



SGS 2012
VIII International Workshop on
Semiconductor Gas Sensors
September 11 - 15, 2012, Cracow, Poland

Open Special Session:

Nanostructures & Sensing Technologies for Environmental Gas Sensors

organized by COST Action TD1105 EuNetAir

European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability

SGS 2012 - VIII International Workshop on Semiconductor Gas Sensors

11 - 15 September, 2012, Cracow, Poland

Visit link: <http://www.sgs.conrego.pl/>

SPECIAL SESSION PROGRAM

Session Chair(s): Prof. Eduard Llobet (MC Member) and Dr. Michele Penza (Chair Action)

Nanostructures & Sensing Technologies for Environmental Gas Sensors

Half-a-Day Session at one day during Conference on 11-15 September 2012

Friday 14 September 2012

AIM of OPEN SPECIAL SESSION

The **Open Special Session** aims to provide to the scientific community of Semiconductor Gas Sensors and Nanostructured Materials for Gas Sensing, as well as to anyone else interested, with information on the current state of play in new sensor technologies, advanced nanostructures for gas sensors, functional sensing materials and new sensing concepts for air quality control. The tutorial will be based on research results achieved by members of the COST Action TD1105 **EuNetAir** and is part of the Action's efforts for dissemination of results and for cross-domain scientific collaborations.

Current trend in the solid-state sensing technology is the development of nanomaterials and nanostructures with novel functionalities and innovative properties at the nanoscale for high-performance chemical sensing. In this direction, great efforts in the ongoing research have been doing to fabricate environmental sensors with advanced sensing nanostructures and high-resolution transducers coupled to proper electronic interfaces and new algorithms of pattern recognition and signal processing.

The key role for high-performance environmental sensors and sensor-systems is the engineering of sensing devices, ICT hardware, ad-hoc software/firmware, emerging transducers and sub-systems to develop air quality control applications with ubiquitous and mobile sensor-systems, including participating sensing and wireless sensor networks.

This **Tutorial** will be completely devoted to **Nanostructures & Sensing Technologies for Environmental Gas Sensors**. This event is based on Tutorial Session focussing environmental hot-issues from at least 3 Speakers from COST Action TD1105 EuNetAir and an Overview of the COST Action TD1105 from Chair (or a MC Delegate) towards large and specialized target audience with high benefit for COST Action TD1105.



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Call for papers

This **Tutorial** openly calls for perspective and original contributions in the field of environmental sensors, sensor-systems, sensor technology and applications, from science and technology worldwide community, *over COST Action* and move towards new interested researchers and stakeholders working in the field of Action core-themes. These contributions related to Action-issues from extra-Action scientists would be submitted free of charge to the new open-access **Journal of Sensors and Sensor Systems (JSSS)** (www.journal-of-sensors-and-sensor-systems.net). The regular issue JSSS accepts contributions to cover a full range of sensors and sensor-systems such as theory, basic properties, design, fabrication, processing, calibration, measurements, integration, characterization, applications. We invite the submission of the manuscripts related to the fundamental and applied aspects for the environmental sensory, sensors science, sensor materials, nanomaterials and nanostructures processing, materials science and nanotechnology, gas sensors, air quality control sensor-systems applications, measuring systems, sensor technologies, environmental smart systems, sensing solutions, environmental ICT applications, mobile sensing, participatory environmental sensing, etc.

Topics of interest include, but not limited to:

- smart sensor materials
- advanced nanostructures for gas sensing
- nanomaterials processing
- functional nanomaterials
- environmental sensors
- outdoor/indoor air quality monitoring
- mobile sensing and participatory sensing
- sensor networks
- gas sensors and sensor arrays
- pattern recognition and signal processing
- electronic interfaces for sensors
- applications of sensor systems

Authors should follow the Journal of Sensors and Sensor Systems (JSSS) manuscript format described at the open-access journal site www.journal-of-sensors-and-sensor-systems.net. Prospective authors should submit an electronic copy of their complete manuscript. Papers should be submitted either in a doc or in a pdf form and they will be peer reviewed by at least 2 academic referees.

A regular issue to be published in *Thin Solid Films* (Elsevier) will be also managed and edited by SGS-2012 Chairman/Organizers to publish peer-review papers, presented to SGS-2012 workshop, and devoted to gas sensor materials. Notice of submission from authors should be emailed to Open Special Session Chairs.

Open Special Session Chairs

Michele Penza, ENEA - Italian National Agency for New Technologies, Energy, and Sustainable Economic Development, Technical Unit of Technologies for Materials Brindisi, Italy; michele.penza@enea.it

Eduard Llobet, Universitat Roviri I Virgili, Tarragona, Spain; eduard.llobet@urv.cat



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Talk 1: 30 minutes (14.00 - 14.30)

Tentative Title: *Overview of COST Action TD1105 EuNetAir*

Speaker: Dr. Michele Penza, ENEA, IT - michele.penza@enea.it

Talk 2: 30 minutes (14.30 - 15.00)

Tentative Title: *Nanowires for low power consumption gas sensors*

Speaker: Dr. J. Daniel Prades, University of Barcelona, ES - dprades@el.ub.es

Talk 3: 30 minutes (15.00 - 15.30)

Tentative Title: *Carbon nanotubes-based gas sensors for pollutants: Elaboration methods for NO₂ and BTX detection*

Speaker: Dr. Amadou L. Ndiaye, LASMEA, Aubiere, France - amalat2005@yahoo.fr

Talk 4: 30 minutes (15.30 - 16.00)

Tentative Title: *TiO₂ Nanotubes Based Heterostructures For Gas Sensing Applications*

Speaker: Prof. Zafer Ziya Ozturk, GEBZE Institute of Technology, Kocaeli, Turkey - zozturk@gyte.edu.tr

Talk 5: 30 minutes (16.00 - 16.30)

Tentative Title: *Array of Polycyclic Aromatic Hydrocarbons and Carbon Nanotubes for Accurate and Predictive Detection of Volatile Organic Compounds under Real-World Environmental Humidity Conditions*

Speaker: Dr. Radu Ionescu, TECHNION, Haifa, Israel; and University Roviri I Virgili, Tarragona, Spain - radu.ionescu@urv.cat

Talk 6: 30 minutes (16.30 - 17.00)

Tentative Title: *Tailoring of WO₃ and V₂O₅ Nanostructures for Gas Sensing Applications*

Speaker: Jyrki Lappalainen, Microelectronics and Materials Physics Laboratories, University of Oulu, Finland - jyrki.lappalainen@oulu.fi



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Open Special Session:

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Invited Talk 1

Overview of COST Action TD1105 EuNetAir

Michele Penza - ENEA, Italian National Agency for New Technologies, Energy and Sustainable Economic Development, PO BOX 51 Br-4, I-72100 Brindisi, Italy - michele.penza@enea.it

This is a short overview of the COST Action TD1105 EuNetAir - *European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability* - funded in the framework *European Cooperation in the field of Scientific and Technical Research* (COST) during the period 2012-2016. The main objective of the Concerted Action is to develop new sensing technologies for Air Quality Control at integrated and multidisciplinary scale by coordinated research on nanomaterials, sensor-systems, air-quality modelling and standardised methods for supporting environmental sustainability with a special focus on Small and Medium Enterprises. This international Networking, coordinated by ENEA (Italy), includes over 60 big institutions from 22 COST Countries (EU-zone) and 5 Non-COST Countries (extra-Europe) to create a S&T critical mass in the environmental issues.

Invited Talk 2

Nanowires for low power consumption gas sensors

J. Daniel Prades, MIND - Departament d'Electrònica, Universitat de Barcelona,
Martí i Franquès 1, Planta 2, E-08028 Barcelona, Spain - dprades@el.ub.es

Harnessing the advantages offered by 1D nanostructures has been one of the most successful strategies to improve of the power consumption of current gas sensors. In this talk, two recent findings will be overviewed: 1) the self-heating effect in nanowires can be used to dramatically reduce the power consumption in temperature-driven applications, as well as to develop a new kind of transient spectroscopy technique with analytic capabilities and 2) the integration of complementary functionalities in one single nanowire can be used to build up new devices with novel capabilities (zero-power consumption, ultra-high selectivity, faster response time, etc.) which were just unfeasible with conventional technologies.



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Invited Talk 3

Carbon nanotubes-based gas sensors for pollutants: Elaboration methods for NO₂ and BTX detection

Amadou L. Ndiaye^{1,2}, J. Brunet^{1,2}, C. Varenne^{1,2}, P. Bonnet^{3,4}, A. Pauly^{1,2}, B. Lauron^{1,2}

⁽¹⁾ Clermont Université, Université Blaise Pascal, Institut Pascal, BP 10448, F-63000 Clermont-Ferrand, ⁽²⁾ CNRS, UMR 6602, Institut Pascal, F-63171 Aubière, ⁽³⁾ Clermont Université, Université Blaise Pascal, Institut de Chimie de Clermont-Ferrand, F-63000 Clermont-Ferrand, ⁽⁴⁾ CNRS, UMR 6296, Institut de Chimie de Clermont-Ferrand, F-63171 Aubière - Amadou.NDIAYE@univ-bpclermont.fr

The monitoring of pollutants for prevention or protection is nowadays an essential task and is the main objective of the COST Action "EuNetAir" in which we are involved.

Owing to their narrow size, nanomaterials present remarkable properties [1-2], which are especially related to their high surface area. Carbon nanotubes (CNTs) present peculiar transport properties which are sensitive to surface reaction (gas adsorption). As a consequence CNTs are a judicious choice for the development of efficient gas sensors. Recently, we have developed SWNTs-based sensors made from dispersions of raw SWNTs for NO₂ and O₃ detection and functionalized CNTs with phthalocyanines for BTX detection. The sensing materials are prepared and characterized by standard techniques. The first results have provided information on the ability of these CNTs to be used as matrix to reach higher sensitivities as well as the macrocycles for targeting the detection.

References

- [1] J. Hilding *et al.*, J. Disp. Sci. Technol. 24/1 (2003) 1.
- [2] V. Derycke *et al.*, C. R. Physique 10/4 (2009) 330.

Invited Talk 4

TiO₂ Nanotubes based Heterostructures for gas sensing applications Erdem SENNIK¹, Sadullah OZTURK¹ Necmettin Kılınç¹, Zafer Ziya Öztürk^{1,2} *

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For monitoring air quality, metals, metal oxides, organic compounds, polymers in different forms such as powder, thin and thick films, nanostructures etc. have been used as gas sensors. With increasing necessity for gas sensors, studies were focused on fast, low cost, lower power consumption. Metal oxides semiconductors are very good candidate with high sensitivity for improving gas sensor technology Metal oxide films have played an increasing role in the last years as sensing devices for various gases. TiO₂ and ZnO nanostructures have been investigated as gas sensors by many groups. TiO₂ based gas sensors have been widely used because of their inert surface properties and high sensing abilities. Recently, many nanotechnology approaches have been followed to enlarge the surface area of TiO₂ without increasing the device dimensions. Highly-ordered titania nanotubes were firstly synthesized by Grimes *et al.* [1].

In this study, we fabricated titanium dioxide (TiO₂) nanotubes based heterostructures by coating copper oxide (CuO) and zinc oxide (ZnO) thin films on the titania nanotubes. We synthesized highly ordered self-organized TiO₂ nanotubes arrays. Ti by anodical oxidation of titanium foil in a HF electrolyte at 20°C. CuO and ZnO thin films were coated on nanotubes with sol-gel methods. Fabricated heterostructures tested to toxic and explosive gases as hydrogen (H₂), nitrogen dioxide (NO₂) and some of the volatile organic compounds (VOCs) and sensor properties of CuO/TiO₂ and ZnO/TiO₂ will be investigated in different temperatures and gas concentrations.

- [1] D. Gong, C.A. Grimes, O.K. Varghese, W. Hu, R. S. Singh, Z. Chen, E. C. Dickey, Titanium oxide nanotube arrays prepared by anodic oxidation, J. Mater. Res., 16 (2001) 3331.

ACKNOWLEDGMENT

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Invited Talk 5

Array of Polycyclic Aromatic Hydrocarbons and Carbon Nanotubes for Accurate and Predictive Detection of Volatile Organic Compounds under Real-World Environmental Humidity Conditions

Radu Ionescu

Technion, Haifa, Israel

Department of Electronics, Electrical and Automatic Engineering, Rovira i Virgili University, Av, Països Catalans 26, 43007 Tarragona, Spain - radu.ionescu@urv.cat

In this talk, I introduce a cross-reactive array of synthetically-designed Polycyclic Aromatic Hydrocarbons (PAH) and single wall carbon nanotube (SWCNT) bilayers, and demonstrate its huge potential in discriminating between a series of volatile organic compounds (VOCs). For fabricating the sensing films, an underlying semiconductive random network of intersecting SWCNT was coated with different PAH derivatives, having various aromatic corona and side groups. Using appropriate combinations of PAH/SWCNT sensors, high sensitivity and accuracy values could be obtained for discriminating the VOCs in samples with different levels of humidity (5-80% RH). Combining the sensors responses with the Partial Least Squares (PLS) algorithm, allowed the prediction of VOCs concentration in various humidity levels. The results obtained are of great importance for the construction of smart, self-learning sensing systems that can work independently under real confounding factors, and could lead to the development of a cost-effective, light-weight, low-power, non-invasive tool for a widespread detection of VOCs in real-world environmental, security, food, health and/or other applications.

Keywords: Polycyclic Aromatic Hydrocarbons; Single Wall Carbon Nanotubes; Chemoresistive Sensors; Volatile Organic Compounds; Humidity

Invited Talk 6

Tailoring of WO_3 and V_2O_5 Nanostructures for Gas Sensing Applications

Jyrki Lappalainen¹, Krisztian Kordas¹, Joni Huotari¹, Jarmo Kukkola¹, and Anita Lloyd Spetz^{1,2}

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²Div. of Applied Sensor Science, Dept. of Physics, Chemistry and Biology, Linköping University, Sweden

Various types of nanostructured WO_3 and V_2O_5 materials including porous films, nanoparticles and nanowires for novel gas sensor applications have been studied. Selective and highly sensitive sensors are based on pure WO_3 nanoparticles, or metal and metal oxide decorated nano-size WO_3 crystals that can detect some analytes even at room temperature. On the other hand, thin films of V_2O_5 and its compositional variations including crystal phases identified as $\text{VO}_x\text{-NT}$, which is generally found in nanotubes, are deposited to form heterojunction multi-phase sensors. The actual sensor devices are achieved by applying thin porous films or inkjet printed microscopic patterns of the sensing layer on tailor made Si chips or MgO substrates allowing a robust platform for functionality testing, packaging and component integration. Thin films, nanoparticles, and nanowires were fabricated using pulsed laser deposition (PLD) or chemical methods. The crystal structure and microstructure of the nanosized materials were studied with X-ray diffraction, Raman spectroscopy, SEM, and SPM methods, for example. Effects of the nanoparticle structures on the gas response of WO_3 and V_2O_5 materials for several analytes were characterized.

Keywords:

WO_3 , V_2O_5 , $\text{VO}_x\text{-NT}$, nanoparticle, nanowire.