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17–28 May 2021, ONLINE

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Welcome from the Chairs

Dear Colleagues,

Gathering of the interdisciplinary community is necessary for synergistic development in the field of sensors and improvement of life quality. Updating the community on the most recent works and building new links between disciplines enables discussion and new collaborations.

This conference will bring together leading researchers, from both academia and industry, to share their recent findings on a range of topics related to Bio- and Nano-Sensors, Bioelectronics, Chemical Sensors, Physical Sensors, Sensor Applications, and Smart Systems. It will focus on significant advances in the area of sensorics, enabling increased sensitivity, portability, and connectivity. Therefore, the target participants for the proposed conference are experts in the sensors community while, at the same time, the conference is expected to be mutually beneficial for young researchers and students.

We very much look forward to your participation.

Professor Gianaurelio Cuniberti
Conference Chair

Dr. Larysa Baraban
Conference Chair

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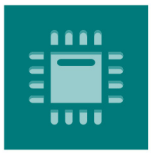

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Program

Invited Speakers

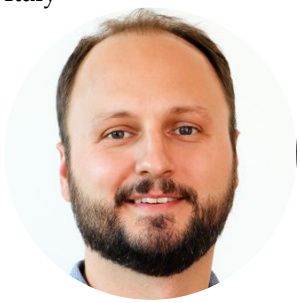
Prof. Dr. Luisa Torsi
Department of Chemistry, University of Bari Aldo Moro, Bari, Italy

Prof. Sergey A Piletsky
Department of Chemistry, University of Leicester, Leicester, UK

Dr. Mario Caironi Istituto Italiano di Tecnologia, Center for Nano Science and Technology, Milano, Italy

Dr. Denys Makarov
Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Dresden, Germany

Prof. Arben Merkoçi
ICREA & Catalan Institute of Nanotechnology, Barcelona, Spain



Prof. Martin Kaltenbrunner
Johannes Kepler Universitat Linz, Linz, Austria

Dr. Mariana Medina Sánchez
Institute for Integrative Nanosciences - IFW Dresden, Dresden, Germany

Prof. Frieder Scheller
Molecular Enzymology, University of Potsdam, Potsdam, Germany

Prof. Paolo Samorì
ISIS, University of Strasbourg & CNRS, Strasbourg, France

Prof. Dr. med. Thomas Hummel
Department of Otorhinolaryngology, TU Dresden, Dresden, Germany

Professor Vladimir M. Mirsky
Department of Nanobiotechnology, Institute of Biotechnology, Brandenburg University of Technology Cottbus - Senftenberg, Cottbus, Germany

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Abstracts

Session 1. Nano(bio)Sensors and Bioelectronics

Abstract

1 About the Amplification Factors in Organic Bioelectronic Sensors

Luisa Torsi [1,2,3]

[1] Dipartimento di Chimica, Università degli Studi di Bari "Aldo Moro", Bari, Itayly
[2] Physics and Center for Functional Materials, Faculty of Science and Engineering, Åbo Akademi University, Turku, Italy
[3] Centre for Colloid and Surface Science, Università degli Studi di Bari "Aldo Moro", Bari, Itayly

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Several three-terminal organic bioelectronic structures have been proposed so far to address the needs for a variety of biosensing applications. The most popular ones utlized organic field-effect transistors immobilizing a layer of bio-recognition elements that are operated in an electrolyte that enables one to selectively detect both proteins and genomic analytes. These features along with the foreseen low-cost for their production, make them very appealing for point-of-care biomedical applications.

However, organic bioelectronic transistors do not always exhibit a performance level beyond state-of-the-art electrochemical sensors, which have been dominating the field since decades.

This review offers a perspective view, based on a systematic comparison between the potentiometric and amperometric electrochemical sensors and their organic bioelectronic transistors counterparts. The key-relevant aspects of the sensing mechanisms are reviewed for both, and when actually in place, the amplification factors are reported as the ratio between the response of a rationally designed transistor and that of a homologous electrochemical sensor. The functional dependence of the bioelectronic sensors responses on the concentration of the species to be detected enabling their correct analytical quantification, is also addressed.

Abstract

2 Evaluation of a Microcantilever-Based Biosensor Surface for Specific Detection of Short–Chain Alcohols Using XPS and AFM

Alexandre Margarido [1], Livia Regina Manzine [2], Fernando M. Araujo-Moreira [3], Renato Vitalino Gonsalves [4] and Paulo Sergio de Paula Herrmann [5]

[1] Department of Mechanical Engineering, University of Sao Paulo-USP, São Carlos, SP, Brazil
[2] Molecular Biotechnology Group, São Carlos Physics Institute, University of São Paulo, São Carlos, SP, Brazil
[3] Department of Physics, Federal University of São Carlos, São Carlos, SP, Brazil
[4] Crystal Growth and Ceramics Group (IFSC-USP)/Center for Development of Ceramic Materials, São Carlos, SP, Brazil
[5] National Nanotechnology Laboratory for Agribusiness, Embrapa Instrumentation, São Carlos, SP, Brazil

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This work describes the development and evaluation using a X-ray photoelectron spectroscopy (XPS) and atomic force microscopy (AFM) of a biosensor designed to enzymatic detection of short-chain alcohols. The biorecognition element, alcohol dehydrogenase, was immobilized on self-assembled monolayers deposited on top of silicon nitride microcantilevers. Biosensor assays provided detection of short-chain alcohols and evaluation of the influence of a biological element immobilization on the analytical performance of the device. The self-assembly process was performed by surface activation using 3-aminopropyltriethoxysilane, followed by glutaraldehyde and biomolecule binding. XPS and AFM were used to verify surface oxidation and reagent binding. The biosensor showed a response time shorter than 1 s, a total renovation of the bioactive layer after 10 min, a sensibility from 0.03 to 1.2 mL/L and a lifetime of 22 days. Its selectivity was analyzed through exposure to pure and mixed volatile solvents. Sensor sensibility was higher in the presence of short-chain alcohols family (methanol, ethanol and propanol) ranging from 0.45 to 0.85 kHz and practically null involving others polar or nonpolar solvents. The biosensor it showed less susceptible to humidity and the temperature variations, presenting a high quality factor, a faster response time, selectivity, sensitivity and durability.

Abstract

3 Gas-Phase Chemical Imaging System by Biofluorometry for Human VOCs Measurement

Kenta Iitani, Koji Toma, Takahiro Arakawa and Kohji Mitsubayashi

Tokyo Medical and Dental University, Tokyo, Japan

Many gas-phase biosensors have been developed for human volatiles (acetone, methyl mercaptan, trimethylamine, ethanol, isopropanol, etc.) and for residential harmful VOCs (formaldehyde, toluene, nicotine) causing some diseases. A novel gas imaging system by biofluorometry with enzyme immobilized mesh has been investigated to demonstrate a spatiotemporal gas-imaging for human volatiles (i.e., ethanol and acetaldehyde after drinking). A biofluorometric technique was applied to improve the performance (sensitivity, calibration range, gas-selectivity, etc.) of the gas-imaging system. The biofluorometric sniff-cam for ethanol was fabricated with ADH (alcohol dehydrogenase) immobilized mesh and an NADH fluorescent-visualization unit (UV-LED sheet array & highly sensitive camera), thus showing the two-dimensional real-time imaging of ethanol vapor distribution (0.5–200 ppm). The system showed rapid and accurate responses and a visible measurement of ethanol in the gas phase. The intensity of fluorescence was linearly related to the concentration of ethanol vapor. The high sensitivity fluorescent imaging of ethanol vapor allows to successfully visualize gaseous ethanol from the human body (exhaled air and skin gas) after drinking. The sniff-cam system would be useful for conventional detecting and imaging the volatile biomarkers.

Abstract

4 Hemocompatible Electrochemical Sensors for Continuous Monitoring of Blood Parameters

Sascha Balakin [1], Bergoi Ibarlucea [2], Dmitry Belyaev [1], Larysa Baraban [3], Stefanie Hänsel [4], Manfred Maitz [4], Carsten Werner [4] and Gianaurelio Cuniberti [1]

[1] Institute for Materials Science and Max Bergmann Center of Biomaterials, Technische Universität Dresden, Dresden, Germany
[2] Center for advancing electronics Dresden (cfaed), Technische Universität Dresden, Dresden, Germany
[3] Helmholtz-Zentrum Dresden-Rossendorf, Institute of Radiopharmaceutical Cancer Research, Dresden, Germany
[4] Max Bergmann Center of Biomaterials Dresden, Leibniz Institute of Polymer Research Dresden, Dresden, Germany

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Real-time monitoring of physiological parameters is essential for point-of-care testing. While nowadays routine tests are done through ex vivo analysis on frequently extracted blood, placing implantable sensors monitoring key blood parameters such as lactate, glucose, ions, and oxygen would suppose a giant step forward in the care of critically ill patients, improving the response time in emergencies and diminishing the invasiveness of the measurements. The recent advances in microelectronics and nanotechnology is a promising technology enabling moving in that direction. The goal of our work is to develop arrays of electrochemical sensors with selective and hemocompatible coatings, allowing future implementation of such measurements in patients. We perform the analysis of blood parameters in a label-free and electrochemical manner which is compatible with the inevitable miniaturization in a real application. The tuneable composition of the layer will allow to pursue further applications in the future by modification of the receptor molecules and their concentrations.

Abstract

5 Modifications of the PAMONO-Sensor Help to Size and Quantify Low Number of Individual Biological and Non-Biological Nano-Particles

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In the series of recently published works (Shpacovitch, 2015; Shpacovitch, 2017; Yayla, 2019), we demonstrated that plasmon assisted microscopy of nano-objects (PAMONO) technique can be successfully employed for the sizing and quantification of single viruses, virus-like particles, microvesicles and charged non-biological particles. This approach enables label-free, but specific detection of biological nano-vesicles (Shpacovitch, 2015; Shpacovitch, 2017). Hence, the sensor, which was built up utilizing plasmon-assisted microscopy, possesses relative versatility and it can be used as a platform for cell-based assays (Shpacovitch, 2018). However, one of the challenging tasks for such a sensor was the ability to reach a homogeneous illumination of the whole surface of the gold sensor slide. Moreover, in order to enable the detection of even relatively low concentrations of nano-particles the focused image area had to be expanded. Both tasks were solved via modifications of previously described PAMONO-sensor set up. Taken together, our latest findings can help to develop a research and diagnostic platform based on the principles of the surface plasmon resonance (SPR)-assisted microscopy of nano-objects.

Abstract

6 Possibility Non-Invasive Detection Magnetic Particles in Biological Objects

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We evaluated the minimum concentration and minimum size of magnetic particles (MPs) within which modern ultra-sensitive magnetic field sensors (MFS) can detect them.

Calculations showed that magnetite MPs with specific magnetization with characteristic sizes of ≥50 nm and a concentration of C_V ~ 0.1 vol.% Can be detected at a distance $l \leq 0.1$ mm using MFS with a magnetic field resolution of $S_B \geq 1$ nT. However, at such a close distance it is impossible to non-invasively approach the biological object of study. On the other hand, the same MPs are easily detected at $l \leq 30$ mm using supersensitive MFS based on the phenomena of superconductivity (SQUID) or superconductivity and spintronics (combined MFS (CMFS)). These sensors require cryogenic operating temperatures (4–77 K), and S_B ~ 10–100 fT are realized in them.

Note that superparamagnetic particles or carbon nanotubes (CNTs) can also be non-invasively detected by SQUID or CMFS sensors, assuming that their concentration in the material is $C_V \geq 0.0000001$ vol.%. It is believed that CNTs may contain catalytic iron particles or encapsulated magnetic nanoparticles in nanotubes.

Thus, modern supersensitive magnetic field sensors with $S_B \leq 100$ fT make it possible to detect MPs in nanoscale, submicron, and micron sizes in biological objects. They can be used for non-invasive control of organs, implants, prostheses and drug carriers in the necessary parts of the body. Particularly important is the non-invasive control of CNTs in functional biocompatible nanomaterials, which have good prospects for widespread use in medical practice.

Abstract

7 Potentials and Shortcomings of Electrochemical MIPs for Proteins

Frieder W. Scheller [1], Aysu Yarman [1], Xiaorong Zhang [1], Katharina J Appelt [1], Ulla Wollenberger [1], Giorgio Caserta [2], Ingo Zebger [2], Goksu Ozcelikay [3], Sevinc Kurbanoglu [3], Sibel A Ozkan [3] and Robert E Gyurcsányi [4]

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After the pioneering work of Wulff and Mosbach in the development of MIPs by chemical polymerization, in the 1980s synthesis of MIPs by electropolymerization has been successfully introduced. Electrosynthesis of MIPs can be performed in aqueous solutions, where protein molecules preserve their natural conformation. The layer thickness can be precisely tuned by controlling the amount of charge passed. A frequently applied indirect method for the characterization of MIPs exploits voltammetry and impedance spectroscopy of ferricyanide. The changes of the current signals are caused by the removal or binding of the target, but also by "nonspecific" pores. Furthermore, target binding brings about minute decreases of the big current signal. Nevertheless, several papers describing MIPs for both low and high molecular weight substances claim measuring ranges over several orders of magnitude with subnanomolar lower limits of detection. On the other hand, evaluation of the enzymatic activity or of direct electron transfer gives a direct quantification of the target bound to the MIP.

MIPs can be synthesized from only *one* monomer and exhibit measuring ranges from micromolar up to the subnanomolar concentration range. On the other hand, many basic and technological problems have not yet been adequately tackled.

We describe in the present talk the electrosynthesis of MIPs and the analytical performance of the electrochemical MIP-sensors for the following proteins: Acetylcholinesterase, Butyrylcholinesterase, Cytochrome P450, Laccase, Tyrosinase, Ferritin, Transferrin, Hemoglobin, and Serum Albumin.

Abstract

8 CuO-Doped Alginate for Simple Electrochemical Vitamin C Sensing in Sweat

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Heat-exposed work activities or prolonged sport sessions suppose a continuous nutrient loss through sweating, leading to long-term health issues. Among prevention steps, the use of miniaturized sensors for real time monitoring of micronutrient presence directly in sweat can be of great interest. Here, we propose a flexible sensor for detection of vitamin C (ascorbic acid), based on a very simple process of electrode modification via electrodeposition of a membrane containing CuO nanoparticles. The reductive effect of ascorbic acid on the nanoparticles produces a shift of the redox peaks in cyclic voltammetry analysis, which can be measured at nearly zero volts as a current increase by amperometry. The detection is performed efficiently at the micromolar ascorbic acid levels found naturally in sweat and works at ultra-low potential (−5 mV), showing no interferences with other typical molecules found in the samples. In combination with sensors for other nutrients, this can be a promising approach for preventive healthcare applications.

Abstract

9 Detection of C-Reactive Protein by Liquid-Gated Carbon Nanotube Field Effect Transistors (LG-CNTFET): A Promising Tool against Antibiotic Resistance

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Respiratory tract infections have the highest rates of antibiotic prescriptions where symptoms like fever, cough and rigors are regularly misinterpreted and bacterial infections cannot be distinguished from viral ones. Nevertheless, it has been recently suggested that C-reactive protein (CRP), a protein produced by the liver in response to infection, could serve as a potential biomarker for the precise differentiation of these two types of infections . Thus, its quick and accurate detection would potentially reduce the unnecessary antibiotic use.

To this end, we present an easy and sensitive approach for the selective detection of C-reactive protein (CRP) by liquid-gated carbon nanotube field effect transistors (LG-CNTFET). Herein, CNT-networks were deposited between electrodes via controlled dielectrophoretic deposition and then functionalized with a novel specific antibody and a polyethylene glycol (PEG) layer in order to overcome the Debye screening. Successful fabrication and functionalization was confirmed by scanning electron microscopy and chemiluminescence immunoassays. The results showed a selective and reproducible detection down to picomolar concentrations in PBS buffer without complicated microfluidics. The simplicity and high sensitivity of this sensor platform make it a promising tool for the quick and precise differential diagnosis of viral and bacterial infections.

Abstract

10 Plasmonic Detection of Particled Analytes: A Play between High Analytical Performance and Fundamental Limitations

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A development of sensors for selective detection of large (or particled) analytes, such as natural and engineered nano- and microparticles is a new challenge of analytical chemistry. Their detection is complicated by very high sensitivity requirements (in most cases in fM–aM particle concentration range), slow diffusion and non-equilibrial detection conditions, intensive adsorption to most surfaces and trend to aggregate. Recently an application of wide field surface plasmon resonance microscopy combined with computer assisted image analysis (WF-SPRM) for detection of large analytes was reported. This new technology provides a real-time detection of interaction of single nanoparticles with sensor surface. A number of the nanoparticle–surface binding events per time characterize volume concentration. A large monitored surface area of the sensor surface allows one to detect hundreds of events in each frame or totally up to a million particles on the sensor surface; this leads to very high dynamic range in the concentration scale. Linear dependence between image intensity and particle size allows one to get histograms of particle size distribution. To determine chemical composition of single nanoparticles separately, the WF-SPRM was used in combination with electrochemistry: electrochemical conversions lead to the change in the particle refractive index while the value of the applied potential of this conversion characterizes material of the particular nanoparticle. Another application field of WF-SPRM comprises surface processes leading to the formation of new nanoparticles, e.g., electrochemical nucleation. Fundamental limitations in the development of analytical techniques for large analytes will be also discussed.

11 Strain Sensor Based on the Biological Nanomaterial

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We investigated prototype of the strain sensor based on the layers of the bionanomaterial contained bovine serum albumin (BSA—matrix), and multi-walled carbon nanotubes (MWCNT—filler). The aqueous dispersion of 25 wt.% BSA/0.3 wt.% MWCNT was applied by screen printing on flexible polyethylene terephthalate substrates. After drying layers by the laser irradiation (~970 nm) various parameters of layers were controlled, i.e., resistance R, bending angle q, number of cycles n, measurement time, etc. One measurement cycle corresponded to a change within the range q = ±150 deg. The layers of BSA/MWCNT bionanomaterial were de mentions: (15 ÷ 20) mm × (8 ÷ 10) mm × (0.5 ÷ 1.5) μm. The dependences of resistance R on the bending angle q were similar for all layers: at q = ±30 deg, the $R(q)$ curves represented approximately linear dependences (with an error of ≤10%); beyond this range, the dependences became nonlinear. The following quantitative values were obtained for the investigated strain sensor: specific conductivity ~1 ÷ 10 S/m, linear strain sensitivity ~160, bending sensitivity 1.0 ÷ 1.5%/deg. These results are high. The examined layers of the bionanomaterial BSA/MWCNT as a strain sensor is of a particular interest for medical practice. In particular strain sensors can be implemented by applying a water dispersion of nanomaterials to human skin using a 3-D printer for monitoring: movements (arms, blinking) and detection of signs of pathology (dysphagia, respiratory diseases, angina, et al.).

12 A Washable Silver-Printed Textile Electrode for Electrocardiography Monitoring

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Electrocardiography (ECG) is one of the most widely used diagnostic methods to examine the development of cardiovascular diseases (CVD). It is important to have a long-term continuous ECG recording to properly monitor the heart activity, which can be measured by placing two or more electrodes on the skin. Ag/AgCl gelled electrodes are often used for the ECG measurement, but they are not suitable for long-term monitoring due to the dehydration of the gel over time and skin irritation. Textile-based electrodes could have an important role in replacing the gelled electrodes and avoid their associated problems. This paper focuses on the development of a textile-based electrode and studying its ECG detecting performance. We developed silver printed textile electrodes via a flat-screen printing of silver ink on knitted polyester fabric. The surface resistance of silver-coated PET fabric was 1.78 Ω/sq and 3.77 Ω/sq before and after washing, respectively. Stretching of the conductive fabric from 5% to 40% caused a 6% to 18.28% increase in surface resistance. The silver-printed PET fabric stayed reasonably conductive after washing and stretching which makes it suitable for wearable applications. Moreover, the ECG measurement at static condition showed that the signal quality collected before and after washing were comparable with the Ag/AgCl standard electrodes. The P, QRS, T waveforms, and heartbeat before washing in respective order were 0.09 mV, 1.20 mV, 0.30 mV for the silver printed fabric electrode and 72 bpm, and 0.10 mV, 1.21 mV, 0.30 mV, and 76 bpm for Ag/AgCl standard electrode.

S1. Nano(bio)Sensors and Bioelectronics
Poster
Abstract

13 Bioelectrical Impedance Spectroscopy (BIS) Monitoring of Lettuce during 19 Hours

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In this study, a lettuce leaf was monitored using a bioimpedance spectroscopy technique for 19 h (6 am to midnight). Water was supplied just after 6 am, and the leaves were irradiated with growing LEDs from 8 am to 8 pm. During 19 h, at every hour, the impedance (resistance and capacitance) of the lettuce was obtained at various frequencies from 1 kHz to 100 kHz. A significant change of impedance after events (watering and LED on) was observed. It implies BIS impedance monitoring can be used for near-realtime monitoring of plant growth. The experimental analysis shows that the bioimpedance system can be used to quantitatively measure the growth and health status of the lettuce leaf. Moreover, the authors propose to use four parameters, the characteristic frequency and the phase of Cole-Cole graph, and the resistance ratios R_{100kHz}/R_{1kHz}, and R_{100kHz}/R_{50kHz} for plant leaf monitoring. When the leaf enters healthier conditions, the characteristic frequency of Cole-Cole graph is getting smaller and the phase is getting bigger. These facts were predicted by referring to the previous articles. However, the authors found the characteristic frequency and the phase angle are not enough to explain the healthiness of lettuce leaf. The proposed two resistance ratio shows different aspects of the healthiness of lettuce leaf during 19 h more clearly.

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Poster
Abstract

14 Design and Simulations of 2D Planar Antenna for Dielectric Characterization of Biological Samples

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The dielectric parameters help in understanding the structural, compositional and functional analysis of biological samples. These parameters have also been widely adopted in biomedical and therapeutic fields. In the microwave region, these parameters carry much interest because the principal constituent of most biological cells is water. Therefore, it is difficult to isolate the dielectric response of water present in a biological-composite. So, the technique with enhanced sensitivity is essential for measuring the dielectric properties of biological samples. In this paper, we report the design and CST simulation of a 2D-planar patch type antenna with capacitive coupling introduced by dividing the patch through a gap. The aforementioned design further improves the antenna's sensitivity towards the dielectric properties of materials. Here, we simulated ten biological phantoms by measuring the shift in resonant frequency and return loss. Our results were identical when loading samples on either of the two introduced patches. These results suggest the repeatability and further improvements in a cavity-based technique where the sample localization is an important issue. Moreover, we analytically studied the dependency of gain and directivity of the antenna on the capacitive coupling, which plays a major role in the antenna's sensitivity towards dielectric characterization.

15 Detection of Biogenic Amines in Canned Tuna Using a Voltammetric Electronic Tongue

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Biogenic amines (BAs), produced naturally due to the decomposition of amino acids, are crucial for food industry because the formation of BAs is directly related to improper storage and the presence of bacteria; high concentrations of BAs could be related easily with the quality and spoilage of the products of this sector.

The necessity to quantify quickly and efficiently these targets makes mandatory the use of alternatives to conventional analytical methods used up to now. For example, sensors combined with chemometric tools are a promising alternative for quick and informative analysis in the food sector. Chemometric tools allow to develop models for the quantification of concrete compounds in complex matrix, making it a feasible tool for the development of more user-friendly methods than the traditional used since now.

This work presents a model created for the detection of histamine (Hys), cadaverine (Cad) and tyramine (Tyr) using a set of 5 modified GEC (Graphite Epoxy Composite) electrodes: ZnO, CuO, SnO_2, Bi_2O_3, and Polypyrrol, used in a voltammetric multisensory array approach.

In the graphics below it could be observed the results obtained with an Artificial Neural Network (ANN) with 51 input neurons, 5 neurons in the hidden layer and 3 neurons in the output layer. The functions used for the hidden and output layers were *Tansig* and *Purelin*, respectively. The results show slopes near to 1 and intercepts close to 0, indicating the feasibility of the model.

16 Detection of Breath Biomarkers for Alzheimer's and Parkinson's Disease Using Quartz Tuning Forks Based Gas Sensors

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Alzheimer's (AD) and Parkinson's (PD) disease are two of the most life-threatening neuro-degenerative diseases. Due to the complex nature of the diseases, diagnosis of AD and PD in the initial stages is very difficult. Recently, studies concentrating on detection of diseases with the help of breath biomarkers have proven to be effective. In this work, we detect two reported volatile organic compound (VOC) breath biomarkers of AD and PD namely styrene (STY) and propyl benzene (PBZ) using quartz tuning fork (QTF) based sensors. These QTFs are modified using polymer films to achieve selectivity. We demonstrate that polymer modified QTF based sensors can detect these analytes with high accuracy even at low (ppm) concentrations. The polymer was selected based on results obtained from Force Spectroscopy studies where we detect the change in elastic modulus of the polymer film upon interaction with the VOCs. Based on the working principle of the sensor, few parameters like recovery time (RcT), response time (RpT) and drop in frequency (Δf) among others can be utilized for better classification. The data collected from the sensor is used to classify the behaviour of the two analytes using machine learning techniques with approximately 90–95% accuracy.

17 Development of a Mechanical Digital Microfluidic Immunoassay with Glass Microspheres

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Digital (droplet-based) microfluidic platform has become an attractive approach for biomedical applications, such as immunoassay, because it requires less sample volume and take shorter time in bio-reaction. However, the digital microfluidic immunoassay based on electrowetting technology often has dielectric breakdown problem due to biofouling and high input voltage. Here a highly reliable mechanical digital microfluidics immunoassay is reported by combining the movable-chip design and the glass microspheres as the carrier of antibody. Since the droplet movement is achieved by moving the chip in the mechanical digital microfluidic system, high voltage is not required, the biofouling won't cause any problem in droplet movement during the process of immunoassay. In addition, owing to the buoyancy, the glass microspheres can self-concentrate to the top of droplet, which helps to improve the detection sensitivity and reduce the limit of detection. The Human IL-1β is used here to demonstrate the performance of the proposed mechanical digital microfluidic immunoassay. It is shown that the limit of detection is 0.246 pg/mL, required sample volume is only 2 μL, and the time for immunoassay process is less than 30 min. which is similar to our previous digital microfluidics immunoassay based on electrowetting technology with much better reliability.

18 Evaluation System of Open Platform Cameras for Bio-Imaging

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Existing bio-imaging devices are often equipped with high-performance cameras that are bulky and expensive, and a large-volume bio-imaging system including such an image sensor is inevitably disadvantageous in terms of space and cost. However, with the development of smart phones, ultra-small, high-definition, and open platform-based cameras have been mass produced. In this paper, we built an emulation system to verify the bio-imaging performance of various cameras. The emulator consists of a test sheet and an adjustable illuminator consisting of an LED and diffuser sheets. Also, the emulator is designed to easily mount the camera to be tested. Images captured by the emulator have a line area with a linear profile, and the slope of the brightness in this area increases in proportion to the intensity of the light. It can be determined that the more linear the slope change is, the better the camera performance is. Four type of cameras were tested in the emulator and we selected three best cameras for the typical bio-imaging device, ultraviolet gel document system. The results of gel image analysis were consistent with the performance evaluation in the emulator.

19 Fast and Cheap Test for Detection of *Streptococcus pyogenes* and *Streptococcus pneumoniae* with Antibiotic Resistance Identification

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We present the development and implementation the Point-of-Care devices for the rapid identification of *Streptococcus pyogenes* and *Streptococcus pneumoniae* with simultaneous identification of antibiotic resistance genes. These bacteria are the main etiological factor of acute pharyngitis, palatine tonsils, scarlet fever, pneumonia, meningitis and development of sepsis, with high mortality and dangerous complications. In cases of alleged streptococci infection, antibiotics are used, and only in the absence of positive treatment results an antibiogram is requested and results are available after a few days. During this time, untreated infection can lead to significant deterioration of a patient's health. The main advantage of the developed test will be fast identification of the bacteria from the throat swab with simultaneous analysis of the antibiotic resistance profile. As a result, the initial treatment will use antibiotics to which the strains are not resistant, leading to fast patient recovery. Results will be available after up to 30 min during the medical appointment. The innovation of the developed test will concern both the polymerase used for amplification of DNA and the approach to resistance testing. Innovation of the concept of drug resistance testing involves the study of not only the resistance genes within the detected bacteria but also the examination of the patient's natural bacterial flora. The presence of β-lactamase-encoding genes that will protect streptococci against antibiotics from the ampicillin group widely used in the treatment of this type of infection will be also identified

20 FLIM Indicators for Quantitative Measurement of pH

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Monitoring of intracellular pH changes in situ can provide valuable information about cellular metabolism and a deeper understanding of physiological processes. Most traditional fluorescent indicators are only capable of a relative assessment of changes in the studied parameter in the cell. We associate the possibility of measuring the absolute values that characterize the analyte with the detection of the indicator signal in the time domain, where its quantitative measure is the fluorescence lifetime (tau).

In this project, we are testing promising pH-sensitive fluorophores with labile fluorescence lifetimes-EYFP-G65T (Sen et al., 2019) and EGFP-Y145L/S205V (Mamontova et al., 2020)—both as fluorescent core for the previously described pH indicators and as independent pH indicators. Measurement of the fluorescence attenuation kinetics of four structures (EYFP-G65T, EGFP-Y145L/S205V, SypHer3s, and SypHer3s-G65T) over a wide pH range revealed areas where tau is linearly dependent on pH. The differences in the fluorescence excitation modes of these molecules makes it possible to use them in one experimental system to assess pH changes in a wide range 4.0–9.0. We showed that under the conditions of traditional fluorescence microscopy (in the cytoplasm of HEK293 cells), the SypHer3s-G65T indicator shows a dynamic response range approximately 3 times wider than the original SypHer3s.

This work is supported by the Russian Foundation for Basic Research—grant 19-34-60019.

21 Highly Sensitive Silicon Nanowire Biosensor Devices for the Investigation of Unicar Platform in Immunotherapy

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Although showing impressive therapeutic potential, treatments of leukemias with T-cells expressing chimeric antigen receptors (CARs) is limited by their risk of several severe side effects. To overcome these problem, a switchable CAR platform has been developed termed UniCAR. Unlike conventional CAR which directed against tumor-associated antigens, UniCAR treatment involve an intermediate target module (TM) which can cross-link UniCAR T cells with tumor cells and lead to destruction. The development of these novel TMs against different tumor targets require numerous repetitive tests on different synthesizing trials which is usually limited in quantity and time-consuming. Meanwhile, nano-biosensors are lately known as analytical tools which are highly sensitive, label-free, rapid and reagent-saving. Among them, silicon nanowire (SiNW) sensor is extensively investigated by researchers over the past decades thanks to its compability with CMOS technology enabling mass production. In this work, we demonstrated the application of previously published SiNW biosensor on detection of the binding of UniCAR and a part of different TMs. The results underline advantage of SiNW sensor over ELISA method in term of ease of preparation, speed and sensitivity. The method is able to evaluate binding affinity of UniCAR to different TMs and open a potential to quantify the number of active UniCAR T-cells in in-vivo-sample in later stage. In the end, the application of nanosensor may speed up the R&D process of UniCAR concept and later play an important role in clinical monitoring of immunotherapy, especially, in the era of precision medicine.

22 Impedance Characterization of Particles One by One Using a Nanosensor Electronic Platform

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Impedance cytometry represents a technique that allows the electronic characterization of colloids and living cells in a highly miniaturized way. In contrast with impedance spectroscopy, the measurements are performed at a fixed frequency, providing real-time monitoring of the species traveling over the sensor. By measuring the electrical properties of particles in suspension, the dielectric characteristics (electric conductivity and capacitance) of both cells and particles can be readily determined. During the last years, this technique has been broadly investigated; however, it is still not trivial to differentiate particles of similar size based on their dielectric characteristics. A way to increase the discrimination abilities of this technique could be the integration of nanostructures into the impedance platforms. In this work, we present the impedance cytometry study of particles using microfluidic channels aligned over interdigitated gold nanowire structures as our impedimetric sensor. The characterization of particles of different sizes and their comparison with particles of different compositions will provide an understanding of the correlation between the electrical signal and the own characteristics of each particle. This approach is an attractive element for label-free detection platforms that can be integrated into lab-on-a-chip systems, and that can be further implemented for single-cell analysis.

S1. Nano(bio)Sensors and Bioelectronics
Poster
Abstract

23 Implantable Blood Pressure Sensors with an Analogic Thermal Drift Compensation

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Implantable pressure sensors represent an important part of research activity in laboratories. Unfortunately, their use is limited by cost, autonomy and temperature-related drifts. The cost of use depends on several parameters, in particular the low battery life and the need for miniaturization to be able to implant the animals and monitor them over time that is long enough to be physiologically relevant. This paper study the possibility to reduce the thermal drift of implantable sensors. To quantify and compensate for thermal drift, we have developed the equivalent model of the piezoresistive probe by using the cadence software. Our model takes into account the temperature [34 °C–39 °C] and also the pressure [0–300 mmHg]. We were thus able to identify the source of the drift and thanks to our model we were able to compensate for it thanks to compensation circuits added to the conditioning circuits of the sensor. The maximum relative drift of the sensor is (0.1 mV/°C)/3.6 mV (2.7%), a drift of the conditioning circuit is (0.98 mV/°C)/916 mV (0.1%) and the whole is (13.4 mV/°C)/420 mV (32%). The compensated sensor show a relative maximum drift of (0.371 mV/°C)/405 mV (0.09%). The output voltage remains stable over the measurement temperature range.

24 LATE-PCR for LoC Molecular Diagnostics Devices and Its Application to the Sensitive Detection of SARS-CoV-2

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The emergence of the novel coronavirus, SARS-CoV-2, has highlighted the need for rapid, accurate, and point-of-care diagnostic testing. Lab-on-a-Chip (LoC) devices offer the possibility to run such tests at a low cost while at the same time permitting the multiplexed detection of several viruses when coupled with microarray detection of the amplified products.

Herein, we report the development of a protocol for the qualitative detection of SARS-CoV-2 through the design of appropriate primers that target evolutionary conserved regions of the virus. The proposed protocol relies on an improved version of asymmetric RT-PCR, the Linear-After-The-Exponential (LATE)-PCR that uses primers that are deliberately designed for use at unequal concentrations. As a result, LATE-PCR exhibits similar efficiency to symmetric PCR while promoting accumulation of single-stranded products that can subsequently hybridize to a single strand DNA probe-spotted microarray. The performance of the developed LATE-PCR protocol was compared to that of symmetric RT-PCR and validated with the use of artificial viral RNA, nasopharyngeal swabs samples from real patients as well as healthy volunteers. Furthermore, and in order to illustrate its potential for integration into a biosensor platform, the amplicons were allowed to hybridize with probes covalently immobilized onto commercially-available functionalized glass slides in the form of a microarray, without the need of heat denaturation.

25 Metabolic Rate Monitoring Using Quartz Tuning Fork Based Sensors

Saurabh Parmar, Bishakha Ray and Suwarna Datar

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Human body produces volatile organic compounds (VOCs) due to various biological processes. Recent research indicates that these VOCs can be utilized to monitor the health of an individual's body. Metabolism is such a biochemical process that varies according to the lifestyle of a person. Researchers have found that metabolic rate can be recorded by detecting the amount of acetone release in an individual's breath. In this work, we demonstrate the use of a polymer modified quartz tuning fork (QTF) based sensor to detect various levels of acetone (5 ppm–400 ppm). As per reports, different levels of acetone expelled in breath can correspond to presence of distinct diseases in a human being. Initially, we tested free standing polymer films for change in elastic modulus (E_m) using Atomic Force Spectroscopy. Since the combination of polystyrene and cellulose acetate (PS + CA) showed good change in E_m, this material was selected to modify the QTF-based sensors. The sensor was able to detect various concentrations of acetone with high accuracy. After testing, various machine learning algorithm were utilized to better improve classification.

26 Photonic Biosensor for Label-Free Detection Based on Photonic Nanostructures on Si-Waveguide Ring Resonator

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Silicon based micro-ring resonator biosensor has been developed as a highly potential label-free biosensing device with advantages of a possibility of all-in-one-chip detection and low-cost fabrication. Nevertheless, the sensitivity has been still a research issue for detection of very small refractive index changes induced by analytes.This research aims to elucidate the effect of photonic nanostructures onto Si-waveguide ring resonator on the sensitivity for sensing nanoparticles and biomolecules attached onto the Si surface. Different photonic nanostructures with periodically arranged nano-holes are formed onto the waveguide of the microring resonator for the enhancement of light-matter interaction inside the holes and contact surface. The simulated results of the ring resonator with photonic nanostructures show three-fold improvement of the sensitivity, which is calculated from the resonance wavelength shifts per refractive index change, compared with the conventional structure of the waveguide while the quality factor remains. This might be due to the large field amplitude inside the nano-holes. The improved sensitivity is promising for detection of nanoparticles in the application of environmental field and clinical diagnostics.

27 Polymer-Modified Quartz Tuning Forks for Breath Biomarker Sensing

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Volatile organic compounds (VOC) present in exhaled breath can serve as biological markers for human physiology. The change in levels of exhaled VOCs can be indicative of bodily disorders. Detection of such low levels of VOCs can allow early detection and diagnosis of diseases. A polymer-modified Quartz Tuning Fork (QTF) is a promising, cost-effective sensor that can detect a change in ppm levels of VOCs exhaled from the breath at room temperature. Acetone and acetaldehyde are biomarkers that are readily exhaled by human beings. Increased levels of these analytes can serve as indicators for toxicity or a wide array of diseases. The present work uses an array of QTFs modified separately using TiO_2 and WO_3-nanostructures embedded in polystyrene to successfully detect low VOC concentrations present in simulated human breath. The frequency shift obtained after exposing the sensor array to breath is noted as the sensor response. The response shows a clear distinction between healthy human breath and breath spiked with varying VOC concentrations (5–400 ppm). The sensor response proves it can potentially serve as an economical and non-invasive tool for disease diagnostics.

28 A Novel Microneedle Biosensor Based on Lignin Nanoparticles for Real Time Monitoring of Glucose

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Microneedle arrays for minimally invasive continuous sensing in the dermal interstitial fluid (ISF) have been demonstrated in both amperometric and potentiometric modes, however there are no publication where microneedle arrays have been modified with lignin nanoparticles. Lignin, the most abundant polyphenol in nature, is the main byproduct in the pulp and paper manufacturing industry and biorefinery. Lignin nanoparticles (LNPs), easily produced by green methods, offer unique properties and have therefore gained interest for electrode modification. In this work, we have developed a novel green LNPs modified microneedles electrode platform for pain free continuous monitoring of glucose in artificial interstitial fluid (ISF). The gold surface of the microneedles has been modified with LNPs and electrochemically characterized. Functionalization with glucose oxidase enzyme and with an Osmium polymer as redox mediator allowed the continuous monitoring of glucose. The performance of the LNPs/microneedle biosensor for glucose detection was assessed in artificial interstitial fluid and in human serum, both spiked with glucose. The results reveal that the new LNPs microneedles biosensor holds interesting promise for the development of biocompatible, wearable, real-time monitoring devices to be used in clinical care and sport medicine. The proposed LNPs microneedles platform can be applied also for the detection of other important bioanalytes (such as lactate, hormones, etc).

S1. Nano(bio)Sensors and Bioelectronics
Poster

29 Development of an Enzyme Coated Microcantilever-Based Biosensor for Specific Detection of Short–Chain Alcohols

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This paper describes the development of a biosensor designed to enzymatic detection of short-chain alcohols. The biorecognition element, alcohol dehydrogenase, was immobilized on self-assembled monolayers deposited on top of silicon nitride microcantilevers. The self-assembly process was performed by surface activation using 3-aminopropyltriethoxysilane, followed by glutaraldehyde and biomolecule binding. X-ray photoelectron spectroscopy and atomic force microscopy were used. The biosensor showed a lower response time, a sensibility from 0.03 to 1.2 mL/L. Its selectivity was analyzed through exposure to pure and mixed volatile solvents. Sensor sensibility was higher in the presence of short-chain alcohols family and practically null involving others polar or nonpolar solvents.

Abstracts

Session 2. Chemical Sensors

Abstract

30 Assessment of a Portable Multi-Gas Sensor System for Discrimination and Monitoring of Unpleasant Odours in a Poultry Shed

Mohammed Moufid [1], Nezha El Bari [1], Tiebe Carlo [2], Matthias Bartholmai [2] and Benachir Bouchikhi [1]

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Unpleasant odours are a natural part of chicken production, which can rather be perceived as odour nuisance by residents at near living areas and may cause anger. Therefore, developing effective could help reducing their effects. This paper describes an artificial sensory odour monitoring system (also known as electronic nose) based on six metal oxide semiconductor gas sensors for discriminating and monitoring malodour emissions from poultry farms. The sample collection was carried out in one week on three different days, with a two-day interval between each sampling. For each hour of sampling (9 a.m, 12 p.m and 6 p.m), fourteen samples were collected using 2 L Tedlar bag. The samples were then pumped to the measuring cell of the developed system. The measuring time for each sample is 15 min. Three features (area, slope and maximum) were extracted from the response of each sensor. The obtained data were processed using pattern recognition methods such as Discriminant Function Analysis (DFA) and Support vector machines (SVMs). Additionally, the effect of relative humidity and temperature on sensor responses were studied. The odour samples onsite the poultry farms were correctly discriminated according to their location, date and time of sampling. In addition, the electronic nose allows clearly distinguishing between polluted and clean air samples. The obtained results suggested that the developed odour monitoring system provides a fast, economical and efficient tool for poultry farm malodour monitoring.

S2. Chemical Sensors
Oral Presentation
Abstract

31 Disclosing the Sensitivity and Selectivity of Metal Oxide/Graphene Oxide-Based Chemoresistors towards VOCs

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The development of high-performing sensing materials, able to detect ppb-trace concentrations of volatile organic compounds (VOCs) at low temperatures and in the presence of interfering species, is required for the development of next-generation miniaturized wireless sensors. Herein, we present the engineering of highly sensitive chemical sensors, comprising of different Metal Oxide Semiconductors (MOS as ZnO, SnO_2 and TiO_2) layouts. Moreover, in order to enhance the selectivity, SnO_2-TiO_2-GO solid solutions were synthesized via a simple hydrothermal route, varying the titanium content in the tin dioxide matrix in the case of solid solutions. The toluene and acetone gas sensing performances of the as-prepared sensors were systematically investigated. Interestingly, at 350 °C, as $Sn_{0.55}Ti_{0.45}$-GO showed promising sensing behavior towards bigger and non-polar gaseous molecules, such as toluene. In particular, these solid solutions seem to be much more selective towards this species rather than acetone one; even if, in both cases, hundreds of ppb concentrations were detected. Conversely, at either high or room temperature conditions, SnO_2-GO showed a higher selectivity towards more polar molecules, as acetone ones. Hence, we believe that these findings can provide guidelines for the engineering of the next generation of miniaturized chemoresistive sensors for selective room-temperature detection of various VOCs.

S2. Chemical Sensors
Oral Presentation
Abstract

32 Fluorescent Carbon Nanodots as Sensors of Toxic Metal Ions and Pesticides

Federico Bruno [1], Alice Sciortino [1], Gianpiero Buscarino [1,2], Marco Cannas [1], Franco Mario Gelardi [1], Simonpietro Agnello [1,2] and Fabrizio Messina [1,2]

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Carbon Dots (CDs) can be defined as carbon nanoparticles with a size from 1–10 nm, with absorption and photoluminescence activity in the UV-vis range. CDs can have crystalline or amorphous structure, this wide range of structures opens up the possibility to design different CDs. The luminescence properties of CDs change not only according to the type of structure, but also according to the type of chemical group that covers the surface, such as: amino groups, carboxylic or ester groups and others. In this work we synthesized CDs with a bottom up approach and we obtained two different CDs graphitic and diamond like, they were purified with Size Exclusion Chromatography (SEC) in order to obtain fairly pure CDs for sensing tests. They have been characterized to study the optical properties with spectroscopic techniques like absorption and fluorescence spectroscopic and with Raman spectroscopic and Atomic Force Microscopy (AFM) we studied the different structure and the morphology of the CDs. Finally with fluorescence we evaluated the interactions between CDs and pollutants.

S2. Chemical Sensors
Oral Presentation
Abstract

33 Palladium Nanoparticles Decorated Electrostatically-Formed Nanowire Sensor for High Performance Hydrogen Gas Detection

Anwesha Mukherjee [1], Mohamad Gnaim [1], Idan Shem Tov [1], Joseph Hayon [1] and Yossi Rosenwaks [1]

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CMOS based Electrostatically-Formed Nanowire (EFN) sensor is based on a silicon nanowire field-effect transistor (FET) with a nanowire that is electrostatically formed and controlled by post fabrication. The EFN-FET is composed of doped silicon region surrounded by three gates: bottom gate and two lateral junction gates. Appropriate biasing at the gates induces depletion regions at the gate-silicon interfaces and an un-depleted silicon region which is electrostatically shaped into a wire of several nm in diameter is now available for conduction. Target gas molecules get adsorbed on the SiO_2 surface and via field-effect modifies the current conduction through the nanowire. Further, surface functionalization of these EFN sensors by metal nanoparticles could be an effective approach to achieve selectivity towards gases. For example, Pd nanoparticles (1 nm) decorated EFN (Pd-EFN) sensor shows promising results towards hydrogen gas. It shows excellent sensor responses at all concentrations ranging from 0.2 to 2.56% with quick response and recovery times. Also, the responses are linear over the entire concentration range and shows good repeatability. A low detection limit of 200 ppm (with a sensor response of 500%) is achieved which is much lower than the lower explosive limit of hydrogen gas which is 4%. The sensor retains good performances even in humid conditions with 80% RH. The sensor performances can further be tuned through application of different gate biases. A comparison of the performance metrics with the state of the art hydrogen sensors show that Pd-EFN proves to be a promising hydrogen sensor.

34 Self-Assembled Monolayers from Symmetrical Di-Thiols: Preparation, Characterization and Application for the Assembly of Electrochemically Active Films

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1,3-dimercaptopropan-2-ol, a symmetrical di-thiol, has been synthesized and applied as a new type of anchor molecule to prepare a self-assembled monolayer (SAM) on the gold surface. The formed monolayers were studied by cyclic voltammetry, impedance spectroscopy, X-ray photoelectron spectroscopy, kinetic capacitance, and contact angle measurements. The SAM structure depends on the adsorption conditions. A short incubation time of the electrode at high concentration of this di-thiol leads to the predominating binding through one thiol group of the adsorbate to the gold surface, while a long incubation at low concentration leads to the predominating binding by both thiol groups. A comparative study of the desorption and replacement of SAMs indicates a strong stability increase when the SAM molecules bond gold surface by two bonds mainly. This monolayer was used to immobilize electrochemically active *p*-benzoquinone moiety. The surface concentration of *p*-benzoquinone obtained from cyclic voltammetry is $2.5 \pm 0.2 \times 10^{-10}$ mol.cm^{-2} which corresponds to the functionalization of 65 ± 5% of SAM molecules. The obtained highly stable SAM with redox-active terminal group can be applied for different tasks of chemical sensing and biosensing. As an example, an application of this system for electrocatalytical oxidation of dihydronicotinamide adenosine dinucleotide (NADH) was tested.

35 Supramolecular Functionalized Pristine Graphene Utilizing a Bio-Compatible Stabilizer towards Ultra-Sensitive Ammonia Detection

Shirong Huang [1], Luis Antonio Panes-Ruiz [1], Alexander Croy [1], Leif Riemenschneider [1], Vyacheslav Khavru [2], Viktor Bezugly [1,2,3] and Gianaurelio Cuniberti [1,3,4]

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Recently, Graphene has attracted intensive attention in the gas sensing field due to its high electrical conductivity as well as large specific surface areas. Lots of graphene-based gas sensor have been reported with excellent gas sensing performance. However, the sensing element materials for most of the above sensors are actually consisted of reduced graphene oxide (GO) derivative rather than pristine graphene, like rGO, rGO/metal particle, rGO/polymers etc. Complex chemical oxidation and reduction are usually involved for the preparation of reduced graphene oxide derivatives. Even though there are some pristine graphene-based gas sensor synthesizing with the approaches of chemical vapor deposition (CVD) or mechanical cleavage, the high cost of the set-up or the low productivity cannot decrease the cost of the practical sensors. In this work, we develop pristine graphene-based gas sensors utilizing flavin monocleotide sodium salt (FMNS) towards ultra-sensitive ammonia detection. The sensor has 3% response upon exposure to 10 ppm NH_3 and a limit of detection of 1.6 ppm at room temperature and shows a good recovery. Raman, UV-vis, FT-IR spectra, as well as SEM measurements are employed to characterized the quality of the graphene flakes, indicating a good structural quality of graphene with few defects. The effects of concentration of graphene dispersion functionalized by FMNS on sensing performance towards ammonia sensing were also investigated. The process is very mild, environmentally friendly, and low cost. We believe this work may pave a path to design high performance gas sensor with low cost and boost the application of graphene for sensing.

36 Two Orders of Magnitude Improvement in the Detection Limit of Droplet-Based Micro-Magnetofluidics with Planar Hall Effect Sensors

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The detection, manipulation and tracking of magnetic nanoparticles is of major importance in the fields of biology, biotechnology, biomedical applications as labels as well as in drug delivery, (bio-)detection and tissue engineering. In this regard, the trend goes towards improvements of existing state-of-the-art methodologies in the spirit of timesaving, high-throughput analysis at ultra-low volumes. Here, microfluidics offers vast advantages to address these requirements as it deals with the control and manipulation of liquids in confined microchannels. This conjunction of microfluidics and magnetism, namely micro-magnetofluidics, is a dynamic research field, which requires novel sensor solutions to boost the detection limit of tiny quantities of magnetized objects. We present a sensing strategy relying on planar Hall Effect (PHE) sensors in droplet-based micro-magnetofluidics for the detection of a multiphase liquid flow, i.e., superparamagnetic aqueous droplets in an oil carrier phase. The high resolution of the sensor allows the detection of nanoliter-sized superparamagnetic droplets with a concentration of 0.58 mg cm^{-3}, even when they are biased in a geomagnetic field only. The limit of detection can be boosted another order of magnitude reaching 0.04 mg cm^{-3} (1.4 million particles in a single 100 nL droplet) when a magnetic field of 5 mT is applied to bias the droplets. With this performance, our sensing platform outperforms the state-of-the-art solutions in droplet-based micro-magnetofluidics by a factor of 100. This allows us to detect ferrofluid droplets in clinically and biologically relevant concentrations and even below without the need of externally applied magnetic fields.

S2. Chemical Sensors
Poster
Abstract

37 Acetone Bio-Sniffer (Gas-Phase Biosensor) for Monitoring of Human Volatile Using Enzymatic Reaction of Secondary Alcohol Dehydrogenase

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We developed a highly sensitive acetone bio-sniffer (gas-phase biosensor) based on an enzyme reductive reaction to monitor breath acetone concentration. The acetone bio-sniffer device was constructed by attaching a flow-cell with nicotinamide adenine dinucleotide (NADH)-dependent secondary alcohol dehydrogenase (S-ADH) immobilized membrane onto a fiber-optic NADH measurement system. This system utilizes an ultraviolet light emitting diode as an excitation light source. Acetone vapor was measured as fluorescence of NADH consumption by the enzymatic reaction of S-ADH. A phosphate buffer that contained oxidized NADH was circulated into the flow-cell to rinse the products and the excessive substrates from the optode; thus, the bio-sniffer enables real-time monitoring of acetone vapor concentration. A photomultiplier tube detects the change in the fluorescence emitted from NADH.

The relationship between fluorescence intensity and acetone concentration was identified from 20 ppb to 5300 ppb. This encompasses the range of concentration of acetone vapor found in breath of healthy people and of those suffering from disorders of carbohydrate metabolism. Then, the acetone bio-sniffer was used to monitor exhaled breath acetone concentration change before and after meal. When the sensing region was exposed to exhaled breath, fluorescence intensity decreased and reached to saturation immediately. Then it returned to the initial state upon cessation of the exhaled breath flow. We anticipate its future use as a non-invasive analytical tool for assessment of lipid metabolism in exercise, fasting and diabetes mellitus.

38 Development of Enzymatic Biosensors to Detect Biocides Disinfectants to Strengthen Self-Monitoring in Industry

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Biocides disinfectants are used in agro-food industries in order to limit the development of pathogens present in environment or on surfaces in contact with food for human or animal consumption. Persistent biocide residues may constitute a toxicological risk for the consumer. Very little feedback from the field on the rates of biocides residues in the industry exist due to a deficit of simple, fast and responsive self-checking methods. Despite the fact that their limits of detection are high, the strip tests are most used. The development of biosensors for the detection of biocides represent a promising way to explore but most of this research remains limited. Many biosensors have been developed for the detection of pesticides in different environmental and food matrices based on enzymes whose activity is modified in their presence. Among the enzymes most frequently used acetylcholinesterase only has been exploited for the detection of a biocide disinfectant. Through the long experience on the detection of pesticides with biosensors, this work will highlight the interest of developing biosensors for the detection of biocides disinfectants in water and in food products.

S2. Chemical Sensors
Poster
Abstract

39 Electrical Control of the Receptor Affinity

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A concept of virtual sensor array based on electrically controlled variation of affinity properties of the receptor layer was realized on the base of integrated electrochemical chemotransistor containing conducting polymer as the receptor layer. An electrical control of the redox-state of the polymer (polyaniline) was performed in five-electrode configuration with four electrodes for conductivity measurements and Ag/AgCl reference electrode integrated on the same glass chip. Using an ionic liquid was provided electrical connection between the reference electrode and chemosensitive material. Conductivity measurements demonstrated potential controlled electrochemical conversions of the receptor material between different redox-states. Binding of trimethylamine at three different potentials, corresponding to these states was studied. The results demonstrated that both kinetic- and equilibrium binding properties of the receptor are controlled by electrical potential thus providing a possibility to form a virtual sensor array using only a single sensing element. The concept was applied for monitoring of fish headspace. Using three characteristics of the sensor response measured at three different redox states of the same sensor material, we have obtained signals from a virtual sensor array consisting of nine chemosensitive elements. The sensor displays systematic changes of its nine signals during fish degradation. This approach can be applied also for the electrical control of affinity of immunoglobulins. A development of a new materials with conducting electrically controlled affinity is in progress.

S2. Chemical Sensors
Poster
Abstract

40 Electrocatalytical Chemical Sensor for Hydrogen Peroxide

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The fast and selective determination of hydrogen peroxide (H_2O_2) is of importance not only because of strong interest to this widely applied analyte but also because of the development of enzymatic biosensors for glucose or other metabolites where the sensor for H_2O_2 can be used as the transducer. We report here electrocatalytical amperometric sensor for detection of H_2O_2. The sensor consists of a gold electrode covered by self-assembled monolayer (SAM) with immobilized *p*-benzoquinone. To provide highly stable immobilization of *p*-benzoquinone at the distance of effective electron tunneling, a new anchor compound—1,3-dimercaptopropan-2-ol—was synthesized and used for the preparation of the SAM. Due to two thiol groups binding gold surface this compound provides a high stability of the SAM. The surface concentration of *p*-benzoquinone obtained from cyclic voltammetry is $2.5 \pm 0.2 \times 10^{-10}$ mol.cm^{-2}. Cyclic voltammetry and chronoamperometry experiments proved that the immobilized benzoquinone exhibited high electrocatalytic activity towards the decomposition of H_2O_2. Amperometric response at fixed potential of +0.4 V vs. Ag/AgCl corresponding to the oxidation of benzoquinone to hydroquinone was studied. The sensor exhibited a linear response over a concentration range of 0.1–2 mM with a low detection limit of 4.24 μM. The reproducibility of three different electrodes prepared was examined at the H_2O_2 concentration range from 0.1 till 3 mM, which resulted in a relative standard deviation below 4.2%.

S2. Chemical Sensors
Poster
Abstract

41 Low Power Multi-Sensors for Selective Gas Detection

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The aim of this work is the realization of a generic gas multi-sensor device based on MOX sensitive layer. We have designed and modeled a novel detection system with several heating zones associated with three sensors supported on a few micrometers thickness membrane. The design has been optimized to overcome the problems of response stability and selectivity, and to reduce the power consumption. The heat repartition and the power consumption in function of the membrane thickness were studied by finite element simulations. The results show that a membrane thickness of 4 μm decrease the heater temperature of more than 100 K versus 2 μm thickness. Ethanol detection performances were studied. The thermo-electrical characterization concluded that the three detection areas can be heated at 533 K with a power of 53 mW. One sensor was tested in ethanol. The sensor response in 1 ppm and 100 ppm of ethanol in 50% relative humidity atmosphere was of 1.4 and 9.2 respectively. We demonstrated that this detection device can detect ethanol with high sensitivity and stability in dry and humid air with a reduced power consumption resulting in 18 mW per sensor.

S2. Chemical Sensors
Poster
Abstract

42 New Potentiometric Surfactant Sensor for Anionic Surfactants Determination in Real System Containing Amphoteric Surfactants

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Surfactants are used for washing, cleaning and disinfection in many every-day products like detergents, cleaning agents, cosmetics, but also in a broad spectra of industry (detergents, pharma, oil exploitations, textile, etc.). Surfactants are divided into four groups: anionic, cationic, nonionic and amphoteric. On the global scale, the demands for surfactants are constantly growing (CAGR of 4.5%. from 2020 to 2025) mainly because of the population growth and life-standard increase. This will make an additional pressure on surfactant pollution of waters. For this reason, it is important to establish fast and sensitive analytical tools for surfactant quantification in water, but also as a quality control tools in production processes.

New ion-pair 1,3-dihexadecyl-1*H*-benzo[*d*]imidazol-3-ium-tetraphenylborate (DHBI-TPB) was used as an ionophore for fabrication of PVC-based potentiometric surfactant sensor for quantification of anionic surfactants in real samples. Direct potentiometric response measurements showed excellent response characteristics with a Nernstian slope in the linear response region for all investigated surfactants. Developed surfactant sensor was used for potentiometric titrations of anionic surfactants in model and real samples containing amphoteric surfactants betaine or amine oxide, and showed excellent performances and good recoveries. The sensor showed high stability, reproducibility and long-lifetime.

S2. Chemical Sensors
Poster
Abstract

43 Sensing of Nickel(II) Ions by Immobilizing Ligands and Using Different SPEs

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The aim of this paper is the development of a sensor for the quantification of nickel ions in food raw materials and foods. It seems that about 15% of the human population suffers from nickel allergy. In addition to digestive manifestations, food intolerance to nickel may also have systemic manifestations, such as: diffuse dermatitis, diffuse itching, fever, rhinitis, headache, altered general condition. Therefore, it is necessary to control this content of nickel ions for the health of the human population by developing this new method that brings advantages such as: it is fast, not expensive, in situ and provides accurate analysis. For this purpose, bismuth oxide –SPEs (screen-printed electrodes) and graphene modified SPEs were used with very small amount of dimethylglyoxime and amino acid L-histidine which were deposited. A potentiostat which displays the response in the form of a cyclic voltammogram was used to study the electrochemical properties of nickel standard solution with different concentration. The results were compared and the most sensitive sensor proved to be bismuth oxide –SPEs with dimethylglyoxime (Bi_2O_3/C—$dmgH_2$) with a linear response over a wide range (0.1–10 ppm) of nickel concentrations. Furthermore, the sensor shows excellent selectivity in the presence of common interfering species. The Bi_2O_3/C—$dmgH_2$ sensor showed good viability for nickel analysis in food samples (cocoa, spinach, cabbage and red wine) and demonstrated significant advancement in sensor technology for practical applications.

S2. Chemical Sensors
Poster
Abstract

44 Tungsten Oxide Based Hydrogen Gas Sensor Prepared by Advanced Magnetron Sputtering

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In this study, we demonstrate the advantages of two advanced sputtering techniques for the preparation of a thin-film conductometric gas sensor. We combined tungsten oxide (WO_3) thin films with other materials to achieve enhanced sensorial behavior towards hydrogen. Thin films of WO_3 were prepared by the DC and HiPIMS technique, which allowed us to tune the phase composition and crystallinity of the oxide by changing the deposition parameters.

Then, the second material was added on-top of these films. We used the copper tungstate $CuWO_4$ in a form of nano-islands deposited by reactive rf sputtering and Pd particles formed during conventional dc sputtering.

The specimens were tested for the response to a time-varied hydrogen concentration in synthetic air at various temperatures. The sensitivity and response time were evaluated. The performance of individual films is presented as well as the details of the synthesis.

Advanced magnetron techniques (such as HiPIMS) allow us to tune the property of the film to improve the sensorial behavior. The method is compatible with the silicon electronics industry, which consists of a few steps that don't require any wet technique and films can be used in an

as-deposited state. Therefore, sensorial nanostructured materials prepared by magnetron sputtering are very suitable for use in miniaturized electronic devices.

S2. Chemical Sensors
Poster
Abstract

45 ZnO Low-Dimensional Thin Films Used as a Potential Material for Water Treatment

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In this paper the properties of zinc oxide (ZnO) low-dimensional conductive oxide nanostructures in the aspect of their potential applications in microelectronics, in toxic gas sensors as well as checking whether they can be also used in water treatment has been determined. ZnO nanostructured porous thin films deposited by DC reactive sputtering (RS) have been deposited on Si substrates at different temperature conditions. For the surface properties and chemical morphology analysis the X-ray photoelectron spectroscopy (XPS) and atomic force microscopy (AFM) have been used. Thanks to those methods, it is possible to obtain information on changes in the structure caused by the adsorption of various gases from the atmosphere, mainly C pollution from air, but also from the water. Investigated ZnO thin films were also tested for their photocatalytic properties performed in UV light. For this purpose the methylene blue as a dye pollutant to evaluate the activity of the nanostructures has been used. Within this work it has been observed that the ZnO thin films, which were used, react in the selected environment and their presence reduces the amount of dye. This shows that in addition to sensor properties, properly selected zinc oxide nanostructures, used so far in toxic gas sensors, can also be used in the process of water purification and treatment, which is crucial in protecting the natural environment primarily from various types of dyes or also medicines.

S2. Chemical Sensors
Poster
Abstract

46 ZnO/RGO Heterojunction Based near Room Temperature Alcohol Sensor with Improved Efficiency

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Systematic optimization of surface engineering (dimensionality) indeed plays a crucial role for achieving efficient vapor sensing performance. Among various semiconducting metal oxides, owing to some of its unique features and advantages, ZnO has attracted worldwide researchers for application in various fields including chemical sensors. Concomitant optimization of the surface attributes (varying different dimensions) of ZnO became a sensation for the entire research family. Moreover, the small thickness and extremely large surface of exfoliated 2D nanosheets render the gas sensing material as an ideal candidate, for achieving strong coupling with different gas molecules. However, temperature is a crucial factor in the field of chemical sensing. Recently, graphene-based gas sensors have attracted attention due to their variety of structures, unique sensing performances and room temperature working conditions. In this work, highly sensitive and fast responsive low temperature (60 °C) based ethanol sensor, based on RGO/2D ZnO nanosheets hybrid structure, is reported. After detailed characterizations, vapor sensing potentiality of such sensor was tested for the detection of ethanol. The ethanol sensor offered the response magnitude of 89% (100 ppm concentration) with response and recovery time of 12 s/29 s respectively. Due to excessively high number of active sites for VOC interaction, with high yield synthesis process and appreciably high carrier mobility, paved the path for developing future generation, miniaturized and flexible (wearable) vapor sensor devices meeting the multidimensional requirements for traditional and upcoming (health/medical sector) applications. Underlying mechanistic framework for vapor sensing, through such hybrid junction, was explained with the Energy Band Diagram.

S2. Chemical Sensors
Poster
Abstract

47 Fix-Wavelength Multi-Analyte Detection with serial SOI Ring Resonators

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We present a method for the read-out of five serially arranged SOI ring resonator-based biosensors at a speed of 3 Hz/sensor and at a fixed wavelength of 1550 nm. The system uses the high thermo-optical coefficient of silicon by applying AC voltages to periodically heat up electrodes adjacent to each sensor. A time-division multiplex scheme allows the allocation of the measured optical output from the mutual spectrum to each specific resonator. We demonstrate our system by immobilizing two different antibodies (biotin and a hexa-His-peptide) at the surface of selected resonators and successfully showing the selective binding characteristics of analyte-probing in a microfluidics supported experiments.

48 Low Cost, High Sensitivity Detection of Waterborne Al^{3+} Cations and F- Anions Via the Fluorescence Response of a Morin Derivative Dye

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Morin dye is known as a cheap and readily available selective ‘off → on’ fluorescent sensitiser when immobilised in a phase transfer membrane for the detection of Al3+ ions. Here, a morin derivative, NaMSA, which readily dissolves in water with good long- term stability is used in conjunction with a fibre optic transducer with lock-in detection to detect Al3+ in drinking water below the potability limit. The combination of a water soluble dye and the fibre optic transducer require neither membrane preparation nor a fluorescence spectrometer yet still display a high figure- of- merit. The known ability to recover morin- based Al3+ cation sensors selectively by exposure to fluoride (F−) anions is further developed enabling a complementary sensing of either fluoride anions, or aluminium cations, using the same dye with a sub- micromolar limit-of-detection for both ions. The sensor performance parameters compare favourably to prior reports on both aqueous aluminium and fluoride ion sensing.

Abstracts

Session 3. Physical Sensors

Abstract

49 Measurement of PM10 and PM2.5 Using SAW Sensors-Based Rayleigh Wave and Love Wave

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Particulate matter (PM) is reported as dangerous and can cause respiratory and health issues. Regulations, based on PM concentration, have been implemented to limit human exposition to air pollution. An innovative system with Surface Acoustic Wave (SAW) sensors combined to 3 Lpm cascade impactor was developed in our team for real time mass concentration measurements. In this study, we compare the PM sensitivity of two types of SAW sensors. The first one consists of delay lines based on Rayleigh waves propagating on a Lithium Niobate Y-X 128° substrate and the second one is a based-on Love waves on AT-Quartz. The aerosols were generated from NaCl for PM2.5 and from Silicon carbide for PM10. The sensor's response was compared to a reference sensor based on optical measurement. The sensitivity of the Rayleigh wave based sensor is clearly lower than the Love wave sensor for both PM. Although less sensitive, Rayleigh wave sensors are very promising for the development of self-cleaning sensors using RF power due to their high electromechanical factor. To check the performance of our system in real conditions, we tested the sensitivity to PM from cigarette smoke using Rayleigh SAW. The PM2.5 stage shows a phase shift while the PM10 does not respond. This result agrees with previous studies which report that the size of particles from cigarette smoke varies between 0.1 to 1.5 μm. A good correlation between the reference sensor's response and the phase variation of SAW sensors was obtained.

Abstract

50 Design and Potential Analysis of an Eddy Current Sensor for Inductive Conductivity Measurement in Fluids

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Eddy current inductive sensors have the potential to become a cost-effective alternative to the industrial standard of transformer-type inductive conductivity sensors (TICS). In the scope of this paper, a first exemplary eddy current sensor for sea water conductivity measurement is developed, based on the derived sensor theory of a previous work. The sensor consists of a ferrite rod carrying two solenoids for excitation and sensing. By a high frequency excitation with a small current, eddy currents are induced in the fluid. The counter-fields are measured with the sensing coil. Since the conductivity of sea-water is comparably low, the resonance point of the coil is used to amplify this effect. The developed prototype is analyzed based on a derived transfer function and FEM-Simulations, to characterize the sensor in optimal conditions. The theory is validated using an implementation. With conducted experiments on a sensor test bench, the characteristic could be confirmed and disturbances identified. Changing temperature has a great effect on the resonance damping due to the correlated copper resistance. However, temperature and conductivity changes have slightly different effects on the frequency spectroscopy, which allows to distinguish between both. The authors were able to prove this also by the derived transfer function. As a result, the experiments can confirm the theoretical understanding of the eddy current sensor. This gives a perspective for a novel sensor to allow sea water conductivity measurement. Yet, the current implementation is to unstable for high resolution measurements and needs further improvements.

S3. Physical Sensors
Oral Presentation
Abstract

51 Hafnium Zirconium Oxide Thin Films for CMOS Compatible Pyroelectric Infrared Sensors

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Pyroelectric infrared sensors are often based on lead-containing materials, which are harmful to the environment and subject of governmental restrictions. Ferroelectric $Hf_{1-x}Zr_xO_2$ thin films offer an environmentally friendly alternative. Additionally, CMOS integration allows for integrated sensor circuits, allowing for scalable and cost-effective applications. In this work, we demonstrate the deposition of pyroelectric thin films on area-enhanced structured substrates via thermal atomic layer deposition. Scanning electron microscopy indicates a conformal deposition of the pyroelectric film in the holes with a diameter of 500 nm and a depth of 8 μm. By using TiN electrodes and photolithography, capacitor structures are formed, which are contacted via the electrically conductive substrate. Ferroelectric hysteresis measurements indicate sizable remanent polarization of up to 331 μCcm^{-2}, which corresponds to an area increase of up to 15 by the nanostructured substrate. For pyroelectric analysis, a sinusoidal temperature oscillation is applied to the sample. Simultaneously, the pyroelectric current is monitored. By assessing the phase of the measured current profile, the pyroelectric origin of the signal is confirmed. The devices show sizable pyroelectric coefficients of −475 $\mu Cm^{-2}K^{-1}$, which is larger than that of lead zirconate titanate (PZT). Based on the experimental evidence, we propose $Hf_{1-x}Zr_xO_2$ as a promising material for future pyroelectric applications.

S3. Physical Sensors
Oral Presentation
Abstract

52 Towards Integrated Plasmonic Gas-Sensors in the Mwir

Andreas Tortschanoff [1], Jasmin Spettel [2], Thang Dao [1], Cristina Consani [1], Clement Fleury [1], Florian Dubois [1], Gerald Stocker [2], Thomas Grille [2], Thomas Ostermann [2], Reyhaneh Jannesari [3] and Gerald Pühringer [3]

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Integrated environmental sensing for personal health care monitoring is a topic of increasing interest. Optical measurement approaches could provide intrinsic selectivity and the sensitivity, required for the development of integrated gas sensors. In an ongoing project, we work towards a Si-photonics non-dispersive infrared gas sensor and are investigating the possibility of the incorporation of IR-active plasmonic materials, which could allow to increase sensitivities and reduce size of such sensors. We will first present the overall idea of combining pillar photonic crystal waveguides with plasmonic elements to provide maximal interaction with gaseous analytes, which was proposed, recently. Then, we describe the characterization of the very first test structures, which were fabricated. Reflectivity measurements on grating structures allow the detailed characterization of the plasmon resonances, which can also be related to theoretical estimations and FEM simulations. The simulation results predicted narrow line widths of only a few wavenumbers for Ag coated gratings, which were, indeed, observed in reflectance measurements with a quantum cascade laser at 4.26 μm. We hope that approaches incorporating plasmonic structures will significantly extend the range of possibilities in the field of integrated infrared sensors.

S3. Physical Sensors
Oral Presentation
Abstract

53 Ultra-Wideband Localization of Pulmonary Nodules during Thoracoscopic Surgery

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Lung cancer is one of the most common causes of cancer-related death worldwide. It is usually detected by CT or MRI and removed through thoracoscopic surgery. However, during the surgery, the lung collapses and a new determination of the position of the pulmonary nodule is necessary which is particularly challenging in the case of minimally invasive surgeries when palpation is not possible. In this contribution, ultra-wideband (UWB) radio technology, which employs a short burst of high-frequency electromagnetic waves, is studied to localize the pulmonary nodule. In short, an antenna in close proximity with the lung surface produces a signal and the echo coming from discontinuities in the lung tissue, i.e., the pulmonary nodule, is used for the localization. A similar approach was already proposed for breast cancer. Simulations were used to explore the relationship between frequency range and penetration depth and showed that shallow nodules, below 2 cm in depth, are difficult to resolve because the echo directly interferes with the propagating signal. On the other hand, given the strong electromagnetic attenuation of lung tissue, echo coming from near organs is suppressed and frequency-band tuning can be employed to range the depth of the investigation. Ultimately, this contribution shows how to employ and design UWB technology to localize deep pulmonary nodules through a minimally invasive approach.

54 Uncertainty Analysis for Low-Cost Transformer Type Inductive Conductivity Sensors

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Transformer-type inductive conductivity sensors (TICS) are the industry standard for long-term conductivity measurement in fluids, since inductive sensors have the major advantage of being protected from corrosion and biofouling. However, TICS are more expensive than conductivity cells, due to the greater complexity of the sensor design. With an increasing demand for large-scale monitoring in oceanography and industry, there is a great need for low-cost inductive conductivity sensors. This paper therefore analyzes the potential of TICS with reduced complexity for the use as a low-cost alternative.

While the theory and design of TICS is well documented by numerous publications, there is little information published about the sensor uncertainty factors, as well as the implementation of low-cost TICS alternatives. In the scope of this work, a simple and cost-effective prototype was manufactured based on the results by Hui et al.. Developed TICS was characterized and compared to a high precision industry standard inductive sensor. In various experiments, linearity and hysteresis error, the short- and long-term reproducibility and temperature error was quantified. The results were interpreted in regards to core material, geometric properties and noise shielding. After temperature compensation, the measurement uncertainty was determined to be around 0.3%, within the operational range between 0 to 60 mS/cm. Considering the outcome of the experiment, this paper provides a better understanding of performance and uncertainty characteristics in order to improve the design of low-cost transformer type inductive conductivity sensors.

S3. Physical Sensors
Poster
Abstract

55 Carrier Mobility in Semiconductors at Very Low Temperatures

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There are a growing number and variety of low-temperature applications of microelectronic devices and micro-electromechanical systems (MEMS) in different areas of science, technology, and medicine. The development and precise functionality of devices at cryogenic temperatures require the detailed knowledge of physical parameters of a large number of materials even in the case of MEMS. For instance, only a few data exist about carrier concentration and mobility in bulk silicon and diffused silicon layers down to liquid helium temperature (T = 5 K) and even below making, among others, applications of TCAD simulation tools for device development difficult. The present paper deals with comprehensive measurements (Hall measurements) of carrier concentration and mobility especially in diffused layers in the temperature range 0.3 K ≤ T ≤ 300 K. The type of the dopant, concentration, and thickness of the layers are varied over a large range. The data are compared with measurements on bulk samples and reference data given in the literature. Effects on the functionality and precision of devices are measured and discussed in the case of temperature sensors. Measured data are integrated into semi-classical and quantum mechanical TCAD simulation tools. The effect of the observed data on simulation results is demonstrated for future high-precession temperature sensors.

S3. Physical Sensors
Poster
Abstract

56 Effect of Milling Time on the Sensing Properties of Fly Ash Zeolite Composite Thin Films

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The purpose of using zeolites in thin film sensing elements usually is to improve sensitivity and selectivity by preferential adsorption and to assure a fast response time of the sensor. FAU (faujasite) is a rare natural zeolite which has its synthetic counterpart zeolite X and it is widely used because of its structural supercage with large pore size and high specific surface area.

In this study thin films consisting of a sol-gel Nb_2O_5 matrix doped with zeolite Na-X were deposited by the spin-coating method. Fly ash of lignite coal collected from the electrostatic precipitators of one of the biggest TPPs in Bulgaria was used as a raw material for obtaining of zeolites. Zeolite Na-X was synthesized by ultrasonic-assisted double stage fusion-hydrothermal alkaline conversion. In order to improve the optical quality and sensing properties of the thin films synthesized zeolites were wet-milled for 60, 120 and 540 s prior to film deposition. The surface morphology and structure of zeolite powders were studied by scanning electron microscopy and X-ray diffraction, respectively, while their porosity was investigated by N_2-physisorption. Refractive index, absorption coefficient and thickness of the films were determined through reflectance spectra fitting. The liquid adsorption ability of thin films were tested by measuring the reflectance spectra prior to and after exposure to liquid acetone and the change in the reflection coefficient ΔR of the films was calculated. The influence of milling time of zeolites on the sensing and optical properties of the films was studied.

S3. Physical Sensors
Poster
Abstract

57 Evaluating Techniques for Joining Piezo-Electric Elements on Test Structures for Performing Vibration-Based Measurement Methods

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When performing vibration-based measurement techniques e.g., for Structural Health Monitoring, piezo-electric elements are often used as sensor and/or actuator part due to their durability. The connection between the piezo-electric element and the test structure plays a decisive role for the quality of the results obtained in the vibration-based measurement process. In addition to stable and mode-independent vibration transmission, further requirements such as reversibility or temperature resistance can be imposed depending on the application. In many preliminary studies, especially bonding by means of a two-component epoxy resin was practically and simulatively validated for a high amount of use cases. Nevertheless, the limited reversibility and the preparation time of the adhesion process can limit the flexibility of the vibration-based measurement method.

The aim of this work is to evaluate different joining technologies of piezo-electric elements on metal and polymer substrates with special respect to reversibility. Different techniques for joining piezo elements are collected considering previous work as well as newly developed approaches within the scope of the work. In the next step, frequency spectra of simple circular blanks are obtained using an EMI-setup from piezo elements joined to the blanks with the appropriate joining technique. Joining by means of a two-component epoxy is considered as the reference method. All joining techniques are evaluated especially based on degree of reversibility, transmission quality, effort for implementation and durability in comparison to the reference method. Finally, recommendations regarding the proper joining technique for different experimental conditions will be given based on the results.

58 Prototyping Platform for Laser-Based Sensor Technologies: Inspection of Conversion Coatings on Alumina

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Transferring laser-based sensors into industrial applications, for instance for the contact-& destruction-free inline quality control of alumina alloys, is very challenging due to laser-safety requirements and the complex implementation in individual technological infrastructures. In order to open laser-based sensor technology even for small to medium size enterprises, we introduce a prototyping platform for laser-based sensor technologies that enables the fast, error-free, flexible and low cost transformation into industry. As an example, the transformation of the laser-based sensor concept using coherent light scattering at technical insulating films (M. Imlau et al., J. Oberfl. Techn. 59, 46 (2019)) is shown. The transformation of this type of sensor is particularly demanding due to the requirement of probing transparent conversion coatings, with a thickness of less than 70 nm so that commonly applied electronic techniques fail. The conversion films are produced on the top of cold-rolled, unpolished alumina so that coherently scattered laser light is regarded as superposition from diffuse scattering processes at the surfaces/interfaces, inclusions and/or layer imperfections. Analysis is realized by extending the principle approach of reflectometry by considering the role of diffuse and specular scattering together with the concepts of light interferometry. The functionality of the transformed sensor is validated using different conversion coating thicknesses on AA3003 alumina substrates.

S3. Physical Sensors
Poster
Abstract

59 Theory and Modeling of Eddy-Current Type Inductive Conductivity Sensors for Salinity Measurement

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To measure salinity in solutions, many applications make use of inductive sensors. Compared to electrode-based conductive sensors, inductive sensors are less prone to biofouling and polarization. Although inductive sensors are well suited for long time operations, distributed monitoring applications, such as low-cost sensor drifter, suffer under high costs. Industrial standard for inductive sensors is the transformer type sensor. An alternative approach is a design based on the eddy current effect, which is different by using magnetic flux through the water. However, the research presented until now is mostly of empirical nature. This paper presents a new theoretical description for inductive eddy current sensors. The fundamental functionality is based on Maxwell's equations and allows an equivalent electrical RLC-circuit representation. The derived model proves that rather than a changing permeability of the fluid, the damping effect by the eddy currents determines the behavior of the sensor. For model validation, magnetic FEM-Simulations and practical experiments with prototypes were conducted. The results confirmed the modeling approach. With the aim to provide fundamentals for future development of more cost-efficient and smaller sensors, this paper gives a better understanding of the physical effects of this sensor type.

S3. Physical Sensors
Poster
Abstract

60 Computer support of analysis optical spectra measurements

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Verification of measurement errors has a big impact on assessment of accuracy of conducted measurements and obtained results. In many cases computer simulation results are compared with measurement results in order to evaluate measurement errors.

The purpose of our research was to check the accuracy of measurements made with Fabry-Perot interferometer working in the transmission mode. In measurement setup, a 1310 nm superluminescent diode light source, single-mode optical fibres and optical spectrum analyser were used. Influence of length of resonating cavity and refractive index on the envelope of interferogram was investigated.

We created a program that models envelope of the interferogram on the basis of: length of the resonating cavity, refractive index and light source output spectral characteristic, which in simulation, was assumed to have shape of Gaussian distribution. After the simulation the program compares simulated and measured interferograms.

The comparison of simulated and measured interferograms proved to be challenging due to the shift in the position of the central peak between the simulated and measured interferogram. There are two ways to perform model fitting: by adjusting the position of central peaks or minimums next to the central peak. It was observed, that the second solution was more optimal and was implemented in the program.

S3. Physical Sensors
Poster
Abstract

61 Failure Analysis of Wire Bonding on Strain Gauge Contact Pads using FIB, SEM and Elemental Mapping

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Stacks consisting of titanium, platinum, and gold layers constitute a popular metallization system for the bond pads of semiconductor chips. Wire bonding on such layer stacks at dif-ferent temperatures has extensively been investigated in the past. However, reliable infor-mation on the bondability of this metallization system after a high-temperature sintering pro-cess is still missing. When performing wire bonding after pressure sintering at, e.g., 875 °C, bonding failures may occur that have to be identified and analyzed. In the present study, fo-cused ion beam (FIB), scanning electron microscopy (SEM), and elemental mapping are uti-lized to characterize the root cause of failure. As probable root cause, infusion of metalliza-tion layers is found which causes an agglomerate formation at the interface of approximately 2 μm height difference on strain gauge contact pads and possibly an inhomogeneous mixing of layers as a consequence of the high-temperature sintering process. Potential treatment to tackle this agglomeration with the removal of above-mentioned height difference during the process of contact pad structuring and alternative electrical interconnect methodologies are hereby suggested in this paper.

62 A study of visible-blind properties of a SnO2's nanowires network photodetector

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We developed a SnO2 nanowire network visible-blind ultraviolet (UV) photodetector for applications in fields such as safety systems, exposure control, decontamination processes, among others. Based on the vapor-liquid-solid (VLS) growth method, a SnO2 nanowire network was synthetized. The sensor was fabricated based on a metal-semicondutor-metal (MSM) structure and Ag paste was used as simple and efficient electrical contact. To understand the visible-blind property two light sources were used: UV (254-365 nm) and VIS (400-900 nm) Lamps. In Current – Voltage measurements, the device under dark and room ambient conditions presented rectifier contacts with different barrier heights; whereas under UV illumination, the barrier heights seem to be aligned. It was observed that the sensor's photoresponse was optimized for UV Light with rise and decay time ~1s and 3s, respectively, and exhibiting an on/off ratio of 42.5; whereas as for the VIS light both times were longer with an on/off ratio of 1.7, both under V = + 0.1 V. These results are highly significant for developing of a visible-blind photodetector.

Abstracts

Session 4. Sensor Applications and Smart Systems

Abstract

63 Evaluation of the Electrochromic Response of Polypyrrole in the Presence of CO_2 in the Solution

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The indium tin oxide (ITO) coated glass was used as a working electrode for electrochemical deposition of conducting polymer polypyrrole (Ppy). Before polymerization, the electrode surface was additionally modified with triethoxymethylsilane (TEMS) to provide better adhesion of polypyrrole to the surface of ITO. Polymerization of Ppy was performed electrochemically as it was described in a previous study. The ionic strength of the solution was supported by $LiClO_4$.

Since the dissolved CO_2 in the solution forms the weak acid and thus the pH of a solution can be slightly changed the electrochromic response to the pH changes was evaluated. Britton–Robinson buffer (BRB) was used as the model system for evaluation of the electrochromic response of polypyrrole at different pH values and concentrations of $NaHCO_3$, which was a source of CO_2 in the solution.

For the evaluation of electrochromic response in the presence of CO_2 the double potential step chronoamperometry method was applied and UV-Vis absorption spectra were registered. To gain insight into the charge transfer phenomenon in more detail, the cyclic voltammetry experiments at different glass/$ITO_{(TEMS)}$/Ppy electrode potential sweep rates were performed.

Abstract

64 Wearable xAI: A Knowledge-Based Federated Learning Framework

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Federated learning is a knowledge transmission and training process that occurring in turn between user models at edge devices and the training model at the central server. Due to privacy policies, concerns and heterogeneous data, this is a widespread requirement in federated learning applications. In this work, we use knowledge-based methods and in particular case-based reasoning (CBR) to develop a wearable explainable artificial intelligence (xAI) framework. CBR is a problem-solving AI approach for knowledge representation and manipulation which considers successful solutions of past conditions that are likely to serve as candidate solutions for a requested problem. It enables federated learning when each user owns not only his/her private data, but also uniquely designed cases. New generated cases can be compared to the knowledge base and the recommendations enable the user to communicate better with the whole system. It improves users' task performance and increases user acceptability while they need explanations to understand why and how AI algorithms arrive at these solutions which is the best decision.

65 Probabilistic Modelling for Unsupervised Analysis of Human Behaviour in Smart Cities

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The growth of urban areas in recent years has motivated a large amount of new sensor applications in smart cities. At the centre of many new applications stands the goal of gaining insights into human activity. Scalable monitoring of urban environments can facilitate better informed city planning, efficient security, regular transport and commerce. A large part of monitoring capabilities have already been deployed, however, most rely on expensive motion imagery and privacy invading video cameras. It is possible to use a low-cost sensor alternative which enables deep understanding of population behaviour such as the Global Positioning System (GPS) data. However, the automated analysis of such low dimensional sensor data, requires new flexible and structured techniques that can describe the generative distribution and time dynamics of the observation data, while accounting for external contextual influences such as time of day or the difference between weekend/weekday trends. We propose a novel time series analysis technique that allows for multiple different transition matrices depending on the data's contextual realisations all following shared adaptive observational models that govern the global distribution of the data given a latent sequence. The proposed approach, which we name Adaptive Input Hidden Markov model (AI-HMM) is tested on two datasets from different sensor types: GPS trajectories of taxis and derived vehicle counts in populated areas. We demonstrate that our model can group different categories of behavioural trends and identify time specific anomalies.

66 A Novel Vision-Based Approach for the Analysis of Volcanic Ash Granulometry

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The volcanic ash fall-out represents a serious hazard for air and road traffic. The forecasting models used to predict its time-space evolution require information about characteristic parameters such as the ash granulometry. Typically, such information is gained by spot direct observation of the ash at the ground or by using expensive instrumentation. A distributed Wireless Sensor Network (WSN) of low-cost monitoring stations would represent a suitable solution in performing a continuous and high spatial resolution monitoring. In this paper, a novel low-cost vision-based methodology together with a dedicated image processing algorithm aimed at the estimation and classification of the ash granulometry is presented. The first prototype developed to investigate the methodology consists of a light-controlled tank and a camera. The acquired images of the ash samples are transmitted to a PC and processed by a dedicated paradigm developed in LabVIEW™. A threshold algorithm has been developed to provide a classification of the detected ash. Optimal thresholds have been estimated by using the theory of Receiver-Operating-Characteristic (ROC) curves. The methodology has been validated experimentally using real ash erupted by Mount Etna, with three different nominal granulometry, ϕ_1 = 0.5 mm, ϕ_2 = 1 mm, and ϕ_3 = 2 mm. The preliminary results demonstrated the viability of the proposed approach showing average accuracies in the estimation of the granulometry of 50 μm, suitable for the implementation of a low-cost distributed early warning solution. The main novelties of this work reside in both the low-cost vision-based methodology and the proposed classification algorithm.

S4. Sensor Applications and Smart Systems
Oral Presentation
Abstract

67 Coupling of Sensors and Machine Learning Algorithms in the Qualitative Analysis of Wine

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This work attempts the identification of the production year, the cultivar's region and the aging method used in the elaboration of different Spanish red wines, all from the "tempranillo" grape variety. The identification of such characteristics relies on the use of a voltammetric Electronic Tongue (ET) system formed by modified graphite-epoxy snd metal electrodes generating a set of six voltammograms per sample, and different chemometric tools to accomplish the final identifications.

A large sample set, that included 199 different wine samples from commercial and own elaboration origin were analysed with the electronic tongue system, using the cyclic voltammetry technique and without any sample pre-treatment. To process the extremely complex, and high dimensionality generated data, a compression strategy was used for the acquired voltammograms, using the Discrete Wavelet Transform (DWT). This treatment reduced the information to ca. 10%, preserving significant features from the voltammetric signals.

Compressed data was evaluated firstly by unsupervised methods, i.e., Principal Component Analysis (PCA), without much success as it was found that such methods were unable to unravel the patterns contained within such complex data samples.

Finally, the processed electrochemical information was evaluated by supervised methods to accomplish the proper identification, among those methods were Linear Discriminant Analysis (LDA), Supported Vector Machines (SVM) or Artificial Neural Networks (ANN). The best results were obtained using Artificial Neural Networks (ANNs) achieving 96.1% of correct classification for bottled year, 86.8% for elaboration region (protected designation of origin) and 98.6% for maturation type with or without use of wood barrel.

68 DEM Embedding in GNSS-Based Navigation Using a Statistical Modeling

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Given the boom linked to smart mobility, transport systems require increasingly precise and relevant navigation applications to offer optimized journeys in terms of time and energy consumption, such as for HEV. Most of these navigation applications are based on the processing of 2D digital road maps while taking into account the GNSS location of vehicles. These localization systems also integrate sensors such as accelerometers and gyroscopes to overcome the well-known problems of GPS positioning even if the current limited introduction of IoT in the transport industry has made it possible to develop new aided-GPS method such as geofencing. This paper focuses on one important parameter in journey optimization of land vehicles: the road slope. We propose a method to estimate the roads inclination parameters by fusing GNSS, INS, OSM and ASTER GDEM data through a nonlinear filter. The incremental estimate of the slope will complement the 2D modeling of the roads already available in OpenStreetMap and could be used in route planning optimization. The scientific novelty lies more specifically in the statistical map-matching approaches that we develop both for OSM and DEM data. Estimation results of the roads slopes are shown in experimental conditions.

69 Multisensing Wearable Technology for Sweat Biomonitoring

Meritxell Rovira Rovira [1], Cesar Fernández-Sánchez [1], Silvia Demuru Demuru [2], Danick Briand [2], Cecilia Jimenez-Jorquera [1] and Paul Kunnel Kunnel Brince [2]

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This work describes a multisensing wearable platform for monitoring biomarkers in sweat during the practice of exercise. Five electrochemical sensors for pH, potassium, sodium, chloride, and lactate are implemented in a flexible patch approach together with a paper microfluidic component to continuously measured sweat composition. The sensors are fabricated with silicon technologies: Ion Selective field effect transistors (ISFETs) for pH and ionic species and a gold thin-film microelectrode for lactate. The latter includes a polymeric membrane based on an electropolymerized polypyrrole structure where all the biocomponents required for carrying out the lactate analyses are entrapped. The flexible patch is fabricated using hybrid integration technologies that include printed pads defined on a polyimide (Kapton®) substrate and wire bonding encapsulation of silicon chips. To fix and align the sensors to the flexible substrate, different laminated materials like polymethyl methacrylate (PMMA), polydimethylsiloxane (PDMS) and silicone-based adhesive are used. The first results show the good performance of the sensors—ISFETS sensitivity between 54–59 mV dec^{-1} for ion ranges in sweat (from 2 mM to 100 mM) and lactate sensor' sensitivity of (-135×10^2 μA M^{-1} cm^{-2} for the range of 2–50 mM). The microfluidic platform has been tested in terms of adequate sensor wettability and rapid response during the time span of exercise activity (2 h) showing excellent results.

70 Design of Wireless and Traceable Sensors for Internally Illuminated Photoreactors

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We have presented methods for the wireless powering of photobioreactors and photocatalytic reactors before. Wireless powering for the internal illumination of those reactors is necessary due to the limited penetration depth of photons in those media.

In order to control the processes in those reactors, several sensors are necessary. In the case of photobioreactors for the cultivation of photosynthetic active microorganisms or cells, the quantities to be measured are e.g., oxygen and carbondioxide concentration, illumination, optical density and temperature. In the case of photocatalytic reactors this can also be chemical concentrations. Classically, the sensors are installed in the reactors through a drill hole. This clearly has the drawback that the desired quantity can only be measured at one point inside the reactor and the spatial distribution is unknown.

Here, we present methods to develop wireless sensor systems to overcome these problems. The floating sensors are wirelessly powered by the magnetic field mentioned above. The sensor signals are transmitted via on-off modulation among other methods which are being tested. The modulation frequency is located a factor of 1.3 above the excitation frequency in order to avoid interference by harmonics. Additionally, standard frequencies like 433 MHz are under consideration, as used by similar projects. The drawback of those high frequency standard protocols is the high damping factor in electrically conducting media.

The traceability of our floating sensors is another important aspect. This goal is reached by evaluating the received sensor signal amplitude with an array of receiving coils.

71 Development of a Metrological Atomic Force Microscope System with Improved Signal Quality

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This article presents a new metrological atomic force microscope (MAFM) with a homodyne interferometer and a tilt measuring system by position sensitive device (PSD). The combination allows the simultaneous three-dimensional detection of the tip displacement by capturing the position, bending and torsion of a reflecting surface of the cantilever realized with one laser beam. Based on an existing interferometric detection head of a micro-tactile 3D probe, the sensor head was revised and adapted for atomic force microscopy. The new measuring system uses two tiltable plane mirrors to adjust direction and position of a focused laser beam. With this adjustment unit, the focused laser beam can be steered perpendicular to the reflecting backside of the cantilever. Regarding the probe system, the optical design of the measuring head has been reengineered to reduce the disturbing interference on the PSD. A simulation applying the optical design program OpticStudio from Zemax shows that the integration of two wedge plates with a wedge angle of 0.5° reduces the disturbing interference significantly. After manufacturing initial measurement results are presented to verify the functionality.

72 Multiple Camera Fluorescence Detection for Real Time PCR

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The general polymerase chain reaction (PCR) amplifies DNA and analyzes the amplification results of the quantified DNA. The process of DNA detection by PCR requires four steps: DNA extraction, DNA amplification, electrophoresis and gel Image analysis. Recently, real-time PCR has been developed to detect DNA amplification in various ways. real-time PCR system based on fluorescence measurement detects DNA amplification to measure fluorescence brightness. In this system, there are a photodiode method including an optical system and a camera-based method to measure fluorescence brightness of amplified DNA. However, the conventional camera-based system is too expensive and difficult to reduce device size. In addition, owing to the simultaneous handling of fluorescence excitation and emission for dozens of tubes, there is a limit to the size, cost, and assembly of optics. Recently, cameras have been continuously developed, so that There are many cameras that are sufficient for image processing. In this paper, we propose a low-cost, compact fluorescence detection system for real-time PCR systems using open platforms camera. To simplify the optics, four low-cost small cameras were fixedly placed and entire tube was divided into four quadrants to minimize the filed of view. In addition, an effective image processing method was used to compensate for the reduction of the signal-to noise ratio of the overlapped image. The proposed system measured the fluorescence detection performance on the basis of the amount of DNA using various fluorescent substances.

73 Simulating Defects in Environmental Sensor Networks Using Stochastic Sensor Models

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Chemiresistive gas sensors are an important tool for monitoring air quality in cities and large areas due to their low cost, low power and, hence, the ability to densely distribute them. Unfortunately, such sensor systems are prone to defects and faults over time such as sensitivity loss of the sensing material, less effective heating of the surface due to battery loss, or random output errors in the sensor electronics, which can lead to signal jumps or sensor stopping. Although these defects usually can be compensated, either algorithmically or physically, this requires an accurate screening of the entire sensor system for such defects. In order to properly develop, test, and benchmark corresponding screening algorithms, however, methods for simulating gas sensor networks and their defects are essential. In this work, we propose such a simulation method based on a stochastic sensor model for chemiresistive sensor systems. The proposed method rests on the idea of simulating the defect-causing processes directly on the sensor surface as a stochastic process and is capable of simulating various defects which can occur in low-cost sensor technologies. The work aims to show the scope and principles of the proposed simulator as well as to demonstrate its applicability using exemplary use cases.

74 A Novel, Reliable and Real-Time Solution for Triage and Unique Identification of Victims of Mass Casualty Incidents

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A mass casualty incident may result to tenths or hundreds of victims. The triage, being the procedure of classification of victims according to their medical emergency, and the unique identification of victims are procedures equally crucial for effectively managing the crisis in respect to personnel (emergency medical services and non-medical civil protection practitioners) and assets (ambulances, medical equipment, hospital beds etc.). The solution developed in this work aims at reducing the time needed for triage and identification procedures and at the same time enhancing the situation awareness of crisis managers. Our system consists of (a) electronic wearable triage tags, aiming at replacing the legacy paper tags, supporting enhanced actuating and connectivity functionalities, visually presenting the status of medical emergency of the victims and uniquely identifying them, (b) a mobile application, connected in real-time with a cloud-based data aggregation node, enabling the emergency personnel to control the wearable device and to record the personal and medical emergency information of the victims, (c) an interoperability layer, supporting different connectivity options and capable of secure and reliable distribution of the collected data to multiple systems, such as Command and Control (C2s) systems of civil protection agencies, (d) a web application, graphically presenting the victims' medical emergency and their personal information in aggregated and in detail views, intended to be utilized by crisis managers in tactical and strategic level of command. The efficiency of our system has been demonstrated in multiple civil protection full scale exercises across Europe.

75 Aerial Cooperative Slam for Ground Mobile Robot Path Planning

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The trajectory planning for ground mobile robots operating in unknown environments can be a difficult task. In many cases, the sensors used for detecting obstacles only provide information about the immediate surroundings, making difficult to generate an efficient long term path. For instance, a robot can easily choose to move along a free path that eventually will have a dead end. This research is intended to develop a cooperative scheme of visual-based aerial simultaneous localization and mapping (SLAM) that will be used for generating a safe long-term trajectory for a ground mobile robot. The general idea is to take advantage of the high-altitude point of view that aerial robots can inherently have, for obtaining spatial information of a wide area of the surroundings of the robot. In this case, it could be seen as having a zenithal picture of the labyrinth for solving the robot's path. More specifically, the system will generate a wide-area spatial map of the ground robot's obstacles from the images taken by a team of aerial robots equipped with onboard cameras, by means of a cooperative visual-based SLAM method. At the same time, the map will be used for generating a safe path for the ground mobile robot. While the ground robot moves, its onboard sensors will be used for refining the map and thus for avoiding obstacles that were not detected from the aerial images.

S4. Sensor Applications and Smart Systems
Poster
Abstract

76 Aspects Regarding of a UGV Fire Fighting Thermal Shield

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This article presents aspects related to the protection with a double shield, made of stainless steel, of a robot for emergency situations against the effect of flames due to a fire. The ground robot is semi-autonomous/autonomous, with a wheeled propeller (6 × 6). The robot, designed and built at TRL 2 level, is intended for fire investigation, monitoring and intervention, in particular for petrochemical plants. The role of the shield is to protect the equipment that is part of the robot, such as: controllers, sensors, communications, power supply, etc. The need to mount a thermal protection shield on the intervention robot was given by the fact that fires at petrochemical plants generate very large thermal fields and gradients, which on the one hand are responsible for creating blind spots. These blind spots do not allow intervention crews to see what is happening in that area. These blind spots are characterized by very high temperatures. The dynamics of fires is unpredictable, therefore, to analyse the performance of the heat shield, we will perform a numerical-experimental analysis

77 Circular Microfluidic System for Electrochemical Continuous Monitoring of Biochemical Processes in Emulsion Droplets

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Droplet microfluidics has proved efficiency in simple manipulating of small volumes of liquid samples, especially in combination with electrochemical means of detection e.g., field-effect transistors, amperometric sensors, impedimetric sensors, and etc. The abovementioned combination has grown in a lab on a chip approach for the detection of various substances. However, the problem of precise droplet manipulation and long-term recirculation over individual sensors still present. Here we present a microfluidic design and the way of liquid control that enables recirculation real-time monitoring of hundreds of droplets with nanowire-based impedimetric sensors. The long-term recirculation of droplets over the nanowire area can be used for monitoring biochemical reactions whose real-time analysis of the kinetics can be advantageous for a more precise analysis. The combination of circular microfluidics and nanosensors allows long term recirculation of droplets over the sensor which can be used for monitoring of bio-chemical reactions within solutions or cell/bacteria cultures. The generation of hundreds of droplet reactors provides high reliability and throughput of the result due to statistical reasons, precise flow-rate manipulation allows viability of the assay and impedimetric way of monitoring provides an immersive analysis of the embedded compounds.

78 Cost-Effective Multiplex Real-Time PCR Chip System Using Open Platform Camera

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This paper proposes a cost-effective real-time multiplex polymerase chain reaction (PCR) chip system for point-of-care (POC) testing. In the proposed system, nucleic acid amplification is performed in a reaction chamber built on a printed-circuit-board (PCB) substrate with a PCB pattern heater and thermistor. Fluorescence can be detected through the transparent plastic on the other side of the substrate. Open platform cameras were used for miniaturization and cost effectiveness. We also used a simple and cost-effective oblique lighting to stimulate fluorescence. Response performance was investigated by observing the change in the average brightness of the chamber images with various reference dye concentrations. In addition, we investigated the interference properties between different colors by measuring the fluorescence response for each dye concentration mixed with the maximum concentration of the different dyes. Quantitative performance was validated using standard DNA solutions. Experimental results show that the proposed system is suitable for POC real-time multi-PCR system.

79 Electrochemical and Hydrodynamic Characterization of a 3D-Printed Electrochemical Flow-Cell

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Additive Manufacturing (AM) also known as 3D-printing comprise a group of versatile technologies that has been used in electrochemistry last years. Among the 3D-printing technologies, Fused Deposition Modelling (FDM) highlights in the fabrication of reliable portable point of need platforms for its rapid prototyping, low cost, design customization, and ease of integration of diverse components as microfluidics, and electrodes. This work propose the electrochemical and hydrodynamic characterization of a novel 3D-printed flow-cell integrated with removable commercial-available screen-printed carbon electrodes. Integration of flow-cell and electrodes resulted in the proposed 3D-printed electrochemical flow-cell adjustable and customizable to detect any desired biomarker. The 3D-printed flow cell was fabricated through FDM and the ESCARGOT (Embedded SCAffold RemovinG Open Technology) protocol. Electrochemical and hydrodynamic characterization comprised an experimental and a computational model study respectively, with the purpose to choose the best working flow rate and to understand the behavior of the fluid through the device. Experimental study was carried out running cyclic voltammetries of $[Fe(CN)_6]^{4-/3-}$ redox probe at different flow rates (0, 50, 100, 200, 300, 400, 500 and 1000 μL min^{-1}) and the hydrodynamic computational model was performed using COMSOL Multiphysics 5.3a setting physics for laminar flow and transport of diluted species at the same flow rates. Results indicated that the best working flow rate was 50 μL min^{-1}, and recirculation and vortices zones are formed at flow rates higher than 200 μL min^{-1}.

S4. Sensor Applications and Smart Systems
Poster
Abstract

80 Enriching Low-Density Terrain Maps from Satellite with Autonomous Robots Data

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Satellite imagery and remote sensoring has been used for some years in agriculture, creating terrain maps for different soil features (humidity, vegetation index, …). Multichannel information provides lots of data but with a big drawback: the low density of information per surface unit, that is, the multichanneled pixels correspond to a large surface, and it is not possible a fine characterization of the targeted areas. In this research, authors propose the enrichment of such a data by the use of autonomous robots which explore and sense the same targeted area of the satellite but yielding a finer detail of terrain, complementing and fusing both information sources. The sensory elements of the autonomous robots are in the visual spectrum as well as in the near-infrared spectrum together with Lidar and radar information. This enrichment will provide to the final user a high-density map of the soil to improve crops, irrigation, seedling and other agricultural processes. The methodology to fuse data and create high-density maps will be deep learning techniques. The system will be validated in real fields with the use of real sensors to measure the data given by satellites and robots' sensors.

81 Flexible Piezoelectric Sensor for Podiatric Applications with Wireless Communication

Samia Adrar [1], Mohammed El Gibari [1], Philippe Saillant [2], Arnaud Chambellan [2], Marc Jubeau [2] and Raynald Seveno [1]

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For reasons of availability and cost, patients are sent home earlier and earlier, with limited follow-up due to the complexity and size of medical devices. In this context, researchers from IETR and MIPS laboratories are working on a device which should monitor the progress of a patient, in order to detect early the aggravation of a disease such as Chronic Obstructive Pulmonary Disease (COPD) or diabetes with walking disorders. The device is based on flexible piezoelectric thin films (3 μm thick) that can be used as podiatric sensors and have been developed by the IETR laboratory. The originality of this work resides both in the approach to the design of the gait monitoring device, because carried out directly in consultation with a doctor from the University Hospital of Nantes and a podiatrist, and in the portability of the device that should eventually allow the follow-up of a patient at home.For this study, the flexible piezoelectric sensors have been elaborated using a Chemical Solution Deposition (CSD) process and a commercial aluminum (Al) foil as substrate. In order to increase the flexibility of sensors and to aid its insertion in a shoe, piezoelectric films have been encapsulated by lamination into polyethylene terephthalate (PET, 150 μm). In this paper, elaboration and characterizations of flexible piezoelectric sensors, analog to digital converter and wireless communication protocol used for data transmission, are presented.

S4. Sensor Applications and Smart Systems
Poster
Abstract

82 Hardware Passwords Manager Based on Biometric Authentication

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The paper presents a portable passwords manager having a two stages biometric based access procedure. Data security using biometric methods was chosen as a variant of reduced complexity, but very effective in preventing cyber theft. The implementation of biometrics for the purpose of identification in high security systems has become a must with the evolution of technology and the spike in identity theft. Unlike, passwords or IDs, a biometric feature is an identifier that can not be lost, stolen or replicated, fact that offers biometric authentication systems an increased level of security. During the first accessing step, the 3DPassManager portable device measures heartbeat and uses fingerprint and iris features to realize a unique biometric based authentication. While the specific characteristics of fingerprint and iris are integrated to ensure that the person using the device is the rightful owner, the pulse is utilized to verify if possible previously acquired static images are not used. During the second accessing step, a password is generated based on fingerprint details, being valid only for a small time interval. The fingerprint is stored in a 1024-bit long key. Once the access is allowed, the passwords will be available trough an extension installed on the web browser. The device has the size of a cigarette pack and communicates with the PC by scanning a QR code. It is safe and was tested for dictionary and brute force attacks.

83 Increasing the Situation Awarness and Response Time of the K9 Units Using a Smart, Integrated Vest for the Canine Companion

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First responders are tasked to intervene in small-scale emergencies and major natural or man-made disasters under unknown environments. They are required to operate around the clock, in situations that are live threatening and potential hazardous, with limited awareness of the operational situation, the mission progress and the time sensitivity. They more often than not risk their own personal safety and well-being in order to keep civilians safe.

During the most demanding and extended incidents, first responders operate under complex response operation plans that involve the collaboration of multiple disciplines and teams including K9 units. Within the context of the INGENIOUS project a K9 vest for the canine of the unit is developed aiming to improve their response time, enhance their situational awareness, support the collaboration between agencies and most importantly increase their safety.

The K9 vest will provide situational awareness from the canine's location. To that end it will offer two video streams (HD and thermal) as well as bidirectional audio. Additionally, it will monitor the canine's location with a high-precision GNSS receiver. Communication will be achieved using Wi-Fi LAN connectivity.

The information will be available to the dog handler, the local field coordinator of the response plan and forwarded to the Command and Control centre upon request. This will allow the dog handler to focus on the operation, ensuring the unit's safety at the field while at the same time providing near-real time information to the operation coordinators, increasing the overall situational awareness.

S4. Sensor Applications and Smart Systems
Poster
Abstract

84 Integration of an Optical Setup for the Characterization of Near-Infrared Detectors Used in Ground and Space-Based Astronomy

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To make Europe competitive in the field of astronomical sensors and detectors, the main goal of this research is to provide the capability to manufacture high performance infrared focal plane arrays (FPA) devoted to scientific and astronomical ground and space telescope missions. This paper presents the main outcome of an international project with the highest standard of quality for this detector. The resulting detector is a sensor with a hybridized MCT (HgCdTe) epilayer on a CdZnTe substrate of 2 k × 2 k pixels and 15 μm of pixel pitch. On this framework, an optical setup has been developed at the IFAE optical laboratory with the capabilities to perform the characterization of a near-infrared (NIR) detector covering the range from 800 to 2500 nm. The optical setup is mainly composed by a power controlled quartz-halogen (QTH) lamp and an astigmatism-corrected Czerny-Turner monochromator with a couple of diffraction gratings covering the detector wavelength range with a minimum resolution of ~1 nm. A temperature stabilized gold-coated integration sphere provides a uniform and monochromatic illumination while a InGaAs photodiode located at the north-pole of the integration sphere is used to measure the radiant flux toward the detector. The whole setup is fully controlled by a Labview™ application and synchronized with the detector's readout electronic (ROE).

85 Low-Cost Wasn for Real-Time Soundmap Generation in a Active-Aging Smart-Home

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Life expectancy has significantly increased over the last decades. This has led governments and organizations to increase the resources devoted to the promotion of healthy and independent aging among elderly people. Recent developments in technology have enabled the development of affordable low-cost monitoring systems, which allow the surveillance of active elderly in their own homes, thus promoting their independence and well-being. This paper presents a low-cost wireless acoustic sensor network developed to gather acoustic data in a smart-home to build a 24/7 real-time soundmap. Each node of the network comprises an omnidirectional microphone and a computation unit, which processes acoustic information locally to obtain non-sensitive data (i.e., equivalent continuous loudness levels or acoustic labels) that are sent to a cloud server. Moreover, it has also been studied the placement of the acoustics sensors in a real scenario, following acoustics criteria. The ultimate goal of the deployed system is (i) to analyze the behavior of an elder living alone in a flat, (ii) to identify anomalous patterns that can lead to alarm activation for family or social services and (iii) to prevent and attend potential domestic incidents. The proposed network aims to encourage the use of real-time non-invasive methods to enable social services and health care providers to remotely track the behavioral status of self-sufficient elderly people.

86 Low-Frequency Magnetic Localization of Capsule Endoscopes with an Integrated Coil

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Wireless capsule endoscopy is a promising and less invasive alternative to conventional endoscopy. A patient swallows a small capsule with an integrated camera to capture a video of the gastrointestinal tract. For accurate diagnosis and therapy, the capsule position in terms of the travelled distance must be known for each video frame. However, up to now, there is no reliable localization method for endoscopy capsules. In this paper, a novel magnetic localization method is proposed. A coil as a magnetic field source is integrated into a capsule and fed with a low-frequency alternating current to prevent static geomagnetic field interference. This alternating magnetic field is measured by twelve magnetic sensors arranged in rings around the abdomen. The coil and the capsule batteries were designed based on the geometry and power supply of a commercially available endoscopy capsule and simulated by COMSOL Multiphysics software. In this way, the coil position and orientation were determined with an accuracy below 1 mm and 1°, respectively. As an analytic model for the magnetic flux density of the coil in that setup, a modified dipole model was derived. It was used to show that the batteries help to increase the amplitude of the magnetic flux density. The model is valid when signals below 100 Hz are applied, and no eddy currents are generated within the batteries. It is concluded that the magnetic flux density generated by the developed coil would be measurable with state-of-the-art magnetic sensors.

87 Method and Sensory System for Determination of the Liquids Surface Tension

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A new method and related sensory system used to determine the surface tension (γ) of a liquid investigated based on the increase of the area (A) of a drop vibrated sinusoidally is presented. The materialization of the method consists in specific device placed on the table of a microscope or a stereomicroscope, both based on the principle of light reflection. A drop of the analyzed liquid deposited with a dispenser on a metal plate, vibrated electrodynamically under the action of a sinusoidal oscillation, of constant frequency and amplitude, increases its surface wetted on the metal plate with each applied sinusoidal oscillation. At each magnification of the droplet surface area, an image acquisition takes place through the optoelectronic system of the microscope or stereomicroscope, the frequency of the oscillations being strictly correlated with the acquisition frequency of the images. At a predetermined number of images/oscillations, using specific software, both the images of the droplets and the graph containing the number of pixels inside the outline of each image and the current number of vibration corresponding to that image are displayed. The surface tension is automatically expressed by the growth speed of the drops surface, speed given by the curve slope of the pixels number of the drops according to the current number of the oscillation. A collateral application, is the possibility of using the sensory system and specialized software for rapid determination of solutions concentration, measuring the surface tension using the Szyszkowski relation.

S4. Sensor Applications and Smart Systems
Poster
Abstract

88 Needleless Electrospun Magnetic Carbon Nanofiber Mats for Sensor Applications

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Magnetic nanofibers can be produced by adding magnetic nanoparticles in polymer solution by electrospinning process. The advantages of such magnetic nanofibers include a large surface-to-volume ratio and high porosity, resulting in excellent sensitivity and high sensory response, making them promising for sensor applications such as the detection of various gases or strain sensors. The carbonization of such nanofibers is promising, since the increasing electrical conductivity expands the possible sensor applications.

In this study, magnetic nanofiber mats were prepared by needleless electrospinning from polyacrylonitrile (PAN) by adding magnetite nanoparticles using low-toxic solvent dimethyl sulfoxide (DMSO), oxidatively stabilized and carbonized at 500 °C, 600 °C, 800 °C and 1000 °C, resulting in different morphologies. Compared to pure PAN nanofibers, the addition of magnetic nanoparticles increased the fiber average and improved the dimensional stability during the thermal treatment of nanofiber mats. Furthermore, the magnetic nanoparticles agglomerate and are located inside and on the surface of the nanofibers.

89 Optoelectronic Sensory System for Raman Spectromicroscopes

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In order to obtain a high microscopic and spectral resolution, both for the microscopic study and for the spectrometric analysis carried out simultaneously at the same area on the sample, an adaptive optoelectronic system for Raman spectromicroscopes with the near-infrared excitation light source is designed. The current system and its working mode have a major disadvantage due to the fact the sample is moved several times to and from the focusing lens of the excitation radiation in the search for the focal point, in order to ensures the maximum spectral resolution. In this process, the peak height for the Stokes spectrum is monitored and the focal point is considered achieved when the peak heghit reaches its maximum. Due to the high energy density in a focal point, repeated searches of this point may lead to the modification of the chemical composition of the investigated material and, in some cases, even to the decomposition of some of its components.The paper presents an advanced technical solution that allows the microscopic study of the sample in the focal point of the visible spectrum, as well as the rapid and automatic search of the focal point in the Raman spectral analysis, at the 1064 nm wavelength in the near-infrared spectral domain, without thermally affecting the sample.

90 PEG-Based Antifouling Strategies for Electrochemical Aptasensors

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The application of biosensors for complex samples is limited by non-specific adsorption of interfering compounds. These so-called fouling agents include a broad range of biomolecules, such as proteins and nucleic acids, as well as whole cells. Their adsorption to the electrode significantly affects the analytical characteristics of the sensor including sensitivity, reproducibility, stability, and overall reliability. Biofouling therefore is a serious challenge that has to be overcome. The majority of antifouling techniques developed for this purpose are limited in their application to optical or mass sensitive sensors because they incorporate high molecular weight compounds. Since these are highly disadvantageous for electrochemical transfer reactions, further research has to be conducted for the fabrication of electrochemical sensors. The gold standard of antifouling agents is Polyethylene glycol, which, when attached to the electrodes' surface, forms thick and compact monolayers that unfortunately inhibit electrochemical transfer reactions. In our work, we therefore aim to investigate different strategies based on PEG that combine the polymers' excellent antifouling properties with sufficient spacing to allow electron transfer and enable their application in electrochemical sensors. We thereby focus on the development of impedimetric sensors that utilize aptamers as bioreceptors for the fast, sensitive, and reliable detection of protein biomarkers in clinical samples.

91 Radar-Based Detection and Classification of Vulnerable Road Users

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Safe and sustainable mobility in urban and rural regions can be fostered by developing intelligent road infrastructure to avoid accidents by warning drivers about approaching vulnerable traffic participants. Radar sensors accurately detect different objects, however the reliable classification still remains challenging. In this paper, a new approach to extract and interpret unique spectral signatures of pedestrians and cyclists is proposed. Moreover, this approach can be also extended to any moving object including wild animals. This method uses Doppler-Range measurements in real time which result from the local dynamic of the moving parts in order to extract statistical parameters of the movement pattern. The movement pattern is represented by a time dependent velocity distribution which can be further analyzed by conventional signal processing techniques. In this work, the intensity-normalized average velocity calculations are based on a probabilistic approach of the detection. Such a velocity series can be further analyzed by applying Fast-Fourier-Transform in order to extract spectral information of the movement. In case of more than one detected object, a spectrogram can be built, therewith it is possible to determine average velocities as well as periodicities of the measured movement patterns. Machine learning algorithms can be also applied to the discussed time series in order to automate the classification.

92 Recognizing Eating Activities in Free-Living Environment Using Consumer Wearable Sensors

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The study of eating behavior has become increasingly important due to the alarming high prevalence of lifestyle related chronic diseases. In this study, we investigated the feasibility of the automatic detection of eating events using affordable consumer wearable devices, including Fitbit wristbands,Mi Bands, and FreeStyle Libre continuous glucose monitoring (CGM) sensors. Two tree-based ensemble learning algorithms, i.e., random forest and XGBoost, were applied to develop binary classification models for distinguishing eating events and non-eating events. We compared different combinations ofmachine learning algorithms and resampling strategies. Our results showed that the proposed method can recognize eating events with an average sensitivity of up to 71%. The classification model using random forest with SMOTE resampling exhibited the best overall performance among all models. The featureswith the strongest differentiation power were from glucose data, and Fitbit heart rate data contributed more features than other modalities. The preliminary results demonstrated the feasibility of leveraging consumer wearable devices for automatic detection of eating events with reasonable accuracy.

93 Small Force Sensor to Measure the Three Components of the Ground Reaction Forces in Mice

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The measurement of the ground reaction forces (GRFs) helps in determining the role of each limb for support and propulsion, in predicting muscle activities, and in determining the strain conditions experienced by bones. Measuring the GRFs in mice models is therefore a cornerstone for understanding the rodent musculoskeletal and neuromotor systems, as well as for improved translation of knowledge to humans. Current force plates are too big in size to allow the measurement of forces for each paw. This limitation is mainly due to the large size of the used sensors. The goal of our study was therefore to develop a small 3D force sensor for application in rodent gait analysis. We designed a flexible and small mechanical structure (8 mm × 8 mm) to isolate force components. Using FEM simulation, we chose the area with the highest strain to fix two strain gauges for each direction. The small size of the sensor allows us to fix four of them under a plate on the mouse paw size (approximately 17 mm). According to our primarily results the force plate has a resolution of 2 mN in the vertical direction and 1 mN in the fore-aft and mediolateral directions. The construction of a runway with such a force plate will allow the measurement of GRFs and the center of pressure of each rodent paw for different steps. Such techniques thus provide a basis for assessing functionality in mice models, towards improved translation of rodent research.

94 System Architecture for IIoT-Based POC Molecular Diagnostic Device

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In this paper, we investigate the efficient structure for point-of-care (POC) molecular diagnostic system based on of the industrial-internet-of-things (IIoT). The target system can perform automated molecular diagnosis including DNA extraction, PCR amplification, and fluorescence detection. Samples and reagents are placed in a multi-room cartridge and loaded into the system. A rotating motor and a syringe motor control the cartridge to extract DNA from the sample. The extracted DNA is transferred to a polymerase chain reaction (PCR) chamber for DNA amplification and detection. The proposed system provides multiplexing of up to 4 colors. For POC molecular diagnostics, World Health Organization demands features such as low volume, low cost, fast results, and user-friendly interface. In this paper, we propose a system structure that can satisfy these requirements by using PCR chip and open platform. A distributed structure is adopted for the convenience of maintenance, and a web-based GUI is adopted for the user's convenience. We also investigated communication problems that may occur between system components. Using the proposed structure, the user can conveniently control from standard computing devices including a smartphone.

95 Tactile Sensor Analysis during Early Stages of Manipulation for Single Grasp Identification of Daily Objects

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Dexterous robotic manipulation in unstructured environments is still challenging, despite the increasing number of robots entering human settings each day. Even though robotic manipulation has complete solutions in factories and industries, it still lacks essential techniques, displaying clumsy or limited operation in unstructured environments. Daily objects typically aim at the human hand, and the human somatosensory system is responsible for solving all the complex calculations required for dexterous manipulations in unstructured settings. Borrowing concepts of the human visuotactile system can improve dexterous manipulation and increase robotics usage in unstructured environments. In humans, required finger and wrist joint adjustments occur after fast identification of the object in the initial stages of manipulation. Fast object identification during those phases may increase robotic dexterous manipulation performance. The present paper explores human-inspired concepts such as haptic glance to develop robotic single-grasp object identification. This concept can assist early phases of robotic manipulation, helping automated decision-making, such as type of grasp and joint position during manipulation tasks. The main stages developed here are detecting sensor activation and sample collection using signal-to-noise and z-score filtering on tactile data. This procedure automates touch detection and reduces the sensor space for classification. Experiments on a daily objects dataset presented compelling results that will assist later stages of early phases of robotic grasping.

96 The Effect of Measurement Trends in Belt Breathing Sensors

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Sensors for respiratory monitoring have been extensively studied. They can be classified into wearable and non-wearable systems. One possible wearable technology is piezoresistive sensing. Wearable sensors can be worn in several positions, the chest being one of the most effective. In this paper, we have studied the performance of a new piezoresistive breathing sensing system to be worn on the chest with a belt. One of the main problems of belt-attached sensing systems is that they present trends in measurements due to subject movements or differences in subject constitution. These trends affect sensor performance. To mitigate them, it is possible to post-process the data to remove trends in measurements. However, important information to determine respiration rate may be lost when signal trends are removed. In this study, we show that the effectiveness of eliminating trends in signals depends on the length of the segmentation window of the measurements. After conducting an experimental study with 21 subjects who breathed in different positions with a chest piezoresistive sensor attached to a belt, we determined that removing trends in measurements was beneficial for segmentation windows of more than 20 s. For shorter windows, the elimination of trends led to higher errors in the respiration rate measured. To calculate respiration rate errors, two well-known algorithms based on zero-crossings detection were used.

S4. Sensor Applications and Smart Systems
Poster

97 Investigation of the Thermally Generated Au and Ag Nanoislands for SERS and LSPR Applications

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Gold and silver nanoparticles are widely used as signal amplification elements in various electrochemical and optical sensor applications. Although these NPs can be synthesized in several ways, perhaps one of the simplest methods is the thermal annealing of pre-deposited thin films on glass. With this method, the parameters of the annealing process (time, temperature) and the pre-deposited thin film thickness influence and define the resulting size and distribution of the NPs on the surface. LSPR is a very sensitive optical phenomenon and can be utilized for a large variety of sensing purposes. SERS is an analytical method that can significantly increase the yield of Raman scattering of target molecules adsorbed on the surface of metallic nanoparticles. In this work, the performance of Au/Ag nanoislands was investigated for SERS and LSPR applications. The nanoislands were generated by thermally annealing thin layers of silver and gold, which were previously sputtered onto glass surfaces. The sensitivity of LSPR and SERS based devices are strongly depending on the used material and also on the size and geometry of the metallic nanoparticles. By controlling these parameters the plasmon absorption band can be tuned and the sensitivity can be optimized. This work was supported by the GINOP-2.3.2-15-2016-00041 project. ICs is grateful for the support of the János Bólyai Research Scholarship of the Hungarian Academy of Sciences.

Abstracts

Session 5. Organic Sensors and Systems

Abstract

98 Chitosan-Based Piezoelectric Flexible and Wearable Patch for Sensing Physiological Strain

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Innovative biocompatible organic materials with piezoelectric properties have a great potential for the development of wearable sensors for monitoring physiological parameters. Among them, Chitosan (CS) is a natural, biodegradable, antibacterial and low cost biopolymer that shows an interesting piezoelectric behaviour. In this context, this work reports on a protocol where plain chitosan films (CS-F) are exploited to easily create a piezoelectric flexible wearable patch.

By adapting a simple drop casting method reported in literature, we here demonstrate that a 70 μm thick CS-F can exhibit good piezoelectric properties. The structure of CS-F was analysed thanks to XRD technique: the spectrum reveals peaks of partially crystalline chitosan film, indicating presence of organized polymeric chains. Piezoresponse Force Microscopy scans confirmed the presence of domains with opposite polarization directions with an extrapolated value of piezoelectric coefficient d_{33} of 2.54 pC/N.

A microfabrication process for patch realization has been set up. The top electrode was created by simple thermal evaporation of gold directly onto the free-standing CS-F. This bilayer was then precisely cutted using a cutting plotter and assembled on the copper bottom electrode. The complete patch can be conformally applied on the skin.

The ability of the device to sense physiological movements was validated by an ad hoc measurement set up generating strain pulses; open circuit voltage peaks up to 20 mV were detected.

This sensor represents an important step towards totally biocompatible and biodegradable wearable devices.

Abstract

99 Using Interdigitated Organic Electrochemical Transistors as Electrophysiological and Biochemical Sensors

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Organic electrochemical transistors (OECTs) have emerged as versatile electrophysiological sensors due to their high transconductance, biocompatibility, and transparent channel material. High maximum transconductances were demonstrated facilitating extracellular recordings from electrogenic cells. However, this often requires large channel dimensions which impedes high transistor densities. To improve the device performance and density, we used interdigitated OECTs (iOECTs), which feature high transconductances at small device areas. Superior device performance was achieved by systematically optimizing the electrode layout regarding channel length, number of electrode digits, and electrode width. Interestingly, the maximum transconductance does not straightforwardly scale with the channel width-to-length ratio, which is different from planar OECTs. We used optimized iOECTs for recording action potentials of cardiomyocyte-like HL-1 cells. Furthermore, we embedded the iOECTs in a matrix of polyimide to achieve flexible and transparent bioelectronic devices. These sensors exhibited electrical characteristics similar to those of solid-substrate devices even after experiencing extremely high bending strain. Finally, we used these devices to detect neurotransmitter dopamine and ATP, which play an important role not only for signal transmission in the central nervous system but also for cardiovascular, neurodegenerative, and immune deficiency diseases. Our novel aptasensor possessed ultralow detection limits, which were several orders of magnitude lower than those of the same aptasensors using an amperometric transducer principle. Our results demonstrate that interdigitated OECTs meet two requirements of both electrophysiological and biochemical sensors, namely high device performance and small channel dimensions, and might represent the optimal transducer to integrate these two types of sensors on one chip.

Abstract

100 A Low-Cost Visible Light Communications System Based on Organic Photodetection for Transmitting Images

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In Visible Light Communication (VLC) Systems, data are transmitted by modulating light from an illumination source, that could be an ordinary lamp or light-emitting diodes (LEDs). Photovoltaic cells based on massive heterojunctions of semiconductor polymers have focused the attention of researchers due to several potential advantages over their inorganic counterparts, such as simplicity, low cost and the ability to process large area devices even on flexible substrates. In this paper, we use commercial LEDs in transmission and organic photodetectors (OPD) based on poly(3-hexylthiophene) (P3HT) and a phenyl-C61-butyric acid methyl ester (PCBM) blend used as active layer in reception. We have fabricated and characterized the I-V curve and the Bit Error Rate (BER) response of the OPD using low cost processing techniques and we have used an Atmel 8-bit microcontroller in order to control the electronics to transmit and modulate the signal. Finally, in this work, we have developed and characterized organic photodetectors in a low cost visible light communications system capable of transmitting an image file in real-time, as a proof of concept that is cost effective, since the whole system was implemented using low cost components.

S5. Organic Sensors and Systems
Poster
Abstract

101 Self-Detachable Body Cavity Sensors with Biocompatible Materials for Medical and Healthcare

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Self-detachable sensors in body cavities such as a contact lens type and a mouthguard are attracted the attention on the preventive medicine. In this paper, a soft contact lens (SCL) sensor for tear sugar monitoring and the mouthguard (MG) sensor with biocompatible materials integrated with Bluetooth wireless module are introduced. The SCL biosensor for tear glucose was fabricated using biocompatible 2-methacryloyloxyethyl phosphorylcholine (MPC) polymer and polydimethyl siloxane (PDMS) as the biosensor material. The biosensor consisted of a flexible Pt working electrode and an Ag/AgCl reference/counter electrode. Glucose oxidase (GOD) was immobilized on the sensing region. The SCL sensor allowed to monitor a rabbit tear glucose (normal concentration: 0.11 mM). Also, the change of tear glucose induced by the change of blood sugar level was assessed by the oral glucose tolerance test. As another body cavity sensor, the MG thermistor with BLE wireless module was developed using a thermoplastic dental material. The MG sensor has succeeded in telemetry of oral temperature on a smart-watch monitoring display. In the future, the self-detachable body cavity sensors are expected to improve the quality of life.

Abstracts

Session 6. Flexible and Stretchable Sensors

Abstract

102 Bioderived and Degradable Materials with Extreme Mechanics for Soft Sensors and Actuators

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Nature inspires a large set of bio-mimetic systems ranging from soft robotic actuators to perceptive electronic skins that enhance and support our life. The growing demand on assistive, medical and bioelectronic technologies however raises concerns on the ecological footprint of these emerging platforms, as they are often designed for a defined, limited operational lifetime. Introducing a key feature essential to nature—biodegradability—will enable soft electronic and robotic devices that reduce (electronic) waste and are paramount for a sustainable future.

We here introduce materials and methods such as tough yet biodegradable materials for soft systems that facilitate a broad range of applications, from transient wearable electronics to metabolizable soft robots. These embodiments are highly stretchable, are able to heal and are resistant to dehydration. Our forms of soft electronics and robots are built from resilient bio-gels with tunable, extreme mechanical properties that uniquely combine performance and durability with degradability. They are engineered for long-term operation in ambient conditions without fatigue, but fully degrade after use through biological triggers. Electronic skins that measure pressure, strain, temperature and humidity serve as human-friendly on-skin interfaces or equip robotic systems with sensory feedback. Such advances in the synthesis of biodegradable, mechanically tough and stable gels that do not compromise in performance when compared to their non-degradable counterparts may bring bionic soft systems a step closer to nature and enable human-friendly technologies with reduced ecological footprint.

Abstract

103 Compliant Magnetic Sensor Technologies

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We will review the recent progress in the field of shapeable magnetoelectronics allowing to realize not only mechanically imperceptible electronic skins, which enable perception of the geomagnetic field (e-skin compasses), but also enable sensitivities down to ultra-small fields of sub-50 nT. We demonstrate that e-skin compasses allow humans to orient with respect to earth's magnetic field ubiquitously. The biomagnetic orientation enables novel interactive devices for virtual and augmented reality applications, which is showcased by realizing touchless control of virtual units in a game engine using omnidirectional magnetosensitive skins. This concept was further extended by demonstrating a compliant magnetic microelectromechanical platform (m-MEMS), which is able to transduce both tactile (via mechanical pressure) and touchless (via magnetic field) stimulations simultaneously and discriminate them in real time. Those devices are crucial for interactive electronics, human-machine interfaces, but also for the realization of smart soft robotics with highly compliant integrated feedback system as well as in medicine for physicians and surgeons.

104 A Soft Pneumatic Actuator with Integrated Deformation Sensing Elements Produced Exclusively with Extrusion Based Additive Manufacturing

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In recent years, soft pneumatic actuators have come in the spotlight because of their simple control and the wide range of complex motions. For the monitoring of soft robotic systems, elastomer-based deformation sensors are being used. However, combination using of conventional mold casting processes for embedding deformation sensors in soft actuators are time consuming and difficult to upscale on an industrial production level. In this study, it is shown how such soft bending pneumatic actuator with integrated sensing elements can be produced using extrusion-based additive manufacturing. The advantage of fused deposition modeling (FDM) against direct printing or robocasting is the significantly higher resolution and the ability to print large objectives. The newly commercial launched pellet-based FDM printers are compatible with thermoplastic elastomers of low shore hardness that are required for the soft robotic applications. In this study, soft pneumatic actuator with the in-situ integrated piezoresistive sensor elements was successfully fabricated using a commercial styrene-based thermoplastic elastomer (TPS) and a TPS/ carbon black (CB) combination, developed at Empa. It has been demonstrated that the integrated sensing elements could monitor the motion of the soft robot with high resolution, linear response and low drift. The findings of this study contribute in extending the applicability of additive manufacturing for integrated soft sensors in large soft robotic systems.

105 Ultralight, Compact, and Stretchable Electronics for Continuous and High-Quality Cardiac Assessment in High User Activities

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The need to monitor electrocardiogram (ECG) in continuous yet comfortable manners has propelled the development of many wearable ECG devices that could replace the roles of traditional systems, such as the Holter monitor. However, despite the reduced form factor and weight, commercially available devices rely on the use of aggressive adhesives for attachment to the skin due to the bulky and rigid electronic module as well as conductive hydrogels to acquire the biopotential. Since the adhesives and gels are known to cause skin irritation and injuries, there has been a critical need to develop a wearable system, which is both compact and safe for the user. Recently, a stretchable and dry-contact ECG device has been reported and the feasibility to continuously transmit ECG safely and reliably has been demonstrated. In this study, we report a further improvement in device weight and size of the device by implementing a two-electrode design as well as optimized power management strategies allowing for robust transmission of continuous ECG on a reduced power budget. With the device weighing just 5.2 g, ECG with a higher signal-to-noise ratio (22 dB) than the previous value (17 dB) could be obtained during excessive user movement, such as running and exercising. Along with the combination of data compression, buffered Bluetooth transmission of 1 min, and a low-power ECG front-end, continuous assessment of ECG could be achieved over 24 h, a milestone for continuous transmission of ECG, the proposed system will bring a paradigm shift in continuous cardiac monitoring.

106 A High-Resolution Fully Inkjet Printed Resonant Mass Sensor

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The rapid prototyping of low cost sensors is assuming a strategic importance in several application fields. In this paper a fully inkjet printed mass sensor is proposed. The device consists of a PET (polyethylene terephthalate) cantilever beam, which is driven to its resonant mode by an electromagnetic actuation mechanism, implemented through the interaction between a current impulse flowing through a planar coil (inkjet printed on the PET beam), and a permanent magnet, facing the actuation coil. Target masses are positioned close to the beam end. The sensing methodology, based on the relationship between the beam first natural frequency and the target mass, is implemented through a Strain Gauge (inkjet printed across the fixed end of the cantilever). The resonant operating mode of the sensor confers intrinsic robustness against instabilities of the strain sensor structure (e.g., the residual stress of the cantilever beam), the target mass material and the magnet-coil distance. The latter indeed changes as a function of the target mass values. The friction-less actuation mode is another shortcoming of the sensor, as well as the low cost feature arising from the adopted technology. As far as we know, the solution proposed is the first example of a low cost fully printed mass sensor. The operating range of the device is 0–0.36 g while its resolution is in the order of 1.0 mg, thus addressing crucial application fields. A Q factor around 35 has been estimated, which confirms the suitable performances of the sensor in term of selectivity and resolution.

S6. Flexible and Stretchable Sensors
Poster
Abstract

107 Development of a Flexible Pressure Sensor Array with Only 2 I/O Ports to Distinguish Object Hardness

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Flexible pressure sensor array can be as tactile sensor array to detect loading pressures and locations in lots of applications, including wearable devices, electronic skins, robotics, and machine learning. Many studies have been proposed high performance flexible tactile sensor array. However, when the sensing points and spatial resolution increase, signal wiring issue arises, but the cumbersome I/O wirings between sensors and readers will greatly affect the user's mobility and comfort. Recently, several methods have been proposed to simplify the signal line. Some common approaches utilize orthogonal electrodes to reduce I/O ports from $2n^2$ to $2n$ in an $n \times n$ array. Some innovative methods can reduce I/O ports to 2 in an $n \times n$ array, but they are unable to perform multi-touch measurement and maintain high spatial resolution at the same time. To achieve multi-touch and high spatial resolution, this research proposes a flexible pressure sensor array is based on parallel RLC resonance circuit and made by PDMS/Graphene mixture as piezoresistive sensor on FPC (Flexible Printed Circuit). In this research, Single pressure sensor can measure the pressure from 37.5 to 250 kPa. Loading multi-points force on the pressure sensor array, it can distinguish different pressure with different loading force on sensor array. The results of the hardness experiment show pressure distribution of hard ball on pressure sensor array is one to two pixels, and soft ball is three to nine pixels by loading force 1.5, 2.7, and 3.9 N. This design successfully distinguishes different hardness, and it is potential to be applied in electronic skin and wearable device.

108 Flexible SERS Sensors Based on Carbon Nanomaterials-Supported Au Nanostructures

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Surface-enhanced Raman scattering (SERS) is a powerful technique to detect analytes in a label-free and non-destructive way at extremely low concentrations, even down to the single-molecule level. In the present study, a series of anisotropic Au nanostructures are integrated onto the platforms of carbon nanomaterials, mainly carbon nanotubes (CNT) and graphene, in order to fabricate high-performance flexible SERS sensors. Sizes, dimensions and shapes of Au nanostructures can be well controlled through this strategy, based on which Au nanowires, nanoribbons, nanoplates, nanobelts, and nanoframes are successfully deposited onto CNT and graphene templates, respectively. Significantly enhanced plasmonic activity originates from these Au nanocrystals, which provide increased SERS signals of the analytes by many orders of magnitude, while CNT films or graphene substrates offer the superior flexibility and accessibility. For instance, A flexible SERS sensor made of graphene supported Au nanoframes can detect the analyte R6G at the concentration as low as 10^{-9} M. The mechanism for the sensitivity enhancement could be attributed to the homogenous distribution of Au nanoframes on the graphene support as well as the strong molecule adsorption to the graphene nanoporous network.

109 Non-Monotonic Sensor Behavior of Carbon Particle-Filled Textile Strain Sensors

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Carbon particle-filled elastomers are a widely researched option to be used as piezoresistive strain sensors for soft robotics or human motion monitoring. Therefore, various polymers can be compounded with carbon black, carbon nano tubes (CNT) or graphene. However, in many studies the electrical resistance's strain response of the carbon-particle filled elastomers is non-monotonic in dynamic evaluation scenarios. The non-monotonic material behavior is also called shoulder phenomenon or secondary peak. Until today, the underlying cause is not sufficiently well understood. In this study, several influencing test parameters on the shoulder phenomena are explored like strain level, strain rate and strain history. Moreover, material parameters like CNT content and anisotropy are varied in melt-spun CNT filled thermoplastic polyurethane filament yarns and their non-monotonic sensor response is evaluated. Additionally, a theoretical concept for the underlying mechanism and thereupon-based model is developed. An equivalent circuit model is used, which incorporates the visco-elastic properties and the characteristic of the percolation network formed by the conductive filler material. The simulation results are in good agreement when compared to the experimental results.

110 Study of the Effect of Bending Deformation on the Performance of Flexible Polymer Layered Humidity Sensor

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Humidity-sensitive polymer, namely poly(vinyl alcohol-co-vinyl acetal) was deposited on a flexible poly(ethylene terephthalate) (PET) substrate pre-covered with sputtered Au:Pd thin layer in order to develop an optical flexible humidity sensor. Spin-coating method was applied for the thin polymer film deposition. The optical and sensing properties of the device were studied after repeated bending deformation in the range 25−1000 times. Transmittance measurements at different levels of relative humidity were conducted in order to examine the sensing properties of probed flexible sample. The influence of the number of bending deformations on performance of the sensor is studied and the possibility for its successful application is demonstrated and discussed.