COST Action TD1105 *EuNetAir*

BOOKLET

FOURTH SCIENTIFIC MEETING

Working Groups and Management Committee

New Sensing Technologies for Outdoor Air Pollution Monitoring

Physics Building, Department of Physics, Chemistry and Biology
Olaus Magnus väg, Campus Valla, Linköping University

organized by Linköping University

Division of Applied Sensor Science

Linköping (Sweden), 3 - 5 June 2015

EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

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

ESSEM Domain

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COST Action TD1105

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

FOURTH SCIENTIFIC MEETING

Working Groups and Management Committee
organized by Linköping University, Division of Applied Sensor Science
3 - 5 June 2015

hosted at Physics Building, Department of Physics, Chemistry and Biology
Olaus Magnus väg, Campus Valla, Linköping University
58183 Linköping, Sweden

Meeting AGENDA		
3 June 2015 - Wednesday		
08:30 - 18:00	***REGISTRATION***	
09:00 - 09:30	**WELCOME SESSION**	
09:30 - 11:00	**PLENARY SESSION 1: Outdoor Environment Quality Applications**	
11:00 - 11:30	*Coffee-Break*	
11:30 - 13:00	**PLENARY SESSION 2: Indoor Environment Quality Applications**	
13:00 - 14:30	*Lunch*	
14:30 - 16:30	**WG1-WG2 Meeting**	**WG3-WG4 Meeting**
16:30 - 17:00	*Coffee-Break*	
17:00 - 18:30	**WG1-WG2 Meeting**	**WG3-WG4 Meeting**
18:30	*Gathering of Day*	
19:15	*Optional Guided Tour at Gamla Linkoping Open-Air Museum*	
20:30 - 23:00	*Social Dinner*	
4 June 2015 - Thursday		
09:00 - 18:00	***REGISTRATION***	
09.00 - 09.30	**Wrap-Up and Inputs from Action TD1105**	
09:30 - 10:30	**KEYNOTE SESSION**	
10:30 - 11:00	*Coffee-Break*	
11:00 - 12:30	**SIG SESSIONs: SIG1-SIG4 Meeting**	
12:30 - 14:00	*Lunch*	
14:00 - 14:50	**ROUNDTABLE: The European Sensor Systems Cluster and EC R&I Policy**	
15:00 - 16:30	**POSTER SESSION** (*outside Planck room*)	
16:30 - 17:00	*Coffee-Break*	
17:00 - 18:30	**Action WGs/SIGs GENERAL ASSEMBLY**	
18:30	**CONCLUSIONS**	
19:00	*Optional Guided Tour at Arwen - Transmission Electron Microscope*	
20:30	*Free Dinner*	
5 June 2015 - Friday		
09:30 - 13:00	**7th MANAGEMENT COMMITTEE MEETING**	
13:00 - 14:00	*Lunch*	
14:30	***Meeting Closing***	

COST is supported by the EU Framework Programme

EUROPEAN SCIENCE FOUNDATION ESF provides the COST Office through a European Commission contract

Background and goals

About COST Action TD1105 *EuNetAir*

COST Action TD 1105 EuNetAir, a Concerted Action on *New Sensing Technologies for Air-Pollution Control and Environmental Sustainability*, is a running Networking funded in the framework *European Cooperation in the field of Scientific and Technical Research* (COST) during 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 80 big institutions from 31 COST Countries (EU-zone: *Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Latvia, Luxembourg, The Former Yugoslav Republic of Macedonia, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom*) and 7 International Partners Countries (extra-Europe: *Australia, Canada, China, Morocco, Russia, Ukraine, USA*) to create a S&T critical mass in the environmental issues.

About the *Fourth Scientific Meeting* at Linköping University, Linköping, 3 - 5 June 2015

The 7th MC Meeting jointly with WG1-4 Meeting will be held at Physics Building of Department of Physics, Chemistry and Biology in Linköping University, under local chairing and organization of Prof. Anita Lloyd Spetz (Action MC Vice-Chair), tentatively organized with a Plenary Session, parallel Inter-WGs Sessions including a General Assembly of the WGs and Special Interest Groups (SIGs), a Roundtable, and finally, the MC Meeting. The Plenary Session will mainly focus on ***New Sensing Technologies for Outdoor Air-Pollution Monitoring*** in a multidisciplinary approach including International Experts and Coordinators of the running FP7 and H2020 research projects to consolidate the **European Sensor Systems Cluster**, supported and sponsored by the EC DG Research and Innovation.

Participation from research, university, industry, environmental agencies, stakeholders, policy-makers and institutional managers is widely planned with large outreach and dissemination activities, at high expected impact (31 Parties involved in the Action on May 2015). Fruitful discussions between Action TD1105 participants, experts, speakers and international organizations delegates (e.g., WHO Europe, JRC, EMRP, EC DG) are strongly expected. At the Open ***Fourth Scientific Meeting*** of the COST Action TD1105 *EuNetAir*, a strong impact on focusing of the critical outdoor and indoor environmental issues would be mutual benefit.

More Information

Dr. Michele Penza
MC Chair/Proposer of COST Action TD1105 EuNetAir
ENEA - Italian National Agency for New Technologies, Energy and Sustainable Economic Development
Technical Unit for Materials Technologies - Brindisi Research Centre
PO BOX 51 Br-4, I-72100 Brindisi, ITALY. Email: michele.penza@enea.it. Action webpages: www.cost.eunetair.it

Prof. Anita Lloyd Spetz
Local Organizing Team Chair and Action MC Vice-Chair
Division of Applied Sensor Science, Department of Physics, Chemistry and Biology
Linköping University, Linköping, Sweden
Olaus Magnus väg, Campus Valla, 58183 Linköping, Sweden
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EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

FOURTH SCIENTIFIC MEETING
Working Groups and Management Committee

New Sensing Technologies for Outdoor Air Pollution Monitoring

Linköping (Sweden), 3 - 5 June 2015

Physics Building at Department of Physics, Chemistry and Biology
Olaus Magnus väg, Campus Valla, Linköping University, 58183 Linköping, Sweden

EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

EuNetAir

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




Meeting Venue: Physics Department

TEM by Jens Birch credit

A Linköping symbol

Action Meeting Programme Committee

Michele Penza, ENEA, Brindisi, Italy
Anita Lloyd Spetz, Linköping University, Sweden
Andreas Schuetze, Saarland University, Germany
Ingrid Bryntse, SenseAir AB, Sweden
Zafer Ziya Ozturk, GEBZE Institute of Technology, Turkey
Carlos Borrego, IDAD, University of Aveiro, Portugal
Iveta Steinberga, University of Latvia, Riga, Latvia
Ole Hertel, Aarhus University, Denmark
Juan Ramon Morante, IREC, Spain
Marco Alvisi, ENEA, Italy
Corinna Hahn, Eurice GmbH, Saarbrucken, Germany
Juliane Rossbach, Eurice GmbH, Saarbrucken, Germany
Annamaria Demarinis Loiotile, University of Bari, Italy
Donatella Puglisi, Linköping University, Sweden
Jens Eriksson, Linköping University, Sweden
Mike Andersson, Linköping University, Sweden

URL: www.cost.eunetair.it

COST Action TD1105 EuNetAir Steering Committee

Michele Penza, ENEA, Brindisi, Italy - *Action Chair*
Anita Lloyd Spetz, Linköping University, Sweden - *Action Vice-Chair*
Juan Ramon Morante, IREC, Spain
Andreas Schuetze, Saarland University, Germany
Ole Hertel, Aarhus University, Denmark
Ingrid Bryntse, SenseAir AB, Sweden
Jan Theunis, VITO, Belgium
Marco Alvisi, ENEA, Brindisi, Italy
Gianluigi De Gennaro, University of Bari, Italy
Fabio Galatioto, Newscastle University, UK
Ralf Moos, University of Bayreuth, Germany
Mar Viana, CSIC-IDAEA, Barcelona, Spain
Iveta Steinberga, University of Latvia, Riga, Latvia
Corinna Hahn, Eurice GmbH, Saarbrucken, Germany - *Grant Holder*
Julian Gardner, University of Warwick, UK
Rod Jones, University of Cambridge, UK
Giorgio Sberveglieri, University of Brescia, Italy
Eduard Llobet, Universitat Roviri I Virgili, Tarragona, Spain
Thomas Kuhlbusch, IUTA eV, Duisburg, Germany
Albert Romano-Rodriguez, Universitat de Barcelona (UB), Spain
Carlos Borrego, IDAD, University of Aveiro, Portugal
Annamaria Demarinis Loiotile, University of Bari, Italy - *Secretary*

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Wednesday, 3 June 2015

COST Action TD1105 Working Groups and Special Interest Groups MEETING

Main Hall: *Planck Room*

8:30 - 18:00	**Registration**
09:00 - 09:30	**Welcome Address Session** *Chairman: Anita Lloyd Spetz, Action Vice-Chair - Linkoping University, Sweden*
09:00 - 09:10	**Welcome: Linköping City Council** *Helena Balthammar*, Linköping Mayor, Sweden
09:10 - 09:20	**Welcome: Linköping University** *Kenneth Järrendahl*, Department Dean, Linköping University, Sweden
09:20 - 09:30	**Welcome Address from COST Action TD1105** *Michele Penza*, Action Chair, ENEA, Brindisi, Italy
09:30 - 11:00	**Plenary Session 1: Outdoor Environment Quality Applications** *Chairman: Anita Lloyd Spetz, Action Vice-Chair - Linkoping University, Sweden*
09:30 - 10:00	**COST Action TD1105: European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability - Updating** *Michele Penza*, Action Chair, ENEA, Italy
10:00 - 10:30	**Review of Gas Sensors to Monitor Benzene and Other VOCs in Ambient Air in the Framework of the EURAMET Key-VOC Project** *Laurent Spinelle and Michel Gerboles*, JRC, EC DG ENV, Institute for Environment and Sustainability, Ispra, Italy
10:30 - 11:00	**Extended Performance Analysis of a Sensor Unit for O_3 and NO_2 and Operation of a Small Static Sensor Network in Zurich, Switzerland** *Christoph Hueglin,* MC Substitute, EMPA, Zurich, Switzerland
11:00 - 11:30	**Coffee Break**
11:30 - 13:00	**Plenary Session 2: Indoor Environment Quality Applications** *Chairman: Michele Penza, Action Chair - ENEA, Italy*
11:30 - 12:00	**The FP7 SENSIndoor Project (NMP-2013-5): Increasing Sensitivity and Selectivity of Gas Sensor-Systems by Using Micromachined Pre-Concentrators with MIP and MOF Layers** *Andreas Schuetze*, Action WG2 Leader & MC Member, Saarland University, Saarbrucken, Germany
12:00 - 12:30	**The FP7 IAQSense Project (NMP-2013-5): Sensors for Indoor Air-Pollution Monitoring** *Mathias Holz*, Nano Analytik GmbH, Ilmenau, Germany
12:30 - 13:00	**Development of SenseAir High Performance Platform (HPP) for Indoor Sensing** *Ingrid Bryntse*, Action WG4 Leader & MC Member, SenseAir AB, Delsbo, Sweden
13:00 - 14:30	**Lunch offered by COST Action organization**

EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

Wednesday, 3 June 2015

Action TD1105 Working Groups Meetings

Parallel Session of WG1-WG2. Location: Main Hall - *Planck Room* (Theatre 300 seats)

14:30 - 16:30	**WG1: Sensor Materials and Nanotechnology** *Chairman: Jyrki Lappalainen, Action WG1 Vice-Chair - Oulu University, Oulu, Finland*
14:30 - 14:50	**Effect of Sensor Configuration for Low-Temperature Gas Detection with Semiconducting Oxides** *Azhar A. Haidry, E. Ciftyürek, Bilge Saruhan-Brings*, WG Member, German Aerospace Center, Institute of Materials Research, Cologne, Germany
14:50 - 15:10	**Pulsed Laser Deposition of Metal Oxide Nanoparticles, Agglomerates, and Nanotrees** *J. Lappalainen[1], J. Huotari[1], T. Baur[2], J. Puustinen[1], T. Sauerland[2], and A. Schütze[2]* [1]Microelectronics and Material Physics Laboratories, University of Oulu, Oulu, Finland; [2]Laboratory for Measurement Technology, Saarland University, Saarbrücken, Germany
15:10 - 15:30	**Graphene Gas Sensors Enhanced by UV Light and Pulsed Laser Deposition** *Raivo Jaaniso*, University of Tartu, Tartu, Estonia
15:30 - 15:45	**Nanostructured BST based Films with Potential Application in Hazardous Gas Detection** *Cristina F. Rusti, Roxana M. Piticescu*, IMNR, Pantelimon, Romania
15:45 - 16:00	**Challenges Performing Outdoor Air Pollution Monitoring with Polymer Nanocomposites** *Gita Sakale, M. Knite, S. Stepina, S. Guzlena, I. Klemenoks*, Riga Technical University, Latvia
16:00 - 16:15	**VOCs Sensing Properties of Hybrid Nanostructures** *Zafer Ziya Ozturk*, Gebze Institute of Technology, Kocaeli, Turkey
16:15 - 16:30	**Low-Temperature Co-Fired Ceramic Package for Lab-on-Chip Application** *Niina Halonen et al.*, University of Oulu, Oulu, Finland
16:30 - 17:00	**Coffee Break**

Parallel Session of WG1-WG2. Location: Main Hall - *Planck Room* (Theatre 300 seats)

17:00 - 18:30	**WG2: Sensors, Devices and Systems for AQC** *Chairman: Andreas Schuetze, Action WG2 Chair - Saarland University, Saarbrücken, Germany*
17:00 - 17:20	**Functionalised Carbon Nanotube Sensors for Detecting Benzene at Trace Levels** *Eduard Llobet, P. Clement, E.J. Parra*, MC Member, Universitat Roviri I Virgili, Tarragona, Spain
17:20 - 17:40	**The Application of Additive Technologies for Ceramic MEMS Gas Sensors** *A.A.Vasiliev[1], A.V.Sokolov[1], N.N.Samotaev[2], V.P.Kim[3], S.V.Tkachev[3], S.P.Gubin[3], G.N.Potapov[4], Yu.V.Kokhtina[4], A.V.Nisan[4]*, [1]NRC Kurchatov Institute, Moscow, Russia, [2]National Research Nuclear University "MEPhI", Moscow, Russia, [3]LLC AkKo Lab, Moscow, Russia, [4]LLC Ostec, Moscow, Russia
17:40 - 18:00	**Measurement of Monoaromatic Hydrocarbons in Air by Phthalocyanine-based QCM Sensors: Results and Outlooks** *Jerome Brunet, A.Kumar, A.L. Ndiaye, A.Pauly*, Université Blaise Pascal/CNRS, Aubiere, France
18:00 - 18:15	**New Principle Theory of QCM and SAW Devices in Sensors and Biosensor Applications** *Marina Voinova[1,2], Anton Wikstrom[2]*, [1]Chalmers University of Technology, Gothenburg, Sweden [2]National Technical University, Kharkiv, Ukraine
18:15 - 18:30	**Views on Inter-Laboratory Reproducibility of Chemosensing Experiments** *J.-M. Suisse[1], M. Bouvet[1], K. Persaud[2], E. Danesh[2]*, [1]Institut de Chimie Moléculaire de l'Université de Bourgogne, UMR CNRS, Dijon, France; [2]The University of Manchester, UK

Parallel Session of WG3-WG4. Location: *Jordan Fermi Room* (40 seats) (*two floors right above Planck*)

14:30 - 16:30	**WG3: Environmental Measurements and Air-Pollution Modelling** *Chairman: Joao Paulo Teixeira, Action MC Substitute, National Institute of Health, Porto, Portugal*
14:30 - 14:50	**Highly Resolved UFP Number Concentration Maps in Zurich based on Data from a Mobile Sensor Network** *Michael Mueller,* WG Member, EMPA, Zurich, Switzerland
14:50 - 15:10	**The Use of Sensors for VOC Emission Control at Industrial Sites** *Jan Peters*, VITO, Mol, Belgium
15:10 - 15:30	**MOX Sensor Systems in Outdoor Odor Nuisance Monitoring** *Wolfhard Reimringer*, WG Member, 3S GmbH, Saarbrucken, Germany
15:30 - 15:50	**Evaluation of Monitoring Gases and PMs with Low-cost and Reference Devices at AMS(s) in Belgrade, Serbia** *Milena Jovasevic-Stojanovic, D. Topalovic, M. Davidovic, M. Zivkovic, I. Lazovic, Z. Ristovski*, Action WG3 Member, Institute Vinca, Belgrade, Serbia
15:50 - 16:10	**Using Lichens as Multi-Pollutant Bioindicators in Air Quality Monitoring** *Maja Maslac, Irena Ciglenecki,* Rudjer Boskovic Institute, Zagreb, Croatia
16:10 - 16:30	**Transforming AQ Data to Personalised Services** *Kostas Karatzas*, Aristotle University of Thessaloniki, Greece
16:30 - 17:00	**Coffee Break**

Parallel Session of WG3-WG4. Location: *Jordan Fermi Room* (40 seats) (*two floors right above Planck*)

17:00 - 18:30	**WG4: Protocols and Standardisation Methods** *Chairman: Ingrid Bryntse, Action WG4 Chair - SenseAir SA, Delsbo, Sweden*
17:00 - 17:20	**Present IAQ Sensor Technologies and Future Trends** *Olivier Martimort*, NanoSense Sarl, Boulogne Billancourt, France
17:20 - 17:40	**Benefits of CMOS Sensors for Environmental Monitoring** *Foysol Chowdhury*, Action WG Member, CCMOSS Ltd, Cambridge, UK
17:40 - 18:00	**Low-Cost IR CO_2 Sensor for Battery Powered Applications** *Maksym Bryzgalov*, *Bengt Jonsson*, Action WG Member, SenseAir AB, Delsbo, Sweden
18:00 - 18:20	**Silicon Carbide Sensor Systems for Harsh Environment Market Applications** *Bo Hammarlund*[1], *Mike Andersson*[1,2], *Anita Lloyd-Spetz*[2], [1]SenSiC AB, Linkoping, Sweden; [2]Linkoping University, Sweden
18:20 - 18:30	*Final remarks, comments and conclusions from WG4 Chair*
18:30	**Gathering of Day**
19:15	**Optional Guided Tour at Gamla Linköping Open-Air Museum** **Register yourself at the Desk for Tour** (*Contact Point: Donatella Puglisi*)
20:30 - 23:00	**Social Dinner at *Värdshuset* - a Swedish Typical Restaurant** ***Värdshuset*** in Gamla (Old) Linköping (20 min. walk or 10 min. by bike from University) Gastgivaregatan 1, 582 46 Linkoping (Gamla Linkoping) (*See map at the end*)

Thursday, 4 June 2015

Action TD1105 Special Interest Groups Meetings

Main Hall: *Planck Room*

09:00 - 18:00	**Registration**
09:00 - 09:30	**Wrap-up and Inputs from Action TD1105**
09:00 - 09:15	**Inputs from Action TD1105: Wrap-up and Upcoming Action Events** *Michele Penza, Action Chair, ENEA, Brindisi, Italy*
09:15 - 09:30	**Inputs from Action TD1105: Online Travel Reimbursement Request & Strong Feature Authentication** *Juliane Rossbach, Grant Holder Manager, Eurice GmbH, Saarbrucken/Berlin, Germany*
09:30 - 10:30	**KEYNOTE SESSION: Key Enabling Technologies for Air Quality Control** *Chairman: Michele Penza, Action Chair* *Italian National Agency for New Technologies, Energy and Sustainable Economic Development - ENEA, Brindisi, Italy*
09:30 - 10:00	**Towards Zero-Power Gas Detection Systems based on Nanowires: Fabrication, Characterization, Benefits and Challenges** *J. Samà[1], J. D. Prades[1], O. Casals[1], S. Barth[2], J. Santander[3], C. Cané[3], I. Gracia[3], Albert Romano-Rodriguez[1]*, MC Substitute, [1]Universitat de Barcelona, Barcelona, Spain; [2]Technical University of Vienna; [3]CSIC, Bellaterra, Spain
10:00 - 10:30	**Cost-Efficient Approaches to Measure Carbon Dioxide (CO_2) Fluxes and Concentrations in Natural Environments Using Mini-Loggers** *David Bastviken*, Expert of Thematic Studies on Environmental Changes, Linkoping University, Linkoping, Sweden
10:30 - 11:00	**Coffee Break**
11:00 - 12:30	**SIGs Session - SIG1: Network of spin-offs** *Chairman: Marco Alvisi, Action SIG1 Leader* *Italian National Agency for New Technologies, Energy and Sustainable Economic Development - ENEA, Brindisi, Italy*
	Specific Presentation from SIG1
11:00 - 11:20	**"KOMpetitive Intelligence" - A New Method for the Identification and Assessment of Technological Alternatives** *Tiziano Montecchi[2] and Davide Russo[1]*, [1]University of Bergamo, [2]Bigflo srl, Italy
11:00 - 12:30	**SIGs Session - SIG2: Smart Sensors for Urban Air Monitoring in Cities** *Chairman: Christoph Hueglin, MC Substitute and SIG2 Member* *EMPA, Zurich, Switzerland*
	Specific Presentation from SIG2
11:20 - 11:40	**The 1st EuNetAir Air Quality Joint-Exercise Intercomparison: Assessment of Micro-Sensors *Versus* Reference Methods (Part II)** *Ana Margarida Costa*, WG Member, IDAD, Aveiro, Portugal

11:00 - 12:30	**SIGs Session - SIG3:Guidelines for Best Coupling Air Pollutants and Transducer** *Chairman: Eduard Llobet, Action SIG3 Vice-Chair, Universitat Roviri I Virgili, Tarragona, Spain*
	Specific Presentation from SIG3
11:40 - 12:00	**Graphene Metal-Oxide Hybrids for Gas Sensor Tuning** *Jens Eriksson[1], D. Puglisi[1], C. Strandqvist[1], R. Yakimova[1], A. Lloyd-Spetz[1]*, [1]Department of Physics, Chemistry and Biology, Linköping University, Linköping, Sweden
11:00 - 12:30	**SIGs Session - SIG4:Expert Comments for the Revision of the Air Quality Directive (AQD)** *Chairman: Ana Margarida Costa, WG Member, IDAD, Aveiro, Portugal*
	Specific Presentation from SIG4
12:00 - 12:20	**Preliminary Indoor and Outdoor Air Pollution Investigation in Naturally Ventilated Classrooms: Results from the ARIA Project** *Joana Mandureira, Joao Cavaleiro-Rufo, Ines Paciencia, Eduardo de Oliveira Fernandes, Livia Aguiar, Cristiana Pereira and Joao Paulo Teixeira*, National Institute of Health, Porto, Portugal
12:20 - 12:30	**DISCUSSION on SIG1-SIG4 Presentations** Questions and Answers from Participants Comments and Inputs from Audience
12:30 - 14:00	**Lunch offered by COST Action organization**

EUROPEAN COOPERATION
IN SCIENCE AND TECHNOLOGY

Thursday, 4 June 2015

COST Action TD1105 for the European Sensor-Systems Cluster (ESSC): The EC DG R&I Policy on the European Clusters

Main Hall: *Planck Room*

14:00 - 14:50	**Action TD1105 ROUND-TABLE DISCUSSION** *Chairman(s):* *Michele Penza, Action Chair and ESSC Chairman, ENEA, Brindisi, Italy* *Andreas Schuetze, Action WG2 Leader and ESSC WG2 IAQ Leader, Saarland University, Saarbrucken, Germany*
	EC Policy of the EU Clusters: **The European Sensor-Systems Cluster (ESSC)**
14:00 - 14:10	**The European Sensor-Systems Cluster (ESSC): Vision, Objectives and Position Paper** *Michele Penza*, COST Action TD1105 Chair and ESSC Chairman, ENEA, Brindisi, Italy
14:10 - 14:20	**The Role of the Project Technical Assistants (PTAs) in the EU Projects and Clusters** *Eberhard Seitz*, EC PTA, Julich, Germany
14:20 - 14:30	**An Industry View in the Commercialization of Gas Sensors for Environmental Sustainability** *Hans Martin*, R&D Director of SenseAir SA, Delsbo, Sweden
14:30 - 14:50	**Discussion of Action/Cluster Participants:** **Comments and Inputs on Priorities, R&I Needs, Strategies, Roadmap for future joint-activities of ESSC Cluster and COST Action TD1105 *EuNetAir*** **Speeches and Comments from Action WGs/SIGs Leaders and Participants** **Free Comments from Action and ESSC Cluster Stakeholders**

Thursday, 4 June 2015

Gallery of Main Hall: Outside Planck Room

15:00 - 16:30	***Poster Session:*** ***New Technologies and Methods for Environmental Monitoring*** *Chairperson: Andreas Schuetze, Action WG2 Leader, Saarland University, Saarbrucken, Germany*

Posters (max sizes: 90 cm width x 120 height) will be exhibited on Panels. The Poster Presenter, preferably Early Stage Researcher, is required to stay near poster for discussion with interested people.

P01	**A Local Integrated Assessment of Air Pollution Impacts on Human Health - A Case Study for Portugal and Grande Porto** *S. Costa* [(1,2)], *C. Costa* [(1)], *C. Silveira* [(3)], *M. Lopes* [(3)], *J. Ferreira*[(3)], *H. Relvas*[(3)], *C. Borrego*[(3)], *P. Roebeling*[(3)], *A. Miranda* [(3)], *J.P. Teixeira*[(1,2)], [(1)]EPIUnit-Institute of Public Health, University of Porto, Portugal; [(2)]National Institute of Health, Environmental Health Department, Portugal; [(3)]Centre for Environmental and Marine Studies & Department of Environment and Planning, University of Aveiro, Portugal
P02	**Non-Resonant High-Frequency Excitation of Nanoelectromechanical Oscillators** *A. M. Eriksson, M. V. Voinova, L. Y. Gorelik*, Department of Applied Physics, Chalmers University of Technology, Kemigården 1, Göteborg, Sweden
P03	**Detection of Harmful Pollutions from NO_2 in Gas Phase by Quartz Crystal Microbalance** *I. Nedkov*[5], Action MC Member, Institute of Electronics, Bulgarian Academy of Sciences, Sofia, *V. Georgieva*[1], *Z. Raicheva*[1], *B. Georgieva*[2], *D.Dimova-Malinovska*[3], *S. Boyadjiev*[4], [1]Institute of Solid States Physics, Bulgarian Academy of Sciences, Sofia, Bulgaria; [2]UCTM bul. " St. Kliment Ohridski" Sofia, Bulgaria; [3]Central Laboratory of Solar Energy and New Energy Sources at the Bulgarian Academy of Sciences, Sofia, Bulgaria; [4]MTA-BME Technical Analytical Research Group, Budapest, Hungary; [5]Institute of Electronics, Bulgarian Academy of Sciences, Sofia, Bulgaria
P04	**AirSensEUR: An Open Software/Open Hardware Multi Sensor for the Monitoring of Air Quality** *Michel Gerboles, Laurent Spinelle, Marco Signorini*, JRC, EC DG ENV, Institute for Environment and Sustainability, Ispra, Italy
P05	**Evaluatuon of Electrochemical Sensors by means of an Handheld Device for Air Quality Monitoring** *Domenico Suriano, Gennaro Cassano, Valerio Pfister, Michele Penza* ENEA, Technical Unit for Materials Technologies - Brindisi Research Centre, Brindisi, Italy
P06	**Sensor of Biogas Ingredient Methane Employing Powerful Pulsed Laser Diodes** *Vasilka Pencheva, Stoyan Penchev, Ivan Nedkov* Institute of Electronics, Bulgarian Academy of Sciences, Sofia, Bulgaria
P07	**Effect of Dopants in Semiconductor Oxide Sensing Layers under Low Oxygen Partial Pressures and at Higher Temperatures** *Azhar A. Haidry*[1], *Engin Ciftyürek*[1], *Bilge Saruhan-Brings*[1], *Sebastian Schröder*[2], *Holger Fritze*[2]; [1]German Aerospace Center, Institute of Materials Research, Linder Höhe, 51147 Cologne, Germany; [2]Technical University Clausthal, Institute for Energy Research and Physical Technologies, 38640 Goslar, Germany

P08	**How to Manage a Project of Citizen Science: Olfactory Annoyance Evaluation in Taranto City (Italy)** *M. Brattoli[a], L. de Gennaro[c], A. Mazzone[a], S. Petraccone[b], A. Demarinis Loiotile[b], R. Giua[a], G. Assennato[a], G. de Gennaro[a,b];* [a]Agenzia Regionale per la Prevenzione e la Protezione Ambientale Puglia - Corso Trieste 27, 70126 Bari; [b]Dipartimento di Chimica, Università degli Studi di Bari, via Orabona, 4, 70126 Bari, Italia; [c]Lenviros srl - spin off dell'Università degli Studi di Bari, via Orabona 4, 70126 Bari, Italia
P09	**Chemical Gas Sensors Array to Monitor Process Stability in Biogas Reactors** *Gilles Adam, Sébastien Lemaigre, Xavier Goux, Philippe Delfosse, Anne-Claude Romain* [1]University of Liège, Arlon Campus Environnement, 185 Avenue de Longwy, B-6700 Arlon, Belgium; [2]Environmental Research and Innovation Department (ERIN), Luxembourg Institute of Science and Technology (LIST), Rue du Brill 41, L-4422 Belvaux, Luxembourg

16:30 - 17:00	**Coffee-Break**

EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

Thursday, 4 June 2015

Action TD1105 Working Groups and Special Interest Groups Meetings

Main Hall: *Planck Room*

17:00 - 18:30	**Action WGs GENERAL ASSEMBLY** *Chairman: Michele Penza, Action Chair* *Italian National Agency for New Technologies, Energy and Sustainable Economic Development - ENEA, Brindisi, Italy*
	Specific Presentations from WGs Leaders
17:00 - 17:10	**Summary of Research and Innovation Needs from WG1 Session: Sensor Materials and Nanotechnology** *Jyrki Lappalainen,* Action WG1 Vice-Chair - Oulu University, Oulu, Finland
17:10 - 17:20	**Summary of Research and Innovation Needs from WG2 Session: Sensors, Devices and Systems for AQC** *Andreas Schuetze*, Action WG2 Chair, Saarland University, Saarbrucken, Germany
17:20 - 17:30	**Summary of Research and Innovation Needs from WG3 Session: Environmental Measurements and Air-Pollution Modelling** *Joao Paulo Teixeira,* Action MC Substitute, National Institute of Health, Porto, Portugal
17:30 - 17:40	**Summary of Research and Innovation Needs from WG4 Session: Protocols and Standardisation Methods** *Ingrid Bryntse*, Action WG4 Chair, SenseAir SA, Delsbo, Sweden
17:00 - 18:30	**Action SIGs GENERAL ASSEMBLY** *Chairman: Anita Lloyd Spetz, Action Vice-Chair* *Linkoping University (Sweden) and Oulu University (Finland)*
	Specific Presentations from SIGs Leaders
17:40 - 17:50	**Summary of Research and Innovation Needs from SIG1: Network of Spin-offs** *Marco Alvisi*, Action SIG1 Leader, ENEA, Brindisi, Italy
17:50 - 18:00	**Summary of Research and Innovation Needs from SIG2: Smart Sensors for Urban Air Monitoring in Cities** *Christoph Hueglin,* MC Substitute and SIG2 Member, EMPA, Zurich, Switzerland
18:00 - 18:10	**Summary of Research and Innovation Needs from SIG3: Guidelines for Best Coupling Air Pollutants and Transducer** *Eduard Llobet,* Action SIG3 Vice-Chair, Universitat Roviri I Virgili, Tarragona, Spain
18:10 - 18:20	**Summary of Research and Innovation Needs from SIG4: Expert Comments for the Revision of the Air Quality Directive (AQD)** *Ana Margarida Costa,* WG Member, IDAD, Aveiro, Portugal
18:30	**CLOSING of WGs and SIGs MEETING**
19:00	**Optional Guided Tour at Arwen** **Europe's Most Precise Transmission Electronic Microscope (TEM)** **Register yourself at the Desk for Tour** (*Contact Point: Donatella Puglisi*)
20:30	**Dinner Freely by Participants**

Friday, 5 June 2015

Action TD1105 MANAGEMENT COMMITTEE Meeting

Main Hall: *Planck Room*

09:30 - 13:00	**Action TD1105 7th MANAGEMENT COMMITTEE MEETING** *Chairman: Michele Penza, Action Chair* *Italian National Agency for New Technologies, Energy and Sustainable Economic Development - ENEA, Brindisi, Italy*

WORLD ENVIRONMENT DAY (WED) 2015
Global Celebration on 5 June
by *United Nations Environment Programme (UNEP)*
*This year's WED slogan is '**Seven Billion Dreams. One Planet. Consume with Care**'*
See more at: http://www.unep.org/wed/news/wed-2015

09:30 - 10:00 **New Methods for Control of Nanoparticles in Indoor-versus-Outdoor Environment**
Anita Lloyd Spetz, Action Vice-Chair, Linkoping University (Sweden) and University of Oulu (Finland)

10:00 : 13:00 **7th Management Committee Meeting**
Michele Penza, Action Chair, ENEA, Brindisi, Italy

- **DISCUSSION** (see MCM AGENDA)
- **Coffee-Break** (timely scheduled)

12:00 : 12:20 **Live VideoChat *Brussels-Linkoping*: Inputs from the COST Association**
Deniz Karaca, Science Officer of the COST Action TD1105, COST Association, Brussels, Belgium

12:20 : 12:30
- **QUESTION TIME with COST Science Officer**

13:00
- **End of the 7th MCM of the COST Action TD1105 - EuNetAir**

13:00 - 14:30
- **Lunch offered by the Conference Organization**

14:30
- **Meeting Closing**

EUROPEAN COOPERATION
IN SCIENCE AND TECHNOLOGY

Draft Agenda
7th Management Committee Meeting
COST Action TD1105

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

FOURTH SCIENTIFIC MEETING

Working Groups and Management Committee

New Sensing Technologies for Outdoor Air Pollution Monitoring

Linköping (Sweden), 3 - 5 June 2015

Planck Room - Physics Building at Department of Physics, Chemistry and Biology
Olaus Magnus väg, Campus Valla, Linköping University, 58183 Linköping, Sweden

Management Committee Meeting, 5 June 2015, 9:30 - 14:30 (local time)

To be completed by the meeting secretary and circulated to the MC, the DC Rapporteur(s) and the COST Office (Science and Administrative Officer)

1. Welcome to participants
2. Adoption of agenda
3. Approval of minutes and matters arising of last meeting
4. Update from the Action Chair
   a. Status of Action, including participating countries
   b. Action budget status
   c. STSM status and new applications
5. Promotion of gender balance and of Early Stage Researchers (ESR)
6. Update from the Grant Holder
7. Update from the COST Office
8. Update from the DC Rapporteur
9. Annual Progress Conference (preparation and/or feedback from DC)
10. Follow-up of MoU objectives
    a. Progress report of working groups
11. Scientific planning
    a. Scientific strategy
    b. Action Budget Planning
    c. Long-term planning (including anticipated locations and dates of future activities)
    d. Dissemination planning (Publications and outreach activities)
12. Requests for new members
13. Non-COST applications to the Actions
14. AOB
15. Location and date of next meeting
16. Summary of MC decisions
17. Closing

COST is supported by the EU Framework Programme

European Science Foundation
ESF provides the COST Office through a European Commission contract

EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

7th MC Meeting Venue/Location of COST Action TD1105 EuNetAir

FOURTH SCIENTIFIC MEETING

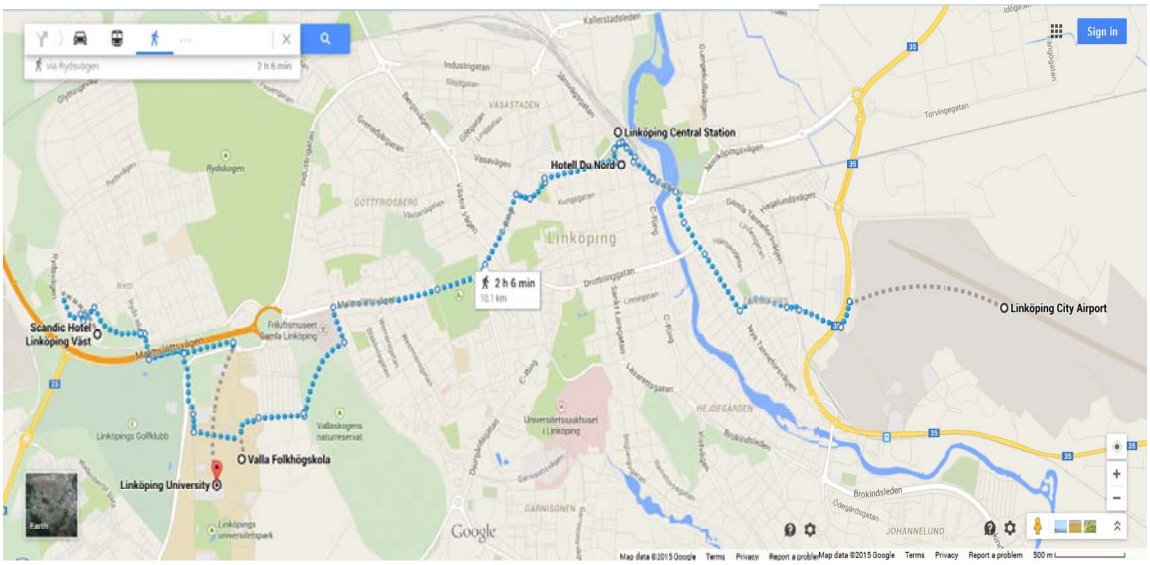
Working Groups and Management Committee

New Sensing Technologies for Outdoor Air Pollution Monitoring

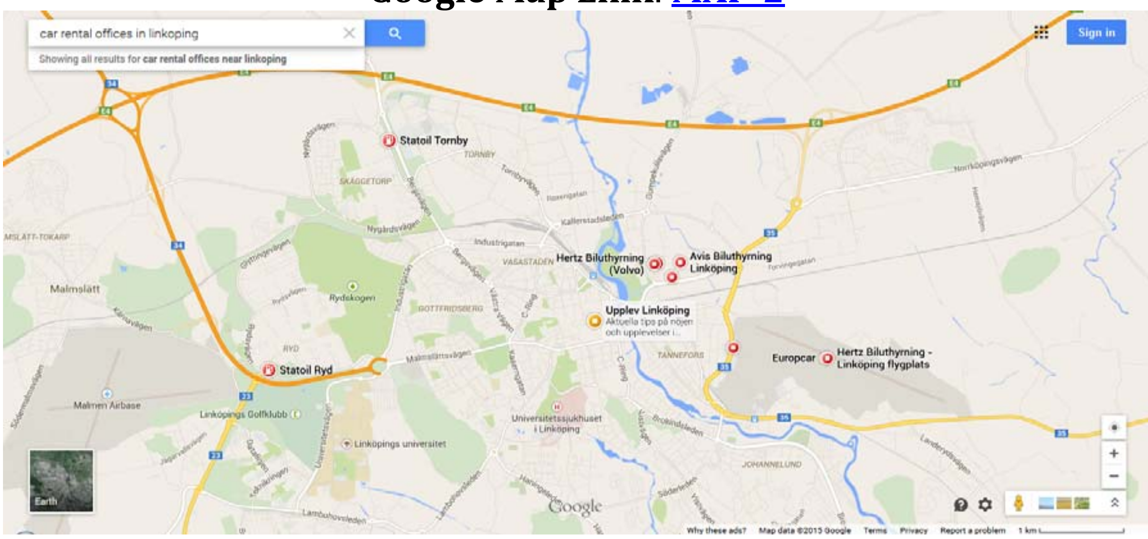
Linköping (Sweden), 3 - 5 June 2015

Physics Building at Department of Physics, Chemistry and Biology
Olaus Magnus väg, Campus Valla, Linköping University, 58183 Linköping, Sweden

Google Map Link: MAP-1



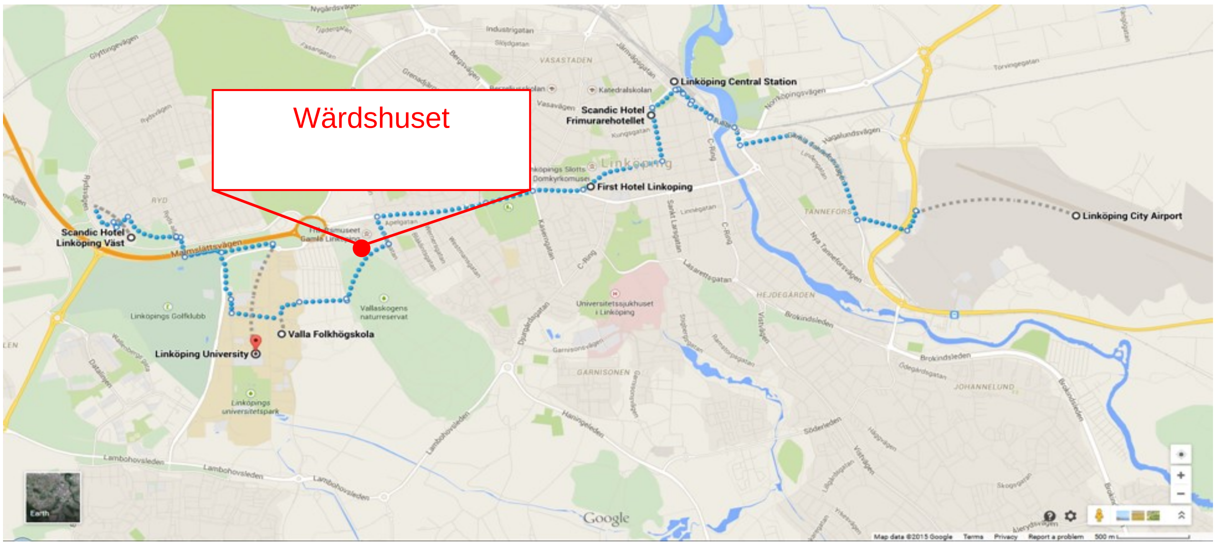
Google Map Link: MAP-2



COST is supported by the EU Framework Programme

ESF provides the COST Office through a European Commission contract

How to arrive to Wärdhuset restaurant in Gamla Linköping



MAP. Location of Wärdshuset

the restaurant in Gamla (Old) Linköping chosen for the Social Dinner on 3rd June 2015, with respect to the suggested / pre-booked hotels and Linköping University.

Walking distances from:

Linköping University, Meeting venue = 650 m
Valla Folkhögskola = 1.2 km
First Hotel Linköping = 1.7 km
Scandic Hotel Linköping Väst = 2.4 km
Scandic Hotel Frimurarehotellet = 2.6 km

Address:
Gästgivaregatan 1
582 46 Linköping (Gamla Linköping)
http://www.wardshuset.com/

WELCOME ADDRESS

This is a great honor and my pleasure to chair and welcome to ALL PARTICIPANTS of the **FOURTH SCIENTIFIC MEETING**, including **Working Groups Meeting** and **Management Committee Meeting**, of our COST Action TD1105 *European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability - EuNetAir*.

This COST Meeting - held on 3-5 June 2015 - on ***New Sensing Technologies for Outdoor Air-Pollution Monitoring*** is organized by **Linkoping University**, under management of Prof. Anita Lloyd Spetz, our Action Vice-Chair, Division of Applied Sensor Science, hosted at *Physics Building*, Campus Valla, with Local Organizing Support from Linkoping University, Sweden.

This **Fourth Scientific Meeting** follows the previous *EuNetAir Meeting in Istanbul* (3-5 December 2014), and it is attended from at least 51 Participants and includes 15 Sessions with 2 Keynote Speakers, 6 Invited Speakers, 26 Contributed Speakers and 9 Poster Presenters from at least 19 COST Countries including 1 Near Neighbour Country (Russia). 2 **Plenary Sessions** devoted to ***Outdoor and Indoor Environment Quality Applications*** were participated by 6 Invited Speakers from 5 COST Countries and EC JRC Ispra. A Round-Table on **EU Policy of the EU Clusters: The European Sensor-Systems Cluster (ESSC)** has been organized with the attendance of an *EC Project Technical Assistant (PTA)* and a SME *manager*. An international Advisory Board (*Steering Committee*) composed by 22 Members served with S&T inputs to define Workshop Programme. *Female participants* are as 31% and *Male participants* are as 69% with a quota of *Early Stage Researchers* as 23%.

The concerted COST Action TD1105 *EuNetAir* - related to R&D issues of the air quality monitoring including environmental technologies, nanomaterials, functional materials, gas sensors, smart systems, air-pollution modelling, measurements, methods, standards and protocols - is very pleased to connect international specialists and excellent scientists to create a networking of Pan-European R&D platform from 31 COST Countries and 7 Non-COST Countries. Most part of COST Countries are represented in this Meeting.

Special thanks to **COST Officers**: Dr. Deniz Karaca, *ESSEM Science Officer* and Dr. Andrea Tortajada, *Administrative Officer*, involved to manage policy & administration in our Action. A *Live Video Chat* with SO from Brussels was managed during 7th MCM in the last day.

On behalf of the Action Management Committee, I would like to thank **ALL Participants**, **Grant Holder**, **Action Scientific Secretary**, **Local Organizing Committee** by **Linkoping University**, represented by *Department Dean*, and Local Authorities - *Linkoping Mayor* - in order to give opportunity to disseminate the results of the COST Action TD1105 *EuNetAir* towards an international targeted audience involved in Air Quality Control, with special focus on *European Sensor-Systems Cluster*. With their valuable scientific work and management, kind availability and great enthusiasm will make our Action Meeting very successful !

Enjoy your *EuNetAir* Meeting at *Linkoping University* in Linkoping !

Brindisi, 28 May 2015

Michele Penza, ENEA, Brindisi, Italy
COST Action TD1105 Chair
michele.penza@enea.it

EuNetAir COST Action TD1105 Logo

LIST OF PRESENTERS

FOURTH SCIENTIFIC MEETING
WORKING GROUPS AND MANAGEMENT COMMITTEE
New Sensing Technologies for Outdoor Air Pollution Monitoring

Welcome Address Session

Welcome: Linköping City Council
Helena Balthammar, Linköping Mayor, Sweden

Welcome: Linköping University
Kenneth Järrendahl, Department Dean, Linköping University, Sweden

Welcome Address from COST Action TD1105
Michele Penza, Action Chair, ENEA, Brindisi, Italy

Plenary Session 1: Outdoor Environment Quality Applications

COST Action TD1105: European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability - Updating
Michele Penza, Action Chair, ENEA, Italy

Review of Gas Sensors to Monitor Benzene and Other VOCs in Ambient Air in the Framework of the EURAMET Key-VOC Project
Laurent Spinelle and Michel Gerboles, JRC, EC DG ENV, Institute for Environment and Sustainability, Ispra, Italy

Extended Performance Analysis of a Sensor Unit for O_3 and NO_2 and Operation of a Small Static Sensor Network in Zurich, Switzerland
Christoph Hueglin, MC Substitute, EMPA, Zurich, Switzerland

Plenary Session 2: Indoor Environment Quality Applications

The FP7 SENSIndoor Project (NMP-2013-5): Increasing Sensitivity and Selectivity of Gas Sensor-Systems by Using Micromachined Pre-Concentrators with MIP and MOF Layers
Andreas Schuetze, Action WG2 Leader & MC Member, Saarland University, Saarbrucken, Germany

The FP7 IAQSense Project (NMP-2013-5): Sensors for Indoor Air-Pollution Monitoring
Mathias Holz, Nano Analytik GmbH, Ilmenau, Germany

Development of SenseAir High Performance Platform (HPP) for Indoor Sensing
Ingrid Bryntse, Action WG4 Leader & MC Member, SenseAir AB, Delsbo, Sweden

Parallel Session of WG1-WG2
WG1: Sensor Materials and Nanotechnology

Effect of Sensor Configuration for Low-Temperature Gas Detection with Semiconducting Oxides

Azhar A. Haidry, E. Ciftyürek, Bilge Saruhan‐Brings, WG Member, German Aerospace Center, Institute of Materials Research, Cologne, Germany

Pulsed Laser Deposition of Metal Oxide Nanoparticles, Agglomerates, and Nanotrees

J. Lappalainen[1], J. Huotari[1], T. Baur[2], J. Puustinen[1], T. Sauerland[2], and A. Schütze[2]
[1]Microelectronics and Material Physics Laboratories, University of Oulu, Oulu, Finland;
[2]Laboratory for Measurement Technology, Saarland University, Saarbrücken, Germany

Graphene Gas Sensors Enhanced by UV Light and Pulsed Laser Deposition

Raivo Jaaniso, University of Tartu, Tartu, Estonia

Nanostructured BST based Films with Potential Application in Hazardous Gas Detection

Cristina F. Rusti, Roxana M. Piticescu, IMNR, Pantelimon, Romania

Challenges Performing Outdoor Air Pollution Monitoring with Polymer Nanocomposites

Gita Sakale, M. Knite, S. Stepina, S. Guzlena, I. Klemenoks, Riga Technical University, Latvia

VOCs Sensing Properties of Hybrid Nanostructures

Zafer Ziya Ozturk, Gebze Institute of Technology, Kocaeli, Turkey

Low-Temperature Co-Fired Ceramic Package for Lab-on-Chip Application

Niina Halonen et al., University of Oulu, Oulu, Finland

WG2: Sensors, Devices and Systems for AQC

Functionalised Carbon Nanotube Sensors for Detecting Benzene at Trace Levels

Eduard Llobet, P. Clement, E.J. Parra, MC Member, Universitat Roviri I Virgili, Tarragona, Spain

The Application of Additive Technologies for Ceramic MEMS Gas Sensors

A.A.Vasiliev[1], A.V.Sokolov[1], N.N.Samotaev[2], V.P.Kim[3], S.V.Tkachev[3], S.P.Gubin[3], G.N.Potapov[4], Yu.V.Kokhtina[4], A.V.Nisan[4], [1]NRC Kurchatov Institute, Moscow, Russia, [2]National Research Nuclear University "MEPhI", Moscow, Russia, [3]LLC AkKo Lab, Moscow, Russia, [4]LLC Ostec, Moscow, Russia

Measurement of Monoaromatic Hydrocarbons in Air by Phthalocyanine-based QCM Sensors: Results and Outlooks

Jerome Brunet, A.Kumar, A.L. Ndiaye, A.Pauly, Université Blaise Pascal/CNRS, Aubiere, France

New Principle Theory of QCM and SAW Devices in Sensors and Biosensor Applications

Marina Voinova[1,2], Anton Wikstrom[2], [1]Chalmers University of Technology, Gothenburg, Sweden
[2]National Technical University, Kharkiv, Ukraine

Views on Inter-Laboratory Reproducibility of Chemosensing Experiments

J.-M. Suisse[1], M. Bouvet[1], K. Persaud[2], E. Danesh[2], [1]Institut de Chimie Moléculaire de l'Université de Bourgogne, UMR CNRS, Dijon, France; [2]The University of Manchester, UK

Parallel Session of WG3-WG4

WG3: Environmental Measurements and Air-Pollution Modelling

Highly Resolved UFP Number Concentration Maps in Zurich based on Data from a Mobile Sensor Network
Michael Mueller, WG Member, EMPA, Zurich, Switzerland

The Use of Sensors for VOC Emission Control at Industrial Sites
Jan Peters, VITO, Mol, Belgium

MOX Sensor Systems in Outdoor Odor Nuisance Monitoring
Wolfhard Reimringer, WG Member, 3S GmbH, Saarbrucken, Germany

Evaluation of Monitoring Gases and PMs with Low-cost and Reference Devices at AMS(s) in Belgrade, Serbia
Milena Jovasevic-Stojanovic, D. Topalovic, M. Davidovic, M. Zivkovic, I. Lazovic, Z. Ristovski, Action WG3 Member, Institute Vinca, Belgrade, Serbia

Using Lichens as Multi-Pollutant Bioindicators in Air Quality Monitoring
Maja Maslac, Irena Ciglenecki, Rudjer Boskovic Institute, Zagreb, Croatia

Transforming AQ Data to Personalised Services
Kostas Karatzas, Aristotle University of Thessaloniki, Greece

WG4: Protocols and Standardisation Methods

Present IAQ Sensor Technologies and Future Trends
Olivier Martimort, NanoSense Sarl, Boulogne Billancourt, France

Benefits of CMOS Sensors for Environmental Monitoring
Foysol Chowdhury, Action WG Member, CCMOSS Ltd, Cambridge, UK

Low-Cost IR CO_2 Sensor for Battery Powered Applications
Maksym Bryzgalov, Bengt Jonsson, Action WG Member, SenseAir AB, Delsbo, Sweden

Silicon Carbide Sensor Systems for Harsh Environment Market Applications
Bo Hammarlund[1], *Mike Andersson*[1,2], *Anita Lloyd-Spetz*[2], [1]SenSiC AB, Linkoping, Sweden; [2]Linkoping University, Sweden

Final remarks, comments and conclusions from WG4 Chair

KEYNOTE SESSION: Key Enabling Technologies for Air Quality Control

Towards Zero-Power Gas Detection Systems based on Nanowires: Fabrication, Characterization, Benefits and Challenges
J. Samà[1], *J. D. Prades*[1], *O. Casals*[1], *S. Barth*[2], *J. Santander*[3], *C. Cané*[3], *I. Gracia*[3], *Albert Romano-Rodriguez*[1], MC Substitute, [1]Universitat de Barcelona, Barcelona, Spain; [2]Technical University of Vienna; [3]CSIC, Bellaterra, Spain

Cost-Efficient Approaches to Measure Carbon Dioxide (CO2) Fluxes and Concentrations in Natural Environments Using Mini-Loggers
David Bastviken, Expert of Thematic Studies on Environmental Changes, Linkoping University, Linkoping, Sweden

SIGs Session - SIG1: Network of spin-offs

Specific Presentation from SIG1

"KOMpetitive Intelligence" - A New Method for the Identification and Assessment of Technological Alternatives
Tiziano Montecchi[2] *and Davide Russo*[1], [1]University of Bergamo, [2]Bigflo srl, Italy

SIGs Session - SIG2: Smart Sensors for Urban Air Monitoring in Cities

Specific Presentation from SIG2

The 1st EuNetAir Air Quality Joint-Exercise Intercomparison: Assessment of Micro-Sensors Versus Reference Methods (Part II)
Ana Margarida Costa, WG Member, IDAD, Aveiro, Portugal

SIGs Session - SIG3:Guidelines for Best Coupling Air Pollutants and Transducer

Specific Presentation from SIG3

Graphene Metal-Oxide Hybrids for Gas Sensor Tuning
Jens Eriksson[1], *D. Puglisi*[1], *C. Strandqvist*[1], *R. Yakimova*[1], *A. Lloyd-Spetz*[1], 1Department of Physics, Chemistry and Biology, Linköping University, Linköping, Sweden

SIGs Session - SIG4:Expert Comments for the Revision of the Air Quality Directive (AQD)

Specific Presentation from SIG4

Preliminary Indoor and Outdoor Air Pollution Investigation in Naturally Ventilated Classrooms: Results from the ARIA Project
Joana Mandureira, *Joao Cavaleiro-Rufo*, *Ines Paciencia*, *Eduardo de Oliveira Fernandes*, *Livia Aguiar*, *Cristiana Pereira and Joao Paulo Teixeira*, National Institute of Health, Porto, Portugal

DISCUSSION on SIG1-SIG4 Presentations
Questions and Answers from Participants
Comments and Inputs from Audience

Action TD1105 ROUND-TABLE DISCUSSION
EC Policy of the EU Clusters: The European Sensor-Systems Cluster (ESSC)

The European Sensor-Systems Cluster (ESSC): Vision, Objectives and Position Paper
Michele Penza, COST Action TD1105 Chair and ESSC Chairman, ENEA, Brindisi, Italy

The Role of the Project Technical Assistants (PTAs) in the EU Projects and Clusters
Eberhard Seitz, EC PTA, Julich, Germany

An Industry View in the Commercialization of Gas Sensors for Environmental Sustainability
Hans Martin, R&D Director of SenseAir SA, Delsbo, Sweden

Discussion of Action/Cluster Participants:

Comments and Inputs on Priorities, R&I Needs, Strategies, Roadmap for future joint-activities of ESSC Cluster and COST Action TD1105 EuNetAir
Speeches and Comments from Action WGs/SIGs Leaders and Participants
Free Comments from Action and ESSC Cluster Stakeholders

Poster Session: New Technologies and Methods for Environmental Monitoring

P01: A Local Integrated Assessment of Air Pollution Impacts on Human Health - A Case Study for Portugal and Grande Porto
S. Costa [(1,2)], *C. Costa* [(1)], *C. Silveira* [(3)], *M. Lopes* [(3)], *J. Ferreira*[(3)], *H. Relvas*[(3)], *C. Borrego*[(3)], *P. Roebeling*[(3)], *A. Miranda* [(3)], *J.P. Teixeira*[(1,2)], [(1)]EPIUnit-Institute of Public Health, University of Porto, Portugal; [(2)]National Institute of Health, Environmental Health Department, Portugal; [(3)]Centre for Environmental and Marine Studies & Department of Environment and Planning, University of Aveiro, Portugal

P02: Non-Resonant High-Frequency Excitation of Nanoelectromechanical Oscillators
A. M. Eriksson, *M. V. Voinova*, *L. Y. Gorelik*, Department of Applied Physics, Chalmers University of Technology, Kemigården 1, Göteborg, Sweden

P03: Detection of Harmful Pollutions from NO2 in Gas Phase by Quartz Crystal Microbalance
I. Nedkov[5], Action MC Member, Institute of Electronics, Bulgarian Academy of Sciences, Sofia, *V. Georgieva*[1], *Z. Raicheva*[1], *B. Georgieva*[2], *D.Dimova-Malinovska*[3], *S. Boyadjiev*[4], [1]Institute of Solid States Physics, Bulgarian Academy of Sciences, Sofia, Bulgaria; [2]UCTM bul. "St. Kliment Ohridski" Sofia, Bulgaria; [3]Central Laboratory of Solar Energy and New Energy Sources at the Bulgarian Academy of Sciences, Sofia, Bulgaria; [4]MTA-BME Technical Analytical Research Group, Budapest, Hungary; [5]Institute of Electronics, Bulgarian Academy of Sciences, Sofia, Bulgaria

P04: AirSensEUR: An Open Software/Open Hardware Multi Sensor for the Monitoring of Air Quality
Michel Gerboles, Laurent Spinelle, Marco Signorini, JRC, EC DG ENV, Institute for Environment and Sustainability, Ispra, Italy

P05: Evaluatuon of Electrochemical Sensors by means of an Handheld Device for Air Quality Monitoring
Domenico Suriano, *Gennaro Cassano*, *Valerio Pfister*, *Michele Penza*, ENEA, Technical Unit for Materials Technologies - Brindisi Research Centre, Brindisi, Italy

P06: Sensor of Biogas Ingredient Methane Employing Powerful Pulsed Laser Diodes
Vasilka Pencheva, Stoyan Penchev, Ivan Nedkov, Institute of Electronics, Bulgarian Academy of Sciences, Sofia, Bulgaria

P07: Effect of Dopants in Semiconductor Oxide Sensing Layers under Low Oxygen Partial Pressures and at Higher Temperatures
Azhar A. Haidry[1], *Engin Ciftyürek*[1], *Bilge Saruhan-Brings*[1], *Sebastian Schröder*[2], *Holger Fritze*[2]; [1]German Aerospace Center, Institute of Materials Research, Linder Höhe, 51147 Cologne, Germany; [2]Technical University Clausthal, Institute for Energy Research and Physical Technologies, 38640 Goslar, Germany

P08: How to Manage a Project of Citizen Science: Olfactory Annoyance Evaluation in Taranto City (Italy)
M. Brattoli[a], *L. de Gennaro*[c], *A. Mazzone*[a], *S. Petraccone*[b], *A. Demarinis Loiotile*[b], *R. Giua*[a], *G. Assennato*[a], *G. de Gennaro*[a,b]; [a]Agenzia Regionale per la Prevenzione e la Protezione Ambientale Puglia - Corso Trieste 27, 70126 Bari; [b]Dipartimento di Chimica, Università degli Studi di Bari, via

Orabona, 4, 70126 Bari, Italia; [c]Lenviros srl - spin off dell'Università degli Studi di Bari, via degli Antichi Pastifici ZI,70056 Molfetta, Italia

P09: Chemical Gas Sensors Array to Monitor Process Stability in Biogas Reactors
*Gilles Adam, Sébastien Lemaigre, Xavier Goux, Philippe Delfosse, Anne-Claude Romain 1*University of Liège, Arlon Campus Environnement, 185 Avenue de Longwy, B-6700 Arlon, Belgium; *2*Environmental Research and Innovation Department (ERIN), Luxembourg Institute of Science and Technology (LIST), Rue du Brill 41, L-4422 Belvaux, Luxembourg

Action WGs GENERAL ASSEMBLY

Specific Presentations from WGs Leaders

Summary of Research and Innovation Needs from WG1 Session: Sensor Materials and Nanotechnology
Jyrki Lappalainen, Action WG1 Vice-Chair - Oulu University, Oulu, Finland

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Andreas Schuetze, Action WG2 Chair, Saarland University, Saarbrucken, Germany

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Joao Paulo Teixeira, Action MC Substitute, National Institute of Health, Porto, Portugal

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Ingrid Bryntse, Action WG4 Chair, SenseAir SA, Delsbo, Sweden

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Marco Alvisi, Action SIG1 Leader, ENEA, Brindisi, Italy

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Christoph Hueglin, MC Substitute and SIG2 Member, EMPA, Zurich, Switzerland

Summary of Research and Innovation Needs from SIG3: Guidelines for Best Coupling Air Pollutants and Transducer
Eduard Llobet, Action SIG3 Vice-Chair, Universitat Roviri I Virgili, Tarragona, Spain

Summary of Research and Innovation Needs from SIG4: Expert Comments for the Revision of the Air Quality Directive (AQD)
Ana Margarida Costa, WG Member, IDAD, Aveiro, Portugal

ABSTRACTS OF ORAL PRESENTATIONS

Invited Talk

COST ACTION TD1105 ON NEW SENSING TECHNOLOGIES FOR AIR-POLLUTION CONTROL AND ENVIRONMENTAL SUSTAINABILITY: OVERVIEW AND PLANS OF ACTION

M. Penza and Consortium *EuNetAir*
ENEA - Italian National Agency for New Technologies, Energy and Sustainable Economic Development, Technical Unit for Materials Technologies-Brindisi Research Center, PO Box 51 Br-4, I-72100 Brindisi, Italy. Email: michele.penza@enea.it

Abstract

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 80 big institutions and over 180 international experts from 31 COST Countries (EU-zone: *Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Latvia, Luxembourg, The Former Yugoslav Republic of Macedonia, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom*) and 7 Non-COST Countries (extra-Europe: *Australia, Canada, China, Morocco, Russia, Ukraine, USA*) to create a S&T critical mass in the environmental issues.

This COST Action [1, 2] (see logo in Fig. 1) will focus on a new detection paradigm based on sensing technologies at low cost for Air Quality Control (AQC) and set up an interdisciplinary top-level coordinated network to define innovative approaches in sensor nanomaterials, gas sensors, devices, wireless sensor-systems, distributed computing, methods, models, standards and protocols for environmental sustainability within the European Research Area (ERA).

The state-of-the-art showed that research on innovative sensing technologies for AQC based on advanced chemical sensors and sensor-systems at low-cost, including functional materials and nanotechnologies for eco-sustainability applications, the outdoor/indoor environment control, olfactometry, air-quality modelling, chemical weather forecasting, and related standardisation methods is performed already at the international level, but still needs serious efforts for coordination to boost new sensing paradigms for research and innovation. Only a close multidisciplinary cooperation will ensure cleaner air in Europe and reduced negative effects on human health for future generations in smart cities, efficient management of green buildings at low CO_2 emissions, and sustainable economic development.

Figure 1. COST Office, ESSEM Domain and Action TD1105 EuNetAir Logo.

Invited Talk

The aim of the Action is to create a cooperative network to explore new sensing technologies for low-cost air-pollution control through field studies and laboratory experiments to transfer the results into preventive real-time control practices and global sustainability for monitoring climate changes and outdoor/indoor energy efficiency. Establishment of such a European network, involving Non-COST key-experts, will enable EU to develop world capabilities in urban sensor technology based on cost-effective nanomaterials and contribute to form a critical mass of researchers suitable for cooperation in science and technology, including training and education, to coordinate outstanding R&D and promote innovation towards industry, and support policy-makers. Main objectives of Action are listed, but not limited to:

- to establish a top-level Pan-European multidisciplinary R&D platform on new sensing paradigm for AQC contributing to sustainable development, green-economy and social welfare
- to create collaborative research teams in the ERA on the new sensing technologies for AQC in an integrated approach to avoid fragmentation of the research efforts
- to train Early Stage Researchers (ESR) and new young scientists in the field for supporting competitiveness of European industry by qualified human potential
- to promote gender balance and involvement of ESR in AQC
- to disseminate R&D results on AQC towards industry community and policy makers as well as general public and high schools.

The Workplan is organized in four complementary Working Groups (WGs), each devoted to a progressive development of synthesis, characterization, fabrication, integration, prototyping, proof-of-concepts, modeling, measurements, methods, standards, tests and application aspects. The four WGs with the specific objectives are:

- **WG1**: *Sensor materials and nanotechnology*
- **WG2**: *Sensors, devices and sensor-systems for AQC*
- **WG3**: *Environmental measurements and air-pollution modeling*
- **WG4**: *Protocols and standardisation methods*

This Action will focus on the study of sensor nanomaterials and nanotechnologies exhibiting unique properties in terms of chemical and thermal stability, high sensitivity, selectivity. Nanosize effects of functional materials will be explored for integration in the gas sensors at low power-consumption. Furthermore, specific nanostructures with tailored sensing properties will be developed for gas sensors and sensor-systems with advanced functionalities.

Selected high-quality research products and innovative technologies developed by the partnership of COST Action TD1105 are shown in the Figure 2.

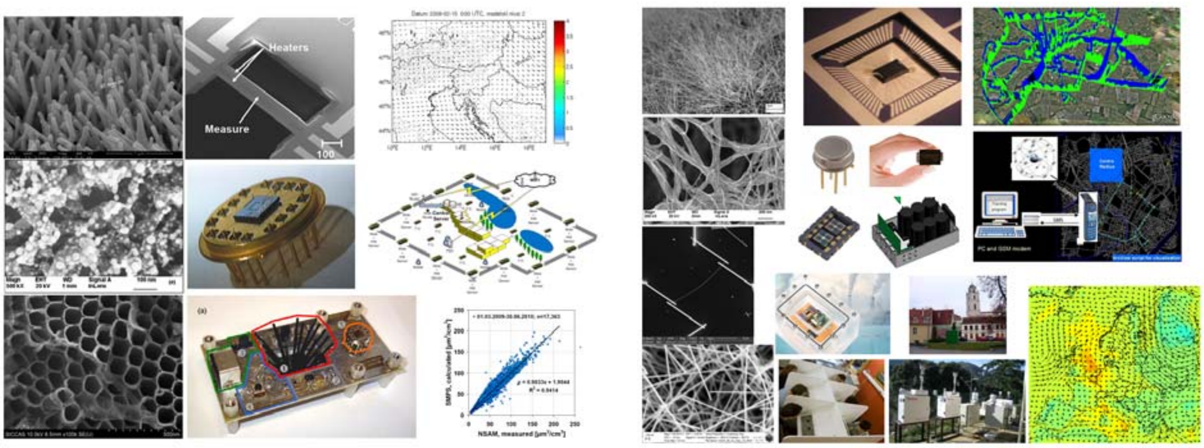

Figure 2. Selected R&D technological products developed by some partners (academia, research institutes, agencies, industry) involved in the COST Action TD1105 *EuNetAir*. Courtesy from *EuNetAir* partnership.

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Invited Talk

REVIEW OF VOC SENSORS FOR AIR QUALITY MONITORING IN THE FRAMEWORK OF EURAMET KEY-VOC PROJECT

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Abstract
Volatile organic compounds (VOCs) are hazardous compounds that may cause damages to human for long time exposure. The principal compounds of interest consists of aromatics such as benzene, toluene, ethylbenzene, xylenes (BTEX) and aldehydes, such as formaldehyde, acetaldehyde. In Europe, the monitoring of benzene in ambient air is mandatory as set by the European Directive for air quality (AQD, [1]). This Directive states that the reference method of measurement shall consist of active or on-line sampling, desorption followed by gas chromatography [2]. This method is time consuming, expensive to implement and it needs skilled personnel to fulfil complex operations. While some implementation of this method may be transportable, it is not easily portable prohibiting estimation of the population exposure. However, the AQD allows using indicative measurements as micro-sensors that are able to supply near to real time air pollution measurements by electronic means making it possible to assess the effect of short term action plans and simplify reporting of air quality to the internet [3].

Commercial low cost sensors represent a big opportunity for developing networks of VOC sensors able to monitor within large areas at limited cost compared to reference measurements [2]. The AQD requires to show that indicative methods can meet a data quality objective (DQO) defined as a relative expanded uncertainty of measurements of 30 %.

In the 2005, Yamazoe [4] concluded that benzene levels in ambient air less than 100 ppb were out of reach by gas sensors. Nowadays, the technological progress resulted in an improvement of sensor sensitivity and a few systems are able to reach the ppb or rarely sub ppb level of sensitivity for monitoring benzene in ambient air [5, 6]. In fact, the AQD set the limit value (LV) for benzene as 5 µg/m³ (about 1.5 ppb) over a calendar year. In the talk, the sensitivity and other performance indicators of gas sensors either commercially available or extracted from research studies are presented. The type of sensor includes metal oxide, electrochemical cells, photo ionisation detectors, micro GCs and electronic noses.

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INVITED TALK

EXTENDED PERFORMANCE ANALYSES OF A SENSOR UNIT FOR O_3 AND NO_2 AND OPERATION OF A SMALL STATIC SENSOR NETWORK IN ZURICH, SWITZERLAND

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Abstract
Concentrations of nitrogen dioxide (NO_2) and ozone (O_3) in urban environments are highly variable in space and time. At many locations in Switzerland they frequently exceed the existing limit values.

Sensor units which are considerably smaller and less expensive than the instruments used today in regulatory air quality monitoring networks may facilitate the deployment of much denser networks. Moreover, they may replace other measuring techniques such as NO_2 passive samplers. In combination with dedicated modelling techniques for generating air pollution maps dense monitoring networks might significantly enhance the information on air pollution fields in urban environments [Mueller et al., 2015]. However, sensor units have to comply with strict demands on accuracy and reliability for a meaningful operation.

We engineered a sensor unit for the measurement of NO_2 and O_3 in ambient air that includes three identical electrochemical NO_2 sensors (Alphasense B42F) and two identical metal-oxide semiconductor sensors for O_3 (Aeroqual SM50). Multiple sensors are used for easier control of the data and detection of malfunctioning individual sensors. These sensor units have been thoroughly tested in the field side by side with reference instruments and are currently deployed in the city of Zurich to form a small sensor network. The aim of this small static sensor network is to complement the mobile sensor network consisting of ten sensor units on top of streetcars operating in Zurich, and additionally to serve as a test bed for the investigation of the potential and the requirements related to the operation of low-cost air quality sensor networks. Our research focuses on the achievement of most accurate sensor data as well as on the development of effective strategies and methods for assurance of the data quality from individual sensors in networks.

We present results of thorough tests conducted with the new sensor unit. Performance characteristics have been determined by operating six units at three different urban air pollution monitoring sites (reference sites) for more than three months. In addition, the response behaviour of the sensors has been investigated in dedicated lab tests.

First results show that the quality of the measurements of the sensor units is promising if appropriate calibration functions are applied. The operation of the sensor units within the sensor network and the related data analysis will elucidate the long-term behaviour of the integrated sensors. Moreover, the sensor deployment will shed light on subjects such as sensor network design and the assurance of data quality.

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Invited Talk

INCREASING SENSITIVITY AND SELECTIVITY OF GAS SENSOR SYSTEMS BY USING MICROMACHINED PRE-CONCENTRATORS WITH MIP AND MOF LAYERS

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Motivation

Several highly relevant applications for gas sensor systems cannot be adequately addressed with today's low-cost sensors due to their limited sensitivity and selectivity [1], e.g. determination of food freshness, detection of explosives, cancer screening by breath analysis or hazardous VOC detection for demand controlled ventilation. Even though sensitivity (down to a few ppb) and selectivity of metal oxide semi-conductor (MOS) or gas-sensitive field effect transistor (GasFETs) devices can be improved by dynamic operation further optimization is required to achieve reliable operation under various ambient conditions.

Simulations and First Results

The new approach for low-cost micro pre-concentrators (µPC) was first evaluated by extensive simulations based on COMSOL Multiphysics based on realistic estimates of gas adsorption in MIP (molecular imprinted polymer) and MOF (metal organic framework) layers and their release in a small confinement. Fig. 1 shows a rough cross section of the basic set-up with the µPC placed near the gas access of the small housing and a gas sensor placed next to it. Simulations show that a sensor placed at a distance of a few mm from the µPC will be exposed to a brief gas pulse with a concentration significantly above the background concentration proving the desired effect to boost sensitivity. The performance can be tuned by optimizing the cross section of the gas access and the internal volume of the sensor/µPC chamber. The resulting gas pulse has a very short duration in the order of seconds, thus a fast response of the sensor is required. First experimental results supporting the simulations will be demonstrated. In these experiments, two MOF coated substrates were placed in an N_2 gas stream through a tube with a diameter of 2 mm and a gas sensor was placed downstream of the µPCs. The gas stream was analyzed with a mass spectrometer (MS). The signals of both gas sensor and MS show no response to heating of the µPCs at the start of the measurement before benzene is added to the gas stream. After introducing benzene the signals of both the MOS gas sensor and the MS at mass 78 (corresponding to benzene) show a clear increase. The signals increase further, for the MS by up to a factor 4, when the µPCs with two different MOF materials are heated to approx. 180 °C indicating the release of adsorbed benzene. The paper will present further experimental results for the detection of hazardous VOCs at sub-ppb level.

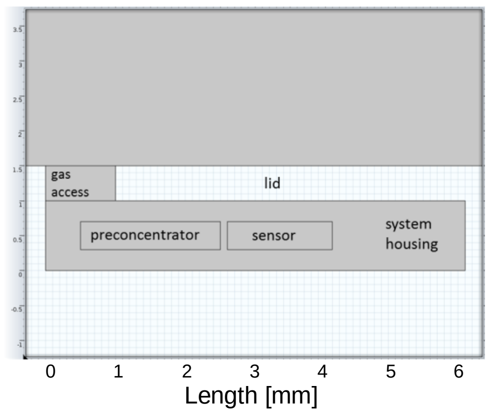

Figure 1. Schematic set-up of a device with a µPC and a microsensor placed side-by-side in a miniaturized housing with a small gas access. Gray areas indicate the gas space simulated during sampling and release. The system housing is connected to a much larger volume to simulate a nearly unlimited gas source with low concentration.

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Invited Talk

SENSORS FOR INDOOR AIR-POLLUTION MONITORING

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This article will focus on a new detection scheme based on low cost, sustainable sensing technologies for Air Quality Control (AQC). We are concerning a combination of (i) transistor based gas sensors (so called "transistor-spectrometer"), (ii) transistor-on tip sensors and (iii) nanomechanical-resonators, functionalized by nanomaterials (nanotubes) for diverse indoor environmental applications. The transistor spectrometer Sensor is capable to detect at ppb-level the key indoor air components (Figure 1). First, ions are collected by adsorption on the transistor-gat surface, equally spread in the absence of a polarisation field. Then, the device is biased in one direction to collect ions on one side, to create a starting point. The transistor is reverse biased and each type of ionised molecule moves at its own speed. Based on surface ion mobility dynamics, it separates each gas component and its density like mass spectrometer and allows fast multi-gas detection [1]. Fig.1 shows that the molecules can be easily identified by the timing of the peak, while the peak level indicate the concentration.

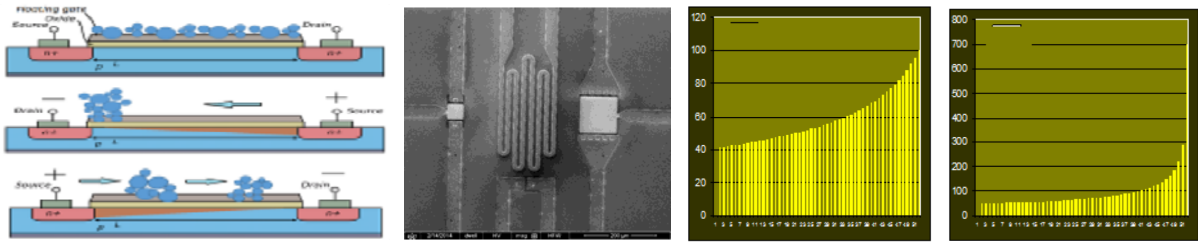


Fig. 1. Principle of operation and realised "transistor spectrometer"

To enlarge the field of detection, the system will include other patented [2] solution for bimolecular detection. This is using the principle of integrated nanoscale field-effect transistor (nanoFET) on the tip. The active device is basically a 3D structure with a specific and flexible behaviour, a controlled command changing its geometry and sensitivity, on the surrounding of the top of the Tip (Figure 2). The detecting transistor is integrated on the Silicon-tip (the channel on the top of the tip) and follows the shape of the tip. The channel size can be modulated (250nm down to 5nm) by applying back side substrate biasing to change the sensitivity. In this manner nanoscale field effect transistor is realized without cost-intensive nanolithography.

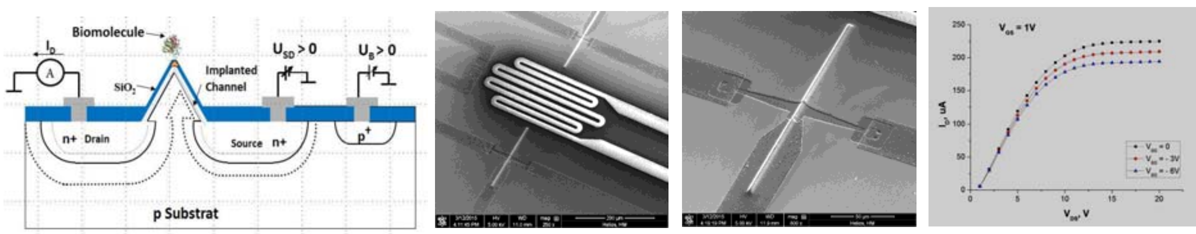
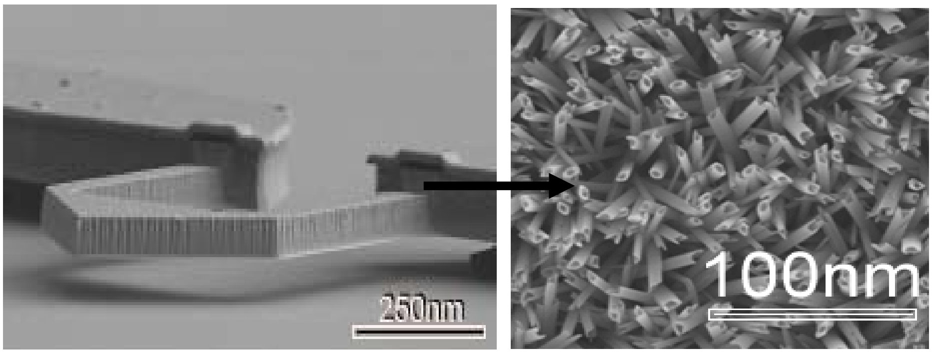
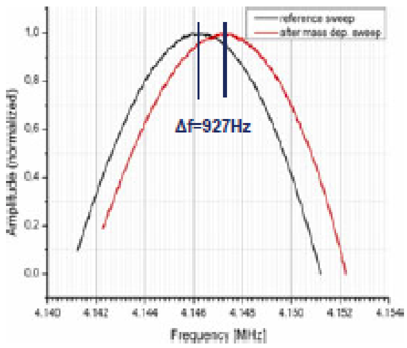


Figure 2. Principle of operation and realised "transistor on the tip" sensor.

Nanomechanical resonators are used as ultra-high sensitive and selective nano-balance sensors because of their high resonant frequency shifts when a molecule adsorbs to the resonator surface. As well known, the relation between shifts in resonant frequency and changes in mass depends on resonator material, the geometry of the resonator and the setting place of the adsorbed molecule. When the resonator is excited to the resonance frequency; the response of molecular capture can be measured due to a change in the resonance frequency (Figure 3). To further improve the detection possibilities of functionalized cantilevers, a third solution has, for the first time, been developed at ISL, consisting in the nano-functionalization of the cantilever surface with metal oxide nanotubes. This allows an increase in the surface accessible for the capture of molecules, thus results in a change of the physical and chemical nano-resonator characteristics. Realization of NEMS mass sensors with single-Dalton (single-Dalton (1 amu)) resolution will facilitate the detection of individual, intact, electrically neutral macromolecules with masses ranging well into the tens and hundreds Dalton range.





$$V = 4.5 * 10^{-21} m^3$$

$$m = 10.485 * 10^{-18} kg$$

$$S = \frac{10.485 * 10^{-15} g}{927\ Hz} = 11.310 * 10^{-18} \frac{g}{Hz}$$

$$= 11.310 \frac{ag}{Hz}$$

Figure 3. Realised “functionalised nano-resonator” sensor and measured frequency-shift corresponding of atto-gram mass sensitivity.

The results described in this article are obtained in the frame of the IAQSense-Project (FP7 Program of the European Commission) grant agreement no 604325 which aims to develop a completely novel nanotechnology based low cost and mass produced sensor solutions.

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Invited Talk

DEVELOPMENT OF SENSEAIR HPP PLATFORM

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Abstract

SenseAir has together with Autoliv, in co-operation with the Automotive industry, developed an alco-lock device with as high performance as evidence instruments - at lower cost and with a drastically reduced size. This stable NDIR based Long Path Length platform, with sub-ppm resolution, is suitable for various greenhouse gases absorbing in the region 3 - 10 µm.

At present, the new HPP (High-Performance Platform) has been developed along four main tracks:

1. Alco-lock system for cars, trains, or safety cupboards, in a joint project with Autoliv Research AB and Hök Instrument AB
2. Methane analysis unit for US fracking industry in collaboration with EDF
3. Green-house gas measurement cuvette in a project with InSitu AB, supported by Fiber Optic Valley in Hudiksvall
4. Carbon dioxide sensor for balloon sonde measurements in the upper atmosphere, together with University of Cambridge

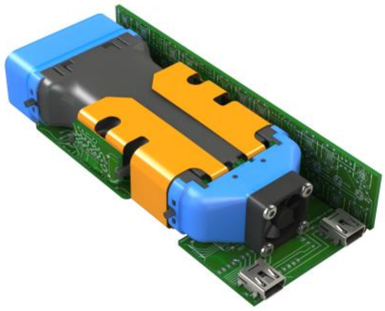

Figure 1. Sensor core of SenseAir HPP, High-Performance Platform, with a device length of 11 cm.

Results from various testing shows that the novel HPP performs satisfactorily in a large temperature range: -40°C - +85°C. At present, we are dealing with issues like communication / application cards, pressure properties, voltage supply units, and encapsulation design depending on final customer demands.

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Oral Presentation

EFFECT OF SENSOR CONFIGURATION FOR LOW TEMPERATURE GAS DETECTION WITH SEMICONDUCTING OXIDES

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Abstract

The most common semiconducting metal oxides such as SnO_2, TiO_2, ZnO, In_2O_3 and NiO have been commonly applied as gas sensing layers. The major drawbacks are high resistance values and the requirement of higher temperatures for better sensor signal during operation. The resistive type gas sensors generally uses inter-digital electrode (IDE) system and requires a heater which consumes power, thus increases the cost as well as complexity of the sensor device. One way to reduce the operating temperature is to prepare nanostructured sensing materials (such as nanotubes, nanowires) [1, 2] as well as electrode systems (e.g. FIB, lithography) using some sophisticated and expensive synthesis techniques. Their long-term stability fades rapidly with time, due to the extreme finer oxide structures and relatively high operating temperatures. Recently, it was reported that fast response and recovery times can be achieved with a newer top-bottom electrode (TBE) configuration and by using nanosized TiO_2 layer between the top and bottom electrodes for room temperature hydrogen sensing [3].

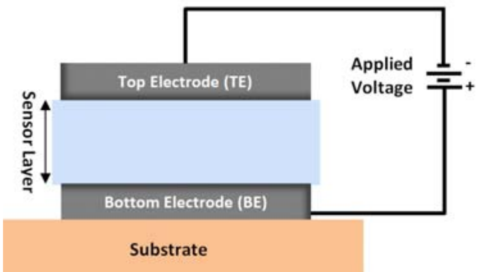

Figure 1. Top Bottom Electrode (TBE) configuration (TBE).

This work presents the results obtained towards NO_2 by using TBE and IDE sensor configurations with the same sensing semiconductor layers. It is known that dopants such as Al^{3+} or Cr^{3+} can improves the sensing properties of semiconductor TiO_2. Nevertheless, temperatures exceeding 400°C are required for reasonable sensor signal. The use of TBE configuration reduces the operation temperature of these sensors far below 400°C requiring no heater. The schematic of such a TBE electrode system is presented in Fig. 1. The sensors with TBE configuration were fabricated in three steps: firstly, 200 nm thick and 300 µm wide bottom Pt electrodes BE were patterned (via sputtering) on a Al_2O_3 substrates. The possible sensing mechanism is the matter of discussion in terms of depletion region (LD) and the potential barrier between grains (eVs at grain boundaries).

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Oral Presentation

PULSED LASER DEPOSITION OF METAL OXIDE NANOPARTICLES, AGGLOMERATES, AND NANOTREES

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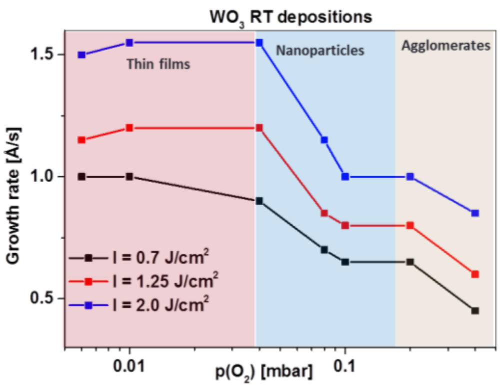
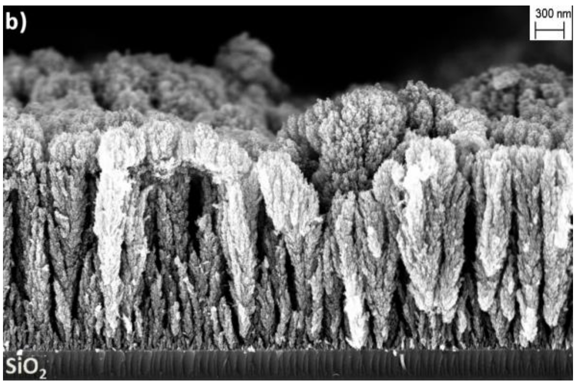
Abstract
In the case of pulsed laser deposition (PLD), one utilizes intense laser pulses guided in to a vacuum chamber to ablate and evaporate the target material surface. Generated plasma is adiabatically expanding in the low-pressure atmosphere, and can be collected onto a substrate some distance away from the target to form a thin film of atomic scale species. However, by carefully adjusting the laser beam properties and increasing the partial oxygen pressure p(O_2) of PLD process, nucleation and clustering of nanoparticles can already be initiated in the plasma, as is shown in Fig. 1(a). At higher values of p(O_2), the plasma emits a brite bluehish glow, as in Fig. 1(b).

PLD of various metal oxides were made at room temperature and in relatively high partial oxygen pressures. The deposited materials were tungsten trioxide (WO_3), vanadium pentoxide (V_2O_5), and tin dioxide (SnO_2), the latter also with platinum (Pt) nanoparticle decoration. Both conventional MEMS microheaters and silicon carbide (SiC) GasFET structures were used as substrates and sensor platforms. The layers have shown to be consisted of small metal oxide nanoparticles below 20 nm in diameter, nanoparticle agglomerates, and nanotrees which sizes and geometry are clearly dependent on values of p(O_2) used during depositions. On the other hand, crystal structure of the nanoparticles was strongly dependent also on post-annealing procedures. The first gas sensing measurements have shown very promising results, e.g. good selectivity and response to ppb-levels for naphthalene and ammonia, for example, detected with WO_3 and V_2O_5 nanoparticle layer sensors, respectively.



(a)



(b)

Figure 1. (a) Quartz crystal microbalance (QCM) measurements of PLD process of WO_3 revealed three modes of growth: (i) thin-film growth in the pressures p(O_2) $\leq$ 0.05 mbar, (ii) nanoparticle, and (iii) agglomerate formation as a function of increasing oxygen pressures. **(b)** With higher p(O_2) values during PLD process, WO_3 nanoparticles form nanotrees with fractal-like geometry.

Oral Presentation

GRAPHENE GAS SENSORS ENHANCED BY UV LIGHT AND PULSED LASER DEPOSITION

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Abstract
Graphene, a single-atomic-layer 2D material, has great potential for creating miniature and low-power gas sensors, which can be used in air-pollution control. Whereas extremely high gas sensitivities have been demonstrated for graphene in inert atmospheres, in ambient air at room temperature the gas sensitivity of pristine CVD graphene is generally very small or even absent [1,2]. However, the sensitivity can be activated by UV light [2] and not only for O_2 but also for NO_2 and NH_3 gases. Furthermore, in order to fully realise the potential of graphene for detecting different polluting gases, graphene has to be functionalised - adsorption centres of different type have to be created at its surface. We demonstrated recently that pulsed laser deposition (PLD) is a versatile and precise tool for this purpose. Versatile - as a variety of defects or clusters can be formed on graphene from different atomic species with different "surface landing energies", and precise - as typically only ~1/100th of a monolayer or less is deposited by a single laser pulse. Our studies have shown that the gas response can be significantly enhanced after creating new adsorption centres by PLD (see Figure 1). The signal recovery times could also be significantly shortened for NO_2 gas by choosing the PLD conditions and/or by UV illumination. The work was supported by Estonian Science Agency (IUT34-27, IUT2-24) and Graphene Flagship.

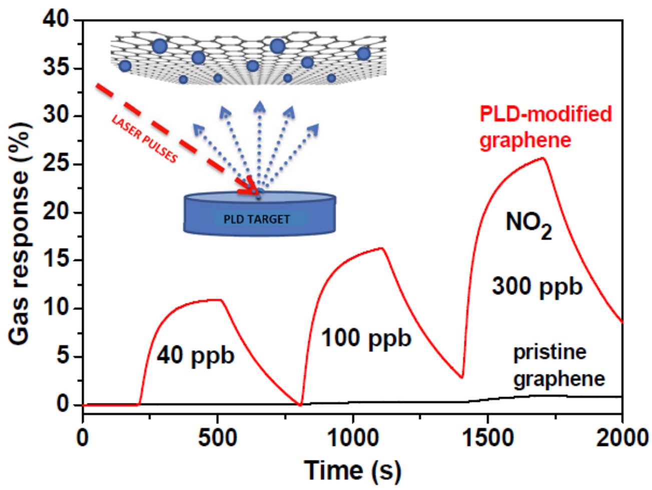

Figure 1. Responses (relative changes of electrical conductance) of pristine and PLD-modified graphene to NO_2 gas. The target material in this PLD process was ZrO_2. The gas response was measured in air at room temperature under illumination of UV light (365 nm, 10 mW/cm^2).

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Oral Presentation

Complex nanostructured perovskite systems developed by chemical processes

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Abstract

Increasing the miniaturisation is a key factor in the manufacturing process of the new, high-performances gas sensors and electronic devices. The challenge at worldwide level is to reduce the consumption of critical raw materials by providing new, innovative technologies environmentally friendly (safety to the environment, low energy consumption). Nanostructured films could represent a solution not only for the miniaturization but also for reducing critical raw materials consumption. Nanostructured films can be determined either by chemical procedures (such as sol-gel, hydrothermal-electrochemical H-E, screen printing and spin coating techniques) or PVD (such as RF-Sputtering, e-beam, thermal evaporation, pulsed laser deposition techniques). The paper described some chemical procedures to obtain nanostructured films compared to RF-Sputtering and thermal evaporation physical vapor deposition methods. Original results are combining PVD technique (thermal evaporation) with a chemical technique (H-E deposition) to obtain BST nanostructured with potential applications in hazardous gases detection, are presented and discussed. Original results on in situ hydrothermal-electrochemical deposition of nanostructured PZT, thin films on substrates are also presented and discussed.BST nanostructured materials with potential for hazardous gases detection (NH_3, H_2S, SO_2) was demonstrated on thick films (50 μm) deposited by screen printing on 96% alumina substrates with Pt electrodes. Work are in progress to determine sensing properties of nanostructured thin films based on doped BST deposited on Sitall substrates with Pt electrodes **Acknowledgement**: UEFISCDI Romania- in the frame of Ctr. 198/2012 **SENSGAS**. **COST Action TD1105 EuNetAir**. The authors would like also to thank to: André Sackmann (University of Tübingen, Institute of Physical Chemistry, Germany) for performing the deposition of BST layers by screen printing, MGM Star Construct srl and SITEX 45 for useful discussions on integration of research activities with innovation and knowledge transfer in industrial applications.

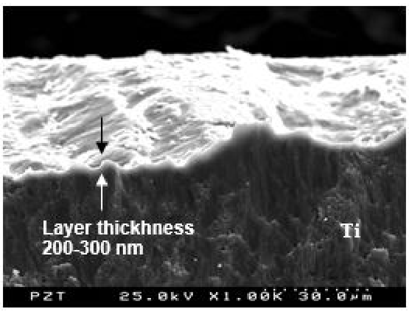

Fig. 1. SEM micrograph of PZT deposited layer synthesized by hydrothermal electrochemical procedure from soluble salts of lead, titanium and zirconium on titanium substrate.

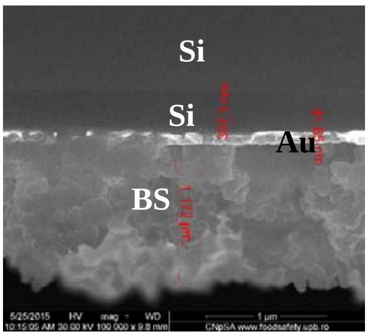

Fig. 2. SEM micrograph of BST films on Si/SiO2/Ti/Au substrate.

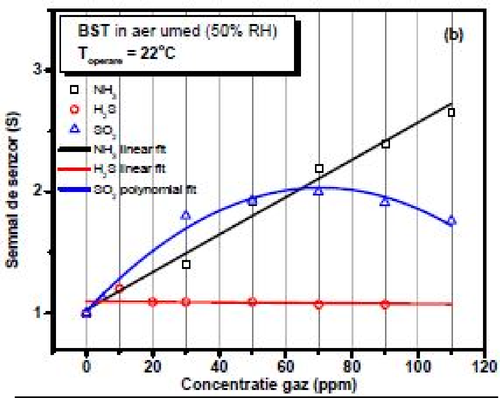

Fig. 3. Gas concentration influence on sensor signal for un-doped BST.

Oral Presentation

CHALLENGES PERFORMING OUTDOOR AIR POLLUTION MONITORING WITH POLYMER NANOCOMPOSITES

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Abstract

There are number of research papers, where promising results in air pollutants (DMMP, H_2S or VOC) detection with polymer based sensors are reported [1, 2]. Several kinds of polymer based sensors exist, which can be applied in air quality control. That is, conductive polymer sensors, conductive polymer sensors with additives like metal nanoparticles Au, Ag, Pt and Cu or carbon nanotubes. This report focuses on polymer nanocomposites, which consists of non-conductive, elastomer like polymer and carbon nanoparticles as conductive filler.

Performing outdoor measurements every sensor is subjected to grate temperature and relative humidity change. These are important factors, which can considerably impact sensors response character or even make sensor senseless. Laboratory experiments performed by our research team has shown that at relative humidity grater than 75% sensor response considerably decreases [1, 3]. Response decrease of the sensor is explained by additional resistance change mechanism (proton conductivity), which emerges due to water molecule layer formation on the surface of the sensor. At high relative humidity values proton conductivity starts to dominate over conventional electrical resistance change mechanism related to tunneling current decrease between conductive particles due to polymer swelling. It is found that polymer nanocomposite baseline electrical resistance is dependent on temperature of surrounding environment. Nanocomposites were heated from +50^{o}C until –50^{o}C and electrical resistance of the nanocomposite were recorded. Greater baseline electrical resistance change is observed for nanocomposites, where multiwall carbon nanotubes (MWCNT) are used as conductive filler.

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Oral Presentation

VOC SENSING PROPERTIES OF HYBRID NANOSTRUCTURES

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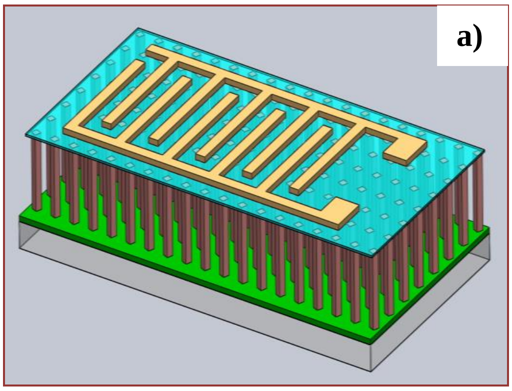
Abstract

The gas sensors are the subject of an intensive research because of their applications in the industry (such as petro chemistry, mining, cosmetic, automobile, and food industry), healthcare, agriculture, environmental protection, military, and security [1, 2]. The several materials such as phthalocyanines, polymers, the metals, and metal oxides are widely used as the sensing layer which can be successfully produced as thin films, nanowires, nanotubes, nano-powders in order to improve the properties of the sensor. Also, different materials such as noble metals, organic compounds can be coated in order to develop sensor parameters.

In this study, TiO_2 nanorods were fabricated by hydrothermal method. The length and diameter of the fabricated TiO_2 nanorods were about 1µm and 100 nm respectively. Then polystyrene polymer was coated on TiO_2 nanorods by spin coating method. The morphologies and structure of the samples were characterized by X-ray diffraction (XRD), scanning electron microscope (SEM) and EDX. Figure 1a shows schematically illustration of TiO_2 nanorods/polymer hybrid nanostrucutres. VOC sensing properties of hybrid nanostructure device were investigated at 100^{o}C and the sensor response of the device is given in Figure 1b. The hybrid nanostructure shows highest sensor response for ethanol (EtOH).



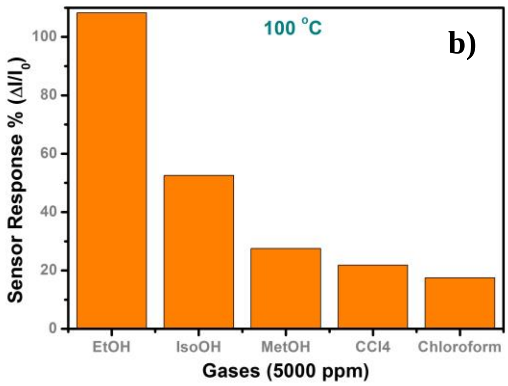


Figure 1. a) A schematically illustration of Hybrid Nanostrucutres; b) VOC sensing of Hybrid Nanostrucutres at 100^{o}C.

Acknowledgement: This study was supported by The Scientific and Technological Research Council of Turkey (TUBITAK) with project number of 113F403.

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Oral/ Presentation

LOW TEMPERATURE CO-FIRED CERAMIC PACKAGE FOR LAB-ON-A-CHIP APPLICATION

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Abstract

Lab-on-a-chip (LOC) systems are miniaturized analytical tools with sophisticated laboratory functionality; recently there has been a move towards monolithic integration of microfluidics with integrated circuits for sensing and control. When the LOC concept is applied to analyzing cells, the challenge is to package the electronics in a biocompatible way to withstand the cell growth environment, which includes electrolytic fluids on the chip surface, elevated temperatures, and constant exposure to high humidity.

We have developed a low temperature co-fired ceramic (LTCC) package for a LOC designed to assess the cytotoxicity of nanomaterials. The core IC is a capacitance sensor [1] designed to detect surface attachement and morphology of adherent cells, with these physical characteristics being used as an indication of their viability during nanoparticle exposure.

A passive silicon chip of size 3x3 mm^2 with gold contact pads mimicking the sensor chip was flip chip bonded on a LTCC substrate using isotropic conductive adhesive (ICA) applied on the contact pads using an alumina stamp. The chip adhesion was reinforced by application of an epoxy underfill which also sealed electrical contacts from cell growth media. The LTCC module was integrated on a PCB with a zero insertion force (ZIF) connector (Fig. 1).

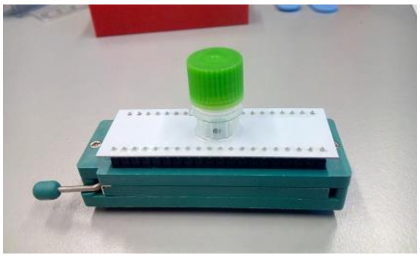

Figure 1. Dummy chip flip chip bonded on LTCC substrate equipped with ZIF connector

The biocompatibility and reliability of the electrical contacts of the LTCC module were tested in standard cell culture conditions for 3-7 days. Human lung epithelial cells (BAES2B) were cultivated on the chip surface while the resistance of the electrical path was monitored using a daisy chain pattern. Results indicate that the cell proliferation was normal and the total resistance remained constant during the follow-up time.

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Oral Presentation

FUNCTIONALISED CARBON NANOTUBE SENSORS FOR DETECTING BENZENE AT TRACE LEVELS

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Abstract

Benzene is a volatile organic compound and the most toxic among the BTEX (benzene, toluene, ethylbenzene and xylenes) compounds that can be found in the environment. Benzene has been recognised as human carcinogen by the US Environmental Protection Agency and the European Commission. . In the last ten years, the permissible exposure limit has been lowered from 10 ppm to 100 ppb. It is obvious, therefore, that we need sensors that detect the presence of benzene and its concentration in order to ensure than the established limits are not exceeded. In the last few years we have been working on the functionalisation of carbon nanotube sidewalls for detecting aromatic VOCs and benzene in particular [1,2]. Here we will review these efforts and discuss our latest results on the use of receptors for aromatic compounds that employ weak interactions, such as CH-π and π-π for binding aromatic guests (e.g. benzene). The preparation of a new sensor based on multi wall carbon nanotubes (MWCNTs) oxygen plasma treated and decorated with gold nanoparticles whose surface is functionalized by quinoxaline-walled deep cavitands and its extreme benzene sensitivity will be shown [3] (see Figure 1). The sensing process is reversible at room temperature with the recovery of the resistance baseline upon air flushing, which is important for low power consumption. This makes it suitable for being integrated in hand-held portable analysers, wearable detectors and semi-passive radio frequency identification tags with sensing capabilities or in the nodes of wireless sensor networks with a wide range of potential applications in environmental monitoring, workplace safety or medical devices, among others.

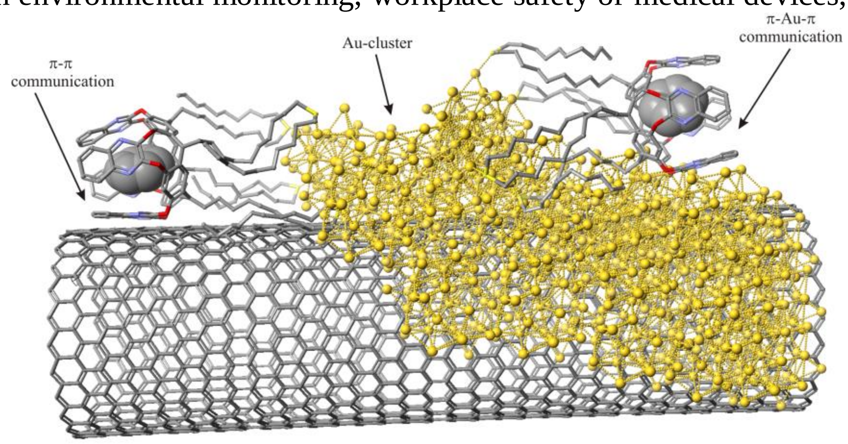

Figure 1. Representation of two proposed types of communication between the cavitand (when a benzene molecule is included) and the CNT. Hydrogen atoms are omitted for the sake of clarity.

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Oral Presentation

THE APPLICATION OF ADDITIVE TECHNOLOGIES FOR CERAMIC MEMS GAS SENSORS

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Abstract

The use of additive technology in combination with thin ceramic substrates for the fabrication of MOX semiconductor and thermos-catalytic gas sensors enables a superposition of advantages of both technologies. Ceramic MEMS based on 12 μm Al_2O_3 or ZrO_2/Y_2O_3 membrane (Fig.1) can operate at 600^0C, withstands technological annealing at 1000^0C, works in harsh environment, and is characterized by perfect adhesion of platinum and other functional layers. However, deposition of platinum heaters by magnetron sputtering leads to very high consumption of platinum and to an increase in cost. Screen printing usage is limited by fragility of ceramic membrane and printing resolution of ~150 μm. As a result, such sensor consumes >150 mW, much more than silicon MEMS.

The application of jet printing for ceramic MEMS chips of semiconductor and thermo-catalytic gas sensors, fast temperature and gas flow sensors, etc. permits the fabrication of devices free of most disadvantages of silicon technology. This approach gives wireless applicable strain-free cantilever devices (Fig. 2), precious metals are used only for the deposition of sensor elements, printing speed is sufficient for medium scale (~1 million per year) production. Sensors are usable under harsh environment, e.g. for the monitoring of technological processes and harsh technological accidents.

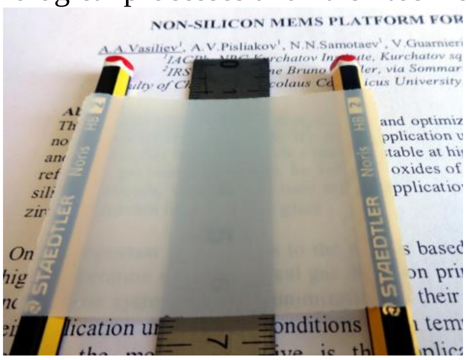

Figure 1: Alumina film (12 μm thick) prepared by anodic oxidation of aluminium followed by annealing at 800^0C. Membrane size is 48x60 mm.

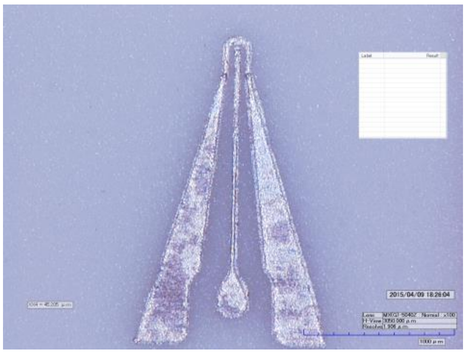

Figure 2. Microheater printed by aerosol jet printer on alumina substrate. Minimum line width is of 40 mm.

The application of cantilever with ~250x250 μm hot area and 30-50 μm wide conductive lines enables the fabrication of sensors with power consumption of about 40-50 mW at continuous heating to 450^0C and with ~100 μW in pulsing heating mode. The printable ink containing ~15 – 20 wt.% of 10-30 nm Ag, Au, and Pt particles suspended in organic solvent were prepared by wet method and optimized for aerosol jet printer. An example of the print of 45 μm wide Ag lines on 12 μm alumina film is presented in Fig. 2. The application of air pre-annealed at 800^0C ceramic film gives high quality print with superficial resistance of about 2 Ohm/□ for ceramic MEMS devices.

Oral Presentation

MEASUREMENT OF MONOAROMATIC HYDROCARBONS IN AIR BY PHTHALOCYANINE-BASED QCM SENSORS: RESULTS AND OUTLOOKS

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Abstract

The consequences of air pollution on the increase in cancer deaths are now well-established. In October 2013, the specialized cancer agency of the World Health Organization, the International Agency for Research on Cancer (IARC), announced that outdoor air pollution is now classified as carcinogenic to humans. In March 2015, the French Association for Research on Cancer (ARC) initiated a project call on the prevention of cancer linked to air pollutant exposures (CANC'AIR project). Thus, it is noticeable that the monitoring of air quality control remains a priority to protect human health and to ensure safety living and working conditions.

Among pollutants, monoaromatic hydrocarbons such as BTEX emanating from exhausts, solvents, paints and household products are ubiquitous and hazardous to health. The International Agency for Research on Cancer (IARC) classifies benzene as carcinogenic to humans (group 1) and éthylbenzène as possibly carcinogenic to humans (group 2B). Because we are daily exposed to these chemicals in indoor and outdoor environments, their continuous monitoring and the assessment of their effects on human health remains a priority in the context of air quality control.

The most recent results on QCM-based sensors coated with phthalocyanines as sensitive materials devoted to the measurement of BTEX concentrations in air will be given [1]. The sensing properties of different substituted and unsubstituted metallophthalocyanines have been studied and correlated with their structural, morphological and chemical properties characterized by SEM, FT-IR and XRD. In the context of this study, we have especially established:

- no significant effect of the central metal atom on the sensing properties,
- the predominant role of substituents on thin film morphology and sensor responses,
- the higher sensitivity (6-10 times as compared to unsubstituted phthalocyanines) and faster kinetics of responses due to tert-butyl peripheral grafting groups,
- threshold and resolution close to 1 ppm,
- the low cross-sensitivities for CO, NO_2 and H_2S and partial selectivity to BTX gases.

Repeatability, response time, hysteresis as well as gas-material interactions will be discussed.

To achieve the discriminated measurement of each monoaromatic hydrocarbon, the development of a sensor-system based on QCM sensor previously described associated to partially fluorinated nanocarbons used as selective filter or sequential thermo-desorption matrix is the aim of a new exploratory project called "ASTHMAA". Strategies and expected results of this project we coordinate and supported by the National Centre for Scientific Research (CNRS) will be detailed at last.

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Oral Presentation

THEORY OF QCM AND SAW DEVICES IN SENSORS AND BIOSENSORS APPLICATIONS

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Abstract

Knowledge of reasons causing the deviation from linear (Sauerbrey) relation between the shift in the resonance Δf and the surface mass is essential for the correct interpretation of gravimetrical results of acoustic sensor measurements, specifically in vapors and liquid environments. One of the possible reasons could be the softness of sensitive layer. Other factors contributing to the observed nonlinear behavior of the resonance frequency changes and the dissipation are viscous losses in the testing material due to its fluidity or viscoelasticity. This so-called ‘’missing mass’’ has been described for the QCM sensors operated in a liquid phase [1,2]. In the present work the ‘’missing mass’’ effect is analyzed within the theoretical model published elsewhere [3] for the SH SAW-type acoustical sensors. The calculated characteristics, namely, the shift in the phase velocity and the attenuation coefficient should be compared with the experimental results of surface mass detection in volatile organic compounds and air quality control measurements for the correction of results accounting for possible losses arising in the system of a guiding layer covered on the top with a fluid or a viscoelastic layer.

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Oral Presentation

VIEWS ON INTER-LABORATORY REPRODUCIBILITY OF CHEMOSENSING EXPERIMENTS

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Abstract

Chemical resistors or chemiresistors, often made of a sensing material processed into thin film over comb-shaped electrodes, have been used for many years as transducers. Those based on molecular materials[1] are easily prepared, cheap to produce, they do not require a lot of power (most often in the nW or µW range) and can operate at room temperature. However, these conductometric sensors usually exhibit a natural current drift and much too slow kinetics to be used for real-world applications. Issues of sensitivity, selectivity and response-time have been the same for several decades and more recently the number of studies taking into account the effect of humidity (required for any real-world application, especially outdoors) has been increasing.

In this context, researches on new materials and devices are ongoing and the number of new reports available every year is increasing[2]. This trend is driven by emerging or niche markets that encourage sensor research for application in air quality monitoring, smart buildings, connected objects, or as a tool to enhance processes, especially in the food industry.

Unfortunately, the performances and limitations of sensors described in published papers are difficult to compare due to the variety of setups and/or experimental conditions used to study them and the lack of a comprehensive description, making it difficult to know for sure whether one system constitutes an improvement over an other when the investigations were conducted by different research teams.

On the basis of a critical review of our sensing experiments with various conductometric sensors and workbenches, enriched with examples from published papers and a comparative study of MSDI heterojunction[3] devices in similar conditions between our workbenches and those of Prof. K. PERSAUD's laboratory at Manchester University, this talk aims at presenting sensing data at a new angle.

It is a critical review of the on the way sensor "metrics" are often introduced in articles (such as the response time, the kinetics, drift, etc.) and a discussion of key information often considered to be of lesser importance that is left out in published papers despite being critical to truly assess the work and improve the communication of results in the sensor research field.

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Oral Presentation

HIGHLY RESOLVED UFP NUMBER CONCENTRATION MAPS IN ZURICH BASED ON DATA FROM A MOBILE SENSOR NETWORK

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Abstract
Ultrafine particles (UFPs) in ambient air are a potential risk for human health. However, the knowledge of the impact of ambient UFPs on humans is still incomplete and further research in this subject is required. Hereby, urban environments are in special focus as their UFP concentration fields are highly variable due to non-uniform source activity and heterogeneous building density. Thus, accurate maps of UFP number concentrations (PNC) with high spatial and temporal resolution for cities can be a valuable tool likewise for exposure assessment (e.g. for epidemiological studies) and urban planning.

The OpenSense mobile sensor network operating in Zurich consists of 10 sensor nodes that are installed on the roof of streetcars. Between 2012 and 2014 each sensor node was equipped among other sensors with a particle counting device (miniature diffusion size classifier) providing measurements at a rate of 5 seconds. In this period the mobile network compiled a comprehensive data set of PNC measurements for the city of Zurich.

We developed a statistical approach in order to model the PNC measurements obtained by the OpenSense network. Our approach employs Generalized Additive models (GAMs) relating PNC measurements and georeferenced predictor variables such as traffic counts, building density and elevation. We computed two PNC model series for the periods July-Sept 2013 and Dec 2013-Feb 2014. Based on these models, we generated PNC maps for the city of Zurich with 30 minutes temporal and 10 m by 10 m spatial resolution.

The performance of the modelling approach was analysed by comparing the mapped UFP concentrations to measurements of four permanent monitoring sites as well as to measurements obtained by pedestrians. In addition, we performed leave-one-out (i.e. sensor node) cross-validation. The accuracy of the statistical models is convincing in areas with geographic features well captured by the tram network. It partly declines for location types associated with a small number of measurements.

The presented approach provides detailed insight into spatial and temporal variability of PNC levels in cities. It can be very useful for improved exposure estimation, for urban planning and for public information.

Oral Presentation

THE USE OF SENSORS FOR VOC EMISSION CONTROL AT INDUSTRIAL SITES

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Abstract

Volatile organic compounds (VOCs) are organic chemicals that have a high vapour pressure. They are a relatively minor components of the atmosphere, yet VOCs have an important role in air quality and climate. As air pollutant VOCs are of concern for both outdoor and indoor environments. In the outdoor environment mainly due to its ability to form photochemical smog, in the indoor environment mainly due to its adverse health effects. The main outdoor sources are traffic and transport at urban areas and the production, storage or use of solvents at industrial areas.

A large contribution comes from industrial activities in the (petro)chemical sector. Regulations concerning the monitoring and control of VOC emissions have been implemented in environmental legislation worldwide. Although differences exist between different countries, strong similarities are prevalent. These include: (1) the characterization of an installation based on the amount and types of the emitted VOCs, and (2) the development of an annual monitoring and control program to reduce VOC emissions from the installation, including the description of the installation, an inventory of equipment, the implementation of a monitoring and repair program (LDAR), a calculation of the emissions and reporting.

Sensor technology has great potential to contribute to LDAR programs and assist current practise by exploiting important features:

(1) Small size: operational at places with limited accessibility
(2) Low cost: mass deployment at strategic equipment (tanks, equipment with leaking history)
(3) Low energy consumption: autonomous operation for long periods
(4) High frequency operational mode: monitoring at high temporal resolution for near real-time screening and alerting

The MultiSensorPlatform project (MSP, FP7, No. 611887) aims at further development of sensor technology for LDAR activities as one of its demonstrator projects. Therefore, new sensor technology is currently tested under laboratory conditions. Field testing and validation are planned for the second half of 2015. Important metrological parameters that will be further tested are sensor drift and lifetime. Also the potential of energy harvesting systems to increase autonomous operation is of major concern.

COST Action TD1105 - *New Sensing Technologies for Air-Pollution Control and Environmental Sustainability* - Fourth Scientific Meeting, organized by Linkoping University, Linkoping, 3-5 June 2015

Oral Presentation

MOX SENSOR SYSTEMS IN OUTDOOR ODOR NUISANCE MONITORING

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Abstract

Citizens of the Warndt region, part of the Saarland, Germany, have been complaining about odor nuisances for years. However, the source could never clearly be identified as several sources are possible. In a current project, several gas sensor systems based on highly sensitive but low cost metal oxide (MOX) gas sensors have been deployed in the region to assess their potential for odor nuisance monitoring. Temperature cycled operation (TCO) mode [1] allows the use of pattern recognition for identification of specific odors as well as a possible increase in sensitivity [2]. In parallel, a citizens' network has been established to provide reference data for training of the sensor network as good correlation of TCO MOX sensors with human panels has been previously shown in [3].

Figure 1. Sensor platform for outdoor odor monitoring

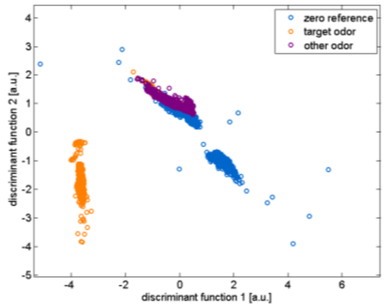

Figure 2. LDA plot of reference events

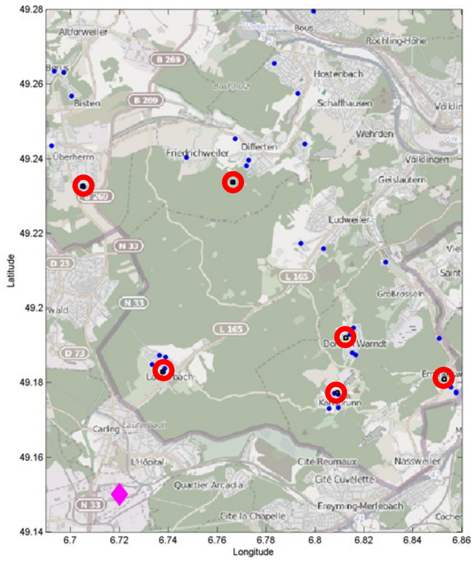

Figure 3. Map showing installed sensor systems (red circles), citizens' network (blue dots) and petrochemical plant (purple diamond)

Results from a first monitoring period covering three months indicate that the sensor systems might be a suitable solution. However, further improvements in sensor sensitivity and calibration of the sensor systems with the citizens' feedback are required for routine application.

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Oral Presentation

EVALUATION OF MONITORING GASES AND PM WITH LOW-COST AND REFERENCE DEVICES AT AMS(S) IN BELGRADE, SERBIA

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Abstract

Atmospheric, urban and indoor air pollution can affect citizen's health in a number of ways. Short-term effects include upper respiratory infections such as pneumonia and bronchitis, while long-term effects include lung and heart diseases and can exacerbate existing conditions such as asthma and emphysema. For such reasons it is important that air quality as well as meteorological data are available for citizens with high temporal and spatial resolution including online resource of near real-time and historical data. Currently inexpensive air quality sensors have been developed and embedded in small monitoring platforms whose characteristic have been evaluated. The questions is how accurate or even realistic may the data collected by these platforms be and for which purpose they could be useful.

This paper shows an evaluation of the characteristics of low cost sensor platforms under field conditions, when they were collocated next to an automatic monitoring station in Belgrade belonging to the State Air Quality Monitoring Network (Grimm monitors for PMs and Thermo monitors for gases). The sensor platforms, used during the CITI-SENSE pilot study consisted of individual electrochemical or infrared sensors monitoring the gaseous pollutants NO_2, NO, O_3, CO, CO_2, and optical devices for $PM_{0.3-2.5}$ and $PM_{2.5-10}$ as well as meteorological sensors monitoring T, p and RH. In duration of two weeks we tested 13 platforms equipped with Aphasense (UK) sensors for gases and DYLOS (USA) monitor for PMs. The figure below presents the Person correlation coefficients between the low-cost sensors and sensors from the reference devices.

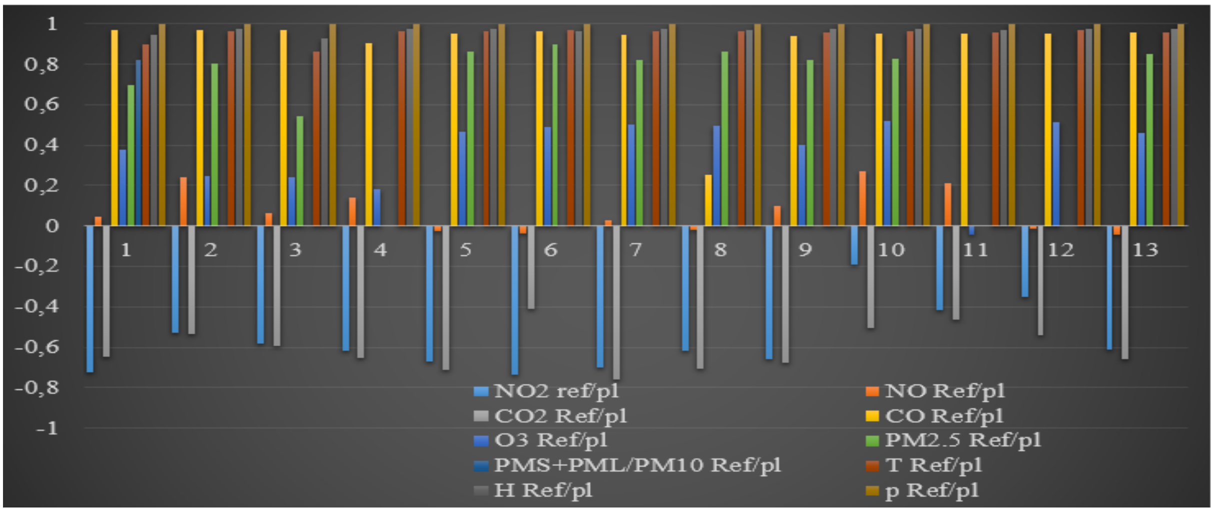

Figure 1. Person coeffiecent correlation between low-cost and reference sensors in the field

Presented results have been obtained within the activities that are carried out as part of the ongoing FP7 European project CITI-SENSE (Grant agreement nº: 308524).

Oral Presentation

USING LICHENS AS MULTI-POLLUTANT BIOINDICATORS IN AIR QUALITY MONITORING

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Abstract

The main motivation for assessing air quality is its impact on human and other living organisms' health. Despite that fact, air quality monitoring is standardly mostly conducted only with emission and immission monitoring stations, using physicochemical methods, while biological indicators are not always a part of a standard monitoring procedure. The physicochemical methods are essential for determining and quantifying pollutants. They also provide great time and relatively low spatial resolution of the results (due to the high cost of the current measuring instruments) and are focused on certain pollutants. But by neglecting the usage of biological indicators, it is overlooked that some pollutants can change into more toxic forms once being in a biological system (biotransformation), that they have different pollutant bioavailability and extractability, and that some highly toxic pollutants could be toxic for organisms even in amounts under the limit of detection.

Since lichens receive all necessary water and nutrients from the air, they are among the most commonly used biological indicators for the assessment of air quality in the world [1], significant for showing the multi-pollutant/multi-effect state of the environment. With analysing either the physiological changes on individuals and/or specifying the range of lichen species (since there are sensitive and resistant species) one can fairly quickly assess and map the long-term (cumulative) effects of air pollution over large areas, something that is practically not possible when using the standard approach with measuring stations. The paper shows that the analysis of the spatial distribution of indicator species of lichen is an ideal supplement to the standard approach, more suitable for identifying vulnerable areas, estimating the scope of air pollution from specific sources and optimization of the locations for the monitoring stations.

Figure 1. Lichen growth forms (from left to right: crustose, foliose, fruticose)

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Oral Presentation

TRANSFORMING AQ DATA TO PERSONALISED SERVICES

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Abstract

The availability of micro sensors make personalised air quality monitoring an imminent reality. This flooding of environmental data is heterogeneous, subjective and biased, thus not appropriate for direct use. Computational Intelligence algorithms can smooth such data and make them comparable and usable, thus appropriate for service design and development. These services can capitalise on the massive nature of individual datasets, can eulogize their geolocation and personalisation, and can be proven essential for the support of quality of life improvement. The presentation will address basic characteristics of the computational approaches that can be used for the analysis of micro-sensor oriented AQ data, and will describe scenarios of their use for service design and development.

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Oral Presentation

PRESENT IAQ SENSOR TECHNOLOGIES AND FUTURE TRENDS

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Abstract

European energy saving objectives applied to building requires controlling air renewal on demand because modern buildings are becoming totally air proof.
Present Indoor Air Quality (IAQ) probes developed by NanoSense are combining CO_2, VOC, temperature and humidity sensors but annex probes like Radon and particles matter can be associated. The goal is to properly balance energy saving objectives with heath and comfort.

IAQ probes are not only a combination of sensors but include algorithms to control actuators based on ecosystem status (comfort, Eco or night mode). For instance, temperature as the main comfort element is controlled by a fuzzy logic PID eliminating the need of skilled installers for commissioning and provide better results than manual PID settings. Merging data from various combined sensors is also part of the control algorithms. VOC can be reduced by air treatment and / or air dilution, humidity can be controlled by air handling unit and / or by air dilution if incoming air is dry or humid enough. Remediation strategies for radon is not limited to air dilution as over pressure can repulse incoming radon or bypassing Canadian well. Shutting down Particles require active filtering by recirculation and / or air dilution. Present Sensor technologies and the multiplicity of building automation standards makes IAQ probe large and expensive.
Temperature and RH MEMS sensor are becoming affordable and allow eliminating costly calibration process. NDIR CO_2 sensors are becoming more compact tanks to IR source and photodiode efficiency improvement. MEMS VOC MOX sensors are becoming available and if properly pulsed control can reach 10 years lifespan as required by main Building Automation Standards. Low energy consumption of such sensors allows close vicinity with temperature sensors and open the way to compact multi sensors probes. VOC calibration will remain the bottle neck for the mass production but small size and low consumption will allow calibrating large quantities per batch in case of VOC sensor pluggable module.
Low consumption NDIR CO_2 sensors using IR LED can now be combined with MEMS VOC MOX sensors to design energy harvesting IAQ probes.
Smart thermostat shall include IAQ as Comfort Room Operating Panel (C-ROP) but also embed sensors thanks to size, consumption and cost reduction.
Bistable display (EPD and BCD) can allow MMI for energy harvesting C-ROP.
Research on VOC identification and quantification (Sensindoor[1]) are on the way to combine low cost MEMS VOC sensor and low cost electronic compatible with energy harvesting.

Wireless standard convergence like Thread (6LoWPAN based) leaded by Google (NEST) or Allseen leaded by Qualcomm (BLE based) associated with compact low consumption IAQ sensors will allow energy harvesting probes to be easily commissioned as IOT devices in a near future.
Easy commissioning is the key of the market growth and the mass market will be the building refurbishing and the DIY.

THREAD GROUP

ALLSEEN ALLIANCE

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Oral Presentation

BENEFITS OF CMOS SENSORS FOR ENVIRONMENTAL MONITORING

M.F. Chowdhury[1], F. Udrea[1,2] and J.W. Gardner[1,3]
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Abstract
Need for environmental monitoring is crucial for present and future generations. This is particularly important due to rapid technological advancements being made in developed and developing nations. The impact of this development, if uncontrolled (as we have seen during the industrial revolutions), will have severe consequences in terms of natural ecological balance of the planet where all life on this earth depends on. The environmental monitoring involves recording as many parameters as possible, for example, temperature, humidity, pressure, particles, toxic and greenhouse gases, liquids, air flow, nuclear radiation, electro-magnetic radiation, vibration (earth quakes), bio-medical threats, human and animal activities, and even unknown extra-terrestrial substances.

Environment problem is a global issue, thus the above parameters need to be monitored on a global scale. Recent report from US, Department of Energy, indicated that cost of collecting water samples and analysis per sample can be between $100 to $1000. Typically in the Savannah River alone, some 40,000 samples are collected [1]. Clearly, monitoring environment is a very expensive process and such system or methods are impractical for global scale deployment.

To monitor environment on a global scale the sensors need to be low cost, provide high volume production capabilities and compact so that they can be readily integrated either in household utilities or in portable devices (such as smartphones) or affordable, purpose built systems for ubiquitous deployment leading to “big data” and internet of things. In order to achieve this goal, CMOS sensors for environmental monitoring are becoming one of most preferred low cost options as compared to other alternative solutions (such as electrochemical and possible printable technologies)[2]. The reason being, with CMOS, nearly all the parameters listed above can be easily measured using the same platform technology and a combination of MEMS and post-CMOS processing steps [3]. In this presentation we will give examples of such sensors and array of sensors that can be integrated on the same silicon die, and highlight the key benefits of using CMOS sensing solutions for future environmental monitoring. Figure 1, shows an example of an environmental monitoring module developed for using electrochemical (for gas sensing) and emerging alternative using metal-oxide CMOS solutions.

(a) (b)

Figure 1. Example of sensor module: (a) Multi-parameter environmental sensing module; (b) Board with CMOS sensor modules providing same functionality (circled in red).

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Oral Presentation

LOW COST CO2 SENSOR FOR BATTERY POWERED APPLICATIONS

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Abstract

There is an increasing demand on sensors with battery power both for indoor and outdoor applications. In the indoor applications the number of sensors is increasing and wired connections represent a significant obstacle in installing more sensors at desired locations. Outdoor sensor networks suffer even more from the absence of power supply and communication interface in proximity and need a long autonomous lifetime. Usually battery life time needed is in the range 1-10 years.

SenseAir sensors use NDIR technique for CO_2 gas concentration measurements. It assumes sending IR energy through detected gas media and measuring absorption. This energy represents an unavoidable source of power consumption and can be optimized by using a novel IR source and detector.

Significant extension sensor battery lifetime to the battery storage limits, or beyond sensor life-time, involves not only novel solution of IR source and detector, electronics with low deep-sleep current, but also enabling flexibility for the host system to control measurement rate and dynamically change it.

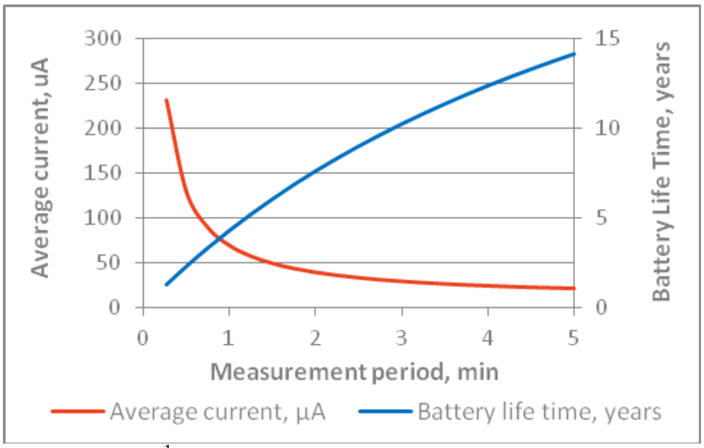

Figure 1. LP8 sensor[1] avg. current and battery lifetime vs. measurement period

Usually a battery powered sensor is a wireless sensor with optional measurements buffering. There is a variety of low-power wireless alliances/standards which are Bluetooth® LE, 6LoWPAN, ZigBee®, WiFi™, LoRa™, EnOcean® and others. When a sensor is used in a wireless network one should consider a balance between power consumed per sample measurement by the sensor and power consumed per transmission by the wireless node. SenseAir LP8 sensor for battery powered applications consumes only 3.6 mC of charge per measurement. For example it fits good LoRa™ typical long range node charge consumption, which is typically in the range of 15-21 mC depending on transceiver chip used and network profile chosen [2].

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Oral Presentation

SILICON CARBIDE SENSOR SYSTEMS FOR HARSH ENVIRONMENT MARKET APPLICATIONS

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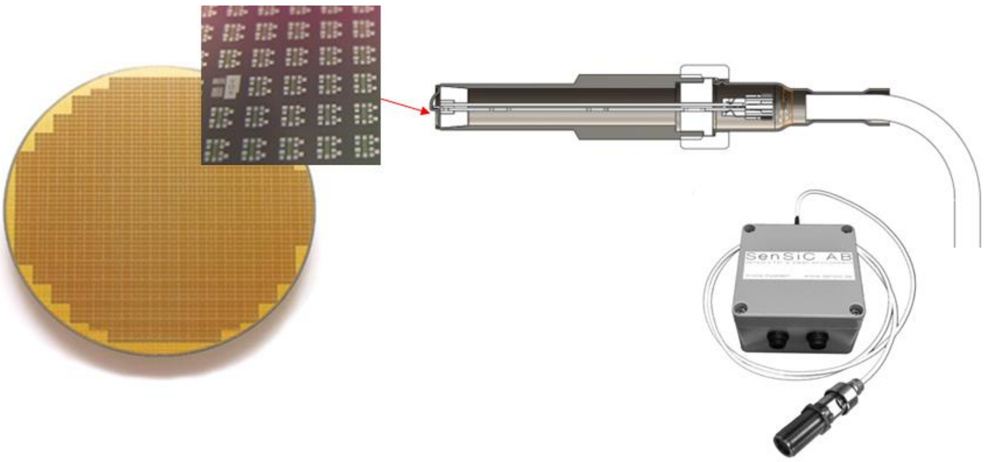
Abstract
The Silicon carbide, SiC, processing technology for 4” wafers, with 6” in the planning phase, has reached matureness of mass production. Devices based on SiC employing for example a porous Ir gate change the current/ voltage characteristics due to gas interaction with the catalytic gate material. Several batches of sensor devices have improved the device and gas response characteristics at the same time as important development of packaging of the sensors, electronics and software have resulted in sensor systems that are commercially available [1].

The SiC transistor device with porous Ir gate detects several gas molecules like CO, NH_3, H_2, HC, depending on the working temperature and the gas environment of the sensor. A sensor system with the possibility to detect the ratio between CO and oxygen is commercialized for control of small and medium sized bioheaters [2]. Also an ammonia sensor is available for control of the injection of urea in stationary engines with SCR, selective catalytic reduction, to reduce nitrogen oxide gases from diesel exhausts.

The silicon carbide offer a very robust substrate platform, which even at an operating temperature of 500°C can withstand sprinkling by water and fuel droplets, which occur in the diesel engine compartment. A SiC based oxygen sensor is under development to control EGR, exhaust gas recirculation, in car engines. Another SiC sensor device under development is devoted to detection of nitrogen oxide gases in car exhausts.



Figur: 4” SiC wafer with transistors for gas sensors, design SenSiC AB, processed at ASCATRON AB. The chips are mounted in a holder designed to withstand harsh environment and vibrations. The electronic box is also displayed.

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Keynote Talk

TOWARDS ZERO-POWER GAS DETECTION SYSTEMS BASED ON NANOWIRES: FABRICATION, CHARACTERIZATION, BENEFITS AND CHALLENGES

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Abstract

Nanowires have emerged as potential building blocks for future sensing devices thanks to their large surface-to-volume ratio [1] and to the possibility of growing them monocrystalline and defect-free [2], which gives rise to controlled and reproducible properties. These nanowires behave in a similar manner as their thick or thin-layer counterparts in what respects to gas sensing properties and, thus, have been successfully implemented.

In this work we will present the results of our research in developing gas detection systems based on individual nanowires for their use as ultra-low power consumption systems. For this purpose we have been using single crystalline, dislocation free SnO_2 nanowires with diameter below 100nm, synthesized by chemical vapor deposition (CVD) of molecular precursors [2]. The nanowires have been removed from these substrates and transferred onto different types and sized suspended microhotplates with integrated heater and interdigitated microelectrodes and have been contacted by advanced metallization techniques based on Focused Electron Beam Induced Deposition (FEBID) inside an SEM instrument have been carried out to fabricate the contacts to the individual nanowires [3], the resulting device being depicted in Figure 1.

Self-heating of the nanowires when a measuring the current flow through them allows simultaneously heating and measuring the nanowire, dramatically reducing the power consumption to some μW and simplifying the practical operation of the devices. However, the required control electronics that assures the correct and stable current flow through the device becomes much more complex. Based on this approach we have developed a portable detection system that uses a thermoelectric generator to provide the required operating power to both heat and read-out the gas sensing results [4].

In this work we will show which is the degree of maturity of this almost zero-power gas detection systems based on individual nanowires and we will critically discuss the steps required to further improve the sensing properties and to advance towards mass production.

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Keynote Talk

COST-EFFICIENT APPROACHES TO MEASURE CARBON DIOXIDE (CO_2) FLUXES AND CONCENTRATIONS IN NATURAL ENVIRONMENTS USING MINI LOGGERS

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Abstract
Fluxes of CO_2 are important for our understanding of the global carbon cycle and greenhouse gas balances. Several significant CO_2 fluxes in nature may still be neglected as illustrated by recent findings of high CO_2 emissions from aquatic ecosystems, previously not recognized in global carbon balances. Further, the local distribution of CO_2 emissions in both natural and urban landscapes, as well as associated with processes in society needs to be better mapped for designing more efficient mitigation efforts. Therefore it is important to develop convenient and affordable ways to measure CO_2 in many types of environments. At present, direct measurements of CO_2 fluxes from soils or waters, or CO_2 concentrations in surface water, or in society, are typically labour intensive or require costly equipment. We here present an approach with measurement units based on small inexpensive CO_2 loggers, originally made for indoor air quality monitoring, that were adapted for field use and tested in sensor-hostile conditions (variable temperatures and high humidity).[1] Measurements of soil-atmosphere and lake-atmosphere fluxes, as well as of spatio-temporal dynamics of water CO_2 concentrations (expressed as the equivalent partial pressure, pCO_{2aq}) in lakes and a stream network are provided as examples. Results from all these examples indicate that this approach can provide cost- and labor efficient alternatives for direct measurements and monitoring of CO_2 flux and pCO_{2aq} in natural environments, providing potential for great progress in our understanding of greenhouse gas cycling and in guiding mitigation efforts.

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Oral Presentation

"KOMPETITIVE INTELLIGENCE" A NEW METHOD FOR THE IDENTIFICATION AND ASSESSMENT OF TECHNOLOGICAL ALTERNATIVES

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Abstract

Every time we need to develop a new technical system or improve an existing one, the evaluation and the identification of potential technological alternatives assume a central role.

In conventional decision making strategies, the decision to invest in one or more alternative technologies is performed by weighting benefits and risks of each alternative.

Both the identification of technological alternatives and weighting are usually performed without a systematic methodology, relying on the experts' knowledge and somehow on the unquestionable judgment of leaders.

The main risks of these approaches are the strong subjectivity of the evaluation and the strong dependence of technological alternatives from experts' knowledge. In the worst case scenario, this situation may lead to an ineffective investment.

The proposed methodology, called "KOMpetitive intelligence" is based on a systematic approach, combining Knowledge search and problem solving developed through several years of experimentation and specifically built to overcome the aforementioned problems.

First, knowledge of experts is integrated with knowledge extracted from patents, market analyses, scientific literature and commercial literature. Second, the generation of technological alternatives is supported with a systematic theory of problem solving and knowledge transfer. Third, decision making and the definition of an innovation strategy is supported with a concise graphical structure that summarizes the gathered knowledge and facilitates the assessment of the technological alternatives.

As a result, gathered knowledge and problem solving foster the ability of experts to identify and assess technological alternatives. In some cases, completely new technologies are identified to be suitable with the considered application. The graphical summary allows experts and leaders to have a comprehensive and fast overview on the situation, increasing awareness and consistency of decision making.

Oral Presentation

THE 1ST EUNETAIR AIR QUALITY JOINT-EXERCISE INTERCOMPARISON: ASSESSMENT OF MICRO-SENSORS VERSUS REFERENCE METHODS (PART II)

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Abstract

This work presents the continuation of the performance evaluation and assessment of different environmental gas/particulate matter micro-sensors versus standardized air quality referenced methods through the 1st EuNetAir Air Quality Joint - Exercise Intercomparison. This experimental urban air quality monitoring campaign was organized by IDAD - Institute of Environment and Development in Aveiro, Portugal, on 13-27 October 2014 in the scope of COST Action TD1105 – EuNetAir.

The two-week experimental campaign was conducted in an urban traffic location in Aveiro city centre counting with 15 teams from research centres, universities and companies coming from 12 COST Countries. The micro-sensors systems were installed side-by-side at IDAD Air Quality Mobile Laboratory that was equipped with standardized equipment and referenced analysers of the following variables: CO, NOx, O_3, SO_2, PM10 and PM2.5, BTEX, temperature, humidity, wind velocity/direction, solar radiation, precipitation.

The statistical analysis of field results was conducted allowing a performance evaluation of several micro-sensors, namely Metal Oxide Semiconductor sensors (MOS), Electrochemical sensors and Optical Particle Counter sensors (OPC).

The analysis shows that for NO_2 and CO measurements performed with electrochemical and MOS sensors a greater correlation with the reference method and a higher efficiency collecting data is noticed for electrochemical sensors. Although for O_3 is observed a greater correlation with the reference method and a higher efficiency collecting data for MOS sensors. The OPC sensors for PM10 and PM2.5 present correlations that vary between 0.45-0.87 and data collection efficiencies in the range of 67-80%.

The statistical analysis included further development of correlation matrices to allow the analysis of both interfering pollutants and meteorological parameters in the measurement error of microsensors. The results point to weak Pearson correlations between the error of microsensors measurement and interfering pollutants measured by the reference equipment for electrochemical sensors.

Concerning the interference of meteorological parameters in electrochemical sensors it was found moderate correlations between the error of O_3 and NO_2 and Rad, RH, T, H_2O. Also, there were found weak correlations between the error of NO and CO measurement and interfering meteorological parameters.

The evaluation of the 1st EuNetAir campaign results shows that it is of paramount importance to further develop the data treatment of sensor signals from field campaigns, namely sensitivity and selectivity (known interference) to stablish an effective evaluation protocol.

Oral Presentation

GRAPHENE METAL-OXIDE HYBRIDS FOR GAS SENSOR TUNING

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Abstract

We report on surface modifications of epitaxial graphene on SiC (EG/SIC) with metal-oxide (MOx) nanoparticles (NPs) and monolayers, formed by reproducible thin film deposition techniques, and their effect on the electronic properties of the graphene and on gas interactions at the graphene surface. The scope is to exploit the sensing properties of MO_x materials for selectivity tuning while utilizing the unique electronic properties of graphene as an ultra-sensitive transducer.

We have previously found that monolayer graphene is crucial for optimum gas sensitivity [1]. This highlights the importance of achieving well-controlled uniform single-layer graphene growth. To that end, we have recently shown [2] that the graphene thickness uniformity can be significantly tuned by careful control of the EG/SiC morphology.

Chemiresistor sensors based on EG/SiC, decorated with Au, Pt, TiO_2 and FeO core-shell NPs (Fe core surrounded by FeO shell), were tested towards parts per million (ppm) down to low parts per billion (ppb) concentrations of hazardous volatile organic compounds (VOCs), e.g. CH_2O and C_6H_6, as well as common pollutants like NO, NO_2, CO, and NH_3. While pristine EG/SiC showed no response to the tested VOCs, it was found that decoration with TiO_2 or FeO NPs can yield selective detection of both CH_2O and C_6H_6. The effect of decoration on the sensor performance strongly depends on the choice, thickness, surface coverage, and size of the NPs. Decoration with nanoporous (2-3 nm) Au improved the detection limit and selectivity for NO_2 [3]. Decoration with TiO_2 NPs allowed detecting low ppb levels of formaldehyde and benzene, where the effect on the sensor performance depends on the diameter and surface coverage of the deposited TiO_2 NPs. Graphene decorated with monodispersed FeO NPs showed an even larger sensitivity to formaldehyde (Fig. 1a) and benzene (Figs. 1b and 1c) compared to EG-TiO_2 NP hybrids.

The results show that graphene decoration can be an effective strategy for tuning the sensor performance in the scope of ultra-sensitive detection of toxic air pollutants.

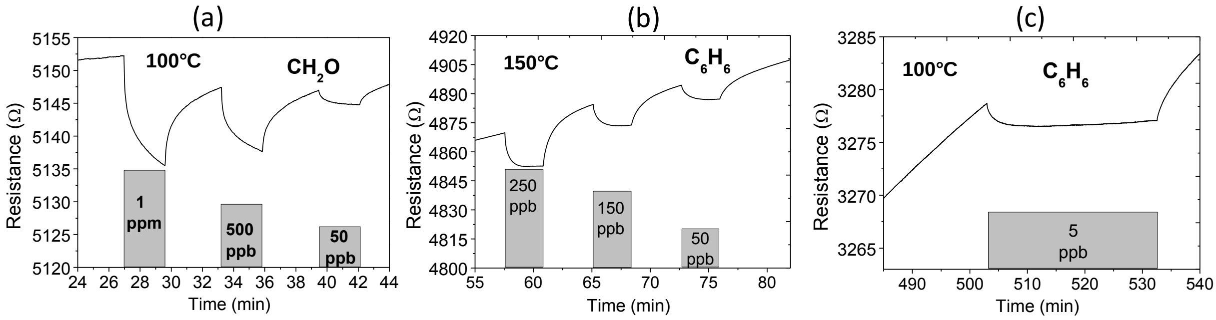

Figure 1. Response of a EG/SiC sensor decorated with FeO core-shell NPs (≈ 60 nm in diameter) to CH_2O concentrations from 1 ppm to 50 ppb (a) and to C_6H_6 concentrations in the range 250-50 ppb (b) and 5 ppb (c).

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Oral Presentation

Preliminary indoor and outdoor air pollution investigation in naturally ventilated classrooms: results from the ARIA project

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Children spend most of their time indoors, mainly in school. They are particularly susceptible to indoor air pollution when compared to adults due to their under-developed immune and respiratory systems and high inhalation rates. Children spend up to 10 hours/day in primary schools. Understanding the air pollution in these environments, documenting their concentrations and determining which factors influence these levels is very important.
As a part of the ongoing ARIA project, preliminary results regarding the levels of IAQ parameters at 10 naturally ventilated primary schools (35 classrooms) were described and discussed.
Total volatile organic compounds (TVOC), formaldehyde, PM_{10}, $PM_{2.5}$ and UFP, bacteria and fungi concentrations, carbon dioxide (CO_2), temperature and relative humidity (RH) levels were measured indoors and outdoors and a walkthrough survey was performed concurrently. The IAQ sampling was performed in one week per school (Monday to Friday) between January and March 2014.
The indoor average concentration for the 10 schools is 251 ±141 $\mu g/m^3$ for TVOC; 18.1 ±7.1 $\mu g/m^3$ for formaldehyde; 65 ±30 and 38 ±24 $\mu g/m^3$ for PM_{10} and $PM_{2.5}$, respectively; 9.06 ±4.6 $x10^3$ pt/cm^3 for UFP; 2246 ±1577 and 1164 ±2130 CFU/m^3 for bacteria and fungi, respectively; 1315 ±583 ppm for CO_2; 19.6 ±1.8 ºC for temperature; and 56.7 ±8.9 % for RH.
In general, the indoor levels of TVOCs were 60% higher than outdoors. Indoor VOCs usually originate from products used in occupancy-related activities such as cleaning procedures (detergents with ammonia or bleach) or in school artwork (dyes, inks, glues). The levels of formaldehyde were also higher indoors (I/O ratio=9.2). Aldehydes are known indoor air pollutants that can have their origin in wood-based furniture, cork ceilings or paint. In the schools with higher levels of indoor PM_{10} and $PM_{2.5}$, the ratios ranged from1.4 to 3.4. However, in S4 the indoor concentrations of PM_{10} were 11 times higher than outdoor ones. The origin of such levels of particulate matter may be associated with the presence of chalk boards in the classroom. Only two schools (S1 and S9) exhibited slightly lower concentrations of fungi indoors than outdoors. Moreover, S4 presented indoor concentrations of fungi 40 times higher than outdoor concentrations, suggesting a serious dampness situation. More problematic were the indoor levels of bacteria which were 2 to 43 times higher than outdoor levels. The increased CO_2 levels suggest poor ventilation conditions in schools, which may be responsible for the highly increased indoor concentrations of other pollutants such as bacteria and fungi. Opening the windows during school breaks may be a solution to overcome this problem. Since all schools had exclusively natural ventilation these results may suggest that the school personnel did not correctly perform the recommended ventilation practices, such as opening windows during recess periods, probably due to unawareness to this situation.
These findings indicate that IAQ problems may persist in classrooms where pollutant sources exist and classrooms are poorly ventilated; source control strategies (related to building location, occupant behaviour, maintenance/cleaning activities) are deemed to be the most reliable for the prevention of adverse health consequences in children in schools.
This study was performed in the framework of the ARIA project that was financed by Fundação para a Ciência e Tecnologia (PTDC/DTP-SPA/1522/2012, FCOMP-01-0124-FEDER-028709).

Roundtable Presentation

AN INDUSTRY VIEW IN THE COMMERCIALIZATION OF GAS SENSORS FOR ENVIRONMENTAL SUSTAINABILITY

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Abstract

The status of Mother Earth as a healthy place for everyone to live on is getting worse for every day passing. The switching over to a sustainable and green economy has started, but the pace is far too slow to avoid serious and irrevocable damages on the earth ecosystem, and hence, down the road, our lives and economy. To get fuel to the politicians in charge, so that they dare to take the big steps required for sustainability, and also make the difficult decisions required, more facts and waterproof evidence on the environmental status is needed, information that can be retrieved by gas sensors. There is a strong need for many more measurement nodes all around the globe, in cities and polluted areas, as well as in rural, mountain, ocean, and atmospheric points of observation. To accomplish this, gas sensors good enough for the tasks need to be lower cost in purchase, as well as in maintenance. By this we are getting closer towards the paradigm shift, where we go from observing the environmental parameters at very high precision at a very limited number of sites around the world, to the situation where huge numbers of fixed and mobile gas sensors are deployed and connected to smart databases accessible for everyone. We eventually will get the full picture, and not just some high resolution single pixels on the world map.

Figure 1. EU cooperation example

This situation drives the evolution of gas sensor technology forward. New inventions and miniaturization efforts, open up for cost efficient batch manufacturing, less raw materials per sensor, lower power consumption, etc., which are pre-requites for low cost Internet-of-Things compatible sensor nodes. Great technical progress has indeed been presented during the past decade in this area within all “traditional” gas sensing techniques (electrochemical, photoionization, semiconductor, catalytic, optical/infrared). However, large investments in R&D, as well as in volume production capabilities, are taking place, and even more is required for making this necessary development to happen. Governmental R&D funding agencies of today realize this fact; supporting for instance innovative SME’s to participate in meeting the global sustainability challenges. From an industry point of view, big opportunities for growth exist in this area of gas sensing, as the market is expected to grow fast[1] when the technical and economic requirements are met. To fully utilize this potential, it is essential that European cooperation is continuously facilitated by the authorities, so that the industry in Europe remains competitive on the international market, including keeping the production locally, which by itself is an important sustainability factor.

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ABSTRACTS OF POSTER PRESENTATIONS

Poster Presentation

A local Integrated Assessment of Air Pollution Impacts on Human Health - A Case Study for Portugal and Grande Porto

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Air pollution is a worldwide problem with broadly known harmful effects on health and environment. The impact of these effects at the individual level may appear low compared to other risk factors. However, since the whole population is exposed, this impact results in a non-negligible public-health burden. Several studies found that current levels of air pollutants in urban areas are associated to an increase risk of morbidity, namely cardiovascular and respiratory diseases, and premature mortality (e.g. years of lost life). Recently, outdoor air pollution was classified carcinogenic to humans.
Quantifying the impact of air pollution on the public's health has become an increasingly critical component in policy discussion. To this end, several methodologies involving exposure-response relationships and economic evaluation of externalities have been developed. The key issues to estimate health costs derived from air pollution are broadly related with two different concerns: how to identify all physical impacts, and how these impacts can be converted in monetary values.
Despite the air quality improvements observed in Europe over the last years there is still a continued wide-spread of exceedances within member states, particularly regarding particulate matter (PM), nitrogen oxides (NO_x) and ozone (O_3). Portugal is not an exception. Recently, significant associations were found between daily mortality and morbidity endpoints and short-term exposures to PM and NOx in Oporto district, stressing the need of a close research. The aim of the project MAPLIA is to analyse the feasibility of an integrated assessment bottom-up approach for air quality planning, including health effects and costs tailored to the local features of Oporto city.

This work is supported by European Funds through the COMPETE Programme and by Fundação para a Ciência e Tecnologia (FCT) within project PEst-C/MAR/LA0017/2013 for the MAPLIA Project (PTDC/AAG-MAA/4077/2012).

Poster Presentation

NONRESONANT HIGH-FREQUENCY EXCITATION OF NANOELECTROMECHANICAL OSCILLATORS

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Abstract

We consider a graphene membrane suspended between two grounded electrodes and symmetrically places between two voltage biased capacitor plates, see Fig. 1. The latter induce an electrical potential on the graphene sheet if it is deflected from the flat position. As it takes place the potential drop between the sheet and electrodes will induce an electronic flow between them. As a consequence the charge on the sheet will follow the voltage drop with a characteristic time delay *RC* (tunnel resistance between electrodes and membrane *R* and membrane capacitance *C*). At the same time the electrical field $E=E_0\cos(\Omega t)$ between the plates will generate a force on the membrane if it is charged establishing by this mean a feedback on the mechanical subsystem.

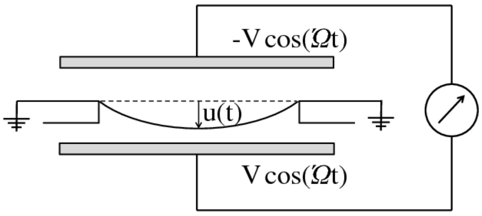

Figure 1. Graphene sheet suspended over a cavity. The electrodes is at zero potential and an external field can be applied from the capacitor plates.

To describe the mechanical motion of the membrane under the action of such feedback we use a classical model. Namely, we reduce the membrane dynamics to the dynamics of the fundamental flexural mode which we treat as a point oscillator with small damping γ. We derive an effective equation for the mechanical motion under condition that the frequency Ω is much greater than the frequency of the mechanical oscillator.

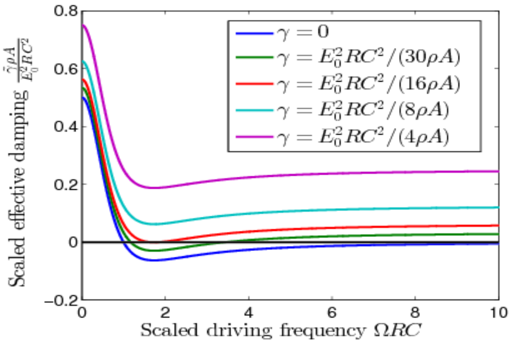

Fig. 2. Effective damping of the mechanical oscillator as a function of driving frequency Ω with mass of the sheet *ρA*. For a finite damping γ the effective damping will be negative in a frequency window determined by the strength of the applied field E_0.

We find that the interplay between the membrane deflection and the charge retardation generates an effective damping of the mechanical oscillator which becomes negative when the external frequency becomes greater than the *RC*-frequency, Ω*RC*>1. Therefore off-resonant excitation of the oscillator arise under such conditions, see Fig. 2. We find that this excitation will not be saturated by nonlinear damping.

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Poster Presentation

Detection of harmful pollutions from NO_2 in gas phase by quartz crystal microbalance

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Abstract

The sensitivity of the Quartz Crystal Microbalance (QCM) technique make rapid progress in the last years, because of the high accuracy and rapidity. The presented work is sharing the new results and experiences in the technology and sensing characteristics of the ZnO nanostructured (NS) films- and TiO_2 films-QCM structures. The ZnO NS layers are deposited by electrochemical method on quartz resonators with Au electrodes. TiO_2 films were prepared by a sol-gel technique with commercial TiO_2 powder as a source material (P25 Degussa AG). After a special treatment, printing paste was prepared. The TiO_2 layers were formed by means of drop-coating on Si-control wafers and on the Au-electrodes of quartz resonators. ZnO and TiO_2 films were deposited on both sides of a 16-MHz QCM. The surface morphology of the films was examined by scanning electron microscopy, Raman spectroscopy and the surface composition was determined by X-ray photoelectron spectroscopy. Sorption properties of layers were defined by measuring the resonant frequency shift (Δf) of the QCM-ZnO or TiO_2-QCM structures for different NO_2 concentrations. The measurements were based on the correlation between the frequency shift of the QCM and additional mass loading (Δm) on the resonator calculated using Sauerbrey equation for the AT-cut quartz plate. Frequency – Time Characteristics (FTCs) of the samples were measured as a function of different NO_2 concentrations in order to define the sorption abilities of ZnO layers. The experiments were carried out on a special set up in a dynamical regime. From FTCs the response and the recovery times of the QCM-ZnO structure were measured with varying NO_2. Frequency shift changed from 23 Hz to 58 Hz when NO_2 was varied in the range of 250 ppm - 5000 ppm. The process of sorption was estimated as reversible and the sorption as physical. The obtained results demonstrated that QCM covered with the electrochemically deposited nanostructured ZnO films can be used as application in NO_2 sensors. The TiO_2 films were tested in the NO_2 concentration interval from 10 ppm to 5000 ppm. It was found that a TiO_2 loading of the QCM by 5.76 kHz corresponded to a system sensitive to NO_2 concentrations above 250 ppm. On the basis of the FTCs measured, ΔF at different NO_2 concentrations was defined, the adsorption/desorption cycles were studied and the response and recovery times were estimated. Results obtained show that a processes in the two investigated structures were reversible for NO_2 in large range of concentrations and suggested that ZnO NS and TiO_2 films combined with QCM technique are suitable as a sensor element for NO_2 detection.

Poster Presentation

AIRSENSEUR: AN OPEN SOFTWARE/HARDWARE MULTI-SENSOR FOR AIR QUALITY MONITORING

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Abstract

A multi-sensor platform, AirSensEUR, has been developed for the monitoring of air pollution at low concentration levels. The system is sensitive enough to measure the low voltages of the sensor responses. AirSensEUR was developed with the aim to create an open software/open data object and to have the capacity to behave as a node within a network of multi sensors assuring interoperability and compliance with the Inspire Directive.

The shield is a high precision 4-channel 3-electrode sensor board (City Technology O3 3E1F, NO2 3E50, NO 3E100 and CO 3E300). The shield also includes a wired board with temperature/humidity (UR100CD) and pressure sensor (BMP180) together with I2C level shifters to interface to the ATMega328 microcontroller managing the shield. Each sensor channel is composed of a fully programmable Analog Front End (AFE, TI LMP91000), a 16-bit A/D converter (TI ADC16S626) and 12bit D/A converter (AD5694RB). The D/A converters dynamically set the range of the A/D converters in order to keep the converter resolution in the sensor output range making AirSensEUR suitable to measure extreme low voltages (< 10's μV) as needed with sensor sensitivity. The ATMega328 controls the AFE of the sensors, A/D and D/A registers, external sensors, then retrieves, filters and averages the sensor responses. The ATMega328 receives a firmware developed in the Arduino framework and IDE through a serial line on the shield. An USB board fitted on the shield allows acquisition of AirSensEUR data for laboratory calibration. Additionally, a JAVA control panel has been developed in order to easily configure the AFE (sensor voltage, A/D conversion limits, gain, R_{load}, bias, IIR filtering, DAQ periodicity and averaging time) and read sensor responses.

The host is based on the Arietta G25 (ACMESystem.it), a low cost Linux embedded module CPU Atmel (ARM9 @ 400 MHz) and 256 MB DDR2. It also accommodates other devices: a GPS, a GPRS and a Wi-Fi access point. Power supply comes from a LiFePO4 High Power Cell (3.2V/20Ah) or through USB/power line. A set of Java programs retrieve data from the shield and the GPS. Together with the timestamp, these data are added to a local sqlite3 database, stored on the SD card of the Arietta. Finally, the data of the local database are pushed via GSM/GPRS to an external server through a transactional Sensor Observation Service (SOS-T). Observations are stored within a PostgreSQL/PostGIS database together with additional metadata. The use of the SOS ensures compliance with the requirements of the INSPIRE Directive. Furthermore, the use of the open source PostgreSQL database makes it easy to interface sensor observations with open source GIS applications, and establish additional INSPIRE services (discovery, view and download). It is also easy to correct data using the R statistical package (for example allowing on-the-fly calibration of sensors against existing monitoring stations). The poster describes this multi-sensor platform and present the preliminary limit of detection and calibration curves of the sensor.

Poster Presentation

EVALUATUON OF ELECTROCHEMICAL SENSORS BY MEANS OF AN HANDHELD DEVICE FOR AIR QUALITY MONITORING

Domenico Suriano, Gennaro Cassano, Valerio Pfister, Michele Penza

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Abstract

Environmental monitoring is strongly required to protect the public health and save the environment from toxic contaminants and pathogens that can be released into air. Air-pollutants include gases like carbon monoxide (CO) and nitrogen dioxide (NO_2), that come from various sources such as vehicle emissions, power plants, refineries, industrial and laboratory processes. However, current monitoring methods are costly and time-consuming, also limitations in sampling and analytical techniques exist. Clearly, a need exists for accurate, inexpensive long-term monitoring of environmental contaminants using low-cost solid-state gas sensors that are able to operate on-site and real-time. Calibrated cost-effective gas sensors are a very interesting solution for networked systems suitable to monitor air-pollutants in urban street and real scenario of smart cities with high spatial and time resolution. In ENEA, at Brindisi Research Center, an handheld and stand-alone gas sensor system called *NASUS IV* based on solid state gas sensors was designed and implemented [1-5]. *NASUS IV* electronics is composed by four modules, or better, by four PCBs: the main module, the sensor module, the wireless module and the power module (figure 1). The device can be powered by network electricity or by its internal battery.

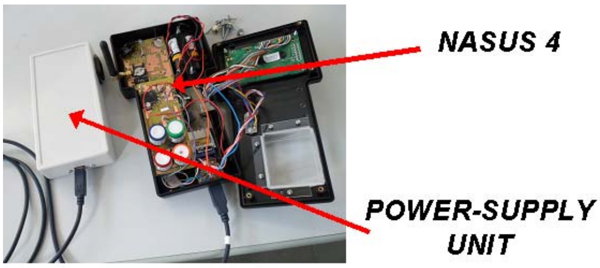

Figure 1. *NASUS IV* inside and power supply unit.

On the sensor module can be arranged up to six sensors: a temperature sensor, an humidity sensors and four electrochemical solid state gas sensors. We performed several tests in collaboration with Joint Research Center in Ispra (Italy) in order to evaluate the sensor performance using traditional chemical analyzers as reference.

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Poster Presentation

SENSOR OF BIOGAS INGREDIENT METHANE EMPLOYING POWERFUL PULSED LASER DIODES

Vasilka Pencheva, Stoyan Penchev, Ivan Nedkov

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Abstract

Biogas methane is a powerful greenhouse gas that plays a key role in several atmospheric environmental domains directly affecting the present enhancement of the greenhouse effect. It is the cause of about 20% of the increased trapping of atmospheric infrared radiation during the past 200 years. In addition, it affects the oxidizing capacity of the atmosphere and, therefore, the lifetimes of other strong greenhouse gases. The methane is monitored over regions of peak concentrations like sewage treatment and biogas production facilities. While future technologies may limit emissions from human activities, the measurement of atmospheric methane is accounted also for reconnaissance of natural resources like petroleum deposits. Among the various techniques of detection of biogas ingredients, laser sensing has the advantage of obtaining three-dimensional profiles with high temporal and spatial resolution unattainable by in-situ analysers. The proposed method optimises the spectral properties of laser radiation within NIR molecular absorption bands of methane. The absorption spectrum is explored by computational convolution method developed for powerful laser diodes. Further advances are related to the appropriate laser technology matching the strong methane absorption bands around 1.5-1.6 μm. A portable laser sensor targeting 1-10 km^2 perimeter of Earth's surface and employing optimal detection has absorption limit estimated to 0.1% of signal amplitude, equivalent to the tropospheric background concentration of 1.7 ppm. Such system is ultimately compact, of low- energy consumption and suggests a large potential for ecological monitoring.

Poster Presentation

EFFECT OF DOPANTS IN SEMICONDUCTOR OXIDE SENSING LAYERS UNDER LOW OXYGEN PARTIAL PRESSURES AND AT HIGHER TEMPERATURE

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Abstract

Sensors based on semiconductor oxides are generally of low cost and high stability even in harsh environments. The disadvantages are lack of sensitivity to detect dilute oxidizing gases, deprivation long-term stability under fluctuating environments of high-temperature and picking-up signals from interfering gases. TiO_2 offers properties suitable to high-temperature gas sensing covering gases such as CO, H_2 and NO_2. TiO_2 is an n-type semiconductor and exhibits low conductivity towards oxidizing gases. Its selectivity can be adjusted by doping with Cr, Al, Nb, Sn, etc. or by forming heterojunctions using other oxides (e.g. CuO and WO_3). Our experiments have confirmed that Cr- and Al-doping of TiO_2 introduces, at critical dopant content of 5 at.%, p-type sensor behavior towards NO_2. Conductivity measurements at high temperatures in air indicate that Cr-doping reduces the conductivity of TiO_2, while no influence of Al is observed. The role of Al and Cr as semiconductor dopants is explained by the retardation of anatase-to-rutile transformation resulting in stabilization of surface state of TiO_2-particles and inhibition of grain growth. Al-doped sensors yield higher sensitivity to NO_2 at temperatures exceeding 500°C which is attributed to the level of achieved crystallinity. Effect of Cr-doping in turn is related to the formation of interstitial vacancies which leads to formation of holes with charge carrier function on reaction with oxidizing gas. Our conductivity measurements on undoped and doped TiO_2 sensing electrodes contribute to the understanding of the role of doping. Reactive magnetron sputtered and annealed undoped and Al- and Cr-doped TiO_2 layers are characterized for microstructural and phase changes and tested under low oxygen pressures. The calculated n-values of the oxygen dependent electrical conductivity changes at 600°C and 700°C yield that Ti is compensated electrically by electrons at 600°C whereas by oxygen vacancies at 700°C.

Poster Presentation

HOW TO MANAGE A PROJECT OF CITIZEN SCIENCE: OLFACTORY ANNOYANCE EVALUATION IN TARANTO CITY (ITALY)

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Abstract

Odour annoyance represents one of the most emerging aspects related to odour emissions, produced by industrial plants and constitutes an indicator of an unhealthy environment, strongly felt by population. Even though real risk for human health have not been demonstrated yet, the association between an annoying odour perception and psycho-physical symptoms such as states of anxiety, headache, depression, eye irritation, respiratory problems, nausea, etc., is verified [1, 2]. So, odour emission is considered as one of the most important causes of population complaints and its evaluation represents a matter characterized by great complexity. The management of the complaints of the citizens, living in the surroundings of odour sources, represents a very hard topic to face for public authorities. Another aspect to take into account is the evaluation of the reliability of population complaints and how it is possible to make objective these warnings since very often an odor event is characterized by high intensity but, at the same time, short duration and so it could be difficult to detect by means of the conventional techniques.

Taranto city, located in the South of Italy, is seriously afflicted by a strong environmental pollution produced by the different plants in the industrial area (the biggest metallurgic center in Europe, an oil refinery, a landfill, a cement plant and a military arsenal). In this area an experimental methodology for the detection and evaluation of olfactory annoyance, called Odortel®, has been applied; it is able to integrate automatic remote systems in order to record the olfactory perception of human receptors and to collect odour samples in real time. The project requires the direct participation of population in the monitoring activities; in fact citizens play a key role to alert the public authority by means of a phone switchboard, communicating in real time the perception of odor events and their intensity. The warnings are displayed on a map together with the meteorological data in order to associate the emissions to the sources on the territory. According to a chosen routine, remote automatic sampling systems, located in particular sites on the territory, are activated in real time in order to collect a representative sample, analyzed through dynamic olfactometry.

The application of Odortel® in the area of Taranto has permitted, for the first time, to manage the population complaints in a systematic way, to prove the refinery as the source and, at the same time, to perform improvements in sampling-analysis process.

References

1. S.S. Schiffman, "Livestock odors: Implications for human health and well-being", *J. Anim. Sci.* (1998) 76, 1343-1355.

2. M. Aatamila, P.K. Verkasalo, M. J. Korhonen, A. L. Suominen, M.R.Hirvonen, M.K.Viluksela, A. Nevalainen,"Odour annoyance and physical symptoms among residents living near waste treatment centres", *Environmental Research* (2011) 111, 164-170.

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COST Action TD1105

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

7th Management Committee and Working Groups Meeting
Linköping, Sweden, 3 - 5 June 2015

Fourth Scientific Meeting

organized by
Linköping University, Division of Applied Sensor Science
hosted at Department of Physics, Chemistry and Biology (IFM)
Physics Building, Campus Valla
Linköping, Sweden, 3 - 5 June 2015

Workshop Venue:

Linköping University
Olaus Magnus väg, Campus Valla
58183 Linköping

Local organizer:

Prof. Dr. Anita LLOYD SPETZ
Head of Div. Applied Sensor Science and VINN Excellence center FunMat
Dept. Pysics, Chemistry and Biology, Linköping University, Linköping, Sweden
FiDiPro at University of Oulu, Finland, Action Vice-Chair
Tel.: +46 13 281710
Tel. Oulu: +358 294 482717
Adm. co.: +46 13 282944
Email: spetz@ifm.liu.se

Meeting and Travel Information

VISA FORMALITIES

All formalities for each citizenship including how to apply for visa, if needed, are detailed on the following links:
http://www.migrationsverket.se/English/Private-individuals/Visiting-Sweden/Visiting-on-business-and-for-conferences.html
http://www.visitsweden.com/sweden/Sweden-Facts/Worth-knowing-about-Sweden/Passports-and-Visas/

ENTERING THE COUNTRY

Visa policy of Sweden depends on the origin country. Details on this topic can be found at http://www.government.se/sb/d/12386**. A list of the foreign citizens who require Visa for entry into Sweden can be found at** http://www.government.se/sb/d/12386/a/241031.

We will be happy to provide more details on request, do not hesitate to ask us for any remaining question mark on this topic.

ARRIVAL ROUTES TO LINKÖPING

Linköping can be reached by airplane, train, bus, car, ferry or boat.

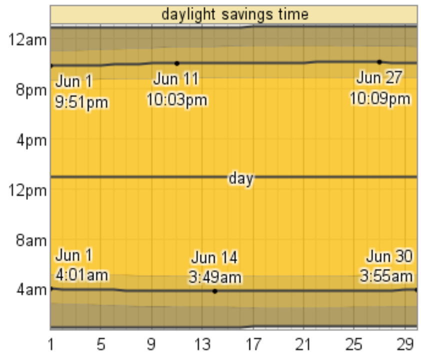
The international airport in Linköping, Linköping City Airport (LPI), serves the routes to/from Amsterdam and Copenhagen. Connections from LPI offer easy means to join the city centre in a few minutes by taxi or rental car. Stockholm Arlanda Airport is at a distance of about 2 hours by train, 2.5 hours by rental car (without traffic), and 3.5 hours by bus. Stockholm Skavsta Airport is at a distance of about 1.5 hours by bus or rental car.

EXPECTED WEATHER

Weather Averages for Linköping in June

Linköping has a humid continental climate with warm summers and no dry season. The area within 40 km of Linköping City Airport is covered by forests (81 %), croplands (10 %), and lakes and rivers (8 %).

Min Temperature	9.5 °C	49.1 °F
Max Temperature	20.7 °C	69.3 °F
Avg. Rainfall	51 mm	
Avg. Rainy Days	9.0 days	
Avg. Daily Sunshine	7.6 hours	



Further information and graphics are available at:
https://weatherspark.com/averages/28956/6/Linkoping-Ostergotland-Sweden

TIME ZONE

Sweden is in the Central European Time (CET) time zone. In June, the Central European Summer Time (CEST) is 2 hours ahead of Coordinated Universal Time (UTC). A time zone converter is available at:
http://www.timeanddate.com/worldclock/converter.html

CURRENCY: **Swedish Krona (SEK)**

INTERNATIONAL TELEPHONE CODE: **+46**

ELECTRIC CURRENT

220 V AC with a frequency of 50 Hertz. European standard plugs with two round pins are used. As your outlet may differ from *Europlug* outlets used in Sweden, you may need a transformer and/or an adapter for your electrical appliances.

Hotel Information

Suggested / pre-booked rooms at special rates (2-7 June 2015):

Overview, MAP-1.

Valla Folkhögskola (Valla Folk High School)

Address: Studievägen 22, 583 29 Linköping
Tel: +46 13-35 55 80
Email: konferens@valla.fhsk.se
Web.page: http://valla.fhsk.se/in-english/conference-and-accomodations/

Prices:
Single Room: 653 SEK/night (69,74 EUR/night) including breakfast (20 single rooms pre-booked at this price).
Booking code: "**LiU 150602**" to be stated at the moment of the reservation via telephone or e-mail.
N.B.: The reservation at this special rate is valid **until April 13**.

Main advantage:
Valla Folkhögskola is a homey and clean hostel, situated in a green and relaxing environment inside Campus Valla, so logistically very convenient. Check the hostel website for more info.

Distance from the meeting venue: 300 m (see MAP-2).

First Hotel

Address: Storgatan 70, 582 28 Linköping
Tel: +46 13-13 02 00
Email: linkoping@firsthotels.se
Webpage: http://www.firsthotels.com/

Prices:
Single Room: 934 SEK/night (99,75 EUR/night) including breakfast (10 single rooms pre-booked at this price)
Booking code: "**LIU150607**" to be stated at the moment of the reservation via telephone or e-mail.
N.B.: The reservation at this special rate is valid **until May 2**.

Main advantage:
First Hotel is a modern style, centrally located hotel, completely renovated in 2013. It is very close to the royal castle, the cathedral, and the city hall. Car parking garage in the same building as the hotel. Check the hotel website for more info.

Distance from the meeting venue: 3.1 km on foot or by bike, 3.5 km by car (see MAP-3).

Scandic Frimurarehotellet

Address: St. Larsgatan 14, 582 24 Linköping
Tel: +46 13-495 30 00
Email: frimis@scandichotels.com
Webpage:
http://www.scandichotels.com/Hotels/Sweden/Linkoping/Scandic-Frimurarehotellet/
Prices:
Single Room: 929 SEK/night (99,21 EUR/night) including breakfast (5 single rooms pre-booked at this price)
Booking code: "**LIN020615**" to be stated at the moment of the reservation via telephone or e-mail.
N.B.: The reservation at this special rate is valid **until May 2**.
Main advantage:
Scandic Frimurahotellet is a modern style hotel, situated close to the railway station and the Stångån river. Car parking at BAGGEN in the corner/driveway up to the hotel. A 24 hour ticket cost approx. 9 EUR (80 SEK). Check the hotel website for more info.
Distance from the meeting venue: 4.0 km on foot or by bike, 4.4 km by car (see MAP-4).

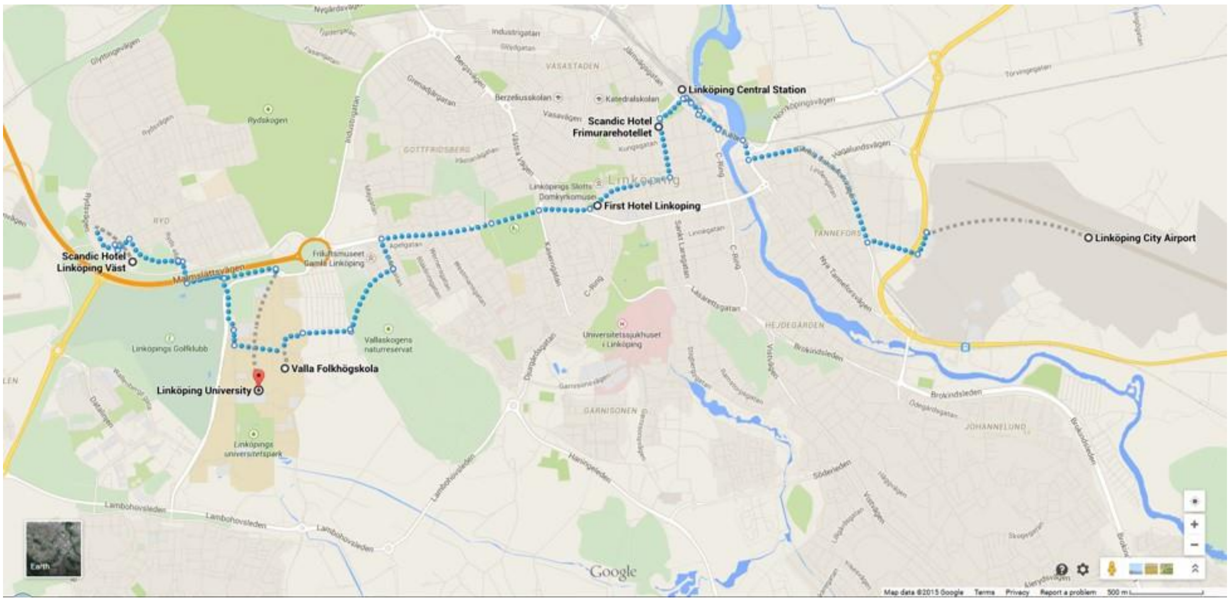
Scandic Linköping Väst (Scandic Linköping West)

Address: Rydsvägen, 584 32 Linköping
Tel: +46 13-495 50 10
Email: linkoping@scandichotels.com
Web.page:
http://www.scandichotels.com/Hotels/Sweden/Linkoping/Scandic-Linkoping-Vast/#.VMJEoU3wu70
Prices:
Single Room: 1030 SEK/night (110 EUR/night) including breakfast (30 single rooms pre-booked at this price).
Booking code: "**LiU 020615**" to be stated at the moment of the reservation via telephone or e-mail.
N.B.: The reservation at this special rate is valid **until May 1.**
Main advantage:
Scandic Linköping Väst hotel has a convenient location close to highways E4, 34, and 36. It is possible to borrow one of hotel's bikes at the hotel reception and head out to reach university and explore Linkoping surroundings. Outdoor parking available. Check the hotel website for more info.
Distance from the meeting venue: 1.9 km on foot or bike, 3.2 km by car (see MAP-5).

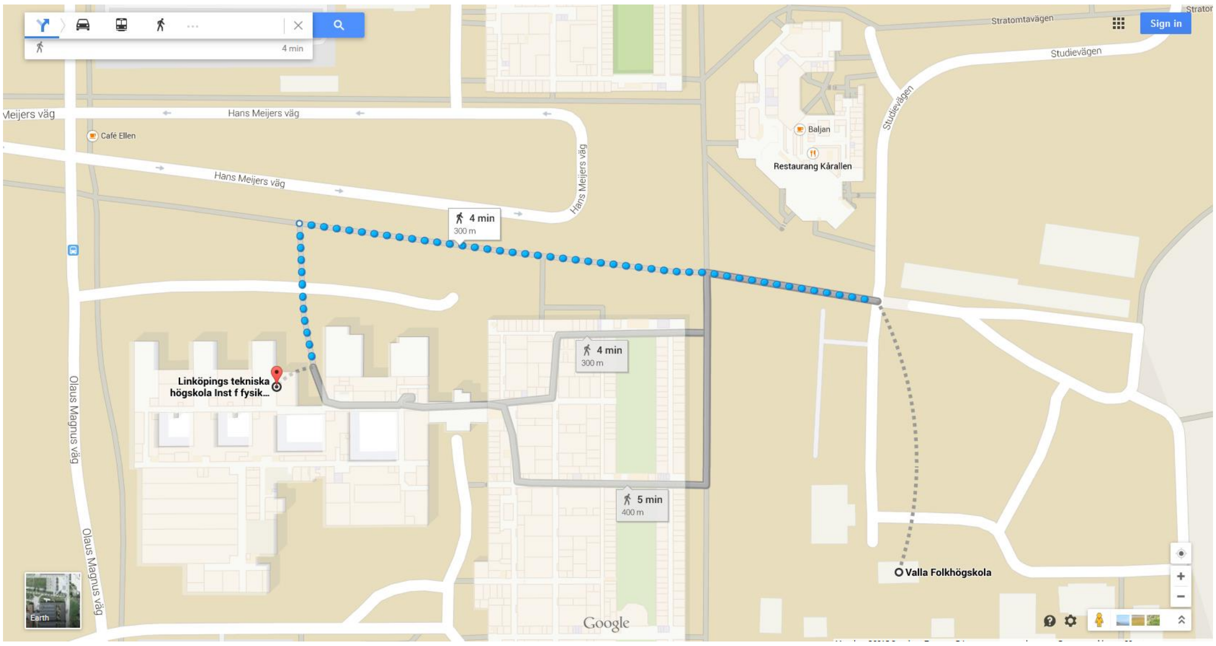
If you would like to have a double room, please specify your request at the moment of your reservation. You will be informed from the hotel about the availability and price of a double room. Don't forget to mention the LiU code!

Conversion rate (last update 27 February 2015): **1.00 SEK = 0.11 EUR; 1.00 EUR = 9.36 SEK**

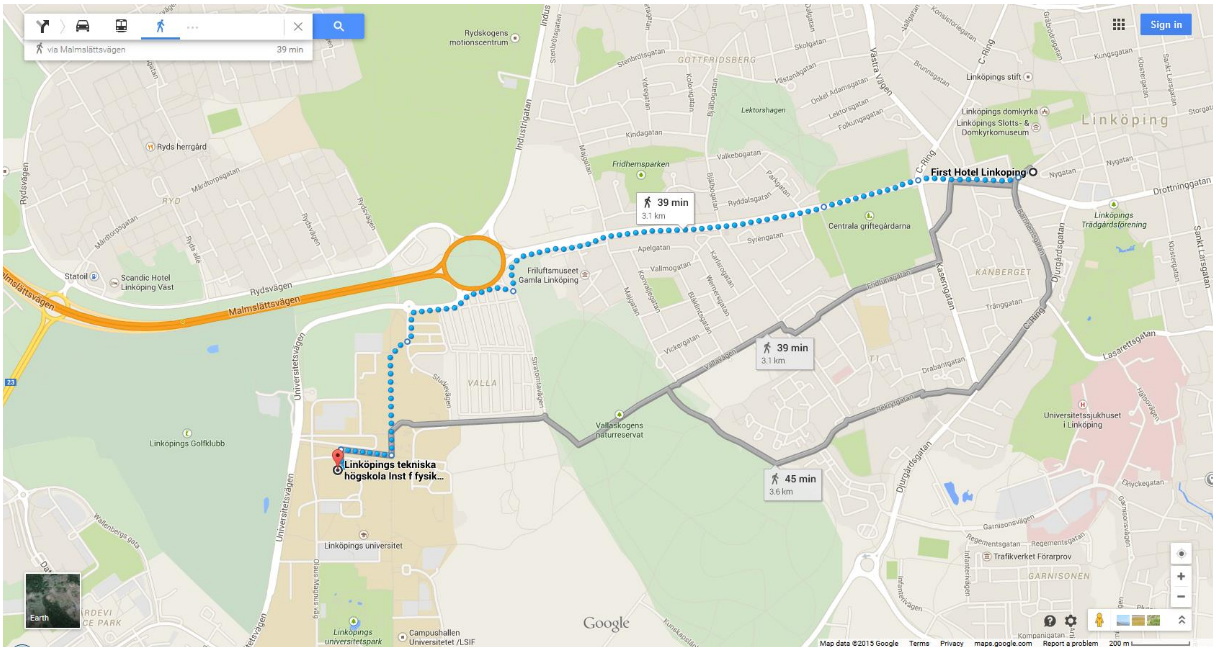
You can click here to find more hotels in Linköping.



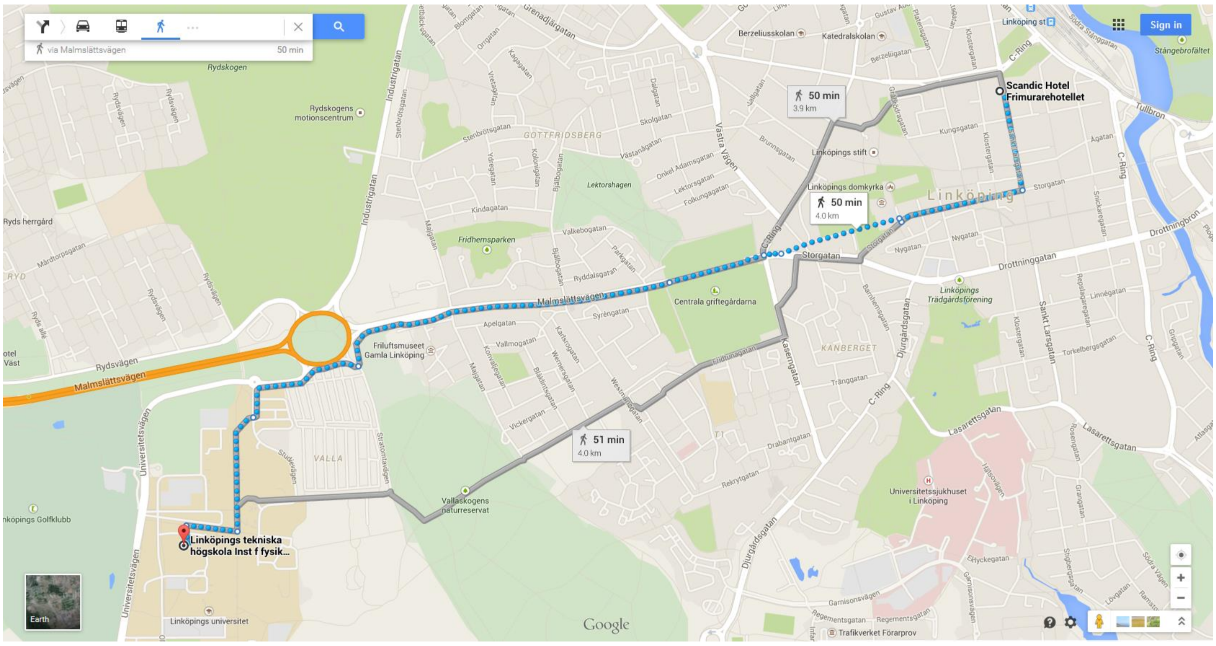
MAP-1. Location of the suggested / pre-booked hotels with respect to Linköping University, Linköping Central Station, and Linköping City Airport.



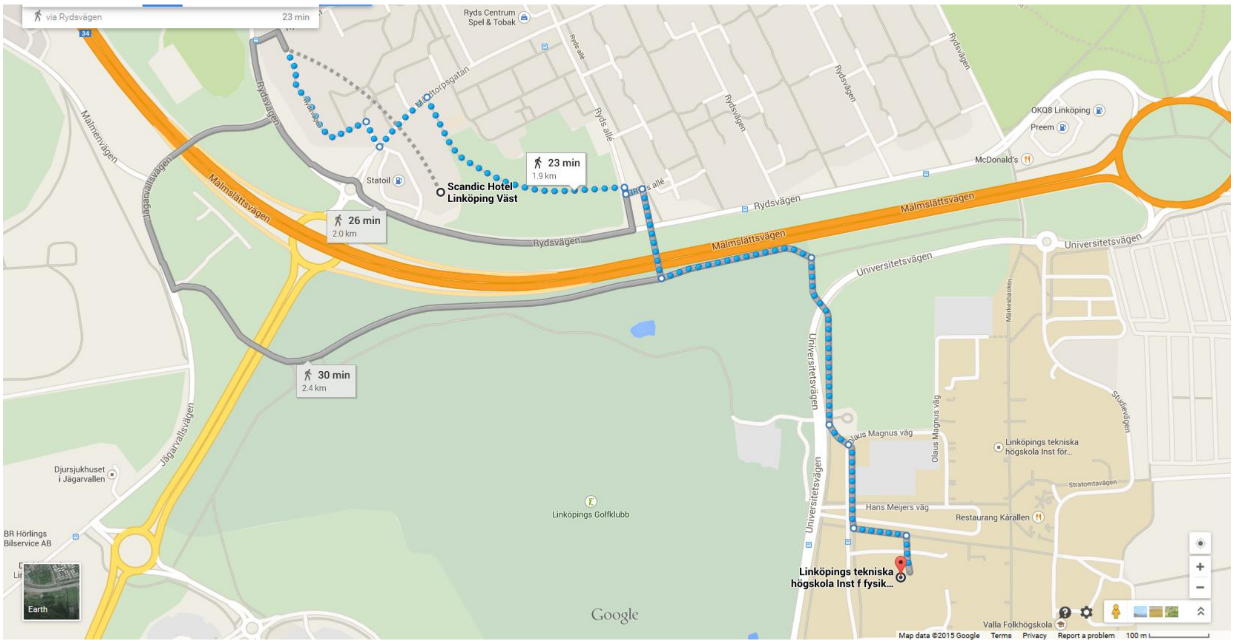
MAP-2. Walking distance between Valla Folkhögskola and the Physics building.



MAP-3. Walking distance between First Hotel and the Physics building.



MAP-4. Walking distance between Scandic Frimurarehotellet and the Physics building.



MAP-5. Walking distance between Scandic Linköping Väst and the Physics building.

MAP-6 of **Campus Valla** and the **conference venue** (Fysikhuset in the map) is available at:

http://www.liu.se/om-liu/till-liu/kartor/start/1.279944/CampusVallaapril2014.pdf

Travel Information

Travelling to Linköping by air

Transportation from Airport to Linköping / Linköping University

There are a few ways to reach Linköping by air.

The closest airport to Linköping University is Linköping City Airport (LPI), located at a distance of ca. 9 km. It is possible to reach the city and university from the airport by taxi or rental car. Linköping City Airport is a small international airport served by the airlines KLM and SAS, and connects the city with Amsterdam and Copenhagen.

The flight from Amsterdam International Airport (AMS) to Linköping takes almost two hours, and from Copenhagen International Airport (CPH) about one hour. Train travel to Linkoping from Copenhagen International Airport takes about 3 hours. Check out the Swedish Railways SJ for train times and ticket booking. Phone number to the Swedish Railways is +46 - 8 - 696 7509.

Stockholm Arlanda Airport (ARN) is the largest airport in Sweden. All international flights (terminals 2 and 5) are handled by SAS and its Star Alliance partners. Direct train travel to Linkoping from Stockholm Arlanda Airport takes about 2 hours using the Swedish railways SJ Regional. As an alternative, it is possible to take the Arlanda Express high-speed train to Stockholm City (Central railway station) and from there a regional train to Linköping.

Travel between Stockholm Arlanda Airport and Stockholm Central railway station can also be made by Airport buses, leaving every 10 minutes. The bus takes 45 minutes at a cost of 119 SEK (~13 Euro) as compared to the Arlanda Express, which takes 20 minutes at a cost of 260 SEK (~28 Euro).

Direct connection from Stockholm Arlanda Airport to Linköping is also possible by Swebus, Express bus. It takes about 3.5 hours.

Stockholm Skavsta Airport (NYO) near Nyköping is the third largest airport in Sweden. It is served by the low cost airlines Ryanair and Wizz Air. Airport buses to/from Linköping operated by Flygbussarna connect the airport to Linköping city centre in about 1.5 hours.

Norrköping Airport (NRK), at a distance of 51 km from Linköping University, offers flights to/from Helsinki operated by the airlines Flybe and Finnair. Trains and buses run regularly between Linköping and Norrköping. Buses as well as commuter trains take about 40 minutes.

Travelling to Linköping by car or rail

Transportation by car or rail via the Öresund Bridge

The 16 km Öresund Bridge, opened in 2000, links Denmark's capital, Copenhagen, with Sweden's third largest city, Malmö, and takes both car and rail traffic. Direct rail services to other cities in Sweden, including Stockholm, also operate across the bridge. From Stockholm, there are frequent regional trains which arrive to Linköping in 2 hours.

For more information on the bridge and prices, please visit their website. For more information on trains to Linköping, please visit the Swedish Railways SJ website.

For travellers by car, there are no tolls (except when crossing the Öresund Bridge) through the entire length of Sweden, and traffic jams are rare. The roads are usually in excellent condition, with easy-to-read traffic signs.

MAP-7 of Sweden.

BROCHURES.

Transportation by rail from the UK

The fastest rail route from the UK to Sweden is via the Eurostar service through the Channel Tunnel from London (St. Pancras) or Ashford International (Kent) to Brussels, with onward trains to Copenhagen for connecting services to Sweden. Through trains operate from Copenhagen to destinations in Sweden via the bridge and tunnel across the Öresund strait.

Transportation into Linköping

Linköping University is at a walking distance (about 3 km) from the city centre's main attractions. Bus and railway stations are at less than 5 km from university. We strongly recommend to enjoy the city on foot or by bike. Of course, it is possible to move by car, taxi, or bus, too.

Linköping by bike

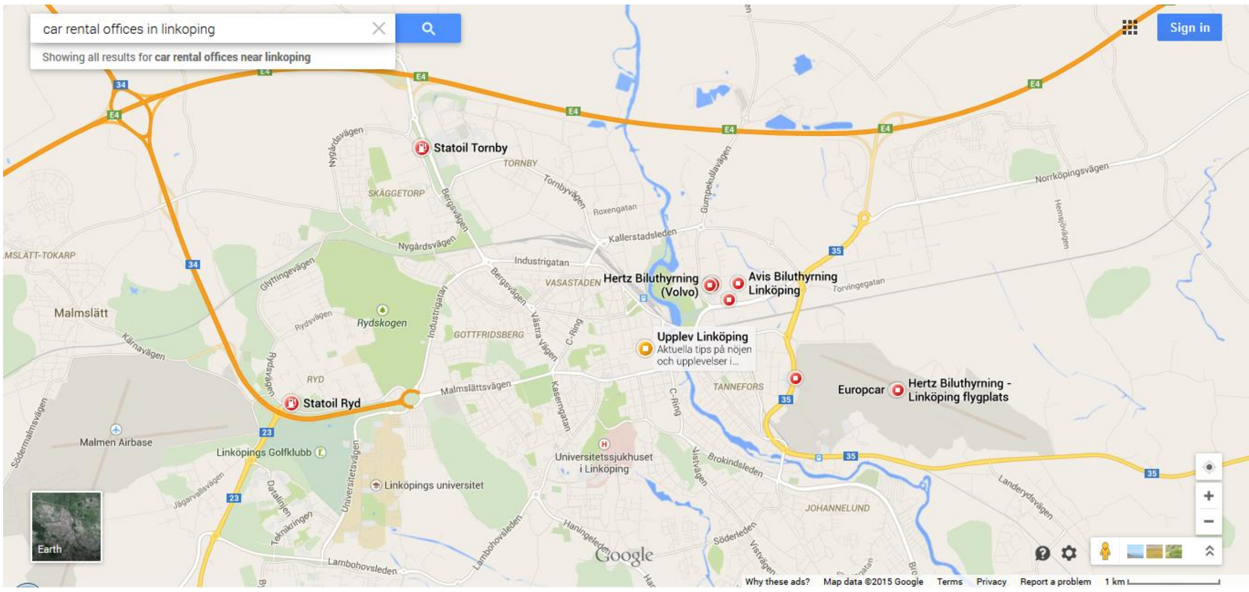
Bikes are the favourite means of transport for Swedes, and June is a very favourable month for cycling. Linköping University offers a service of rental bikes. If you are interested, we will be glad to help you to rent your bike during your stay! Please, contact us in advance.

How to get to campus Valla from the city centre by bus

From Linköping's train station Resecentrum buses 2, 12 and 20 run to campus Valla.
Buses run from early morning until late evening, later on Fridays and Saturdays. It is not possible to buy a single ticket on the bus, but there are vending machines in many locations where you can purchase single tickets using a credit card. These vending machines are called "Quickomat" and are easily recognised by their green colour.
It is also possible to buy a single ticket, which is valid within the city boundaries, by sending a text message, SMS, to 72365. Send the message a couple of minutes before the bus is due (look at the timetable at the bus stop). The ticket is then valid for one hour. The code in Linköping is LU for youth (under 26) or LV for adult (over 26).

Linköping by car

When driving into the city, pay attention to the street markings and observe strictly the rules (traffic lights, driving side, parking times and allowed places, etc.). The driving side is often on the left side, since the right side is for busses and taxi! Finding free parking slots could be tricky, but hotels usually have free parking for their guests. There is a wide free parking area at campus Valla.



MAP-8. Location of the rental car offices in Linköping. It is also possible to rent your car at the airport.

To find cheap offers, we suggest you to visit the websites of Statoil gas stations (website in Swedish, but if you need any support, we will be glad to help you!), Rentalcars and Autoeurope.

Further information on how to get to Campus Valla is available at:
http://www.liu.se/om-liu/till-liu?l=en

Further information on how to get to Sweden via car and rail, coach, ferry and boat is available at:
http://www.visitsweden.com/sweden/Travel-guide/Getting-to-Sweden/

Other Useful Links

For taking a tour of Campus Valla:
http://www.liu.se/om-liu/campus/valla?l=en

For inspiration to discover Linköping and its attractions, sightseeing, culture, castles, rural areas, etc.:
http://www.visitlinkoping.se/en.

For further information on worth knowing about Sweden:
http://www.visitsweden.com/sweden/Sweden-Facts/

For information material about Linköping University (LiU) and the LiU magazine:
http://www.liu.se/om-liu/info?l=en

For a free PDF travel guide, and a map/brochure 2015 of Linköping:
http://www.visitlinkoping.se/en