936: A High-Throughput SERS-Droplet System for Label-Free, Real-Time Microbial Metabolite Profiling

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Chongqing University

High-throughput screening of microbial engineered strains is a critical step in biomanufacturing, and researchers in this field rely on rapid and sensitive detection technologies for metabolic products. However, conventional methods such as mass spectrometry (MS), high-performance liquid chromatography (HPLC), and fluorescence detection (FLD) face limitations, including time-consuming processes, complex equipment, low throughput, and sample destruction. In this study, we developed a droplet microfluidics (DMFs) system integrated with surface-enhanced Raman spectroscopy (SERS), enabling non-destructive, real-time analysis of strain metabolites. The DMF-SERS platform employs a reflective microfluidic chip to enhance signal acquisition, optimizes plasmonic nanostructures to improve SERS stability, and integrates a miniaturized Raman spectrometer (a confocal cage-type detection probe) with optical modules, allowing dynamic spectral capture and in situ analysis to be performed during droplet flow. We tested Raman spectra of 10 organic acids and amino acid metabolites. By combining picoliter-level droplet microfluidics (>3,000 droplets/minute) with SERS technology, the system achieved a sensitivity of 0.01 g/L for metabolites while maintaining cell viability, with a detection speed as low as 15 ms per droplet. This approach eliminates sample pretreatment and enables dynamic metabolic monitoring, successfully addressing technical challenges such as signal attenuation and flow instability in droplet environments. The experimental results demonstrate the system's label-free and high-throughput capabilities, as it seamlessly interfaces with downstream strain sorting. This work provides an innovative platform for strain selection, single-cell metabolomics, and real-time bioprocess monitoring, advancing the development of intelligent biomanufacturing systems.



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sciforum-121741: A Multifunctional Microfluidic Chip Based on Single Nanoparticle Scattering for PSA Detection

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Highly sensitive and accurate quantitative detection of prostate-specific antigens (PSAs) in clinical samples is of critical importance in the early screening and monitoring of prostate cancer. Typically, the detection of tumor markers in the blood involves single-model detecting of the serum, which is separated from the whole blood samples by an external driving force. However, this method requires bulky instruments and tedious procedures, which can lead to false-positive results. To overcome these limitations, In this paper, we develop a multifunctional PDMS/glass microfluidic chip that integrates pretreatment, derivatization, and detection regions and combines dark-field microimaging and fluorescence bimodal detection techniques. Combined with the synergistic effect of the check valve and finger compression, the core-satellite nanostructures formed by the hybridization of magnetic nanoparticle probes and AuNPs probes and the pretreated serum are delivered to each functional area through the number of compressions. To improve the detection sensitivity of the sensor, a strategy for accurately detecting the prostate antigen recognition-release mechanism was proposed. In the absence of PSAs, not only was there no signal in the dark-field microscopic images, but the fluorescence signal was quenched between Carboxyfluorescein (FAM) and AuNPs due to the fluorescence resonance energy transfer (FRET) effect. When PSAs are present, the core-satellite magnetic nanostructures specifically recognize the target and bind to it, which in turn releases the AuNPs into the serum. Further, using the magnetic separation technique, significant signal enhancement was observed in the fluorescence and dark-field microscope detection functional areas. The results showed that the method could achieve an ultra-low PSA detection limit of 0.5 pg/ml. The proposed self-pumping microfluidic sensing chip is expected to show promising applications in the field of point-of-care testing (POCT) and clinical diagnostics.



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sciforum-125407: Acoustic Microfluidics for Biomedical Applications

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Biological cells in human bodies, as the fundamental unit of life, are heterogeneous in nature. It is essential to identify and sort specific cell populations from highly heterogeneous biological samples for a variety of applications in biology, diagnostics, and medicine. Microfluidic technologies capable of accurate cell analysis and precise cell manipulation can provide unprecedented capabilities to automate conventional biological assays. As acoustic waves can easily propagate through solids and fluids, acoustic technique readily enables non-contact cell manipulation in relatively long operating distances. The merging of acoustics into microfluidics has led to a new research direction, acoustofluidics, which generally exploits the use of ultrasonic waves to manipulate biological cells and other types of biological particles. In this talk, I will present our acoustic microfluidic platforms for precise microscale manipulation. We have further integrated single cell analysis (i.e., single cell fluorescence detection and single cell biophysical phenotyping) with our acoustic microfluidic platforms to implement detection activated sorting of single cells and droplets. We have demonstrated these integrated acoustic microfluidic platforms for different biomedical applications, for example sorting of live cells from cryopreserved cell samples and purification of droplets containing one cell and one gel bead for single-cell sequencing. This new type of acoustic manipulation platform has enabled high-precision and on-demand single-cell sorting in diverse biomedical applications.



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sciforum-121949: Addressing unmet clinical needs with additive manufacturing of bioelectronics

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The integration of electronics with 3D constructs can enable advanced sensing, actuation, and computational capability. Yet, at the fundamental level, such integration remains challenging due to the inherent geometrical, mechanical, and material dichotomies between conventional manufactured electronics and three-dimensional systems. My research develops electronics printing strategies that are fundamentally free from the constraints of the conventional manufacturing approach, enabling the creation of biomedical devices and architecture with an unprecedented level of functional integration. First, we demonstrated the ability to incorporate active electronics with a three-dimensional construct by achieving multiscale control of nanomaterials assembly with soft matter physics phenomena and machine intelligence. Second, we developed the ability to selectively anneal nanomaterials on temperature-sensitive constructs by exploiting metamaterials-inspired electromagnetic structure, enabling local programming of electronic and mechanical properties of spatially freeform microstructure on biomedical devices and biological constructs. Third, we explored the novel integration of freeform electronics with digitally designed architecture and metastructure to create next-generation biomedical electronics, such as ingestible gastric resident electronics systems and self-learning robots that can realize a surgical-free digital-based diagnosis and treatment strategy. Ultimately, we strive to overcome challenges associated with the conventional manufacturing approach, creating fundamentally new classes of bioelectronics that can address a broad range of unmet clinical needs.



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sciforum-121709: Design of an organoid chip that mimics the structure of human placenta

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Safe pregnancy and childbirth are essential for the sustainable growth of a country. Although advances in medical technology have led to extremely low maternal and neonatal mortality rates, obstetric complications still occur in approximately 50% of all pregnancies and newborns. Among these, the disease mechanism behind pregnancy-induced hypertension has not yet been elucidated. This is partly because the placental structure varies between animal species, and pregnancy itself is a phenomenon that causes dramatic changes in the mother, making it difficult to reproduce the pathogenesis of the disease. Here, we aim to reproduce the pathogenesis of pregnancy-induced hypertension by placing organoids that mimic the structure of human placenta on a microfluidic chip. Extracellular matrix containing a mixture of human placental trophoblasts and umbilical vein endothelial cells was injected into the flow channels on a comb to artificially construct a placental villous interstitium containing a capillary network. Combined with a perfusion system for long-term culture, we were able to induce placental trophoblast cell fusion and the expression of pregnancy-specific proteins. In the future, a system to control the pressure conditions inside the chip will be introduced to reproduce the pathophysiology of pregnancy-induced hypertension. We anticipate that our approach will deepen research into the mechanisms of pregnancy-induced hypertension and lead to the identification of biomolecules that can be targeted for its treatment.



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sciforum-124618: Development of cryomicroneedles for the transdermal delivery of biologics

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The transdermal delivery of biologics, such as proteins, peptides, and nucleic acids, presents a significant challenge due to the skin's natural barrier properties. Traditional methods of delivery, including injections and oral administration, often come with limitations such as patient discomfort, risk of infection, and degradation of biologics in the gastrointestinal tract. To overcome these challenges, the development of innovative delivery systems is crucial.

Microneedles (MNs) are an emerging platform for transdermal applications including drug delivery, insulin delivery, vaccination, biosensing, disease diagnosis, and cosmeceutical industry. Their advantages lie at their easy-to-use, pain-free, minimally invasive, and self-administrable features. This overcomes the skin barrier to enhance transdermal delivery of drugs and biomolecules with different physicochemical properties in vitro, ex vivo and in vivo. We have developed cryomicroneedle technology to address the need in transdermal delivery of biologics. These microneedles are fabricated by freezing a biologic-containing medium into a microneedle mold, creating solid needles that can encapsulate and protect sensitive biologics. Upon application to the skin, cryomicroneedles rapidly dissolve, releasing their payload directly into the dermal layer.

This presentation aims to discuss the potentials of cryomicroneedles for the transdermal delivery of biologics including melanocytes, dendritic cells, T cells, and mRNA vaccine, paving the way for new therapeutic modalities that are both effective and patient-friendly.



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sciforum-122083: Extracellular potential analysis of neuromuscular system using a microelectrode array

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Co-cultures of motor neurons and myotubes have demonstrated muscle contraction via neural signal transmission. However, extracellular potentials involved in neuromuscular communication have not been systematically characterized. To address this issue, we propose a system integrating a high-density microelectrode array (HD-MEA) with a polydimethylsiloxane (PDMS) structure. The system features separate compartments for motor neuron spheroids and myotubes, allowing differentiation of muscle cells to myotubes on the HD-MEA while preventing direct contact with neuronal bodies. After the differentiation, the removal of the PDMS structure initiates co-culture, enabling extracellular potential recordings.

In the experiments, the PDMS structure was first attached to the HD-MEA, and myoblasts were seeded in the designated compartment. Motor neuron spheroids, pre-aggregated in well plates, were placed in the other compartment. Once myotubes matured, the PDMS structure was removed to start the co-culture. For comparison, monocultures of motor neurons were also prepared. The extracellular potential recordings under both conditions were performed using the HD-MEA. Additionally, immunostaining with Neural β -III Tubulin was conducted on dish-cultured samples to visualize axon growth.

HD-MEA analysis revealed higher spike frequency in the co-cultures compared to motor neuron monocultures, indicating that myotubes enhanced motor neuron excitability. Additionally, fluorescence images of immunostained co-culture samples showed axonal outgrowth from motor neuron spheroids, with axons adhering to myotubes and forming neuromuscular-like connections. Furthermore, co-culture conditions led to a greater number of axons and increased their length compared to motor neuron monoculture, suggesting that interaction with myotubes promotes axonal outgrowth.

These results suggest that co-culture with myotubes promotes morphological and functional maturation of motor neurons, enhancing axonal extension and extracellular potential activity. The integration of HD-MEA and PDMS structure provides a promising platform for studying neuromuscular signal transmission and advancing functional neuromuscular interfaces.



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sciforum-120986: Flexible and Multi-Mode Acoustofluidics Enabled by Thin-Film Acoustic Waves

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Surface acoustic wave (SAW) technologies have garnered widespread attention in fluid manipulation, particle/cell sorting and alignment, and bio-sensing. Bulk piezoelectric materials, e.g., LiNbO_3 , are widely used for microfluidic actuators owing to their high piezoelectric constants and strong electromechanical coupling. However, their inherent rigidity poses challenges for integration with flexible, wearable devices or smart skins. Furthermore, their fixed thickness constrains the ability to excite multiple acoustic wave modes, thereby limiting the versatility of acoustofluidic functionalities. In contrast, piezoelectric thin films offer distinct advantages, including low cost, ease of deposition, and isotropic piezoelectric properties. For example, they can be deposited on a variety of substrates such as silicon, glass, polymers, and metals, enabling tunable acoustic wave propagation characteristics and diverse vibration modes. Notably, depositing piezoelectric thin films on flexible substrates facilitates the fabrication of flexible SAW devices. However, conventional flexible polymer substrates often introduce significant acoustic energy dissipation, thereby reducing microfluidic actuation efficiency. To mitigate this issue, piezoelectric thin films can be deposited on rigid metal substrates, with device flexibility achieved through substrate thinning. However, as the substrate thickness decreases, variations in the ratio of device wavelength to substrate thickness lead to transition in acoustic wave vibration modes, ultimately influencing microfluidic behaviors and performance. In this report, we systematically investigate the acoustic wave vibration modes and fluid actuation behaviors of ZnO thin-film acoustic wave devices on aluminum substrates with varying thicknesses. By utilizing the fabricated flexible devices, we successfully achieve curved-surface fluid transportation. Additionally, multimodal excitation on a single chip enables the realization of diverse particle patterning behaviors. These innovations not only expand the application potential of flexible acoustofluidic devices but also provide new perspectives on the precise control of multimodal acoustic wave-driven microfluidics.



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sciforum-125487: High-Throughput and Efficient Intracellular Delivery via Parallel-Periodic Mechanoporation with Viscoelastic Fluids

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Efficient intracellular delivery of biomolecules is essential for applications in gene editing and cell therapy. However, conventional methods like viral transduction, lipofection, and electroporation often struggle with low delivery efficiency, reduced cell viability, and limited capacity for large cargoes. This study introduces a scalable microfluidic platform for high-efficiency intracellular delivery that combines parallel-periodic mechanoporation with viscoelastic fluids. The platform utilizes nine parallel microchannels, each featuring four periodic constrictions that induce gentle and repeatable deformation of cells through fluid-assisted mechanical stress. This transient deformation temporarily disrupts the membrane, allowing efficient cytosolic entry of biomolecules without compromising viability. Three biocompatible viscoelastic fluids—methylcellulose (MC), polyethylene oxide (PEO), and xanthan gum (XG)—were systematically evaluated to identify the optimal delivery medium. Among these, methylcellulose consistently demonstrated superior performance, supporting high delivery efficiency and excellent cell viability. Constriction widths were optimized to 1.5–2 times the cell diameter, resulting in effective membrane poration across multiple cell types. Under optimized conditions, the platform achieved 95.4% delivery efficiency, 95.7% cell viability, and 91.5% recovery, processing a cell suspension at 3 million cells/mL and maintaining a throughput exceeding 50,000 cells/second. The system successfully delivered a wide range of macromolecules, from 4 kDa to 2,000 kDa fluorescein isothiocyanate–dextran (FITC–Dextran), into both hard-to-transfect Jurkat cells and adherent MDA-MB-231 cells. This work establishes a high-throughput intracellular delivery strategy that is broadly applicable across diverse cell types and cargo sizes. The integration of parallel-periodic mechanoporation with viscoelastic fluids provides a versatile platform for advancing gene editing, targeted therapeutic delivery, and precision medicine.



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sciforum-122070: Machine Learning-Enabled Analysis of Reaction Processes in Microdroplet Reactors

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Microdroplets, typically at the microliter or picoliter scale, serve as essential information carriers in microfluidics due to their ability to isolate reagents and minimize contamination, thereby enhancing biochemical analysis and medical diagnostics. Liquid marbles (LMs), a distinct class of open microdroplet systems, exhibit strong independence and high manipulability owing to their encapsulating particle shells. Optically transparent liquid marbles (OLMs), fabricated with functionalized nanoparticles, enable chemical analysis via digital colorimetry through the correlation of the RGB intensity values of OLM images with analyte concentrations. To overcome the limitations of traditional univariate colorimetric analysis, integrating machine learning with RGB three-channel information facilitates the development of adaptive and robust concentration prediction models. This approach achieves a limit of detection (LOD) of 0.08 mg for single-component analytes. By leveraging additive color theory to deconvolute overlapping spectral signals, this framework further extends to multi-component mixture quantification, broadening its applicability in complex systems. Combining the prediction model with spatiotemporal image processing, our approach dynamically resolves concentration gradients and reaction kinetics in OLMs, quantifying the reaction rates, diffusion coefficients, and mixing efficiency in real time. Beyond static concentration prediction, the extensive processing of OLM reaction image datasets enables the machine learning model to autonomously optimize the OLM reactor parameters (e.g., the reactant volume, concentration, and mixing protocols) to achieve the target reaction outcomes. The integration of machine learning not only enables quantitative reaction analysis and precise product quantification but also establishes a closed-loop control system for OLM-based microreactors. This work highlights the potential of LM-based systems in advancing precision reaction control and autonomous analytical workflows.



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sciforum-122206: Measurement of extracellular potentials using electrode anchors for skeletal muscle tissue

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Since action potentials trigger contractions of skeletal muscle, extracellular potential measurements serve as an important indicator of muscle function. Therefore, they can be a valuable tool for evaluating the physiological effects of compounds on muscle tissue. However, reliable extracellular potential recording requires a stable contact between the electrodes and the muscle tissue. Conventional methods struggle to maintain the stable contact between electrodes and muscle tissue due to muscle contraction, which can disrupt electrode contacts. Here, we propose a system for recording extracellular potentials during muscle contractions by embedding Au-deposited electrode anchors, at the end of cultured skeletal muscle tissue to ensure stable contact.

To fabricate the electrode anchors, Cr and Au were deposited onto the surface of the 3D printed anchors, followed by wiring with Ag paste. A skeletal muscle tissue was formed on the electrode anchor by culturing C2C12 cells in a hydrogel block. To evaluate the ability to record extracellular potentials, the anchors were connected to a recording system, and electrical stimulation ranging from 3 Vpp to 51 Vpp was applied to the muscle tissue.

To evaluate the measurement of extracellular potentials, electrical stimulation was applied to muscle tissue at different culture time points. After stimulation, extracellular potentials were detected alongside muscle contraction. On day 7 of culture, stimulation with voltages above 30 Vpp resulted in higher extracellular potentials compared to voltages below 30 Vpp. Furthermore, at the same applied stimulation voltage, the day 7 muscle tissue exhibited higher extracellular potentials than the day 0 and day 2 muscle tissue. These results suggest that the extracellular potentials increase with both higher stimulation voltage and longer culture dates.

We conclude that this measurement system successfully records extracellular potentials and is useful for studying action potentials in skeletal muscle tissue.



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sciforum-121850: Microfluidic sensor for direct measurement of micro-pressures in micro-tissues in vivo

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In vivo pressure measurement is essential for understanding processes such as cell differentiation and organ morphogenesis. However, current technologies face limitations in measuring microenvironments within living tissues. Conventional methods, like servo-null systems, are sensitive to the ion composition, electrical resistance, and noise, compromising accuracy. They also require immersion in liquid, are expensive, and need specialized equipment, making them unsuitable for direct measurements in animals such as mice. We developed a microfluidic device that measures the pressure by tracking fluid displacement in a PDMS microchannel (250 μm wide, 100 μm high) bonded to glass. When a glass capillary is inserted into tissue, the external pressure shifts the fluid interface, enabling direct pressure measurement without electrical components or immersion. The device does not rely on electrical sensing and is thus unaffected by the environmental resistance or ion diffusion, providing accurate readings in air and multilayered tissues. The microfluidic device was validated through calibration and the direct measurement of the brain pressure in E12.5 mouse embryos. For calibration, hydrostatic pressures of 0–500 Pa were generated by immersing the glass capillary tip in liquid at depths of 0–50 mm ($P = \rho gh$). A linear relationship emerged between the applied pressure (dp) and displacement (dx), given by $dx = 0.79 dp$ ($R^2 = 0.93$). For in vivo validation, the brain ventricular pressure in E12.5 mouse embryos was measured, with the dx averaging $996 \pm 79 \mu\text{m}$. This corresponded to 1260 ± 100 Pa, matching the reported values. These findings demonstrate that the device enables direct pressure measurement in multilayered tissues without using electrical components or immersion-based methods.



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sciforum-124268: Microfluidics-Guided Assembly of Fluorescent Nanodiamonds for High-Sensitivity Thermometry

Yoshikazu Hirai

Kyoto University

Fluorescent nanodiamonds (FNDs) containing a nitrogen-vacancy center have emerged as promising candidates for nanoscale temperature sensing because of their exceptional photostability and biocompatibility. However, achieving high sensitivity in thermometric applications requires precise control over the spatial arrangement of the FNDs to enhance the signal intensity and reduce background noise. In this study, a microfluidics-guided assembly method was devised to allow for the fabrication of vertically aggregated FND clusters on the target substrate in order to enhance the signal-to-noise ratio (SNR) and sensitivity. A polydimethylsiloxane (PDMS)-based microfluidic structure fabricated using multilayered soft lithography was used as a microfluidic template. The microfluidic template consisted of two layers—a pattern layer and a channel layer. The pattern layer, with a thickness of 40 μm , featured an array of through-holes, while the channel layer contained a 150- μm -high conduit for the introduction of the FND suspension. For example, this technique allows for the formation of FND clusters with diameters of approximately 10 μm , arranged at 20 μm intervals over millimeter-scale areas. The resulting arrays exhibit a significantly improved SNR, facilitating real-time temperature mapping with sub-kelvin-level sensitivity and accuracy. The microfluidic approach offers several advantages, including scalability, reproducibility, and compatibility with various substrates, making it suitable for integration into diverse sensing platforms. Potential applications span across fields such as microelectronics, where precise thermal monitoring is critical, and biological systems, where noninvasive temperature measurements at the cellular level are desired.



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sciforum-126752: On-Skin Bioelectronic Systems with Liquid Metal Microchannels for Electrophysiological Signal Monitoring

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Recent advances in soft electronics have enabled skin-conformable systems capable of high-fidelity electrophysiological signal monitoring during natural body motion. However, conventional wearable devices often suffer from mechanical mismatch with skin, causing discomfort, motion artifacts, or signal degradation, particularly during intense physical activity or at sensitive locations such as the palm or sole.

To address these limitations, we have developed ultrathin electronic films—termed "electronic nano-bandages"—based on conductive polymer nanosheets that adhere to the skin without adhesives. These devices achieve intimate contact with the epidermis and maintain stable electrical performance under mechanical deformation. By integrating kirigami-inspired stretchable wiring, we successfully realized a fully skin-conformable system capable of reliable electromyographic (EMG) monitoring during complex movements such as pitching.

Building upon this platform, we recently introduced liquid metal-based microchannel interconnects that provide both high electrical conductivity and mechanical compliance. These interconnects maintain stable function under large strains, enhancing the durability and usability of on-skin bioelectronic systems. This hybrid integration of ultrathin electrodes and liquid metal wiring represents a significant step toward practical and scalable lab-on-skin applications for electrophysiological monitoring.

In this presentation, we will introduce the materials design, device architecture, and experimental results of our latest systems, with a focus on the use of liquid metal microchannels to realize robust, stretchable, and skin-conformable bioelectronics for high-resolution and motion-tolerant recording of electrophysiological signals.



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sciforum-125841: Pioneering Nanofluidics for Next-Generation Chemical and Biological Sensing

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Nanofluidics, which investigates fluid behavior within nanoscale channels, offers a powerful platform for advancing chemical and biological sensing. Its ability to manipulate molecules with single-molecule precision opens new possibilities for detecting and controlling molecular interactions with exceptional accuracy [1–6]. These features position nanofluidics at the forefront of next-generation sensor technologies.

Despite its potential, the field faces critical challenges—most notably, the difficulty of integrating functional components into tiny nanofluidic channels, which hampers the development of fully controllable and versatile sensing devices. To overcome these limitations, our team has introduced a "Nano-in-Nano Integration" approach [7–12], establishing techniques for constructing functionalized nanochannels capable of precise fluid control, analyte manipulation, and real-time molecular detection [13–19].

In this presentation, I will highlight our recent progress in designing and fabricating nanofluidic devices specifically tailored for chemical and biological sensing. These advancements illustrate how nanofluidics can be engineered not only to understand molecular-scale phenomena but also to revolutionize sensing applications across chemical synthesis, healthcare, and diagnostics.

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Session 2. Biosensors and Biomedical Devices

sciforum-124827: Development of Electrochemiluminescence-based Biosensor using Nitrogen-doped Carbon Dots for Bisphenol A Detection

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This work reports the development of a sensitive and cost-effective electrochemiluminescence (ECL)-based biosensor for the detection of bisphenol A (BPA), utilizing nitrogen-doped carbon dots (NCDs) as luminophores. The NCDs were synthesized via a microwave-assisted pyrolysis method using citric acid and varying concentrations of urea to tune their nitrogen content. Characterization by UV-Vis spectroscopy, FTIR, EDX, and photoluminescence confirmed the successful incorporation of nitrogen and the modulation of surface functionalities that enhance ECL properties. ECL performance was evaluated using both bare and gold nanoparticle (AuNP)-modified screen-printed electrodes (SPEs), with potassium persulfate ($K_2S_2O_8$) as the co-reactant. The results showed that NCDs produced luminescence only through the co-reactant pathway and not via the annihilation pathway. The incorporation of KCl facilitated the generation of $SO_4^{\bullet-}$ radicals, promoting the formation of $CD^{\bullet-}$ intermediates and enhancing ECL intensity. Electrodeposition of AuNPs on the SPE further improved electron transfer kinetics, as evidenced by a more rapid reduction current, resulting in an 87.2% increase in ECL intensity and a 510 mV earlier onset of emission. These enhancements demonstrate the catalytic role of AuNPs in facilitating radical formation and improving ECL response. Under optimized conditions, the ECL intensity showed a linear decrease with increasing BPA concentrations in the range of 7.68 μM to 1.5 mM. The quenching effect was attributed to energy transfer between quinone species (oxidized BPA) and the light-emitting radicals. This ECL sensor exhibits excellent reproducibility, stability, and sensitivity, making it a promising platform for BPA detection in environmental and food safety applications.



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sciforum-124045: Enhancing sensitivity of Schottky contact biosensor by modulating interface property

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Nanomaterial-based field-effect transistors (nano-FETs) are pivotal bioelectronic devices that are employed for the detection of biomolecular signals, cellular interactions, and tissue responses within biosystems. The performance of these nano-FETs is significantly influenced by the interfacial characteristics between the metal electrodes and semiconductor nanomaterials, necessitating precise regulation. Here, Schottky barrier height (SBH) is successfully tuned by triboelectric nanogenerator (TENG) and magnetic field (MF)-induced piezotronic effect.

Through tuning SBH by TENG treatment, reversible conversion between Schottky contact and Ohmic contact can be realized, and a Schottky to Ohmic reversible (SOR) biosensor was developed for achieving higher sensitive detections of DA in Schottky-contact state and neural electric signal in Ohmic-contact state. The as-fabricated multifunctional SOR biosensor verified the feasibility of using just one device to detect multiple information.

By combining the principles of piezoelectric nano-FET biosensors with the flexibility of magnetic soft robots, a novel magnetically controllable piezoelectric device (MCPD) is designed. This allows for remote, precise, and stable modulation of SBH of the MCPD through the magnetic field. Consequently, this leads to enhanced sensitivity in the detection of biomolecules such as dopamine and the recording of neural electrical impulses. Furthermore, the unique structure of MCPD facilitates semi-invasive neural electrodes that can be brought into contact with the cerebral cortex only when required, thereby improving biocompatibility and reducing invasiveness. This innovation enables remote regulation, offering expanded utility in bioelectronic applications, such as implanted neural interface devices, and provides a potential strategy for the activation of implantable piezoelectric materials.



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sciforum-127397: Enzyme-based fluorometry for gas-imaging applications

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Hundreds of volatile organic compounds (VOCs) are released into the atmosphere from objects following the physical laws of permeation and diffusion. In humans, for example, acetone generated through lipid metabolism is present in the bloodstream and is further emitted from throughout the body via transdermal diffusion. Additionally, ethanol produced by spontaneous fermentation in ripe fruits is released through the epicarp. To understand the emission dynamics and sites of VOC release, it is essential to measure their concentration distribution. We have developed a system capable of selectively imaging the concentration distribution of target VOC components. The system detects VOCs utilizing the catalytic reactions of nicotinamide adenine dinucleotide (NAD)-dependent enzymes. Specifically, for imaging ethanol, alcohol dehydrogenase (ADH) is immobilized on a two-dimensional mesh and used by moistening it with NAD⁺. ADH catalyzes the reaction of ethanol and NAD⁺, producing acetaldehyde and NADH. NADH exhibits autofluorescence (excitation wavelength: 340 nm, emission wavelength: 490 nm). The concentration distribution of NADH reflects the location and activity of the ADH-catalyzed reaction on the two-dimensional mesh, and this reaction occurs specifically in the presence of ethanol. Furthermore, since NADH concentration correlates with fluorescence intensity, capturing the fluorescence intensity distribution of NADH on the mesh with a camera enables the observation of ethanol concentration distribution. In this presentation, we will introduce the developed biofluorescence-based gas imaging system and its applications.



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sciforum-125405: Label-free electrochemical aptasensor for sensitive detection of estradiol

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17 β -estradiol (E2), an important endocrine regulator, has an important impact on human physiological and reproductive health. The abnormal concentration of E2 may adversely affect the development and maintenance of the female reproductive system. Therefore, the sensitive and reliable detection of E2 concentration is essential for monitoring human endocrine health. In this study, a kind of label-free electrochemical aptamer sensor was developed for sensitive detection of estradiol. Such sensors can be electrodes in the form of microfluidic paper chips or electrodes integrated with microneedles. The specific recognition of estradiol was achieved by modifying the aptamer on the surface of the electrode, and the quantitative detection was achieved by such electrochemical methods. At the same time, nanocomposites such as carbon nanotubes, colloidal gold, or graphene colloidal gold were modified on the surface of the electrode to improve the detection sensitivity. The experimental results showed that the detection limit of the aptamer sensor based on microfluidic paper for estradiol was 5 pg/mL, and the detection value of clinical serum showed a good linear relationship with the detection value of the clinical immunoluminescence instrument. In order to determine the continuous monitoring of estradiol in interstitial fluid, the electrode was integrated with a microneedle, which could sample the substances in interstitial fluid minimally, and the quantitative detection of estradiol was determined by electrochemical impedance spectroscopy. The results showed that the linear response range of estradiol detection was 0.01 mg/mL to 0.06 mg/mL. This technology is expected to be extended to quantitative detection of glucose and tumor markers, and has a wide application prospect in clinical diagnosis and treatment. In the future, we will continue to explore the electrochemical aptamers for the sensitive detection of multiple parameters, including estradiol and other hormones.



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sciforum-121455: On-Site Screening of Salmonella in Food Using a Polydopamine-Based Lipopolysaccharide Imprinted Polymer

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Salmonella typhimurium (S.typhimurium) is a (commonly foodborne) pathogen that causes salmonellosis. Typical methods for detecting S.typhimurium are often time-consuming, including methods such as plating culture, ELISA, and PCR. In this study, we present a polydopamine-based S.typhimurium LPS-imprinted polymer sensor (SL-MIP) designed for simple on-site detection, which offers rapid detection capabilities, high sensitivity, and high selectivity. Polydopamine was used as the imprinting matrix because of its cost efficiency and functional versatility. By imprinting species-specific lipopolysaccharide (LPS), the sensor's selectivity can be enhanced while improving stability and reproducibility during fabrication. The detection performance of SL-MIP was evaluated by drop-casting it onto a screen-printed electrode, followed by differential pulse voltammetry (DPV) measurement. The fabricated sensor demonstrated a linear response for LPS concentrations ranging from 0.1 to 100 ug/mL, and a linear correlation for S.typhimurium in the range of 10^2 to 10^8 CFU/mL, with a detection limit of 10 CFU/mL. The specificity of the sensor was validated against other Gram-positive and Gram-negative bacteria and showed no significant cross-reactivity. Furthermore, the sensor exhibited high performance in detecting S.typhimurium in various real food samples, including tap water, milk, and meat, through direct sample loading without any preprocessing steps. The proposed sensor provides rapid, accurate, and selective on-site detection, making it a promising tool for food safety monitoring.



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sciforum-125454: A fluorescent probe for in situ imaging of hydrogen peroxide and sulfur dioxide in biological oxidative stress models

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The regulation of the dynamic balance between reactive oxygen species (ROS) and gaseous signaling molecules (e.g., SO_2) during oxidative stress is key to understanding the disease mechanism, but it is difficult for existing tools to achieve simultaneous and highly sensitive detection of H_2O_2 and SO_2 . Fluorescent probes, with their high sensitivity, high temporal and spatial resolution, and non-invasiveness, are expected to be an important tool for elucidating the onset mechanisms of diseases associated with oxidative stress through the fluorescence imaging of H_2O_2 and SO_2 . In this paper, C=C and phenylboronic acid pinacol ester were simultaneously introduced as the response sites for SO_2 and H_2O_2 , respectively, and the phototransfer mechanism (ICT) was utilized to modulate the fluorescence changes of the probe to achieve the fluorescence sensing of SO_2 and H_2O_2 in different channels. Compared with the existing probes for detecting H_2O_2 and SO_2 , the probe shows excellent optical performance in vitro and in vivo, with high selectivity, high sensitivity, a lower detection limit, and a faster response speed. In addition, the probe enabled the fluorescence imaging of endogenous and exogenous H_2O_2 and SO_2 in living cells and zebrafish. In addition, utilizing fluorescence imaging, this probe enables the dynamic monitoring of H_2O_2 and SO_2 in an oxidative stress model of drought stress in *Arabidopsis thaliana*. These superior characteristics of the probe endow it with great application potential in biological systems or in vivo related research.



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sciforum-125410: Automatic Localization of Seizure Onset Zone using Directed Transfer Function on Stereotactic Electroencephalogram

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Objective

Stereotactic electroencephalogram (SEEG) has been widely applied in clinical practice for further seizure onset zone (SOZ) localization. However, SEEG recordings are characterized by long-term, multi-channel, and low-quality results, making it challenging to localize SOZ through manual analysis of SEEG recordings. This is also because of lack of an effective method to determine target channels, which is the key to localizing SOZ.

Methods

We propose an SOZ localization method using SEEG signals recorded in the preoperative planning of surgical resection. Given that DTF can reliably reflect the connectivity between different regions of the brain, the DTF-based high-frequency information inflow images are generated, and CNN is utilized to determine the seizure segments in SEEG recordings. Then, high-frequency information outflow variation is proposed as a criterion to identify target channels for SOZ localization.

Results

The proposed method is applied to localize the SOZ of one focal epilepsy successful surgical resection patient. The results demonstrate that the determination of our method is basically consistent with the determination of clinicians and the performance of our proposed method is superior to the state-of-the-art method.

Conclusions

The proposed method can precisely determine target channels, which helps clinicians to automatically and effectively localize SOZ.

Significance

High-frequency information outflow based on DTF effectively localizes the critical region of epileptic seizures, which could potentially help in clinical SOZ localization.



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sciforum-123431: CMOS implants for at-scale brain machine interfaces

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The human brain contains billions of neurons, communicating via trillions of synapses. The ideal neural interface should offer at-scale, high resolution interactions with the brain while minimizing biological invasiveness. Despite tremendous progress, neural engineering and neuroscience have largely operated on an under-sampling regime, spatially, temporally, or both. This limits our ability to study the brain and hampers the effectiveness of many neurological therapeutics.

In this talk I will describe some of our efforts over the past decade in designing at-scale, CMOS microelectronic recording and stimulation neural interfaces, for applications across different timescales – from acute, ex vivo interfaces to chronic implantables for non-human primates, for a range of geometric modalities in the central nervous system – ranging from planar arrays, penetrating neural probes, and soft, optically transparent planar brain surface arrays.

In particular, we have been developing soft, electrophysiology arrays with foundry-grade CMOS (complementary metal-oxide semiconductor) microelectronics. Our devices significantly reduce invasiveness, improve usability for chronic experiments. Here, I will describe our 256-channel prototype brain surface recording and stimulation devices, with purpose-built CMOS integrated circuits and custom-made soft electrode arrays. These components are assembled using low-temperature flip-chip processes we refined in-house. These devices have the ability to record action potentials of individual neurons, and are also capable of electrical stimulation, to artificially elicit neuronal responses, offering the possibility of real-time, closed-loop scientific investigations and medical interventions in the cortex.



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sciforum-124436: Conical Nanopores for Enhanced Sensing Applications Engineered via Surface Modification

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Solid-state nanopores have become essential tools for biosensing, offering label-free, single-molecule detection with high sensitivity. However, conventional fabrication methods often lead to asymmetric pores, affecting both performance and reproducibility. In this study, we present a strategy to control nanopore symmetry and size through surface modification prior to dielectric breakdown. By introducing silane compounds with different surface charges, we demonstrate that the membrane's chemical environment plays a key role in shaping the local electric field during nanopore formation. Experimental data, supported by all-atom molecular dynamics simulations, reveal that charged silanes can guide pore opening and improve structural uniformity. Additionally, this approach enables the fabrication of conical nanopores, which enhance ionic selectivity and molecular transport. The unique geometry of these nanopores facilitates controlled translocation dynamics, improving molecular recognition and signal resolution. Electrical measurements confirm that these conical nanopores offer greater sensitivity in detecting biomolecules such as DNA and proteins compared to conventional cylindrical pores. Moreover, the tunability of pore size and charge distribution achieved through this method allows for optimized sensing performance across a range of analytes. Our findings provide a reliable and scalable method for tuning nanopore properties, paving the way for more precise and efficient biosensing applications, particularly in medical diagnostics, environmental monitoring, and biomolecular analysis.



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sciforum-125166: Dual-Modal PtNPs/PEDOT-rGO Microelectrode Arrays Reveals Synergistic Encoding of Social-Related Neurons and Dopamine

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Background

The exploration of neural mechanisms underlying social behavior requires advanced tools that can monitor complex brain activities in dynamic environments. Our development of a microelectrode array (MEA) aims to address this need by enabling the simultaneous detection of neuronal firing and dopamine levels in behaving animals. This technological advancement provides a pivotal means to study the entwined processes of environmental perception and social interactions.

Objective

By integrating real-time neurophysiological recordings with behavioral analyses, our goal is to decode the complex neural circuits that govern social behavior and cognitive function.

Methods

Utilizing microelectromechanical systems (MEMS) technology, we fabricated a multi-site silicon-based MEA that incorporates both electrophysiological and electrochemical dopamine detection sites. The surface of the MEA was modified with platinum nanoparticles (PtNPs) and poly(3,4-ethylenedioxythiophene) (PEDOT) with reduced graphene oxide (rGO) layered with to decrease electrophysiological impedance and enhance the catalytic activity for dopamine. This MEA was implanted in the medial entorhinal cortex of freely moving mice. Neural discharges and dopamine signals were systematically collected under both social and nonsocial stimuli to analyze the neural dynamics of social cognition.

Results and Conclusions

The PtNPs/PEDOT-rGO modified MEA successfully captured high-resolution signals of neuronal firing and dopamine levels. We identified a subset of neurons, termed "social-related cells," which showed intensified activity near social landmarks. Concurrently, we observed elevated dopamine levels in these areas, suggesting a synergistic encoding of social cues. The patterns of neuronal and dopamine responses were analyzed to determine their role in spatial and social recognition.



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sciforum-129121: Electrochemiluminescent Biosensors Using Printed Electrodes and Mobile Diagnostic Devices and Their Biomedical Applications

Eiichi Tamiya

Osaka University

We have developed electrochemiluminescent biosensors using printed electrodes and mobile devices. Luminol and Ru(bpy)₃ were used as the electrochemiluminescent system. The former (luminol) emits light in response to the hydrogen peroxide generated by oxidase, while the latter (Ru(bpy)₃) emits light in response to NADH bound to dehydrogenase. Therefore, this system is applicable to diagnostics that utilize oxidase or dehydrogenase. We enzymatically decomposed glycated albumin, a diagnostic marker for diabetes, into glycated amino acids and then measured them using luminol electrochemical luminescence with fructoamino oxidase. As a result, while blood samples require 100 times the sensitivity required for measurements in saliva, this highly sensitive electrochemical luminescence system enabled measurements (Anal. Chem. 89, 5909 (2017)). Additionally, we successfully implemented electrochemical luminescence digital imaging by arranging catalase-enzyme-immobilized particles in a microchamber array (Electrochim. Acta, 240, 447 (2017)). We first demonstrated that gold nanoparticles enhance the electrochemical luminescence when treated with tris reagents and applied this to biosensor applications (Anal. Chem. 90, 57738 (2018) Electroanalysis, 34, 8 (2022)). Our electrochemical luminescence system was also used to measure antioxidant active substances, enabling rapid measurements of antioxidant substances in various beverages (Electrochim. Acta, 222, 580 (2016)). It was also applied to diagnosing the antioxidant activity in saliva (Biosensors 13,167 (2023)). The ROS generation by neutrophils was monitored in real time (Chem. Lett. 47, 1337 (2018)). We developed a wireless biosensor that enabled electrochemical luminescence imaging sensing using a smartphone camera by inducing electrochemical luminescence without a battery via a wireless power supply. This method can be used in an IoT biosensor device, enabling measurements at home. Furthermore, it can also be applied as a remote diagnostic tool (Biosens. Bioelectron. 252, 116083 (2024)).



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sciforum-138650: Engineering High Signal-to-Noise Performance in TiO₂/rGO FET Biosensors through Precise Control of Annealing and rGO Content

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The signal-to-noise (S/N) ratio is a crucial metric determining the sensitivity and reliability of field effect transistor (FET) biosensors in practical applications. In this study, TiO₂/reduced graphene oxide (rGO) nanocomposite films were synthesized via the sol-gel method, enabling uniform distribution of rGO and fine control over material purity and morphology. The sol-gel approach facilitated the formation of smooth, homogenous films suitable for FET integration. rGO was incorporated at weight ratios of 0%, 0.1%, 0.5%, 1.0% and 3.0%, followed by thermal annealing at temperatures ranging from 300 °C to 800 °C for 30 to 90 minutes. Electrical characterization revealed a clear dependence of S/N performance on both material composition and thermal treatment. The optimal condition—300 °C for 30 minutes with 0.5% rGO—yielded the highest S/N ratio, attributed to enhanced crystallinity, reduced defect density, and improved carrier mobility in the active layer. Adopting a “larger-the-better” approach to S/N optimization highlighted the importance of maximizing signal strength while minimizing background noise. Excessive rGO or over-annealing, however, introduced structural disorder and elevated noise levels. This work underscores the importance of precise material engineering and process optimization in achieving high-performance, low-noise FET biosensors for DNA sensing and broader biomedical applications, in real-world clinical and environmental robust diagnostic settings globally deployed confirmed through extensive real-world testing.



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sciforum-125646: Enhancing the Sensitivity, Selectivity, and Sustainability of Nanotechnology-Driven Biosensors

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The integration of nanotechnology into biosensor design has opened new pathways for ultra-sensitive and highly selective molecular detection. This work explores how engineered nanostructures and smart surface modifications drive major performance gains in electrochemical biosensors. We compared traditional enzyme-based systems with nanomaterial-enhanced designs, focusing on optimized enzyme immobilization and detection parameters to improve stability and selectivity.

Key nanomaterials—graphene (G), carbon nanotubes (CNTs), and NiCo_2O_4 —were used to enhance electron transfer and catalytic activity in sensor platforms. Gold nanoparticles (AuNPs), synthesized chemically and biologically, were assessed for their enzyme-mimetic (nanozyme) and antioxidant properties. For thyroxine detection, CNT-based sensors achieved a detection limit of 23 nM, while integrating NiCo_2O_4 on graphene oxide platforms further improved sensitivity, lowering the limit to 6.1 pM. Additionally, biologically derived AuNPs enabled efficient H_2O_2 detection, retaining the antioxidant traits of their plant-based origin and offering a sustainable, biocompatible alternative for oxidative stress sensing via H_2O_2 quenching.

Our results demonstrate that nanostructured electrochemical biosensors not only enhance analytical performance but also support real-world diagnostic applications. This work underlines the promise of nanostructured materials in shaping the future of point-of-care sensing technologies, combining efficiency, sustainability, and clinical relevance.

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sciforum-122072: Flow control in microfluidic paper-based analytical devices using valves made with a thermoresponsive polymer

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Microfluidic paper-based analytical devices (μ PADs) are expected to be point-of-care testing (POCT) devices, since they have various advantages such as their low cost, ease of use, and easy fabrication. However, it is difficult to use them to perform complex immunoassays, for example, enzyme-linked immunosorbent assay (ELISA), because flow control in μ PADs is difficult. To resolve this challenge, we developed a controllable thermoresponsive valve for μ PADs. N-isopropylacrylamide (NIPAAm), which is a thermoresponsive polymer that changes its hydrophilic/hydrophobic properties at the lower critical solution temperature (LCST; 32 °C), was polymerized in a porous polyvinylidene difluoride membrane by plasma-induced graft polymerization. Below the LCST, PNIPAAm swells and closes the pores of the PVDF membrane, stopping the flow in the paper channel. On the other hand, above the LCST, PNIPAAm shrinks and opens the pores of the PVDF membrane, and fluid can pass through the valve. We evaluated the performance of the thermoresponsive valve by placing a valve in each of multiple branching channels to control the flow of multiple reagents into the reaction area. The temperature of the valve was controlled using Peltier elements placed under the valve. As a result, we succeeded in introducing multiple reagents to the reaction area in order. This result suggests that the thermoresponsive valve enables complex immunoassays such as ELISA using μ PADs.



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sciforum-132449: High speed optical tomographic imaging for biomedical applications based on MEMS technology

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Optical coherence tomography (OCT) is a non-invasive optical imaging technology that can provide real-time and two- or three-dimensional information about the sample architecture based on intrinsic optical scattering contrast. The emergence of the second generation of OCT with so-called Fourier-domain interferometry has revolutionized OCT in biomedical applications, leveraging the increased imaging speed and detection sensitivity and the reduced system complexity by adding the functional information of the imaging tissue, for example, the OCT angiography (OCTA), and polarization-sensitive OCT (PS-OCT). These functional extensions of OCT have further facilitated the exploration of OCT in various applications. However, to meet the challenges of these new applications, either the hardware, for example, the light source used in the OCT system, or the software of the OCT technology needs to be improved. In this talk, I am going to share some of our recent work on high-speed OCT imaging with a newly developed MEMS-tunable wavelength-swept laser. Also, thanks to the long coherence of the light source, it allows long-range imaging, for example, full-eye imaging. Lastly, leveraging the MEMS technology, we have developed various handheld imaging devices, allowing volumetric imaging of different sites of the human skin or even the middle ear. The developed imaging device could provide quantitative analysis of human skin conditions by combining AI algorithms.



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sciforum-122617: MMP-9 and IL-6 biomarkers are detected using a biosensor based on Au-IDEs for the quick diagnosis of sepsis

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Sepsis is a worldwide health concern, resulting in high mortality and morbidity rates worldwide. During the acute phase of sepsis, cytokines, which upregulate the immune response are released in large quantities; this can, in turn, promote infectious complications. Sepsis patients are more likely to survive if they receive appropriate therapies and antibiotics early in the disease process. Diagnostic delays are associated with both delayed and prolonged treatment. Developing reliable, predictive methods for recognizing sepsis is urgently needed; these techniques would assist clinicians in identifying patients at risk. We urgently need low-cost and fast sepsis testing. We predict a novel diagnostic tool non-faradaic **detection of MMP-9 and IL-6 Biosensors in patients with Sepsis**, to monitor and promote sepsis within 10 min. **Au-IDEs** were employed with cysteamine glutaraldehyde layer due to the **MMP-9 antibody and IL-6 antibody binding**. Moreover, we supported our data by performing a **Westron Blot and ELISA**. As a result, non-radaic **MMP-9 and IL-6 biosensors** present a promising screen test for sepsis patients. By improving the health care system, these biosensors can contribute to the reduction of mortality and morbidity in sepsis patients, and assist in improving their quality of life by improving their quality of life with a rapid, cheap diagnosis.



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sciforum-124789: MR compatible sensors for a focused ultrasound robotic system for brain cancer.

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Background

MR compatible sensors are needed in order to move accurately a magnetic resonance image (MRI) guided robotic system dedicated for brain cancer. The robotic system carries a compact spherically focused, single element, ultrasonic transducer. The intended use of this robotic device is the thermal ablation of tumours in the brain.

Materials and Methods

The developed robotic device utilizes three computer-controlled axes. An agar-based phantom was developed to evaluate the motion of the robotic system. MR compatible encoders were developed to monitor the motion of the robotic system. Experiments with the system were performed in a 3 T MRI system using the agar-based phantom. The transducer has a diameter of 50 mm, operates with 1 MHz, and focuses energy at 65 mm.

Results

The accuracy of the robot was assessed by means of high-resolution MR pulse sequences, demonstrating accurate motion of the robotic device. The evaluation was performed in the MRI by producing lesions in the agar-based phantom, in a thin plastic film and by moving a plastic thin rod attached to the robotic arm.

Conclusions

A functional MRI guided robotic system was produced which moves accurately due the optical sensor used (encoder). The intention is to use the proposed device clinically for treating brain cancer using focused ultrasound.



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sciforum-131601: Multi-Modal and Multi-Channel Sensing Platform for Rapid, Multiplexed Pathogen Detection

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Conventional pathogen detection methods often face limitations in speed, sensitivity, multiplexing capability, and field applicability. This study presents a novel rapid detection platform integrating multi-channel and multi-modal sensing strategies to overcome these challenges. We developed innovative plasmonic nanostructures and advanced fluorescent materials as highly efficient labeling agents, significantly enhancing signal generation and stability. By constructing multifunctional nanoprobe with different structures and different components, the platform uniquely combines multiple detection modalities, including colorimetry for direct visual observation by the naked eye, color amplification for enzyme-catalyzed mimicry, photothermal imaging for label-free quantification, surface-enhanced Raman scattering (SERS) for fingerprint specificity, and ratiometric fluorescence for sensitive signal readout. Crucially, this system enables simultaneous multi-channel detection of diverse pathogen targets within a single assay, drastically improving throughput and diagnostic efficiency. Furthermore, artificial intelligence (AI) algorithms were integrated to analyze the complex multi-modal data streams. The AI component aids in robust pattern recognition, significantly reducing background interference, automating result interpretation, and enhancing detection accuracy and reliability. The synergy of advanced nanomaterials, multi-modal sensing, parallel multi-channel detection, and AI-powered data analysis resulted in a rapid, highly sensitive, and user-friendly platform. This integrated approach holds significant promise for point-of-care testing (POCT) and effective surveillance of infectious diseases, particularly in resource-limited settings.



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sciforum-125404: Multifunctional Trimer Nanoparticle Synthesis Based on Lattice Mismatch for Multi-mode Identification of Multiple Bacteria

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Multi-functional multi-component nanoparticles can combine the intrinsic properties of each component and as create synergistic effects at interfaces, which will lead to better performance and new applications. In this work, we synthesized multifunctional M_1 -Au M_2 -Fe₃O₄ trimer nanoparticles (M_1 = Au, Ag; M_2 = Pt, Pd, Ir, Rh) based on the lattice mismatch method. The introduction of the lattice-mismatched metal M_2 (Pt, Pd, Ir and Rh) can increase the interfacial energy of the seed surface and break the conformal growth between lattice-matched metal to construct nanoparticles with special morphologies. This trimeric structure can integrate the localized surface plasmon resonance effect of Au or Ag, the catalytic properties of platinum metals and the magnetic properties of Fe₃O₄. Subsequently, we used 4-mercaptophenylboronic acid to prepare non-specific recognition probes and applied them in the identification of multiple food-borne pathogenic bacteria. These probes bound to cis-dihydroxyl groups in the bacterial wall via covalent bonding and can inhibit assembly caused by high concentrations of NaCl. Since the quantity of cis-dihydroxyl groups on the surface of different bacteria varies and the number of bound probes differs among individual bacteria, magnetic separation of the probes after capturing the bacteria led to dissimilar amounts of probes in the supernatant and the precipitates. By analyzing the UV-vis and Raman signals of the supernatant and the photothermal signals of the precipitates, multi-modal discrimination of multiple bacteria was achieved with the help of the linear discriminant analysis method. This method serves as a guide for the preparation of polymeric nanoparticles and provides new ideas for the simultaneous multi-mode detection of multiple targets.



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sciforum-121841: Nanovesicle-based ultrasensitive biosensor for Drug discovery of CB1 receptor

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The endocannabinoid system, particularly cannabinoid receptor 1 (CB1), plays a vital role in regulating numerous physiological processes such as pain perception, mood, appetite, and neurodegeneration. Given its central function, CB1 has emerged as a promising target for therapeutic interventions for a wide range of neurological and psychiatric disorders. However, conventional methods for detecting CB1 activity, including calcium imaging and patch-clamp electrophysiology, are limited in sensitivity and typically detect drug concentrations only in the nanomolar to micromolar range. This limitation underscores the urgent need for more sensitive and scalable drug screening platforms. To address this, we developed an ultrasensitive biosensor that integrates cell-derived CB1 nanovesicles (CB1-NVs) with carbon nanotube (CNT)-printed electrodes. This sensor enables the detection of cannabinoid compounds at picomolar concentrations by transducing the receptor-mediated Ca^{2+} influx into quantifiable electrical signals. The CB1-NV sensor exhibited exceptional sensitivity, successfully detecting trace amounts of tetrahydrocannabinol (THC, $\sim 0.001\%$) in hemp seed oil—a level undetectable by conventional methods. Remarkably, it demonstrated an improvement of over 1,000-fold in sensitivity compared to traditional techniques. Moreover, by employing CB1-NVs, this system maintains key aspects of the cellular signaling environment without relying on live cells, eliminating the need for cell maintenance and improving operational stability. This approach offers a powerful and practical platform for drug discovery.



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sciforum-121945: Non-Contact Colorimetric Sensor for Rapid Pre-Screening of Urinary Tract Infection

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Urinary tract infections (UTIs) are among the most common infectious diseases, necessitating efficient and non-invasive diagnostic tools, particularly in scenarios where traditional sample collection methods are challenging. This study presents the development of a non-contact colorimetric sensor capable of detecting volatile organic compounds (VOCs) produced by UTI pathogens, specifically targeting *E. coli*, the most prevalent causative agent of UTIs. By employing bromocresol green as the primary pH-sensitive dye, the sensor demonstrated significant ΔE changes in response to *E. coli*, enabling rapid pre-screening. To further enhance the specificity and stability of the sensor, Nafion was incorporated. This modification conferred resistance to environmental impurities, such as ammonia, and optimized the sensor's performance for practical applications. The sensor's responsiveness to pH variations, VOCs, and ammonia was evaluated through a series of controlled experiments. The sensor's practical utility was demonstrated in diagnostic kits and diaper-integrated systems, employing a two-stripe method that reliably differentiated between normal urine and *E. coli* contaminated samples. The uncoated strip exhibited a color change in response to normal urine, while both coated and uncoated strips responded to *E. coli* contaminated urine, thereby enabling enhanced infection detection. Imaging techniques were employed to analyze sensor responses, converting RGB data into the perceptually uniform CIE-LAB color space, allowing for the precise quantification of color differences. FT-IR analysis further validated the sensor's interaction with VOCs and microorganisms, confirming its robustness and reliability. This study underscores the potential of non-contact colorimetric sensor technology as a rapid, cost-effective, and non-invasive pre-screening tool for UTIs. By facilitating early detection, this approach holds significant promise for improving diagnostic accessibility and reducing healthcare burdens in both clinical and resource-limited settings.



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sciforum-138746: Optical Characterization of Lignocaine-impregnated Maltose-based Dissolvable Microneedles

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The application of dissolvable microneedles (DMNs) in medicine demonstrates the necessity of effective medical methods of drug delivery and patient-friendly drug delivery approaches. This study focuses on the fabrication and characterization of DMNs based on a maltose-polymer mixture loaded with lignocaine as a drug of local anaesthetic. The methodology encompassed processes from the raw material until the development of the microneedle. DMNs were fabricated using via a micro-moulding technique incorporating lignocaine into the mixture before the casting process and undergoing a drying process for a period of 9 hours. The optical characterization uses the Field Emission Scanning Electron Microscopy (FESEM) to evaluate the geometry and surface smoothness of the microneedle. CLSM verified the uniform presence and distribution of lignocaine within the microneedle matrix. Additionally, the FESEM images confirmed the well-formed microneedle structure along with smooth surfaces, sharp tips, and consistent dimensions (average height $\pm 435 \mu\text{m}$, width $\pm 116 \mu\text{m}$), indicating uniform fabrication. While FESEM and CLSM confirm their structural integrity and drug loading, future work will focus on evaluating the mechanical strength and in-vitro dissolution kinetics to evaluate the potential. The preliminary findings indicate that the potential of dissolvable microneedles for safe and effective approach in drug delivery particularly for applications where localized anaesthesia is beneficial.



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sciforum-127608: Optical Nanomaterials as Frequency Converters for Imaging and Sensing

Xiaogang Liu

National University of Singapore

Imaging technology has revolutionized our understanding of the world, from medical diagnosis to astronomical exploration. Advancements in imaging tools have led to significant breakthroughs across various sectors. The field continually evolves, with technologies like lanthanide doping in optical nanomaterials emerging as a promising research area. This technique aims to improve image resolution and open up new application possibilities. Lanthanide-doped nanoparticles exhibit unique luminescence properties, including massive Stokes shift, sharp emission bandwidth, and high resistance to optical blinking and photobleaching. They are also unique in that they can convert long-wavelength stimulation to short-wavelength emission. These properties offer the opportunity of developing alternative luminescent markers to organic fluorophores and quantum dots. In recent years, researchers have demonstrated the use of spectral-conversion nanocrystals for many biological applications, such as highly-sensitive detections of molecules and autofluorescence-free imaging. With significant advances over the past decade, we can now design and fabricate nanoparticles that exhibit tailored optical properties. In particular, by rationally controlling different combinations of dopants and dopant concentrations, we can produce a plethora of colors upon excitation with a single wavelength. By incorporating a series of lanthanide ions in defined concentrations into different layers of a core-shell structure, we have expanded the emission spectra of the particles to cover almost the entire visible range, which is not possible for conventional bulk phosphors. In this talk, I will highlight recent advances in the broad use of lanthanide-based nanocrystals for multimodal imaging, bio-detection, therapy, 3D volumetric display, X-ray scintillation and nanophotonics, as well as assistive technologies.



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sciforum-126698: Predicting Blood Pressures for Pregnant Women by PPG and Personalized Deep Learning

Paul C.-P. Chao

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—Blood pressure (BP) is predicted by this effort based on photoplethysmography (PPG) data to provide effective pre-warning of possible preeclampsia of pregnant women. Towards frequent BP measurement, a PPG sensor device is utilized in this study as a solution to offer continuous, cuffless blood pressure monitoring frequently for pregnant women. PPG data were collected using a flexible sensor patch from the wrist arteries of 194 subjects, which included 154 normal individuals and 40 pregnant women. Deep-learning models in 3 stages were built and trained to predict BP. The first stage involves developing a baseline deep-learning BP model using a dataset from common subjects. In the 2nd stage, this model was fine-tuned with data from pregnant women, using a 1-Dimensional Convolutional Neural Network (1D-CNN) with Convolutional Block Attention Module (CBAMs), followed by bi-directional Gated Recurrent Units (GRUs) layers and attention layers. The fine-tuned model results in a meanerror (ME) of -1.40 ± 7.15 (standard deviation, SD) for systolic blood pressure (SBP) and -0.44 (ME) ± 5.06 (SD) for diastolic blood pressure (DBP). At the final stage is the personalization for individual pregnant women using transfer learning again, enhancing further the model accuracy to -0.17 (ME) ± 1.45 (SD) for SBP and 0.27 (ME) ± 0.64 (SD) for DBP showing a promising solution for continuous, noninvasive BP monitoring in precision by the proposed 3 stage of modeling, fine-tuning and personalization.



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sciforum-138770: Process Optimization of Maltose-based Microneedles for Anesthetic Delivery using Taguchi Method

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Dissolvable microneedles (DMNs) are a promising solution for minimally invasive transdermal drug delivery, particularly in anesthetic applications. However, balancing mechanical strength is essential for clinical viability to ensure the device withstands physiological loads (compression, tension, cyclic fatigue) without failure or excessive deformation. Additionally, fabrication efficiency encompasses build speed, material utilization, energy consumption, tooling complexity, and overall cost per part. This study utilized a Taguchi L9 (3³) orthogonal array to optimize three fabrication parameters—centrifugation time (20, 40, 60 min), centrifugal force (348.5, 750.1, 993.3 ×g), and oven drying time (300, 420, 540 min)—for maltose-based DMNs produced via mould casting. Mechanical strength was assessed through nanoindentation, and the results were analyzed using the signal-to-noise (S/N) ratio approach under the "larger-the-better" criterion. The optimum parameter combination was identified at 40 minutes centrifuge time, 993.3 ×g centrifugal force, and 420 minutes oven time, yielding the highest hardness of 0.00318 GPa with an S/N ratio of −49.95 dB. In contrast, the lowest strength was observed at 20 minutes centrifuge time, 750.1 ×g, and 420 minutes oven time, with a hardness of 0.00113 GPa and an S/N ratio of −58.94 dB. The results confirm that increased centrifugal force and a balanced drying duration significantly enhance microneedle strength. This work provides a reliable pathway for efficient fabrication of mechanically robust DMNs suitable for anesthetic drug delivery.



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sciforum-125347: Revolutionizing Point-of-Care Diagnostics: A Daylight-Driven Zero-Background Phosphorescent Lateral Flow Assay Enabled by Solid Silica-Encapsulated Carbon Dots

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In this study, a daylight-excited zero-background phosphorescent test strip was developed for the first time. Solid Silica-Encapsulated Carbon Dots (SSE-CDs) were developed as a new type of phosphorescent labeling probe. This system has solved bottlenecks like the insufficient sensitivity of the colorimetric method, background fluorescence interference of the fluorescence method, and the reliance of traditional phosphorescence technology on ultraviolet light sources. SSE-CDs can store photon energy after being excited by sunlight through band regulation. After sunlight exposure, their lattice defect states can store photon energy and release yellow afterglow for up to 20 seconds, while the afterglow time of the chromatographic test strips constructed based on SSE-CDs is stably maintained for more than 5 seconds. Through the precise regulation of the trap energy level depth, the material can achieve a light energy storage efficiency of 94% at room temperature, completely getting rid of the limitation of ultraviolet excitation. Combined with time-resolved imaging technology, this test strip effectively avoids the autofluorescence interference of protein/hemoglobin, and the signal-to-noise comparison fluorescence method is improved by 28 times. The accelerated aging test shows that the signal attenuation rate of the test strip is less than 5% within 30 days, significantly improving the stability compared with the traditional ultraviolet-excited phosphorescent material. In the performance verification, its detection limit for the inflammatory marker procalcitonin (PCT) reached 0.08 pM, respectively. The actual sample recovery rate was 92.3-107.8%, and the inter-batch coefficient of variation was less than 4.8%. This research provides an innovative detection platform with high sensitivity, strong anti-interference ability, and no need for external optical instruments for the field of real-time detection, demonstrating significant application value in scenarios such as the early diagnosis of sepsis and on-site monitoring of environmental pollutants.



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sciforum-121594: Self-Powered Medical Devices

Zhou LI

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Electrical activity is fundamental to human biological functions. By regulating electrical activity, we can alter the excitation and inhibition states of cells, tissues, and organs, thereby achieving disease treatment. Nanogenerators are a new type of energy conversion device that can convert low-frequency mechanical energy into electrical energy. Due to the diverse and flexible structures, a wide range of selectable materials, and high output voltage, nanogenerators offer novel approaches for developing self-powered medical devices. Our research has developed several innovative systems based on this technology: 1. Self-powered cardiac pacemakers powered by heartbeat-derived energy, which can operate long-term, and for the first time, conducted large animal experiments to enhance heart rates and treat arrhythmias. 2. Fully biodegradable self-powered electrical stimulation devices which directionally guide neural growth, enhance cardiomyocyte electrical coupling, promote osteogenesis, and accelerate wound healing before complete biosorption post-therapy. 3. Closed-loop self-powered LL-VNS system that can monitor the patient's pulse wave status in real time and conduct stimulation impulses automatically during the development of atrial fibrillation with minimizing neurological side effects. 4. Minimally invasive implantable biosensors with exceptional biocompatibility for continuous cardiovascular monitoring. These studies focus on self-powered electronic medical devices and electrical stimulation therapy, holding significant potential for transformation into clinically usable electronic medical devices and sensors.



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sciforum-123641: Single-Cell Detection and Microsensors

Jian Chen

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Single-cell detection has emerged as a transformative tool in both fundamental biological research and clinical diagnostics. At the forefront of global scientific innovation, it enables detailed analysis of tumor heterogeneity and cellular biology, with more than 150 studies published in top-tier journals (Cell, Nature, Science) over the past five years. In the realm of healthcare, it plays a crucial role in precision medicine, particularly in whole-blood analysis and the diagnosis of hematologic malignancies. However, a major technological challenge persists: the inability to rapidly quantify key physicochemical properties of individual cells—such as electrical, mechanical, and protein expression features. This limitation stems from an incomplete understanding of the quantitative relationships between these properties and cell classification or disease subtyping, thus impeding progress in oncology and hematology.

To address this challenge, a decade-long research effort has pioneered a MEMS-based "constrictional microchannel" platform capable of enabling high-throughput quantification of single-cell biophysical and biochemical characteristics. The fundamental principles for detecting single-cell electrical, mechanical, and proteomic profiles have been established, and, for the first time, their quantitative correlations with peripheral blood leukocyte differential and acute leukemia subtypes have been revealed. This breakthrough not only enhances the understanding of single-cell behavior but also provides a robust and scalable platform for next-generation diagnostics and therapeutic monitoring, effectively bridging the gap between biophysical research and clinical translation.



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sciforum-127215: Stimulated Raman scattering tomography for label-free dynamic and functional imaging of live cells and tissues

Zhiwei Huang

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Stimulated Raman Scattering (SRS) microscopy is an appealing vibrational spectroscopic imaging technique for label-free molecular imaging of live tissues and cells with high biochemical specificity and sensitivity. Conventional SRS microscopy uses tightly focused Gaussian beams to excite the tissue samples. These suffer from strong light scattering in turbid media (e.g., tissue), resulting in a very limited penetration depth, which is not suitable for acquiring volumetric deep tissue images. Here, we present a unique z-coded SRS tomography (SRST) technique for dynamic and functional biomolecular 3D imaging in time- and frequency-domains. In SRST, Bessel excitation beams are generated to enhance the imaging penetration depth, while the time- or frequency-domain encoding approach enables us to retrieve the depth information without the need for mechanical z-scanning for SRST 3D biomolecular imaging. SRST provides an over 2- to 3-fold improvement in penetration depth in highly scattering media as compared to conventional point-scan SRS microscopy. SRST has also proven useful in monitoring the pharmacodynamic and metabolic imaging of live cells, biofilm, and small animal models. The z-scanning free optical sectioning ability developed in SRST is universal and can be readily extended to any other optical imaging modality for advancing 3D tissue and cell imaging in biological and biomedical systems.



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sciforum-119606: Using rational in silico design to develop peptide-based sensors for detection of bacteria

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Biosensors are devices that detect and measure target molecules, such as bacteria, with applications in various industries, including food safety. Biosensor effectiveness relies on biorecognition elements—such as antibodies, bacteriophages, enzymes, DNAszymes, peptide nucleic acids, aptamers, receptor proteins, and peptides—to interact specifically with the analyte, triggering a catalytic or binding event. This interaction is then transduced into a measurable signal by the transduction platform. Peptide-based biorecognition elements offer many advantages, including high stability compared to other biomolecules and facile synthesis via solid-phase peptide methods. This can make them low-cost, scalable, and customizable with chemical groups for selective functionalization.

The use of peptides in biosensors has been found to achieve selectivity, allowing the sensor to distinguish between various types of bacteria. This is similar to the 'lock and key' analogy, where peptides bind with different strengths to bacterial cell walls due to variations in bacterial lipid II structures. These variations can be taken advantage of to develop in silico protocols to design more specific peptides for the recognition of foodborne bacteria in a cost-effective manner. Based on this, we developed an in silico approach to enhance the sensitivity of peptide-based biorecognition elements. This approach involves high-throughput computational screening, significantly reducing both time and cost compared to traditional lab methods. The first step of our approach consists of generating peptide candidates inspired by the original sequence of a previously identified peptide-based biorecognition element. The peptide candidates are evaluated based on their affinity to the bacteria and the stability of the complex they form upon binding. The molecular docking of the peptide candidates is used to determine affinity, and molecular dynamics are used to determine stability. The results show that this in silico protocol could develop peptides with higher affinity compared to the parent peptide and achieve a significantly lower detection limit.



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sciforum-122084: Utilization of plant microstructure as a straightforward lab-on-a-chip for rabies virus detection

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Plant microstructures are remarkable microarchitectures. In particular, the tracheary elements, which facilitate water transport, are lightweight yet efficient in low-energy microfluidic transport and offer good biocompatibility. Consequently, we developed a plant microstructure-based laboratory-on-a-chip assay for the rapid detection of the rabies virus. The chip unit was simply fabricated using a tracheary element from the desiccated leaf of the resin tree (*Dipterocarpus alatus* Roxb. ex G.Don), glass fiber, and plastic lamination. This was partitioned into two segments: one for isothermal nucleic acid amplification and the other for signal detection. The rabies test entailed the specific amplification of the nucleoprotein (N) gene via RT-RAA (reverse-transcription recombinase aided amplification), with cDNA signals detection achieved through colorimetric changes in 20 nm gold nanoparticles (AuNPs). Positive results caused dispersal of the ruby red AuNPs on the glass fiber pad, whereas negative results induced colorimetric changes in the AuNPs on the pad, from ruby red to purple, due to salt-induced aggregation. The assay exhibited a detection limit of 100 copies of the target nucleoprotein gene and showed great specificity compared to other types of infectious viruses. The assay required merely 40 minutes to finalize and incurred a cost of USD 5 per test. This study demonstrates a straightforward and rapid assay for viruses via a cost-effective, plant microstructure-based lab-on-a-chip platform.



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Session 3. In-Body IoT Sensing Technology, Electroceuticals and Neural Interfaces

sciforum-125458: Tracking of Dopamine Dynamics and Cellular-Level Electrophysiological Activity during Different Sleep Stages

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Understanding the neurochemical and electrophysiological basis of sleep regulation requires tools capable of capturing dynamic, in situ changes in neural activity with high temporal and spatial resolution. In this study, we developed targeted modified microelectrode arrays (TM MEAs) to enable real-time, simultaneous detection of cellular-level electrophysiological and neurotransmitter signals in the brain during natural sleep–wake cycles. The biosensing platform integrates a three-electrode configuration: PtNPs/PEDOT:PSS-modified sites for electrophysiological signal acquisition, PtNPs/PEDOT:PSS/Nafion-coated electrodes for selective dopamine detection, and an IrOx-modified reference electrode to ensure low noise and minimal signal interference. This design enhances stability and selectivity while effectively reducing crosstalk between sensing modalities. Implanted in the nucleus accumbens (NAc)—a key region involved in arousal and motivation—TM MEAs were used in conjunction with electroencephalogram (EEG) and electromyogram (EMG) recordings to track brain state transitions. The system successfully distinguished sleep stages and revealed three distinct neuronal spike types, including a subset of REM-related neurons. Notably, electrophysiological signatures from local field potentials (LFPs) and the EEG varied significantly between wakefulness and sleep states, and dopamine levels exhibited state-dependent fluctuations, being highest during wakefulness and lowest in non-rapid eye movement (NREM) sleep. These results provide new insights into the interplay between dopaminergic signaling and neural activity across sleep states. Our findings demonstrate that TM MEAs serve as an advanced biosensing platform for decoding the neural substrates of sleep regulation. This work establishes a novel avenue for integrating neurotransmitter and electrophysiological measurements in vivo, offering high-fidelity, multimodal insights for sleep research and the broader field of neurophysiology.



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sciforum-120858: Enhancing Microelectronic Neural Interfaces by versatile 3D structuring, multi-modality, and substrate-electrode materials

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Implantable neural engineering devices are required to establish a stable and intimate interface with neural systems for up to several decades under harsh physiological conditions. This study addresses key technical challenges in microelectronic neural interfaces from three perspectives: 1) versatile 3D structuring for optimized neuron-electrode contacts, 2) the synergistic integration of hybrid electro-optical neural interfaces, and 3) development of high-performance electrode materials for efficient charge transfer, along with long-term reliable substrate materials for decades-long durability. Higher proximity between electrodes and target neurons is enabled through the fabrication of microelectrode arrays (MEAs) with microscopic 3D structures tailored to specific tissues through the microelectrothermoforming (μ ETF) process. Protruding and/or recessed MEAs enhance the neural interfaces by reducing the stimulation thresholds and increasing stimulation resolution in retinal prosthetic applications. The synergistic combination of electro-optical neural interfaces is demonstrated by an optically transparent and electrically conductive microneedle array, which facilitates rehabilitation of brain damage by augmenting the glymphatic system. Lastly, material considerations are explored for both electrode and encapsulation applications for a broad range of MEAs. Liquid crystal polymer (LCP) films serve as substrates for laser-inscribed graphene featuring high charge storage and injection capacities, but also as long-term reliable encapsulation materials, potentially enabling decades-long durability in implanted conditions



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sciforum-125477: PEDOT:DSS-Modified Microelectrode Arrays for Simultaneous Recording of Neural Activity in Dual Brain Regions

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Poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate) (PEDOT:PSS) is favored as a conductive polymer with high conductivity and good histocompatibility in the construction of high-performance electrode interfaces. However, recent studies have shown that high concentrations of PEDOT:PSS exhibit certain defects in biocompatibility. Here, we propose the use of a novel dispersant, dextran sulfate (DSS), to form poly(3,4-ethylenedioxythiophene):(dextran sulfate) (PEDOT:DSS) polymers. PEDOT:DSS was modified through electrodeposition with cyclic voltammetry onto microelectrodes prepared using the MEMS process. The electrode sites had a diameter of 20 μm , and the plating solution comprised 0.014 g of DSS, along with 0.028 g of EDOT, to a 10 mL volume. Animal studies were conducted using female C57BL/6N mice.

PEDOT:DSS showed a dense and smooth black color after modification, and further observation of SEM images showed its smooth and uniform membrane-like structure, which indicated that the material on the plating was uniform and well oriented. Further, PEDOT:DSS had a lower impedance and better water affinity. Specifically, the impedance of the electrode was reduced from $1197.2 \pm 34.1 \text{ k}\Omega$ (bare) to $45.4 \pm 1.8 \text{ k}\Omega$ (PEDOT:PSS), as well as $12.6 \pm 1.1 \text{ k}\Omega$ (PEDOT:DSS) at 1 kHz. The PEDOT:DSS-modified interface also had the lowest water contact angle ($43.1 \pm 5.7^\circ$). More importantly, the PEDOT:DSS-modified microelectrode arrays were utilized in this study for the simultaneous detection of the neural activity in the lateral preoptic area (LPO) and the ventral pallidum (VP) of free-ranging mice. The statistical analysis demonstrated that the PEDOT:DSS-modified microelectrodes exhibited a lower noise baseline ($7.57 \pm 0.86 \mu\text{V}$) and enhanced spike amplitudes ($99.11 \pm 15.85 \mu\text{V}$) and achieved an average signal-to-noise ratio (SNR) of 6.55 during in vivo detection.

Electropolymerized PEDOT:DSS conductive films were used to construct high-performance electrode-neural interfaces in a convenient and efficient manner, substantially advancing the translational potential of implantable electrodes in both neuroscience research and clinical neurotherapeutics.



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sciforum-122903: A Robust AI Gesture Classification System for Unexpected Situations in Smart Manufacturing Using The Decision Transformer Algorithm

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This paper presents a compact and robust AI-based gesture classification system for managing unexpected situations in smart manufacturing environments, utilizing the Decision Transformer algorithm. The ongoing integration of cutting-edge technologies, such as artificial intelligence and IoT, is transforming conventional manufacturing into smart, autonomous systems that aim to maximize operational efficiency and productivity while minimizing the need for human intervention. However, smart manufacturing systems remain susceptible to unplanned events or anomalies that can occur during specific processes. These incidents often disrupt pre-planned workflows, leading to decreased productivity, delayed operations, and significant economic losses. To address this critical issue, we propose an AI-driven task control system based on human gesture recognition, allowing field engineers to issue rapid and accurate task commands in emergency situations. For this purpose, a wearable glove was developed, equipped with Flex sensors and an Arduino Nano BLE 33 Sense microcontroller, in order to capture detailed motion data. The system was designed to recognize 11 distinct task gestures that are applicable across 15 different manufacturing processes. By employing the Decision Transformer algorithm—a model known for its exceptional robustness in processing time-series data—the system demonstrated highly accurate real-time gesture classification. The experimental evaluation revealed that the proposed model achieved a classification accuracy of 94.5%, a precision of 95.4%, a recall of 94.5%, and an F1-score of 94.5%. These results significantly outperform conventional deep learning approaches, including Convolutional Neural Networks (CNNs) and Long Short-Term Memory (LSTM) networks, highlighting the superior temporal context understanding of the Decision Transformer algorithm. The proposed system not only improves the adaptability and resilience of smart manufacturing systems under unexpected conditions but also offers a promising solution for real-time human-in-the-loop control in future industrial applications.



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sciforum-125611: Advanced Electro-Chemical Neural Interfaces for Brain Health and Cognition

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Deep-brain regions, including the subthalamic nucleus (STN), globus pallidus (GPi), hippocampus (HPC), entorhinal cortex (EC), etc., are closely related to neurological diseases such as Parkinson's disease and Alzheimer's disease. Investigating neuronal activities in these regions is of great importance for developing effective treatments, particularly in non-human primate models with brain diseases. In recent years, high-density flexible Microelectrode Arrays (fMEA) have been implemented for electrophysiological recordings. However, their typical probe length is no more than 20 mm, which cannot reach the deep brain nucleus under cortical regions. In order to detect deep brain neural information in non-human primates, a versatile long fMEA neural probe was designed and fabricated based on parylene substrate.

With reference to the histology atlas of the rhesus monkey brain in stereotaxic coordinates, the distance from the skull top surface to the deepest brain region is less than 5 cm. Accordingly, the fMEA was designed to be integrated on a single probe with the length of 6 cm and the width of 550 μm , to ensure access to the depth of all target deep-brain nuclei. The 32-channel microelectrode sites were arranged into 2 $\times$ 16 array at the tip of the probe. Each site was 10 μm in diameter with the center-to-center spacing of 70 μm . Fabrication process of the fMEA probe was based on Micro-electromechanical Systems technology. The released fMEA probe exhibited excellent flexibility. The probe was implanted into the STN of anesthetized rhesus monkey, and neuronal action potentials were successfully detected with the signal-to-noise ratio of more than 9:1. The development of the deep-brain fMEA enhances the ability to study neural activities in non-human primates, offering insights into brain function and pathology, contributing to both therapeutic strategies and fundamental neuroscience research.



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sciforum-122006: Advanced Neuromuscular Interface for Application in Bionic Limbs

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The number of amputees is steadily increasing each year due to factors like war, chronic diseases, and accidents, creating a growing demand for bidirectional neural prosthetics. These devices must accurately interpret user intentions and provide sensory feedback, which requires advanced neural interfaces capable of recording high-quality neural signals and delivering diverse feedback. However, ensuring the long-term functionality of implanted neural interfaces remains a challenge.

Recent advancements in mechanoneural interfaces, which involve biological components, have aimed to overcome these limitations. Techniques such as targeted muscle reinnervation (TMR), regenerative peripheral nerve interfaces (RPNI), and agonist-antagonist myoneural interfaces (AMIs) have shown promising results. However, achieving high-quality recording and diverse sensory feedback still demands further advancements in peripheral nerve interface technologies.

Non-invasive muscle signal interfaces provide an alternative for detecting user intent without surgery. However, conventional surface electrodes face performance challenges in bidirectional prosthetics, particularly in lower-limb prosthetics. In these cases, EMG-based control requires electrodes within the silicone liner, a challenging environment due to the high pressure, moisture, and movement.

This talk will present two approaches, (1) an invasive hybrid bionic nerve interface combining RPNI and peripheral nerve interfaces (PNI) in a rabbit model and (2) non-invasive interfaces, such as imperceptible/reusable dermal surface EMG and advanced microneedle muscle interfaces, aimed at improving lower-limb neuroprosthetic control and clinical assessment.



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sciforum-125494: An Intelligent Precision Brain Function Localization System for Non-human Primates Based on a Microelectrode Array

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Deep brain stimulation (DBS) is a remarkably effective surgical intervention for managing Parkinson's disease and epilepsy. The key to the success of DBS lies in the precise localization of target nuclei. Microelectrode recording technology not only enables functional confirmation of anatomical targets but also improves localization accuracy to the cellular level. There is an urgent need to develop a multi-channel brain function localization system based on a microelectrode array.

The intelligent precision brain function localization system includes a long tungsten microelectrode array, a headstage, an electrophysiological signal detection module, an electrical modulation module, a multi-stage power supply module, and precision intelligent functional localization analysis software. Based on MEMS technology, microelectrodes are fabricated on a 4-inch tungsten wafer. The microelectrodes are then cut and released using femtosecond laser-cutting technology to form a tungsten microelectrode array. The microelectrode array is 10 cm long and consists of eight detection electrodes and two stimulation electrodes. The detection electrodes are circular, with a diameter of 10 micrometers. The stimulation electrodes are elliptical, creating a stable electric stimulation field and confining the electrical stimulation within the target nucleus.

Based on the intelligent brain function localization system, multi-channel neural electrophysiological signals from the Globus Pallidus internus (GPi) and its upper and lower boundaries were obtained, enabling precise localization of GPi in macaques. This intelligent functional localization system holds broad application prospects for rapid and precise brain functional localization and stimulation efficacy assessment in deep brain stimulation surgery.

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sciforum-125490: Chronic Flexible Probe Reveals Epileptic Spatial Coding Deficits

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Introduction

Temporal lobe epilepsy (TLE) is characterized by seizures and cognitive decline linked to hippocampal dysfunction. Conventional rigid neural probes are unsuitable for long-term epilepsy monitoring due to mechanical mismatch with brain tissue, leading to unreliable recordings. To overcome this, we developed a novel parylene-C-based flexible electrode probe with a hydrophilic surface and biodegradable silk fibroin-PEG coating, enabling stable, long-term neural recordings with a minimal foreign body response. This study investigates epilepsy-induced cognitive deficits by the long-term monitoring of hippocampal place cells in mice.

Methods

The probe, featuring 64 recording sites on a parylene-C substrate with a Cr/Au conductive layer, was implanted in the mouse hippocampus. Neural signals, including place-cell activity, were recorded over 8 months. Spatial encoding was assessed via electrophysiological recordings and behavioral tests (novel object recognition) before and after TLE induction.

Results

The probe's biomimetic design, oxygen plasma-induced hydrophilization, and SF-PEG coating ensured biocompatibility and stable implantation. It maintained high-quality recordings (>80% active channels, signal-to-noise ratio >7) over 8 months. In healthy mice, place cells showed robust spatial selectivity. Post-TLE, place-cell activity declined significantly, with fewer active cells, lower firing rates, and impaired spatial precision (e.g., increased firing field area, reduced sparsity). These changes correlated with deficits in spatial memory tasks.

Discussion & Conclusions

Our results demonstrate that the flexible probe enables reliable, long-term neural monitoring with minimal inflammatory response. Critically, this study reveals that TLE disrupts the spatial coding of hippocampal place cells, providing a cellular basis for the associated cognitive deficits. This innovative neural interface holds promise for advancing both fundamental neuroscience research and the clinical management of epilepsy.



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sciforum-120561: Controlled drug release method combined with ultrasonic sensing and therapy

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Targeted drug delivery faces critical challenges, including insufficient lesion-specific accumulation and low therapeutic efficacy under physiological constraints. Our study proposes two complementary ultrasound (US)-based strategies to address these limitations. First, an ultrasound-induced trapping and ultrafast imaging system was developed to enhance localized drug deposition. By analysing microbubble dynamics in a 2.5 MHz fluid flow model through finite element method (FEM) simulations, we demonstrate how the synergy between acoustic radiation force (ARF) and fluid drag enables precise microbubble trapping at 10 mm depth. Real-time positioning is achieved through 18 MHz ultrafast plane wave imaging, allowing non-invasive monitoring and spatial control of drug-loaded microbubbles. Second, for gastrointestinal malignancies constrained by peristalsis and anatomical complexity, a novel endoscopic system integrates a bidirectional piezoelectric actuator with an ultrasound transducer. This configuration enables adaptive positioning within biopsy channels while employing FEM-optimized US thermal fields ($41 \pm 1^\circ\text{C}$ phase transition temperature) for triggered drug release. A LabVIEW-controlled pulse-echo system achieved real-time thermal feedback, increasing drug release rates from 2.2×10^{-4} mg/min (baseline) to 45.8×10^{-4} mg/min—an 18-fold enhancement through actuator parameter optimization. Both systems leverage US physics to overcome biological barriers: the microbubble platform enhances spatial precision through ARF-mediated trapping, while the endoscopic system addresses gastrointestinal motility challenges via piezoelectric actuation. Cross-validation of FEM models with experimental data confirmed temperature control accuracy and microbubble displacement predictability. Our results establish a framework for improving local drug concentrations by integrating responsive materials, advanced actuation, and US-mediated monitoring—critical advancements for precision oncology and gastrointestinal therapeutics.



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sciforum-125533: High-Stability Microelectrode Arrays for Precise Neural Electrophysiological Monitoring During Sleep–Wake Cycle

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Sleep is a fundamental physiological process essential for maintaining overall health and promoting optimal brain function. However, the precise mechanisms of neural information encoding in deep brain regions during the sleep–wake cycle remain challenging to investigate due to the lack of high-temporal-resolution recording tools. In this study, we successfully fabricated a multi-channel microelectrode array (MEA) using MEMS technology. The electrodes were further enhanced with a composite coating of poly(3,4-ethylenedioxythiophene):polystyrene sulfonate (PEDOT:PSS) and polydopamine (PDA), significantly improving their electrochemical and mechanical stability while maintaining excellent biocompatibility at the neural–electrode interface.

The MEAs were implanted into the ventral tegmental area (VTA) and substantia nigra pars reticulata (SNr) of mice, enabling high-temporal-resolution recordings of neuronal firing activities throughout the sleep–wake cycle. Intriguingly, single-cell spike analysis within the VTA revealed three distinct neuronal subtypes: sleep-responsive, wake-responsive, and sleep-independent neurons. Each subtype exhibits significantly different firing rate characteristics across behavioral states. In contrast, no such sleep-specific neuronal subtypes were identified in the SNr, highlighting the critical role of the VTA in sleep regulation. Moreover, electroencephalogram (EEG) and local field potential (LFP) recordings indicated that theta band (4–8 Hz) activity predominated during wakefulness and rapid eye movement (REM) sleep, while delta band (0.5–4 Hz) activity dominated during non-REM (NREM) sleep. Further analysis revealed that certain neurons exhibited phase-locked firing with specific LFP frequency bands.

Overall, this study provides a highly stable neural interface for deep brain circuit analysis and uncovers the dynamic single-neuron coding principles within the VTA during the sleep–wake cycle, offering critical insights for targeted neuromodulation therapies for sleep disorders.



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sciforum-118524: Minimally invasive implantable flexible brain-computer interface sensors

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As a front-end sensor for neural signal acquisition and control, the flexible electrode is one of the core basic devices of brain-computer interface technology. Among them, the minimally invasive cortical brain-computer interface sensor is attached to the epidural or subdural, and will not destroy the brain tissue, so the implantation safety is high, and the technical path is easier to be practiced and applied in the medical field. On the one hand, with the progress of MEMS technology, the large-size cortical flexible electrodes used in traditional epilepsy focal location are developing towards miniaturization and high throughput, which can obtain more abundant and accurate brain activity information. On the other hand, more and more attention has been paid to electrodes that are more flexible and suitable for the mechanical properties of piniencephalic tissue, and new challenges have been presented in fine micro-nano processing and long-life in vivo work. In recent years, starting from the application needs, the applicant has enabled the realization of a series of key design and manufacturing technologies of advanced flexible brain-computer interface sensors with neural monitoring and regulation functions, achieving significant advantages such as soft mechanical properties, a minimally invasive implantation process, reliable multi-mode integration, long-term stability in vivo, etc., and has been used to explore the mechanism of action between a large number of neurons in neural networks. This has advanced the understanding and treatment of neurological diseases. At the same time, we continue to promote the transformation of basic research results into clinical applications: key problems such as short implantation time, high surgical trauma, and the poor matching of soft brain have been effectively solved.



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sciforum-121661: Minimally Invasive Soft Bioelectronic Interfaces enabled by Soft Robotic Technologies

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This talk introduces the emerging concept of deployable bioelectronic interfaces for minimally invasive implantation, which integrate soft robotics with bioelectronics through advanced micromachining techniques. Designed to be inserted through small incisions, these implantable devices employ soft robotic actuation strategies—such as eversion, unfolding, and bending—to deliver functional components, including electrodes, light sources, and strain sensors, onto complex anatomical surfaces. A key case study features a soft robotic electrocorticography (ECoG) array, a recent advancement successfully deployed in a minipig model using eversion—a bio-inspired deployment mechanism that enables navigation through narrow openings by growing outward.

The ECoG prototype, fabricated via a monolithic soft microfabrication process, consists of spiral-shaped legs embedded with strain sensors that provide real-time feedback during deployment. This capability eliminates the need for external imaging tools such as fluoroscopy and helps reduce operating time. In vivo experiments demonstrated the device's ability to reliably record somatosensory evoked potentials (SSEPs) without causing significant tissue damage, validating both its mechanical and functional performance.

Future directions for deployable bioelectronics targeting organs such as the brain, heart, cochlea, and peripheral nervous systems include the miniaturization of actuators, integration with additional sensing and therapeutic modalities, and the incorporation of biocompatible, bioresorbable materials for long-term implantation, among others. Collectively, these innovations hold the potential to make soft bioelectronic systems safer, more efficient, and widely applicable in clinical settings, ultimately reducing procedural risks, improving patient outcomes, and opening up new frontiers in medical technology.



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sciforum-125336: Multimodal Biofeedback-Guided Closed-Loop Electrical Stimulation for Cognitive Rehabilitation in Alzheimer's Disease

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Alzheimer's disease (AD) pathogenesis involves complex hippocampal neurodegeneration, dopaminergic system dysfunction, and aberrant neuronal synchronization. However, existing technologies lack the capability to simultaneously monitor neurotransmitter dynamics, record neural activity, and deliver precise electrical stimulation. Therefore, we developed NeuroRevive-FlexChip, an innovative neural interface that enables in vivo investigation of the effects of 40Hz gamma oscillation electrical stimulation (ES) on dopamine (DA) release kinetics and neuronal firing pattern plasticity in the hippocampal CA1 of APP/PS1 transgenic mice.

The NeuroRevive-FlexChip features stimulation electrodes achieving enhanced charge storage capacity ($2.97 \text{ mC}\cdot\text{cm}^{-2}$) and detection electrodes optimized for high sensitivity ($13.09 \text{ pA}/\mu\text{M}$) and exceptional dopamine selectivity (10% interference). Following implantation in the hippocampus, the system delivered intermittent 40Hz electrical stimulation while concurrently monitoring dopamine dynamics via chronoamperometry and recording neural activity. This multimodal approach, combined with Y-maze behavioral assessment and A β 42/Iba1 immunohistochemical analysis, enabled investigation of treatment effects across molecular, cellular, and behavioral levels.

Additionally, 40 Hz stimulation triggered a dopamine 'reboot', increasing levels from $1 \mu\text{M}$ to $3 \mu\text{M}$ during stimulation, with a secondary post-stimulation peak coinciding with firing transitions. The stimulation normalized pathological hyper-synchronization in AD mice, reducing firing rates from $4.79\pm0.2 \text{ Hz}$ to wild-type levels of $0.84\pm0.1\text{Hz}$. At the molecular level, stimulated animals showed a 52% reduction in A β 42 deposition in CA1. These improvements translated to behavioral recovery, with Y-maze alternation accuracy increasing from $47\pm3\%$ to $61\pm2\%$, approaching wild-type performance ($63\pm2\%$).

Using the NeuroRevive-FlexChip platform, we identified that 40 Hz electrical stimulation modulates dopamine release dynamics, leading to suppression of pathological neuronal synchronization. Furthermore, this work establishes the precise temporal coupling between dopamine fluctuations and transitions in neuronal firing patterns. Most importantly, the technology demonstrates that electrical stimulation can synergistically ameliorate both A β pathology and cognitive dysfunction, providing novel insights into AD neural circuit mechanisms and establishing a technological foundation for next-generation closed-loop neuromodulation therapies.



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sciforum-121528: Next-generation Biomedical and Neural Interfaces using Multifunctional Thermally Drawn Fibers with Soft Materials

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Understanding and controlling the dynamics of biological or neural systems requires developing technologies that can record the signals used by cells or neurons and control bio-systems. However, current engineering technologies for this purpose have limitations in many factors, such as the lack of cell-specific stimulation for precise control, severe invasiveness and bio-incompatibility that are difficult to apply to actual medical treatment. Therefore, developing a new micro-interface system that is biocompatible while fully exerting multi-functionality and can precisely manipulate and monitor cell and nerve activity is a major demand in the current biomedical and brain engineering fields. In this presentation, I would like to introduce various strategies of our laboratory to solve these problems: (1) First, I will introduce a flexible and stretchable fiber-based probe for interfacing with biological and neural systems. Through this technology, I intend to predict the appearance of future biomedical devices in various fields such as ultra-long-term brain-machine interface. (2) Second, I will introduce tissue regeneration support technology using biocompatible materials and fibers, and introduce an engineering approach for tissue engineering. (3) Lastly, I will introduce various wearable and biomedical applications using the soft materials and new manufacturing processes. The technologies to be introduced in this presentation will not only contribute to human health and well-being by enabling natural interfacing between biological/neural circuits and external machines/computers, but are also expected to contribute to the development of a future with hyper-connectivity.



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sciforum-121887: Peripheral nerve coil interface for enhancement of axial-direction-induced magnetic field gradient

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Peripheral nerve electrical stimulation is widely used for neuropathic pain treatment and neural regeneration. However, it has limitations such as unintended neural activation in surrounding tissues and adverse biological reactions. As an alternative, peripheral nerve magnetic stimulation presents a promising, less-invasive approach that enables targeted nerve modulation without direct tissue contact. Nevertheless, its practical application is hindered by challenges such as the bulkiness of coils and excessive heat generation due to high current levels. To address these limitations, we developed a miniaturized, custom-designed coil interface specifically for peripheral nerve modulation. Previous studies have established the axial electric field gradient as a key factor influencing the membrane voltage of peripheral nerves. Based on this, we designed a coil interface measuring 6.2 mm × 2.2 mm. Among the tested configurations, a four-leaf rhombus coil design produced the highest electric field gradient at the center of the coil interface. In rat sciatic nerve experiments, a rectangular pulse with a 200 μ s rise time and a 25 V amplitude successfully induced compound muscle action potentials in the tibialis anterior and gastrocnemius muscles. Through simulations and animal experiments, we optimized the coil design to generate a strong induced electric field gradient. Additionally, we identified that the key geometric factors enhancing the induced electric field gradient of the coil interface were line segments aligned with the nerve axis, while the norm of the magnetic field did not necessarily follow the same trend as the induced electric field gradient. This study highlights the potential of small-scale, low-energy magnetic coils as a viable and effective alternative to traditional electrical stimulation, may pave the way for advanced, minimally invasive neural modulation and future therapeutic applications.



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sciforum-119750: Self-healing and Stretchable Bioelectronic Devices for Stable Neuroprosthesis

Donghee Son

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Soft wearable/implantable bioelectronic systems capable of monitoring electrophysiological signals evoked by external mechanical/optical/electrical stimuli and delivering the feedback information, have been considered essential functional components in realizing the future closed-loop prostheses. Despite such significant progress, materials fatigue and the corresponding electrical malfunction issues still remain challenging due to the lack of optimal materials/fabrication/integration/system strategies that simultaneously meet robust tissue-device bonding, spontaneous stiffness matching, long-term electrical/mechanical durability, biocompatibility, areal uniformity, device-to-device reproducibility, and even strain-induced error correction.

Herein, we describe optimal materials design strategies and device fabrication/integration technologies for the two different kinds of self-healing, stretchable, and tissue-adhesive bioelectronics: i) Self-healing and stretchable bioelectronic adhesive platforms for sutureless nerve repair in rodents and nonhuman primates; ii) Shape-morphing and cortex-adhesive sensor for closed-loop transcranial ultrasound neurostimulation; iii) Self-healing and stretchable closed-loop neuroprosthetic system with spontaneous performance recovery. The two kinds of patch-type self-healing bioelectronic systems (i & ii) consist of an ionically conductive hydrogel adhesive, tough self-healing substrate/encapsulation layers, and stretchable electrodes, enabling both strain-insensitive electrical sensing/stimulating performance and mechanical adaptation. In addition, the closed-loop neuroprosthetic system, consisting of wearable and implantable sensors coupled with AI assistance, was successfully implemented to achieve artificial afferent/efferent neural pathways.



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sciforum-122412: Wireless Implantable Optogenetics: Revolutionizing Neuroscience Behavior Studies and Treatment of Neuro-Disorders

Yiyuan Yang

National University of Singapore

Understanding the fundamental principles of neural systems is central to modern neuroscience and critical for addressing neurological disorders. Among various neural modulation techniques, optogenetics combined with high-resolution light delivery tools provides a unique advantage by allowing precise modulation of targeted cell groups with exceptional temporal accuracy. To fully utilize these capabilities, it is essential to integrate advanced light delivery interfaces into device platforms designed for studies with freely moving animals.

In this presentation, I will introduce a groundbreaking device platform that merges flexible neural interfaces for seamless biological integration with μ LED-driven optogenetic stimulation. This system is battery-free and wirelessly controlled, enabling dynamic, real-time programming of the stimulation parameters. With a mechanically compliant design, the device allows for easy subdermal implantation. This platform not only generates artificial perceptions through spatiotemporally coordinated optogenetic stimulation across specific cortical regions during behavioral studies but also enhances our understanding of how synthetic cortical activity is perceived. Additionally, this technology facilitates the exploration of the neural dynamics in multi-brain networks, enabling real-time modulation of social interaction behaviors in freely moving rodents. Finally, I will present our vision of applying this technology in future treatments for neurological disorders. These advancements not only deepen our comprehension of neural dynamics but also open new avenues in translational neuroscience and the treatment of neurological disorders.



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Session 4. Nanophotonics and Metasurface

sciforum-121920: Carrier Transport Modulation via Surface and Interfacial Engineering

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The performance of optoelectronic devices is fundamentally constrained by the efficiency of charge carrier generation, separation, and transport, while the growing demand for broadband, high-sensitivity, and low-power photodetection presents significant challenges for materials and device design. Interfacial engineering offers a crucial solution by precisely modulating carrier transport behavior, enabling breakthroughs in material limitations and substantial performance enhancements. This report examines the mechanisms and strategies of interfacial engineering for optimizing optoelectronic devices. Surface nanostructuring significantly improves near-infrared absorption in silicon-based heterojunctions (p-Si/n-ZnO), while the piezo-phototronic effect optimizes interfacial barriers, achieving a 78% enhancement in responsivity and linearity. Expanding to ternary semiconductors, composition-tunable $\text{CdS}_x\text{Se}_{1-x}$ nanowires reveal the relationship between the piezo-phototronic effect and material composition, providing insights into charge screening and piezoelectric modulation. In perovskite systems, capillary-assisted solution printing (CASP) enables controlled integration of highly crystalline nanowire arrays, where electric field poling induces ion migration and polarization potential, boosting photocurrent tenfold and reducing response time by 50%—highlighting the critical role of interfacial polarization in carrier separation and transport. Additionally, an ultrathin Al_2O_3 dielectric layer in Si-ZnO tunneling heterojunctions enhances carrier collection via quantum tunneling, while the piezo-phototronic effect dynamically adjusts interfacial barriers, improving sensitivity and responsivity by nearly an order of magnitude. By exploring material design (composition tuning), structural engineering (nanostructuring/heterojunction tunneling), and external field coupling (piezoelectric/electrical poling), this work elucidates the mechanisms of interfacial engineering in regulating carrier dynamics, offering diverse strategies for developing high-performance, low-power optoelectronic devices.



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sciforum-126377: Light control with synthetic temporal interfaces

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We present the experimental construction of a synthetic temporal photonic lattice using a dual-loop coupled fiber architecture, showcasing its versatile applications in gauging potential modulation and nonlinear photonics. By precisely tailoring the spatial distribution of scalar and vector potentials within the lattice, we demonstrate reconfigurable temporal interfaces that enable fundamental optical phenomena, including refraction, total internal reflection (TIR), and perfect imaging. For instance, applying identical phase modulations to the long and short fiber loops induces an effective scalar potential, leading to a vertical shift in the Floquet band structure, while opposite phase modulations generate a vector potential that horizontally displaces the bands. We further investigate the temporal Goos-Hänchen shift (GHS), a lateral displacement of the reflected wave packet during TIR, which is jointly governed by scalar and vector potentials. Through a novel accumulation-based reflection scheme, the precision for detecting minute GHS values is significantly enhanced, revealing the physical connection between GHS induced by single-interface TIR and finite-width potential barriers. In the realm of nonlinear photonics, we introduce optoelectronic Kerr nonlinearity to realize the nonlinear non-Hermitian skin effect (NHSE). By leveraging Kerr self-trapping, the localization and robustness of light at the lattice boundary are enhanced, suppressing NHSE transport to form stable skin solitons. Experimental results show that these solitons maintain stability under varying Kerr coefficients, as demonstrated by simulated and measured intensity evolutions of nonlinear skin modes. This capability is further utilized to design a tunable nonlinear optical router, offering dynamic control over optical signal routing.



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sciforum-121832: Light-Controlled Antimony Sulfide Phase Change for Reconfigurable Photonic Devices

Ting Mei *, Kun Gao, Feifan Qiang, Jiajie Chen and Wanqi Yang

Northwestern Polytechnical University

Reconfigurable photonics represents a pivotal direction in the intelligent development of photonic systems, focusing on the dynamic alteration and stabilization of system states or functionalities through physical control methods. A key challenge in this field is achieving non-volatile reconfiguration, which holds significant implications for applications such as structured optical field manipulation, holographic displays, and diffraction-based photonic neural network weight settings. Antimony sulfide (SbS), a chalcogenide phase change material, exhibits substantial refractive index changes through phase changes and offers non-volatile state retention, making it a promising solution for non-volatile reconfiguration challenges. We demonstrate optically-controlled reversible phase changes in SbS and propose a physical model to elucidate the formation of multi-level intermediate states during amorphization. An in-situ, quantitative method is developed to characterize the intermediate phase states of SbS, known as phase change degree. By optimizing femtosecond laser parameters such as pulse energy, pulse count, and wavelength, we achieve precise control over these intermediate states, significantly enhancing cycling durability. Furthermore, we present a Fabry-Pérot resonant multilayer thin-film device based on SbS, employing a layered strategy to mitigate refractive index inhomogeneity. This device enables pixel-level, programmable multi-level phase modulation by leveraging SbS phase transitions to adjust FP resonance wavelengths. Additionally, we demonstrate a visible-band tunable optical chirality metasurface device utilizing SbS phase transitions, showcasing its potential for advanced optical applications. This research not only addresses critical challenges in non-volatile reconfiguration but also opens new avenues for advanced photonic applications.



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sciforum-120710: Micro Phase Retarder Based on Bottom-up Grown Quasi-1D Fibrous Red Phosphorus Flake

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Fibrous red phosphorus (RP) has triggered growing attention as an emerging quasi-one-dimensional (quasi-1D) van der Waals crystal recently. Unfortunately, it is difficult to achieve substrate growth of high-quality fibrous RP flakes due to their inherent quasi-1D structure, which impedes their fundamental property exploration and device integration. Herein, we achieved the growth of high-crystallinity fibrous RP flakes on diverse substrates with (001)-preferred orientation via a chemical vapor transport (CVT) reaction [1]. The growth mechanism of fibrous RP flakes was investigated in depth through experiments and theoretical calculations, which can be attributed to the Sn-mediated P_4 partial pressure and the SnI_2 capping layer-directed growth. The complex refractive index of the fibrous RP flakes within the ab-plane was determined through Kramers–Kronig analysis and theoretical calculation [2]. Notably, the maximum birefringence of fibrous RP reaches $0.642@475\text{ nm}$ with an absolute extinction coefficient of only 0.08, superior to the reported traditional optical crystals and the emerging low-dimensional materials as well. The remarkable birefringence can be attributed to the synergistic influence of the large electronic dipole polarizability, anisotropic electron density distribution and the distortion of stereochemically active lone pair. Additionally, we employed polarization-resolved monochromatic transmitted light intensity mapping to visually display the potential application of fibrous RP flakes directly grown on transparent quartz substrates as micro phase retarders for polarization conversion.

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sciforum-125179: Mid-Infrared Metasurface with Grating-Enhanced Plasmon Resonance for Spectral Imaging

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Metasurfaces, composed of subwavelength meta-atoms, offer precise control over light's phase, polarization, and amplitude, enabling novel applications in imaging, sensing, and on-chip photonics. However, wafer-scale fabrication in the mid-infrared (MIR) range faces challenges due to the strong absorption of commonly used SiO_2 . To address this, we propose a CMOS-compatible metasurface design using a metal-insulator-metal (MIM) grating structure that suppresses SiO_2 absorption and enhances plasmonic resonance.

Our method involves incorporating a grating into an MIM architecture with a $1\ \mu\text{m}$ thick SiO_2 layer. Simulations show that the grating structure effectively reduces bulk absorption originating from the imaginary component of SiO_2 's refractive index. When nanoantennas are integrated into the grating-based metasurface, a strong plasmon resonance is observed, in contrast to the absence of resonance in conventional nanorod structures due to SiO_2 loss.

Experimental measurements confirm the enhanced absorption and resonance in the grating-integrated metasurfaces. Using this approach, we designed single- and double-resonance unit cells for encoding information. By spatially arranging different resonant structures, we demonstrated wavelength-dependent spectral imaging, successfully encoding letters that appear at distinct MIR wavelengths.

In summary, this grating-assisted design enables the effective suppression of SiO_2 absorption and boosts MIR plasmonic performance, offering a scalable route for high-throughput metasurface fabrication and advanced imaging applications.



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sciforum-121497: Chalcogenide Visible Metasurfaces: A New Platform for High-Performance Optical Devices

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The evolution of metasurface optics relies on the continuous development of advanced dielectric materials. Chalcogenide glasses, known for their high refractive index, low optical loss, and broadband transparency from visible to infrared light, have emerged as a promising platform for transmissive metasurface applications. However, their utilization in visible metasurfaces remains largely unexplored. In this work, we present the first demonstration of chalcogenide visible metasurface optics, leveraging the unique optical properties of $\text{Ge}_{23}\text{Sb}_7\text{S}_{70}$ (GSS). By designing and fabricating a series of high-performance metasurface devices—including metalenses, focused vortex metasurfaces, holographic displays, and computational spectrometers—we validate the viability of chalcogenide metasurfaces for visible applications. The fabricated metalenses achieve near-diffraction-limit focusing with efficiencies of approximately 70–80% across the visible spectrum. The vortex metasurfaces enable high-quality generation of structured optical fields with various topological charges in an efficient manner. Additionally, the holographic devices achieve high-fidelity image reconstruction and operate effectively across the visible wavelength range. Furthermore, we develop a chalcogenide-based computational visible spectrometer, achieving a spectral resolution of 7 nm and a reconstruction accuracy exceeding 99.2% across the 450–750 nm range. These results establish chalcogenide materials as a robust and versatile platform for next-generation visible metasurface optics, paving the way for reconfigurable and multifunctional optical devices with applications in imaging, holography, and spectroscopy.



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sciforum-122132: Chaos-based communication in synthetic temporal lattices

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We propose a tunable nonlinearity approach in synthetic temporal lattices using opto-electric feedback, experimentally demonstrating bistability-to-chaos transitions and developing a high-entropy chaos-based encryption system. This work opens new possibilities for secure communication within synthetic dimension platforms. Our system consists of two coupled fiber loops of different lengths combined with an opto-electric circuit. By introducing temporal nonlinear feedback, we construct a discrete temporal system where the feedback phase undergoes iterative variations rather than continuous changes. When the system operates in a steady state, we derive a simulated bistable curve illustrating the relationship between the nonlinear coefficient χ and the output light intensity. As the nonlinear coefficient increases, the lower branch of the bistable curve undergoes period-doubling bifurcations, ultimately leading to chaotic behavior. The generated chaotic pulse sequences are extracted via an optical coupler in the long loop and modulated using a voltage-controlled oscillator (VOC) driven by an arbitrary waveform generator (AWG) to encode messages. The modulated signal is detected by a photodetector (PD) and displayed on an oscilloscope, while the unmodulated chaotic signal is separately extracted and recorded. Through this method, we construct a temporally chaotic emitter. This study marks the first experimental realization of temporal chaos in synthetic lattices, paving the way for advanced high-security chaos-based communication systems.



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sciforum-125314: CMOS-enabled mid-infrared chiroptic platform for polarization--wavelength multiplexed imaging

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Three-dimensional (3D) chiral metamaterials, characterized by their lack of out-of-plane symmetry, exhibit stronger circular dichroism (CD) compared to their two-dimensional counterparts due to their intrinsic chirality. Among the various types of 3D metamaterials, those fabricated by stacking multiple layers are especially promising because they are more amenable to large-scale production. However, research in this area has largely focused on longer wavelengths (such as THz and GHz), since scaling resonator structures down to shorter wavelengths poses significant fabrication challenges. In this study, we present the development of multilayered chiral metamaterials operating in the mid-infrared range, using a standard CMOS-compatible fabrication technique. The structure consists of a triple-layer configuration with twisted resonators. We also apply a temporal coupled-mode theory to analyze how the twist angle influences the far-field coupling coefficient—a relationship that we confirm both through simulations and experimental results. In addition to these findings, we introduce the concept of supercells to achieve polarization- and wavelength-dependent encryption. By strategically arranging chiral and achiral unit cells in a 5×5 array, we create a system that reveals different letters based on the specific combination of wavelength and circular polarization used. This selective visibility ensures that the encrypted message can only be deciphered under precise optical conditions. The demonstrated platform holds promise for applications in secure optical communications, advanced encryption technologies, and highly sensitive detection systems.



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sciforum-122003: Experimental realization of convolution processing in photonic synthetic dimensions

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Convolution operations are fundamental to signal processing and convolutional neural networks (CNNs), forming the backbone of feature extraction algorithms in image, speech, and data analyses. Optical systems offer an attractive alternative for overcoming the computational bottlenecks of traditional electronic processors, thanks to their inherent parallelism and low energy dissipation. However, many conventional optical computing systems are constrained by fixed architectures and limited reconfigurability, hindering their practical applications. In this work, we present a novel approach by harnessing a synthetic temporal lattice within a fiber-loop system to realize convolution operations. Our scheme is capable of implementing various types of convolution kernels, including symmetric, asymmetric, and complex-valued forms. We encode one-dimensional signals into a sequence of temporally correlated optical pulses, which are then injected into the fiber-loop network. By applying a controlled intensity and phase modulation at each time step, the convolution operation is achieved through the intrinsic coupling characteristics of the synthetic lattice. Furthermore, we introduce a method for transforming two-dimensional convolution into a one-dimensional process, enabling the effective processing of two-dimensional images. Both the theoretical analysis and experimental results validate our approach, demonstrating excellent agreement between the designed kernel operations and the observed convolution outputs. This work not only advances the field of optical computing by introducing a reconfigurable and compact convolution platform but also opens new avenues for photonic signal processing and neuromorphic computing applications, offering promising solutions for next-generation, high-speed, low-power information processing systems.



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sciforum-121103: Fabrication and Applications of Ultrathin Suspended Chiral Metasurfaces

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Artificially designed chiroptical metasurfaces can exhibit a strong circular dichroism, but they are usually limited by the complicated fabrication procedure and alignment errors. Here, we demonstrate a new type of self-aligned suspended bilayer metasurface with only one-step electron beam lithography (EBL) exposure [1, 2]. The suspended bilayer metasurface consists of two layers of twisted stacking gold nanoarrays spaced by a thin Si_3N_4 membrane (only 50 nm in thickness). A significant optical chirality of 309°um^{-1} can be realized using suspended metasurfaces with a thickness of 100 nm. Furthermore, we demonstrate that: 1) such suspended chiral metasurfaces can be utilized for label-free discrimination of the chiral molecules at zeptomole level, exhibiting a much higher sensitivity (orders of magnitude) compared to the conventional circular dichroism spectroscopy [2, 3]; 2) such suspended chiral metasurfaces can be utilized to induce strong circularly polarized luminescence from achiral nanocrystals including both upconversion nanoparticles (UCNPs) and quantum dots (QDs) [4, 5]. Due to the giant chiroptical response, the proposed metadvice may offer promising applications for ultrathin circular polarizers, chiral molecular discrimination, imaging and sensing, etc.

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sciforum-122069: Hybrid plasmonic antenna arrays for the detection of volatile organic compounds

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Volatile Organic Compounds (VOCs) are a diverse group of carbon-based chemicals that can easily evaporate at atmospheric pressure and room temperature. Many industrial and human activities are accompanied by the generation of VOCs, which could pose significant environmental and health concerns. The ability to detect and monitor VOCs at low concentrations is crucial for various applications. Plasmonic sensors show great potential for their compactness, high sensitivity and versatile sensing capabilities. They often consist of optical nanoantennas and functional sensing materials. Here we demonstrate a hybrid plasmonic sensor composed of gold nanohole arrays and in-situ synthesized multifunctional zeolitic imidazolate framework (ZIF-8) layers. The ordered gold nanohole arrays are fabricated with scalable colloidal lithography and support multiple plasmonic modes. When ZIF-8 layers are deposited, mode coupling occurs between the plasmon modes of the nanoholes and the waveguide-like modes in the ZIF-8 layers leading to narrow-band hybrid modes that are highly sensitive to the presence of ethanol vapor. A sensitivity of 50.1 pm/ppm is achieved in a concentration range of 455 to 1543 ppm. Ethanol vapor as low as 47 ppm was experimentally detected. The proposed sensor with its cost-effective fabrication and high performance provides a promising and competitive solution for low-cost, highly sensitive and real-time detection of volatile organic compounds in a variety of practical applications.



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sciforum-127187: Light Manipulation via Near-field Coupling Control in Plasmonic Metasurface

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Coupled photonic systems exhibit intriguing optical responses attracting intensive attention, but available theoretical tools either cannot reveal the underlying physics or are empirical in nature. We firstly present recently established rigorous theoretical framework from first principles (i.e., Maxwell's equations), with all parameters directly computable via wave function integrations, to study coupled photonic systems containing multiple resonators. We will illustrate how to utilize it to freely tailor the lineshape of a coupled system involving two plasmonic resonators exhibiting arbitrary radiative losses, particularly how to create a completely "dark" mode with vanishing radiative loss (e.g., a bound state in continuum). Our results not only help understand the profound physics in such coupled photonic systems but also offer a powerful tool for fast designing functional devices to meet diversified application requests.

We will further present how to manipulate the angular dispersion of metasurface with CMT by controlling the radiation pattern and the near-field coupling among the meta-atom. finally, we will present how to control the inter-resonators near-field coupling and far-field coupling to manipulate the EM response in the plasmonic metasurfaces. We experimentally demonstrate that a realistic metasurface satisfying the discovered criteria exhibits the desired achromatic reflectionless property with bilayered metasurfaces. Our findings pave the road to realize meta-devices exhibiting designable transmission spectra immune from reflections, which may find many applications in practice.



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sciforum-126535: Lithium Niobate Metasurface for Flexible Color Sensor Application

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This study elucidates the development and characterization of a flexible color sensor (FCS) with a lithium niobate metasurface (LNM) architecture, which demonstrates remarkable efficacy in chromatic detection applications. The FCS contains a tripartite configuration of periodically arranged half-ellipse LN arrays (designated as LNM-1, LNM-2, and LNM-3) superimposed upon a polydimethylsiloxane (PDMS) substrate. A schematic representation of the FCS's morphology and the tensile mechanism employed for the modulation of parameter w were provided. The reflection and transmission spectra manifesting as blue (B) and green (G) are also simulated, revealing promising results. Red (R) chromatic outputs from their respective LNM configurations illustrates the correlation between sensitivity metrics and figure of merit (FOM) values. The electromagnetic response characteristics of the FCS can be continuously modulated through the precise calibration of the periodicities of its constituent LNMs—specifically, LNM-1 (w_1), LNM-2 (w_2), and LNM-3 (w_3)—along the y -axis. The FCS demonstrates exceptional quality in its reflection spectra, which range from 90 to 155 for LNM-1, 260 to 340 for LNM-2, and 100 to 200 for LNM-3, while its transmission spectra exhibit quality factors spanning from 100 to 200 for LNM-1, 290 to 360 for LNM-2, and 140 to 300 for LNM-3. Upon exposure to environments characterized by varying refractive indices, the FCS manifests a figure of merit reaching up to 900 RIU^{-1} and sensitivity parameters approaching 130 nm/RIU . Analyses of electromagnetic field energy distributions reveal pronounced field confinement within the LNM nanostructures, thereby corroborating the existence of efficient light-matter interaction phenomena. The empirical findings presented herein substantiate the assertion that the proposed LNM-based FCS possesses considerable potential for implementation in high-performance chromatic sensing and filtering applications, thus representing a significant advancement in metasurface-based optical sensing technology.



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sciforum-122160: MOCVD Growth of β -Ga₂O₃ Based Heterojunctions for Solar Blind Deep UV Photodetector

Bingsheng Li

Northeast Normal University

β -Ga₂O₃ with bandgap of 4.5-5.0 eV has significant application prospects in ultraviolet photodetector. This presentation reports the preparation and optoelectronic detection characteristics of two heterojunctions: Ga₂O₃/silicon (1) and Ga₂O₃/(Al_xGa_{1-x})₂O₃/GaN Heterojunction (2).

(1) The β -Ga₂O₃/Si heterojunction solar blind ultraviolet photodetectors by MOCVD. Beneficial to the advantages of dual chamber MOCVD, an AlN buffer layer is introduced on silicon to reduce lattice mismatch and avoid surface reoxidation, resulting in high-quality β -Ga₂O₃ thin films. This enables a solar blind detector with a signal-to-noise ratio of 2.7×10^3 , a detection rate of $8.31 \times 10^{13} \text{ cm} \cdot \text{Hz}^{1/2}/\text{W}$, and good spectral selectivity. With further optimizing growth, the highest response is 131.3 A/W, and the detectivity is 2.9×10^{15} Jones, with an ultrahigh UV/visible ($R_{\text{peak}}/R_{400\text{nm}}$) rejection ratio up to 5.2×10^5 has been realized in a β -Ga₂O₃/AlN/Si nBn heterojunction.

(2) High Gain Solar-blind UV Photodetector of Ga₂O₃/(Al_xGa_{1-x})₂O₃/GaN nBp Heterojunction. By inserting an (Al_xGa_{1-x})₂O₃ barrier layer between β -Ga₂O₃ and GaN in a p-GaN/n-Ga₂O₃ diode photodetector, the dark current got reduced greatly, and the device performance improved significantly. The β -Ga₂O₃/ β -(Al_xGa_{1-x})₂O₃/GaN nBp photodetector achieved a high photocurrent gain of 1246, a high responsivity of 237 A/W, and a specific detectivity of $5.23 \times 10^{15} \text{ cmHz}^{1/2}\text{W}^{-1}$ under a bias of -20 V. With the irradiation of 250 nm light, photocurrent exhibits a dramatic nonlinear increase beyond a bias of about -4 V, attributed to the interband electron tunneling. The onset of the interband tunneling is due to the strong internal electric field formed from the self-trap holes (STHs) in Ga₂O₃. The study also proposes an effective way to suppress the persistent photoconductivity and to significantly increase the device operation speed in photodetectors fabricated from Ga₂O₃ through light-induced neutralization of STHs.



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sciforum-122195: Nanosphere lithography of III-nitride nanowires

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III-nitride materials have a direct and wide bandgap, enabling the development of optoelectronic devices with a broad range of emission wavelengths, spanning from the visible to the ultraviolet (UV) spectrum. This capability has led to advancements in high-efficiency light-emitting diodes (LEDs), laser diodes, and photodetectors for applications in solid-state lighting, biomedical imaging, water purification, and optical communication. Compared to conventional planar structures, nanowire-based III-nitride emitters offer superior performance due to their high surface-to-volume ratio, which enhances carrier injection, light extraction, and thermal dissipation. These advantages are particularly crucial in the deep UV regime, where light emission is primarily transverse magnetic (TM)-polarized. However, controlling the complex bottom-up growth process of nanowires remains a significant challenge, often leading to variations in diameter, height, and spacing that negatively impact device performance and scalability. Here, we demonstrate the wafer-scale fabrication of high-aspect-ratio, uniform III-nitride nanowire arrays using nanosphere lithography (NSL). By utilizing self-assembled monolayers of monodisperse nanospheres as an etching mask, we show that the geometry of the nanowire arrays can be tailored to optimize the resultant optical and electrical properties. This scalable and cost-effective fabrication technique paves the way for integrating III-nitride nanowires into next-generation optoelectronic devices, including high-performance UV LEDs, quantum light sources, and photodetectors for advanced sensing applications.



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sciforum-127142: Nanowire Metasurfaces with Continuous Superconfined Modes for Ultrabroadband and Wide-angle Meta-optics

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Optical metasurfaces have subwavelength pixels where discrete planar nanostructures are located. By carefully designing shapes or dimensions of the nanostructures, one can manipulate the amplitude, phase, and polarization of light via optically induced nano-modes. To obtain high efficiency, these nano-modes are excited efficiently only under the normal incidence of light at the designed wavelength, which leads to quite limited field of view (FOV) and narrow bandwidth of metasurfaces, especially for transmissive dielectric metasurfaces.

Inspired by nanowires, we propose continuous dielectric metasurfaces for wavefront shaping. Theoretically, we show the theoretical evidences for nanowire metasurfaces in demonstrating large-angle and ultrabroadband operations by using the model of periodic discrete dipole approximation, which reveals high immunity to the incident angle and operating wavelengths. By organizing the tangent of continuous dielectric nanowires, arbitrary phase modulation can be realized under large FOV and ultrabroad bandwidth. Experimental results show that continuous silicon nanowires can shape optical wavefronts with high efficiency under the tilting illumination of 85 degrees at the wavelengths from 500 nm to 1100 nm, as verified by using a nanowire meta-hologram. Furthermore, the large-FOV feature enables a nanowire-based metalens to collect large-angle incident light that carries the information with high spatial frequencies, thus demonstrating higher imaging resolution than previous nano-pillar/brick discrete metasurfaces. The nanowire metasurfaces suggest an alternative approach to realize high-efficiency, large-FOV and ultra-broad wavefront shaping of light.



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sciforum-126124: Precision beam steering and optical metrology enabled by micro-meta-lens array

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Flexible beam steering and precision displacement sensing are critical technologies underpinning advancements in nanomanufacturing, optical metrology, and sensing systems. This paper presents two innovative photonic systems based on micrometalens arrays (MMLAs), addressing challenges in high-precision adaptive beam control and metrology. First, we demonstrate a semisolid micromechanical beam steering system using decentered MMLAs driven by high-speed piezoelectric motors. Existing beam steerers struggle to balance wide field of view (FOV), aberration correction, and lateral reproducibility. Our design optimizes these parameters through MMLAs with small f-numbers and pre-engineered aberrations, enabling diffraction-limited resolution over a large $30^\circ \times 30^\circ$ FOV. The semisolid structure ensures stable beam manipulation while allowing dynamic reconfiguration, validated by 3D depth sensing experiments with millimeter-range precision. This platform shows promise for applications in lidar, optical communication, and adaptive imaging, where versatile beam control across diverse scenarios is essential. Second, we introduce a compact 2D transverse displacement nanoruler leveraging confocal MMLAs. Conventional lateral metrology often requires complex postprocessing or bulky setups, limiting real-time precision. Our system constructs a "blazed grating" by aligning two MMLA layers with a tunable relative angle, where the grating's blaze angle is directly proportional to displacement. By analyzing the interference pattern via a Fourier transform lens and image sensor, we achieve subnanometer resolution (0.5 nm) with minimal environmental noise, eliminating the need for algorithmic correction. The system's simplicity—comprising only a laser, two MMLAs, and basic optical components—enables compact, high-speed displacement sensing for nanoscale positioning systems. Both systems highlight the transformative potential of MMLAs in merging precision metrology with adaptive photonics.



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sciforum-122193: Printable Photonic Materials

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The rapid development of additive manufacturing technologies raises tremendous research interests in exploring functional materials for emerging applications in electronics and photonics. Photonic materials with unique and multifunctional optical characteristics demonstrate promising applications in light detection and ranging (LiDAR), AR/VR, smartphone camera modules, etc. To address the demand for nanophotonics, printing techniques that can make nanometer-scale features emerge as one of the facile, scalable, and cost-effective strategies. In the context of this talk, the development of two-photon lithography (TPL) and nanoimprint lithography offers a solution for both fast prototyping and mass production. However, the optical properties of commercial resins for both TPL and NIL are very limited, which hinders the development of printed photonics devices.

In this talk, I will introduce our recent work on the development of advanced nanoprinting technologies.

1) Nanoprinting of 3D photonic crystal: Woodpile photonic crystals (WPCs) fabricated via two-photon lithography (TPL) are promising building blocks to produce 3D geometries that generate structural colors due to their ability to exhibit omnidirectional or anisotropic photonic stopbands. Here, we devised a new strategy to support high-order photonic cavity modes upon side-illumination on WPCs that surprisingly generate prominent reflectance peaks in the visible spectrum. Based on that, we demonstrate the one-step printing of 3D photonic structural colors without requiring post-processing or subwavelength features.

2) High refractive index nanocomposite (HRIN) for metalenses technology: By modulating printable resins with different filler morphologies/low-loss dielectric nanoparticles, solvent composition, and viscosity, we developed HRINs with a high refractive index in the visible region ($n \sim 1.92\text{--}2.07$), which show excellent capability in single-step nanoimprinting for flat optics and metalens fabrication. We demonstrated the proof-of-concept of scaling up via NIL towards the mass manufacturing of metalenses. Such advancements hold significant implications for the wider adoption of metalenses across various technological domains.



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sciforum-121757: Single-pixel imaging for advanced spectroscopy and LiDAR sensor applications

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Single-Pixel Imaging (SPI) is an advanced computational imaging technique that captures images using a single-pixel detector instead of a traditional multi-pixel sensor. By leveraging coded light patterns and computational decoding algorithms, SPI reconstructs images from a series of measurements. SPI offers advantages such as cost-effectiveness, the capability of imaging at any wavelength—even those where arrayed sensors are unavailable—and flexibility in signal modulation techniques.

In this talk, I will highlight our recent developments in combining photonics, computational algorithms, and single-pixel imaging technology to achieve mid-infrared (Mid-IR) spectroscopy, hyperspectral imaging, and LiDAR applications, all using only a single-element detector.

In our first application, a Mid-IR spectrometer (3 μm to 5 μm) employing Hadamard transformation and using a single-pixel photodetector is described. This spectrometer has high spectral resolution (5 nm) and is low-cost, portable, and field-deployable, making it suitable for detecting a wide range of gas, liquid, and solid transmission spectra, thereby enabling real-time chemical analysis and sensing.

In our second application, flexible signal modulation in single-pixel imaging is exploited to develop a LiDAR (Light Detection and Ranging) sensor, which can measure the distances of multiple locations simultaneously within its field of view using a single-pixel receiver. This LiDAR system combines Random Modulated Continuous Wave (RMCW) technology with single-pixel imaging. Further details will be provided in this talk.



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sciforum-121627: Tunable optics using phase change and van der Waals materials for sensing and imaging

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Phase change materials (PCMs) and van der Waals (vdW) materials offer exciting opportunities for tunable optics, enabling dynamic control over optical properties of such as phase, absorption or reflection. PCMs exhibiting reversible phase transitions between amorphous and crystalline states allow non-volatile large refractive index tuning. Meanwhile, vdW materials exhibit strong light-matter interactions, electrically tunable properties and flexible integration with other materials. Integrating these materials into optical structures will enable tunable optical devices and drive significant innovations in imaging, sensing and communications. In this talk, I will introduce our recent works on using chalcogenide PCMs and vdW materials for electrically tunable optics for sensing and imaging applications.

We use Sb_2S_3 to construct a tunable Tamm plasmon polariton (TPP) cavity and experimentally demonstrate dual phase singularity at lower incident angle, and the potentials for improving the sensitivity of hydrogen sensors and the spectral tunability in a metal free Tamm cavity. Using the similar TPP cavity, a scalable sensing platform for surface enhanced resonance Raman spectroscopy is demonstrated by tuning the TPP resonance to match the laser excitation wavelength with the plasmonic resonance and the absorption peak of the biomolecules. Combining a broad-band and a narrow-band absorber made up of Sb_2S_3 , we show tunable optical Fano resonance in the visible wavelength for high purity color. Meanwhile, by manipulating the carrier density and interaction of excitons in 2D transition metal dichalcogenides, we show the large phase and refractive index tuning in a monolayer WS_2 assisted by optical cavity effect. Exploring the linear electro-optic effect in ferroelectric van der Waals material CuInP_2S_6 , a Fresnel lens is made on CuInP_2S_6 and showed non-volatile modulation of light beam focusing by electrical bias.



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Session 5. Acoustic, RF, THz Metamaterials and AI-Enabled Metamaterials

sciforum-125680: Active Learning Enabled Designs for Near-Field Enhanced THz Metamaterial Biosensors

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Terahertz (THz) biosensors have garnered significant attention due to their potential for non-contact, high-sensitivity detection of biomolecules. Metamaterials, with specific designed resonant units, enable locally near-field enhancement, facilitating augmented interaction with analytes at the molecular level. However, enhancing the recognition capability of such metamaterial-based sensors for specific target molecules remains a major challenge. Traditional design methodologies for the metamaterial pattern heavily rely on expert intuition and iterative trial-and-error processes, resulting in substantial time and computational costs. Recent advances in deep learning have markedly improved design efficiency while reducing dependence on conventional electromagnetic theory and simulation expertise. Nevertheless, the performance of conventional data-driven approaches is often constrained by the need for large-scale training datasets. To address this limitation, we propose a novel design framework for THz metamaterial biosensors that integrates near-field enhancement with an active learning strategy. Initially, a pixelated, classical metamaterial structure is used to define the design space, and finite-difference time-domain (FDTD) simulations are performed to extract electromagnetic responses and near-field distributions. A diffusion model is then employed to learn structural features from a small subset of classical designs and to generate novel candidate patterns. An active learning loop is incorporated to iteratively select samples with higher average near-field intensities, which are subsequently added to the training set to refine the model. From this framework, eight optimized sensor designs were selected and fabricated using micro-scale processing techniques. These metamaterials were experimentally validated for the detection of trace amounts of lactose molecules. Results demonstrate that the proposed method substantially reduces computational overhead while achieving significantly enhanced near-field confinement and sensitivity compared to conventional designs. This study offers a promising paradigm for the intelligent, data-efficient development of high-performance THz metamaterial biosensors.



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sciforum-125531: Activation of Millimeter-Wave Sensors Based On Surface Currents On 3D Periodic Gratings

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This work introduces a novel radio-frequency (RF) sensing architecture capable of recovering and amplifying surface currents on a three-dimensional periodic array. Unlike conventional RF-to-DC energy harvesting systems, the proposed approach preserves the RF energy in its native form and redirects it via a dedicated antenna to activate multiple spatially distributed wireless sensors. The platform used to demonstrate this concept is entirely passive, comprising a metamaterial structure and an antenna illuminated by an obliquely incident electromagnetic plane wave. To assess system performance, full-wave electromagnetic simulations were conducted on the system (meta-antenna) configuration under varying angles of incidence. The three-dimensional periodic structure is designed to enhance surface current excitation and propagation across a broad angular range. The induced RF surface currents are collected and transmitted through the antenna to energize a network of remote active sensors, without employing any rectification or RF-to-DC conversion. This preserves signal fidelity and enables efficient RF relaying across a distributed sensor array. Simulation results confirm strong angular resilience, with activation efficiency maintained up to 60° incidence angles along with minimal signal degradation. These results underscore the system's suitability for dynamic or non-line-of-sight environments, presenting a new model in passive RF-powered sensing and energy redirection, as well as distributed wireless energy harvesting.



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sciforum-121870: Electromagnetically Induced Transparency in Reconfigurable K-Architecture Metamaterials: Toward Multifunctional Optoelectronic Logic and Biochemical Sensing

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This study presents a multifunctional reconfigurable K-architecture metamaterial (RKM) with dual applications in opto-logic operations and environmental sensing. The proposed architecture comprises two components: a mechanically reconfigurable K-shaped metallic resonator and a stationary I-shaped metallic strip, forming a coupled plasmonic system as Fig. 1(a) shows. Through the systematic modulation of the horizontal distance (d) and vertical height (h) between elements, polarization-dependent multi-resonant modes exhibiting characteristic electromagnetically induced transparency (EIT) effects are observed in Fig. 1(b). Notably, a peak quality factor of 132 with a full width at half maximum (FWHM) of 0.005 THz is achieved at 0.667 THz, as Fig. 1(c)(d) show. Fig. 1(e) describes numerical simulations, which demonstrate that the binary encoding of horizontal and vertical displacements in the K-shaped resonator enables programmable logic operations. Fig. 1(f) shows an XNOR gate response at 0.587 THz and AND gate functionality at 0.703 THz, establishing direct signal conversion between optical responses and mechanical inputs. The RKM exhibits exceptional environmental sensitivity, with Fig. 1(g)(h) demonstrating a 0.660 THz redshift in resonance frequency under refractive index variations from 1.0 to 2.0. Fig. 1(j)(k) show a refractive index sensitivity of 72 GHz/RIU. A deeper investigation into simultaneous vertical and horizontal adjustments is demonstrated in Fig. 1(i)(m). These combined features—the dynamic logic reconfigurability, the high spectral resolution, and the environmental responsiveness—position the RKM as a promising platform for developing intelligent photonic systems, particularly in integrated optoelectronic circuits and precision sensing applications.



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sciforum-123858: Epsilon-near-zero photonics: infinite potentials

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Epsilon-near-zero (ENZ) metamaterials, characterized by a near-zero permittivity within specific wavelength ranges, have emerged as a promising and competitive optical platform with remarkable optical properties, high nonlinearity and CMOS compatibility. Based on these unique features and great performance, ENZ materials can play a significant role in optical communication, data processing and laser technology. Here, a comprehensive overview of ENZ photonics is presented, revealing its fundamental principles and highlighting our research endeavors. In the past decade, ENZ photonics has drawn a great amount of attention in the fields of nanophotonics, nonlinear optics, and plasmonics. Our recent investigations of ENZ photonics include ultrafast electro- and all-optical switching, ENZ modulators, ENZ multilayers tailored for enhanced light absorption via genetic algorithm, light-matter interactions in ENZ devices and the manipulation of ENZ properties. We also achieve breakthrough in fiber laser with intra-cavity ENZ effect, offering a deeper insight into ENZ photonics and pave the way to the potential applications in nanophotonic on-chip devices. In addition, combining with the enhanced genetic algorithm (EGA), we can break the limitation of the periodicity of traditional ENZ multilayer structures, and optimizes the absorption performance of the aperiodic ENZ transparent conducting oxide (TCO)-dielectric multilayer structures. In the 6-layer structure with a total thickness of 600 nm studied in this work, EGA can optimize the peak absorption from 0.91 to 0.95. Additionally, the absorption bandwidth is optimized from 120 nm to 227 nm, which is enhanced more than 180%. By merging ENZ photonics with AI-driven design strategies, we demonstrate the transformative potential of intelligent optimization in photonic systems and unveils a pathway toward unlocking the infinite potentials of next-generation, AI-enabled ENZ devices for on-chip applications.



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sciforum-122053: MEMS Device Fabrication Based on Printing Technology

Sang-Seok Lee

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2D and 3D printing technology is wide spreading in device or component production due to its high-cost performance and rapid prototyping or fabrication time. Recently, those printing technology has also been paid attention in MEMS device fabrication. In this report, we review printing technology and introduce MEMS devices fabricated based on printing technology. Specifically, here, we focus on RFMEMS devices fabricated using 3D printing technology. Those contains the RFMEMS devices we developed that were fabricated using either polymer or metal 3D printers. We also discuss challenging points of 3D printing technology for RFMEMS device fabrication. Furthermore, we present our efforts to overcome the most important problem of bad surface roughness in 3D printed RFMEMS devices. We investigated influence of surface roughness of 3D printed surface on RF characteristics. It revealed that the surface roughness control is the most important to obtain high performance printed RF devices. Based on experiment results, we also proposed relationship model between surface roughness of 3D printed metal surface and RF characteristics. The prospect of fine inkjet printing technology for MEMS and micro-scaled device fabrication will be also discussed. Finally, we introduce research on Q- and V-band band pass filter researches undergoing for beyond 5G satellite communication.

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sciforum-124373: Metamaterial-Enabled Integrated Photonic Devices for Advanced Spectral-Scanning LiDAR Systems

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Metamaterials, with their subwavelength structures and tunable electromagnetic responses, offer transformative capabilities for manipulating light beyond the limits of conventional optics. Their ability to manipulate phase, polarization, and dispersion makes them highly promising for integrated photonics, especially in compact and efficient LiDAR (Light Detection and Ranging) systems. In frequency-modulated continuous wave (FMCW) LiDAR systems, metamaterials open new avenues for non-mechanical beam steering, spectral multiplexing, and polarization diversity—critical features for building solid-state, high-resolution 3D imaging systems.

Spectral scanning has emerged as a promising beam-steering technique by combining dispersive optical components with wavelength-swept laser sources. Based on our prior research, we have demonstrated several spectral-scanning LiDAR systems capable of high-speed 3D imaging, simultaneous velocity measurement, extended ranging distance and wide field of view detection.

This presentation highlights our recent progress in integrating metasurface-based components into silicon photonic platforms for LiDAR applications. We focus on the design and simulation of the metasurface with dielectric layer sandwiched between a metal ground and a metallic structured layer, specifically cross-shaped Al-SiO₂-Al structures, which enable circular polarization manipulation and broadband spectral beam steering under swept-wavelength excitation. These metasurfaces significantly enhance the steering range while maintaining stable performance under severe environmental conditions—addressing key limitations of existing LiDAR systems.

Our results suggest that metamaterial-enabled design significantly enhances the functionality and integration level of LiDAR systems, paving the way for the next generation of intelligent sensing platforms. Future work will focus on AI-assisted inverse design of metasurfaces to further improve their performance and accelerate the optimization process, particularly for spectral-scanning LiDAR applications.



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sciforum-121318: Multi-channel metasurface for full-polarization modulation of electromagnetic wavefronts

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Metasurfaces have been extensively investigated for their ability to flexibly manipulate the wavefront and polarization of electromagnetic waves, leveraging ultra-thin profiles and low insertion losses. However, the conventional metasurfaces typically achieve only single-polarization modulation, and concurrent polarization-state and wavefront manipulation within a single structure remains challenging. Here, we propose a single-layer anisotropic metasurface design that enables independent wavefront control across multiple polarization channels. The meta-atom consists of two orthogonal dumbbell-shaped metal patches placed on top of a dielectric layer with a grounded plane on the bottom. By adjusting the dimensions of the dumbbell resonator, the phases of two orthogonal linearly polarized waves can be independently tuned, thereby decoupling the propagation phase and the polarization state of the outgoing wave.

As a proof-of-concept, we demonstrate a four-focus holographic imaging system that converges the beams of four distinct polarization states (horizontal/vertical linear and left/right circular) to predefined positions when the linearly polarized waves are vertically incident. The experimental results, validated against full-wave simulations, show excellent agreement and confirm the feasibility of arbitrary polarization conversion combined with independent wavefront shaping. Compared to the existing traditional meta-devices with single-polarization modulation, the proposed polarization multiplexing metasurface achieves mixed polarization and phase control, which can greatly improve the system's functional richness.



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sciforum-125699: Multifunctional electrically tunable split-ring resonator for dynamic modulation applications

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This work proposes a multifunctional electrically tunable split-ring resonator (eSRR) architecture with dynamic reconfigurability for advanced optical modulation and environmental sensing applications. The designed eSRR incorporates four centrally symmetric meta-atoms (MAs) featuring L-shaped metallic patterns, as shown in Fig. 1(a). Through the coordinated horizontal displacement (d_x and d_y) and vertical elevation (h) of individual MAs, the system achieves precise control over seven distinct resonance modes with switchable spectral characteristics. A translational motion analysis revealed that x-axis displacement in TE polarization enables broadband frequency tuning with a 0.41 THz spectral shift, as shown in Fig. 1(b), while y-axis modulation in TM polarization facilitates dual-band switching at 0.54 THz and 0.88 THz, as shown in Fig. 1(c). Fig. 1(d) shows that the resonances were blueshifted from 0.55 THz to 0.91 THz and then redshifted to 0.88 THz through the concurrent modulation of the d_x and d_y parameters between MAs. The vertical electro-optical responses of the eSRR were methodically analyzed for three distinct configurations: individual MA displacement (Fig. 1(e) and (f)), diagonal MA pair elevation, and adjacent MA pair actuation (Fig. 1(g) and (h)). Through the systematic variation of the h parameter, the eSRR demonstrates tunable multi-band operation with selectable single-, dual-, and tri-band resonance characteristics (Fig. 1(e)). Resonance intensity values up to 0.69 can be achieved in different operational modes. Fig. 1(i) shows that the eSRR exhibits notable environmental sensitivity through its refractive index responses when the environmental refractive index varies from 1.0 to 2.0, achieving a maximum sensitivity of 126 GHz/RIU when $d_x = 20 \mu\text{m}$, $d_y = 36 \mu\text{m}$, and $h = 0 \mu\text{m}$, as shown in Fig. 1(j). These results demonstrate the proposed eSRR's potential multifunctional applications, including optical filtering, switching, modulation, biosensing, and environmental monitoring.



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sciforum-125467: Split-Disk Terahertz Metamaterial with Ultra-High Polarization Ratio for Reconfigurable All-Optical Logic

Junle Li, Wenwen Yang *, Hao Peng, Daoye Zheng, Yunchu Zhu and Yusheng Lin

Sichuan University

Terahertz (THz) systems urgently need compact components that combine a high polarization selectivity with on-chip logic capabilities, yet most of the existing metamaterials offer only limited tuning ranges or rely on complex external stimuli. Here, we numerically design two concentric Au split-disk resonators (SDR-1 and SDR-2) on a silicon substrate and analyze their responses using three-dimensional finite-difference time-domain simulations. By independently varying the vertical separation between the disks (height h , 0–6 μm) and the in-plane rotation angle (θ), we systematically map the transmission spectra, field distributions, and polarization ratios (PRs) for transverse-electric (TE) and transverse-magnetic (TM) incidences. Logic functionality is achieved by encoding h and the incident polarization as binary inputs and applying a 46 % transmission threshold as the digital output. For SDR-1, synergistic optimisation at $h = 5 \mu\text{m}$ and $\theta = 180^\circ$ maximises the electric-field confinement, delivering an ultra-high polarization ratio (PR) > 3579 at 0.79 THz, as shown in Fig. 4, where the spectral contrast between the TE and TM modes reaches its peak. Increasing the value of h progressively decouples the top and bottom disks, leading to a redshift in the TM resonances and enhanced TE transmission, as evidenced by the spectral evolution and field distributions in Fig. 6. Exploiting this tunability, SDR-1 realizes reconfigurable NOT and XNOR logic gates at 0.60 THz and 0.66 THz, respectively, by encoding h and the incident polarization as binary inputs, as illustrated in Fig. 10. These logic functions are implemented without any external bias, demonstrating the potential for on-chip all-optical computing. Overall, the proposed split-disk architecture provides record-level polarization discrimination and integrates programmable logic within a single, fabrication-friendly THz metasurface. These results open pathways toward highly selective sensors, compact polarimetric components, and all-optical computing elements in the THz regime.



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Session 6. Neuromorphic Computing, In-Memory Computing and Applications

sciforum-125886: Scalable 2D-CMOS Heterointegration for Energy-Efficient Compute-in-Memory AI Hardware

Kah-Wee Ang

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As artificial intelligence (AI) applications scale, the inefficiencies of data movement between memory and logic in von Neumann architectures have become a critical bottleneck. Compute-in-memory (CIM) systems have emerged as a promising alternative, enabling parallel data processing within memory arrays to drastically improve energy efficiency. Among various memory technologies, memristor crossbar arrays based on two-dimensional (2D) materials offer compelling advantages due to their atomic thickness, low switching voltage, and back-end-of-line compatibility. However, large-scale implementation remains hindered by integration challenges, sneak path currents, and lack of peripheral circuitry support. In this talk, I will present a fully integrated CIM hardware system that addresses these challenges through the heterogeneous integration of wafer-scale 2D HfSe₂ memristors with CMOS-compatible silicon selectors in a one-selector-one-resistor (1S1R) configuration. The fabricated 32×32 crossbar array achieves an 89% device yield, sub-60 ns switching speed, and robust endurance. Coupled with low-power, time-domain peripheral sensing circuits, the system enables efficient analog vector-matrix multiplication and supports in-built activation functions. We demonstrate a complete hardware implementation of a binary convolutional neural network (CNN), achieving 97.5% classification accuracy in a pattern recognition task, with energy efficiency surpassing that of conventional ADC-based systems by 2.5×. This work underscores the viability of 2D materials for scalable, low-power AI hardware and highlights a practical path forward for integrating memory and computation within the same platform.



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sciforum-125504: High-performance memristors based on two-dimensional transition metal phosphorus trichalcogenides for neuromorphic computing

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Memristors represent promising candidates in the race toward the implementation of a neuromorphic computing system beyond von Neumann architectures. To meet the requirements of high-performance and energy-efficient nonvolatile memristors, novel resistive switching materials are constantly being explored and investigated. Two-dimensional layered transition metal phosphorus trichalcogenides (MPX_3) are novel two-dimensional nanomaterials that have recently been exploited as resistive switching mediums for memristive devices due to their abundance and rich variety of structural and electronic properties. However, experimental studies on MPX_3 -based memristors are still in their early stages, with device performance being less than ideal. Here, we report high-yield, high-performance, and reliable memristors that use layered $\text{MnPS}_3(\text{NiPS}_3)$ nanosheets as switching mediums, which exhibit small switching voltage (1 V), long memory retention (10^4 s), fast switching speed, and a high On/Off ratio (nearly two orders of magnitude). Direct experimental evidence reveals that the resistive switching mechanism in the $\text{Ti/MnPS}_3(\text{NiPS}_3)/\text{Au}$ device is related to the formation and dissolution of Ti conductive filaments. Additionally, synaptic plasticity behaviors are successfully emulated. Notably, a high recognition accuracy is achieved in the artificial neural network owing to the highly linear and symmetric multiple conductance states, and multiply-and-accumulate (MAC) operations are implemented by utilizing a crossbar array, manifesting the potential of two-dimensional transition metal phosphorus trichalcogenides-based memristors for neuromorphic computing and beyond von Neumann computing.



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Session 7. Photonics Integrated Circuits (PIC) and Novel Materials

sciforum-121620: Integrated Photonic Devices on thin-film AlScN platform

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Scandium-doped aluminum nitride (AlScN) has emerged as a promising material for integrated photonics due to its exceptional piezoelectric, electro-optic (EO), and acousto-optic (AO) properties. In this work, high-quality AlScN thin films with 9.6% and 20% Sc concentrations were grown by magnetron sputtering. Key photonic devices, from fundamental passive devices including Mach-Zehnder interferometers (MZIs) and micro-ring resonators (MRRs) to active devices such as AO and EO modulators, have been successfully fabricated on the AlScN photonic platform using CMOS-compatible fabrication processes. The fabricated devices exhibit maximum extinction ratios of 24 dB in the MZIs and quality factors up to 3.2×10^4 in the MRRs. The AlScN EO modulator shows a minimum half-wave voltage-length product of 3.12 V-cm at a modulation frequency of 14 GHz, and achieves a 3 dB modulation bandwidth of approximately 22 GHz. Broadband (>20 nm) intramodal AO modulation is achieved, with the AO modulator showing a -19.2 dB modulation efficiency at 25 dBm of RF drive power and with a 5.9 MHz 3 dB bandwidth. Additionally, intermodal AO modulation and non-reciprocity are demonstrated using a multi-mode spiral waveguide, achieving >10 dB of non-reciprocal contrast over a 0.48 nm optical bandwidth. Furthermore, the PL properties of Er-doped AlScN films are investigated systematically across different Er and Sc concentrations. Strong PL emission at communication wavelengths was observed at room temperature. The 0.3% Er-doped $\text{Al}_{0.904}\text{Sc}_{0.096}\text{N}$ sample exhibited a PL intensity up to 70 times higher than that of the commercially available 0.5%Er-doped lithium niobate on the insulator sample, demonstrating a strong potential for applications in integrated optical amplifiers and lasers on silicon photonic platforms. This work establishes AlScN as a versatile platform for high-performance active and passive photonic devices, paving the way for the scalable integration of piezoelectric, electro-optic, and rare-earth-doped functionalities in silicon photonics.



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sciforum-122034: All-solid-state beam steering based on the electro-optical effect of thin-film lithium niobate

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All-solid-state beam steering technologies, such as optical phased arrays (OPAs), lens-assisted focus plane arrays (FPAs), and spatial light modulators (SLMs), are regarded as effective solutions for various applications, including free-space optical communication, light detection and ranging (LiDAR), and laser projection. In this presentation, we introduce our recent progress on all-solid-state beam steering chips based on thin-film lithium niobate (TFLN). Over the past decade, FPAs utilizing the thermo-optical (TO) effect of Si, SiN, and SiO₂ photonics have been proposed. However, these traditional TO FPAs exhibit slow operating speeds and high power consumption. Here, we report, to the best of our knowledge, the first electro-optical (EO) FPA based on TFLN. Thanks to the excellent EO properties of TFLN, we achieved an ultra-fast operating speed of 26.4 ns and an ultra-low power consumption of 35.8 nJ/π in the fabricated EO FPA, which are at least two orders of magnitude smaller than those of previous all-solid-state FPAs. We also present the elimination of blind-zones in one direction and the potential application of laser projection using the proposed EO FPA. Additionally, for the first time, we incorporate the Taylor amplitude distribution into the design of the OPA, resulting in a nearly sidelobe-free TFLN-OPA. Although electro-optical (EO) phased arrays based on TFLN have been reported recently, they have suffered from a low sidelobe suppression ratio (SLSR) of 7.4 dB. Here, we designed a Taylor-amplitude-distributed TFLN-OPA using a cascaded asymmetric multimode interference array on a silicon nitride strip-loaded TFLN platform and experimentally demonstrated a TFLN-SiN OPA with a peak sidelobe level of 20.3 dB at 0° and an average SLSR of 15.8 dB across the entire field of view. Finally, we present an SLM based on TFLN. Benefiting from the ultra-high Q factor in a 2D guided mode resonant metasurface, we demonstrate a high modulation depth of 20%.



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sciforum-121575: Chip-Based Photonics in Barium Titanate

Aaron Danner

National University of Singapore

Barium titanate is a material with a very strong electro-optic effect, exceeding that of lithium niobate by over an order of magnitude. We have grown high-quality single-crystal barium titanate on insulator and fabricated low-loss waveguides and chip-based interferometers which facilitated the extraction of important material parameters, such as the Pockels parameter matrix. Due to the extraordinary electro-optic effect of the material, it may find future use in the manufacture of high-speed optical modulators. However, because the electro-optic effect of barium titanate applies to off-diagonal tensor elements in its permittivity, traditional modulator designs making use of Mach-Zehnder interferometers are unlikely to function as desired and new modulation methods will be necessary.

We have used pulsed laser deposition to fabricate barium titanate thin optical films on a number of different substrates, including dysprosium scandate, which is lattice-matched; we have also developed fabrication processing capabilities which address some of the unique challenges of working with the material compared to lithium niobate, such as its lack of resistance to buffered oxide etching. In this talk, I will describe our group's recent work growing and characterizing barium titanate on scandate substrates, as well as the challenges and advantages of the unusual optical effects resulting from the off-diagonal permittivity tensor changes in the material.



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sciforum-127326: Denoising-autoencoder-facilitated MEMS computational spectrometer with high performance

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Optical spectrometry is a highly effective analytical tool employed in both academic and industrial areas. Its applications encompass material analysis, medical diagnostics, and environmental monitoring. To cater to the demands of portable, handheld, and wearable applications, miniature spectrometers are rapidly advancing. Chip-scale spectrometers based on silicon photonic integrated circuits boast several advantages, including CMOS compatibility and high integration level, making them an appealing option for developing high-performance miniature spectrometers, in which those using a single tunable interferometer provide a simple and cost-effective solution. Among various tuning mechanisms, electrostatic MEMS reconfiguration stands out as an ideal candidate, given its high tuning efficiency and ultra-low power consumption. Nonetheless, MEMS devices face significant noise challenges arising from their susceptible minuscule components, adversely impacting spectral resolution. Here, we propose a distinct paradigm of spectrometers through synergizing an easily-fabricated MEMS-reconfigurable low-loss waveguide coupler on a silicon photonic chip and a convolutional autoencoder denoising (CAED) mechanism. The spectrometer offers a 300 nm bandwidth and a reconstruction resolution of 0.3 nm in a noise-free condition. In a noisy environment with a signal-to-noise ratio as low as 30 dB, the reconstruction resolution of the interferograms processed by the CAED exhibits an enhancement from 1.2 to 0.4 nm, approaching the noise-free value. Our technology is envisaged to provide a powerful and cost-effective solution for applications requiring accurate, broadband, and energy-efficient spectral analysis.



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sciforum-121732: High power, high efficiency GaInAsP/InP single mode lasers

Akihiko Kasukawa

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GaInAsP/InP Strained-Layer Quantum Well (SL-QW) lasers in long-wavelength region (1300–1550nm) with Graded Index Separate Confinement Heterostructure (GRIN-SCH) will be reviewed, together with Buried Heterostructure (BH) for high efficiency operation with single transverse mode operation, showing 1W single-mode-fiber coupled power. I also will introduce high power Distributed Feedback (DFB) lasers, and various types of tunable lasers for telecommunication and data center applications. My talk will focus on how we can achieve high power operation with high efficiency (power conversion efficiency). These studies indicate that the importance of the waveguide design play an important role to make the best use of SL-QW active layer.

The output power from the front facet is given by the following equation.

Where, η_i : internal quantum efficiency, α_i : internal loss, α_m : mirror loss, I : injection current, I_{th} : threshold current, I_{ac} : effective current which contributes to the lasing, I_L : leakage current, R is the facet reflectivity, and $\Theta(T)$ is the term representing the optical power output saturation due to heat generation. From the equation, it is found that internal quantum efficiency, internal loss and temperature characteristics play an important role to achieve high power operation as well as high power conversion efficiency (PCE).

GRIN-SCH SL QW is found to be effective to realize these. In my talk, I will explain our results obtained in GaInAsP/InP GRIN-SCH SL QW lasers.

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sciforum-121740: High-Performance Optical Sensing using Non-Hermitian Photonics

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Non-Hermitian photonics is emerging as a promising field for the development of high-performance optical sensors, due to the theoretically infinite sensitivity of non-Hermitian sensors to external perturbations in the proximity of exceptional points (EPs), and will be elucidated on in this invited keynote. For example, angular velocity sensing has been investigated due to the interesting property shown by non-Hermitian optical gyroscopes of the independence of the eigenfrequency splitting from the device's size, which is different from other optical approaches. Moreover, some non-Hermitian sensors have been proposed for the detection of the presence of nanoparticles, as well as EP-based architectures for refractive index and absorption sensing, with applications in label-free biosensing and chemical analysis.

Moreover, the concept of an exceptional surface (ES) will be expanded on, as this is a surface through which the system can still operate while preserving its exceptional sensitivity, even in the presence of unwanted fluctuations in the parameters of the system. Nevertheless, the robustness of this architecture is obtained at the cost of a limited number of possible sensing schemes. In terms of the simultaneous increase in signal and noise in some configurations of non-Hermitian sensors in the proximity of an EP, an effectively increased signal-to-noise ratio can be achieved while using classical Hermitian architectures under specific operating conditions. This signal-to-noise ratio improvement in non-Hermitian architectures confirms the promising prospects for this physical approach to high-performance sensors in the future.



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sciforum-122204: Novel 2D material-integrated SiN waveguides for chip-based photonic processing

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Photonic devices offer a promising alternative to traditional metallic interconnects by leveraging light for information transfer, enabling both high-speed operation and low power consumption—critical requirements for next-generation computing and communication systems. While state-of-the-art silicon (Si) photonic chips provide an excellent platform for guiding and manipulating light, they still rely on external active components such as lasers and photodetectors, limiting their scalability and efficiency. A promising solution lies in the integration of atomically thin two-dimensional (2D) materials, which exhibit extraordinary optoelectronic properties that can be precisely tuned through doping, strain engineering, and external fields. Their ultra-thin nature and strong light-matter interactions make them ideal candidates for enhancing photonic functionalities while maintaining compatibility with existing Si photonic platforms.

In this talk, I will present my research on novel photonic and optoelectronic functionalities enabled by the integration of 2D materials with Si photonic circuits. I will discuss the key challenges in achieving seamless integration, including material transfer techniques, interface engineering, and performance optimization. Additionally, I will highlight experimental demonstrations showcasing how 2D materials can significantly enhance device performance, such as improved modulation efficiency, enhanced nonlinear optical effects, and high-responsivity photodetection. The synergy between 2D materials and Si waveguides leads to stronger light-matter interactions, unlocking new possibilities for applications in ultrafast optical signal processing, on-chip optical communications, ultrasensitive sensing, and quantum photonics. By addressing both fundamental and practical aspects of this integration, my work aims to pave the way for next-generation hybrid photonic devices that combine the scalability of Si photonics with the versatile optoelectronic properties of 2D materials.



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sciforum-122032: Thin-Film Lithium Niobate Spatial Light Modulator Based on High-Q Guided Mode Resonance

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Spatial light modulators (SLMs), which are utilized to control the amplitude, phase, and polarization of free-space light, play a crucial role in a variety of applications, including free-space optical (FSO) communication, light detection and ranging (LiDAR), wavefront shaping, and holographic optical tweezers. In this study, we present a thin-film lithium niobate (TFLN)-based SLM with high amplitude modulation efficiency. As an exceptional electro-optical (EO) material, the use of TFLN promises SLMs with ultra-fast modulation speeds and ultra-low power consumption. However, the relatively weak EO effect of TFLN limits the modulation depth to 10%. To overcome this limitation, we introduced a high-Q-factor asymmetric 2D guided mode resonance (GMR) grating into the TFLN platform by patterning an 80 nm thick silicon dioxide layer on top of the TFLN. This approach is CMOS-compatible as it avoids the etching of the TFLN. By breaking the symmetry of the GMR structure and using a 2D configuration, we achieved a four-times-higher Q factor than that of a 1D GMR grating. Benefiting from our sample's ultra-high Q factor of up to 3000, we realized a two-times-higher modulation depth of 20%. This enhancement enabled the application of this EO-SLM in FSO communication, through which we realized the transmission of an image between two computers through free space. This work represents a significant advancement in the modulation efficiency of TFLN-based SLMs achieved by introducing a high-Q 2D GMR structure. The corresponding FSO communication experiment may propel TFLN-based SLMs into practical applications.



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Session 8. Enabling Technology for Photonic Neural Networks (PNN) and Applications

sciforum-130192: Photonic Bayesian neural network for robust and uncertainty-aware computing

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Photonic neural networks (PNNs) based on silicon photonic integrated circuits (Si-PICs) offer compelling advantages over electronic counterparts, such as lower energy consumption, higher bandwidth, and ultrafast computing speeds. These benefits make PNNs promising candidates for next-generation AI hardware. However, the analog nature of optical signals makes Si-PIC-based PNNs highly sensitive to device noise and fabrication imperfections, particularly when deterministic, fixed-weight models are used. Such models lack robustness to hardware variations and cannot effectively model data uncertainty—an essential capability in safety-critical applications like autonomous driving, medical diagnostics, and financial forecasting.

To overcome these limitations, we propose a photonic Bayesian neural network (PBNN) architecture that integrates Bayesian principles into photonic computing. In this architecture, photonic noise is treated not as a drawback but as a computational resource. We demonstrate a noise-based random number generator that utilizes the partial coherence of amplified spontaneous emission (ASE) light, along with Mach-Zehnder interferometers and micro-ring resonators, to independently tune the output's mean and standard deviation. This enables the direct implementation of Bayesian weights and probabilistic inference in the optical domain.

Simulation results based on experimentally extracted parameters show that the PBNN achieves up to 98% accuracy on handwritten digit classification—on par with full-precision electronic models. Moreover, the architecture supports multimodal inference, regression, and out-of-distribution detection. By transforming unavoidable photonic noise into a functional feature, this scalable and energy-efficient platform paves the way for uncertainty-aware, all-optical computing systems in real-world scenarios.



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Session 9. In-Sensor Computing and Enabling Technology for Edge Computing

sciforum-125540: s-fDDFT: A Few-Shot Learning Framework for Real-Time Motion Detection Using Flexible Sensors on Edge AI Devices

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In recent years, wearable devices have undergone significant advancements, particularly in integrating edge-based artificial intelligence models for real-time motion detection. However, existing approaches often rely on large datasets for training and suffer from slow inference speeds and the need for advanced hardware. This paper proposes an innovative sequential fast Data Density Functional Transform (s-fDDFT), a few-shot, lightweight model designed for instant motion detection on mobile devices. Leveraging biomechanical sensors as the primary data source, our method integrates theoretical foundations from both differential geometry and quantum physics. The s-fDDFT framework maps signal intensity into an energy space comprising electronic kinetic and potential energy by applying the convolution method with the Coulomb potential. A Lagrangian Energy Density (LED) is then iteratively optimized using a scaling factor to maintain physical balance and establish a negative-value boundary for motion signal segmentation. We apply domain-adaptive averaging to segmented data for each motion label to extract generalizable signal features during training. During inference, motion classification is performed in real-time by computing the structural similarity and soft Dice score between the learned features and the test data segmented via s-fDDFT. We evaluate our method against several convolutional neural network variants on mobile devices for a three-motion classification task. The s-fDDFT demonstrates superior performance in both accuracy and inference time. Particularly in scenarios with limited training data, conventional CNN-based methods suffer from severe underfitting, achieving only 33% accuracy and thus failing at the classification task. In contrast, the proposed method outperforms prior approaches and achieves a significantly higher accuracy of 87%. Our results confirm that s-fDDFT is well suited for real-time motion detection on edge devices.



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sciforum-130193: Artificial Intelligence-Integrated Near-Infrared Photonic Multi-Modality All-optical Edge Computing Platform for Spectroscopic Sensing

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In recent years, on-chip nanophotonic waveguide sensors have emerged as promising platforms for miniaturized, label-free biomolecular detection by leveraging absorption signatures and refractive index changes. With rapid advancements in nanophotonic integration, these sensors now offer unprecedented efficiency and sensing resolution, enabling rich multi-modal data acquisition from a compact footprint. Multi-modality sensing allows a single device to simultaneously extract diverse optical features—such as absorption spectra, refractive index shifts, and scattering patterns—greatly improving detection accuracy while reducing chip area and system complexity. However, conventional nanophotonic sensor systems often rely on optical-electrical-optical (OEO) conversions and external computing, leading to significant power consumption, latency, and architectural overhead. To overcome these limitations, we introduce a multi-modality all-optical edge computing platform for spectroscopic sensing, which eliminates the need for any electrical signal conversion and performs real-time inference entirely in the optical domain. This architecture combines sensing, signal processing, and computing into a unified photonic platform, offering ultrafast response, low energy consumption, and scalable integration. Specifically, the system employs a near-infrared liquid-sensing waveguide for multi-modal data acquisition, and a 4×4 microring resonator array for optical matrix-vector multiplication based on wavelength tuning. Nonlinear activation is implemented using an erbium-doped fiber amplifier, forming a complete all-optical neural network pipeline. The system achieves a classification accuracy 92.6% across 27 distinct liquid mixtures, including varying concentrations (0–33%) of acetone, IPA, and ethanol. This AI-enhanced, all-optical edge computing system offers a fundamentally new paradigm for photonic sensing—delivering high-speed, low-power, compact, and intelligent processing capabilities, and paving the way for next-generation NIR spectroscopic sensors in portable and scalable applications.



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sciforum-121797: Micro- and Nano-Mechanical Resonant Sensors with In-Sensor NEUROMORPHIC COMPUTING CAPABILITY

Xudong Zou

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Reservoir computing (RC) is a promising neuromorphic paradigm for edge computing with temporal signals, particularly given the recent advancements in physical RC. We propose a novel non-delayed physical RC that uses a resonator through amplitude modulation for the classification of action signals. Subsequently, we developed a stiffness modulation method to process digital signals. Finally, we achieved a comprehensively integrated prototype of a resonant sensor with neuromorphic computing capability. The proposed resonant sensor can sense temperature, acceleration, strain/stress, etc. This prototype enables signal acquisition and nonlinear computation during motion, transmitting the results to virtual nodes for data enrichment and feedback loops, ultimately generating classification outcomes for various movements. We refer to this process as IN-SENSOR NEUROMORPHIC COMPUTING. The novelty of our prototype is that it streamlines the interface between sensing and computing, enabling physical stimuli to directly influence reservoir dynamics. Consequently, this prototype allows for the local processing of raw sensing signals, offering a more efficient and integrated approach. Furthermore, the prototype eliminates dependence on external computing resources, thereby reducing both latency and power consumption, which are key factors in edge computing. Given its streamlined architecture and compatibility with MEMS technology, the proposed neuromorphic resonant sensor architecture holds significant promise for advancing innovative MEMS-based applications in the rapidly evolving Internet of Things landscape.



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Session 10. MEMS/NEMS Sensors

sciforum-124753: A Micromechanical Wide-Range Stiffness-Tuning Mechanism for MEMS Applications

Tongtian Zhang *, Junhui Wu and Guangya Zhou

National University of Singapore

MEMS stiffness-tunable devices, owing to their low resonant frequency and high sensitivity, have been widely adopted in fields such as biological force sensing, vibration sensing, and inertial sensing. However, traditional stress-effect-based stiffness adjustment methods, while eliminating the need for continuous power and high operating voltage, suffer from limited tuning range. To address this limitation, this work introduces a novel stiffness-tuning mechanism based on the principle of stiffness compensation, integrating positive stiffness springs with V-shaped negative stiffness springs in a parallel configuration. A self-locking mechanism enables precise control of the mechanical preloading on the negative stiffness structures to realize stiffness adjustment. The concept is validated through an analytical model and finite element simulations, and a prototype is fabricated with the standard silicon on insulator multi-user MEMS process (SOIMUMPs) to confirm manufacturability. The frequency response curves visually illustrate that the device's resonant frequency decreases from 20.13 kHz to 1.03 kHz, accompanied by nonlinear phenomena transitioning from spring softening to hardening effect. The experimental results confirm a stiffness reduction exceeding 90% and demonstrate bistable behavior under a preloading displacement of 48.89 μm . These findings highlight the potential of the design for high-sensitivity MEMS accelerometers and dual-mode actuators such as optical switches or grippers with low switching voltage.



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sciforum-122157: High-frequency surface acoustic wave sensors and their applications

Jian Zhou *, Yihao Guo and Shengyu Wen

Hunan University

Surface acoustic wave (SAW) sensors have gained widespread applications in sensing physical parameters such as the temperature, pressure, and strain, the trace detection of chemical warfare agents (e.g., nerve agents and blister agents), and biosensing (e.g., DNA and protein detection), owing to their unique advantages of wireless and passive operation, miniaturization, and a quasi-digital output. As such, they have become a key research focus in the field of MEMS devices in recent years. However, traditional SAW sensors typically operate at frequencies below GHz, where achieving further enhancements in their sensitivity based on mass loading effects is challenging. This study reports the development of an ultra-sensitive, ultra-high-frequency (UHF) SAW sensor based on electrode mass loading. Theoretical calculations, simulations, and experimental validation confirmed the ultra-sensitive effect induced by UHF electrode mass loading. A novel electron beam lithography process was developed to achieve the uniform, precise, and reliable nanoscale fabrication of UHF SAW interdigital transducers (IDTs), with a minimum line width of 35 nm and a resonant frequency as high as 44 GHz. Furthermore, UHF SAW sensors for micro-mass, smoke, humidity, TNT, and DMMP gas detection were fabricated, and their ultra-high-frequency, high-sensitivity sensing performance was demonstrated in typical application tests. Finally, we also demonstrated that UHF SAW sensors operating in the GHz range exhibit a significant sensitivity advantage over their MHz-range low-frequency counterparts.



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sciforum-125741: 2D Wide-Angle Beam Steering with a MEMS Diffraction Mirror for High-Resolution Scanning LiDAR

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Introduction

LiDAR technology has become increasingly crucial in the automotive industry, serving as a core sensing modality for high-level autonomous driving systems by providing high-resolution, accurate 3D maps under various environmental conditions. Among LiDAR architectures, MEMS-based optical phased arrays stand out for their rapid scanning and compact design. This study introduces a novel high-resolution scanning diffraction mirror, actuated by vertically configured electrostatic comb drives, enabling fast, precise beam steering in two dimensions.

Model Description and Methodology

To ensure sufficient far-field resolution, a 2 mm × 2 mm square mirror is used, consistent with reported requirements. Robustness against ambient vibrations is achieved by maintaining a resonant frequency above 500 Hz. The micromirror is supported by V-shaped flexures and driven by self-aligned vertical comb drives, eliminating the need for precise lateral alignment between moving and fixed fingers. The structure can be fabricated using a single-mask deep reactive ion etching (DRIE) process through the device silicon, buried oxide, and handle layers. A surface grating with a rectangular profile is patterned on the mirror, with a 5 μm period and 1 μm depth (approximately three-quarters of the LiDAR operating wavelength). This configuration suppresses zeroth-order diffraction via destructive interference and enhances the first- and second-order beams through constructive interference, enabling directional control of the reflected light.

Results

Theoretical analysis estimates angular beam steering of ±18° and ±38° for the first and second diffracted orders, respectively. The V-shaped suspension improves lateral stiffness and delays electrostatic pull-in, ensuring stable torsional motion. A mechanical tilt of ±5° is achieved under 140 V, realizing vertical beam steering. Numerical validation is performed using COMSOL Multiphysics.

Conclusions

The proposed system provides a compact, high-speed, wide-angle scanning solution for next-generation MEMS-based LiDAR used in 3D mapping.



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sciforum-119803: Acoustofluidic particle localization on piezoelectric resonators for liquid-phase mass sensing

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The detection and analysis of microanalytes at low concentrations are essential for biochemical analyses and environmental monitoring. MEMS resonators, with their high sensitivity and low sample requirements, have been widely explored for mass-based sensing. However, a major challenge remains: efficiently gathering and localizing extensively scattered microanalytes on highly miniaturized devices. To address this, we integrated surface acoustic wave (SAW) devices with MEMS chips, enabling the precise localization of microparticles in microfluidic droplets. This platform achieved real-time mass measurements through resonant frequency shifts and featured a detachable design for SAW device reuse, minimizing waste while retaining the advantages of noncontact and label-free sensing. Building on this, we introduced an elliptic plate resonator (EPR) for acoustofluidic localization and mass sensing, improving the particle focusing efficiency and detection sensitivity in liquid-phase environments. The EPR's high liquid-phase quality factor (Q) and low motional resistance (R_m) enhanced the precision of detection, while its detachable design allowed the chip to be replaced for high-throughput applications. We further explored highly localized acoustic waves for particle manipulation, proposing a multisite acoustofluidic manipulation approach using a 3×3 piezoelectric micromachined ultrasonic transducer (PMUT) array. This method enabled synchronized particle enrichment and stirring across multiple channels, achieving versatile array-based particle manipulation. Finally, we developed a self-excited localized acoustic manipulation methodology using a piezoelectric micromechanical diaphragm resonator (PMDR), integrating acoustofluidic actuation and mass sensing into a single device. This system significantly improved the particle enrichment efficiency and detection limits, addressing challenges such as low capture rates and non-uniform distribution. These advancements represent a progressive development in integrated acoustofluidic and mass sensing platforms, addressing challenges related to precision, scalability, and compatibility with lab-on-a-chip systems. These innovations pave the way for highly sensitive and versatile tools for analyzing sparse microsubstances in complex environments.



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sciforum-125711: Design and Manufacture of Suspended MEMS-Based Infrared Sensors with 3D Stacking Technology

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Uncooled Micro-Electro-Mechanical Systems (MEMSs) infrared sensors exhibit significant potential for real-time thermal source detection and high-sensitivity temperature variation measurement. Suspended structures are widely adopted in sensor design, with thermal response performance closely linked to critical parameters such as membrane thickness and support beam geometry. This study proposes a structure-oriented design methodology for infrared MEMS sensors featuring stacked suspended architectures, systematically analyzing the impact of geometric parameters on thermal behavior through multiphysics simulations.

The simulations focus on membrane thickness variation ($0.5\mu\text{m}$ to $1\mu\text{m}$) and its influence on thermal time constant (TTC) and responsivity. The optimization criteria are established based on reported noise equivalent power (NEP) values for uncooled sensors in the existing literature, typically within the range of 5–12 pW/. The design target is to achieve a thermal time constant below 10 ms and a responsivity exceeding 15 MV/W. A parameter-mapped performance chart is established to quantify the correlation between geometric design variables and thermal sensing efficiency.

Simply put, the core objective of this study is to integrate the aforementioned design concepts and propose a practical optimization strategy for membrane thickness and geometric parameters. This strategy aims to demonstrate improvements in the thermal response and noise stability of MEMS infrared sensors. The suspended stacked structure adopted in the design, configured on a floating base, not only effectively enhances thermal isolation but also allows for precise control of the thermal capacity and response rate. Preliminary simulation results suggest that such structures may potentially exhibit excellent performance in uncooled architectures



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sciforum-122099: Efficiency Enhancement and Performance Analysis of Temperature-Responsive Silicon-Based Grating Coupler

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This study examines the impact of temperature variations on grating coupler stability, aiming to develop temperature-compensated optical components for enhanced reliability in silicon photonics. While silicon photonics is widely used in optical communications and sensing, its performance remains sensitive to temperature fluctuations. The coupling efficiency of existing grating couplers is influenced by structural and environmental factors, yet most of the research has focused on their materials and fabrication, with limited attention to temperature compensation. This design employs a Si/Si₃N₄/SiO₂ three-layer structure to improve the temperature stability [1]. Si₃N₄ has a low thermo-optic coefficient and low absorption loss, minimizing thermally induced refractive index changes [2]. Combined with SiO₂, it forms a high refractive index contrast that enhances the coupling efficiency. This material system expands the wavelength operating range, making it suitable for DWDM/CWDM applications. Additionally, integrating MEMS-based tunable structures enables dynamic optical control, further improving the temperature stability. The temperature compensation mechanism mitigates thermal effects through grating structure optimization and refractive index matching [3]. Adjusting the grating period, etching depth, and fill factor reduces the modal shifts from thermal expansion, stabilizing the wavelength response [4]. Combining materials with complementary thermo-optic coefficients offsets the refractive index variations, achieving effective compensation. MEMS actuators fine-tune the coupling conditions in real time, enhancing the stability under varying temperatures. Experiments will be conducted using a 655 nm tunable laser and a high-precision fiber coupling system to measure the optical response from 0 to 60°C, verifying the temperature compensation. Key parameters include the wavelength drift (targeted within ± 0.1 nm/°C) and the variation in the coupling efficiency (within ± 1 dB) [4]. Optimized grating and material design improve the fiber-to-waveguide coupling efficiency, enhancing the PIC (silicon photonic integrated circuit)'s stability across environments. This technology reduces thermal effects on DWDM/CWDM transceivers, improving their wavelength selectivity and power transmission efficiency. Integrating MEMS solutions enhances the thermal resilience and tunability, expanding the applicability of high-precision photonic systems.



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sciforum-125327: Electrically Reconfigurable Photonic Quasi-Bound States in the Continuum (BIC) Platform via MEMS Actuation

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Bound states in the continuum (BICs) feature ultrahigh quality factors by confining light through interference, but their practical deployment is hindered by fixed resonance frequencies and the stringent nanometer-scale tolerances required for their static geometries. Here, we report the first experimental realization of an electrically reconfigurable quasi-BIC in the mid-infrared, enabled by a mirror-coupled nanoantenna array integrated with an electrostatic MEMS actuator. By tuning the spacing between the nanoantenna array and a movable gold mirror, we actively modulate the interference condition that gives rise to the quasi-BIC, achieving continuous spectral tuning across a 400 nm window (in the 3–4 μm band). Our platform exhibits microsecond-scale response times and reversible, cycle-stable actuation, all while preserving the narrow linewidth and strong field enhancement intrinsic to BIC modes. In a gas sensing proof-of-concept, electrical reconfiguration of the quasi-BIC resonance compensates for detuning relative to the absorption lines of target gas molecules, leading to a 2.9-fold increase in the normalized sensing signal. This enhancement directly stems from the optimized overlap between the dynamically tuned quasi-BIC and molecular absorption features. The demonstrated MEMS-BIC methodology unites ultrahigh-Q photonic resonances with on-chip, real-time reconfigurability under low-power electrical control. Such adaptive platforms promise broadly tunable infrared filters, spectrally agile sensors, and dynamically programmable photonic elements for applications in environmental monitoring, chemical detection, and beyond.



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sciforum-127457: Flexible sensors and soft robotics

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Flexible sensors have been extensively investigated and developed in recent years, with the distinctive advantage of surface conformability. As a result, flexible sensors are prime candidates for applications in wearable technologies, implantable devices, and other systems requiring surface adaptability. This inherent advantage further establishes their potential for integration with soft robotics systems. Current soft robots typically exhibit limited self-sensing capabilities, particularly lacking integrated sensing-actuation functionality. Two researches relevant to Integrated flexible sensor and soft actuator are presented below:

First, we present a compact polymer-based underwater robot with integrated self-sensing and communication capabilities. The system employs a multilayer polyvinylidene fluoride (PVDF) actuator co-fabricated with a hydrophone unit through a novel single-step manufacturing process. This integrated fabrication methodology effectively mitigates stiffness mismatch issues traditionally associated with rigid-flexible sensor-actuator systems, demonstrating significant potential for cost-effective swarm robotics development.

Second, we introduce a deep-sea compliant tactile sensor array (>2,000 m operational depth) integrated with a soft gripper, addressing the critical challenge of extreme hydrostatic pressure environments. The dynamic pressure signals generated by gripper actuation are negligible compared to the ambient hydrostatic pressure, leading to significant detection challenges for low-stiffness targets such as marine organisms (e.g., sea cucumbers). Most of the conventional pressure sensors experience saturation under a high hydrostatic pressure of 20 MPa, as a result, specialized solutions are necessary. A Capacitive sensor with Ionic gel and hemisphere micro-structures are adopted for sensitivity improvement. Dielectric fluid-filled cavities inside the sensor are incorporated for adaptive hydrostatic pressure compensation. This configuration achieves high sensitivity through low-stiffness structural layer deformation under localized compressive stresses, enabling precise tactile detection in extreme environments.



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sciforum-120964: Parity--Time Symmetry for Silicon Micromechanical Resonators

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The research and commercial development of a silicon micromechanical resonator has been pursued for applications in both resonant sensors (including pressure, accelerometer, and magnetometer sensors) and signal processing devices (such as filters and oscillators). In general, the frequency shift in these silicon resonant sensors scales linearly with the perturbation to be sensed, while the silicon resonator typically manifests as reciprocal transmission. In this article, we adapt two coupled resonators into parity--time (PT) symmetric resonators with linear loss and nonlinear saturable gain, by equipping one of them with a positive feedback circuit. Through leveraging an exceptional point (EP) that arises in PT symmetry, a frequency shift exhibits a cubic root singularity of perturbation when one of the two coupled resonators undergoes a perturbation. In experiments, a perturbation to the stiffness of the loss resonator is achieved by an external voltage. The resonator stiffness changes in response to the electrostatic voltage. We reveal that the sensitivity in the small perturbation limits has increased by several orders of magnitude in comparison with conventional solutions. On the other hand, by biasing PT-symmetric silicon micromechanical resonators at the broken phase, we theoretically and experimentally demonstrate 7.5 dB of non-reciprocal transmission with an isolation over 18 dB in a pair of electrically-coupled silicon micromechanical resonators. The findings of our study pave the way for novel applications of silicon micromechanical resonators.



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sciforum-121225: Preliminary test for MEMS-based wearable respiratory self-training system

Dong Wook Kim

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Respiratory training has been recommended to deliver planned radiation accurately to tumors that are moved by respiration in the thorax and abdomen. However, it is difficult to provide respiratory training to all patients because it requires additional space, time, and professional human resources. We developed a portable self-respiratory training system that is based on a patch-type magnetic sensor and evaluated the system regarding its basic performance and clinical applicability. The sensor had a noise ratio of 5% of the signal. The average errors of the signal amplitude and period were measured for the breathing patterns. The signal could be measured consistently when the sensor-magnet distance was from 5 cm to 20 cm. The signal difference was 1.89% for the presence or absence of a material, indicating that its influence on the measured signal was relatively small. The potential of the respiratory self-training system was confirmed through performance tests and a clinical usability evaluation. In the future, we believe that the system could provide precise respiratory training to various patients in clinical trials.



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sciforum-121694: Quantum Magnetometry Based on Ensemble NV-Centers in Integrated MEMS

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Nitrogen-vacancy (NV) centers in diamond have emerged as powerful quantum sensors for high-sensitivity magnetic field detection and biosensing, owing to their exceptional optical readout capability, long coherence time, and biocompatibility. However, challenges in excitation efficiency, fluorescence collection, and surface functionalization remain obstacles to practical applications. To address these limitations, we developed a fiber-integrated MEMS-based diamond NV quantum probe optimized for both magnetic sensing and biomedical applications. The probe consists of an ensemble of NV-doped diamond particles (20 μm) attached to a tapered multimode optical fiber tip (50 μm diameter), fabricated using a flame-heated tapering process. The NV centers are integrated with a small microwave antenna to form a MEMS microdevice. In addition, a microcavity is formed via the Tollens reaction to enhance excitation efficiency and fluorescence collection. This MEMS and optical fiber integrated design resulted in a 3.86-fold increase in fluorescence intensity and a 46% reduction in optically detected magnetic resonance (ODMR) linewidth, significantly improving sensing resolution and signal-to-noise ratio. The ODMR response of the probe was characterized under varying magnetic fields, achieving a sensitivity of 10 nT/ $\sqrt{\text{Hz}}$. It exhibited stable signal output over extended measurement periods, with less than 5% signal drift over 12 hours, confirming its robustness for long-term sensing applications. The high sensitivity, nanoscale spatial resolution, and compact MEMS-integrated design of the probe establish it as a promising tool for weak magnetic field detection in complex biological environments, offering new opportunities for advanced applications in nanoscale magnetometry.



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sciforum-122458: Research on MEMS Alkali Metal Atomic Vapor Cell and Miniature Atomic Magnetometer

Mingzhi Yu

Xi'an Jiaotong University

Alkali metal atomic vapor cells constitute the sensitive core of numerous quantum devices, fundamentally determining critical performance metrics such as sensitivity and precision in these systems. Research on MEMS-based alkali metal atomic vapor cells, aimed at achieving their miniaturization and batch fabrication, holds significant potential for substantially reducing the volume, power consumption, and cost of quantum devices, thereby advancing their large-scale applications. This presentation outlines our research group's progress in MEMS atomic vapor cells and MEMS-based miniature atomic magnetometers, including the following: the development of a low-temperature, high-strength composite bonding process under anhydrous and oxygen-free conditions, with systematic analysis of process parameters' effects on bonding interface microstructure and elucidation of the composite bonding mechanism for gap closure; the implementation of a non-isothermal anodic bonding process, significantly improving the success rate of low-temperature hermetic sealing for MEMS alkali metal vapor cells; the creation of a precision lateral compression molding technique, enabling batch fabrication of MEMS vapor cells with orthogonal optical paths; the investigation of quadrupole frequency shifts and the relaxation properties of ^{131}Xe nuclear spins during collisions with silicon sidewalls in MEMS cells, providing insights into nuclear spin relaxation mechanisms at silicon interfaces; and the design and fabrication of a miniaturized hybrid optically pumped atomic magnetometer with single-beam configuration, achieving a sensitivity of 30 fT/Hz^{1/2}, which lays a foundation for advancing quantum device miniaturization and mass production.



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sciforum-121991: Simulation Analysis of MEMS Scanning-Grating-Micromirror-Integrated Quantum Cascade Laser External Cavity Systems

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Quantum Cascade Lasers (QCLs) are extensively utilized in spectroscopic analyses and optical communication due to their versatile performance. However, the conventional Fabry–Pérot (F-P) cavity structures exhibit limitations such as mode-hopping and narrow spectral bandwidths, which constrain their tuning range and spectral resolution. To overcome these challenges, this study introduces an integrated external cavity system incorporating a MEMS scanning grating micromirror (SG). This approach effectively resolves the mode mismatch and nonlinear tuning issues observed in the traditional external cavity configurations.

To address the miniaturization and integration challenges for tunable QCLs operating in the mid- to far-infrared band (7.5–10.5 μm), this study proposes an optimized external cavity configuration based on the Littrow arrangement (Fig. 1). By incorporating a MEMS SG as the external cavity feedback element, a compact, external cavity system with a folded optical path geometry and a high feedback efficiency was realized. Utilizing a three-mirror coupled cavity theoretical model, the effects of the cavity length and feedback efficiency on the laser performance were systematically analyzed. The theoretical results demonstrate that reducing the cavity length increases the spectral linewidth, whereas enhancing the feedback efficiency improves the side-mode suppression ratio (Fig. 2). A parametric model derived from the Littrow grating equation was used to systematically evaluate the coupling between the grating periodicity (Λ) and the blaze angle (θ). Through rigorous coupled-wave analysis (RCWA)-based optimization, the optimal grating parameters were determined as $\Lambda = 7 \mu\text{m}$ and $\theta = 40^\circ$, achieving an angular dispersion of 5.3 nm/mrad and a diffraction efficiency exceeding 80% (Fig. 3(a)). Numerical simulations confirmed continuous wavelength tuning over 3.2 μm (35.6% relative to the 9 μm central wavelength) with a mechanical angular span of 17.2° (Fig. 3(b)). These results validate the potential of integrating MEMS technology with optimized grating designs to enhance QCLs' performance in mid- to far-infrared applications.



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sciforum-128156: Transferred carbon nanotubes for Sensors and Actuators

Jongbaeg Kim

Yonsei University

Since their discovery more than three decades ago, carbon nanotubes (CNTs) have remained at the forefront of materials research due to their exceptional intrinsic properties. Their remarkable mechanical characteristics—such as high tensile strength and durability—combined with outstanding electrical conductivity, make them highly attractive for a wide range of applications. One particularly important property is their low percolation threshold, which allows the formation of electrically conductive pathways with a minimal amount of material. This feature is especially advantageous in the field of flexible and stretchable electronics, where maintaining electrical performance under mechanical deformation is critical.

However, a major challenge in CNT-based device fabrication lies in the high synthesis temperature, which typically exceeds 700°C. Such conditions are incompatible with many target substrates that possess low melting points or require mechanical flexibility, such as polymers used in wearable and biomedical devices. To overcome this limitation, CNTs are often synthesized on high-temperature-compatible substrates and then transferred to the final functional substrate. Transfer methods include maintaining the morphology of vertically aligned CNTs during physical relocation, or dispersing CNTs into liquid media for deposition via printing or spraying.

This presentation will highlight several examples of these transfer techniques and discuss their integration into practical devices. Applications span both sensing and actuation, including tactile sensors, neural probes, thermoacoustic speakers, and flexible tactile displays. These examples demonstrate the versatility and continued promise of CNTs as core materials for next-generation multifunctional devices.



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sciforum-123130: Uniform Metal-Assisted Chemical Etching for High-Aspect-Ratio Microstructure Fabrication with Low Cost

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Southeast University

Metal-assisted chemical etching (MaCE) is a method for etching silicon in hydrofluoric-acid-based aqueous solutions. The reaction is catalyzed by a metal such as gold, silver, palladium, etc. Silicon micro- and nanostructures with a specific geometry, such as nanowires/micropores, can be fabricated using metal catalysts with controlled shapes. In the fabrication of high-aspect-ratio trenches and vias, however, MaCE exhibits a severe tendency towards slow etching rates and random etching. This paper reports a novel wet chemical etching process, named uniform metal-assisted chemical etching (UMaCE), for high-aspect-ratio microstructure fabrication on silicon substrates. The process managed to achieve the highly uniform fabrication of deep vias and trenches that have traditionally been fabricated using the deep reactive ion etch method (DRIE). Since the process utilizes an aqueous solution as the etching media and proceeds at room temperature, it is able to significantly reduce the manufacturing cost and increase the throughput. This paper examines the relationship between the TSV diameter and the optimal etching conditions, including the catalyst thickness ratios, the etchant composition proportions, and their collective effects during UMaCE-stabilized etching processes. In this paper, through-silicon vias (TSVs) with a diameter of 10 μm and an aspect ratio exceeding 46:1 are successfully fabricated. Through an in-depth investigation of the etching mechanism at the nanoscale, the diameter of the TSVs is further scaled down to 500 nm with aspect ratios of up to 10:1. These results demonstrate the potential of UMaCE for applications such as MEMSs and 3D microelectronic packaging.



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sciforum-125693: Wide-temperature-range flexible thin-film temperature sensor

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Flexible temperature sensors have been extensively investigated due to their prospect of wide application in various flexible electronic products. However, most of the current flexible temperature sensors only work well in a narrow temperature range, with their application at high or low temperatures still being a big challenge. This work proposes a flexible thermocouple temperature sensor based on aerogel blanket substrate, the temperature-sensitive layer of which uses the screen-printing technology to prepare indium oxide and indium tin oxide. It has good temperature sensitivity, with the test sensitivity reaching $226.7 \mu\text{V}/^\circ\text{C}$. Since the flexible aerogel blanket substrate has a relatively rough surface, ascreen-printing technology is innovatively designed to prepare the sensitive layer film instead of the traditional micro-nano preparation technology. Most importantly, the sensor can work in a wide temperature range, from extremely low temperatures down to liquid nitrogen temperature to high temperatures up to 1200°C , which is difficult to be achieved by other existing flexible temperature sensors. The temperature range optimization of flexible thin-film temperature sensors enables them to expand their application scope. The series of sensors prepared have realized the online monitoring of the temperature of high-temperature gas flow and metallurgical crucibles. The initial application of flexible sensors has been achieved in the fields of aerospace and steel metallurgy.



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Session 11. Semiconductor Sensors, Photodetectors and CMOS MEMS

sciforum-122094: Electrostatic MEMS-Driven Silicon Photonics Switch with Zero Static Power Consumption

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In high-speed data transmission and computing, optical transmission outperforms electrical transmission, making silicon photonics a key technology for CMOS integration [1]. It improves bandwidth and energy efficiency while reducing power consumption and thermal effects. A major challenge is developing a silicon photonic architecture with flexible configuration and high-performance switching. A promising solution is a silicon photonic switch based on Micro-Electro-Mechanical Systems (MEMSs) [2-3], integrating MEMS actuators with photonics for low-power, highly tunable optical switching. This study uses a non-volatile Single-Pole Double-Throw (SPDT) switch [4-5] with a MEMS phase modulator for improved phase control and stability. The bistable SPDT switch ensures stability across various optical waveguide structures. During operation, a control voltage applied to the MEMS actuator precisely adjusts the waveguide position, routing optical signals between different outputs. The MEMS structure's mechanical latching maintains stability even without power, reducing energy consumption and enhancing system reliability, resulting in a zero-power steady-state silicon photonic switch.

A silicon photonic architecture with a flexible configuration and high-performance switching is developed, efficiently providing low-power, highly tunable optical signal switching capabilities. This design employs a non-volatile SPDT switch and utilizes a bistable mechanism to achieve stable states. Equipped with a MEMS actuator, it precisely adjusts the waveguide position by controlling the applied voltage, enabling optical signal switching between different output waveguides. The input and output waveguide widths are set to 4.5 μm , with the optimal effective refractive index achieving complete coupling under a coupling length of 370 μm and a coupling gap of 0.7 μm . Further analysis will be conducted on both the electrical and optical properties. Its mechanical latching characteristic allows the switch to maintain a stable state even when powered off, reducing energy consumption and enhancing the system's long-term stability. Ultimately, this results in a zero-power steady-state silicon photonic switch.



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sciforum-124855: First-Principles Investigation of Work Function Modulations Induced by Co-adsorption of NO, NO₂, CO, CO₂, H₂S, and O₃ on ZnGa₂O₄(111) for Gas Sensing Applications

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Gas sensing materials with high selectivity and tunable surface electronic properties are essential for the development of next-generation gas sensors. In this work, we investigate the effects of co-adsorption of oxidizing and reducing gases on the work function and electronic structure of ZnGa₂O₄(111) surfaces using first-principles calculations. Six target gases (NO, NO₂, CO, CO₂, H₂S, and O₃) were modeled in various binary combinations across four representative surface sites (Ga₃c, Zn₃c, O₃c, and O₄c), resulting in 15 distinct co-adsorption configurations. The simulations were conducted using the Vienna Ab initio Simulation Package (VASP) within the GGA-PW91 framework, with a 50 Å vacuum layer and a 3×3×1 Monkhorst-Pack k-point grid. By analyzing changes in vacuum level, Fermi energy, and work function (Φ), we evaluated the potential of ZnGa₂O₄ as a selective gas sensing platform. The simulation results reveal that NO₂-O₃ co-adsorption induces the largest work function change ($\Delta\Phi = +1.88$ eV) and strongest adsorption energy ($\Delta E = -3.98$ eV), indicating a synergistic effect in modifying the electronic structure and enhancing sensing responsiveness. Similar trends are observed in CO-O₃ and CO₂-O₃ systems, while single-gas adsorption generally results in smaller $\Delta\Phi$ values (< 0.5 eV). These findings demonstrate that electron-withdrawing gas pairs such as NO₂ and O₃ significantly enhance surface charge redistribution and vacuum level modulation. Our results highlight ZnGa₂O₄(111) as a promising candidate for gas sensors with high sensitivity and selectivity. The marked difference in electronic responses under co-adsorption scenarios provides theoretical support for multi-gas discrimination mechanisms and real-time environmental monitoring applications.



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sciforum-122021: First-Principles Study of NO Co-adsorbed with Multiple Gases on SnO₂(110): Work Function Modulation and Sensing Potential

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Metal oxide semiconductors (MOS), especially SnO₂, are widely used in gas sensors due to their high sensitivity, low cost, and operational stability. However, target gases often coexist in realistic environments, making it essential to understand how multi-gas adsorption affects the electronic properties of sensing surfaces. This study focuses on nitric oxide (NO) as the base molecule, co-adsorbed with common atmospheric gases, including carbon monoxide (CO), hydrogen sulfide (H₂S), carbon dioxide (CO₂), nitrogen dioxide (NO₂), and ozone (O₃) on the SnO₂(110) surface. Using density functional theory (DFT) with the Vienna Ab initio Simulation Package (VASP), the Generalized Gradient Approximation (GGA) describes the exchange-correlation interactions with the Perdew-Wang (PW91) correction. We systematically investigate multiple co-adsorption configurations involving four representative surface sites such as Sn5c, Sn6c, O2c, and O3c. The computed work function changes ($\Delta\Phi$), band structures, and charge density distributions reveal significant modulation of surface electronic properties. Among all configurations, the most significant work function reductions are observed when NO is co-adsorbed with O₃ at the surface bridging oxygen site (O3c) with $\Delta\Phi$ values of -0.49 eV. Bandgap narrowing from 0.730 eV (pristine surface) to 0.553 eV is also found in our cases. These findings offer insights into the electronic impact of gas co-adsorption and provide theoretical guidance for designing highly sensitive and selective SnO₂-based gas sensors in mixed-gas environments.



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sciforum-133721: Induced sensing via ferroelectric and piezoelectric

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As the world strives to reduce carbon foot-print, many technologies and electronic devices are advancing towards energy efficiency to reduce energy consumption supporting the global carbon net-zero ambition. Here, we make progress in energy efficiency via ferroelectric and piezoelectric in several applications, namely: i) field-effect modulated photoelectrode, and ii) optoelectromechanical sensors and actuators. The former forms an electrolytic conducting channel due to the field-effect induced by photoexcited charge carriers via ferroelectrics. With a 4.5 mm channel length and an overall upward ferroelectric polarization direction, a ~30% increase in water-splitting performance in a neutral-pH electrolyte is achieved in the presence of field-effect induced by a 20 mW 405 nm light source. The mechanism is further verified by monitoring the pH of the electrolyte during the water-splitting process. The field-effect modulation not only can enhance water splitting system, but can be utilized in electrochemical sensing applications. Meanwhile, the latter demonstrates an effective piezoelectric coefficient, by 38-50% (along 33-mode) from gallium nitride (GaN)-based multiple quantum wells (MQWs). The driving mechanism of such behavior involves a three-way coupling of electronic, piezoelectric, and optical properties of the GaN-based materials. This could be used in developing chips with both optical and electronic functionality essential to realizing next-generation applications such as photonic computing.



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sciforum-124343: Mid-infrared Detection and Spectroscopy with 2D Materials

Qijie Wang

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Mid-infrared (MIR) detection is widely used in life sciences, remote sensing, security, industrial imaging, and environmental monitoring. Despite significant attempts, development of simple, low-cost, low-noise systems for MIR detection and imaging at room temperature remains a challenge. Two-dimensional (2D) materials have attracted tremendous research interests due to their unique and intriguing electrical and optical properties. In this talk, I am going to present our early research in applying 2D materials for applications in the MIR regime, in particularly, broadband PtSex-based photodetector and a high responsivity hybrid MIR photodetector based on graphene integrated with broadband oxide-based nanoparticles. Furthermore, converting MIR radiation to visible and near-infrared regions is an ideal approach, which can be easily detected and imaged with silicon photodetectors due to their high sensitivity, low cost, and CMOS compatible. Here, we report a transducer using lanthanide nanocrystals that realize broadband MIR detection under ambient conditions. The broadband wavelength response ensures its application for MIR spectroscopy and imaging, including multidimensional detection in light intensity, polarization, and spectrum, simultaneously.

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sciforum-138106: Piezoelectric Ultrasonic Transducer for Flow Rate, Occlusion and Bubble Detection in Portable Peritoneal Dialysis System

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A piezoelectric ultrasonic transducer was developed to detect flow rate, occlusion and bubble occurrence in a portable peritoneal dialysis system. The piezoelectric transducer generate and transmit ultrasonic signal across the tubing wall, and detect the reflected wave. The piezoelectric ultrasonic transducer converts electrical energy into ultrasonic waves and vice versa, using the piezoelectric effect. When a voltage is applied to a piezoelectric transducer, changing its shape, producing mechanical vibrations hence ultrasonic waves. Conversely, when the returning (reflected) ultrasonic waves deforms the piezoelectric material, voltage is generated. The transducer is embedded into PeritoCare®, a portable peritoneal dialysis system developed in Universiti Kebangsaan Malaysia (UKM), Malaysia. The detection system was tested with 5mm OD and 3 mm ID tube, with a dialysate flow rate of 100-150 ml/min. The ultrasonic transducer can detect the presence of bubble of diameter down to approximately 10% of the ID of the tube, with detection time as fast as 20 milliseconds. PeritoCare® has a pump in / pump out 100-180 ml/min, with dialysate dwell time of 1-3 hours. The dialysate amount used is 1-1.5L for tidal peritoneal dialysis (TAPD) setting, for performing dialysis in portable mode, and 2-2.5L for automated peritoneal dialysis (APD) setting. The implementation of the piezoelectric ultrasonic transducer into PeritoCare® has enable development of a portable peritoneal dialysis system that alleviate mobility problem among young and active ESRD patient on-the-go.



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sciforum-135539: Redefining Limits: Advanced Organic Infrared Photodetectors for Next-Gen Optoelectronics

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Room-temperature femtowatt sensitivity remains a highly sought-after attribute, even among commercial inorganic infrared (IR) photodetectors (PDs). While organic IR PDs promise next-generation sensing, they still lag behind inorganic counterparts. The inherent deficiencies of current organic IR PDs, including limited spectral absorption ($>1.0\ \mu\text{m}$), low external quantum efficiency (EQE), and low detectivity (D^*), are inextricably linked to trap-induced non-radiative recombination in narrow-bandgap organic semiconductors.

To overcome these limitations, we employ prototypical organic integer charge transfer (ICT) and partial charge transfer (PCT) donor-acceptor complexes that exhibit strong low-energy subgap absorption extending up to $2.5\ \mu\text{m}$. We observe that polaron excitation in these radical-neutral blends allows bound charges to overcome Coulombic attraction to their counterions, leading to elevated EQE (in the polaron absorption region) compared to conventional Frenkel excitons. In this system, electrostatically tunable deep trap states (enabled by partial charge localization) amplify photo gating-driven gain, while low-energy photoactivated ionic donor-acceptor pairs establish delocalized conduction pathways that suppress carrier scattering and Johnson-Nyquist noise.

As a result, our devices achieve high EQE, femtowatt-level noise-equivalent power (NEP), and fast response times at room temperature for UV to SWIR wavelengths. Our innovative strategic deployment of CT complexes epitomizes a significant advance in monolithically organic SWIR optoelectronics, obviating the reliance on hybrid architectures while rivaling the performance of state-of-the-art inorganic counterparts.



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sciforum-125667: SnS2 nanosheets-Niobium diselenide@C60 hybrid materials-based self-power broadband photodetectors for advanced neuromorphic AI vision systems

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Transition metal dichalcogenides (TMDs) material-based hybrid photodetectors are promising due to their unique structures and excellent optoelectronic properties. In particular, Niobium diselenide (NbSe₂) has become an attractive material due to its extraordinary physical properties of superconducting transition and doping of NbSe₂ into other materials, which make it a material of great interest to researchers working to create high-performance devices. On the other hand, SnS₂ nanosheets have garnered attention due to their excellent optical properties, and hence they are a good choice for optoelectronic applications. Significantly, 2D TMD-based bidirectional photodetectors are promising for the development of advanced visible-light communication, next-generation artificial neuromorphic systems, and future optoelectronic logic gates. Importantly, in visible-light communication, color shift keying is commonly employed to satisfy non-negative light-intensity modulation requirements. However, the device's cost is increased and the communication system becomes more complex when a minimum of two photodetectors with filters are needed to decode optical data. Here, we present advanced bidirectional self-powered broadband photodetector SnS₂-NbSe₂-C60 heterostructures, which exhibit an excellent photoresponse and switch ratio compared with existing materials. Additionally, the programmable bidirectional photoresponse achieved wavelengths between 520, 632 and 850 nm for positive polarity and wavelengths and wavelengths between 420 and 365 nm for negative polarity. The present research work based on SnS₂-NbSe₂-C60 heterostructures is promising for advanced neuromorphic AI vision systems.



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sciforum-125534: Tailoring MXene Thickness and Functionalization for Enhanced Room-Temperature Trace NO₂ Sensing

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In recent years, interest in 2D materials, especially MXenes, has grown due to their unique properties and applications in electronics, energy storage, and sensors [1–3]. MXenes, derived from MAX phases, exhibit exceptional properties, including high electrical conductivity, large surface area, and tailorable functional groups [4, 5]. The key to obtaining high-quality MXenes lies in the selective etching of the A-layer, resulting in surface functional groups such as –O, –OH, and –F. In this study, precise control over the thickness and termination of Ti₃C₂TX MXene flakes is achieved to enhance their electrical properties, environmental stability, and gas-sensing performance. Utilizing a hybrid method involving high-pressure processing, stirring, and immiscible solutions, sub-100 nm MXene flake thickness is achieved within the MXene film on the Si-wafer. Functionalization control is achieved by defunctionalizing MXene at 650 °C under vacuum and H₂ gas in a CVD furnace, followed by refunctionalization with iodine and bromine vaporization from a bubbler attached to the CVD. Notably, the introduction of iodine, which has a larger atomic size, lower electronegativity, reduce shielding effect, and lower hydrophilicity (contact angle: 99°), profoundly affecting MXene. It improves the surface area (36.2 cm² g^{–1}), oxidation stability in aqueous/ambient environments (21 days/80 days), and film conductivity (749 S m^{–1}). Additionally, it significantly enhances the gas-sensing performance, including the sensitivity (0.1119 Ω ppm^{–1}), response (0.2% and 23% to 50 ppb and 200 ppm NO₂), and response/recovery times (90/100 s). The reduced shielding effect of the –I-terminals and the metallic characteristics of MXene enhance the selectivity of I-MXene toward NO₂. This approach paves the way for the development of stable and high-performance gas-sensing two-dimensional materials with promising prospects for future studies.



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sciforum-127104: Van der Waals mid-wave infrared photodetector linear array

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Passive imaging in the mid-wave infrared (MWIR) region is highly advantageous due to its resistance to atmospheric pollutants, which ensures image clarity and accuracy even under adverse environmental conditions. Arrayed photodetectors, which enable simultaneous multi-pixel sensing, greatly enhance imaging efficiency over single-pixel devices. However, developing arrays from emerging materials like van der Waals (vdWs) photodetectors remains challenging due to lattice mismatch and non-uniformity issues.

In our work, we present an 8×1 black phosphorus/molybdenum sulfide (BP/MoS₂) vdWs photodetector linear array. This array was fabricated using a temperature-assisted sloping transfer method, which ensures a flat interface and uniform thickness across the entire structure. These features are critical for facilitating efficient carrier transport and minimizing pixel non-uniformities, which are common issues in large-area devices. As a result, the array exhibits an average peak detectivity (D^*) of $2.34 \times 10^9 \text{ cm} \cdot \text{Hz}^{1/2} \cdot \text{W}^{-1}$ in the MWIR region, a performance level that is highly competitive for practical applications.

The efficiency of push-broom scanning passive imaging is improved by 8 times compared to a single-pixel. This enhancement is further augmented through advanced signal processing techniques, such as mean filtering and fast Fourier transform filtering, which effectively correct strip noise and improve the overall image quality. Our study not only demonstrates the feasibility of fabricating high-performance vdWs photodetector arrays but also provides valuable guidance for the development of vdWs arrayed devices for a wide range of engineering applications.



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Session 12. Piezoelectric MEMS and Resonators—FBAR, SAW, pMUT

sciforum-122103: High-Accuracy Simulation Model for Temperature–Frequency Characteristics of Single-Port SAW Resonators Based on Asymptotic Waveform Evaluation

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Introduction

Single-port surface acoustic wave (SAW) resonators are widely utilized for wireless, passive temperature sensing under harsh environmental conditions. Their resonance frequencies monotonically shift with temperature, forming the fundamental basis for wireless passive temperature measurements. Accurate simulation of the temperature–frequency characteristics of SAW sensors is thus essential for effective sensor design.

Methods

The existing finite element (FE) simulation models of single-port SAW resonators typically consist of periodic, repetitive, three-dimensional models containing only a pair of interdigital transducers (IDTs). These models fail to consider the effect of the spacing between the reflector gratings and the IDTs on the resonant frequency. To address this, we employed COMSOL's built-in asymptotic waveform evaluation (AWE) method to efficiently and accurately simulate this effect for a TiAl alloy Y-X quartz SAW resonator with a wavelength of 12 μm and a metallization ratio of 0.5.

Results

Our simulations reveal that considering the spacing between the reflector gratings and the IDTs results in a frequency variation of approximately 2 MHz, corresponding to an equivalent temperature measurement error exceeding 300°C, given the temperature sensitivity of 6.6 kHz/°C. Compared to the traditional frequency-domain simulations, the proposed AWE-based method reduces the computation time nearly 40-fold. Experimental validations using fabricated TiAl alloy SAW temperature sensors with varying reflector–IDT spacings confirmed our simulation results.

Conclusions

The developed AWE-based SAW slice model significantly enhances the simulation accuracy for the temperature–frequency characteristics of SAW resonators while maintaining computational efficiency, making it suitable for the optimization and precise design of SAW temperature sensors.



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sciforum-124635: Polarity-Inverted Aluminum Scandium Nitride Resonators and Ferroelectric Modulations

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Bulk acoustic wave (BAW) filters are essential components in RF communication, offering a low loss, compact size, and high power handling capability. However, traditional frequency scaling approaches for high-frequency applications require the progressive thinning of unipolar piezoelectric films, resulting in increased electrical loss and exacerbated power durability issues. In contrast, novel BAW resonators incorporating polarity-inverted piezoelectric stacks enable high-frequency operation while maintaining the optimal film thickness, thereby preserving the intrinsic advantages of BAW technology. Aluminum scandium nitride (AlScN), with its dual piezoelectric and ferroelectric properties, serves as a cornerstone material for BAW resonators. In this work, polarity-inverted AlN/AlScN film stacks were grown using a novel two-step method, resulting in high crystalline quality. FBAR resonators with a resonant frequency above 10 GHz were fabricated. By introducing polarity-inverted film stacks with a considerable thickness and high crystalline quality, the device performance was significantly enhanced. By adopting an SMR structure, the mechanical stability and temperature sensitivity were further improved. In addition, the polarity of AlScN films can be switched by applying an external voltage; the modulation mechanisms and frequency adjustment were also explored. Distinct frequency-switching behavior was observed between the TE2 mode and fundamental TE1 mode, which matched well with the results for the resonator performance. It was found that the precise tuning of the voltage parameters enabled the stabilization of the intermediate state, thereby unlocking the potential of frequency tuning and multi-mode operation in FBAR resonators.



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sciforum-133321: Strain engineering for regulating the behavior of nitrogen vacancies in $\text{Al}_{1-x}\text{Sc}_x\text{N}$ film

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Sc-doped AlN ($\text{Al}_{1-x}\text{Sc}_x\text{N}$) showed enormous application prospects in comparison to conventional oxide ferroelectrics due to their distinctive ferroelectric properties such as large remnant polarization, nearly pure ferroelectric phase, and CMOS compatibility. However, ferroelectric memory devices based on $\text{Al}_{1-x}\text{Sc}_x\text{N}$ films are suffering from several disadvantages such as large leakage current, imprint effect, and fatigue. Numerous investigations have found that nitrogen vacancies (V_{N} s) play a crucial role in determining the electronic and piezoelectric properties of $\text{Al}_{1-x}\text{Sc}_x\text{N}$. However, there are few literatures in terms of how to effectively prevent the impact of V_{N} s on $\text{Al}_{1-x}\text{Sc}_x\text{N}$. Here, we systematically investigate the impact of strain engineering on the formation energy and migration behavior of V_{N} in $\text{Al}_{1-x}\text{Sc}_x\text{N}$. Our results reveal that strain can effectively modulate the thermodynamic stability and kinetic behavior of V_{N} . Compressive strain is found to reduce the formation energy of V_{N} , while tensile strain increases it, suggesting strain as an effective tool for defect engineering. Furthermore, the migration barrier is strongly affected by strain, tensile strain can prevent the migration of V_{N} s, while compressive strain facilitates it, revealing a potential pathway to control defect dynamics, thereby optimizing material performance. These findings provide critical insights into strain engineering strategies for enhancing the stability and functional properties of $\text{Al}_{1-x}\text{Sc}_x\text{N}$ based devices.



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sciforum-121788: AI-Enhanced Quantification of Abnormally Oriented Grains in ScAlN Thin Films for In-Line Process Monitoring

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Introduction

Abnormally oriented grains (AOGs) in scandium aluminum nitride (ScAlN) thin films disrupt the preferred c-axis orientation, adversely affecting piezoelectric MEMS devices. The traditional intensity-based segmentation of SEM images often fails to accurately quantify AOGs due to challenges in differentiating grain sizes based on grayscale intensity. This study explores AI and ML techniques for enhancing AOG detection and quantification in ScAlN films.

Methods

A dataset of SEM images of ScAlN films, including proprietary and public images, was assembled. Synthetic SEM images with realistic AOG features were also generated using generative adversarial networks (GANs) to augment the training dataset. Supervised learning models, particularly convolutional neural networks (CNNs), were trained on real and synthetic annotated images. Unsupervised learning approaches, such as autoencoders and clustering algorithms, were also employed to detect AOG patterns without extensive labeling. The performance of these AI models was compared to that of traditional intensity-based segmentation methods in terms of their accuracy, precision, and recall.

Results

AI-assisted methods significantly improved AOG detection and quantification compared to those of the traditional techniques. The CNN-based supervised model achieved a detection accuracy of approximately 93%, outperforming the 78% accuracy of the intensity-based methods. Including synthetic SEM images enhanced the model's ability to generalize across diverse SEM datasets. Unsupervised learning approaches also showed promising results, with the clustering algorithms identifying AOG patterns with an accuracy of around 85%. These findings align with previous studies where AI-driven image analysis enhanced the defect detection rates by up to 25% over those of classical methods.

Conclusions

Implementing AI and ML techniques, particularly synthetic SEM image generation, to analyze SEM images of ScAlN thin films significantly enhances the AOG quantification accuracy over that of traditional methods. This advancement facilitates a more reliable assessment of film quality, optimizing the deposition processes to improve piezoelectric MEMS devices' performance. Future work will focus on refining these AI models and integrating them into real-time monitoring systems for thin-film fabrication.



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sciforum-121930: Extract Temperature Coefficients of LGS for High-Temperature Applications Based on the Finite Element Method

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SAW sensors have the advantages of simple structure, miniaturization and wireless and multi-parameter integration. Thanks to these, SAW sensors have great potential for the real-time monitoring of temperature, pressure and other parameters in harsh environments. Langasite (LGS) is a new type of high-temperature piezoelectric material with a high melting point (1470°C) and no phase transition from room temperature to melting point. It is an attractive high-temperature piezoelectric material for the preparation of high-temperature SAW sensors. In order to better simulate and predict the performance of an LGS SAW sensor at high temperature, including its frequency variation, temperature sensitivity and other indicators, high requirements are put forward for the material temperature coefficient of LGS. However, up to now, the widely used temperature coefficient has been suitable for scenarios below 300 °C, and it does not have good accuracy for scenarios above 800 °C. In view of this, Nicolay et al. used the numerical calculation method to fit the material temperature coefficient of LGS using measured data. However, the numerical method of frequency calculation is only suitable for thin and small-density-metal electrodes, such as aluminum; for large-thickness and high-density platinum electrode devices applied in high-temperature scenarios, the frequency calculation has a certain deviation. In addition, the numerical calculation method cannot be used with diverse acoustic modes other than the Rayleigh wave. We fabricated LGS devices on (0, 138.5°, 0°) with 11 different cuts and measured their temperature–frequency curves from room temperature to 800°C. Based on the FEM, the measured LGS frequency–temperature curves were used to fit the temperature coefficients of LGS. Using the fitted temperature coefficients, the performance of multiple resonant peaks of different cuts and different modes can be predicted at 800°C and above.



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sciforum-125659: MEMS Transducers Empower Ultrasonic and RF Applications

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Acoustic micro-electro-mechanical system (MEMS) devices have experienced a remarkable evolution, driven by rapid advancements in micromachining and thin-film technologies. These devices are no longer confined to conventional domains of electronics and mechanics; instead, they are expanding into multiple physical domains, such as acoustics, optics, and thermodynamics. The miniaturization and functional diversification of acoustic MEMS have enabled the engineering of platforms that span an exceptionally wide acoustic wave spectrum, from megahertz (MHz) to millimeter-wave (mmWave) frequencies. This wide spectral range has stimulated renewed research and industrial interest, leading to the emergence of novel device architectures and materials. Notable developments include high-resolution ultrasonic imaging transducers for biomedical applications, and ultra-compact radio-frequency (RF) filters and resonators for next-generation wireless communications. These innovations are underpinned by the precise control and utilization of acoustic wave propagation in micro- and nano-scale piezoelectric structures. Acoustic MEMS devices now serve as essential enablers for the translation of fundamental wave phenomena into practical technologies, significantly impacting consumer electronics, mobile communication, and sensing systems. This talk will present a series of recent innovations in acoustic MEMS transducer platforms, emphasizing piezoelectric thin films, advanced microfabrication techniques, novel structure designs, and their application to broadband, efficient transduction across a wide frequency range (from MHz to mmWave).



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sciforum-125740: Piezoelectric MEMS cooler

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Passive cooling devices for miniature equipment primarily utilize principles such as natural convection, conduction, and radiation to transfer heat from the heat source to a cooler environment without requiring additional external power. In contrast, active cooling devices achieve stronger convective heat transfer or more efficient heat transmission through external power, offering superior temperature control performance in high-heat-flux applications. The most common active cooling method involves using miniature fans or blowers to rapidly remove heat from the surface of devices via forced convection. Liquid cooling systems driven by micro-pumps rely on the circulation of coolant in microchannels, effectively increasing the heat convection coefficient and significantly enhancing cooling efficiency. Notably, emerging active cooling techniques, such as piezoelectric cooling devices like piezoelectric fans, are continuously evolving. These devices modulate the airflow distribution near the device surface to enhance heat transfer, enabling more precise temperature control for miniature devices. Piezoelectric cooling devices can be fabricated using MEMS (Micro-Electro-Mechanical System) technology. It constructs mechanical structures and electronic components at the micrometer scale through, for example, photolithography, thin-film deposition, and etching. This technology is suitable for the mass production of complex microstructures with high precision, high integration, and miniaturization. The application of MEMS technology in piezoelectric cooling devices and some recent developments will be introduced in this presentation.



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sciforum-122123: ScAlN-Based Piezoelectric Micromachined Ultrasound Transducers as a Multipurpose Lead-Free Solution

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Ultrasound technology offers a pivotal role in diverse applications which span from non-contact particle manipulation to environmental mapping for AR and VR. Traditionally, these applications are dominated by ultrasound transducers made of lead-containing piezoceramics. Given the environmental and health concerns from lead, and the large form factor of bulk-ultrasound transducers, there has been an interest to develop small form factor micromachined ultrasound transducers (MUTs) with lead-free piezoelectric thin-films. Scandium (Sc)-doped Aluminum nitride (AlN) thin-film is one of the promising candidates as lead-free piezoelectric thin-film due to its CMOS compatibility and higher piezoelectric coefficient ($e_{31,f}$) as compared to pure AlN films.

At Institute of Microelectronics (IME), we developed a novel fabrication platform for piezoelectric MUTs (PMUTs) employing 1 μm -thick 30% Sc-doped AlN (ScAlN) as an active piezoelectric thin-film with $e_{31,f}$ upto 2.36 C/m² and surface roughness of the order of 1-1.2 nm. The superior quality of the ScAlN thin-film allows high performance PMUTs which were applied in ultrasound levitation for non-contact manipulation of mm-sized particles as well as long distance ranging towards landing assistance for drones and environmental mapping for AR and VR. In contrast to state-of-art levitation system with large sized bulk-ultrasound transducers (> 20 mm), we demonstrated a PMUT-based miniaturized ultrasonic particle levitation system for non-contact particle manipulation with a 3 × 3 PMUT array, which has an overall size of 9 mm × 9 mm. Enclosing the PMUT array with an ultrasound waveguide and a reflector on top allows the formation of stable ultrasound standing waves for levitation. In addition to ultrasonic levitation, we have also demonstrated single PMUT element with large output transmit pressure and high receive sensitivity to achieve time-of-flight distance ranging upto 20 m.



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sciforum-121800: Submersible Soft Robotics with Ultrasonic Echolocation Capabilities

Qilin Hua * and Zhongming Chen

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Submersible robots, engineered for diverse underwater operations such as search and rescue missions, resource exploration, urban pipeline inspections, and more, are vital tools in underwater exploration. The emergence of advanced soft robotics has captured attention for their superior flexibility, adaptability, eco-friendliness, and lightweight attributes, positioning them as a promising frontier in underwater endeavors. Echo-based sensors play a pivotal role in object detection and localization underwater. With the advancements in flexible electronics, traditional rigid ultrasonic arrays are transitioning towards more pliable configurations, enabling three-dimensional (3D) imaging of intricate underwater surfaces and objects. Ultrasonic detection methods offer inherent advantages, including high sensitivity, deep penetration capabilities, and cost-effectiveness. The integration of flexible ultrasonic arrays with soft robots represents a significant step towards enhancing underwater exploration capabilities.

To address challenging scenarios like weld and inherent defects in underwater pipelines, we introduce a versatile programmable ultrasonic soft robot inspired by the locomotion of worms and jellyfish. Driven by gas, this robot adeptly navigates aquatic environments, featuring a flexible ultrasonic array that enhances detection capabilities during its movements. Capitalizing on the unique material properties and robust encapsulation of the soft robot, it excels in underwater missions, offering enhanced capabilities in underwater terrain imaging, bathymetry, and related tasks. This technology holds vast potential across industrial inspections, disaster response efforts, and underwater surveillance applications, opening up a realm of opportunities in underwater exploration and operations.



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Session 13. Piezoelectric Transducers and Energy Harvesters

sciforum-126025: MEMS energy harvesting and sensing techniques for health monitoring and fault diagnosis

Huicong Liu

Soochow University

This talk will introduce our research on MEMS energy harvesting and sensing techniques towards divisive self-powered sensing systems and intelligent machine health monitoring. In response to different vibration characteristics of environmental kinetic energy, we have developed key technologies of MEMS energy harvesting and sensing. Innovative application demonstrations have been carried out in major national demand areas such as self-powered monitoring of major coal mining equipment status, multi-parameter sensing for transportation and engineering security monitoring. To be more specific, we integrated piezoelectric-based vibration energy harvester and vibration sensor as self-powered wireless sensing nodes for status monitoring and fault diagnosis. We also developed flexible and multi-parameter wireless MEMS monitoring system for status monitoring and fault diagnosis of ball screws. The sensing module, MCU module, wireless module and power management module are integrated in this system, which can be flexibly attached to ball screws, improving integration and reducing wiring complexity. Intelligent skin with multi-information sensing can greatly improve the environment adaptability and autonomous working ability of key components. Machine learning model enhanced with multi-scale feature extraction are employed for accurate fault classification. These works provide technical support for strategic emerging industries such as intelligent manufacturing, high-end equipment, aerospace transmission components and smart health.



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sciforum-126409: AI-Informed Mechanical Piezo-Metamaterials for Self-Powered Sensing

Pengcheng Jiao

Zhejiang university

In this presentation, we first introduce ultra-stretchable kirigami piezo-metamaterials capable of efficiently sensing coupled large deformations, showcasing exceptional potential in flexible sensing applications. These materials leverage innovative kirigami structural designs to surpass the deformation limits of conventional sensors, offering a new paradigm for precise perception in complex deformation scenarios. Next, we elaborate on a dual-mode wireless integrated system for the real-time monitoring and early warning of large-scale marine structures. By integrating multimodal data fusion and wireless transmission technologies, this system significantly enhances the safety and reliability of marine engineering, providing an innovative technical solution for the health monitoring of offshore infrastructure. Additionally, we propose an artificial intelligence-guided inverse design model that combines neural networks with genetic optimization algorithms, specifically tailored for the structural design of corrugated mechanical metamaterials. Through iterative optimization using intelligent algorithms, this model drastically shortens the design cycle of mechanical metamaterial sensors, enabling inverse mapping from performance requirements to structural parameters and opening up new pathways for the rapid design of functional metamaterials. Looking ahead, by integrating AI algorithms with self-powered systems, we anticipate the realization of highly sensitive, self-sustaining sensing solutions applicable to wearable health monitoring devices, remote environmental sensing in harsh conditions, and other fields. This technological integration not only optimizes the performance of self-powered sensors but also paves the way for the leapfrog development of intelligent and energy-efficient sensing systems.



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sciforum-121161: AlN/AlScN Piezoelectric Thin Film Transducers

Tao Wu

ShanghaiTech University

Aluminum nitride (AlN) is widely used in RF filters, piezoelectric ultrasonic transducers and other applications due to its high acoustic velocity, easy growth processing, CMOS process compatibility and good thermal dispersion properties. With the development of communication technology and the demand for higher sensitivity transducers has raised higher requirements for the device performance. The disadvantage of the lower piezoelectric constants of aluminum nitride compared to piezoelectric materials such as PZT and lithium niobate is exposed. Recently, scandium (Sc) doping in AlN thin film has been studied for piezoelectric property enhancement. Significant improvement in K^2 enables wideband aluminum scandium nitride (AlScN) resonators, energy harvesters, and sensors.

Miniaturized ultrasound transducers have emerged as a significant development due to their small size, flexibility, and high resolution. Chipscale ultrasound transducers facilitate the use of higher frequencies and finer detection beams, leading to marked improvements in imaging resolution—crucial for detailed diagnostic imaging and early disease detection. Scandium doping has become a hot research topic as a way to significantly improve the piezoelectric properties of aluminum nitride, which can remarkably enhance the performance of the piezoelectric transducers. In this talk, we will report recent development on AlScN thin film material growth, fabrication process and piezoelectric devices. Several transducer devices and applications, such as acoustic delay lines (ADL), piezoelectric micromachined ultrasonic transducers (PMUT), photoacoustic imaging (PAI), as well as emerging research fields, will be discussed.



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sciforum-121953: An Intelligent Cube-Designed Piezoelectric Node (iCUPE) with Simultaneous Sensing and Energy-Harvesting Capabilities

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The artificial intelligence of Things (AIoT) is widely used in intelligent sensing and seamless communication, and is an important component of achieving information interconnection in smart cities. However, AIoT sensor nodes work in small and unmanned environments over a long period of time, and improving integration and sustainability has become a problem that various AIoT nodes need to solve. In this article, an intelligent piezoelectric AIoT node intelligent cubic-designed piezoelectric (iCUPE) with a self-powered cubic design is presented. It integrates high-performance energy harvesting and self-powered sensing modules via a micromachined lead zirconate titanate (PZT) thick film-based high-frequency (HF)-piezoelectric generator (PEG) and poly (vinylidene fluoride-co-trifluoroethylene) (P(VDF-TrFE)) nanofiber thin film-based low-frequency (LF)-PEGs, respectively. The LF-PEG and HF-PEG with specific frequency upconversion (FUC) mechanisms ensure a continuous power supply can be maintained over a wide range of low-frequency vibrations, optimizing the shape of HF-PEG through specific collision simulation to improve energy-harvesting efficiency. The higher power generation can supply power to the temperature and humidity sensors integrated in the iCUPE node, enabling real-time monitoring of the surrounding environment of the node. Due to the use of a cube design, three FUC-PEGs can be placed orthogonally and respond to broadband vibration energy sources from different directions, and wireless sensing signal transmission is achieved through the Bluetooth module integrated inside the cube. The combination of self-powered three-axis piezoelectric sensors (TPSs) and machine learning (ML) facilitates high-precision, multifunctional vibration recognition, acceleration, frequency, and tilt angle by using three LF-PEGs to assist three orthogonal piezoelectric sensing units. This work demonstrates the feasibility of developing ML-based intelligent sensors for accelerometer and gyroscope functions at resonant frequencies.



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sciforum-121509: Electret-Based Self-Powered Flexible Vibration Sensor with High Sensitivity and Durability

Jia Lu

Harbin Institute of Technology

Vibration is ubiquitous in our environment. The identification of key parameters such as its frequency and amplitude can provide useful information of a vibration's source. Vibration sensors are widely used in areas such as aerospace, health monitoring, and so on. Battery-less self-powered vibration sensors have the advantage of reduced maintenance costs and environmental burden. Electrets are dielectrics with a quasi-permanent space charge or dipole polarization. They have been applied to making self-powered sensors. To address the issues of the low sensitivity and poor durability of existing vibration sensors, an electret-based, self-powered flexible vibration sensor was proposed through a stacking assembly of a polytetrafluoroethylene (PTFE) electret film, a polydimethylsiloxane (PDMS) silicone layer, and a polyimide (PI) spacer. The top layer of the sensor is an integrally molded structure consisting of a suspended perforated PDMS film, a seismic mass, and a micro bump structure to avoid contact discharge of the electret. The middle part is a PI tape spacer that bonds the PTFE film and the PDMS structure. The bottom layer is a 50 μm thick corona-charged PTFE film with a stable surface voltage of -530 V. A testbench was built to measure the output electrical signal of the sensor when subjected to different excitations. The open-circuit voltage outputs corresponding to an acceleration from 0 to 5 g in the frequency range of 15 to 600 Hz were measured. Due to the low Young's modulus of the PDMS film, reduced air damping, and the large seismic mass of the PDMS block, the sensitivity reached 1.15 V/g. In terms of the sensor's durability, the output voltage of the sensor dropped by merely 0.75% after one million vibration tests. When combined with deep learning, the sensor achieved a 99.17% detection accuracy in state identification for self-made miniaturized fan machinery.



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sciforum-125270: Flexible Dual-Directional Electromechanical Transducers for Human–Machine Interactive Applications

Junwen Zhong

University of Macau

A fully interconnected and intelligent living environment has been a great challenge for a future smart society, and it is critically essential to develop the interactive sensing and actuating systems to bridge the human–machine interfaces. Here, flexible electromechanical transducers based on high-performanced piezoelectret or piezoelectric polymers are fabricated to selectively perform either the actuating or sensing function. As sensors, both a low-pressure detection limit for sensing resolution and excellent stability have been achieved, with typical application in monitoring human physiological signals. For instance, these sensors can be used to detect subtle changes in respiratory patterns, providing real-time health monitoring for individuals. As actuators, mechanical vibrations with large output force have been produced for providing haptics feedback to human skin. This can be particularly useful in virtual reality applications, where users can feel physical sensations corresponding to virtual interactions. Such actuators are also used to construct soft robotics with high agility and controllability to explore surroundings, like detecting gas leakage. These soft robots can be designed to navigate through complex environments, such as pipelines or disaster sites, to perform tasks that are hazardous or inaccessible to humans. The design principle together with the sensing and driving characteristics can be further developed and extended to other soft matters and flexible devices, potentially leading to a wide range of applications in fields like healthcare, robotics, and wearable technology. By leveraging the unique properties of piezoelectret and piezoelectric polymers, researchers can create more advanced and versatile systems that enhance the interaction between humans and machines, paving the way for a more intelligent and interconnected future.



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sciforum-121614: The Advanced Functionalities of Ions

Shimpei Ono

International Center for Synchrotron Radiation Innovation Smart, Tohoku University

The modern electronics industry has developed by creating new functional materials such as metals, semiconductors, insulators, and magnetic materials, and by controlling the physical properties of each material. In general, new functional materials are developed by changing the electronic state of materials through changes in chemical composition or chemical substitution. On the other hand, it is also possible to electrically control the electronic state of semiconductors by making use of the electric field. This is applied to field-effect transistors (FETs), which are used as switching devices in logic circuits and a critical technology that supports the modern, advanced information society.

In recent decades, a different route for carrier doping which relies on an electrochemical concept has been extensively investigated to control materials properties with an electric field. It is well known that when a voltage is applied to an electrolyte, a huge electric field of the order of 10 MV/cm is generated at the solid/liquid interface due to the formation of an electric double layer (EDL). Owing to this extremely high electric field, EDL gating has the unique capability to push the charge density accumulation that is well beyond the limitations of any solid gate dielectric.

In this talk, we are going to explore this window of extreme electric fields using “an electric double layer electret (EDLE)” which is a second-generation EDL gating allowing for the control of novel states of matter. The EDLE is formed by anchoring the motion of ions inside the IL gel after the formation of the EDL, and it can sustain the EDL without any external bias-voltage source. Simply sticking the EDL electrets containing the gate array on top of the semiconductor, we can modulate the electric states of the materials.



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sciforum-121997: Vibration Energy Harvesting for Sustainable IoT: Advances in Piezoelectric Polymer Materials

Takashi Nakajima

Tokyo University of Science

The talk will explore the emerging field of vibration energy harvesting using piezoelectric polymers, a technology poised to revolutionize the power supply for distributed sensor systems in IoT and CPS applications. Vibrational energy harvesting converts ambient mechanical vibrations into electrical energy, offering the remarkable advantage of a permanent power source without the need for battery replacement or wiring. Piezoelectric polymers, with their inherent softness, excellent processability, and large surface areas, are particularly well-suited for these applications.

The talk will begin by outlining the fundamental mechanisms of vibrational energy harvesting and how the design of these systems can be optimized by leveraging the unique properties of piezoelectric polymers. Detailed quantitative analyses will be presented, including discussions on key material parameters such as dielectric constants, piezoelectric coefficients, and electromechanical coupling factors, all of which play crucial roles in determining the efficiency of energy conversion. Practical examples using PVDF-based films will illustrate the performance under various mechanical strains and configurations, highlighting the potential for scaling these technologies to power extensive sensor networks.

In addition, the integration of machine learning for battery-less anomaly detection will be examined. By harnessing the intermittent energy output from vibration harvesters, novel sensor systems can achieve reliable real-time monitoring and diagnostics, ensuring robust operation in challenging environments. This lecture aims to provide a comprehensive overview of current advancements and future prospects in the field, fostering innovative approaches to sustainable energy solutions in smart sensor applications.



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Session 14. Ferroelectric/Perovskite/2D Materials Thin Film and Applications

sciforum-125770: Flexible High Entropy Nonlinear Dielectrics with Superior Performance

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A high configurational entropy, achieved through a proper design of compositions, can minimize the Gibbs free energy and stabilize the quasi-equilibrium phases in a solid-solution form. This leads to developing high-entropy materials with unique structural characteristics and excellent performance, which otherwise could not be achieved through conventional pathways. This work develops a high-entropy nonlinear dielectric system based on the expansion of lead magnesium niobate–lead titanate. A dense and uniform distribution of nano-polar regions is observed in the samples owing to the addition of Ba, Hf, and Zr ions, which lead to enhanced performance of nonlinear dielectrics. No structural phase transformation is detected up to 250 °C, and no noticeable change or a steep drop in structural and electrical characteristics is observed at high temperatures, suggesting a robust thermal stability of the developed dielectric systems. With these advantages, these materials hold vast potential for applications such as dielectric energy storage, dielectric tunability, and the piezoelectric effect. Thus, this work offers a new high-entropy configuration with elemental modulation and enhanced dielectric material features. In addition to the material growth, I demonstrate how to integrate this new material with the membrane structure on Si and flexible muscovite. The expansion of practical applications will also show a new approach to obtaining a freestanding sample. This study broadens the material selection for AI sensors based on nonlinear dielectrics.



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sciforum-124407: NCIR's WS₂ 2D Material R&D Collaboration and Its Application In Gas Sensors

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WS₂ is a relatively new TMD semiconductor with potential applications in 2D FETs and gas sensors due to its bandgap in the range of 1.5–2 eV. However, many studies have reported inconsistent fundamental properties due to incomplete characterization. In this presentation, the National Center for Instrumentation Research (NCIR) shows the development of a wafer-scale 2D materials research platform. This platform includes 1-, 8-, and 12-inch gas-source metal-organic chemical vapor deposition (MOCVD) systems, using metal-organic (MO) precursors and H₂S as the reactive gas. Currently, single-crystalline WS₂ has been successfully deposited on 6-inch substrates, achieving an electron mobility greater than 10 cm²/V·s. In-plane X-ray diffraction (XRD) analysis confirms the growth of single-domain WS₂ crystals, with an epitaxial relationship of WS₂(100)//Al₂O₃(110) and WS₂(002)//Al₂O₃(006) on sapphire substrates. In addition, heteroepitaxial SnSe/SnSe₂ structures have been applied to the development of gas sensors, demonstrating high sensitivity. Beyond in-house research and development, the 2D materials platform also offers collaborative research opportunities to academic and research institutions, supporting the advancement of sub-3 nm semiconductor device technologies and the exploration of novel physical, chemical, optoelectronic, and material properties of emerging 2D materials. In this presentation, the case studies of gas sensors using the 2D materials based on NCIR's services are also shown to demonstrate the gas sensors development and collaboration achievements.



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sciforum-130894: Weakened phonon scattering in Schottky junction of large-area black phosphorus/PtSe₂ films for high operating temperature broadband photodetectors

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High-performance broadband photodetectors with high operating temperature (HOT) capability are critically demanded for extreme-environment applications, including infrared-guided missiles, night vision systems, fire safety monitoring, and deep-space exploration. Conventional photodetectors suffer from severe performance degradation at elevated temperatures due to increased carrier scattering, leading to mobility reduction and photoresponse deterioration. To overcome these limitations, we demonstrate, for the first time, a large-area black phosphorus/platinum diselenide (BP/PtSe₂) Schottky junction photodetector array that achieves stable broadband detection from room temperature up to 470 K. By employing a depletion-enhanced photocarrier dynamics strategy, the device effectively suppresses impurity scattering and minimizes carrier loss even under high-temperature conditions. The unique 2D Schottky junction at the BP/PtSe₂ interface induces a fully depleted channel, significantly enhancing carrier transport stability across a broad spectral range (532–2200 nm). As a result, the optimized photodetector exhibits exceptional performance at 470 K, with a record-high responsivity (R) of 25 A W^{-1} and a specific detectivity (D^*) of 6.4×10^{11} Jones under 1850 nm illumination. Furthermore, the fabricated photodetector array demonstrates excellent spatial uniformity over large areas, highlighting its potential for scalable integration. This work not only establishes a new benchmark for HOT broadband photodetection but also provides a generalizable strategy for designing next-generation optoelectronic devices using van der Waals heterostructures, paving the way for robust sensing technologies in harsh environments.



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Session 15. Gas Sensors and Chemosensors

sciforum-135701: Applications of Surface-Enhanced Infrared Absorption Spectroscopy in Molecular Sensing

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Infrared (IR) spectroscopy is a powerful tool for molecular fingerprint identification and has been widely applied in fields such as biomedicine, environmental monitoring, and chemical analysis. However, conventional IR spectroscopy suffers from limited sensitivity due to the intrinsically weak absorption cross-section of molecules and low signal-to-noise ratios. To overcome this challenge, Surface-Enhanced Infrared Absorption (SEIRA) technology has emerged, leveraging plasmonic nanostructures and metamaterials to create strong electromagnetic near-field enhancement at the nanoscale, thereby amplifying molecular vibrational signals by several orders of magnitude.

SEIRA works by exciting localized surface plasmon or phonon polariton resonances through engineered nanoantennas or resonators. Advanced designs such as multi-resonant and overcoupled structures allow for broadband enhancement, detuning compensation, and spectral deconvolution. These innovations enable SEIRA to achieve ultra-sensitive, label-free, and real-time molecular sensing across various environments.

Recent applications include COVID-19 diagnostics, microRNA detection for early cancer screening, multi-gas environmental monitoring, and real-time observation of chemical reactions. With integration of metal-organic frameworks (MOFs), DNA nanostructures, and AI-assisted analysis, SEIRA continues to expand its capabilities in complex systems.

Looking ahead, SEIRA holds great potential for development into a smart molecular sensing platform suited for in vivo diagnostics, wearable health monitoring, and lab-on-chip systems, while also advancing fundamental understanding of light-matter interactions at the nanoscale.



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sciforum-124786: Nano-chemical Sensors Technology for Diet-monitoring/Cancer-screening Systems using Exhaled Breath

Dae-Sik Lee

ETRI

We have developed a novel olfactory sensor system by integrating BioMEMS technologies with functional nanoparticles, aiming to push the boundaries of gas sensing in healthcare applications. In this presentation, I will detail the complete process—design, fabrication, characterization, and efforts toward industrialization—by sharing several representative research and development case studies that highlight both technical innovation and real-world applicability.

Our focus lies in the advancement of gas sensor device technologies, with particular emphasis on their use in mobile healthcare systems, such as diet monitoring platforms. One of the primary goals in sensor development is achieving both high sensitivity—capable of detecting target gases at sub-ppm (parts per million) levels—and high selectivity, allowing the sensors to distinguish between chemically similar volatile compounds with strong specificity. To this end, we employed nano-structured metal oxide materials, which have shown excellent performance in enhancing signal response and stability under various operating conditions.

In addition to presenting our latest research findings on material performance and sensor calibration, I will introduce our work on electronic nose systems specifically tailored for dietary monitoring. These systems, which mimic human olfaction through sensor arrays and machine learning algorithms, have undergone preliminary clinical testing, demonstrating promising results in tracking metabolic changes and dietary habits.

We believe that these cutting-edge, sensor-based technologies have the potential to revolutionize point-of-care diagnostics. By enabling non-invasive, continuous, and real-time monitoring of health indicators, they could significantly enhance the practicality and adoption of digital healthcare in both clinical and personal settings.



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sciforum-122068: Non-Invasive Human Volatiles Detection via a Wearable Biochemical Gas Sensor

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² Institute of Science Tokyo

Volatile organic compounds (VOCs) in human exhalations are closely linked to metabolic processes and health conditions. Detecting and quantifying these compounds holds great promise for non-invasive metabolic assessments and disease diagnosis. Among these, skin-emitted gases enable continuous sampling without physical constraints, making them particularly suitable for next-generation wearable monitoring devices.

In this study, we introduce a wearable biochemical gas sensor specifically designed for ethanol detection. Our system features an unobtrusive ear canal gas measurement mechanism integrated into a headset. This setup employs a complementary metal-oxide semiconductor (CMOS) camera to detect ethanol gas by measuring the fluorescence intensity of NADH, a byproduct of ethanol oxidation catalyzed by alcohol dehydrogenase (ADH). A UV-LED light source, in conjunction with a band-pass filter, excites an ADH enzyme-immobilized membrane, while a compact CMOS camera with Wi-Fi functionality captures NADH fluorescence in real time.

The entire system is housed within an earmuff-style headset, enabling seamless and wearable ethanol detection. Fluorescence imaging demonstrates a concentration-dependent response, allowing ethanol gas measurement within a dynamic range of 11 ppb to 444 ppm, encompassing typical skin ethanol levels post-alcohol consumption. Furthermore, real-time monitoring in alcohol-consuming individuals reveals fluctuations in ethanol gas levels, indicating that this device offers a direct and reliable method for ethanol detection in the ear canal, even in the presence of perspiration.



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sciforum-121886: SnO₂-functionalized MoS₂ nanostructures for high-performance NH₃ sensing

Sikai Zhao * and jinzhou Bai

Northeastern University

In this study, MoS₂ with different microstructures was prepared using both “top-down” and “bottom-up” approaches. The few-layer MoS₂ nanosheets were exfoliated from natural molybdenite in liquid through ultrasonication, while flower-like MoS₂ hierarchical architectures, assembled using ultrathin 2D nanosheets, were obtained by following a solvothermal method. Subsequently, fine-size SnO₂ was functionalized onto the surfaces of the different MoS₂ nanostructures to form the heterostructure gas sensing materials. The optimal SnO₂/MoS₂ nanosheet sensor exhibits a high response of 6.0 to 100 ppm NH₃, with rapid response/recovery times of 81/198 s, along with good reversibility, selectivity, and long-term stability at a low operating temperature of 100 °C. The heterojunction structure, enriched with sulfur vacancies introduced via probe sonication, facilitates efficient charge transfer and enhances the gas diffusion across the extensive surface of the few-layer MoS₂ nanosheets, substantially improving the sensing performance. The SnO₂/MoS₂ sensor exhibited a high response of 8.6 and short response/recovery times of 6 s/121 s to 100 ppm NH₃ with good selectivity, excellent repeatability, and outstanding long-term stability at a room temperature of 25 °C. Such a highly enhanced response toward NH₃ was ascribed to the synergistic effect between active SnO₂ with abundant dangling bonds and MoS₂ nanosheets with a large specific surface area and high carrier mobility. Moreover, the underlying sensing mechanisms were further explored through density functional theory (DFT) calculations.



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sciforum-131367: A high-sensitivity gas sensor for simultaneous detection of methane and ethane in urban gas networks

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Southeast University School of Energy and Environment

To address the challenge of precise discrimination of multi-component trace gases for urban natural gas leakage monitoring, a dual-component gas sensor based on mid-infrared laser absorption spectroscopy was developed for simultaneous detection of methane (CH₄) and ethane (C₂H₆). The sensor integrates an interband cascade laser, a 13-m optical path length multi-pass gas cell and a high-sensitivity detector. The optimal absorption lines of CH₄ and C₂H₆ were identified through analysis of gas absorption spectra, and the negative-pressure (0.24 atm) operation was applied to effectively suppress water vapor interference, which significantly improved the anti-cross-interference capability. Experimental results demonstrate minimum detection limits of 17.77 parts-per-billion in volume (ppbv) for CH₄ and 1.02 ppbv for C₂H₆ at a 1-second averaging time, and the dynamic response time is approximately 6 s. During the In-vehicle mobile monitoring experiment, the changes of CH₄ and C₂H₆ concentrations near the leakage source show a high degree of correlation (Pearson correlation coefficient of 0.9991), which effectively distinguishes natural gas leakage from biogenic and anthropogenic interference sources such as landfills, automobile exhaust. This research provides a high-precision and low-false-alarm solution for the safety inspection of urban gas pipeline networks, and the application scenarios can be further expanded through miniaturization and intelligent optimization in the future.



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sciforum-129048: Anti-interference acetone gas detection system for exhaled breath monitoring

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With an increasing focus on health, portable civilian health indicator detection devices have gradually entered the public eye. In recent years, exhaled breath analysis has garnered widespread attention across numerous disease domains. Among these, acetone gas sensors are frequently employed for the detection and screening of diabetes. However, previous studies have demonstrated that gas flow rate and humidity significantly influence the accuracy of sensor measurements during detection.

To address this issue, we have designed an acetone gas testing system based on the Venturi effect, utilizing a multi-layer gas pre-treatment chamber to construct a gas channel that reduces both flow rate and humidity. Through fluid mechanics and aerodynamics simulations using ANSYS and COMSOL, we verified the system's effectiveness in suppressing the gas flow rate. By designing the pore size of the chamber and the arrangement of porous materials, we successfully separated water molecules from the gas, enabling the testing system to maintain good responsiveness and stability in humid environments with a relative humidity range of 40% to 80%.

The testing system developed in this work effectively resolves the common issues encountered in practical applications, such as unstable sensor response and interference with specific recognition due to the high flow rate and humidity of exhaled human breath. In addition, the system integrates data processing and Bluetooth communication functionalities commonly found in commercial products, holding great potential for widespread application in the future field of diabetes detection.



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sciforum-123057: Applications of Polymer Network-Liquid Crystals (PNLC) as Chemical and Gas Sensors

Yang Kun Lin

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In this presentation, we explore the application of polymer-network nematic liquid crystal (PNLC) as sensing materials for the development of real-time temperature and chemical sensors. The novel material comprises a LC polymeric scaffold that supports low-molecular-weight liquid crystal (LMWLC) 4'-pentyl-4-biphenylcarbonitrile (5CB). PNLCs are synthesized by blending reactive mesogens, 5CB, and a photo-initiator, followed by controlled UV light exposure to cross-link the reactive mesogens. The interaction between the mesogenic units in the LC polymer and 5CB results in multiple intriguing sensing properties, such as dual transitions, and introduces new sensing capabilities (e.g. oxygen sensing).

Firstly, PNLCs serve as colorimetric temperature sensing materials. Unlike pure LMWLC 5CB, which changes colors abruptly upon heating beyond its clearing temperature, PNLCs with linear polymer threads exhibit a full color spectrum over a broad temperature range. The color transition from blue to purple, then to orange, occurs as the temperature increases from 50 °C to 140 °C. Through pattern recognition techniques, specific temperatures can be identified by utilizing PNLCs with varying compositions. Secondly, PNLCs function as chemical sensors for detecting toluene vapor and oxygen gas. For PNLC with linear polymer threads, their interference colors change in response to different toluene vapor concentrations from 2,800 ppm to 9,300 ppm. For PNLC with a sphere-like polymer network, the appearance changes from transparent to cloudy at 4,000 ppm, and then becomes transparent again (dual transition) with a further increase in the toluene vapor concentration to 10,000 ppm. By controlling UV exposure time during sample preparation, it is possible to intentionally leave free radicals within the PNLCs. These free radicals are highly reactive and they offer sensing capabilities for the detection of oxygen gas. The appearance of PNLCs can be analyzed to produce a histogram of oxygen exposure, displayed as a color map.



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sciforum-121937: Artificial Olfaction Platform based on MEMS Gas Sensor Array

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In recent years, artificial olfaction (also named e-nose) based on the MEMS gas sensor array and artificial intelligence (AI) algorithms has been developed and widely applied in various areas such as environmental air monitoring, public safety, healthcare, food safety, etc. As the core component of artificial olfaction, gas sensors that detect the types and concentrations of gases in the environment should meet the essential requirements of a small size, low power consumption, high sensitivity, and a broad spectrum for various gases. With the development of MEMS technology and artificial intelligence (AI) technology, the integration of MEMS gas sensor arrays (analogous to olfactory receptors in biological olfaction) and AI algorithms (analogous to the olfactory nervous system in biological olfaction) makes it possible to construct an artificial olfaction platform, allowing gas sensors to develop from "functional implementation" to "performance improvement" to the "intelligent recognition" stage. This talk introduces the development of MEMS gas sensor technology, including the synthesis of high-sensitivity sensing materials and fabrication of MEMS hotplates with low power consumption. Then, the integration of artificial olfaction platform based on gas sensor arrays and stable, reliable signal acquisition system is presented. Based on the data collection and pattern recognition algorithm established based on different gas scenarios, practical applications in various fields such as industrial safety, smart home appliances, environment monitoring, quality control, clinic diagnosis, etc., are described in detail.



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sciforum-125689: DMPA-GWO++: A Dynamic Multi-Pack Adaptive Grey Wolf Optimizer for IoT Sensor Network Recovery in Smart Farms

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Introduction

A IoT-driven agriculture demands intelligent, adaptive deployment of wireless sensor networks (WSNs) to ensure real-time monitoring of environmental conditions across vast, non-uniform terrains. However, achieving high coverage, strong inter-node connectivity, and energy efficiency in such dynamic settings remains a persistent IoT challenge. Conventional metaheuristics often lack the flexibility and contextual awareness required for optimal sensor layouts in field deployments. This motivates the need for self-organizing, AI-enhanced strategies tailored for the evolving demands of large-scale agricultural IoT systems.

Methods

We introduce DMPA-GWO++, a neuro-adaptive, modular extension of the Grey Wolf Optimizer (GWO), purpose-built for smart WSN deployment in IoT-based agriculture. The framework integrates five key enhancements: (i) Dynamic Multi-Pack Formation for decentralized swarm coordination, (ii) Entropy-Guided Diversity Control for adaptive exploration, (iii) Role-Based Agent Behaviors (explorer, exploiter, scout) to balance global-local search, (iv) Momentum-Driven Updates for smoother convergence, and (v) Neuro-Adaptive Leadership Modulation to dynamically scale influence based on swarm performance. Together, these mechanisms support scalable, multiobjective optimization under real-world constraints.

Results

Tested across diverse farm-like scenarios, DMPA-GWO++ demonstrated compelling improvements over traditional GWO—achieving a 22% reduction in over-coverage, 10% higher connectivity, and a 7.6% lower composite fitness score. The framework's marginal reduction in raw coverage was a calculated trade-off, yielding IoT-grade efficiency by minimizing redundancy, conserving energy, and enhancing network cohesion. Its faster convergence and robustness under spatial complexity make it ideal for distributed, adaptive IoT sensor deployments.

Conclusions

DMPA-GWO++ offers a deployment-optimized sensor layout framework that directly addresses key IoT challenges—connectivity resilience, redundancy control, and adaptability at scale. Its entropy-aware swarm dynamics and learning-enabled leadership make it a compelling solution for real-world AIoT use cases. Moving beyond theoretical improvements, this framework positions itself as a practical optimization layer for the next generation of autonomous, intelligent sensor networks in agriculture, environmental sensing, and smart infrastructure.

<https://www.overleaf.com/read/rrfkgdgzksgv#a3b967>



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sciforum-122013: From single-element to multicomponent materials: A rapid high-throughput screening method to develop gas-sensing layers based on an automated dry printing technology

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Determining promising materials to target gases molecules is a crucial aspect in many application fields that use chemiresistive devices. In this context, spark ablation is an attractive technology to produce nanoparticles (NPs). This fully dry approach is characterized by the absence of chemical wastes, precursors, or binder requirements, leading to layers that are highly pure throughout. Furthermore, it is considered a versatile NP generator, since any solid (semi)-conductor (pure metals, alloys, or properly doped semiconductors) can be used and mixed, meaning that a myriad of material compositions can be produced. The VSP-P1 nanoprinter enables the deposition of nanoparticulate material onto the desired substrate using inertial impaction through an automated, single-step process. Such a platform tool is a deterministic nanomanufacturing method capable of producing both complex nanoporous layers (NPLs) and sample arrays implemented in high-throughput screening. In this work, NPLs based on pure metal-oxide- semiconductors (MOSs) up to quaternary materials based on MOSs and metal catalysts were printed onto a multi-sensor array platform and exposed to target toluene and formaldehyde gas molecules. The influence of the material composition on the gas-sensing performance is analysed in terms of key metrics of gas sensor devices, such as sensitivity, selectivity, response/recovery time, and limit of detection (LOD). Depending on the material composition, ultra-sensitive sensing devices were prepared, with a LOD in the ppb level for both target gas molecules, in a wide concentration range (0-25 ppm for toluene and 0-10 ppm for formaldehyde). The presented procedure based on screening different material compositions can be extended to a variety of other materials and target gas molecules. Hence, this work aims to dynamize gas-sensing layer fabrication, showcasing a platform tool that drastically reduces the time needed for material discovery for the next generation of gas-sensing devices based on nanostructures.



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sciforum-119397: High responsivity and selectivity of hydrogen sensors based on sandwich-structured $\text{MSn}_x\text{-rGO-SnO}_2$ composites

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SnO_2 nanoparticles were grown on the surface of reduced graphene oxide (rGO) via a simple reflux reaction, resulting in the formation of rGO-SnO_2 composites with excellent hydrogen (H_2) sensing performance. Noble metal sensitizers, known for their electronic and chemical sensitization effects, have been shown to significantly enhance the sensing performance of metal oxide semiconductor (MOS)-based gas sensors. In recent years, intermetallic compounds have gained significant attention in catalysis research due to their tunable electronic structure, excellent stability, and low cost. In particular, intermetallic compounds have demonstrated exceptional catalytic performance. Based on the theoretical basis of the above two aspects, it is hypothesized that intermetallic compounds will offer high sensitization performance in MOS gas sensing. Herein, an in situ synthetic approach to produce a series of intermetallic sensitizers consisting of three binary M-Sn (M: Au, Pt, Pd) intermetallic compounds is reported. All three intermetallic compounds significantly enhanced the H_2 sensing performance of rGO-SnO_2 composites, with Pd_3Sn_2 exhibiting the most potent sensitizing effect. The 2.0% $\text{Pd}_3\text{Sn}_2\text{-rGO-SnO}_2$ composites with a sandwich structure showed a significant decrease in the optimal operating temperature of rGO-SnO_2 composites in response to H_2 from 225 °C to 90 °C, and its sensor response to 500 ppm H_2 was 250.9, which was 125 times higher than that of the rGO-SnO_2 composites.



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sciforum-125695: High-dimensional Localized Surface Plasmon Resonance gas sensor with subpixel structure

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Introduction

Localized Surface Plasmon Resonance (LSPR), which arises from the collective oscillation of free electrons in metallic nanoparticles, enables the absorption of light at specific wavelengths. Gas sensors based on this phenomenon can accurately detect gas concentration gradients and are characterized by high sensitivity and fast response and recovery times, and the ability to track dynamically changing gas flows with high spatial resolution. These features make LSPR-based gas sensors suitable for a wide range of applications, including drug detection, biological testing, cellular labeling, and disease diagnostics.

Methods

In this study, we employed printed electronics technology to fabricate dense array sensors in a simple and cost-effective manner using inkjet printing. By introducing a pixel structure with spatial encoding, we enabled high-precision two-dimensional gas sensing, allowing us to visualize both the concentration distribution and identity of gases within a given space. The viscosities and surface tensions of Au and Ag nanoparticle inks, as well as dye solutions, were optimized for inkjet printing. These materials were sequentially printed onto PET substrates to form a 4×4 subpixel structure within each sensing pixel. Moreover, due to slight printing non-uniformities between the center and edges of the inkjet-printed dots, we interpreted each pixel as having distinguishable zones and redefined it as a 12×12 subpixel grid, effectively increasing the sensing resolution to 144 features per pixel.

Results and Conclusions

Gas response measurements for 16 different gases were conducted using a hyperspectral camera, and the data were analyzed using Principal Component Analysis (PCA) and Linear Discriminant Analysis (LDA). As a result, we confirmed that the inkjet-printed LSPR gas sensor was capable of distinguishing 16 gases. Although the current subdivision is based on print-induced non-uniformities, future work will explore more optimal strategies for defining subpixel regions to enhance classification performance.



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sciforum-125660: Identification of mixed VOC gas species Using Surface-Enhanced Raman Scattering Sensor

Ginji Akinaga *, Fumihiro Sassa and Kenshi Hayashi

Kyushu University

Introduction

Biomarker-based diagnostics such as blood and urine tests are commonly used to detect diseases. However, these conventional methods are often invasive, time-consuming, and labor-intensive. Therefore, non-invasive and rapid diagnostic methods are highly desirable. Analyzing skin gas or exhaled breath enables the early detection and monitoring of disease progression. However, these gaseous biomarkers are typically present at low concentrations and as complex mixtures, requiring highly sensitive and selective sensors.

Methods

In this study, we aimed to detect and identify volatile compound mixtures using a high-sensitivity, high-selectivity Surface-Enhanced Raman Scattering (SERS) gas sensor. To enhance the sensor's molecular detection range, we fabricated surface-modified SERS sensors using 4-aminothiophenol (4-ATP) and 4-mercaptobenzoic acid (4-MBA), both of which contain thiol groups with strong metal affinity. We measured four individual gases and ten gas mixtures using these modified sensors. As sampling methods for volatile compounds, we investigated both the bubbling method and the direct contact method. Data analysis included dimensionality reduction for visualization, spectral separation for mixed gas analysis, and machine learning for classification.

Results

Visualization using Linear Discriminant Analysis (LDA) showed that combined spectral data improved separability compared to individual sensor data. Additionally, 10-fold cross-validation with Support Vector Machines (SVMs) demonstrated the highest classification accuracy using combined spectra. This suggests that combining spectral information enhances data richness.

Conclusions

Overall, this study demonstrated that surface modification expanded the detection capabilities of SERS gas sensors and enabled the effective classification of volatile compounds using machine learning. The combined spectral approach contributed significantly to high-accuracy identification by increasing the available chemical information.



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sciforum-125223: MEMS Gas Sensors with Wafer Level Fabrication and Testing Techniques

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Recently, MEMS gas sensors have attracted more and more attention thanks to their compact size, high sensitivity and compatible fabrication process. Great efforts have been made to develop chemiresistive gas sensors based on metal-oxide semiconductor nanomaterials, for the potential applications such as gas emission monitoring for industrial plants, indoor and outdoor pollution detection, and breath analysis.

Though many new materials and devices have been developed, there are still a few technical challenges for the MEMS gas sensors such as the process compatibility and the wafer-level testing for the device. In a typical fabrication process of MOS gas sensor, MOS materials may be loaded on the designated area through dip-coating, drop-coating, spraying, or inkjet printing. While wafer-level patterning of sensing materials, which are highly desirable for the large-scale production, still faces challenges in terms of process incompatibility between the deposition techniques and the microelectromechanical systems (MEMS) fabrication of the sensing device.

This talk will report our recent works on (1) the new compatible fabrication technique for the sensing materials, and (2) the intelligent and fast test strategy for device sorting at wafer level. We have adopted a 'top down' strategy for wafer-level fabrication of sensors with high-throughput and good reproducibility. We have also developed a pulse heating (PH) method to detect transient characteristics of multivariable response, which provides better stability, sensitivity, and selectivity, making it a promising candidate for establishing a relationship between conductance information and gas concentration.



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sciforum-124144: Predicting liver function from breath VOCs via machine learning with support for ISFET sensor Integration

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This work presents the development of a miniaturized ISFET-based gas sensor for detecting isoprene in exhaled human breath and its application in non-invasive liver function assessment. Isoprene, a well-known volatile organic compound (VOC) associated with cholesterol biosynthesis and hepatic metabolism, serves as a biomarker for early-stage liver dysfunction. While gas chromatography-mass spectrometry (GC-MS) was used to validate VOC profiles and support model training, the core objective is to enable real-time sensing through a solid-state platform. The proposed sensing system is built upon an ion-sensitive field-effect transistor (ISFET) architecture, utilizing a high-electron mobility indium nitride (InN) thin film as the gas-sensitive channel. InN is selected for its superior surface conductivity modulation and sensitivity to electron-donating species such as isoprene. The InN epitaxial layers were grown via molecular beam epitaxy (MBE), with fabrication conducted in collaboration with NTHU and NSYSU. Process challenges, including MBE beam source calibration, were addressed to achieve high-quality crystallinity, confirmed via RHEED patterns, SEM imaging, and Hall effect characterization. To facilitate sensor calibration and controlled exposure, a bubbler-based isoprene delivery system was constructed to simulate ppb-level gas conditions. The sensor's response is modeled as a field-effect modulation mechanism, where isoprene adsorption alters the surface charge distribution and modulates channel conductivity. Initial tests are under way to characterize dynamic response, sensitivity, and baseline drift. These characteristics will be used to inform machine learning models trained on GC-MS validated data, enabling hybrid sensor-data fusion for liver function prediction. This study not only highlights the promise of ISFET sensors for VOC detection but also demonstrates a pathway toward integrating semiconductor sensing with predictive health analytics. The long-term goal is to realize a portable, low-power, real time breath analyzer capable of supporting early diagnosis and monitoring of liver disease progression.



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sciforum-125662: Quick and Highly Sensitive Gas Detection Using LSPR-SERS Dual-Mode Sensor

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Introduction

Rapid and sensitive gas detection is crucial for real-time environmental monitoring and industrial safety. In this study, we present a dual-mode gas sensor that combines Localized Surface Plasmon Resonance (LSPR) and Surface-Enhanced Raman Scattering (SERS) to enable a fast response and high molecular sensitivity. By integrating these optical effects, the sensor provides complementary information: LSPR enables the visualization of gas adsorption behavior, while SERS delivers precise molecular identification.

Methods

The sensor was fabricated by immobilizing silver nanoparticles on amine-functionalized glass substrates using a light-assisted growth method. This approach ensured the formation of uniformly distributed nanostructures with optimized plasmonic and Raman enhancement properties. Four structurally similar aromatic aldehydes—P-anisaldehyde, benzaldehyde, 4-ethylbenzaldehyde, and m-tolualdehyde—were used as target gases to evaluate the sensing performance of the sensor.

LSPR responses were captured through hyperspectral imaging, and image differencing algorithms were used to detect subtle spectral changes over time. This enabled the spatial mapping and visualization of gas adsorption at the sensor surface. For the SERS analysis, the acquired Raman spectra were processed using non-negative matrix factorization (NMF) to decompose complex spectral mixtures into individual component spectra. The extracted features were then used as inputs for a supervised machine learning classifier to distinguish between the gas species, improving the sensor's identification accuracy even when overlapping signals were present.

Results

Our experimental results showed that the sensor achieved both rapid signal acquisition and high sensitivity, successfully distinguishing all four gases with good spatial and molecular resolution. The dual-mode system enhances its detection speed and selectivity while maintaining a simple structure and ensuring cost-effective fabrication.

Conclusions

This study demonstrates the feasibility of combining nanostructured sensing surfaces with lightweight algorithmic processing for fast and accurate gas monitoring. The proposed approach holds great potential for smart sensing applications in environmental surveillance, indoor air quality control, and industrial hazard prevention.



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sciforum-125654: Randomized 2-Dimensional LSPR Gas Sensor using Fluorescent dyes and Au/Ag NP coupling

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Introduction

In recent years, there has been an increasing demand for gas sensors that offer high speed, sensitivity, and accuracy, particularly in the context of disaster response and industrial monitoring. Previous studies have shown that the gas selectivity of localized surface plasmon resonance (LSPR) sensors can be enhanced by coupling them with fluorescent dyes. In this study, instead of uniformly coating a sensor substrate with predetermined concentrations of dyes, we aimed to significantly enhance the sensing dimensionality by randomly coating multiple fluorescent dyes onto a single LSPR sensor substrate.

Method

To fabricate the sensor, gold and silver nanoparticles were deposited onto a glass substrate via sputtering, followed by the random coating of several fluorescent dyes, such as Rhodamine 6G, Fluorescein, and Eosin Y. The gas responses of the resulting substrate were measured using a hyperspectral imaging system, which captured changes in the absorbance spectra upon exposure to various target gases.

Results

Machine learning techniques were applied to analyze the spectral data, enabling successful discrimination between multiple gas species. This result demonstrates that introducing a spatially random distribution of fluorescent dyes improves the gas selectivity of LSPR-based sensors.

Conclusions

The proposed approach offers a novel strategy for enhancing the functionality of optical gas sensors without increasing their structural complexity. It holds promise for real-world applications in environmental monitoring and the prevention of secondary damage during disaster events, where rapid and accurate gas identification is critical.



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sciforum-119549: Space confinement strategy and nano sensing performance of MXene materials

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Gas-humidity sensors are widely used in modern industries, environmental monitoring, agriculture, healthcare, and daily life. However, current gas-humidity sensors still have problems such as the inability to capture changes in gas concentration in a timely manner and low sensitivity when detecting low concentration analytes, which cannot meet the application requirements in extreme environments. To this end, we propose a new strategy for two-dimensional (2D) fluid confined sensing, using a layered 2D transition metal carbide (Ti_3C_2 MXene) to provide a 2D sensitive channel. By combining molecular dynamics simulations, first principles calculations, multi physics simulations, and in-situ spectroscopic experiments, it was found that low current can cause polarization of water molecules, resulting in ordered and dense arrangement of confined water in the two-dimensional channel, while high current can induce confined water dissociation and aggregation into large molecular clusters, blocking the 2D channel. By adjusting the channel size and combining the concepts of metal cations and electric field longitudinal, the equilibrium transition of two-dimensional confined water between three structural types is promoted: monomer $\rightleftharpoons$ dimer $\rightleftharpoons$ cluster, and the response and recovery time of the sensor are optimized simultaneously. This strategy can quickly adjust the transport dynamics of confined molecules in 2D channels, and is expected to have wide applications in sensing, water treatment, gas separation, energy storage and conversion, and other fields.



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sciforum-125198: Study of alcohol selectivity of a room temperature operated gas sensor based on TiO₂

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High-temperature operation and poor selectivity are two main shortcomings of metal oxide (MOX)-based gas sensors. Gas selectivity is an important but complex issue. In this study, alcohol selectivity at room temperature was studied systematically from two dimensions: carbon chain lengths and isomers. A room temperature-operated alcohol sensor based on TiO₂ burr-like nanorods was developed. Its responses to alcohols increase as their carbon chain lengths increase, and decrease in the order of primary, secondary, and tertiary alcohols. Overall, a new relationship between the gas molecular structure and response is reported here: the more slender the gas molecule, the higher the response. A novel sensing mechanism is reported here by studying the anomalous p-type responses to the alcohols at room temperature and a temperature-driven p-n response transition. The mechanisms for all the above results were studied experimentally and theoretically by characterizing the reaction path using Fourier transform infrared spectroscopy and analyzing adsorption characteristics by density functional theory calculations. The anomalous p-type response is caused by the surface adsorption of the alcohols. The adsorption energies, electronegativity, and steric hindrance contribute to the gas selectivity together. Besides the fundamental research, a homemade portable system for on-field n-butanol concentration monitoring was built. This study provides new insights into the gas selectivity and development of room temperature-operated MOX-based gas sensors.



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sciforum-125095: Surface Functionalization of Metal–Oxide–Semiconductors for Enhanced Chemiresistive Gas Sensing

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Chemiresistive gas sensors employing semiconducting metal oxides have emerged as a cornerstone in gas sensing technologies due to their structural simplicity, cost-effectiveness, and ease of integration with nanostructured platforms. Their sensing mechanism, which relies on resistance changes induced by gas adsorption and desorption, makes them suitable for a wide range of applications, including environmental monitoring, industrial safety, and health diagnostics. However, practical deployment remains limited by challenges such as poor selectivity, baseline drift over time, sensitivity to humidity, and a strong dependence on operating temperature. In this study, we present a systematic investigation of surface functionalization strategies designed to overcome these performance bottlenecks. Specifically, we explore three complementary approaches: (1) noble metal nanoparticle decoration to enhance catalytic reactivity and accelerate charge transfer; (2) formation of heterojunctions with secondary metal oxides to improve electronic modulation and broaden selectivity; and (3) beam irradiation to introduce molecular-level specificity and reduce interference from non-target gases. Thin-film sensors were fabricated using controlled deposition techniques and tested across multiple gas species under both dry and humid ambient conditions. Experimental results indicate notable enhancements in sensing performance, including increased response magnitude, reduced detection limits down to sub-ppm levels, and significantly improved signal stability. These findings highlight the critical role of surface/interface engineering in optimizing chemiresistive sensor behavior and offer a viable route toward developing highly selective and robust sensors suitable for deployment in real-world and harsh environments.



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Session 16. Triboelectric Nanogenerators and Self-Powered Sensors

sciforum-125021: A Portable and Recyclable Biomechanical Sensor Design based on Triboelectrification

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The development of multifunctional triboelectric nanogenerators (TENGs) that can sense and harvest energy has attracted much attention recently [1, 2]. However, the advancement and application of such TENGs have been limited by insufficient output performance and device sustainability. This study introduces a new sulfide-based nanomaterial used to create a nanocomposite for biomechanical sensors [3,4]. The results show that adding sulfide-based nanomaterials can effectively enhance triboelectric output [5]. In addition, these nanocomposites are combined with nanocellulose to explore the potential of this combination in TENG design, focusing on portability, recyclability, and biocompatibility. This study ultimately demonstrates the applicability of this device system in wearable biomechanical sensors.

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sciforum-125480: Abrasive wear detection for metal-polymer plain bearing based on triboelectric effect under dry and boundary working condition

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With the quick advancement of triboelectric nanogenerators (TENG), the self-powered sensing ability with triboelectric effect has been applied to various application areas, such as machines, wearable electronics, IoT devices, etc. The wear monitoring of metal-polymer plain bearing (MPPB) is a critical and challenging issue with traditional methods, however, the TENG paves a new route to resolve this problem. In this study, the triboelectric effect was applied as a self-powered sensing technology to a MPPB, which can achieve wear detection under dry and boundary lubrication. The coated silicone incorporated diamond-liked-carbon (Si-DLC) on the steel shaft was employed to achieve the signal output with a minor change to the original structure. Firstly, different wear situations are simulated to explore the influence on the wear area and wear depth. Then, real MPPBs with different wear states are subsequently used to verify the simulation results under dry and boundary lubrication. Finally, a deep learning neural network was employed to achieve the wear stated detection accurately. The study focused on creating a bearing with integrated wear detection capabilities, achieved through the synergistic application of triboelectric principles and AI technology. This research demonstrated a way for wear condition monitoring for MPPB and potential smart bearing by the triboelectric effect, which contributes a significant step towards AIoT integration in smart condition monitoring for smart factories.



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sciforum-121685: An Antifreeze Gel as a Strain Sensor and Machine-Learning-Assisted Intelligent Motion Monitoring of Triboelectric Nanogenerators in Extreme Environments

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With the rise of 5G technology, wearable flexible sensors have gained attention due to their potential in human-machine interfaces, medical monitoring, and soft robotics. These sensors can quickly convert external stimuli into electrical signals, crucial for portable and wearable electronics. To power these devices, the development of flexible, environmentally friendly energy solutions has become a key research area, with triboelectric nanogenerators (TENGs) showing promise. TENGs convert physical stimuli into electrical energy, offering self-powered sensors that extend devices' lifespans. Hydrogels, known for their high water content and flexibility, have emerged as ideal materials for flexible electronics due to their biocompatibility and adjustable mechanical properties. However, the traditional hydrogels freeze at low temperatures, limiting their use in critical environments. To address this, binary solvent systems like glycerol/water are used to prevent water crystallization and enhance the temperature tolerance. However, alcohol/water systems often exhibit low conductivity. Zwitterions, which improve the conductivity by facilitating salt dissociation, have emerged as a solution. In our work, we synthesized a dual-network conductive gel by polymerizing acrylamide (AM) and zwitterionic SBMA in a Gly/water binary solvent containing NaCl and gelatin, named PASG/NaCl/Gly. The gel's mechanical properties and stability were improved by the hydrogen bonds between the gelatin and P(AM-co-SBMA). The addition of NaCl and SBMA enhanced the gel's ionic conductivity, while glycerol improved its antifreeze properties. The gel exhibited excellent cyclic stability, adhesiveness, and electrical stability, making it ideal for wearable strain sensors in low-temperature environments. We demonstrated its application in a gel-TENG system, creating a portable smart insole for foot pressure and motion recognition. This work advances flexible sensor developments for extreme environments.



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sciforum-122112: An Ultrasensitive Triboelectric Pressure Sensor for Multimodal Healthcare Applications

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Sensors have been regarded as milestones of 'Industry 4.0' and are considered to be the most important node for exchanging information between devices and signal control terminals in the Internet of Things. The birth of triboelectric nanogenerators in 2012 enabled effective collection of low-frequency mechanical energy to provide continuous power for sensors, showing their great potential to act as pressure sensors with a lower power supply. However, the most significant challenges for existing triboelectric pressure sensors are the degradation of sensing performance and weak interfacial adhesion owing to low mechanical transfer efficiency and interfacial differences at the skin-sensor interface. We introduce an ultrasensitive wearable pressure sensor with a stress-concentrated tip-array design and self-adhesive interface for improving the detection limit. A microstructure with various Young's moduli is designed to improve mechanical transfer efficiency. Increasing the difference in moduli also mechanically amplifies the sensitivity with a low detection limit. A self-adhesive hydrogel is developed to strengthen the sensor-skin interface, which facilitates stable signals for long-term and real-time monitoring. It enables the generation of high signal-to-noise ratios and multiple features when wirelessly monitoring weak pulse signals and eye muscle movements. Finally, combined with a deep learning bimodal fused network, the accuracy of fatigued driving identification is significantly increased.



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sciforum-124713: Enhancing Self-Induced Polarization of PVDF-Based Triboelectric Film by Introducing Functional g-C₃N₄ layers for Ultrasensitive Triboelectric Pressure Sensors

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Progress in wearable energy devices has reached the point of popularity over a few decades, as reflected by the rise of numerous sensors and storage devices driven by the urgent need for Internet of Things (IoT) applications. Triboelectric sensor (TES), on the basis of triboelectric nanogenerators (TENGs), exhibits high sensitivity and stability for pressure detection. Maximizing the sensitivity of the TES hinges upon the triboelectric layer selection capable of harnessing triboelectrification and electrostatic induction. Among them, PVDF has gained attention owing to its exceptional flexibility and tribo-negativity. However, the multiphase of pristine PVDF poses challenges, limiting its potential for TES with higher sensitivity. Tackling this issue, herein, we introduced phosphorus-doped graphitic carbon nitride (PCN) into the PVDF films to achieve self-induced polarization to enhance the sensitivity of the triboelectric pressure sensor. Through a controlled annealing temperature, phosphorus atoms are incorporated into the g-C₃N₄ (CN) matrix, enhancing the electronegativity of PVDF/PCN composite film while inducing a polarized β crystal phase in PVDF, thereby enabling greater attraction of positive charges. Consequently, the triboelectric output with PVDF/PCN composite film exhibited a significant improvement compared to the pristine PVDF film, achieving over a 100 V increment and the ability to power more than 100 LEDs. Furthermore, for the pressure-sensing applications, the TES with flexible PVDF/PCN triboelectric film exhibits a pressure sensitivity of 1.48 V/kPa, which shows a threefold increase in sensitivity compared to the pristine PVDF film (0.51 V/kPa), suggesting their great potential in self-powered wearable pressure sensors.



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sciforum-121946: Implementation of Triboelectric nanogenerator-based wearable sensors for Muscle Activity Monitoring

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Flexible Triboelectric nanogenerator-based sensors have recently begun to attract more attention in sports, healthcare, and rehabilitation applications. With the rise of human-computer interaction technologies, individuals and medical specialists are becoming increasingly interested in smart devices that can help monitor health conditions from a numerical standpoint. These sensors are also essential for personalized muscle activity monitoring, where real-time data supports treatment decisions and improves patient outcomes. This study presents a TENG-based optimized sensor, which can be used for muscle activity monitoring applications by providing precise, durable, cost-effective, and scalable solutions through proper material selection and structural novelty. The TENG can convert mechanical energy from human biomechanics into electrical output, enabling stable and continuous monitoring of physiological parameters. These devices directly connect to external circuits without requiring additional energy sources, significantly reducing the power consumption and environmental impacts associated with battery production, usage, and disposal that align with the green energy concept. The methodology includes sensor preparation with biocompatible polymers through advanced fabrication methods and electrical and mechanical performance testing to ensure their adjustability for monitoring device applications. Finally, integrating machine learning algorithms into the designed wearable sensor device enabled real-time feedback and data-driven insights about patterns and correlations, expanding the possibilities for their use in evidence-based diagnostics, rehabilitation, and preventative care to improve athletic performance.



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sciforum-125700: Laser processing and molding of flexible polymer for unique triboelectric nanogenerator and self-powered sensor application

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TENG may harvest the wasted mechanical energy in the nature such as motion, wave, windy, and vibration turned into electricity for the sustainable and renewable energy. The flexible polydimethylsiloxane (PDMS) elastomer polymer with the merits of biocompatibility, fast casting, insulating and flexibility in shape is widely used in the microelectromechanical systems, biomedical, and optoelectronic categories. Laser processing is one of the important manufacturing technologies for various materials including polymer, glass, compounds and metals/alloys. In this talk, combining both technologies of the CO₂ laser ablation of polymethyl methacrylate and PDMS molding, we have fabricated the micro-needled (MN) or doped PDMS and assembled with aluminum (Al) into an unique triboelectric nanogenerators (MN-PDMS TENG) that is an energy generating device to convert mechanical energy into electrical energy through the cycling contact-separation operation as well for the **self-powered sensor**. The traditional TENGs were generally formed by two triboelectric materials in a multilayer or simple pattern using a complex, long-time, high-cost fabrication to generate a triboelectricity. The unique high-aspect-ratio MN-PDMS-Al TENG is a cost-effective, facile-fabrication and friendly mechanical energy harvester that can highly enhance triboelectric performance with a mechanism of randomly closed bending-friction-deformation behavior of MNs for potential applications in energy section, human care, biomedical, portable power, wearable and self-powered sensors for IoT.



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sciforum-119664: Recent Advances in Functional Wearable Design Using Layered Nanomaterials

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The growing demand for high-performance wearable electronics has necessitated the development of advanced materials that combine flexibility, durability, and multifunctionality. Among the various material candidates, layered nanomaterials have gained significant attention due to their exceptional properties, including high surface area, tunable electrical and optical characteristics, mechanical robustness, and adaptability to diverse substrates. These attributes make them highly suitable for next-generation wearable devices, enabling enhanced functionality in areas such as sensing, energy storage, and self-powered systems. In this presentation, we would like to provide an overview of recent advancements in the integration of layered nanomaterials into functional wearable platforms. We will explore innovative fabrication techniques, material processing strategies, and device architectures that leverage the unique properties of these materials to improve device performance and efficiency. Furthermore, we will examine the role of layered nanomaterials in enabling stretchable, lightweight, and highly responsive wearable systems, with applications in health monitoring, human-machine interfaces, and smart textiles. Despite their immense potential, several challenges remain, including scalability, long-term stability, biocompatibility, and integration with existing manufacturing processes. Addressing these challenges is crucial for translating laboratory-scale developments into commercially viable products. Finally, we will discuss emerging trends and future research directions that could drive further advancements in layered nanomaterial-based wearable technologies.



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sciforum-122109: Self-Powered Triboelectric Neuromorphic Devices for Bioinspired Tactile Perception

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The growing demand for energy-efficient integrated systems combining sensing and computing has driven innovations in self-powered sensing and neuromorphic computation. The triboelectrically driven three-terminal synaptic transistor device demonstrates unique technical advantages through the integration of mechano-electric conversion and neuromorphic computing. Its gate electrode incorporates a triboelectric nanogenerator unit that can directly convert mechanical energy generated by force application into gate voltage pulses regulating channel conductance, thereby achieving self-powered in-memory sensing. However, the current triboelectric mechano-electric conversion strategies are constrained by the limited surface charge density of triboelectric materials, resulting in low areal power density in single devices. Therefore, we proposed a high-performance HPEBL-based TENG (H-TENG). We embedded a solution-processed high-permittivity electron-blocking layer into the classical contact-separation mode TENG to build an energy barrier between ITO and PDMS, which could effectively block the transportation of electrons towards the bottom electrode. The outputs of $\text{La}_{0.1}\text{Zr}_{0.9}\text{O}_x$ -based H-TENG were boosted to a remarkable extent. Furthermore, the external stimuli induced triboelectric potentials through the H-TENG and thus activated biological synaptic behavior, such as the excitatory postsynaptic current (EPSC) of the artificial synaptic device (e.g., AlO_x synaptic transistor). Moreover, we proposed a liquid metal-based flexible dual-mode triboelectric-capacitive-coupled tactile sensor (TCTS) array of 4×4 pixels that achieved a spatial resolution of 7 mm, exhibiting a pressure detection limit of 0.8 Pa and a fast response of 6 ms. Neuromorphic computing using the MXene-based synaptic transistor achieved 100% recognition accuracy of handwritten numbers/letters within 90 epochs based on dynamic triboelectric signals collected by the TCTS array, and cross-spatial information communication from the perceived multichannel tactile data was realized in the mixed-reality space, exhibiting broad application prospects in self-powered biomimetic sensors and intelligent robotics.



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sciforum-122015: Sensory Evolution of Intelligent Robots: Innovative Exploration of Triboelectric Sensing for Object Identification

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All kinds of sensors carried by robots are like human sensory organs, which are crucial media for robots to perceive the world. Object characteristics are one of the important pieces of information that robots need in order to interact effectively with the surrounding environment. And different kinds of sensors focus on collecting measurement information of objects in different states. Among them, advanced tactile sensors can provide characteristic information about touching solid materials, while taste sensors can analyze the composition of liquids and determine the type of liquid. To achieve the qualitative development of intelligent robots and improve the perception system, the introduction of new technologies is undoubtedly a challenge. The rise of triboelectric nanogenerator (TENG) technology has brought a new approach for the realization of object recognition by various sensing sensors. With the rapid progress in triboelectric sensors, a body of research findings has convincingly demonstrated the viability and immense potential of this innovative approach. This report centers on the domain of intelligent robot perception and recognition, with a primary focus on object identification across different material states. It is dedicated to a thorough investigation of the application of TENG-based sensors for object identification. Through relevant research, this work aims to enhance the sensory capabilities of intelligent robots and further propel the innovation and practical development of related technologies.



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sciforum-122018: Smart Gripper with Triboelectric Sensors and Data-Driven Machine Learning for Object Classification

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Efficient waste sorting remains a critical challenge in recycling systems, often relying on expensive, vision-based technologies. This project presents a smart robotic gripper integrated with triboelectric nanogenerator (TENG) sensors and a data-driven machine learning algorithm for object classification, specifically designed to enhance automated waste sorting processes. Triboelectric nanogenerators (TENGs) are devices that harvest energy from mechanical motions, and when embedded into the gripper, they generate electrical signals during contact, enabling a self-powered mechanism for capturing tactile information such as the material type and texture. These tactile signals will serve as the input for supervised machine learning algorithms aimed at distinguishing between common categories of waste such as plastic, metal, paper, and organic materials. By learning from these interactions, the system aspires to facilitate intelligent decision-making during the sorting process, increasing the sorting accuracy. This approach is expected to reduce the reliance on manual labor and vision-based systems while enhancing the precision, scalability, and energy efficiency of automated recycling operations. By combining low-power sensing with intelligent data-driven classification, this work contributes a novel solution to the automation of waste sorting in recycling and environmental management industries. Furthermore, this technology promises significant cost reductions and improved operational efficiency, offering a sustainable alternative that aligns with global environmental conservation efforts.



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sciforum-121678: Study on interface electrical properties of tribodielectric materials

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Most of the proposed high performance of devices based on triboelectric nanogenerator (TENG) face the challenge of stability and low conversion efficiency. As is well known, triboelectric dielectric materials are one of the key parameters of triboelectric nanogenerator. Here, based on the performance improvement of triboelectric nanogenerator, the key parameter of triboelectric dielectric materials has been systematically studied. The charge generation, transfer, and accumulation of dielectric materials are explored systematically. The relative experimental results are explained theoretically by quantum tunneling effect, material matching, quasi-piezoelectric model and leakage current. Direct-current triboelectric nanogenerator (DC-TENG) serves as an innovative technology for harvesting micromechanical energy from the environment, crucial for directly powering sensor networks. However, research bottleneck in enhancing the triboelectric electrification capability and charge storage capability of dielectric materials has hindered the overall performance breakthroughs of DC-TENG. Therefore, DC-TENG (FEM-TENG) is proposed by structure design and circuit management. At the same time, triboelectric nanogenerator guided by the theory of fluid dynamics needs further exploration. Herein, a dynamic model is proposed to study the intrinsic interaction between the electrical properties of triboelectric nanogenerator and fluid dynamics of gas and liquid. These works can provide a direction for in-depth understanding of the electromechanical conversion mechanism, and enhancing the performance for triboelectric nanogenerator.



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sciforum-120146: Tribo-photonics: an Emerging Field toward Fully-Self-Powered Wireless Sensing

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With the development of the Internet of Things (IoT) and smart cities, wireless sensor networks (WSNs) have played a significant role in our society. Achieving fully self-powered wireless sensing is an important and urgent task. Tribo-photonics represents a new field. It uses the electrostatic induction brought by triboelectric charges to tune or control optical or electromagnetic wave transmission, coupling triboelectricity with photonics. This emerging field provides novel methods to convert high-voltage electric signals into optical signals, delivering a new method of wireless sensing through the optical way. As triggered by TENG, such wireless sensing can be conducted in a fully self-powered manner. Nowadays, emerging tribo-phonic devices have been developed; examples include self-powered wireless sensing e-stickers, tribo-induced smart windows, tribo-induced liquid lenses, triboelectrification-induced electroluminescence, etc.

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sciforum-125453: Triboelectric Tactile Sensors

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Flexible tactile sensors have attracted much attention for their potential applications in health monitoring, wearable devices, electronic skin, smart robots and so on. With the rapid development of Internet of things, considering the large number and small scale of sensors, power consumption also plays a significant role in influencing their large-scale application. A new generation of self-powered tactile sensor based on triboelectric nanogenerator has been developed in terms of its incomparable advantages in power consumption and potential performance. Based on the coupling effect of contact-electrification and electrostatic induction, it enables to obtain the information on the mechanical input, e.g., magnitude and frequency, by analysing electrical output signals. Intensive efforts have been devoted to improve the sensing performance of triboelectric tactile sensor to meet the demand of the practicality. In this talk, the key advancements in materials, structures and applications of flexible triboelectric sensors will be systematically introduced. Then, the theoretical basis, impact mechanism and the approaches to optimize the pressure sensing performance will be comprehensively analysed. Afterwards, I will summarize the typical applications of triboelectric tactile sensors in different pressure ranges and working frequencies. Finally, the future perspectives of flexible triboelectric tactile sensor and microsystem will also be discussed.



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Session 17. Energy Harvesting Technology and Applications

sciforum-122101: Integrated Electrostimulation Cell Culture System Powered by Chemically Modified Twistron Harvesters

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Self-powered electrostimulation platforms are attracting interest in tissue engineering and regenerative medicine by removing the need for external power supplies. In this study, we present an integrated cell culture system that combines a polydopamine (PDA)-modified twistron as an energy harvester with a Poly(3,4-ethylenedioxythiophene) (PEDOT)-coated scaffold to deliver electrical stimulation to cells. The energy harvester is based on coiled carbon nanotube (CNT) yarns coated with PDA, which improves biocompatibility, hydrophilicity, and electrical conductivity. These enhancements lead to increased electrochemical capacitance and stable current output when the system is mechanically activated. Electrical energy generated from the twistron is transferred to a PEDOT-coated scaffold, which serves as a biocompatible and conductive platform for cell growth and stimulation. The overall system demonstrated a current stimulation range of approximately $\sim 75.4 \mu\text{A cm}^{-2}$, which is the highest reported among existing self-powered electrostimulation-based cell culture systems. We validated the system using chondrocyte cultures, where electrically stimulated cells showed enhanced proliferation and significant upregulation of cartilage-specific markers. The stimulation was entirely self-powered, requiring no external electronics or batteries. This work presents a compact and flexible platform that integrates chemo-mechanical energy harvesting with efficient electrostimulation delivery. By achieving the highest current output range in its class, our system offers a promising foundation for future implantable and wearable regenerative devices.



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sciforum-125923: Research on a self-powered rolling bearing fault diagnosis method with vibration energy harvesters for self-sensing

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The self-powered fault diagnosis methods provide a new idea to realize fault diagnosis without using wired sensors or battery-supported sensors. However, current self-powered fault diagnosis methods mainly depend on self-powered sensors, most of which may destroy the original structure of mechanical parts or contain connected energy harvesters and sensors, resulting in reduced reliability and stability. In this paper, a self-powered rolling bearing fault diagnosis method with vibration energy harvesters for self-sensing is proposed. The harvesters can be simply installed without destroying the bearing structure, and the electrical outputs excited by the mechanical vibrations can be further used for fault diagnosis. The energy conversion mechanism of two harvesters and the basic knowledge of the convolutional neural network (CNN) model are first introduced, based on which the self-powered fault diagnosis approach is proposed. Experimental work is conducted to identify the parameters of the harvesters' governing equation and verify its effectiveness. The responses of the harvesters installed onto a rolling bearing experimental table are further measured and analyzed. Finally, the CNN model is trained based on the electrical outputs of the harvesters under different installation positions, different rotation speeds and different healthy statuses of the bearings. The research results show that the average classification accuracies of this method for rotational speeds of 1200 rpm, 3000 rpm and 4800 rpm can achieve 88.389%, 98.99% and 98.431%, respectively, which are quite feasible in practical applications. This work shows a totally new idea of adopting a vibration energy harvester as a self-sensing device to achieve self-powered fault diagnosis, which has wide application potential in the future.



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sciforum-121584: Achieving High Output Performance and Efficient Energy Utilization of TENG

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Triboelectric nanogenerator (TENG) is a new technology used for collecting low-frequency mechanical energy, which is one of the most important technologies used to solve the distributed energy supply of wireless sensor networks where wired electricity is not available. However, it is a great challenge to improve the output energy density, reduce interface abrasion and efficiently extract energy for electronics. Herein, I will introduce the strategies adopted in our research group to improve the output performance and durability, and energy utilization of the TENG, which include (1) boosting the output charge density enabled by charge excitation strategy, asymmetric electrode designs, self-polarization of polar high-k materials, charge trapping failure of dielectric polymers, ultra-fast charge injection technique, charge migration in dielectric materials, suppressing charge loss and increasing load voltage in charge extraction process, (2) ultra-durability enabled by automatic mode switching with charge excitation, floating self-excited sliding mode, interface static friction, interfacial lubrication, and (3) efficient energy managements enabled by switched-capacitor convertors, specific matched transformer/inductor design and efficient energy conversion mechanism and energy storage strategy. Through multi-dimensional analysis and regulation of charge behavior, these works have made substantial advancements in optimizing the performance of TENG and provided a theoretical foundation for the development of high-energy-density, self-powered TENG systems.

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sciforum-129495: Biocompatible Ionic Hydrogel with Stable Energy Harvesting and Self-Powered Leaf Health Monitoring for Future Smart Farming

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Continuous and reliable monitoring in outdoor farming is essential to maximize agricultural productivity; however, it faces significant challenges due to limited access to consistent power sources and the maintenance burdens associated with conventional battery-based systems. Traditional energy-harvesting techniques relying on solar, vibrational, or thermal stimuli are often intermittent and heavily influenced by environmental conditions, highlighting the need for truly self-sustainable monitoring solutions.

In this work, we introduce a biocompatible ionic hydrogel composed of poly(vinyl alcohol), polyacrylamide, lithium chloride, and glycerol, interfaced with copper and aluminum electrodes, designed for simultaneous high-performance energy harvesting and self-powered plant-health sensing. This hydrogel continuously generates electricity from ambient oxygen and humidity without requiring any external stimuli, delivering a stable direct current at an average power density of 1.9 W m^{-3} under matched load conditions, significantly surpassing conventional vibrational energy harvesters. Extended outdoor testing at 24°C and 60% relative humidity demonstrated the device's robust performance, sustaining a cumulative energy output of $1.36 \times 10^7 \text{ J m}^{-3}$ over 56 days and fully recovering its energy-generation capabilities across repeated drought and humidity cycles.

Additionally, when laminated directly onto plant leaves, this hydrogel uniquely enables self-powered, non-invasive monitoring of leaf relative water content (RWC), achieving linear, real-time sensing across multiple crop species without the need for conventional high-power consumption equipment or optical components. This capability represents a significant advancement for outdoor smart farming, offering timely and accurate assessments of crop water status.

Combining the hydrogel's exceptional energy-harvesting efficiency with its self-powered RWC sensing functionality enables integration with various environmental and physiological sensors, allowing for fully autonomous, self-sustaining Internet of Things (IoT) systems. This approach contributes to the development of maintenance-free, scalable sensor networks, which are essential for the advancement of precision agriculture and future smart farming technologies.



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sciforum-110088: Cylinder bluff body modified with counter-flow fin-shape rods for enhanced wind-induced vibration energy harvester

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Wireless sensor networks can collect and transmit data through distributed sensor nodes, playing a crucial role in environmental monitoring of marine, mountain, forest, and urban areas. These sensor nodes typically use low-power components and operate in unattended environments. To ensure the long-term sustainable operation of these components, the choice of power source is critical. Naturally abundant and renewable wind energy has emerged as a highly competitive potential solution. Improving the output power and bandwidth of small-scale wind-induced vibration piezoelectric energy harvesters (WIVPEHs) is attracting increasing attention.

This study proposes a new CFSR design that modifies cylindrical bluff bodies via parametric geometry variations, examining its impact on WIVPEH performance. Numerical simulations based on Computational Fluid Dynamics (CFD) demonstrate that the CFSR cylinder not only achieves a cut-in wind speed of less than 1 m/s but also delivers a substantial energy output (0.27 mW of mechanical energy and an energy conversion efficiency of 58%) at a wind speed of 1 m/s. Under low wind speed conditions ranging from 1.5 to 8 m/s, the CFSR cylinder maintains a minimum amplitude of 0.6D, greatly extending the operational bandwidth of the energy harvester. By optimizing geometric parameters, the performance of WIVPEHs is enhanced through improved coupling between VIV (Vortex-Induced Vibration) and galloping. This study demonstrates that rods symmetrically mounted at 90° on the cylinder surface should maintain a specific groove depth (effect of parameter H) and a specific tilt angle relative to the windward side (effect of parameter X). When $H = 4$ mm and $X = 24$ mm, the system achieves an oscillation amplitude of 29.14 mm at 8 m/s wind speed, converting 17.35 mW of mechanical energy from wind energy. This study provides valuable insights into the parametric design and optimization of small-scale WIVPEHs.



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sciforum-121728: Design and analysis of galloping energy harvesters

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In this talk, firstly, the performance of the galloping energy harvester under Gaussian white noise excitation is investigated. By means of the equivalent linearization method and the method of moments, the exact closed expressions for the mean square voltage and the average output power are derived and the response properties of the moments are studied in detail. Then, the complexification-averaging method is firstly used to derive the theoretical solutions and analyze the dynamical performance of the energy harvesters under galloping and base excitations. The critical condition for identifying the unstable region is obtained. And with the different parameters, the critical unstable boundary can be identified. In order to improve the harvesting performance, the optimization of parameters of the energy harvesters are considered based on the maximum voltage amplitude. Finally, a novel galloping energy harvester is established by combining with an elastic structure. The nonlinear model is derived, due to the complex nonlinear properties, the partial linearization technique and Fokker-Planck-Kolmogorov equation are used to further explore the probability density function of displacement and velocity. The joint probability density function and the stationary probability density function of displacement and velocity are derived analytically. Numerical results are derived by means of the Monte Carlo simulation to illustrate the efficient of the theoretical results.



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sciforum-121495: Development of Microbial Fuel Cells Using Waste Cutting Fluids

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Microbial power generation devices are called microbial fuel cells (MFCs). MFCs can be used as power supplies for sensors in harsh environments, etc. One of their mechanisms is the formation of a conductive biofilm on the anode surface of the MFCs by power-generating microorganisms and transfer of electrons to the anode.

MFCs can be used as fuels from a wide variety of organic materials and can react at room temperature and pressure, making them particularly promising for use in sewage and wastewater treatment. In the various types of wastewaters, cutting fluids may contain residual biocides for preservation. For MFCs to generate power in such an environment, the power-generating microorganisms in the biofilm must maintain metabolic activity in the wastewater. We examined the conditions for biofilm formation of power-generating bacteria that can maintain metabolic activity in cutting fluids.

We used *Shewanella oneidensis*, which has been studied as a power-generating bacterium. We also used as a comparison *Pseudomonas* sp., which is known to frequently occur in cutting fluids. We examined the incubation time for biofilm formation from 18 to 72 hours, and the amount of biofilm was measured by the crystal violet (CV) method. The results showed that the amount of biofilm increased with increasing incubation time.

We further examined the metabolic activity of the bacteria in the biofilm after a dip in cutting fluid. The metabolic activity of the bacteria in the biofilm was compared using water-soluble tetrazolium salt (WST), a reducing chromogenic agent, after a dip treatment in cutting fluid. The results confirmed that the longer the incubation time, the more metabolic activity could be maintained in the cutting fluid.

These results suggest that the metabolic activity of MFCs used for the treatment of wastewater such as cutting fluid can be maintained by increasing the amount of biofilm formation of power-generating bacteria on the anode surface.



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sciforum-126348: Dynamics analysis of a hybrid piezoelectric-dielectric harvester

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With the continuous development of modern technology and artificial intelligence, a variety of sensors have become ubiquitous in every corner. In order to improve the reliability and ease of installation of sensors, wireless sensing technology has become an inevitable trend. Battery power technology and energy harvesting technology provide the foundation for the development of wireless sensing technology. Compared to battery-powered technology, energy harvesting technology can convert energy from the surrounding environment it into electrical energy to power electronic device, avoiding the need for unnecessary battery replacements. Therefore, energy harvesting technology has become a popular research direction. For energy harvesting technology, enhancing its energy output density and power is an important issue to address. Based on this, this work first proposes a hybrid piezoelectric-dielectric energy harvesting structure, which, under the influence of external environmental excitation, can simultaneously generate energy output from both piezoelectric-dielectric structures, thereby increasing energy output density and power while enhancing the stability of electrical energy output. Secondly, the dynamic model of this hybrid energy harvesting structure is established through the Euler-Lagrange equations, and simulation analysis is conducted to study the dynamic effects of different excitation parameters on this hybrid energy harvesting structure. Finally, the dynamic output characteristics of this hybrid energy harvesting structure under different structural parameters are discussed.



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sciforum-126039: Energy concentration pipe based on passive jet control for enhancing flow-induced vibration energy harvesting

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This study introduces an Energy Concentration Pipe (ECP), a hollow structure with passive windward inlet and jet outlets, mounted on a cylinder to enhance the performance of flow-induced vibration piezoelectric energy harvesting system. The effects of ECP configurations single outlet, symmetrical dual outlet, and asymmetrical dual outlet are investigated both experimentally and numerically. Experimental results show that the ECP significantly broadens the lock-in region and generates higher output voltage compared to conventional cylinders. Specifically, the lock-in region of the symmetrical dual outlet configurations increases by 108.33% and the maximum output voltage improves by 12.69%. Numerical simulations further reveal that the energy concentration effect effectively regulates the vortex shedding frequency behind the bluff body, especially under high reduced velocity conditions, where modal competition phenomena are observed. When the outlet angle θ is 30° , the vortex shedding frequency remains synchronized with both the vibration and natural frequencies, resulting in a sustained extension of the lock-in region. In contrast, at $\theta = 45^\circ$ and 60° , the vortex shedding frequency gradually deviates from the natural frequency while the vibration frequency remains locked to it, indicating a transition from vortex-induced vibration to galloping. Near-wall flow dynamics analysis shows that the ECP with outlet angles of 45° and 60° induces additional stress on both sides of the bluff body. At low reduced velocities, the Reynolds stress amplitude for $\theta = 45^\circ$ reaches approximately twice that of a smooth cylinder, while for $\theta = 60^\circ$, it is about 1.4 times higher. This work provides an essential foundation in designing more efficient piezoelectric energy harvester by utilizing ECP.



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sciforum-121794: Equivalent Circuit Modeling Methods and Their Applications in Vibration Energy Harvesting and Control

Guobiao Hu

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Equivalent circuit modeling is a powerful tool that bridges mechanical structures, electrical behavior, and control strategies, with broad applications in vibration energy harvesting and control. Our research focuses on efficient low-frequency energy harvesting and system-level modeling. We have developed a multi-level framework covering the process from device modeling to system integration. For flow-induced vibrations, including vortex-induced vibration (VIV) and galloping, we proposed modeling strategies for both linear and nonlinear systems, incorporating magnetic coupling to broaden the operational bandwidth. Advanced interface circuits such as SSHI and SECE were integrated to improve the energy harvesting efficiency and output stability. To address coupled VIV–galloping excitation, we developed a unified flow structure electrical equivalent model, enabling system-level simulation and optimization under nonlinear conditions. A standardized system-level modeling approach was further established to integrate harvesters, interface circuits, energy management, and loads, enabling end-to-end performance evaluation. Experimental validation under multi-mode excitation, intermittent loads, and self-powered operation demonstrated the practical feasibility of our models. These findings support the design of low-power IoT and edge sensing systems. Additionally, we extended the modeling approach to vibration control by proposing a bias-flip synchronized switch damping technique. With adaptive bias capacitors and multi-stage LC oscillation, we achieved improved voltage inversion and damping performance without using external power. This method offers strong frequency adaptability and control robustness for engineering applications. In summary, our work advances the theory and application of equivalent circuit modeling in energy harvesting and vibration control, providing solid foundations for developing intelligent, self-powered systems with promising academic and practical impacts.



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sciforum-119168: Harvesting Energy using Electromagnetic, Piezoelectric, and Triboelectric Technologies

Kean Aw

University of Auckland

In an era increasingly defined by the urgent need for sustainable energy solutions, capturing and utilizing ambient energy sources present transformative opportunities to address global challenges such as climate change, resource depletion, and energy accessibility. The research interest of Professor Kean Aw of the University of Auckland involves converting ambient mechanical energy into electrical power. His work focuses on three core methodologies: electromagnetic, piezoelectric, and triboelectric energy harvesting. Electromagnetic systems leverage the motion of coils and magnets to generate electricity from vibrations, while piezoelectric materials produce charge under mechanical stress, and triboelectric devices harness friction between dissimilar materials to create power. These technologies efficiently transform mechanical vibrations, human activity, and environmental movements—such as wind, waves, and footsteps—into viable electrical energy, offering decentralized and eco-friendly alternatives to conventional power sources. This keynote will highlight Professor Aw's research across several critical domains, such as smart agriculture, ocean wave energy harvesting, etc. Professor Aw's interdisciplinary approach bridges materials science, mechanical engineering, and environmental innovation. His team addresses critical challenges in device durability, energy conversion efficiency, and real-world integration, such as optimizing material selection for harsh environments or ensuring cost-effective manufacturing. The presentation will also explore emerging trends, including hybrid harvesters that synergize multiple technologies to maximize output and bio-inspired designs mimicking natural structures such as fish gills for efficiency to enhance the capture of mechanical energy. By merging scientific rigour with practical relevance, Professor Aw's work underscores the pivotal role of ambient energy harvesting in advancing renewable energy transition.



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sciforum-126461: Insulation Monitoring of Power Equipment and Green Electrical Technology

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The power grid system is composed of individual power equipment units. The reliable operation of power equipment (including transformers, GIS, bushings, etc.) is directly related to the reliability of power supply in the power grid system. Insulation defects (discharge defects, overheating defects) are the main causes of power equipment failures. Our team has long been engaged in research on the characteristic signals of ultrasonic pulses, electromagnetic pulses, optical pulses, and high-frequency current pulses of insulation defects in power equipment, as well as the diagnosis and early warning technology of insulation defects in power equipment based on multi-source characteristic signals. We have established a complete experimental platform for the detection of insulation defects in power equipment. We were the first in the world to conduct research on the decomposition mechanism of SF₆ under typical insulation fault conditions. Our research results have been adopted by CIGRE B3.24 and B3.40. We have led the development of international industry standards for SF₆ decomposition component fault diagnosis and pioneered the detection technology of trace gas components based on spectral detection. In addition, in response to the green and environmental protection development needs of the power industry, we have explored the optimal formula for the application of environmentally friendly insulating gases in switchgear and mastered the application technology of new environmentally friendly insulating gases in equipment of different voltage levels. By designing a double-layer dielectric barrier discharge (DBD) reactor, we have explored the treatment effect of DBD on SF₆ under different operating conditions, and developed a DBD degradation device. Besides, We have and developed the world's first 35kV degradable epoxy resin cast dry-type transformer. We have also conducted relevant research on the characteristic signals of insulation defects and corresponding sensing technologies for these green insulating electrical equipment.



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sciforum-120547: Mechanical energy harvesters for powering wireless sensors in rail transit infrastructure

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Over the past few decades, there has been remarkable progress in the development of low-powered wireless sensors, embedded and portable devices. How to continuously power these sensors and devices becomes a challenging issue. Meanwhile, there are plentiful environmental vibrations, especially in rail transit infrastructure. Thus, the mechanical energy harvester (MEH) utilizing the environmental vibrations is considered to be a promising way to solve the above challenge. Based on the recent research progress, this presentation will discuss the design, theoretical model, dynamic analysis, and experimental tests of MEHs for powering wireless sensors in rail transit infrastructure. Firstly, for typical applications in the railway, railway bridge, and subway, three types of MEHs are designed, with each characterized by structural design, output power, and coupled model, respectively. Through different multi-stage mechanical transmission mechanisms, these three MEHs convert the small-amplitude vibrations of the main structure into the high-speed rotational motion of a generator, thereby transforming vibrations into electrical energy. In addition, electromechanical coupling models are respectively established for the three MEHs, enabling accurate characterization of their output performance and dynamic responses. Furthermore, prototypes are fabricated and tested under laboratory conditions. Overall, this work provides a promotion of the design, model, and test of high-performance energy harvesters, advancing the application of self-powered wireless sensors in rail transit infrastructure.



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sciforum-126891: Reactive Crystallization of Halide Perovskites for High-performance Solar Cells

Shuang Xiao

Shenzhen Technology University

The understanding of the physicochemical mechanisms governing the nucleation and growth of halide perovskites is of paramount importance. Thereafter, the development of effective strategies to control the kinetic and thermodynamic processes of crystallization is essential. Such efforts are necessary to achieve ordered crystal growth, which is fundamental to the fabrication of high-performance perovskite-based optoelectronic devices—a key objective in the field of halide perovskite materials. To advance the precision in the synthesis of halide perovskites, we have introduced an innovative strategy aimed at enhancing the growth orientation of perovskite crystal facets. Our research has shown that propylamine exhibits a higher affinity for the (001) crystal plane of formamidinium lead iodide. By employing propylamine hydrochloride, we have facilitated (001)-oriented growth, thereby reducing internal tensile stress, mitigating defect formation, and enhancing phase stability. In a separate study, we addressed the significant challenge posed by the presence of multiple defect types in wide-bandgap halide perovskites. We have devised a novel method that utilizes ethylenediamine and 4-trifluoromethylphenethylamine, two bulky amines, to achieve synergistic passivation of defects in mixed-ion halide perovskites. This method enables the simultaneous passivation of various ionic defects, leading to a substantial reduction in the material's non-radiative recombination rate. Through the integration of these methodologies, we have successfully cultivated high-quality perovskite materials with a markedly reduced defect density. These materials have been effectively employed in optoelectronic conversion devices, including solar cells.



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sciforum-125267: Track-borne magnetic field energy harvesters for electrified railways

Yang Kuang

Central South University

Magnetic field energy, abundant in electrified railways, can be harnessed to power condition-monitoring sensors distributed along rail infrastructures. Despite its potential, this energy source has received little attention. This work proposes a track-borne magnetic field energy harvester (MFEH) designed to scavenge the magnetic field energy generated by traction-returning current conducted in rail tracks. The MFEH, featuring a low-profile magnetic core made of laminated silicon steel, is designed for reliability in the harsh railway environment and for simplicity in manufacturing, packaging, and installation. Finite element analysis and lab tests were conducted to characterize its performance under the influence of eddy current generation and nonlinear magnetization. Field tests at a high-speed railway were performed to evaluate the MFEH's performance in real-world settings. Lab tests indicate that the MFEH can generate an average power of 184 to 5178 mW when the current conducting in the track varies from 100 to 500 A. Field tests show that the passing of each high-speed train generates a burst of magnetic field up to $43 \pm 29 \mu\text{T}$, suggesting a current of up to $109 \pm 73 \text{ A}$ in the rail track. This results in a power output of up to $670 \pm 837 \text{ mW}$ and an energy output of $1138 \pm 1603 \text{ mJ}$ from the MFEH as each train passes. This energy output enables the MFEH to power a wide range of wireless sensors, offering a promising future for rail infrastructure health monitoring.



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sciforum-125852: Ultrasonic and RF Pulse Sensing Multi-modal Sensing Technology for Partial Discharge of Power Equipment

Guozhi Zhang

Hubei University of Technology

Long-term partial discharge insulation defects are likely to deteriorate into breakdown discharge, resulting in structural damage to power equipment and even deflagration accidents, affecting the reliability of power supply systems. Ultrasonic pulse and electromagnetic pulse are typical characteristic signals of partial discharge insulation defects in power equipment. Due to the complex process of partial discharge, affected by the insulation material itself and the environment, the intensity of ultrasonic pulse and electromagnetic pulse characteristic signals generated by different partial discharge defects is different, which leads to the common ultrasonic sensors and RF antenna sensors having different sensitivities to different types of partial discharge insulation defects in power equipment. Based on this, the team proposed a single multi-modal sensing technology with the sensing function of the ultrasonic pulse and RF pulse at the same time, and designed and optimized the multi-modal sensor according to the main frequency energy characteristics of the ultrasonic pulse and RF pulse radiated by power equipment partial discharge defects. Through simulation and experimental verification, the multi-modal sensor realized the effective sensing of ultrasonic pulse and electromagnetic wave pulse of power equipment partial discharge insulation defects. In addition, the propagation speed of ultrasonic waves is at the kilometer per second level, while the speed of electromagnetic waves is close to the speed of light. By using multi-modal sensors, the RF pulse signal will be detected first, followed by the ultrasonic pulse signal after a certain time delay. Based on this time difference, the location of the partial discharge source can be determined, providing additional information for the hazard assessment of insulation defects in power equipment due to partial discharge.



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Session 18. Flexible, Stretchable and Wearable Sensors

sciforum-119656: A Machine Learning-Based Knee Brace System for Walking Gait Analysis

Shang Liu, Lei Shi * and Kean Chin Aw

University of Auckland, Department of Mechanical and Mechatronics Engineering

This research proposes a knee brace system based on flexible capacitive stretching sensors for real-time monitoring of knee joint angle changes and dynamic characteristics of calf and thigh muscle activity. This system combines flexible sensors and basic machine learning models, which can efficiently distinguish different gaits. It has important application value, especially in rehabilitation training and motion evaluation. Compared with traditional electromyography (EMG) monitoring technology, the capacitive sensor used in this study has advantages such as non-invasiveness, comfortable wearing, and adaptability to real environments. It can overcome the problems of weak electrode attachment and limited applicability, providing a new solution for gait monitoring. The designed capacitive sensor is based on the principle of parallel plate capacitor, using Ecoflex™ and mixed carbon black as conductive materials and Ecoflex™ as a flexible substrate, which can be produced at low cost through mould casting and curing process. Three sensors are integrated into the knee brace, located at the rectus femoris muscle of the thigh, the centre of the knee, and the gastrocnemius muscle of the calf, creating a lightweight and comfortable wearing system. The system can accurately capture knee joint motion and muscle activity signals and perform gait classification analysis through a multi-layer perceptron (MLP) model. The experiment showed that the system achieved a classification accuracy of 99.3% on the test set and an accuracy of 80% on unseen samples, verifying its efficiency and potential in gait recognition.



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sciforum-125562: Deformation/Fracture Behavior and Electromechanical Response of Metal Films

Kai Wu

Xi'an Jiaotong University

Metallic thin films are critical functional components (e.g., electrodes, conductors, and sensing layers) in flexible electronics, where their deformation/fracture behavior and electromechanical reliability dictate device performance and operational durability. However, the inherent mechanical mismatch between metallic films and polymer substrates often leads to premature fracture and electrical failure at low strains, resulting in fundamental trade-offs: conductivity versus stretchability and sensitivity versus stretchability. To address these challenges, (i) we proposed an in-plane crack control strategy for engineering hierarchical microstructures to achieve an outstanding electromechanical performance via harnessing the strain distribution in metal films. The wrinkles delay crack initiation at the undercuts, and the protrusions/grooves inhibit crack propagation via effective strain redistribution. Hierarchical microstructures significantly improve the cyclic stability due to the strong interfacial adhesion and stable crack patterns. (ii) We also proposed an out-of-plane crack control strategy to ensure a strain-insensitive electrical performance in thin-film-based conductors, enabled by film-induced substrate cracking and liquid-metal-induced electrical self-repairing; (iii) we proposed a strategy for constructing coherent gradient nanolayers to achieve an ultra-high fatigue resistance. The grain/phase boundary constraints, controlled grain coarsening, and the mitigation of interface stress concentrations prevent localized damage accumulation, postponing fatigue crack initiation. The moderate interface adhesion and multiaxial stress state induced by the gradient structure promote interface delamination and crack deflection, inhibiting fatigue crack propagation. (iv) We proposed a facile, low-cost, and spontaneous strategy that incorporated topological gradients into metal-film-based strain sensors, composed of intrinsic (grain size and interface) and extrinsic (film thickness and wrinkle) microstructures. The topological-gradient strain sensor exhibits an ultra-wide stretchability of 100% while simultaneously maintaining an ultra-high sensitivity of 1.4×10^6 at an optimal topological gradient of 4.5, due to the topological-gradient-induced multistage film cracking. These findings provide new insights for next-generation, flexible electronic systems.



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sciforum-121940: Design, Manufacturing, and Applications of Carbon Nanomaterial-Based Physical Sensors

Jungwook Choi

School of Mechanical Engineering, Chung-Ang University

Soft devices with mechanical flexibility and stretchability serve as fundamental components for a wide range of emerging applications, including wearable electronics, soft robotics, and human-machine interfaces. Among the various materials investigated for soft device fabrication, carbon nanomaterials such as carbon nanotubes and graphene have garnered significant attention due to their exceptional electrical, mechanical, and chemical properties. This talk will introduce recent advances in the development of deformable physical sensors, with a particular focus on the strategic integration of multidimensional and hybrid carbon nanomaterials to enhance the device performance and address existing limitations in sensitivity, stretchability, and mechanical toughness. Furthermore, this talk will highlight the design principles and scalable fabrication methods for high-performance strain and pressure sensors capable of real-time monitoring of the mechanical changes in energy storage systems. These sensors offer a promising solution for ensuring operational safety and reliability by providing early detection of mechanical stress or failure in batteries and related devices. The methodologies and material strategies discussed in this presentation are not limited to energy applications but are also extendable to a broader class of sensing systems. This work aims to contribute to the advancement of next-generation flexible and stretchable sensor technologies through material innovation, engineering design, and manufacturing processes.



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sciforum-121807: Electret-based Wearable Pressure Sensor for Human Pulse and Blood Pressure Monitoring

Yiming Li, Jia Lu * and Yingyu Zhou

Harbin Institute of Technology

Regular monitoring of the human pulse and blood pressure is crucial for the early diagnosis of cardiovascular diseases (CVDs). However, current clinical monitoring devices are often bulky and complex, while emerging wearable pressure or pulse sensors primarily rely on pulse transit time (PTT) algorithms, which necessitate multiple devices for accurate measurements. In this study, we have proposed an innovative electret-based wearable pressure sensor that utilizes a charged dielectric material to measure the human pulse. By incorporating a cross-shaped polymer gap spacer that effectively suppresses electret contact discharge, the sensor achieves an impressively low elastic modulus of 12.04 kPa, comparable to that of human skin (5.1–13.3 kPa), a high sensitivity of 3.86 V kPa^{-1} , an extremely low detection limit of only 3.8 Pa, and an ultra-short response time of merely 20 ms. Furthermore, we have developed a comprehensive real-time monitoring system for human pulse and blood pressure. This system integrates the proposed sensor with a signal processing circuit, a Bluetooth transmission module, a blood pressure estimation algorithm based on pulse waveform feature extraction, and a user-friendly interface for data visualization. Preliminary measurements of blood pressure using our system show good consistency with readings obtained from a commercial OMRON wrist-type blood pressure sensor. These results highlight the system's significant potential for wearable health monitoring applications, particularly in the early diagnosis of cardiovascular diseases.



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sciforum-124072: Self-Adhesive Electronic Skin with Bio-inspired 3D Architecture for Mechanical Stimuli Monitoring and Human-machine Interactions

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The recent development of wearable devices is revolutionizing artificial electronic skins (E-skin), physiological health monitoring and human-machine interactions (HMI). However, the challenge of fitting flexible electronic devices to the human skin with conformal deformation and identifiable electrical feedback, according to mechanical stimuli, remains ongoing. Herein, we developed an adhesive E-skin that can firmly attach to human skin to identify mechanical stimuli. The laser-induced adhesive layer serves as the essential component that ensures the conformal attachment of E-skin on a curved surface, which ensures accurate conversion from mechanical deformation to precise electrical readouts. The optimized E-skin with bio-inspired micro-cilia exhibited significantly improved sensing performances with sensitivity of 0.652 kPa^{-1} in $0\sim 4 \text{ kPa}$ and a gauge factor of 8.13 for strain ($0\sim 15\%$) with robustness. The traditional non-adhesive sensor obviously detached from the human skin, while the adhesive E-skin could firmly adhere to the skin's surface. Furthermore, due to the excellent conformability of the adhesive E-skins, the adhesive E-skin could distinguish inward/outward joint bending in non-overlapping behaviors, allowing the establishment of a ternary system to expand the communication capacity for logic outputs such as effective Morse code and intelligent control. We expect that the adhesive E-skin could serve as a functional bridge between human and electrical terminals for applications from daily mechanical monitoring to efficient HMI.



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sciforum-122603: Three Synchronized, Miniaturized, Wireless IMU Sensors for Automated Gait and Balance Analysis System

Min Ho Seo

Pusan National University

Gait and balance analysis are essential for diagnosing a wide range of diseases and for monitoring overall health, playing a critical role in various fields such as neurology, orthopedics, geriatrics, and rehabilitation medicine. These assessments help clinicians understand motor function impairments, predict fall risks, and design appropriate treatment or intervention strategies. However, traditional gait and balance assessment methods often rely on subjective clinical observations or require the use of bulky, expensive, and often inaccessible motion capture systems. These limitations make routine and widespread assessments challenging, particularly outside of specialized clinical environments. Recent advances have focused on wearable motion sensors, but many of these solutions involve the use of numerous (typically seven or more) sensors attached to multiple body parts, which can be inconvenient, time-consuming to set up, and uncomfortable for users. In this study, we propose a compact and user-friendly system for gait and balance analysis that utilizes only three miniaturized, synchronized wireless inertial measurement units (IMUs). These IMUs, comprising Bluetooth Low Energy microcontrollers and 6-axis sensors, are strategically placed on the sternum and the metatarsal bones of both feet. This minimal configuration allows for the accurate extraction of various gait parameters, including gait cycle, intensity, swing phase, stance phase, initial double support (IDS), and terminal double support (TDS). To demonstrate the system's potential in balance assessment, we implemented it for automated evaluation of the Berg Balance Scale (BBS). Using gait data from 50 individuals and a Random Forest machine learning algorithm, we developed a predictive model that achieved over 80% accuracy in estimating BBS scores, indicating strong promise for practical clinical applications.



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sciforum-121781: Wearable triboelectric sensors and their output enhancement

Xianjie Pu

Chongqing University

Silicone, due to its flexibility, skin-friendliness, and ease of processing, is an excellent material for fabricating flexible triboelectric sensors. Here, we present several triboelectric sensors based on silicone which are designed for neck motion detection, finger-worn texture recognition, and keyboard-based music performance. These involve measurements of bending curvature, surface texture, and pressure, respectively. For these wearable sensors, the influence of human body potential and environmental noise is significant. To address this, a flexible shielding layer was developed using carbon-doped silicone, which effectively suppressed interference and improved the signal-to-noise ratio. Practical application interfaces and outcomes were demonstrated through backend programs and algorithms. To further enhance the performance of the triboelectric sensors, we explored the introduction of a self-excitation strategy. This strategy was demonstrated using a tin-can telephone system, which has been used to represent triboelectric sensors with lower output performance. The designed triboelectric sensor can detect mechanical waves and convert them into electrical signals without external power sources, while the self-charge excitation triboelectric nanogenerator (SCE-TENG) is integrated to improve the sensitivity of the receiver. After charge pumping, the average output of the triboelectric sensor can increase by 88 times within the frequency range of 0–1000 Hz, indicating the successful application of self-charge excitation (SCE) in triboelectric sensing for the first time.



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sciforum-135134: A fully-integrated stretchable device platform for swallowing disorder

Hongcheng Xu * and Xueyong Wei

Xi'an Jiaotong University

Post-surgical treatments of the human throat and various diseases often require continuous monitoring of diverse vital and muscle activities. However, wireless, continuous monitoring and analysis of these activities directly from the (throat) skin still retain elusive. Here, we report the design and validation of a fully integrated standalone stretchable device platform that provides wireless measurements and cloud analysis of diverse vibrations and muscle electrical activities from the suprasternal throat. The modified composite hydrogel with low contact impedance and reduced adhesion provides high-quality long-term monitoring of local muscle electrical signals. The integrated triaxial broad-band accelerometer also measures large body movements and subtle physiological activities/vibrations. The platform integrates the interfacial low-impedance gel electrodes, three-axis acceleration sensor, and signal acquisition/processing/wireless communication circuits into an ultra-soft patch. It can be attached to the human larynx to achieve the in-situ acquisition across wide range submental signals, from swallowing, coughing, drink, heartbeat to respiration, etc. To help automatically evaluate the post-surgical rehabilitative condition, a CNN-based 2D-like sequential feature extractor (2D-SFE) is explored to classify and infer pathological status based on the classification of physiological events. The measured data from 13 general signatures/states during laryngeal activities processed by a 2D-like sequential feature extractor based on the CNN can be classified with a high accuracy of 98.2%. In addition, the custom-built interface to process the data on the cloud opens up new opportunities for remote diagnosis and treatment evaluation.



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sciforum-119822: A Sheet-type image sensor

Tomoyuki Yokota

The University of Tokyo

We have developed a sheet-type image sensor that enables high-resolution and high-speed reading. This sheet-type image sensor can take high-resolution images of fingerprints and veins to be used for biometric authentication. In addition, the same sheet-type image sensor can measure the pulse wave, which is one of the vital signs, and its distribution. The developed sheet-type image sensor was fabricated by densely integrating a high-efficiency readout circuit using an active matrix of a low-temperature polysilicon thin-film transistor and a photodetector that uses a highly efficient organic semiconductor as a photosensitive layer. The resolution of the image sensor achieves 508 dots per inch (dpi) required for fingerprint authentication, and the organic photodetector consists of a bulk hetero structure organic layer which has a high photosensitivity to near-infrared light with a wavelength of 850 nanometers (external quantum efficiency of 50% or more). It is easy to integrate the sheet-type image sensor into equipment and attach it to curved surfaces due to the thickness of the polymer base material being 10 micrometers, and the total thickness of the sheet-type image sensor is 15 micrometers.

Evaluation of vein and fingerprint images taken by this sheet-type image sensor showed that the contrast difference of the veins was less than 5% compared to images using a general CMOS image sensor. We confirmed that the conformable image sensor has a high image quality equivalent to that of conventional CMOS image sensors. Since the sheet-type image sensor is thin and bendable, it can easily be integrated into wearable devices, and it is possible to measure health condition and perform biometric authentication at the same time.



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sciforum-126732: A wearable non-contact radar sensor with DC offset canceling for vital-sign sensing

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This paper presents a vital-sign radar equipped with digital-assisted calibration to enhance the signal quality by eliminating the DC offset. In recent years, healthcare and long-term physiological monitoring have gained significant attention due to the increasing demand for continuous and non-invasive health assessments. The traditional contact-based measurement methods, which require multiple signal lines to be attached to a subject's body, are gradually being replaced by non-contact devices. These advanced systems offer greater convenience and comfort, especially for elderly individuals or patients requiring prolonged observation. However, wireless detection techniques are often affected by signal degradation and RF transmission loss, which can compromise the measurement accuracy. To address these challenges, this work focuses on improving vital-sign detection by leveraging digital signal processing techniques to clearly capture the heart rate and the respiration rate. The received signals undergo extensive filtering and processing to enhance the overall signal-to-noise ratio (SNR), ensuring high precision. The analog signals are digitized using a 16-bit analog-to-digital converter (ADC), enabling more accurate data representation. The extracted data can then be transmitted in real time to various display devices, such as personal computers or mobile phones, via a Bluetooth wireless communication interface. The proposed sensing radar system enables immediate, non-contact, long-term, and continuous monitoring, making it highly suitable for healthcare applications. Furthermore, the presence of the DC offset, which can severely degrade the signal integrity, is effectively mitigated through a calibrated digital processing algorithm. This correction ensures the accuracy and reliability of the detected physiological parameters. The experimental results confirm that the proposed technique successfully detects and monitors vital signs.



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sciforum-122081: Additive Manufacturing of Porous Structure for Flexible Sensors and Multi-objective Optimization using Taguchi-based GRA

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This paper designs a flexible sensor with a porous structure for achieving higher sensitivity, fabricated by additive manufacturing technology. Five types of structures (Tetrahedral, Voronoi, Rhombic, Kagome, and Icosahedral) and three types of Rockwell hardness material were employed to make different porous structures for comparison. Both Young's modulus and sensitivity were assessed to obtain the optimal porous structure using multi-objective optimization with Taguchi-based GRA. The experimental design was carried out using the Taguchi orthogonal table L9 after preliminary experiments for the best three structures. Different porous structures, Rockwell hardnesses, wire diameters, and thicknesses were used as the parameters of the orthogonal table for structural printing. The Young's modulus, sensitivity, and porosity of each printed sample were evaluated, with multi-objective Gray relational analysis. The best parameter combination was obtained to give a Young's modulus closer to human skin and a porous structure with higher sensitivity. Finally, the effectiveness of Taguchi Gray relational test with the best combination was confirmed. Three designed patterns for evaluating the effect of a flexible sensor pad include bi-directional strip type(A), multi-directional cross type (B), and scattering type (C). From the experimental results, the optimal porous structure for sensitivity testing was matched with the application requirement. In practical applications, the scattered pattern (C) exhibited the highest sensitivity for the gripping cylinder-shape object, and the cross pattern (B) exhibited the highest sensitivity for gripping the sphere-shape object.



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sciforum-122291: All-inorganic nanoribbon yarns for wearable transducers

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The advancement of all-inorganic nanoribbon yarns is revolutionizing wearable transducer technologies by integrating energy storage, sensing, and thermoelectric energy harvesting into a single, flexible platform. These yarns, fabricated using nanoimprinting and physical vapor deposition, exhibit exceptional mechanical resilience, high surface-area-to-volume ratios, and tunable electrical and thermoelectric properties. Transition metal oxide (TMO)-based nanoribbon yarns have been successfully implemented in fiber supercapacitors, offering high energy/power densities and long-term stability, making them ideal for energy storage in wearable electronics. Additionally, these yarns demonstrate high sensitivity in gas and pressure sensors, broadening their application in environmental monitoring and biomedical devices. Furthermore, all-inorganic thermoelectric yarns composed of Bi_2Te_3 nanoribbons enable efficient waste heat harvesting, providing a new avenue for self-powered wearable systems. These thermoelectric yarns maintain excellent mechanical flexibility, withstanding extreme bending and stretching conditions while maintaining electrical stability. Beyond their standalone functionalities, the nanoribbon yarns can be seamlessly integrated into various textiles through weaving or embroidery, allowing for large-area, distributed sensing and power generation. Their fully inorganic nature ensures their long-term reliability under harsh environmental conditions, including humidity, temperature variations, and mechanical fatigue. By integrating energy harvesting, storage, and transduction functionalities, all-inorganic nanoribbon yarns offer a scalable and versatile solution for next-generation self-powered smart textiles and bio-integrated electronics. Their unique material properties and structural adaptability pave the way for high-performance, autonomous wearable systems in health monitoring, soft robotics, and sustainable energy applications.



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sciforum-125269: Artificial skin for accurate measurement of pressure and vibration

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Soft artificial skin with sensing functions can convert stimuli in the environment, such as pressure and vibration, into electrical signals. This technology has attracted widespread attention in many fields such as robotics and healthcare. A key challenge in this field is that flexible sensors composed of viscoelastic materials often fail to accurately measure steady-state or dynamic pressure due to the creep and hysteresis effects of soft materials. Other factors, such as sensor interfaces that experience contact and disengagement, may slow down the sensor's response by consuming energy. Here, we focus on material-structure-interface-performance correlations of soft ionic materials and demonstrate ionic skin using low creep and low hysteresis polyion liquids. Pressure and vibration can be measured accurately, with low signal drift or hysteresis. We also show that bonding interfaces, preferably with microstructures, can effectively speed up responses because microstructures can restore and release strain energy, while bonding interfaces consume very little energy. As a result, under high constant loads of hundreds of kilopa, our sensors show negligible signal drifts or respond to high-frequency vibrations up to 10k Hz. This ionic electronic skin may provide high-fidelity data for applications in humanoid robotic tactile and human physiological signal collection. The bonding interface consumes very little energy. Therefore, under high constant loads of hundreds of kilowatts, our sensors can display negligible signal drifts or respond to high-frequency vibrations up to 10k Hz. This ionic electronic skin can provide high-fidelity data for applications in humanoid robots' tactile sense and human physiological signal collection. The bonding interface consumes very little energy. Therefore, under high constant loads of hundreds of kilowatts, our sensors can display negligible signal drifts or respond to high-frequency vibrations up to 10k Hz. This ionic electronic skin can provide high-fidelity data for applications in humanoid robots' tactile sense and human physiological signal collection.



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sciforum-126058: Bioinspired Hierarchical Soft Materials for Sensing Under Mechanical Stress

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Hydrogels have emerged as highly promising materials for applications in diverse fields, such as biomedicine, energy storage, soft robotics, and flexible electronics, owing to their soft, tissue-like mechanical properties, high water content, and tunable chemistry. Despite their advantages, a major limitation hindering their broader practical application is their relatively low mechanical strength, typically below 1 MPa, which makes them prone to damage or failure under external stress. This is particularly problematic in dynamic or mechanically demanding environments, such as wearable or implantable devices, where mechanical robustness is essential. Furthermore, the integration of multiple functional features—such as high sensitivity to stimuli, reliable self-healing capability, and strong tissue adhesion—into a single hydrogel system remains a significant challenge.

In this talk, we take inspiration from the hierarchical structures commonly found in natural materials and introduce several design strategies to address these limitations. These include self-assembly-induced bridge cross-linking to reinforce the hydrogel network, self-assembly-assisted stretch training to enhance toughness without compromising sensitivity, and the construction of semi-interpenetrating networks to improve skin adhesion and long-term stability. We also apply in situ fabrication strategies to better match the interface with biological tissues.

The resulting hydrogels exhibit excellent performance under complex mechanical stress. They enable practical applications such as motion sensing during sports and the stable acquisition of electrophysiological signals during deformation. These properties make them highly suitable for real-time physiological monitoring, including in situ, in vivo cardiac sensing under continuous mechanical load.



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sciforum-127390: Elastic Nanoparticle-Reinforced, Conductive Structural Color Hydrogel with Superior Stretchability, Self-Adhesion, and Self-Healing as an Electrical/Optical Dual-responsive Visual Electronic Skin

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Developing smart hydrogels with excellent physicochemical properties and multiple signal output capabilities for interactive electronic skins still remains challenging. Here, a conductive structural color hydrogel with desirable physicochemical properties (including high stretchability and robustness, self-adhesion, and self-healing) was developed to provide synchronous electronic and visual color signals for e-skins. Highly charged elastic nanoparticles were elaborately used as building units for structural color, and the hydrogel was prepared by the self-assembly of the nanoparticles to form a non-close-packed array in a mixture composed of acrylamide, silkworm silk fiber (SF) proteins, and reduced graphene oxide (rGO), followed by photopolymerization. Benefiting from an improved interfacial compatibility between the flexible hydrogel network and the elastic nanoparticles, a covalent cross-linking network structure, and synergistic multiple non-covalent bonding interactions, the hydrogel exhibits extraordinary mechanical properties, excellent self-adhesion to diverse substrates, and self-healing at room temperature. In addition, the hydrogel exhibits sensitive resistance changes and synchronous structural color changes under strain. As a proof-of-concept, the hydrogel displayed superior capability for color response and electrical signal response to various human motions, the spatial distribution of external mechanical stimuli, and the identification of different external stimuli, indicating promising applications in the fields of interactive visual electronic skins, wearable devices, and advanced human-machine interfaces.



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sciforum-121963: Electronic skins for continuous health monitoring

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One limitation of commercial wearables, such as smartwatches and fitness bands, is their inability to establish conformable contact with human skin due to their rigid form factors, which restrict their monitoring capabilities. In contrast, soft bioelectronics offer a promising platform for personalized health care, thanks to their unique attributes, including thinness, lightweight design, excellent biocompatibility, mechanical robustness, and superior skin conformability. Permeable, skin-mountable electronics designed for long-term use have emerged as powerful tools for early disease prevention, screening, diagnosis, and treatment. Dr. Wang's research primarily focuses on the development of unconventional soft materials for advanced electronic skins. In today's presentation, Dr. Wang will discuss high-performance electronic skins created using intrinsically stretchable materials, such as nanomeshes and hydrogels, for continuous health monitoring. These innovations enable precise measurement of various electrophysiological signals without compromising comfort, accuracy, or stability, supporting long-term health monitoring applications. By integrating these materials, her group is overcoming previous limitations and enhancing device adherence to complex body contours. Moreover, these developments pave the way for real-time data collection and remote diagnostics, significantly improving patient outcomes and preventive care strategies. The interdisciplinary approach combines materials science, engineering, and biomedical research, fostering next-generation health monitoring solutions that adapt to the human body.



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sciforum-121062: Flexible and Wearable Magnetized Interface

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The development of IoT indicates that human beings are playing an essential role in interacting and exchanging information with our surroundings. Sensors that can record and transmit multiple physiological human signals in real time facilitate our interaction with the complex environment and promote the healthy development of our society. Recently, wearable sensors have been indicated as a key technology with promising applications, including the human--machine interface and health monitoring. Herein, we will introduce our recent studies and achievements on the coupling of magnetism into flexible and wearable systems. We will mainly focus on how magnetism can help to facilitate mechanical sensing, information exchange, and mechanical--electrical conversion. For example, an interface that can perceive finger sweeping direction, flexible microcilia for topology perception, and a sensor that can significantly increase memory capacity will be introduced. In particular, the eigenfrequency-dominant methodology will be introduced, which includes FFT analysis for signal conversion from the time-to-frequency domain. The working mechanism and optimization principle of magnetism coupled with flexible devices will be discussed in detail.

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sciforum-121677: Flexible Sensors for Food Processing and Food Disgestion Monitoring

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Flexible sensors have attracted great attention because of their important applications in many areas. It is important to monitor food processing because it can provide key information related to the appearance, texture level, and chewiness of the food. However, there is no report on real-time monitoring of the surface of steamed bread in the literature. Here, we report self-adhesive and stretchable compliant sensors that can provide real-time signals for the steaming process. The sensors consisting of biocompatible poly(3,4-ethylenedioxythiophene): polystyrenesulfonate (PEDOT:PSS) blends can be fabricated by solution processing. Its resistance varies with the shape and volume of the dough and thus can be monitored in a real-time manner.

In addition, to monitor the gastric digestive function is important for the diagnosis of gastric disorders and drug development. However, there is no report on the in situ and real-time monitoring of digestive functions. Herein, we report flexible fully organic sensors to effectively monitor protein digestion in situ in a simulated gastric environment for the first time. The sensors are made of a blend of gluten that is a protein and PEDOT:PSS. During the protein digestion, the breakdown of the polypeptides increases the level of separation among the PEDOT chains, thereby increasing the resistance. The resistance variation is sensitive to various conditions, including the concentration of pepsin that is the enzyme for protein digestion, temperature, pH value, and digestive drugs. Hence, these sensors can provide real-time information about the digestion and efficacy of digestive drugs.

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sciforum-124262: Harnessing built-in electric fields for enhanced electron transfer in biosensor for precise digital health assessment

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The development of highly sensitive sweat sensors for real-time biomarker monitoring is critical for advancing noninvasive and precise digital health assessment. However, this progress is often hindered by the low efficiency of electron transfer between the catalyst and the conductive electrode matrix, which leads to the limitation of sensitivity and detection precision. To address this challenge, we propose using a built-in electric field within the sensor to enhance electron transport, thereby significantly improving the sensing performance. H_2PtCl_6 was doped into a poly(3,4-ethylenedioxythiophene)/poly(styrene sulfonic acid) (PEDOT:PSS) solution under thermal conditions, initiating a redox reaction. As a result, H_2PtCl_6 was reduced to catalytic PtCl_2 nanoparticles carrying negative charges, while PEDOT was oxidized to generate additional positive charges, i.e., hole carriers, and the conductivity was improved. This process facilitated the formation of a molecular electric field, which accelerated electron transport from the catalysts to the conductive PEDOT chains. The built-in electric field transformed the sensor from being non-responsive to highly sensitive to H_2O_2 , a crucial intermediate product in numerous enzyme-based biosensors, with robust stability. The resulting PEDOT:PSS electrode demonstrated an extraordinary 208-fold increase in conductivity, reaching 162.4 S/cm^2 with PtCl_2 nanoparticle loading exceeding 10 wt%. When further modified with various enzymes through chemical crosslinking, the sensor demonstrated exceptional performance in glucose and uric acid detection, with sensitivities of 132.7 and $393.5 \mu\text{A mM}^{-1} \text{ cm}^{-2}$, respectively. This advancement enables the accurate and real-time monitoring of glucose and uric acid fluctuations in human sweat, paving the way for the development of more effective noninvasive health assessment technologies.



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sciforum-121882: Jellyfish-like Gold Nanowires as FlexoSERS Sensors for Sweat Analysis

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We introduce the FlexoSERS sensor, a novel wearable sensing platform distinguished by its exceptional stretchability, high sensitivity, and customizable patterns. This sensor features a hierarchically oriented jellyfish-like architecture constructed from stretchable gold nanowires, which enables an ultrasensitive surface-enhanced Raman scattering (SERS) signal even under 50% mechanical strain, achieving an impressive enhancement factor (EF) of 3.3×10^{10} . Remarkably, this high-performance sensing capability remains stable and reproducible over 2,500 stretch-release cycles, demonstrating its robustness for long-term applications. The seamless integration of nanowires with a 3D-printed hydrogel matrix not only facilitates a highly flexible and adaptable design but also enables efficient localized sweat collection and real-time biochemical analysis. This innovative platform successfully detects and quantifies uric acid (UA) in both artificial and human sweat with high sensitivity and selectivity. Furthermore, it functions as a reliable pH sensor, providing repeatable and accurate measurements across a pH range of 4.2–7.8, making it highly suitable for continuous sweat monitoring during physical activity. The synergistic combination of stretchable nanowires and hydrogel ensures both mechanical adaptability and a stable sensing interface, enhancing usability in dynamic conditions. In summary, the rational architectural design, scalable fabrication process, and efficient hydrogel integration collectively position this nanowire-based FlexoSERS sensor as a highly promising and customizable platform for wearable sweat diagnostics, offering new opportunities for non-invasive health monitoring, real-time biomarker detection, and personalized medicine.



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sciforum-121691: Machine-Learning-Assisted Gel-based Flexible Sensors and Human–Machine Interaction

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Flexible electronics are assuming an increasingly vital role in human health monitoring and healthcare diagnostics. Gel materials, renowned for their flexibility and sensitivity, have found widespread application in wearable sensing. Leveraging their unique properties, gel-based sensors exhibit responsiveness to chemical and physical stimuli, enabling the conversion of physiological activity signals into detectable electronic signals. This capability holds significant promise for applications ranging from flexible electronic skin to human-machine interaction and. This report highlights the development of gel-based flexible sensors tailored for human-machine interaction applications under the assistance of machine learning. First, as a sensor, the gel must have excellent mechanical properties. We have systematically expounded its tensile, compression and fatigue resistance. Second, the sensing properties of the gel must be sensitive and stable, including stretchable sensor and compressive sensor. Thirdly, combined with machine learning, the role of gel sensors in human-machine interaction is studied, with an accuracy rate above 90%. Finally, because the gel as a sensor needs an external power supply, which is inconvenient to use, the gel can be made into thermoelectricity or triboelectricity, which can avoid the problem of external power supply. All of the above ensures that the gel as a flexible sensor can be better applied to intelligent control, temperature detection, action correction, and so on.



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sciforum-119444: Micro/nano-enabled wearable/flexible sensors for smart healthcare and medical applications

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Smart healthcare technology and wearable sensors are revolutionizing modern patient care by enabling continuous, real-time monitoring of physiological parameters. These advancements support the early detection of potential health issues and empower individuals with actionable health insights, promoting preventative care and personalized treatment strategies. Central to this transformation is the integration of smart materials and micro/nanostructured sensors, which enhance the sensitivity, responsiveness, and reliability of healthcare interventions. This talk presents recent developments in micro/nanostructure-based wearable sensors for smart healthcare applications, with a focus on innovations from our research group. We introduce self-powered, highly stretchable strain sensors based on mechanical metamaterials, designed for monitoring physical activity and exercise. Additionally, we discuss porous elastomer-carbon nanotube (CNT) composite sensors capable of detecting a wide dynamic range of pressures, ideal for wrist pulse, motion, and posture tracking. We further explore biomimetic 3D-structured pressure sensors that maintain linearity over a large range and a tree-root-inspired interface that achieves ultra-high stretchability and mechanical robustness for hybrid electronics. A micro/nano-hierarchical structure-based sensor system for wristbands is presented as a tool for preventing carpal tunnel syndrome (CTS). Lastly, we highlight wireless, battery-free sensors using near field communication (NFC) technology for pressure, temperature, and humidity monitoring in clinical settings—enabling early prevention of pressure injuries in patients. Together, these smart, wearable sensing platforms demonstrate the potential for improving healthcare delivery and outcomes through real-time, non-invasive, and personalized monitoring.



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sciforum-122303: Multilayered Bio-Adhesive Architectures for Sensor Interfaces: Reversible Skin Attachment and Structured Suction Layers

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The development of next-generation soft electronic interfaces requires robust, reversible integration with dynamic and deformable biological surfaces. Inspired by the hierarchical adhesive strategies observed in natural organisms such as octopus suckers and tree frog toe pads, we introduce a multilayered bio-adhesive architecture that enables reliable and skin-conformal attachment for sensor platforms. This system combines a low-modulus, reversible polymer interface with precisely engineered suction-based microstructures, allowing for strong yet easily detachable adhesion to both flat and curved skin surfaces without the need for external adhesives or mechanical fixtures. Our platform supports seamless signal transmission even during continuous motion, owing to its intimate skin contact and pressure-distributing architecture. By leveraging a stacked structural design and controllable surface morphologies, we achieve tunable adhesive performance and enhanced sensor integration, including high-resolution pressure mapping and localized tactile feedback. Furthermore, the modularity of the layered architecture facilitates mechanical decoupling between functional sensor layers and the adhesive base, enabling long-term use, multi-functionality, and compatibility with soft robotic systems and wearable electronics. This presentation will detail the material design, fabrication processes, and system-level performance evaluation, and will outline how such biologically inspired hierarchical architectures open new directions in advanced electronic skin development, wearable haptic interfaces, and human-interactive devices.



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sciforum-121686: Regulating Anti-Freezing Properties of Gels by Adjusting Polymer Monomer Ratios for Object Recognition using Flexible Sensors

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Hydrogels face significant challenges due to freezing in cold environments, which disrupts their mechanical integrity and conductivity, limiting their utility in flexible electronics and low-temperature applications. This study proposes a novel method to develop an anti-freezing gel by strategically regulating the ratio of polymer monomers in a dimethyl sulfoxide (DMSO)/water binary solvent system, effectively addressing the challenges of hydrogel freezing in cold environments. Gels were synthesized via the free radical polymerization of acrylic acid (AA) and acrylamide (AM) in varying ratios while maintaining a fixed total monomer mass. The DMSO/water solvent (optimized at a 7:3 ratio) disrupted the water hydrogen bond network to suppress ice crystallization. Raman spectroscopy, low-field NMR, and density functional theory (DFT) analyses quantified the bound/free water content and hydrogen bonding interactions. The mechanical properties were evaluated via compression/tensile tests and rheological measurements. The electrical conductivity and sensing performance were assessed under extreme conditions (-80°C). An increasing AA concentration enhanced the polymer–water hydrogen bonding, elevating the bound water content (confirmed by Raman spectroscopy and NMR) and suppressing ice formation, achieving a freezing point below -80°C . The optimized gel (AA:AM=3:7, DMSO:H₂O=7:3) exhibited exceptional compressive resilience (80% strain at -80°C), stable adhesion to diverse substrates (wood, metal), and reliable conductivity at -20°C . As a strain sensor, it demonstrated a gauge factor of 1.66 under low strain and maintained a stable signal output over 1,000 compression cycles. Integrated into a mechanical clamp, the gel enabled precise object recognition in cold storage environments through deformation-to-digital signal conversion. This work presents a scalable strategy for designing anti-freezing gels by balancing monomer ratios and solvent interactions. The optimized gel combines mechanical durability (adaptability to -80°C), environmental stability, and sensing accuracy, making it a promising candidate for use in cold-chain logistics and low-temperature flexible electronics. This approach advances the development of robust, multifunctional materials for extreme-environment applications.



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sciforum-122996: Revisiting the “Stick-slip” Process via Magnetism-coupled Flexible Sensors with Bio-inspired Ridge Architecture

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The “stick-slip” phenomenon, observed when a human fingertip scans across a specific surface, is essential for perceiving interactions between the skin and the surface. Understanding this behavior is critical for bionic flexible systems, with applications ranging from advanced robotics to intelligent tactile sensors. However, it is often overlooked owing to the limitations to mimic the soft skin that can deform/recover tangentially with informative electrical feedback is help for revisiting “stick-slip” process. To overcome the above limitation, we proposed a sandwich-type device with deformable ridge-layer to analyze the characteristic of stick/slip states in the “stick-slip” process. Specifically, we observed that fast recovery of the sensing architecture was caused by dynamic slip phase that generates periodical signals based on principle of induction. Experimental results demonstrate that periods of the electrical pulses are dependent on factors such as inherent properties (e.g. modulus and geometry) and operational parameters (e.g. scanning speed and normal load), which is consistent with the theoretical model. Furthermore, we found that the transition between “stick-slip” and full slip could qualitatively reflect interfacial properties such as moisture, roughness, and topology. We anticipate that these results will deepen our understanding of “stick-slip” behavior when fingertip interacts with a surface, and provide guidance of flexible sensor design to enrich the biomimetic perceptions.



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sciforum-122089: Self-Powered Flexible Sensors Based on Chemo-Mechanical Energy Harvesting for Organ Motion Monitoring

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Self-powered flexible sensors are emerging as essential components in next-generation wearable electronics, personalized health monitoring, and soft robotic systems. These sensors eliminate the need for external power sources by harvesting mechanical energy from the environment or the human body. In particular, chemo-mechanical energy harvesters offer a highly effective approach for enabling such autonomous sensors, especially in immersed or biologically relevant environments such as oceans, rivers, and internal organs. In this study, we present a novel flexible and stretchable energy-generating electrode based on carbon nanotube (CNT) structures, designed to function as the active component of a self-powered mechanical sensor. The device includes a CNT-based working electrode, a platinum (Pt) mesh counter electrode, and an electrolyte. The CNT electrode demonstrates significant variation in electrochemical capacitance in response to mechanical deformation, enabling both energy harvesting and motion detection. To accommodate large strains and complex dynamic deformations, we engineered a layered CNT electrode incorporating randomly distributed microwrinkles. This design provides exceptional mechanical robustness and adaptability, supporting up to 200% strain while maintaining stable performance under stretching, twisting, and bending conditions. We validated the sensor's functionality in a simulated gastric environment, where the electrode reliably captured mechanical motions resembling those of internal organs. The generated electrical signals correlate directly with mechanical activity, demonstrating the feasibility of the system for implantable, biocompatible motion sensing applications. This work provides a versatile platform for integrating chemo-mechanical energy harvesting into flexible electronics, paving the way for battery-free sensors in biomedical and wearable systems requiring durability, and self-sustainability.



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sciforum-121736: Shear force-enabled liquid metal circuits with hierarchical embedded structure for paper electronics

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The seamless integration of deformable liquid metal (LM) conductors into recyclable paper is highly promising for developing flexible, breathable, and green electronics. However, the weak interfacial adhesion between paper substrates and LM significantly impedes efficient high-resolution patterning. In addition, the poor damage endurance of LM, a persistent challenge for on-surface conductors, restricts its practical applications. Herein, we report a simple yet efficient shear printing method that allows us to directly pattern hierarchically embedded LM circuits with erasure resistance onto various paper substrates, including printing paper, newspaper, and napkins. This process involves applying shear force to a solid gallium film to induce adhesive wear, embedding the gallium into the paper's microfiber network. In addition, pressure-induced microgrooves in the paper enable the surface embedding of LM circuits. Using the Archard wear equation, we optimized our printing parameters (e.g., temperature and load), achieving LM circuits with a minimum line width of 230 μm and a line spacing of 140 μm . The hierarchical embedded structure endows the LM circuits with enhanced mechanical damage endurance so that they can even withstand eraser rubbing and tape peeling. The LM-embedded paper also exhibits excellent electromechanical stability, permeability, biocompatibility, and recyclability. We further demonstrate the use of these LM-enabled paper electronics in contact/non-contact sensing, respiratory monitoring, electrophysiology, and digital droplet microfluidics. This work paves the way for sustainable, robust paper electronics leveraging the solid-state properties of low-melting-point metals.



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sciforum-127236: Skin-attachable next-generation wearable electronics

Sunghoon Lee

RIKEN

An ultimate goal of biological measurement is to monitor the states of a living body in a non-invasive, continuous, and accurate manner without disturbing the natural functions or activities of the living body. Because sensors in direct contact with biological tissues are inevitably exposed to physical disturbances caused by physical contact, considerable efforts have been made to minimize the effects of sensors. In temperature measurement, for example, it is preferable to reduce the heat capacity or thermal conductance of a sensor in order to suppress the effect of heat transfer from the object to the sensor. Furthermore, mechanical compliance with electronics is extremely important for biological objects. The skin is soft and has a three-dimensional structure. Flexible and/or stretchable sensors have been proposed to reduce the effects of modulus differences between the skin and the electronics.

In this talk, I will introduce skin-attachable nanomesh electronics to further improve biocompatibility by introducing an extremely soft, thin, and porous structure. They electrically functionalize the skin while allowing its inherent functionalities. The nanomesh electrode having sufficiently high gas-permeability can be attached to the skin without additional adhesives. It results in a continuous attachment to the skin for a week without any skin inflammation issues. Furthermore, the nanomesh pressure sensor enables the monitoring of finger manipulation without interfering with the inherent skin sensation, although the sensor is directly applied to the highly sensitive fingertip. Finally, we demonstrate the monitoring of skin deformation under mechanically harsh conditions, such as when the fingertip comes into contact with a ball during a pitching motion.



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sciforum-127085: Soft Electronic Packaging

Yanhao Yu

Southern University of Science and Technology

Soft packaging materials are the foundation for the large-scale application of various soft electronic devices, such as flexible sensors, implantable diagnostics, and stretchable displays. However, soft packaging system faces multidimensional challenges between mechanical deformation and packaging properties, including water and oxygen barrier, device integration, and material compositing. This presentation will introduce a class of stretchable packaging substrates that combine area-selective modulus design with strong interfacial adhesion, resolving the conflict between deformation and device integration, as well as material compositing. These substrates can mechanically match with various device units and universally adhere to organic and inorganic surfaces, therefore enabling stable integration of multiple device units under 600% tensile strain. It extends the in vivo operational lifespan of stretchable and self-powered sensors to over 10 weeks. Additionally, this substrate exhibits low water vapor transmission rates and can prolong the lifetime of hydrogels by orders of magnitude without altering their mechanical properties. This substrate derives an interfacial percolation network design, substantially lowering the conductive percolation thresholds for silver nanowires, liquid metals, and two-dimensional carbon materials. We further develop an interfacial compositing strategy based on this substrate to address the issue of reduced entropy elasticity in polymers caused by inorganic fillers, such as oxide particles, nanowires, and nanosheets.



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sciforum-120259: Soft, Skin-Conformal Multifunctional Microfluidic Platforms for Precise Monitoring of Sweat Biomarkers and Temperature

Jungil Choi * and Sekar Madhu

Ajou University

Wearable sweat sensors provide a non-invasive means for continuous health monitoring by detecting key biomarkers in real time. This study introduces a multifunctional, fabric-based, skin-mounted microfluidic system designed for electrochemical pH monitoring and colorimetric chloride estimation in sweat. The integrated pH sensor, utilizing electrodeposited polyaniline (PANI) on carbon cloth, exhibits high sensitivity (75.15 mV/pH) within a pH range of 2–9, closely following Nernstian behavior. The sensor demonstrates excellent repeatability, selectivity for target ions, and mechanical flexibility, ensuring reliable performance during movement. Additionally, the sweat chloride concentration is measured through image processing, covering a broad linear range of 10–125 mM with a detection limit of 8.3 mM. A miniaturized circuit module wirelessly transmits data to a smartphone, allowing for the real-time tracking of the sweat pH, chloride levels, local sweat loss, and skin temperature. The system integrates a soft microfluidic network that efficiently collects, stores, and transports sweat for analysis, ensuring precise measurements. Human trials conducted on volunteers during physical activity confirmed the system's accuracy, showing a strong correlation with conventional lab-based measurements. This technology enables real-time monitoring without requiring specialized laboratory equipment, making it highly practical for applications in personalized healthcare, sports performance assessment, and clinical diagnostics. The sustainable, non-invasive nature of this device offers a promising solution for continuous physiological monitoring, providing valuable insights into the wearer's hydration status, electrolyte balance, and overall health. The combination of electrochemical sensing, microfluidics, and wireless connectivity paves the way for the next generation of wearable biosensing platforms, enhancing the accessibility to real-time health data in both clinical and everyday settings.



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sciforum-127179: Synergistic Interface Integration in Multi-Layered Systems for a Resilient and Adaptive Electronic Skin

Junlong Yang

Sichuan University

Flexible electronic skin represents a foundational frontier technology in wearable intelligent systems. It functions by transducing external stimuli—such as a human pulse, electromyographic signals, and motion—into electrical or chemical signals, thereby enabling the acquisition and analysis of physiological data for health monitoring and evaluation. This technology holds significant promise for application in early cardiovascular disease diagnosis, rehabilitation medicine, and intelligent robotic manipulation. Conventional electronic skins typically adopt multi-layered, multi-material architectures. Due to substantial mismatches in the mechanical properties—with mismatches often exceeding five orders of magnitude in Young's modulus—among functional layers and the frequent use of simple stacking assembly methods, these devices suffer from heterogeneous compositions and weak interfacial adhesion. As a result, they are prone to interfacial delamination under complex mechanical loads, leading to signal distortion or even device failure. To overcome these limitations, we developed a multifunctional polymer nanocomposite platform with tunable electrical and mechanical properties. In parallel, we introduced an interface fusion strategy based on the regulation of polymer aggregation states at interfaces, effectively addressing the compatibility issues arising from multi-material integration. This presentation will first outline the fundamental principles of flexible pressure sensing, followed by recent advances made by our team in developing high-sensitivity, long-lifetime tactile sensing systems using integrated design strategies. These systems' potential applications in gait monitoring, pulse signal visualization, and intelligent robotic gripping will also be discussed.



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sciforum-125683: Textile-Based Temperature Sensing for Smart Wearable Heating Systems

Rawat Jaisutti

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Textile-based electric heaters have attracted attention for their potential applications in comfortable personal thermal management. In this work, flexible temperature sensors were developed for measuring and controlling the temperature generated by wearable electric heaters. The sensor was fabricated by dip-coating cotton yarn in poly(3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT:PSS) solution, followed by encapsulation with polystyrene (PS). The surface morphology observed using scanning electron microscopy indicates a uniform distribution of PEDOT:PSS on the cotton yarn surface. The electrical resistance, measured using two probe configurations, was approximately 10 k Ω /cm. For temperature test, the results show that the sensing resistance decreases approximately linearly as the temperature increases within the range of 30–60 °C. The PS encapsulation layer provides moisture resistance for the sensor by exhibiting a more hydrophobic surface than that of the pristine PEDOT:PSS-coated yarn. Additionally, the sensor exhibits high electrical resistance stability during stretching–releasing cycles, maintaining performance for up to 1000 cycles. By integrating with a textile-based electric heater, prepared using silver nanowires and PEDOT:PSS coated on cotton yarn, the sensor demonstrated the capability to measure the temperature from the heater and send signals to a controller for temperature adjustment. These results highlight the challenges of using fully conductive yarn based on PEDOT:PSS for smart wearable electric heaters and temperature control systems.



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sciforum-125237: Topological Gradients for Metal Film-Based Strain Sensors

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Metal film-based stretchable strain sensors are promising for applications requiring a precise balance among sensitivity, stretchability, and stability. However, their implementation is limited by two key issues: a trade-off between sensitivity, typically enhanced by crack formation, and stretchability, which is governed by film continuity; and mechanical mismatch at the metal-elastomer interface, which leads to delamination and fatigue under cyclic loading.

To address these challenges, we propose an extremely facile, low-cost and spontaneous strategy that incorporates topological gradients in metal film-based strain sensors, composed of intrinsic (grain size and interface) and extrinsic (film thickness and wrinkle) microstructures. The topological gradient strain sensor exhibits an ultrawide stretchability of 100% while simultaneously maintaining a high sensitivity at an optimal topological gradient of 4.5, due to the topological gradients induced multistage film cracking. Additionally, it possesses a decent cyclic stability for >10000 cycles between 0 and 40% strain enabled by the gradient-mixed metal/elastomer interfaces.

These results demonstrate the sensor's strong applicability in full-range human activity monitoring, from subtle physiological signals to large-scale joint movements. Beyond its excellent mechanical performance, the proposed strategy is simple, low-cost, and material-independent, offering broad compatibility with various metal and polymer systems. This work opens a promising pathway for the scalable design of next-generation metal film-based stretchable strain sensors for advanced wearable electronics.



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sciforum-121549: Tough and strong soft materials for flexible electronics

Wei Zhai

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Nature's composite systems, such as collagen-based tissues, bamboo, and nacre, exemplify how complex hierarchical structures and synergistic material integration can result in extraordinary combinations of strength, toughness, and functionality. These biological materials are often composed of relatively weak constituents, yet through sophisticated multiscale organization, from molecular arrangements to microscale architectures, they achieve mechanical properties that rival or exceed those of synthetic materials. For instance, collagen fibrils in tendons are aligned to resist tensile loads, bamboo combines stiff fibers with softer matrix regions to balance rigidity and flexibility, and nacre's brick-and-mortar layering of aragonite platelets and organic polymers yields both strength and impact resistance. These examples demonstrate that architecture, not just composition, plays a central role in material performance. Drawing inspiration from such natural paradigms, we present a versatile materials design framework for engineering soft, yet mechanically robust hydrogel-based systems specifically suited for flexible electronics. Using freeze-casting-assisted solution substitution, we developed organo-hydrogels with tendon-inspired architectures that integrate molecular interactions, nanoscale fibril alignment, and microscale organization, validated through multiscale simulations. Bamboo-inspired nanofiber-reinforced hydrogels were created using a bottom-up assembly strategy to replicate the balance of strength and flexibility observed in fibrous natural composites. Nacre-inspired ceramic-reinforced organo-hydrogels were fabricated using direct-ink-write 3D printing, where shear-induced alignment of ceramic platelets formed layered architectures with tunable mechanical performance and conductivity. By integrating nature's design principles with advanced processing techniques, these hydrogel systems open new possibilities for the scalable development of materials in flexible electronics, robotics, and biomedical devices.



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sciforum-125329: Ultra-Thin Stretchable Multifunctional Wearable Sensor for On-Skin Smart Healthcare Monitoring

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Introduction

Flexible and stretchable multifunctional sensors are crucial for the next generation of wearable electronics, especially in the field of precise physiological health monitoring. However, the integration of multiple sensing functions—such as strain, temperature, and electrocardiogram (ECG) detection—into a single platform without signal interference remains a major challenge.

Method and Result

In this study, we developed a multifunctional sensor based on a composite of MXene ($\text{Ti}_3\text{C}_2\text{T}_x$) and 3,4-ethylenedioxythiophene (EDOT) deposited on laser-induced graphene (LIG). The composite material (LIG/MXene- $\text{Ti}_3\text{C}_2\text{T}_x$ @EDOT) was integrated via in-situ electrophoretic deposition (EPD), enabling uniform and stable coverage on the LIG surface. The sensing layer was encapsulated in an ultrathin, highly resilient polystyrene-block-poly(ethylene-ran-butylene)-block-polystyrene (SEBS) substrate for enhanced mechanical flexibility. The resulting sensor demonstrated a high strain sensitivity with a gauge factor of 2,075, a temperature coefficient of resistance (TCR) of 0.86%, and low skin-contact impedance for ECG monitoring. The platform enabled simultaneous detection of human strain, temperature, and ECG signals without mutual interference. These features were validated through on-body demonstrations involving real-time monitoring of joint movement, body temperature, and ECG waveforms.

Conclusions

This multifunctional sensor platform offers a promising solution for next-generation smart healthcare devices. By combining high sensitivity, mechanical durability, and multi-signal detection capability in a single integrated system, it advances the development of wearable smart skins and personalized health monitoring technologies.



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sciforum-122149: WAND v2: Seamless Indoor And Outdoor Navigation Using GPS and IMU Data Fusion

Bismark Kweku Asiedu Asante * and Hiroki Imamura

Soka University

Accurate and seamless navigation across both indoor and outdoor environments remains a persistent challenge for wearable systems designed to assist visually impaired individuals. This difficulty primarily stems from the inherent limitations of the Global Positioning System (GPS) in indoor settings and the cumulative drift associated with Inertial Measurement Units (IMUs) during extended use. To address these challenges, this research proposes a novel GPS-IMU data fusion framework that enables reliable, real-time navigation by dynamically adapting to environmental contexts. The system intelligently detects transitions between indoor and outdoor environments and seamlessly switches between GPS-dominant tracking for outdoor navigation and IMU-based dead reckoning indoors. At its core lies a hybrid sensor fusion algorithm that combines an Extended Kalman Filter (EKF) with contextual environment recognition, thereby compensating for GPS signal loss indoors and correcting IMU drift over time. This dual-mode approach ensures consistent localization accuracy and robust performance in varied and dynamic environments. The proposed navigation solution builds upon a previously developed prototype that employed a Jetson microcontroller and stereo camera system for localization. The new design significantly enhances the system by incorporating more compact hardware, improved power efficiency, and intelligent sensor coordination. The resulting wearable platform is well-suited for a wide range of applications, including smart mobility, autonomous navigation, and assistive guidance for visually impaired users, offering a more seamless and dependable navigation experience.



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sciforum-122077: Wearable Biosensor Patches for Digital Healthcare and Medical Applications

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This talk introduces bio-patch sensor technology as a key component for implementing digital healthcare and IoT in medicine. It covers various biosensor technologies for measuring physiological and biochemical signals in the human body, including continuous glucose monitoring sensors based on microneedles and low-dimensional nanomaterials; hybrid skin patch sensors for non-invasive sweat-based glucose, electrocardiogram, and various electrolyte ions monitoring; multi-sensor patches capable of measuring pulse, gait, and body temperature; pressure sensor patches utilizing hybrid ion nanofiber polymer membranes for real-time monitoring of various physiological and physical signals such as pulse, respiration, voice, and touch; and smart skin patches for chronic wound monitoring using seven biomarkers, including glucose, lactate, uric acid, electrolytes (Na⁺, K⁺), pH, and temperature. The skin patch can enable the in-situ quantification of multiple biomarkers of chronic wound infection. An SU-8-based microfluidic channel with arrowhead micropatterns is formed directly on the sensor via the lithography process. The integration of passive microfluidics into the skin patch for use in wound fluid sampling exhibits considerable potential for application in determining the real-time status of the wound environment. The microfluidic system utilizes microchannels to efficiently collect and continuously deliver the wound fluid to a sensor chamber, enabling the in-situ detection of biomarkers with an improved temporal resolution. These technologies hold significant potential for applications in metabolic syndrome and chronic disease management, as well as in digital healthcare and the medical industry through real-time bio-signal monitoring.



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sciforum-125492: Wearable Flexible Sensing Devices and Applications

Ting Zhang

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Smart wearable flexible sensing devices are important core components of information systems in the post-Moore's Law era., involving interdisciplinary research fields such as sensitive electronics, materials science, mechanics, micro/nano fabrication technologies, and artificial intelligence. It is of great scientific significance to develop new materials, principles, and innovative designing methods for wearable flexible sensing devices, and to realize the application of these devices in the fields of intelligent robotics, wearable devices, and brain-computer interfaces, etc. In this talk, I will present our recent progress in developing smart wearable, attachable, and implantable flexible sensing devices. These sensing devices include multi-modal flexible biomimetic tactile sensors, novel flexible sweat sensor based on microfluidics and the hydrovoltaic effect, and highly biocompatible flexible neural electrodes and brain-computer interface sensors. The innovative designs of the flexible biomimetic sensitization structures and sensor devices to achieve high-sensitivity, high-stability real-time detection of the tactile information, biochemical signals, and Electroencephalogram/Electromyography (EEG/EMG) signals will be discussed. The discussion will extend to the integration of wearable intelligent systems and their applications in humanoid robots/prosthetic hands, smart healthcare, smart sports and other fields. The challenges and opportunities in the engineering and applications of smart flexible sensing devices will also be discussed.



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Session 19. Wearable AI Sensors

sciforum-134279: A Strain-Insensitive and Multifunctional Triboelectric Fiber Based on Liquid Metal and Silver Nanowires Synergic Network

Huiyun Zhang * and Qiongfang Shi

Southeast University

In recent years, wearable sensors have garnered widespread attention from academia and industry. Serving as critical interfaces between the Internet of Things (IoT) and the human body, these sensors drive revolutionary advancements in health monitoring, motion tracking, and medical diagnostics. Among various technological paradigms, triboelectric sensors (TESs)—based on the coupling effects of contact electrification and electrostatic induction—stand out due to their unique self-powered capabilities. Despite extensive studies on TESs, limited work has focused on the relationship between electrode properties and electrical output, particularly for fiber electrodes with inherently small diameters that often suffer from instability and performance degradation during bending and stretching. Herein, this study examines the correlation between electrical conductivity and triboelectric output of fibrous electrodes under dynamic tensile strains, and proposes the successful development of a strain-insensitive triboelectric fiber. Specifically, the fiber features a synergistic network of thermoplastic polyurethane (TPU), liquid metal (LM), and silver nanowires (Ag NWs), fabricated via scalable wet-spinning. Leveraging LM's intrinsic fluidity, high conductivity, and biocompatibility as the primary conductive phase, Ag NWs are strategically incorporated to address the activation challenges of conventional LM-based electrodes. Through capillary-driven LM activation and mechanically reinforced network stability, the composite fiber can be easily activated by light stretching and achieve stable conductivity across 740% strain. Furthermore, utilizing the trapping effect and dielectric enhancement synergistically provided by LM and Ag NWs, this work overcomes the charge density limitations inherent in conventional fibrous triboelectric sensors—which stem from their intrinsically small contact areas—thereby achieving significantly enhanced triboelectric output. Building on its exceptional performance, the fiber demonstrates multifunctional applications, including strain-insensitive self-powered sensing, energy harvesting, Joule heating, and electromagnetic interference shielding. The advancements establish a paradigm for strain-robust, multifunctional triboelectric fiber sensors, addressing critical limitations in fibrous wearable TESs and flexible electronics.



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sciforum-121189: A stretchable, self-assembled Janus structured electronic skin for gesture recognition in deep learning

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Electronic skin (e-skin) as the key component for device functionality and signal readout can be applied to various types of flexible devices such as resistors, capacitors, piezoelectrics, and triboelectrics. E-skin transitions from flexible to stretchable modality to accommodate rapidly evolving demands in wearable electronics and more complex application scenarios. Liquid metal (LM) is considered as a good material for stretchable electrodes. However, the high surface tension of LM greatly restricts it from forming a stable structure with other materials. Moreover, stretchable electrodes prepared by LM have long preparation cycles, complex technology, and low long-term stability. Here, inspired by human skin, we report a Janus-structured stretchable e-skin (JSE-skin) that can spontaneously and rapidly form using a phase separation technology. The Janus structure aggregates LM on one side and TPU on the other, providing high stretchable and high conductivity for the entire JSS film. The JSE-skin has high conductivity (10^6 S/m), high stretchability (260%), fast preparation time (15 s), ultra-thin thickness (50–1000 μm), good resistance stability (stretching, folding, and rotation states), as well as excellent cuttable, transferable, recyclable, reconfigurable, and biocompatible property. Furthermore, the JSE-skin successfully achieves effective acquisition of physiological electrical signals, triboelectric signals, and mechanical sensing signals, when applies as standalone devices and integrated electrodes for electrophysiological signal recording, energy harvesting, and wearable sensing. With its high performance and broad adaptability, the proposed JSE-skin is expected to significantly promote the practical applications of flexible and stretchable devices in industrial and consumer electronics.



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sciforum-121279: Fiber-based tactile sensor for intelligent human-machine interaction

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With the rapid development of intelligent technology, human-machine interfaces, as an important bridge connecting human and machine intelligence, are undergoing a revolutionary change. E-textiles are attracting attention due to their unique advantages. By combining functional electronic devices with textiles, e-textiles not only retain the inherent softness, comfort and wearability of textiles but also endow traditional textiles with the functions of sensing, responding and interacting. Among them, fiber-based sensors, as the core sensing elements of e-textiles, can achieve the sensitive detection of various external stimuli, such as pressure, strain, temperature, etc., which provides a new realization path for human-machine interaction. This study focuses on the development of a high-performance fiber-based pressure sensor aimed at providing a more accurate and reliable sensing unit for human-machine interaction interfaces. The sensor is designed with structure and material to significantly enhance its pressure sensing performance while maintaining the flexibility and comfort of the fiber. Further, the fiber-based pressure sensor is integrated with signal acquisition, processing and wireless transmission modules to construct a complete intelligent e-textile interaction system. The system is able to monitor and parse the pressure signals generated by human body movements in real time and convert them into control commands. In order to verify its practical application potential, the interaction control capability in a virtual reality environment is demonstrated. The smart e-textile system provides a new idea and technical support for the development of future human-machine interaction interfaces.



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sciforum-129535: Metaverse-Enabled Yoga Coach Avatar Using Multimodal Insole Sensing System

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Foot is a vital body part that supports human movement, by discovering gait abnormalities and analyzing plantar pressure, early disease detection, health assessment, human activity detection can be realized. Existing insole systems have been developed for health assessment and motion recognition, but show limited focus on posture correction, exercise intensity assessment, training feedback, and performance optimization. Herein, we proposed an AI-driven virtual yoga coaching system that integrates a multifunctional smart insole, a metaverse-based virtual coaching avatar, and haptic feedback to deliver immersive, real-time posture correction and personalized training guidance. The system is based on a self-powered multimodal insole sensing platform, utilizing polyvinyl alcohol (PVA)/ polyacrylamide (PAAm)/ lithium chloride (LiCl)/ glycerol (Gly) ionic hydrogel. This platform integrates a 32-channel hydrogel-based sensor array for plantar pressure, temperature, and sweat monitoring, and embedded vibrators for localized haptic feedback. By leveraging Internet of Things (IoT) module and machine learning algorithms, the system performs yoga posture classification and evaluates imbalance levels during prolonged posture holding. Beyond conventional recognition tasks, we propose a multi-user adaptive yoga coaching framework capable of identifying individual users and adapting personalized feedback. In addition, haptic feedback is provided through vibration while incorrect pressure distribution is detected. A metaverse-enabled yoga coach avatar is built within an augmented reality (AR)/virtual reality (VR) environment, where the avatar interacts with the user to offer personalized coaching and corrections based on the sensor data. An AI-enhanced yoga training paradigm is established, integrating multimodal sensing, multi-user yoga coaching, and haptic feedback into an immersive yoga training ecosystem. Our smart insole system effectively bridges the physical and virtual domains, enhancing user experience and the effectiveness of yoga guidance.



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sciforum-129483: Transfer learning enhanced lip language interface for silent speech recognition

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Lip language decoding has gained significant attention due to its privacy-preserving nature, resilience to acoustic noise, and potential applications in assisting individuals with speech impairments. Existing lip language recognition systems, commonly known as silent speech interfaces (SSIs), face challenges in real-world deployment due to limitations in robustness, generalizability, and real-time decoding efficiency. Here, we propose a flexible lip language interface with multimodal sensory for silent speech recognition and emotional detection that uses transfer learning enhanced lip language decoding approach to rapidly adapt to new users using limited training data. Compared to traditional deep learning approaches, transfer learning drastically reduces the requirements for large-scale individual datasets and enables real-time adaptation to new users, making it ideal for practical deployment in wearable systems. Our approach enables rapid model adaptation while achieving a recognition accuracy of over 85%, ensuring more reliable and personalized lip language decoding for different individuals. To build our system, we use a hybrid method for interfacing flexible sensing electrodes and custom-designed printed circuit boards (PCBs) with the wireless communication functionality. The custom-designed flexible printed circuit boards (FPCBs) are capable of simultaneously acquiring lip muscle activity through the sensing array and capturing facial movements via embedded inertial sensors (accelerometers and gyroscopes), which expands our system to realize the interference-free lip motion tracking and facial expression recognition. Additionally, our system is extended beyond lip language communication to encompass user emotion regulation and immersive virtual interactions. Our work presents a promising approach to significantly improving comprehensive SSI in VR/ mixed reality (MR) applications, demonstrating the potential for developing a fully portable, multifunctional lip language interface and feedback-based HMI for metaverse applications.



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Session 20. AI-Enhanced Tactile Sensors and e-Skin

sciforum-133642: Bio-inspired tactile sensor integrated with dexterous robotic hand for object grasping

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Tactile sensing is essential for human when grasping and manipulating objects in daily life. Similarly, service robots rely on tactile sensors to estimate the grasping force magnitude, contact location and force direction when grasping objects in order to improve objects manipulation safety. However, the current robotic tactile sensing solution have serious limitations regarding to simplicity, sensitivity, robustness, and bulkiness.

Integration of tactile sensors and robotic hands is still not common in current service robots. We develop a biomimetic tactile sensing hardware, GTac, which can estimate task-essential contact information, i.e. contact force and force direction, and easily integrated for robotic hands. GTac adopts multilayer structure consisting of separate layers for intrinsic tri-axis force sensing and dense extrinsic normal force sensing to mimic the functions of SA-II and FA-I tactile afferent in human skin.

Based on the novel tactile sensor, we develop an anthropomorphic robotic hand to equip GTac at fingertips and palm. Since anthropomorphic hand has a natural adaptability to human daily environment, GTac at fingertips and palm such contact-rich positions can perceive essential contact information for grasping, in-hand manipulation, etc. In Total, the robotic hand can perceive 285 tactile signals.

In this talk, we will introduce the design and fabrication of the sensor and demonstrate the sensing and grasping capability of the robotic hand and gripper and discuss about its future applications.



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sciforum-125086: Capacitive Tactile Sensors: Morphological Engineering and Applications

Quanyi Cheng

Lanzhou University

Capacitive tactile sensors are widely noted for their simple structure, temperature independence, and wide applicability, but developing sensors involves several performance considerations. This work gives a review on capacitive tactile sensors based on morphological engineering. Capacitive sensors have many structures, including devices with single-layer structures and multilayer structures. There are two types of single-layer structures, namely uniform-distribution structures and random-distribution structures, which have the advantages of a relatively simple design and processing, fast response speeds, and high sensitivity to low pressures. However, due to their single-layer characteristics, they also suffer from poor linearity and low compressibility saturation, resulting in a lower linear pressure detection range, which is not conducive to high-pressure detection. Multilayer structures can be divided into two types: interlocking and stacking. Although they partially solve the linear sensitivity problem within a wide pressure detection range, they still have significant limitations in expanding the pressure detection range. In addition, 3D porous structures have many advantages, especially in terms of their compressibility saturation and lightweight properties. However, they also face challenges such as insensitivity for detecting small pressures and limited structural strength. Fiber network structures have significant advantages in their breathability, contact areas, and large-scale manufacturing (low cost) but face challenges in terms of accuracy, long-term stability, and compressibility saturation. The layered structure has many significant advantages due to its complex integrated structure characteristics, but it also faces some limitations, including complex manufacturing and packaging processes, poor consistency and repeatability, and interface incompatibility. Fabrication technologies, including template transfer, electrospinning, magnetic-assisted, and solution synthesis technologies, are used to create these structures. The abovementioned sensors find applications in advanced intelligent systems, such as tactile sensing array systems, human-machine interaction systems, and intelligent perception systems.



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sciforum-121276: Deep Learning-Assisted Triboelectric Smart Mats for Comprehensive Personnel Monitoring for Maritime Safety

Yan Wang

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Monitoring the crew of a ship can be done by combining sensors and artificial intelligence methods to process sensing data. In this study, we developed a deep learning-assisted minimalist-structure triboelectric smart mat system for obtaining abundant crew information without the privacy concerns of taking videos. The smart mat system is fabricated using a conductive sponge with different filling rates and a fluorinated ethylene propylene (FEP) membrane. The proposed dual-channel measurement method improves the stability of the generated signal. Comprehensive crew and cargo monitoring including personnel and status identification, as well as positioning and counting functions, are realized by the deep learning-assisted triboelectric smart mat system according to the analysis of instant sensory data. The designed dedicated signal noise reduction circuit improves the signal-to-noise ratio, which is helpful for subsequent signal feature extraction and signal processing based on deep learning. The data feature extraction and processing method based on deep learning improves the ability to identify the identity and status of crew members. The real-time monitoring of crews through fixed and mobile devices improves the ability and efficiency of handling emergencies. The smart mat system reduces privacy concerns and is an effective way to build a ship-based Internet of Things (IoT) and to ensure personnel safety.



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sciforum-125663: Edge-AI Enhanced Multimodal Tactile Glove with In-Sensor Computing

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Tactile sensors play a key role in enhancing human–robot interaction, enabling robotic systems to collaborate with humans more efficiently and effectively. Traditionally, tactile sensing research has required the use of data acquisition cards to collect large volumes of raw data, which are subsequently processed by high-performance computing processors. However, such systems often face challenges including bulky size, reduced real-time performance, high system complexity, and elevated power consumption.

In this work, we present a neuromorphic tactile glove that addresses challenges by achieving low power consumption, high integration, edge-computing and compact form-factor. This sensory glove uses an in-sensor computing tactile array that leverages the multimodal perception capabilities and signal output of a hydrogel sensing material. Furthermore, we incorporate edge computing techniques to deploy embedded neural networks on a microcontroller unit (MCU), enabling low-latency interpretation of sensor signals. Through the synergy of in-sensor computing and edge processing, the total data volume is significantly reduced from 4.8 MB to 0.24 MB, and the energy consumption for data processing is reduced from 10 $\mu\text{J/bit}$ to 100 nJ/bit. The output terminals of sensory data are reduced from 40 channels to 2 channels while maintaining classification accuracy.

In experimental evaluations, the tactile glove successfully distinguishes between 12 different objects with an accuracy exceeding 90%. With low power consumption and strong flexibility, this edge-AI enhanced neuromorphic tactile glove is ideal for integration into intelligent robotics and wearable human–machine interfaces.



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sciforum-121831: Flexible tactile devices and intelligent systems

Jun Wu

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Flexible tactile devices and intelligent systems play a pivotal role in advancing human-machine interaction, medical robotics, and next-generation wearable technologies by bridging the gap between physical touch and digital intelligence. This presentation systematically outlines our research trajectory in flexible tactile devices and intelligent systems, progressing through three evolutionary phases: monomodal sensing, multimodal sensing, and AI-integrated intelligent systems.

In the monomodal phase, we focused on achieving high-performance tactile sensors, encompassing bioinspired structural design, micro/nano material selection, interfacial structure modulation, and molecular-level material engineering. These efforts yielded sensors with enhanced sensitivity, durability, and adaptability to complex environments. Subsequently, we advanced to multimodal tactile sensing by integrating sensor arrays to achieve super-attribute perception. This phase emphasized decoupling strategies to resolve signal interference across modalities while expanding the diversity of tactile sensing modes. Recently, driven by the demand for system-level intelligence, our work has shifted toward integrated and AI-enhanced tactile systems. We developed robotic multidimensional force sensing systems, explored embodied intelligence frameworks based on tactile semantics, and investigated natural emotional intelligence based on affective touch.

In the future, we aim to deepen the convergence of flexible tactile devices with AI-driven architectures, emphasizing scalable system integration, real-time adaptive learning, and applications in robotics and augmented reality.



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sciforum-125036: Hybrid Wearable Device Based on Integrated Pressure Sensing and Visualization

Yang Li

Shandong University

Through the preparation of two functional gels by a light-curing process and the effective reuse of their color-changing layer and electrodes, this study has successfully developed a wearable hybrid device that integrates precise pressure detection and visualization, while maintaining high transparency. Thanks to its microstructured pressure-sensing design, the device has an excellent pressure-sensing performance in terms of its sensitivity, LOD, response time, and durability. Meanwhile, in terms of electrochromics, the device has the advantages of a low driving voltage, large transmittance modulation, and strong cycling stability. This comprehensive performance allows the device not only to achieve real-time and accurate quantitative analyses during pressure monitoring, but also to present different states in a qualitative manner by means of visual signals. Based on these two advantages, the concealment and identification of visual information by the color-changing device are first verified, and then an advanced QR code encryption system is designed. This system cleverly combines color-changing pattern technology and information encryption technology, aiming to protect information through double encryption. In addition, human physiological monitoring is achieved by sensing the pressure at different locations of the human body and visualizing this information with a PSE; during the monitoring process, the device does not affect its observations of the skin's state. Finally, a smart wireless wristband system consisting of a hybrid device, a SoC, and a customized wristband is developed for monitoring physiological parameters. The pressure signals collected by the system can be displayed on both a mobile phone and the PSE, so as to reflect the different states of the wearer. This research provides a simple and generally applicable approach to a “one-stone-two-birds” hybrid device for the visualization of pressure sensing and color changes, and the overall effectiveness of the integrated system provides new ideas for intelligence technology.



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sciforum-122126: Optical Force Sensing for Precision Epidural Injections

Gichan Cho, Jintaek Im and Cheol Song *

DGIST

Accurate needle placement is crucial for the safety and effectiveness of epidural procedures. Traditional techniques such as the loss-of-resistance (LOR) method can be inconsistent, particularly in patients with narrowed epidural spaces, while fluoroscopic imaging exposes healthcare professionals to radiation. To address these challenges, this study introduces a novel epidural needle system incorporating an optical-interferometry-based force sensor to enhance the precision and safety. The proposed system integrates a fiber-optic force sensor into a commercially available epidural needle and employs a robotic injection mechanism powered by a piezoelectric actuator for controlled insertion. A graphical user interface (GUI) provides real-time feedback by detecting puncture points through force variations. Additionally, an adaptive time-delay control algorithm compensates for unpredictable disturbances, ensuring stable and accurate needle placement. To validate the system's performance, an experimental study was conducted using a porcine spine model. The results demonstrated that the system successfully detected epidural punctures with an average accuracy over 70%. Furthermore, an injection algorithm operating in two distinct modes—force-locking and puncture detection—ensured precise needle positioning within the epidural space. By integrating optical interferometry with robotic-assisted injection, this study represents a significant advancement in epidural procedures, reducing the reliance on radiation-based imaging while improving procedural accuracy. These findings highlight the potential for enhanced patient safety and procedural efficiency. Future developments may focus on refining the system's sensitivity, expanding clinical testing, and adapting the technology to broader applications in pain management and anesthesia.



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Session 21. Haptic Technology and Applications

sciforum-124230: Wearable robotic haptic feedback technologies

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Haptic feedback technology represents a cutting-edge research focus in the field of immersive human-machine interaction. By delivering physical stimuli such as force and vibration, haptic feedback enables users to perceive objects in virtual or remote environments, fundamentally determining the realism and immersion of natural human-machine interaction. Achieving high-fidelity haptic feedback and interaction requires addressing three key challenges: haptic actuation must reach skin physiological-level resolution; actuation encoding must align with skin perceptual characteristics; and haptic interaction must achieve precise force-temporal alignment. To tackle these challenges, we conducted research in the field of haptic feedback and achieved results in three key aspects. Firstly, we established an electromagnetic resonance model for haptic actuators and developed a miniaturized unit design approach, achieving high-resolution (5mm) haptic stimulation on skin surfaces. Secondly, we proposed a resonant frequency modulation method for actuators and investigated regional response variations to haptic stimulation across different body areas, achieving skin-adaptive haptic actuation. Finally, we created a self-sensing actuator design and invented a touch intercom system using the same device, successfully constructing a bidirectional haptic communication channel with precise force-temporal alignment, thereby building a haptic IoT platform that enables interactive communication between multiple haptic interfaces. This series of haptic feedback research achievements provides crucial technical support for immersive human-machine interaction.



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sciforum-127367: Developing advanced human-machine mechanical interfaces

Yuan Ma

Department of Mechanical Engineering, The Hong Kong Polytechnic University

Over the last several decades, human-machine interactions have been limited to vision and audio channels. The introduction of haptics technologies has enabled users to receive mechanical feedbacks in the form of virtual touch. While the rapidly advancing haptics technologies in wearable devices and surface haptic devices have enabled many exciting applications in virtual reality (VR), augmented reality (AR), telecommunication, and teleoperation, they still suffer from issues in bulkiness, comfortability, and consistency. The solutions to these issues lie in the fundamental understanding of the multi-physics interactions in the human-machine interface, which include contact deformation, capillary formation, electric field, heat transfer, material non-linearity, and their complicated coupling effects. In this talk, Dr. Ma will discuss models on the multi-physics interactions in human-machine interface, with a special emphasis on modeling the finger friction variation on textured surfaces. This talk will also include how the multi-physics models have been applied in developing new wearable sensors, actuators, and surface haptics devices. The discussed models lay the foundation to develop haptics artificial materials (metamaterials) that can deliver any desired haptics performances for the next generation of human-machine mechanical interfaces. This talk will also discuss the urgent need of visually impaired population and how haptic technologies may help.



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sciforum-125236: Origami-Based Structures for Multimodal Soft Actuation and High-Fidelity Haptics

Zhuang Zhang

Fudan University

Unlike conventional rigid robots, soft robots have gained significant attention in the robotics community due to their excellent human-robot interaction capabilities. However, achieving similar levels of multimodal, high-performance motion as rigid robots while maintaining the structural compliance of soft robots remains a huge challenge, which is also one of the key limitations preventing soft robots from industrial applications. At the same time, in the field of haptics, although substantial progress on various haptic devices has been made, these advances are mainly vibration-based passive devices generating sensations very different from what we experience in the natural world. Missing or inaccurate sensory perceptions fail to create an authentic immersive virtual reality that convincingly mimics the physical universe. In this talk, I will introduce design approaches for multimodal soft actuation from three perspectives: how to realize multiple motion modes and high output force with conventional pneumatic methods, how to achieve high positioning accuracy and stiffness tuning through antagonistic actuation, and how to leverage innovative origami structures to enable all-purpose motion modes. Finally, I will discuss the potential of combining origami structures and multimodal soft actuation to enrich haptic interactions in both the virtual world and the physical world, aiming to open new technical pathways in the field of human-robot interaction.



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sciforum-125682: Wide Bandwidth Tactile Sensing of Human and Embodied Intelligence

Yitian Shao

HITSZ

Touch is among the most important senses of humans to perceive and interact with their environment. Even simple touch interactions generate complex tactile signals in the tissues of the human body. Among these, broadband tactile signals propagate over long distances on the body surface in the form of mechanical waves, exhibiting a wide range and heterogeneous spatiotemporal distribution. This talk presents research investigating the dynamic tactile sensing of humans, including how such sensing mechanism permits an efficient encoding of touch information that minimizes the corresponding energy consumption, and how it can inspire novel designs of tactile sensing systems of wearable machines and robots. It introduces the physical principles that generate these tactile signals and the corresponding human tactile mechanisms, together with how to capture and reconstruct the signal distribution in real-time using a distributed wearable tactile sensor array, and how to decode rich tactile interaction information from these signals. It will also introduce tactile sensing systems inspired by human touch sensing mechanisms, explaining how it can imitate human-like multimodal tactile sensing together with its potential applications, including the usage in capturing tactile signals from robot touch and utilizing the signals to perceive the environment or for providing haptic feedback to human users.



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Session 22. Advanced Sensors for Robots and Autonomous Systems

sciforum-119994: Application of AI-Based Surrogate Models Utilizing FEA Data in Advanced Sensors for Unmanned Robots

Changmin Pyo * and Jisun Kim

Korea institute of industrial technology

Automation and unmanned systems are emerging as key trends across industries, including shipbuilding. This study focuses on an advanced sensor for the automation of block painting and welding in shipbuilding. Shipbuilding blocks are typically larger than 3m × 3m and feature complex geometries for structural stability. Multiscopic robots are being explored as a viable solution, accompanied by research on ensuring stable operation.

For stable operation, fault prediction through sensors is essential. However, conventional sensors have a limited range of measurable data, making their application challenging. In particular, acceleration motion, which is crucial for robotic arm movement, introduces dynamic loads that affect the robot's structural integrity. Currently, no technology exists to predict faults by assessing the impact of these dynamic loads.

To address this issue, we developed an AI-based surrogate model that predicts structural stability using 2,000 dynamic load cases. The surrogate model was constructed using a Deep Neural Network (DNN), which has been validated in other studies based on the Universal Approximation Theorem for its high accuracy and reliability. A dataset was created using FEA simulations to estimate stress based on acceleration data measurable by sensors. Specifically, the surrogate model was designed with acceleration data as the input and the maximum stress as the output.

To verify the model's validity, statistical metrics such as R^2 , RMSE, and MAE were used for evaluation, confirming an R^2 value exceeding 0.9 when tested on 200 independent test sets that were not used for training. Additionally, a system was developed to trigger an alarm when the predicted maximum stress exceeds the allowable strength considering the safety factor. This approach enables a novel fault detection system that conventional sensors cannot achieve.

Integrating this surrogate model into an AI-embedded sensor allows for the acquisition of multi-modal data, significantly improving predictive accuracy in fault detection.



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sciforum-121131: Advanced Sensing Algorithm for Slewing Bearings Using Multi-Feature Extraction and Self-Attention

Kyoung Su Park * and Jung-Woo Kim

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Slewing bearings are widely used in various mechanical industries, where they must support heavy loads while maintaining high rotational accuracy. To ensure reliability, continuous performance monitoring and early fault detection are essential. Recently, AI-based fault detection techniques combined with vibration sensors have shown promising results in improving sensing accuracy. However, variations in rotational speed and structural size limit their accuracy to the low 90% range. Since industrial applications require at least 95% accuracy, further advancements in sensing techniques are necessary.

In this study, we propose a fault detection method that enhances accuracy beyond 95% by leveraging a self-attention deep learning model and multi-feature extraction. An experimental setup using a slewing bearing was developed to validate the proposed method. A low-frequency accelerator was employed to measure vibration characteristics in both axial and radial directions. Fault detection was performed under different operating conditions at 5 RPM and 20 RPM, demonstrating that radial data can effectively verify axial data and vice versa. This cross-validation approach reduces reliance on multiple sensors while maintaining high accuracy. Experimental results indicate that even with a single-axis sensing dataset, our method accurately detects faults across varying RPM conditions. The proposed technique enhances fault detection efficiency, making it more practical for real-world industrial applications. These findings confirm that AI-driven sensing methods can significantly improve the reliability and performance monitoring of slewing bearings, providing a robust and efficient solution for predictive maintenance.



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sciforum-123206: Analyzing Camera Recognition under Simulated Visual Contamination with Real-World Validation

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Camera sensors are widely used in autonomous vehicles due to their cost-effectiveness and high-resolution capabilities. However, their recognition performance can degrade significantly under visual contamination, posing a challenge to safe perception.

This study proposes a simulation-based evaluation method to quantify camera recognition performance under various visual blockage scenarios. Using a virtual test drive toolkit, synthetic contaminants were overlaid onto camera input data, with four key factors analyzed: blockage concentration, blockage color, object type, and object color. Additionally, real-world tests were conducted under matched conditions to compare recognition performance across environments.

Among all tested variables, blockage concentration had the greatest impact on recognition accuracy, followed by object type, blockage color, and object color. Black-colored blockages showed better recognition performance than gray and yellow. The interaction between blockage color and object type also affected detection outcomes. Importantly, the recognition patterns observed in simulated environments closely aligned with those from real-world tests, validating the reliability of the simulation-based evaluation method.

This study presents a practical framework for assessing camera sensor performance under contaminated conditions, with potential applications in the training and validation of AI-based object recognition systems. By interfacing the virtual platform with real camera hardware, the proposed method enables standardized benchmarking across vendors. These findings offer valuable insights for improving perception robustness and optimizing camera cleaning strategies in autonomous driving systems.



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sciforum-121941: Cyber-Physical Systems with Edge Computing for Robotic Automation in Chemical Development

Chee-Kong Chui

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Edge computing has the potential to revolutionize the landscape of robotic automation in drug and fine chemical development by bringing computation closer to the source of data generation. This talk explores the integration of edge computing with robotic systems to enhance the efficiency, precision, and responsiveness of chemical synthesis and formulation processes. By decentralizing data processing, edge-enabled robots can analyze sensor inputs, adapt control strategies, and make real-time decisions without relying solely on cloud infrastructure. This capability is particularly critical in fine chemical manufacturing, where tight control over reaction conditions, safety, and product quality is essential.

We present an intelligent cyber-physical system framework that incorporates edge computing and AI-driven decision making, along with the deployment of intelligent edge nodes within robotic platforms. These nodes enable real-time sensing, autonomous operation, anomaly detection, and adaptive control, while also supporting advanced functions such as anomaly detection, preventive maintenance, and process optimization. Our approach facilitates efficient operation in dynamic lab and pilot-scale environments, where flexibility and responsiveness are key.

In addition to technical advancements, the talk addresses key challenges in system integration, cybersecurity, and scalability. We will also discuss how such edge-intelligent robotic systems can transform pharmaceutical R&D and specialty chemical production by accelerating innovation, reducing time-to-market, and promoting more sustainable and resource-efficient chemical processes.



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sciforum-122134: Human Presence Detection for Rescue Applications by Using Ultra-Wideband Radar and Deep Neural Networks: A Framework for Drone Integration

Juan Augusto Heins Herrera Ollachica * and Hiroki Imamura

Soka University of Japan

After an earthquake, many buildings are destroyed, and the number of collapsed structures increases, especially in countries without proper geophysical surveys. Furthermore, the death toll is often high in regions lacking disaster prevention strategies and effective search-and-rescue programs. Consequently, urban search-and-rescue (USAR) teams face significant challenges when attempting to locate survivors quickly under heavy rubble. This research focuses on detecting human body presence and estimating the breathing activity of people trapped under debris.

First, the millimetric movement of survivors' chests was measured using an ultra-wideband (UWB) radar. Then, a proposed algorithm acquired data corresponding to three respiration cycles. Clutter in the radar signal was suppressed using a moving average filter. A threshold was applied to enhance the signal-to-noise ratio (SNR) and generate clear images for training a deep neural network. A dataset of 680 images was created, including 370 representing human presence and 310 representing non-human presence. A convolutional neural network (CNN) based on the VGG16 architecture was trained using transfer learning to classify human presence behind a wall. Additionally, the Lomb-Scargle algorithm was implemented to estimate breathing frequency. Finally, the trained CNN model was evaluated and achieved a validation accuracy of 98.3% in detecting human presence through the wall.

This study demonstrates that UWB radar combined with deep learning techniques can be an effective tool for detecting survivors in post-disaster scenarios, providing valuable support for USAR teams and enabling future deployment on autonomous aerial platforms such as drones.



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sciforum-121784: Magnetically Gated Mechanosensing with Adaptive Sensitivity Enabled by Machine Learning

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Drawing inspiration from biological sensors that adapt to wide ranges of stimuli and prioritize the detection of relative changes rather than absolute values, we present a versatile mechanosensing approach with a dynamically tunable resolution. Conventional mechanosensors often struggle to distinguish subtle pressure changes across large stimulus spans, limiting their applicability in diverse environments. In contrast, our design leverages magnetic field (H) gating to control the formation of pillared assemblies composed of soft, ferromagnetic, electrically conductive particles between planar electrodes. By applying a voltage bias, resistive sensing captures the pressure-induced changes in these H-responsive pillars.

A key advantage of this approach lies in its ability to modulate the mechanical sensitivity: stronger magnetic fields enhance the sensor's resolution but also introduce scatter due to increased structural jamming among the colloidal particles. To optimize performance, we employed machine learning methods to identify the optimal H gating strategies that balance the resolution with measurement consistency. This data-driven approach not only improves the accuracy and repeatability but also showcases how adaptive, bioinspired sensors can be fine-tuned on the fly.

Looking ahead, such magnetic field-gated mechanosensors could find applications in soft robotics, wearable devices, and health monitoring systems, where detecting subtle changes in the force or pressure is essential. By integrating design principles observed in nature—such as adaptive sensitivity and resource efficiency—our method demonstrates an effective way to push beyond the limitations of traditional mechanosensors. Ultimately, this synergy between mechanical adaptability and machine learning offers a promising roadmap for developing next-generation, highly responsive sensing platforms.



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sciforum-120450: Perception and interaction for minimally invasive surgical robots

Dongsheng Li

Soochow University

Robot assisted minimally invasive surgery (RMIS) is favored for its precision, minimally invasive nature, and shortened recovery time. However, most RMIS are performed in complex environments, and surgeons typically rely solely on visual information and their surgical experience to judge the surgical environment. The lack of sufficient perception ability remains a serious problem for surgical robots: firstly, the lack of direct perception of the interaction between human tissue and robot end effectors increases the risk of tissue damage, and the lack of force feedback requires surgeons to perform higher accuracy, thereby increasing the complexity of surgery; Secondly, it is difficult for doctors to accurately determine the distance between robots and fragile tissues, and the lack of feedback information may lead to accidental tissue damage, especially in narrow anatomical areas, which limits the safety of surgery; In addition, palpation, as one of the most important preoperative procedures, can identify buried structures (such as blood vessels) that must be avoided during surgery and determine the edge of tumor resection. Surgeons in RMIS cannot perform tissue palpation. This report introduces the preliminary micro nano sensing work carried out by the research group to address the above issues, mainly including MEMS 3D force sensors for end effectors, full range sensing proximity contact sensors, tissue palpation probes based on micro nano sensors, and corresponding interactive feedback systems.



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sciforum-124363: Sensors for Predicting Structural Failure in Support Arms for Autonomous Welding Robots with a Deep Learning Surrogate Model

Changmin Pyo *, Jisun Kim, Suseong Woo, Chungwoo Lee and Jaehwan Lee

Korea institute of industrial technology

Welding is a fundamental joining process that involves the local melting and solidification of metal plates using thermal energy. Although widely used in various industries due to its simplicity, high-quality welding typically requires skilled labor. In South Korea, workforce reduction driven by the shipbuilding industry's decline and increased automation has led to a growing demand for autonomous welding solutions. Consequently, cantilever-type welding robots have been introduced into manufacturing environments. However, the operational movement of these robots imposes dynamic loads on their support structures, necessitating both structural safety assessments and sensing systems capable of predicting potential failures. Existing sensor systems are insufficient for predicting structural instability during robot movement. To address this limitation, this study analyzes the mechanical influence of robot motion on support structures using finite element analysis (FEA), generating over 2,000 high-fidelity simulation data points. A dataset linking robot motion parameters and structural responses was constructed, from which a deep learning-based surrogate model was developed. The proposed model enables real-time prediction of structural stability using sensor-measurable inputs such as position and velocity. This sensing approach is expected to enhance industrial safety and improve the reliability of autonomous welding operations. In addition, the proposed system offers scalable integration into existing robotic platforms, facilitating practical deployment in manufacturing environments.



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sciforum-122058: The Design of an AI Vision-Based Recognition System for Welding in Complex Curved-Block Ship Assembly Processes

Dayeon Yang, Eulyong Ha, Younghyun Kim, Soonho Kim, Teahoon Seo, Jaewoong Kim and Chanyoung Ju *

Korea Institute of Industrial Technology

In this study, we propose an AI vision-based recognition system tailored for welding tasks in the complex curved-block assembly processes of shipbuilding. The system architecture is designed to recognize diverse types of welding targets such as block and cell structures by utilizing RGB-D cameras and deep learning-based object detection models. To address distortions caused by varying camera angles, a calibration-based preprocessing pipeline and curvature-aware correction algorithm were designed. Furthermore, we identified key environmental and process-related variables (e.g., temperature, humidity, welding speed, and current) that significantly influence welding quality. These variables were analyzed and integrated into a preliminary AI model to predict optimal welding conditions under varying field scenarios. Data acquisition environments were constructed in lab-scale testbeds, and labeling and augmentation techniques were applied to enhance model robustness. Additionally, various welding trajectory types were simulated to test generalization across linear and curved paths. The proposed system lays the groundwork for high-precision welding in intelligent shipyards, reducing defect rates, improving consistency, and enabling adaptive process control in real-time. This study contributes to the advancement of smart manufacturing in the shipbuilding domain by establishing an AI-driven foundation for autonomous decision making and precision manufacturing. In future work, integration with digital twin environments is planned to enable predictive control and closed-loop feedback during welding operations.



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Session 23. Intelligent Sensors and AI-Enhanced Humanoids

sciforum-125065: A High-Sensitivity Trace Sebum Gas Sensor for Ultra-Early Diagnosis of Parkinson's Disease

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Parkinson's disease (PD), a progressive neurodegenerative disorder, is characterized by the insidious aggregation of α -synuclein during a prolonged asymptomatic latency period spanning 10–15 years. Current clinical diagnostic must be made after the presentation of common initial-to-mid-stage motor symptoms, fail to exploit the critical preclinical intervention window. Leveraging the characteristic release of volatile organic compounds (VOCs) in sebum during PD's asymptomatic latency phase, this study introduces a surface plasmon resonance-enhanced infrared spectroscopy sensing technology, offering a groundbreaking solution for ultra-early PD screening. A plasmonic fan-rod architecture gold nanoarray with a minimum inter-gap distance of 43 nm was fabricated on a layered MoS₂/CaF₂ composite substrate. By synergistically engineering bright-bright mode capacitive coupling and dark-axis loss mechanisms, the sensor achieves dual functionality: efficient capture of trace organic analytes and enhancement of infrared spectral signals. Experimental results demonstrate the emergence of dual plasmonic resonance peaks at 5.99 μm (C=O stretching vibration) and 6.99 μm (C–H bending vibration), accompanied by a structural gap electric field enhancement factor of 6.64×10^3 ($|E/E_0|^2$), a 91.9% improvement over the current state-of-the-art. The sensing system exhibits an exceptional sensitivity of 0.02546 %/ppm ($R^2=0.998$), enabling ultralow-concentration detection of airborne C₁₀H₁₄O (a key PD biomarker) at 10 ppb and perfume molecules at 8 ppb, with an infrared absorption enhancement rate of 0.47%. This novel trace sebum gas sensor represents a breakthrough in detecting low-concentration, freely diffusing macromolecular organic compounds. Its ability to detect the sub-ppb range sebum gas establishes a new paradigm for noninvasive, ultra-early PD screening, holding significant promise for early therapeutic intervention.



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sciforum-120304: Intelligent Tactile Sensors for Multimodal Perception and Robotic E-Skins

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Advanced tactile sensor with bionic functionalities as human skins, is a key component to enable intelligent robotic perception and humanoid robots. To accommodate for more complex environment and diversified tasks, tactile sensors are now developing toward multimodality and higher intelligence. Herein, we first developed a silk-based hydrogel nanocomposite incorporating Ca^{2+} , H^+ , and MXene as the multimodal sensing material. This hydrogel material shows comprehensive skin-like physicochemical characteristics, including enhanced stretchability (>400% strain), autonomous self-healing capability (rapid recovery rate within 30 s with addition of water), and potent antibacterial efficacy. Meanwhile, it can achieve multimodal sensory functionalities encompassing pressure, temperature, and humidity detection, coupling with dynamic function reconfigurability and system evolvability. Then to address multimodal-signal crosstalk in a single device, we proposed a vertical high-low-modulus device structure to decouple applied pressure and temperature. The bionic device structure achieves an effective signal decoupling ability, with temperature-insensitive pressure sensing (91.2% reduction of temperature inference) and pressure-insensitive temperature sensing. Furthermore, we adopted the developed tactile sensors as the robotic e-skin for multimodal information perception and intelligent interaction by coupling with advanced deep learning algorithms and large language model. The advancements in sensing material, device structure and system integration will shed light on the further innovations in intelligent tactile sensors for wearable electronics, prosthetics, and humanoid robots.



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sciforum-125171: optical flow based obstacle avoidance of autonomous nano quadcopter using on board computing

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Safe navigation of autonomous aerial vehicles in narrow, cluttered, and GPS-denied environments remains a significant challenge. Nano quadcopters, a class of micro air vehicles (MAVs) weighing under 100 g with rotor spans around 10 cm, offer advantages in size, agility, and cost, making them ideal for such tasks. However, their limited payload severely restricts onboard computational resources, complicating the use of conventional vision-based navigation methods. This work presents an efficient optical flow-based obstacle avoidance algorithm suitable for resource-constrained nano quadcopters. Our work is motivated by the low-resolution but efficient motion detection mechanisms in insects. We validate our approach using the Bitcraze Crazyflie, a ~30 g quadcopter equipped with a monocular camera and the GAP8 multi-core processor. The algorithm estimates forward velocity through downward-facing two-dimensional optical flow and executes fully onboard using the GAP8 SDK and RISC-V GNU toolchain. Employing an optimized pyramidal Lucas-Kanade method, the system achieves real-time performance at 14 frames per second during flight. Experimental results confirm the feasibility and reliability of our solution for single and multiple obstacle avoidance in cluttered environments. The environment consists of textured poles and wall and its dimensions is ~ 2.4 m x 1.5 m. The result demonstrates a practical pathway toward fully autonomous MAV navigation without reliance on external localization and computation systems.



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sciforum-121690: Self-powered Human-Robot Interaction Sensing System as a Dexterous Teaching Platform for Embodied Artificial Intelligence Learning

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In recent years, the humanoid robot market has witnessed explosive growth driven by substantial capital investments and accelerated product iterations. Despite this progress, critical challenges persist: commercial models remain prohibitively expensive, while application scenarios lack clear definition. Enterprises and users urgently require customizable behavioral frameworks tailored to specific operational needs, a demand that fundamentally depends on advancements in human-robot interaction (HRI) technologies. The Embodied Artificial Intelligence (EAI) embedded within humanoid robots provides autonomous environmental perception and adaptive learning capabilities through multimodal interactions with external environments. These systems typically integrate speech recognition and computer vision modules to facilitate communication with both individual users and enterprise-level operators. However, this approach contrasts sharply with human cognitive development, which originates from nonverbal communication—particularly gesture-based interactions that serve as primary educational tools during early learning stages. Our technical analysis confirms the effectiveness of gesture-driven interaction in conveying user intent to humanoid robots. We have developed a Triboelectric Nanogenerator (TENG)-based self-powered sensing system that operationalizes this paradigm. The system incorporates: 1) Phalanges-adaptive sensors employing segmented designs to minimize motion interference while preserving natural finger kinematics; 2) Phase-differential electrode configurations that amplify gesture-encoded signals through strategic temporal offsets. Functioning as a dexterous teaching platform, this HRI solution enables users to systematically program robots through intuitive gestures. Initial implementations demonstrate enhanced robotic perception of environmental subtleties via gesture-mediated communication, significantly improving contextual intelligence compared to traditional command-line interfaces. These technical advancements position gesture-driven interaction as a pivotal application domain for humanoid robots, particularly within the education sector, where nonverbal instruction aligns with pedagogical best practices.



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Session 24. Enabling Technology for Digital Twin, Metaverse, and Smart Sensing Systems

sciforum-125706: In-situ Measurement of Residual Stress and Parameter Optimization in Laser Drilling

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In modern manufacturing engineering, residual stress control and measurement are key technologies that directly influence product accuracy, mechanical performance, and service life. To address the high costs and complex processes associated with traditional stress detection methods, this study proposes an integrated system combining photoelastic measurement, laser processing technology, and parameter optimization for quality analysis. The optimization of laser drilling processing parameters for polypropylene materials is applied to explore the feasibility of using photoelastic measurement for quality inspection of laser-processed components, with the expectation that it can also be applied to high-cost substrate materials such as sapphire. This study uses an orthogonal array design for parameter planning. Strain rosettes are used to derive stress, which is then compared with photoelastic fringes to quantify the principal stress difference corresponding to the fringes. A stress fringe level correspondence model is established. The experimental results show that different delay parameters significantly affect processing quality and residual stress distribution. Among them, a delay parameter of 100 ms effectively reduces stress concentration and processing defects, thereby improving processing quality. Based on the integration of stress calculations and photoelastic image analysis results, this study confirms that photoelastic measurement is a feasible, fast, and non-destructive stress detection tool that can be applied to laser processing parameter optimization and quality inspection.



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sciforum-122117: Sensing and feedback fusion for mutual perception in metaverse and robotics

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The rapid evolution of metaverse and intelligent robots has been a catalyst for innovation in human-machine interface (HMI), ushering in a new era of more natural and intelligent user experiences. The continuous refinement of Internet of Things (IoT) infrastructure has facilitated enhanced information exchange technologies between HMIs and various terminals. Wearable and portable multifunctional HMIs, functioning as the cornerstone for implementing the transmission of various types of data, have obtained considerable attention due to several advantages, including intuitiveness, intimate sensing, and high flexibility. A dual-way communication is eventually required for more effective interactions. The current visual and audio feedback approaches are still lack of providing operators with immersive experiences regarding the environment variations. To fill this gap, haptic feedback systems have been developed to offer the capability of regenerating skin perception. This enables operators to have a better understanding about the operation condition. However, the integration of haptic feedback and sensing devices is still challenging for establishing close-loop interactions. For the purpose of achieving mutual perception between user and digital world, the way of perceiving and regenerating multimodal tactile information with better spatiotemporal consistency is becoming an essential requirement, along with the development of humanoid robot, teleoperation technique, and metaverse concept.



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Session 25. AIoT Technology and Applications

sciforum-125307: Development of AIoT-integrated Smart Monitoring Platform for Modular Batteries in Small Electric Vehicles

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The widespread adoption of electric vehicles, especially smaller mobility solutions such as scooters and e-bikes, is driving the demand for compact and modular battery systems that are easily replaceable. Unlike conventional fixed, large battery packs, modular battery systems not only minimize the time required for charging but are also able to optimize battery configurations for different environmental and driving conditions. To respond to this demand, this study investigates an AIoT-integrated smart monitoring platform for modular batteries specialized for small electric vehicles.

The main objective of this study is to analyze and predict the performance of batteries through real-time monitoring to improve the safety, efficiency, and lifetime of battery modules. The battery performance prediction and monitoring platform utilizes data from the battery management system (BMS) and from carbon nanotube (CNT) sensors embedded in the battery module enclosure to analyze battery health and predict performance. Initially, the AI model was trained using an open-to-public battery dataset combined with simulated operating scenarios. Time series deep learning algorithms, including long short-term memory (LSTM) and gated recurrent units (GRUs), were used to accurately predict state of charge (SOC) and state of health (SOH) under simulated conditions.

To facilitate practical application, we designed a cloud-based visualization system to provide intuitive monitoring and early detection of potential battery faults. This system will be further refined through the development of modular battery prototypes and linkage with operational data.

The results of this study have important implications for future urban electric mobility by providing a flexible alternative to conventional battery management approaches. The proposed platform is expected to not only improve operational reliability and user-friendliness but also advance battery performance prediction and management techniques, contributing broadly to the sustainability and practicality of small electric vehicles.



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sciforum-121839: A Study Validating an IoT-based Drug Pills Feature Point Extracting Algorithm

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Since the COVID-19 pandemic, narcotics-related problems have increased rapidly. Various countries are responding to regulations, but there are different views on narcotics and psychoactive substances from country to country, causing unnecessary problems. These problems especially arise with substances or drug pills. For example, some active ingredients permitted by certain countries in cold medicines or headache pills are considered a serious crime in other countries, even if they contain them. Ignorance surrounding medicine and its active ingredients can lead to crime. Therefore, this study was intended to help detect drug pills using Feature Point Extracting Algorithm to provide accurate, rapid, and convenient information about drug pills. Specifically, this study extracted drug pills' feature points by using the ORB (Oriented FAST and Rotated BRIEF) algorithm and the KAZE algorithm, and then conducted image matching based on the feature points to verify the effectiveness. As a result, both algorithms were able to effectively extract the drug pills' feature points and detect the drug pills through image matching. Moreover, it was found that two different algorithms can be used for complementarity by extracting different feature points from the same image. The results show the effectiveness of the ORB algorithm and the KAZE algorithm and suggest a new direction for utilization.



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sciforum-125723: An Integrated AIoT and Generative AI Framework for Predictive Maintenance and Automated Resource Planning

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Unforeseen failures in critical rotating machinery like pumps and compressors represent significant operational bottlenecks and incur substantial costs in industrial settings. This concept proposes a novel, integrated framework leveraging the Artificial Intelligence of Things (AIoT) and advanced Artificial Intelligence (AI), specifically Generative AI, to facilitate a transition from reactive to predictive and autonomously planned maintenance. The core system relies on AIoT deployment, utilizing sensors to continuously acquire high-granularity, multi-dimensional operational data streams from target assets. We assume approximately 6–10 key data points per asset, encompassing parameters such as multi-axis vibration, multiple temperature readings, pressure, flow rate, and electrical current. This continuous numerical data is subjected to rigorous analysis, including sophisticated regression techniques, to establish dynamic baselines, detect subtle deviations, and identify when machinery is entering a 'declined state' indicative of early degradation. A subsequent machine learning layer builds predictive models to forecast potential failures, identify high-risk assets ('bad actors'), and perform granular fault severity assessments and prognostics (estimated time-to-failure). A key innovation is the integration of a Generative AI engine, envisioned potentially utilizing models like Gemini 2.5 Pro for complex maintenance plan synthesis and OpenAI o3 mini for generating structured reports. This GenAI engine consumes the predictive outputs (identified faults, bad actors, severity, prognosis) and contextualizes them with real-time operational constraints, including asset availability and scheduled maintenance outages. Based on this synthesis, the GenAI autonomously generates detailed, actionable maintenance resolution plans and provides data-driven budget estimations for necessary interventions. Based on assumptions regarding data quality, model performance, and seamless integration into workflows, this framework is projected to yield significant operational outcomes, including an estimated 20–30% reduction in unplanned downtime, improved accuracy in budget forecasting (assumed variance 15%), and substantial enhancements in maintenance planning efficiency through automation, ultimately transforming industrial asset management.



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sciforum-125315: Diffraction-Integrated AOM-Based Φ -OTDR Achieves 1.5 m Spatial Resolution for Distributed Acoustic Sensing over a 50 km range

Zixuan Zhong * and Tao Zhu

Chongqing University

Conventional IoT technologies interconnect terminal sensors (e.g., temperature, humidity, pressure) via wired/wireless networks to achieve centralized data management and analysis. Distributed acoustic sensing (DAS) complements IoT systems by enabling large-scale, high-sensitivity, and continuous physical monitoring—such as pipeline leakage detection, perimeter security, and traffic flow analysis—capabilities that are unattainable by traditional active IoT sensors, thereby establishing a holistic sensing network. This paper presents a phase-sensitive optical time-domain reflectometry (Φ -OTDR) system featuring a novel modulation architecture based on diffraction integrated acousto-optic modulator (AOM). By exploiting the ± 1 st-order diffraction of AOM, the modulation bandwidth is broadened and intermediate frequency is reduced. An ultra-narrow-linewidth continuous-wave light is modulated into linear frequency-modulated (LFM) pulsed light by the AOM. Spatial resolution is enhanced via pulse compression, while sidelobe suppression is achieved through Hanning windowing. Interference fading and polarization fading are mitigated via inner-pulse frequency division and polarization diversity, respectively. In experimental validation, a piezoelectric transducer (PZT) wrapped with 5 m of fiber, positioned at the 50 km fiber end, generated vibrations by applying 10 Hz sinusoidal and DC-500 Hz chirp voltages. Successful demodulation of vibrations confirmed the system's distributed sensing capability, while the full width at half maximum (FWHM) of the end reflection verified a spatial resolution of 1.5 m. This technology provides a robust pathway for implementing high-spatial-resolution, large-scale vibration-sensing IoT networks.



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sciforum-121978: The early identification of MCI via the integration of the ensemble learning approach and the depth-sensing technique

Yang Zhao

Sun Yat-sen University

The early identification of Mild Cognitive Impairment (MCI) is crucial for slowing down dementia progression with timely intervention. Instrumented motor function assessments have been recognized as non-invasive and reliable tools for identifying MCI through kinematic indicators. However, most existing methods lack sufficient motor representation and the capability to deal with incomplete data in practical applications. In this study, we develop an effective approach to MCI identification via incorporating interpretable Random Forest (RF) and multi-task ensemble strategies based on the 3D skeleton data collected from depth-sensing cameras. The developed approach employs weighted soft voting to handle incomplete data in scenarios with missing subtasks, allowing robust evaluations of motor function in MCI. To enable a comprehensive representation of motor function in MCI patients, we introduce a novel feature extraction scheme based on Symmetric Stability Features (SSFs) derived from 3D skeleton data, which effectively analyzes limb movement direction, amplitude, and speed across three axes. A set of validation experiments on a real-world dataset shows that the performance of our model is superior on both complete and incomplete datasets. The model maintains a high AUC of 0.97 even under the condition of missing subtasks, highlighting the robustness of the ensemble approach. Our developed approach offers a non-invasive, cost-effective, and interpretable tool for early MCI identification, which has significant potential for future large-scale MCI screening and proactive dementia prevention.



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sciforum-121988: A Novel Approach for Large-Scale Characterization of Residential Cooking-Generated PM with Computer Vision and Low-Cost Sensors

Jianbang Xiang

Sun Yat-sen University

Cooking is one of the major sources of indoor particulate matter (PM), which poses significant health risks and is a severe health hazard. Current studies lack an economical and effective analytical framework for quantifying inhalable particles (PM₁₀) and fine particulate matter (PM_{2.5}) from residential cooking activities on a large scale under real-world scenarios. This study bridges this gap by employing computer vision (CV) technology and readily available sensors. We collected data over a month in real-world settings, including cooking videos and air quality data (indoor PM₁₀, PM_{2.5}, CO₂, temperature, relative humidity, and outdoor PM₁₀ and PM_{2.5} concentrations). To classify high-emission (pan-frying, stir-frying, deep-frying) and low-emission (stewing, steaming, boiling, non-cooking) activities, we developed and validated a robust CV model named “Cooking-I3D.” This model leverages a pre-trained Two-Stream Inflated 3D ConvNet (I3D) architecture. We then assessed the efficacy of the CV-predicted cooking method in PM characterization using a first-order multivariate autoregressive model, controlling for environmental factors. The Cooking-I3D model achieved exceptional performance, boasting an accuracy of 95% and an Area Under the Curve (AUC) of 0.98. Our results indicate that a single 6-minute high-emission cooking event triggers a 21 – 25% increase in indoor PM concentrations and a 23 – 24% increase in the indoor/outdoor ratio, with relative errors in these estimates ranging from 10 – 21%. This innovative method offers a powerful tool for long-term assessment of cooking-related indoor air pollution and facilitates precision exposure assessment in human health studies.



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sciforum-121304: An Adaptive IoT-Based Platform for CO₂ Forecasting Using Generative Adversarial Networks: Enhancing Indoor Air-Quality Management with Minimal Data

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National Research Council of Italy - Institute for Microelectronics and Microsystems

Monitoring indoor air quality is vital for health, as CO₂ is a major pollutant. An automated system for forecasting CO₂ levels can optimize HVAC management, preventing sudden increases and reducing energy waste while maintaining occupant comfort. To address the limitations of systems that require an extensive number of datasets to be collected, an adaptive IoT-based platform has been developed, leveraging a limited set of recent data to forecast CO₂ trends. Tested in a real-world setting, the system analyzed parameters such as physical activity, temperature, humidity, and CO₂ to ensure accurate predictions. Data acquisition was performed using the Smartex WWS T-shirt for physical activity data and the UPSense UPAI3-CPVTHA environmental sensor for other measurements (the sensors are wireless and minimally invasive).

The proposed forecasting model adopts an innovative approach. After a 5-day training period, a Generative Adversarial Network (GAN) enhances the dataset by simulating a 10-day training period. The model utilizes a GAN with a Long Short-Term Memory (LSTM) network as the generator to predict future CO₂ values based on historical data, while the discriminator, also an LSTM, distinguishes between actual and generated CO₂ values. This approach, based on Generative Conditional Adversarial Networks, effectively captures data distributions, enabling more accurate multi-step probabilistic forecasts.

In this way, the framework maintains a Root Mean Square Error of approximately 10 ppm, matching the performance of the approach we previously proposed in [1], whilst reducing the amount of real training data needed from 10 to just 5 days. Furthermore, it achieves accuracy comparable to other state-of-the-art methods that typically require weeks or even months of training. This advancement significantly enhances computational efficiency and reduces data requirements for model training, improving the system's practicality for real-world applications.

[1] Rescio, G., Manni, A., Caroppo, A., Carluccio, A. M., Siciliano, P., & Leone, A., "Multi-sensor platform for predictive air quality monitoring", *Sensors*, 2023, 23(11), 5139



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sciforum-124723: Smartphone-based Oil Drop Counter for Industrial Lubrication Systems

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Accurate oil drop monitoring plays a vital role in industrial lubrication systems, preventing equipment wear and reducing oil waste. However, conventional methods such as manual counting or flow meters are either labor-intensive, error-prone, or expensive and maintenance-heavy. To address these challenges, we propose a low-cost, smartphone-based solution for automated oil drop counting. In our approach, users record short videos of oil cans using handheld smartphones. These videos are then transmitted via Wi-Fi to a server for AI-based processing. Unlike static camera setups, our system must handle dynamic conditions, as both the handheld smartphone and the machinery being monitored are subject to vibrations and movement during operation. This results in moving backgrounds and moving objects, creating a complex scene for detection algorithms. To overcome this, we implement a two-stage YOLOv11-based deep learning pipeline. The YOLOv11-det model robustly detects oil cans under frame-wise jitter, while the YOLOv11-cls classifier evaluates the temporal image patches to determine oil drop occurrences. Despite motion-induced challenges, our system maintains high accuracy, achieving an error rate of under 6%. The final results are then sent back to the user's smartphone for real-time review. This approach demonstrates that low-cost, mobile hardware, when combined with advanced deep learning techniques, can effectively perform fine-grained tasks like oil drop counting even under industrial conditions with substantial camera and object motion.



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Session 26. Sensors for Applications in Agriculture, Aquaculture, Food Technology (A2FT) and Harsh Environment

sciforum-129711: A Multi-Branch Hybrid Convolution-Transformer Architecture for Intelligent Microseismic Event Detection

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The automation of microseismic event detection is critical for real-time safety monitoring in mining and subsurface engineering. Traditional classification methods often struggle to generalize across variable noise environments and event types due to their reliance on handcrafted features or local context alone. We present a Multi-Branch Hybrid Convolution-Transformer (MBHCT) model that integrates 1D/2D convolutional branches with a multi-layer Transformer encoder, merging their outputs via a learnable gating mechanism to capture both fine-grained local and long-range global dependencies in seismic signals.

Our approach processes high-frequency microseismic waveforms by segmenting each signal into overlapping frames and extracting a matrix of time–frequency descriptors—including zero-crossing rate, short-time energy, spectral features, and Mel-frequency cepstral coefficients. This rich input representation enables the MBHCT architecture to effectively differentiate microseismic events from blasting vibrations and ambient noise. The model was trained and evaluated on two real-world datasets from the Dongguashan and Tongkuangyu copper mines, achieving classification accuracies of 98.2% and 98.6%, respectively, and consistently outperforming baseline models such as pure Transformer, VGG16, and SVM by a margin of 1–2 percentage points.

Ablation studies highlight the complementary strengths of convolutional and attention-based pathways, while the adaptive gating mitigates overfitting and ensures robust performance even with limited training data. The MBHCT architecture maintains low computational latency (10 ms per inference on GPU), making it highly suitable for edge deployment in real-time microseismic monitoring systems. These results demonstrate that hybrid deep learning models offer a scalable and reliable solution for intelligent sensor applications in harsh or dynamic environments, paving the way for advanced AI-enabled sensing platforms in geotechnical and industrial domains.



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sciforum-121944: Microperfusion needle for minimally invasive monitoring of biological components of individual plants

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Th Currently, there is active research and development on plant factories and smart agriculture utilizing IT technology, which can achieve stable production regardless of climatic conditions. One of our focuses is to achieve more efficient and sustainable agriculture through data-driven farming. It is essential not only to rely on the experience and intuition of farmers, but also to optimize cultivation environments using sensors and data collection technology. This is necessary to optimize growth conditions and the environment. Thus, various quantified data regarding the state of the plants are required.

Microperfusion is a technique that collects biological components by perfusing liquids inside tissues. A micro flow channel covered by a perforated membrane was fabricated around a thin steel needle using our developed nonplanar microfabrication process. This needle enables the minimally invasive monitoring of plant biomolecules. For instance, plants continuously synthesize and metabolize sugars as energy sources, making carbohydrates critical biomarkers that directly regulate growth and adaptive responses to environmental fluctuations. The microperfusion needle allows for the real-time tracking of sugar metabolism and related physiological processes without requiring destructive sampling, thereby facilitating prolonged and repeated measurements of growth dynamics in the same plant specimen. This capability provides insights into the interplay between cultivation conditions and plant physiology, supporting the precise management of plant development. Ultimately, this technology could optimize the temporal coordination between growth parameters and environmental factors.



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sciforum-122075: Automatic light environment measurement system for plant cultivation utilizing fine-cut optic fibers

Tadao Matsunaga

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In this research, utilizing fine-cut optic fibers for an expanded aperture angle, an automatic light environment measurement system has been developed.

Light, necessary for photosynthesis, is essential for plant growth, and not only direct sunlight but also reflected light is extremely important. Reflected light includes various types, such as reflections from the surface of the leaves, reflections from the ground, and so on. Additionally, as plants grow, the color of their leaves changes, leading to changes in the optimal light environment for plant cultivation. Therefore, it is necessary to measure and evaluate the wavelength and intensity of the light irradiated onto the plant's surface over time and from multiple directions. Furthermore, the small size of these sensors is crucial to avoid them interfering with photosynthesis.

To expand the aperture angle, a multimode optic fiber, the diameter of which was 125 μm , was cut obliquely to allow light to enter from the side of the fabricated optic fiber. Since the optic fiber is thin and transparent, it does not interfere with photosynthesis. The proposed automatic light environment measurement system was fabricated using a timing belt driven by a stepping motor. The Z-axis unit includes a spectrometer, a 16 ch optical switch, and a cooler fan. In addition, the fabricated optic fiber was assembled as a light-receiving sensor.

The fabricated optic fiber and the automatic light environment measurement system were evaluated and demonstrated.



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sciforum-121164: Development of a Molecular Weight Measurement Method using Whistle Acoustic Signals for Remote Sensing of Cattle-emitted Gases

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Recently, methane gas emitted by cattle has garnered significant attention as a major contributor to global warming. Thus, there is a growing need for simple, non-invasive, and scalable methods to measure exhaled gases from livestock, especially cattle. In response to this need, we are developing a novel gas-sensing technique that utilizes acoustic signals generated by whistles to determine the molecular weight of the gas.

The principle of this proposed method is that the acoustic frequency of a whistle is affected by the physical properties of the gas flowing through it, particularly its molecular weight, temperature, and flow rate. As the composition of exhaled gas from cattle changes, so does its molecular weight, which in turn alters the frequency of the sound produced by the whistle. Thus, by combining several types of whistles and capturing and analyzing these frequency shifts using a microphone, changes in gas composition can be estimated.

One of the key advantages of this approach is its non-contact nature: microphones can be placed at a distance from the cattle, allowing for the simultaneous monitoring of multiple cattle with minimal stress or interference.

In this presentation, we report on recent progress, including selecting suitable whistle types, geometric optimization, and methods to compensate for varying gas flow rates using multiple whistles.



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sciforum-119517: Development of an Integrated Satellite-Based Estimation Method for Water Transparency and Algal Beds in the Mekong River

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This study presents a novel, integrated approach for estimating water transparency and algal bed distribution in the dynamic environment of the Mekong River using satellite imagery. Recognizing that previous research has predominantly focused on marine settings, this work addresses the unique challenges inherent in riverine systems like the Mekong, where low and variable transparency demands specialized techniques. Utilizing Sentinel-2 satellite data processed on the Google Earth Engine platform, a system was developed that compensates for water depth effects through the Bottom Index—a metric derived from the reflective properties of the riverbed. This approach effectively minimizes the influence of water depth variability on remote sensing data and enhances the accuracy of bottom characterization. Concurrently, water transparency is estimated via a ratio-based statistical model that correlates reflectance values from two selected bands to compute the Secchi-Disk Depth. Field experiments conducted in both coastal waters demonstrated that the estimated results align with in situ observations in algal bed distribution. Despite challenges such as reduced accuracy due to cloud cover during the rainy season and conditions of extremely low transparency, the proposed method shows promising potential. Future work will focus on further field validation and model refinement, contributing not only to international water resource conservation and environmental monitoring but also to supporting local agriculture and fisheries by providing valuable data on water conditions.



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sciforum-127519: Development of Maintenance-Friendly Water Quality Sensing Devices: Approaches Using ISFET and WiFi-CSI

Tomoaki Kageyama * and Sang-Seok Lee

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Monitoring water quality in environments such as agriculture—particularly in livestock operations—and construction sites is critical for environmental protection and regulatory compliance. However, conventional water quality sensors, such as those using glass electrodes or Ag/AgCl reference electrodes, often require frequent maintenance. This can be a significant obstacle in field applications where stable and long-term operation is needed. In this study, we propose two maintenance-friendly water quality sensing devices that aim to reduce operational burden while maintaining accuracy and functionality.

The first approach involves an electrochemical sensor utilizing an ion-sensitive field-effect transistor (ISFET) in combination with platinum electrodes. Electrolysis is performed between two platinum electrodes to dynamically control the surface conditions, forming a pseudo-reference electrode. Experimental results demonstrate that the electrolysis-treated platinum electrode exhibited potential responses more similar to those of a traditional Ag/AgCl electrode compared to untreated ones. Furthermore, because water flow affects the electrode surface conditions, the sensor also shows promise for flow rate detection.

The second approach explores non-contact sensing using WiFi Channel State Information (CSI). Variations in the CSI were observed when sucrose was added to water, suggesting that changes in organic matter concentration can be inferred through wireless signals.

Both methods generate large volumes of complex data, making them suitable for machine learning-based analysis. In future work, we plan to integrate AI algorithms to estimate water quality parameters from sensor data. This integration is expected to enhance robustness, and adaptability, especially in harsh and maintenance-limited environments.



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sciforum-124312: Enhanced Taste and Quality Analysis of Soft Drinks and Milk Samples Using a Single-Channel Hybrid E-Tongue with an Unsupervised Machine Learning Approach

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Electronic tongues (e-tongues) often rely on complex and costly sensor arrays for series measurements in taste analysis. In this work, we introduce a hybrid e-tongue that fuses data from potentiometric and impedimetric responses within a single channel, utilizing unfunctionalized metal electrodes and a pH electrode. The potentiometric response includes the pH and the open circuit potential, while the impedimetric response accounts for parameters such as the charge transfer resistance and double-layer capacitance. The performance of this low-cost, single-channel hybrid e-tongue was validated using platinum (Pt) and nickel (Ni) electrodes with two sample preparations of basic taste analytes at concentrations near the human taste thresholds. A principal component analysis (PCA) was used to evaluate the qualitative discrimination and clustering of the analytes, with the clustering quality assessed through silhouette coefficients (SCs) and hierarchical clustering. Heatmaps and PCA loading plots were employed to explore the correlations between the taste analytes and the physicochemical properties. While taste discriminability was slightly affected by the buffer activity of the standard reference solution (aqueous KCl and tartaric acid), the Pt and Ni electrodes demonstrated strong clustering, with SC values of 0.83 and 0.74, respectively, without requiring specialized sample preparation. The hybrid e-tongue, utilizing data fusion within a single channel, significantly improved the accuracy and clustering compared to those with independent potentiometric and impedimetric measurements. The developed hybrid e-tongue could classify soft drinks with different artificial sweeteners. Milk samples with different fat contents and containing different adulterants were also classified using the hybrid e-tongue. This development presents a promising path toward cost-effective commercial e-tongues for use in a variety of industries.



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sciforum-119812: Fiber-Optic Marine Sensors for Dual-Parameter Measurement of Salinity and Temperature

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The ocean requires continuous monitoring of critical parameters such as salinity, temperature, pH, conductivity, turbidity, etc. Prevalent electronic sensors often suffer from high cost, electromagnetic interference (EMI), and low stability due to moisture, salt and corrosion. In contrast, fiber-optic sensors have strong resistance to EMI and corrosion while having compact size and ease of multi-point detection. Our study developed 3 advanced fiber-optic sensing systems for simultaneous monitoring of salinity and temperature.

First, we employed a tapered polarization maintaining fiber (PMF) integrated into a Sagnac fiber-optic sensor based on a fiber ring laser (FRL) [1,2]. It achieved dual sensing with sensitivities of 0.173 nm/‰ for salinity and -0.306 nm/°C for temperature, while enhancing SNR to 50 dB. However, we encountered cross-sensitivity issues.

Second, we introduced a Sagnac loop (SL) with a tapered PMF and a fiber Bragg grating for temperature-only sensing, effectively compensating for cross-sensitivity [3]. It improved sensitivities to 0.356 nm/‰ for salinity and -0.616 nm/°C for temperature, but still had the problem in long-term stability.

Finally, we replaced the tapered fiber with a robust SL composed of PMF and tilted fiber Bragg gratings, enabling simultaneous detection of salinity and temperature [4]. We also integrated AI algorithms to further enhance sensitivity and adaptability.

In conclusion, we have developed 3 innovative fiber-optic sensors with significantly improved performance for marine monitoring.

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sciforum-123523: Integration of pH and DO sensor based on ISFET

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We are developing sensors for water quality monitoring and wireless systems for remote sensing. Fundamental physical quantities for water quality monitoring are pH, dissolved oxygen (DO) concentration, turbidity, electric conductivity (EC) and temperature. We developed those sensors separately and tested in the lake using IoT technology based wireless system. Here, we present a novel sensor integrated pH and DO sensors. For both pH and DO sensing, we use ion sensitive field effect transistors (ISFETs). To obtain DO sensor based on ISFET, Au nanoparticles are formed on ion sensitive film layer acting as a gate of the ISFET. In other words, using an ISFET with double gates, we detect pH and DO values at the same time. One gate exhibits only sensitive film layer is used for pH sensing and another gate coated by Au nanoparticles is used for DO sensing. After usual fabrication process of ISFET, the Au particle coating is performed using printing technology. As a result, we achieved pH and DO sensing with the same ISFET successfully. In the presentation, we also discuss influence of Au particle coating thickness and pattern on sensitivity of DO sensor. Proposed IoT technology based wireless systems for remote sensing will be also presented.



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sciforum-123089: Submersible Pump Fault Diagnosis Using a Simple Optical Measurement

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We propose a simple optical measurement system to diagnose fault of submersible pump. Submersible pump is working inside water and used for 24 hours. Therefore, to predict fault of the submersible pump is very important issue to prevent sudden malfunction or breakdown. Main reason of submersible pump fault is mechanical seal damage, which causes water or soil particle inflow into oil room. To detect water droplets or soil particles at early stage, we propose an optical measurement method. The proposed optical measurement method consists of pairs of LED and photodiode. By detecting transmitted light attenuation due to water droplet and scattered light attenuation due to soil particles, we could achieve early fault diagnosis of the submersible pump. As a result, relationship between photodiode output voltage and quantity of water or oil contains. We also discuss the distance effect between the pairs of LED and photodiode and oil rotation influence on the detection results. The proposed simple optical measurement method can be applied to other environmental sensing such as water quality monitoring and classification of oil types. For instance, the proposed measurement method can be applied to classify automobile engine oil and the detection results are also correlated mileage of the automobile.



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sciforum-122064: Wearable Bioacoustic Devices for Animal Health Monitoring

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This report describes bioacoustic sensing techniques for animal health monitoring. Biometric sounds that contain a variety of useful biometric information can be acquired by wearable devices that are less burdensome to wear. The presentation includes wearable bioacoustics devices for animal health monitoring, canine heart sound measurement using a harness-type device, and an algorithm for separating the measured heart sound data into the constituent valvular sounds.

Most of animals have a coat of fur that makes it difficult to keep the device in close contact with the skin surface. We developed a wearable device integrated with a sensor structure that can measure heart sounds over fur. The proposed structure transmits the minute heart sounds propagated through the body surface to an intermediate medium via acoustic impedance matching and subsequently further amplifies the signal using a spatial sound-collecting structure in a sealed air chamber. With respect to ambient noise reduction, the designed structure suppressed ambient noise (airborne sound) by approximately -30 dB at the intermediate medium and -19 dB in the sealed air chamber, resulting in a total suppression of around -49 dB. Collar-type devices with the structure for cattle have been able to detect body conductive sounds related to breathing, burping, and chewing, independently. Using the prototyped harness device for canine, heart sounds in dogs at rest could be measured with an SNR over 17 dB.

Since heart sounds are composed of valve sounds, it is considered effective to separate heart sounds into their respective valve sounds in order to make automatic diagnosis from heart sounds. This presentation also describes a technique to separate the measured heart sound data into valvular sounds using heart sound models and demixing vectors.



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sciforum-121919: Weight-Detectable Resonant Sensors for Monitoring Volatile Fatty Acids (VFAs) in the Rumen of Cows

Naoki Shiraishi

National Agriculture and Food Research Organization

The increase in human population emphasizes the importance of a stable supply of food. The development of the livestock industry, which supports food, is important. Also, methane produced by ruminants is a cause of global warming, and greenhouse gas emissions from livestock have increased globally. Therefore, it is essential to simultaneously reduce greenhouse gas emissions while increasing the productivity of agricultural and food products. To date, additives that have the effect of reducing methane have been discovered; however, the mechanisms of feed decomposition in the rumen of ruminants and the production of volatile fatty acids (VFAs) and methane, which are fermentation products, have not been clarified, and there have been no reports on the effects of sustained methane suppression.

In this study, we have developed a small, low-power, smart pill with weight-detectable resonant VFA sensors for monitoring VFAs in the rumen of cows to elucidate the mechanisms behind feed decomposition, fermentation products, and methane production. In this lecture, we will also explain the basic characteristics required for cow rumen sensors through the developed VFA sensors. This work was supported by the Cabinet Office, Government of Japan, Moonshot Research and Development Program for Agriculture, Forestry and Fisheries (funding agency: Bio-oriented Technology Research Advancement Institution) (JPJ009237).



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Session 27. Industry Forum and Commercialization of Sensors and Transducers

sciforum-127537: Marine Environment Observation using an Acoustic Tomography System with Multi-Channel Acoustic Sensors and an Efficient Phase Correlation Signal Processing Algorithm

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In this paper, we design a new coastal acoustic tomography system with multi-channel acoustic sensors for real-time seawater flow observations and underwater environment monitoring. To this end, we devise a new type of cross-correlator with a small memory size and low computational complexity. Further, simulations are conducted to compare the characteristics of the conventional correlator and the proposed correlator. The received signal is a BPSK signal (20 dB) in which a sine wave is modulated in PN code, and an A/D converter input signal is created by adding 6 dB of AWGN noise, assuming underwater noise. As a result, the S/N ratio is 25.6 dB. In order to provide greater convenience to users, we apply this technology to the system design and prove its effectiveness through testing in real sea conditions. Further, we install four tomography systems based on the ideas presented here in Yeosu Bay, Korea, with an installation distance of about 5 km. In addition, we make it so that when one unit is transmitting, the remaining three units receive simultaneously in different locations, and we observe the ocean current for a week. The measurement error is less than 1% in the simulation results. However, in the actual equipment operation situation, in about 10% of cases, some underwater acoustic sensors do not receive signals. Therefore, we plan to conduct additional research to use artificial intelligence technology to make the current information reliable based on past information.



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sciforum-125185: Integrated Micro-LED Light Module and MEMS Mirror on a Chip for Visible Light Communication Application

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With the continuous advancement of technology, the development of wireless communication, fiber optic networks, and 5G technology is evolving rapidly. Researchers are also placing increasing emphasis on stable and high-quality data transmission. Micro light-emitting diodes (Micro-LEDs) have garnered significant attention in various fields, including visible light communication (VLC), display technology, and biomedical applications, due to their high brightness, high bandwidth, high modulation speed, and low power consumption. In VLC technology, however, existing systems still suffer from limitations such as fixed beam direction and a lack of dynamic adjustment capabilities. To address these challenges, our research team integrates Micro-LED arrays with micro lens array, leveraging the focusing properties of micro lens array to achieve beam shaping by carefully designing their size and arrangement. The modified beam is converted from the vertical to the horizontal direction using a 45° structure, then integrated with a MEMS mirror for dynamic beam control and multi-channel light transmission.

The core objective of this study is to integrate these innovative design concepts to achieve miniaturization, reduced power consumption, expanded scanning range, cost reduction, and simplified fabrication. Under a photodetector (PD) gain of 0 dB, the received optical power (RoP) exceeds -40 dBm, enabling a data transmission rate of 2 Mbps. In the future, this research seeks to commercialize the proposed concept and expand its applications in fields such as the Internet of Things (IoT) and smart lighting, thereby driving innovation and advancements in communication technology.



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sciforum-130862: Multiple Sensors aided intelligent control in ironmaking and steelmaking

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This paper reviews the application of sensors in a traditional and large-scale manufacturing industrial sector: ironmaking and steelmaking. Based on the integration of multiple sensors and intelligent control systems, the ironmaking and steelmaking industries are undergoing a transformative shift toward enhanced efficiency, safety, and sustainability. Multi-sensor networks—encompassing IoT devices, machine vision, 3D radar, laser sensors, and gas detectors—enable real-time monitoring of critical parameters such as temperature, material composition, equipment status, and process anomalies across blast furnaces, converters, and rolling mills. These data streams feed into AI-driven platforms, which leverage deep learning for predictive maintenance, dynamic optimization of parameters, and autonomous decision-making. Key implementations include process optimization, safety and quality control, and resource efficiency. AI models at Baosteel predict hot-rolling outcomes, boosting accuracy by 5% and generating annual savings exceeding ¥100 million. Smart helmets (Nippon Steel) and visual inspection systems detect hazardous zones/defects, reducing accidents and improving coating consistency. Sensors also enable energy/cost savings, exemplified by Ansteel AI-driven packaging optimization. Multimodal fusion enhances intelligent control in ironmaking/steelmaking by integrating heterogeneous data (vision, temperature, vibration, acoustics) from diverse sensors. Utilizing techniques like feature-level fusion, cross-modal attention networks, and decision-level fusion, it provides a comprehensive real-time understanding of complex processes. This enables superior defect detection (e.g., slag carry-over >95% accuracy), improved material tracking, and holistic control optimization under harsh industrial conditions. Future directions focus on refining multi-sensor data fusion and expanding industrial metaverse applications for digital and intelligent steel production.



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Session 28. Regular Symposium

sciforum-117996: AI empowered wearable ultrasound technology

Sheng Xu

UC San Diego

The burgeoning field of wearable electronic devices has emerged as a transformative force in modern healthcare, offering a paradigm shift from traditional monitoring methods to continuous, noninvasive data acquisition. This evolution is underpinned by a convergence of innovative materials design and sophisticated microfabrication techniques, which enable the seamless integration of multifaceted components onto wearable platforms. Consequently, these systems deliver robust functionality while imposing minimal constraints on the wearer's mobility and comfort. Central to this technological revolution is the acquisition of physiological signals from deep tissues, which offer unparalleled insights into the body's internal dynamics. Unlike surface signals, which may be prone to distortion or interference, deep tissue signals provide a more accurate and nuanced understanding of physiological processes. Within this landscape, the presentation introduces a groundbreaking soft ultrasonic technology, representing a pinnacle achievement in noninvasive, continuous monitoring. This technology transcends conventional boundaries by enabling real-time acquisition of dynamic information from deep tissues and central organs, revolutionizing the landscape of healthcare diagnostics. Throughout the presentation, compelling demonstrations illustrate the versatility and efficacy of the soft ultrasonic platform. From capturing intricate blood pressure and flow waveforms in central vessels to monitoring subtle cardiac chamber activities and precisely measuring core body temperatures, the capabilities of this technology are vast and transformative. I will also illustrate how we used AI to process the data and images to enhance our monitoring outcomes. Moreover, the implications of this innovation extend far beyond the realm of healthcare. Its potential applications span diverse sectors, including consumer electronics, defense medicine, and clinical practices. As such, the soft ultrasonic platform represents not only a technological milestone but also a catalyst for broader societal impact, driving advancements in health monitoring and enhancing quality of life on a global scale.



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sciforum-125066: Enhancing Speech Localization and Separation with Convolutional Neural Network-Based Voice Activity Detection in Noisy Acoustic Scenarios

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Voice activity detection (VAD) plays a critical role in speech signal processing. However, low signal-to-noise ratio (SNR) conditions degrade VAD performance. To address this issue, this paper presents a robust voice activity detection (VAD) framework designed for operation in noisy and reverberant acoustic environments, with potential applications in human--machine interaction. A convolutional neural network (CNN) is trained to distinguish speech from noise by leveraging two acoustic features—zero crossing rate (ZCR) and log-likelihood ratio (LLR)—which capture the temporal and statistical characteristics of the input signal. Prior to VAD estimation, a weighted prediction error (WPE) method is applied to mitigate reverberation effects. The VAD output is subsequently used to estimate the noise power spectral density (PSD) for integration into a diagonal unloading (DU) beamformer for source localization. In parallel, direction of arrival (DOA) and VAD-derived information are used to construct a noise covariance matrix, which is employed in a linearly constrained minimum variance (LCMV) beamformer to achieve source separation. Simulation results across various noisy and reverberant scenarios indicate that the proposed system yields improvements in the perceptual evaluation of speech quality (PESQ), short-time objective intelligibility (STOI), and segmental SNR (SSNR), compared to conventional methods without noise modeling. These findings highlight the feasibility of deploying the proposed VAD and beamforming pipeline in real-world voice-based human--machine interfaces.

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sciforum-118526: Intelligent soft electronics for healthcare monitoring and VR

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City University of Hong Kong

Skin-integrated electronics have attracted great attentions due to the advantages of soft, lightweight, ultrathin architecture, and stretchable/bendable, thus has the potential to apply in various areas, especially in the field of biomedical engineering. By engineering the classes of materials processing and devices integration, the mechanical properties of the flexible electronics can well match the soft biological tissues to enable measuring bio signals and monitoring human body health. So, solving the materials and mechanics are two key issues for such kind of electronics to be used in a broad range of applications

In this report, we will present materials, device structures, power delivery strategies and communication schemes as the basis for novel soft bio-integrated electronics. For instance, we will discuss a wireless, battery-free platform of electronic systems and haptic interfaces capable of softly laminating onto the skin to communicate information via spatio-temporally programmable patterns of localized mechanical vibrations, which we refer as skin VR. It creates many opportunities where the skin provides an electronically programmable communication and sensory input channel to the body, as demonstrated through example applications in social media/personal engagement, prosthetic control/feedback and gaming/entertainment. Other demonstrations will include skin-interfaces human machine interface for closed loop sensing and feedback, sensitive materials as function layers for monitoring health related signals, air and sweat permeable electronics and skin like patches as sensors for healthcare monitoring etc.



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sciforum-135926: Rare Immune Effector Cell Isolation for Precision Immunotherapy via Microfluidic LISA

Chia-Hung Chen

City University of Hong Kong

Immunotherapy, like adoptive cell therapy, is a major step forward in personalized medicine by using a patient's own immune system to fight cancer. Traditional tools—such as flow cytometry and intracellular cytokine staining (ICS)—have limits in how many signals they can detect and often produce noisy results. Newer microwell-based systems can study immune cell interactions at the single-cell level, but they are slow and can only handle a few fluorescent markers, and they cannot link immune behavior to gene expression. To solve these problems, we developed Living Surface-Anchored Immunosorbent Assay (LISA)—a fast, high-throughput microfluidic platform for single-cell immune profiling based on what cells secrete and how they kill targets. LISA coats immune cell surfaces with antibodies that catch secreted cytokines and cytotoxic molecules directly on the cell. This lets us detect immune activity clearly and quickly (10^3 – 10^4 cells per second), offering over 10 times the speed of droplet-based methods. LISA can therefore detect rare functional immune cells (0.1%) in large samples (over 10^7 cells) in under 30 minutes. LISA is highly sensitive, can measure multiple functions at once, and works on a large scale. We used it to study immune cell products like TCR-T cells made by retroviral or mRNA methods to find tumor-specific cells. For the first time, we isolated more than 10^4 active killer immune cells and analyzed their gene expression one by one, uncovering the gene programs behind their multi-functional behavior. By linking what immune cells do with what genes they express, LISA gives us a powerful way to understand immune diversity.



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