COST Action TD1105 *EuNetAir*

BOOKLET

FOURTH INTERNATIONAL ACTION WORKSHOP

ON

INNOVATIONS AND CHALLENGES FOR AIR QUALITY CONTROL SENSORS

hosted at FFG - Austrian Research Promotion Agency

organized by Materials Center Leoben Forschung GmbH

co-supported by Techkonnex - High-Tech Promotion

Vienna (Austria), 25 - 26 February 2016

cost EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

FFG Austrian Research Promotion Agency

MCL MATERIALS CENTER LEOBEN

TECHKONNEX High-Tech Promotion

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

FOURTH INTERNATIONAL ACTION WORKSHOP on *Innovations and Challenges for Air Quality Control Sensors*

Vienna (Austria), 25 - 26 February 2016

hosted at FFG - Austrian Research Promotion Agency - AT COST Association
Sensengasse 1, 1090 Vienna, Austria

organized by **Materials Center Leoben Forschung GmbH**	
co-supported by **Techkonnex - High-Tech Promotion**	

AGENDA	
25 February 2016 - Thursday	
09:00 - 18:00	***REGISTRATION***
09:30 - 10:00	**Welcome Address**
10:00 - 11:00	**Session 1: Plenary Session**
11:00 - 11:30	*Coffee Break*
11:30 - 13:00	**Session 2: Oral Presentations**
13:00 - 14:30	*Lunch*
14:30 - 16:00	**Session 3: Oral Presentations**
16:00 - 16:30	*Coffee Break*
16:30 - 18:00	**Session 4: Oral Presentations**
20:00 - 23:00	*Social Dinner*
26 February 2016 - Friday	
09:00 - 16:00	***REGISTRATION***
09:00 - 11:00	**Session 5: Oral Presentations**
11:00 - 11:30	*Coffee Break*
11:30 - 13:00	**Session 6: Oral Presentations**
13:00 - 14:30	*Lunch*
14:30 - 15:30	**Session 7: Poster Presentations**
15:30 - 17:00	**Session 8: Keynote Presentations**
17:00	**Closure of Meeting**

COST is supported by the EU Framework Programme

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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 120 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 *4th International Action Workshop* at FFG, Vienna, 25 - 26 February 2016

The **4th International Workshop EuNetAir** on ***Innovations and Challenges for Air Quality Control Sensors*** will be held at FFG - Austrian Research Promotion Agency, Vienna (Austria) under management of the MCL, and locally coordinated by Dr. Anton Köck (AT MC Member). This fourth workshop of the Action TD1105 *EuNetAir* follows the first one organized at Barcelona, Spain (20 June 2013) as Satellite Event inside *Transducers 2013 - Eurosensors XXVII*, the second one organized at Brindisi, Italy (25-26 March 2014), and the third one organized at Riga, Latvia (26-27 March 2015).

The core-issues of the COST Action TD1105 on the **new trends and challenges** in the sensing technologies for indoor and outdoor monitoring and air quality control will be surveyed by Action partners in **visionary approach** with emphasis at *functional materials and nanotechnologies for gas sensors, low-cost and low-power chemical sensors, portable sensor-systems, sensor-instrumentations, air-pollution modelling, methods, measurements and protocols for air quality control and environmental monitoring, experimental campaigns of air quality monitoring, air-pollutants and new metrics, health-effects of air pollution, guidelines and regulations*.

Fruitful discussions between Action TD1105 participants, international experts, speakers and international institutional organizations delegates are strongly expected. At the ***Open Fourth Action Workshop*** of the COST Action TD1105 *EuNetAir*, a strong impact on critical 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
Department for Sustainability - Laboratory of Functional Materials and Technologies for Sustainable Applications
PO BOX 51 Br-4, I-72100 Brindisi, ITALY. Email: michele.penza@enea.it. Action webpages: www.cost.eunetair.it

Dr. Anton KÖCK
MC AT Member and Local Organizing Team Chair
Material Center Leoben Forschung GmbH
Roseggerstrasse 12, 8700, Leoben, AUSTRIA
Email: Anton.Koeck@mcl.at

DI (FH) Margit MALATSCHNIG
Local Organizing Team Co-Chair
Techkonnex - High Tech Promotion
URL: http://www.techkonnex.at, Vienna, AUSTRIA
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FOURTH INTERNATIONAL ACTION WORKSHOP on

Innovations and Challenges for Air Quality Control Sensors

Vienna (Austria), 25 - 26 February 2016

hosted at FFG - Austrian Research Promotion Agency - AT COST Association
Sensengasse 1, 1090 Vienna, Austria

Action Workshop Programme Committee

Michele Penza, ENEA, Brindisi, Italy
Anita Lloyd Spetz, Linkoping University, Sweden
Anton Köck, MCL, Austria
Iveta Steinberga, University of Latvia, Riga, Latvia
Gita Sakale, Riga Technical University, Riga, Latvia
Andreas Schuetze, Saarland University, Germany
Zafer Ziya Ozturk, GEBZE Technical University, Turkey
Carlos Borrego, IDAD, University of Aveiro, Portugal
Ole Hertel, Aarhus University, Denmark
Ingrid Bryntse, SenseAir AB, Sweden
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
Stefan Defregger, MCL, Austria
Margit Malatschnig, Techkonnex - High-Tech Promotion, Austria
Nicole Schmidt, FFG - AT COST Association, Austria

URL: www.cost.eunetair.it

COST Action TD1105 EuNetAir Steering Committee

Michele Penza, ENEA, Brindisi, Italy - *Action Chair*
Anita Lloyd Spetz, Linkoping 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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Thursday, 25 February 2016

COST Action TD1105 EuNetAir WORKSHOP

hosted at FFG - Austrian Research Promotion Agency - AT COST Association
Sensengasse 1, 1090 Vienna, Austria

09:00 - 18:00	**COST Event Registration**
09:30 - 10:00	***Welcome Address*** *Chairperson: Anton Köck, Local Organizing Committee Chair and MC AT Member - Materials Center Leoben Forschung GmbH (MCL), Leoben, Austria*
	Welcome: Austrian COST Association - FFG, Austria *Nicole Schmidt*, Member of AT CNC COST Association, Austria
	Welcome: Material Center Leoben Forschung GmbH *Anton Köck*, Delegate MCL, Leoben, Austria
	Welcome: COST Action TD1105 *EuNetAir* *Michele Penza*, Action Chair, ENEA, Brindisi, Italy
10:00 - 11:00	***Session 1 - Plenary Session*** *Chairperson: Anton Köck, Local Organizing Committee Chair and MC AT Member - Materials Center Leoben Forschung GmbH (MCL), Leoben, Austria*
10:00 - 10:30	**COST Action TD1105: European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability. Overview and Plans of COST Action TD1105** *Michele Penza*, Action Chair, ENEA, Brindisi, Italy
10:30 - 11:00	**Air Quality Current Status in Europe** *Cristina Guerreiro*, EEA Report Leader, NILU - Norwegian Institute for Air Research, Kjeller, Norway
11:00 - 11:30	**Coffee Break**
11:30 - 13:00	***Session 2 - Environmental Informatics and AQ Sensors Calibration*** *Chairperson: Michele Penza, Action Chair - ENEA, Brindisi, Italy*
11:30 - 12:00	**Air Quality Modelling at Different Scales** *Camillo Silibello*, WG Member, Project manager, ARIANET srl, Milan, Italy
12:00 - 12:20	**Challenges for Environmental Information Services Resulting from Sensors Integrated to Smartphones** *Kostas Karatzas*, Aristotle University of Thessaloniki, Greece
12:20 - 12:40	**A New Approach for On-site Calibration and Calibrated Quantification of VOCs with Low-Cost Sensors** *Andreas Schuetze*, Action WG2 Leader & MC Member, Saarland University, Saarbrucken, Germany
12:40 - 13:00	**Noise-Based Techniques for Gas Sensing** *Dionyz Pogany*, Vienna University of Technology, Institute for Solid State Electronics, Vienna, Austria
13:00 - 14:30	**Lunch Break**

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14:30 - 16:00	***Session 3 - Sensors for Environmental Sustainability*** *Chairperson: Andreas Schuetze*, Action WG2 Leader & MC Member, Saarland University, Saarbrucken, Germany
14:30 - 15:00	**New Strategies for Odor Annoyance Assessment: from Sampling to Dispersion Modelling** *Carlos Borrego*, IDAD and University of Aveiro, MC Member, Aveiro, Portugal
15:00 - 15:20	**Use of Novel Sensor Technologies in the Environmental Health and Climate Change Domain: The Citi-Sense-MOB Experience in Oslo, Norway** *Nuria Castell-Balaguer*, NILU - Norwegian Institute for Air Research, MC Member, Kjeller, Norway
15:20 - 15:40	**O_3 and NO_2 Sensor Network in Zurich: Operation and Strategies for QA/QC** *Michael Mueller,* WG Member, EMPA, Zurich, Switzerland
15:40 - 16:00	**On Field Stochastic Calibration of Fast Indicative Air Quality Sensing Systems with Dynamic Approaches** *Saverio De Vito[a], E. Esposito[a], M. Salvato[a], V. Bright[b], R. L. Jones[b], O. Popoola[b]* [a] ENEA, CR Portici (Napoli), Italy; [b] Dept. Of Chemistry, University of Cambridge, Cambridge, UK
16:00 - 16:30	**Coffee Break**
16:30 - 18:00	***Session 4 - Modelling and Applications for Air Quality Control*** *Chairperson: Carlos Borrego, MC Member, IDAD and University of Aveiro, Aveiro, Portugal*
16:30 - 16:50	**The Air Pollution in the Cross-Border Region Turkey-Bulgaria: Model Simulations vs. Measurements** *Emilia Georgieva,* Bulgarian Academy of Sciences, WG Member, Sofia, Bulgaria
16:50 - 17:10	**Chemical Characterization of the Sea Surface and Ambient Marine Aerosols of Middle Adriatic Area During Spring and Summer Seasons** *Ana Cvitešić[1], Sanja Frka[1, 2], Ana Kroflič[2] Martin Šala[2], Irena Grgić[2], Irena Ciglenečki[1]* [1] Laboratory for Physical Chemistry of Aquatic Systems, Division for Marine and Environmental Research, Rudjer Boskovic Institute, Zagreb, Croatia [2] Analytical Chemistry Laboratory, National Institute of Chemistry, Ljubljana, Slovenia
17:10 - 17:30	**Evaluation of Monitoring PM with Low-Cost Monitor and Conventional Devices** *Milena Jovašević-Stojanović[1], Alena Bartonova[2], Dušan Topalović[3,1], Miloš Davidović[1], Ivan Lazovic[1], Zoran Ristovski[4]* [1] Vinča Institute of Nuclear Sciences, University of Belgrade, Belgrade Serbia [2] NILU Norwegian Institute for Air Research, Kjeller, Norway [3] School of Electrical Engineering, University of Belgrade, Belgrade, Serbia [4] LAQH, Queensland University of Technology, Brisbane, Australia
17:30 - 17:50	**Complexity of Softcomputing Models for Big Data Processing** *Vera Kurkova*, MC Member, Institute of Computer Science, Academy of Sciences of the Czech Republic, Prague, Czech Republic
18:00	*Gathering of Day*
20:00 - 23:00	**Social Dinner**

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Friday, 26 February 2016

COST Action TD1105 EuNetAir WORKSHOP

hosted at FFG - Austrian Research Promotion Agency - AT COST Association
Sensengasse 1, 1090 Vienna, Austria

09:00 - 16:00	**COST Event Registration**
09:00 - 11:00	***Session 5 - Advanced Materials for Chemical Sensors*** *Chairperson: Michele Penza, Action Chair - ENEA, Brindisi, Italy*
09:00 - 09:20	**Functionalization of Carbon Nanomaterials: Towards Devices for the Molecular Recognition of Aromatic Compounds in the Environment** *Eduard Llobet,* MC Member, Universitat Roviri I Virgili, Tarragona, Spain
09:20 - 09:40	**MSDI Heterojunctions, How Conductivity and Impedance Allow for Discrimination between Ammonia and Humidity** *M. Bouvet[1], T. Sauerwald[2], M. Schüler[2], J.-M. Suisse[1], A. Schütze[2],* [1]Universitè de Bourgogne, Institut de Chimie Molèculaire, MC Member, Dijon, France; [2]Saarland University, Action WG2 Leader & MC Member, Saarbrucken, Germany
09:40 - 10:00	**Site-Selective Synthesis of SnO_2 Nanowires for Ammonia Sensing in the Presence of High Levels of Humidity** *J. Samà[1], S. Barth[2], G. Domènech-Gil[1], J.D. Prades[1], O. Casals[1], F. Hernández-Ramírez[1,3], I. Gracia[4], C. Cané[4], A. Romano-Rodríguez[1],* MC Substitute, [1]Universitat de Barcelona, Barcelona, Spain; [2]Technical University of Vienna; [3]IREC, Barcelona, Spain; [4]CSIC-CNM-IMB, Bellaterra, Spain
10:00 - 10:20	**Developing Air Quality Sensors by Laser Deposition on Graphene** *Raivo Jaaniso,* Institute of Physics, University of Tartu, Estonia
10:20 - 10:40	**Metal Loaded Tıtanıa Nanostructures for Air Quality Sensors** *E. Sennik and Zafer Ziya Ozturk*, Gebze Technical University, Kocaeli, Turkey
10:40 - 11:00	**Monitoring of Hydrocarbon Contamination Gas and Emission from Water using Pervaporation Membrane Unit and MOX Sensors** Alexey A.Vasiliev[1,2], [1]National Research Center "Kurchatov Institute", Moscow, Russia; [2]*Institute of Problems of Chemical Physics, Chernogolovka, Moscow region, Russia*
11:00 - 11:30	**Coffee Break**
11:30 - 13:00	***Session 6 - Sensors and Systems for Air Quality Control*** *Chairperson: Eduard Llobet,* MC Member, Universitat Roviri I Virgili, Tarragona, Spain
11:30 - 12:00	**Environmental Sensors and Miniaturization** *Martin Schrems*, ams AG, Director R&D, Unterpremstätten, Austria
12:00 - 12:20	**What Brings Formaldehyde's Continuous Monitoring to the Analysis of Building's Air Quality and Ways to Manage/Improve it?** *Frederic Hammel*, Ethera, Gif-sur-Yvette Cedex, France
12:20 - 12:40	**CMOS Infrared Emitters and Detectors for Environmental Monitoring** *Foysol Chowdhury*, Action WG Member, CCMOSS Ltd, Cambridge, UK
12:40 - 13:00	**Concepts for Mobile Sensing of Inorganic Nitrogenous Pollutants in Exhaust and the Atmosphere** *Martin Kraft*, CTR Carinthian Tech Research AG, Photonics Systems, Villach, Austria

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13:00 - 14:30	**Lunch Break**

14:30 - 15:30	***Session 7 - Poster Session*** *Chairperson: Marcel Bouvet*, MC Member, Universitè de Bourgogne, Dijon, France

MATERIALS, SENSORS, SYSTEMS AND METHODS FOR AIR QUALITY MONITORING

Posters will be presented using exhibition panels, preferably by Early Stage Researchers.
Posters are listed as-received.

P01 **Long-Term Trends in Concentration of SO_2 Near Copper Smelter Bor - Serbia**
V. Tasić[1], T. Apostolovski-Trujić[1], M. Jovašević-Stojanović[2], N. Milošević[1]
[1]Mining and Metallurgy Institute Bor, Zeleni bulevar 35, 19210 Bor, Serbia;
[2]*University of Belgrade, VINCA Institute of Nuclear Sciences, Belgrade, Serbia*

P02 **Indoor Environment and Respiratory Health of Older People in Elderly Care Centers**
Ana Sofia Mendes, Cristiana Pereira, Livia Aguiar, João Paulo Teixeira, National Institute of Health, Porto, Portugal

P03 **Perylene-based MSDI Heterojunctions for Ammonia Sensing in Genuine Atmosphere**
A. Wannebroucq, J.-M. Suisse, M. Bouvet, Universitè de Bourgogne, Institut de Chimie Molèculaire, MC Member, Dijon, France

P04 **The Methodological Approach to a Health Impact Assessment (HIA) for Promoting Sustainable and Healthy Community in Val d'Agri (Basilicata - Italy)**
Annamaria Demarinis, Gianluigi De Gennaro, Stefania Petraccone, University of Bari, Department of Biology, Core-Group Member, Bari, Italy

P05 **Comparison of Multivariate Linear Regression and Artificial Neural Networks for Calibration of Low Cost Electrochemical Sensors for CO and O_3**
Dusan Topalovic1, Milos Davidovic1, Zoran Ristovksi2, Milena Jovasevic-Stojanovic1, 1) Action MC Member, Institute Vinca, Belgrade, Serbia; 2) QUT, Brisbane, Australia

P06 **Some Practical Aspects of Predictor Variables Layer Creation for LUR Modeling of Air Pollution in Belgrade**
Milos Davidovic, Dusan Topalovic, Milena Jovasevic-Stojanovic, Action MC Member, Institute Vinca, Belgrade, Serbia

P07 **CMOS Integrated Nanocrystalline SnO_2 Gas Sensors for Air Quality Control**
Eva Lackner, J. Krainer, R. Wimmer-Teubenbacher, C. Gspan, K. Rohracher, E. Wachmann, A. Köck, Materials Center Leoben Forschung GmbH, Leoben (Austria)

P08 **CMOS Integrated Tungsten Oxide Nanowire Networks for ppb-Level H_2S Sensing**
Johanna Krainer, E. Lackner, R. Wimmer-Teubenbacher, C. Gspan, K. Rohracher, E. Wachmann, A. Köck, Materials Center Leoben Forschung GmbH, Leoben (Austria)

P09 **Opto-Chemical Sensor Systems based on Electrospun Nanofibers for Ultra-Fast Oxygen Detection and Their Application in Exhaled Breath Gas Analysis**
C. Wolf, Stefan Köstler, Joanneum Research, Materials, Graz (Austria)

P10 **A Nanosecond Luminescence Lifetime Measurement System for Optical Sensing**
A.Tschepp, H. Wang, C. Wolf, G. Mohr, C. Salthouse, Stefan Köstler, Joanneum Research, Materials, Graz (Austria)

P11 **The Influence of Nb on Surface Chemistry and Morphology of TiO_2 Nanotubular Arrays**
M.Kwoka [1], V. Galstyan [2], E. Comini [2], A. Kuliś[1], J.Szuber [1]
[1] Institute of Electronics, Silesian University of Technology, Gliwice, Poland
[2] SENSOR Lab, Department of Information Engineering, Brescia University, and CNR-IDASC, Brescia, Italy

15:30 - 17:00	***Session 8 - Keynote Presentations: Case-Studies on Air Quality Sensors*** *Chairperson: Michele Penza, Action Chair - ENEA, Brindisi, Italy*
15:30 - 16:00	**AirSensEUR: An Open-source Multi-Sensor Platform for Air Quality Monitoring** *Michel Gerboles, L. Spinelle, A. Kotsev, M. Signorini*, JRC, EC DG ENV, Institute for Environment and Sustainability, Ispra, Italy
16:00 - 16:20	**FLAMENCO: Air Quality Sensing in Flanders Mobile Enacted Citizen Observatories** Jan Peters and Jan Theunis*, VITO, Mol, Belgium*
16:20 - 16:50	**FP7 Project MSP - Multi Sensor Platform for Smart Building Management: Status and Progress** *Anton Köck,* Materials Center Leoben Forschung GmbH, MC Member, Leoben, Austria
16:50	**Conclusions** *Michele Penza*, ENEA, Brindisi, Italy
17:00	**Closure of COST Action TD1105 *EuNetAir* WORKSHOP**

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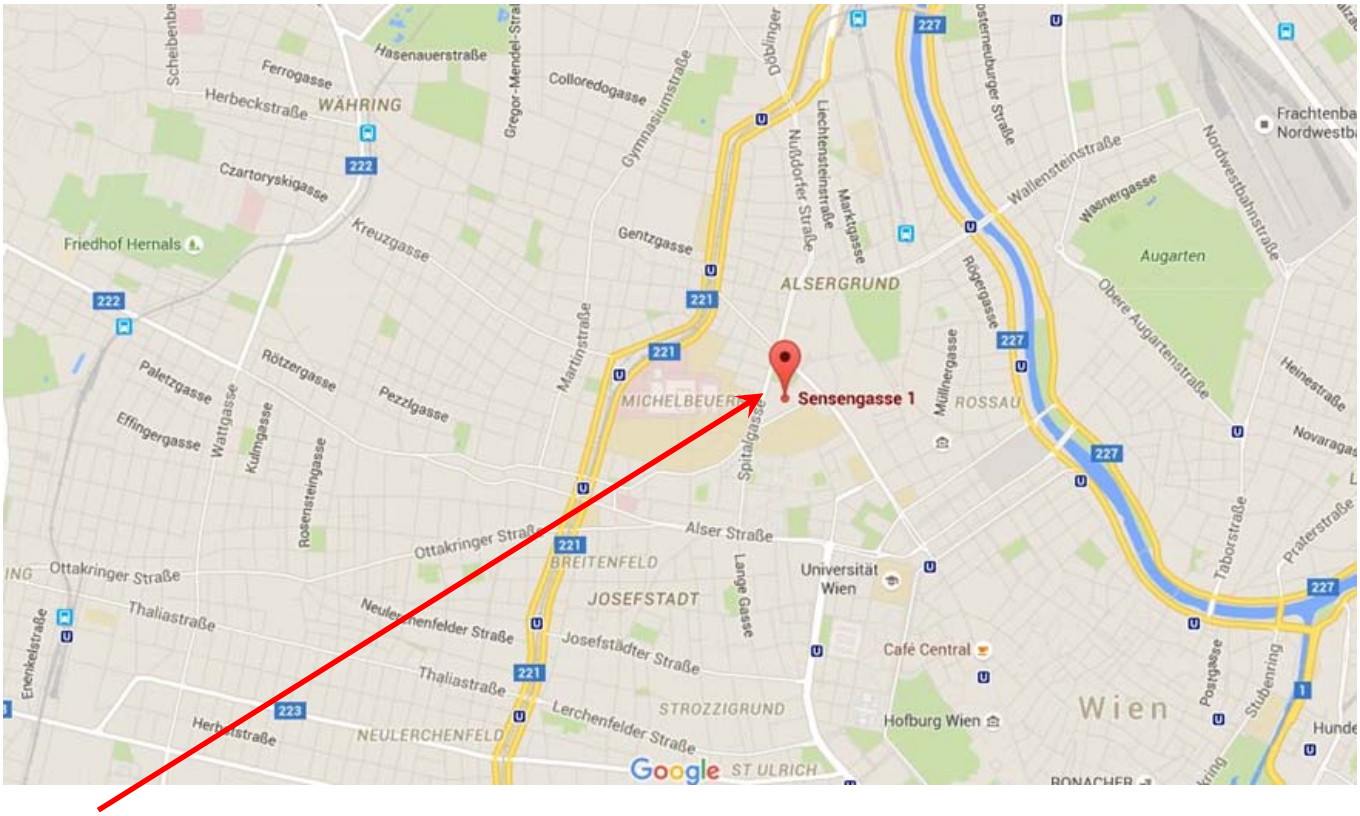
4th Action Workshop Venue/Location of COST Action TD1105 EuNetAir

FOURTH INTERNATIONAL ACTION WORKSHOP on

Innovations and Challenges for Air Quality Control Sensors

Vienna (Austria), 25 - 26 February 2016

hosted at FFG - Austrian Research Promotion Agency - AT COST Association
Sensengasse 1, 1090 Vienna, Austria (*Room "Franziska Seidl", Ground Floor*)



Venue: FFG - Austrian Research Promotion Agency - AT COST Association, Sensengasse 1, 1090 Vienna, Austria

The House of Research is located in the ninth District of Vienna near the General Hospital (AKH) and the University campus.
GPS Coordinates (WGS-84): N 48°13"11" - E 16°21"11"

How to reach us by public transport

The No. 5 and 33 trams stop right in front of the House of Research ("Lazarettgasse" stop).

... from Hauptbahnhof railway station:
No. 13A bus bound for Skodagasse, get off at the "Laudongasse" stop and change to No. 5 tram bound for Praterstern or No. 33 bound for Friedrich-Engels-Platz; get off at "Lazarettgasse".

... from the airport:
Take the S-Bahn or the City-Airport Train to Wien-Mitte, change to U4 metro bound for Heiligenstadt; get off at "Friedensbrücke" and change to No. 5 tram bound for Westbahnhof; get off at "Lazarettgasse".

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Welcome from Action Chair

WELCOME ADDRESS

This is a great honor and my pleasure to chair and welcome to ALL PARTICIPANTS of the **FOURTH INTERNATIONAL ACTION WORKSHOP** of our COST Action TD1105 *European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability - EuNetAir*.

This COST Workshop - held on 25-26 February 2016 - on ***Innovations and Challenges for Air Quality Control Sensors*** is organized by **Materials Center Leoben Forschung GmbH**, co-supported by **Techkonnex High-Tech Promotion** and hosted at *FFG - Austrian Research Promotion Agency* - AT COST Association, with Local Organizing Support from **Materials Center Leoben Forschung GmbH**, Leoben, Austria.

This **Fourth International *EuNetAir* Workshop** follows the first one organized at *Barcelona*, Spain (20 June 2013) as Satellite Event inside *Transducers 2013 - Eurosensors XXVII*, the second one organized at Brindisi, Italy (25-26 March 2014), and the third one organized at Riga, Latvia (26-27 March 2015). This **Vienna Workshop** is attended from at least 43 Participants and includes 8 Sessions with 2 Keynote Speakers, 6 Invited Speakers, 19 Oral Speakers and 11 Poster Presenters from at least 19 COST Countries, including 1 NNC. An international Advisory Board (*Steering Committee*) composed by 22 Members has served with S&T inputs to define Workshop Programme. *Female participants* are as 30% and *Male participants* are as 70% with a quota of *Early Stage Researchers* as 26%.

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.

On behalf of the Action Management Committee, I would like to thank **ALL Participants**, **Grant Holder**, **Action Scientific Secretary**, **Local Organizing Committee** by **Materials Center Leoben Forschung GmbH**, represented by *Director*, and **Techkonnex High-Tech Promotion**, represented by *Delegate*, and **FFG - Austrian Research Promotion Agency - AT COST Association**, represented by ***Austrian COST National Coordinator*** (CNC), in order to give us the opportunity to disseminate the results of the COST Action TD1105 *EuNetAir* towards a wide international targeted audience involved in the Air Quality Control, with special focus on *Air Quality Sensors*. With their valuable scientific work and management, kind availability and great enthusiasm will make our Action Workshop very successful !

Enjoy your *EuNetAir* Workshop at *FFG Headquarters* in Vienna !

Brindisi, 20 February 2016

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

EuNetAir COST Action TD1105 Logo

LIST OF PRESENTERS

FOURTH INTERNATIONAL ACTION WORKSHOP on *Innovations and Challenges for Air Quality Control Sensors*

Welcome Address

Welcome: Austrian COST Association - FFG, Austria
Nicole Schmidt, Member of AT CNC COST Association, Austria

Welcome: Material Center Leoben Forschung GmbH
Anton Köck, Delegate MCL, Leoben, Austria

Welcome: COST Action TD1105 EuNetAir
Michele Penza, Action Chair, ENEA, Brindisi, Italy

Session 1 - Plenary Session

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

Air Quality Current Status in Europe
Cristina Guerreiro, EEA Report Leader, NILU - Norwegian Institute for Air Research, Kjeller, Norway

Session 2 - Environmental Informatics and AQ Sensors Calibration

Air Quality Modelling at Different Scales
Camillo Silibello, WG Member, Project manager, ARIANET srl, Milan, Italy

Challenges for Environmental Information Services Resulting from Sensors Integrated to Smartphones
Kostas Karatzas, Aristotle University of Thessaloniki, Greece

A New Approach for On-site Calibration and Calibrated Quantification of VOCs with Low-Cost Sensors
Andreas Schuetze, Action WG2 Leader & MC Member, Saarland University, Saarbrucken, Germany

Noise-Based Techniques for Gas Sensing
Dionyz Pogany, Vienna University of Technology, Institute for Solid State Electronics, Vienna, Austria

Session 3 - Sensors for Environmental Sustainability

New Strategies for Odor Annoyance Assessment: from Sampling to Dispersion Modelling
Carlos Borrego, IDAD and University of Aveiro, MC Member, Aveiro, Portugal

Use of Novel Sensor Technologies in the Environmental Health and Climate Change Domain: The Citi-Sense-MOB Experience in Oslo, Norway
Nuria Castell-Balaguer, NILU - Norwegian Institute for Air Research, MC Member, Kjeller, Norway

O_3 and NO_2 Sensor Network in Zurich: Operation and Strategies for QA/QC
Michael Mueller, WG Member, EMPA, Zurich, Switzerland

On Field Stochastic Calibration of Fast Indicative Air Quality Sensing Systems with Dynamic Approaches
Saverio De Vito[a], E. Esposito[a], M. Salvato[a], V. Bright[b], R. L. Jones[b], O. Popoola[b]
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Session 4 - Modelling and Applications for Air Quality Control

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Emilia Georgieva, Bulgarian Academy of Sciences, WG Member, Sofia, Bulgaria

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Area During Spring and Summer Seasons
Ana Cvitešić[1], *Sanja Frka*[1, 2], *Ana Kroflič*[2], *Martin Šala*[2], *Irena Grgić*[2], *Irena Ciglenečki*[1]
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Research, Rudjer Boskovic Institute, Zagreb, Croatia
[2]*Analytical Chemistry Laboratory, National Institute of Chemistry, Ljubljana, Slovenia*

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Milena Jovasevic-Stojanovic[1], Alena Bartonova[2],Dusan Topalovic[3,1], Milos Davidovic[1], Ivan Lazovic[1], Zoran Ristovski[4]; 1) Vinča Institute of Nuclear Sciences, University of Belgrade, Belgrade Serbia; 2) NILU Norwegian Institute for Air Research, Kjeller, Norway; 3) School of Electrical Engineering, University of Belgrade, Belgrade, Serbia; 4) LAQH, Queensland University of Technology, Brisbane, Australia

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Vera Kurkova, MC Member, Institute of Computer Science, Academy of Sciences of the Czech Republic, Prague, Czech Republic

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Jan Peters, VITO, Mol, Belgium

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Eduard Llobet, MC Member, Universitat Roviri I Virgili, Tarragona, Spain

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M. Bouvet[1], T. Sauerwald[2], M. Schüler[2], J.-M. Suisse[1], A. Schütze[2], [1]Universitè de Bourgogne, Institut de Chimie Molèculaire, MC Member, Dijon, France; [2]Saarland University, Action WG2 Leader & MC Member, Saarbrucken, Germany

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J. Samà[1], S. Barth[2], G. Domènech-Gil[1], J.D. Prades[1], O. Casals[1], F. Hernández-Ramírez[1,3], I. Gracia[4], C. Cané[4], A. Romano-Rodríguez[1], MC Substitute; [1]Universitat de Barcelona, Barcelona, Spain; [2]Technical University of Vienna; [3]IREC, Barcelona, Spain; [4]CSIC-CNM-IMB, Bellaterra, Spain

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Raivo Jaaniso, Institute of Physics, University of Tartu, Estonia

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E. Sennik and *Zafer Ziya Ozturk*, Gebze Technical University, Kocaeli, Turkey

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Alexey A.Vasiliev[1,2], [1]National Research Center "Kurchatov Institute", Moscow, Russia; [2]Institute of Problems of Chemical Physics, Chernogolovka, Moscow region, Russia

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Martin Schrems, ams AG, Director R&D, Unterpremstätten, Austria

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Frederic Hammel, Ethera, Gif-sur-Yvette Cedex, France

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Foysol Chowdhury, Action WG Member, CCMOSS Ltd, Cambridge, UK

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Martin Kraft, CTR Carinthian Tech Research AG, Photonics Systems, Villach, Austria

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V. Tasić[1], T. Apostolovski-Trujić[1], M. Jovašević-Stojanović[2], N. Milošević[1]
[1]Mining and Metallurgy Institute Bor, Zeleni bulevar 35, 19210 Bor, Serbia;

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P02: Indoor Environment and Respiratory Health of Older People in Elderly Care Centers
Ana Sofia Mendes, Cristiana Pereira, Livia Aguiar, *João Paulo Teixeira*
National Institute of Health, Porto, Portugal

P03: Perylene-based MSDI Heterojunctions for Ammonia Sensing in Genuine Atmosphere
A. Wannebroucq, J.-M. Suisse, *M. Bouvet*
Universitè de Bourgogne, Institut de Chimie Molèculaire, MC Member, Dijon, France

P04: The Methodological Approach to a Health Impact Assessment (HIA) for Promoting Sustainable and Healthy Community in Val d'Agri (Basilicata - Italy)
Annamaria Demarinis, Gianluigi de Gennaro, Stefania Petraccone
University of Bari, Department of Biology, Core-Group Member, Bari, Italy

P05: Comparison of Multivariate Linear Regression and Artificial Neural Networks for Calibration of Low Cost Electrochemical Sensors for CO and O_3
Dusan Topalovic[1], Milos Davidovic[1], Zoran Ristovksi[2], Milena Jovasevic-Stojanovic[1]
[1]Action MC Member, Institute Vinca, Belgrade, Serbia;
[2]QUT, Brisbane, Australia

P06: Some Practical Aspects of Predictor Variables Layer Creation for LUR Modeling of Air Pollution in Belgrade
Milos Davidovic, Dusan Topalovic, Milena Jovasevic-Stojanovic, Action MC Member, Institute Vinca, Belgrade, Serbia

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Eva Lackner, J. Krainer, R. Wimmer-Teubenbacher, C. Gspan, K. Rohracher, E. Wachmann, A. Köck
Materials Center Leoben Forschung GmbH, Leoben (Austria)

P08: CMOS Integrated Tungsten Oxide Nanowire Networks for ppb-Level H_2S Sensing
Johanna Krainer, E. Lackner, R. Wimmer-Teubenbacher, C. Gspan, K. Rohracher, E. Wachmann, A. Köck
Materials Center Leoben Forschung GmbH, Leoben (Austria)

P09: Opto-Chemical Sensor Systems based on Electrospun Nanofibers for Ultra-Fast Oxygen Detection and Their Application in Exhaled Breath Gas Analysis
C. Wolf, *Stefan Köstler*
Joanneum Research, Materials, Graz (Austria)

P10: A Nanosecond Luminescence Lifetime Measurement System for Optical Sensing
A.Tschepp, H. Wang, C. Wolf, G. Mohr, C. Salthouse, *Stefan Köstler*
Joanneum Research, Materials, Graz (Austria)

P11: The Influence of Nb on Surface Chemistry and Morphology of TiO_2 Nanotubular Arrays
M.Kwoka[1], V. Galstyan[2], E. Comini[2], A. Kuliś[1], J.Szuber[1]

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[2]SENSOR Lab, Department of Information Engineering, Brescia University, and CNR-IDASC, Brescia, Italy

Session 8 - Keynote Presentations: Case-Studies on Air Quality Sensors

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Michel Gerboles, L. Spinelle, A. Kotsev, M. Signorini, JRC, EC DG ENV, Institute for Environment and Sustainability, Ispra, Italy

FP7 Project MSP - Multi Sensor Platform for Smart Building Management: Status and Progress
Anton Köck, Materials Center Leoben Forschung GmbH, MC Member, Leoben, Austria

Conclusions
Michele Penza, ENEA, Brindisi, Italy

ABSTRACTS OF INVITED TALKS

Invited Talk

COST ACTION TD1105: EUROPEAN NETWORK ON NEW SENSING TECHNOLOGIES FOR AIR-POLLUTION CONTROL AND ENVIRONMENTAL SUSTAINABILITY. OVERVIEW

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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 120 big institutions and over 200 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 Association and COST 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.

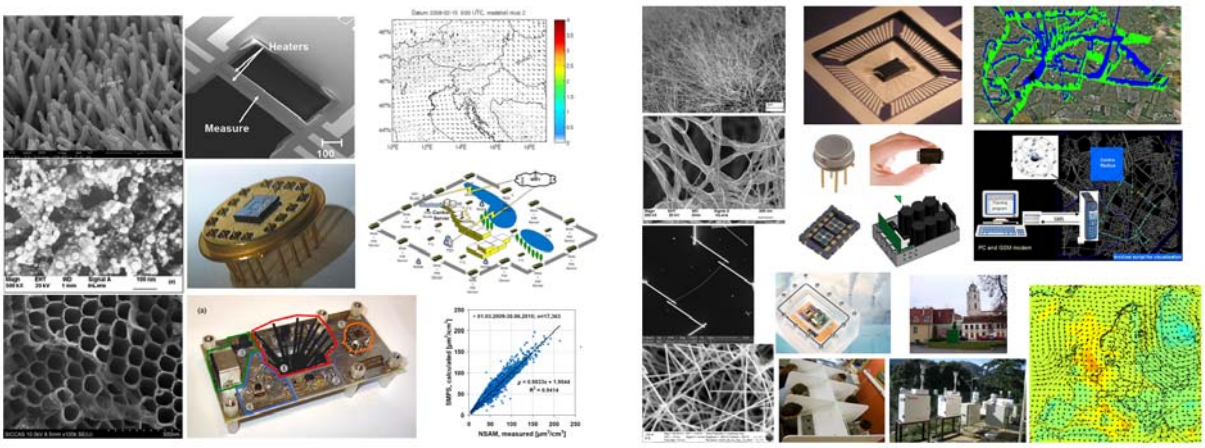

Figure 2. Selected R&D technological products developed by some partners (academia, research institutes, agencies, industry) involved in the COST Action TD1105 *EuNetAir*. Courtesy from *EuNetAir* partnership.

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1. Action Memorandum of Understanding: http://www.cost.eu/domains_actions/essem/Actions/TD1105
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Invited Talk

AIR QUALITY CURRENT STATUS IN EUROPE

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Abstract
The present analysis indicates that air quality policies have delivered many improvements. Reduced emissions have improved air quality in Europe, and, for a number of pollutants, exceedances of European standards are rare. However, substantial challenges remain and considerable impacts on human health and on the environment persist. A large proportion of European populations and ecosystems are still exposed to air pollution in exceedance of European standards and mainly WHO Air Quality Guidelines (AQGs).

Particulate matter (PM) poses the most serious air pollution health risk in the EU, leading to premature mortality and morbidity. The EU limit and target values for particulate matter (PM) continued to be exceeded in large parts of Europe in 2013. The EU daily limit value for PM_{10} was exceeded in 22 of the 28 EU Member States, and the target value for $PM_{2.5}$ was exceeded in 7 Member States. A total of 17% of the EU-28 urban population was exposed to PM_{10} levels above the daily limit value and approximately 61% was exposed to concentrations exceeding the stricter WHO air quality guideline (AQG) for PM_{10} in 2013. Regarding $PM_{2.5}$, 9% of the urban population in the EU-28 was exposed to $PM_{2.5}$ levels above the EU target value and approximately 87% was exposed to concentrations exceeding the stricter WHO AQG value for $PM_{2.5}$ in 2013 (Table 1) [1].

Ozone (O_3) can cause respiratory health problems and lead to premature mortality. The EU O_3 target value for the protection of human health was exceeded in 18 of the 28 EU Member States in 2013. Conformity with the WHO AQG value for O_3 was observed in less than 3% of all stations in Europe in 2013. Some 15% of the EU-28 urban population lives in areas in which the EU O_3 target value threshold for protecting human health was exceeded in 2013. The EU urban population exposed to O_3 levels exceeding the WHO AQG was significantly higher, comprising 98% of the total urban population in 2013 (Table 1) [1]. In 2012, 27% of arable land in the EU-28 was exposed to damaging concentrations of O_3 leading to agricultural losses, i.e. above the EU standard of 18000 ($\mu g/m^3$).h for AOT40 (accumulated over May to July) [1]. On the other hand, the UNECE–CLRTAP critical level for the protection of forest (10000 ($\mu g/m^3$).h for AOT40 (accumulated over April to September) was exceeded in 67% of the total EU-28 forest area in 2012 [1].

The annual limit value for nitrogen dioxide (NO_2) is widely exceeded across Europe (in 19 EU Countries), but 93% of the exceedances in 2013 were measured at traffic stations. Of the EU-28 urban population, 9% lives in areas in which the annual EU limit value and the WHO AQG for NO_2 were exceeded in 2013 (Table 1). In addition to its health effects, NO_2 is a major cause of eutrophication and acidification, and is also contributing to the formation of PM and O_3.

Invited Talk

Benzo(a)pyrene (BaP) is a carcinogen and an indicator for the carcinogenic risk of PAHs. Exposure to BaP is quite significant and widespread, in particular in central and eastern Europe. Approximately half of the BaP measurement stations in Europe were in exceedance of the EU target value in 2013, mostly in urban areas. About 20% of the total European population was exposed to BaP annual mean concentrations above the European target value in 2012 and about 88% lives in areas with concentrations above the estimated reference level (estimated assuming an acceptable additional lifetime cancer risk of $1x10^{-5}$). Considering only urban populations, in 2013 25% of the EU-28 urban population was exposed to BaP concentrations above the target value, and as much as 91% was exposed to BaP concentrations above the estimated reference level (Table 1).

The EU-28 urban population was exposed to only a few exceedances of the sulphur dioxide (SO_2) EU daily limit value in 2013. However, 37% of the EU-28 urban population was exposed to SO_2 levels exceeding the WHO AQG in 2012. Carbon monoxide, benzene and heavy metals (arsenic, cadmium, nickel, lead) concentrations in outdoor air are generally low, and the few exceedances of the set EU limit and target values are localised and sporadic in the EU [1].

Estimates of the health impacts attributable to long-term exposure to $PM_{2.5}$ concentrations in 2012 were responsible for about 403 000 premature deaths in the EU-28. In the same year, the estimated impact of exposure to NO_2 (long-term exposure) and O_3 (short-term exposure) concentrations on the EU-28 population was around 72 000 and 16 000 premature deaths, respectively [1].

Table 1 Estimate of percentage of the urban population in the EU exposed to air pollutant concentrations above the EU and WHO reference levels (2011-2013)

Pollutant	EU reference value	Exposure estimate	WHO AQG	Exposure estimate
$PM_{2.5}$	Year (25)	9–14	Year (10)	87–93
PM_{10}	Day (50)	17–30	Year (20)	61–83
O_3	8-hour (120)	14–15	8-hour (100)	97–98
NO_2	Year (40)	8–12	Year (40)	8–12
BaP	Year (1 ng/m³)	25–28	Year (RL, 0.12 ng/m³)	85–91
SO_2	Day (125)	<1	Day (20)	36–37

Key: < 5% | 5–50% | 50–75% | > 75%

Notes: The reference levels in brackets are in µg/m³ except for BaP in ng/m³. The comparison is made for the most stringent EU limit or target values set for the protection of human health. As the WHO has not set AQG for BaP and C_6H_6, the WHO reference level in the table was estimated assuming an additional lifetime risk of 1×10^{-5}. **Source**: [1].

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Invited Talk

AIR QUALITY MODELLING AT DIFFERENT SCALES

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Abstract
Air quality (AQ) models simulate the chemical/physical processes involving airborne pollutants. On the basis of the meteorological conditions and the emission data (diffuse and point sources) these models permit to reconstruct the temporal and spatial distribution of primary pollutants that are emitted directly into the atmosphere and, in some cases, secondary pollutants that are formed as a result of complex chemical reactions. Different modelling approaches are adopted depending on the investigated environmental issues. ***Chemical-Transport models*** (CTMs) are typically used in regulatory or policy assessments to simulate the impacts on air quality levels and deposition of both inert and chemically reactive pollutants over spatial scales ranging from the regional to the urban scale. ***Gaussian*** and ***Lagrangian models*** are most often used for predicting the dispersion of air pollution plumes originating from ground-level (e.g. highways) or elevated sources (stacks) and generally do not consider the chemical reactions involving the atmospheric pollutants or include parameterised formulations (e.g. NO_2 formation). To simulate the AQ levels within urban street canyons, in which buildings affect the meteorological and turbulence fields, ***parameterised street canyon models*** (Gaussian models considering wind field within the street canyon in a parameterised way) and ***obstacle resolving models*** (Computational Fluid Dynamics and Lagrangian models taking into account the presence of obstacles) are commonly used. The evaluation of such modelling tools is performed using air quality data from stationary networks that typically do not cover the studied areas and consider the pollutants considered by the AQ Directives. The deployment of low-cost sensors at many sites, possibly measuring a larger number of pollutants, would permit: *a*) to improve our knowledge about the processes involving the airborne pollutants, *b*) to better evaluate the performance of adopted AQ models and *c*) to obtain more realistic representation of the spatial distribution of pollutants by combining AQ models output with experimental data ("data fusion"). Recent studies performed by ARIANET evidence the potential of low-cost sensors for further applications: to inform the public living in vulnerability zones close to industrial/chemical hazardous facilities, to track pollutants having a relevant role in the formation of secondary pollutants (e.g. ammonia emissions from livestock and agriculture), In this perspective, the close link between AQ models and low-cost sensors provides not only useful recommendations about the location of the sensors to be deployed, but also information about the actual impact on air quality of investigated sources or adopted emission control strategies As an example, in Figure 1 is presented the ground level chlorine concentrations estimated by the MSS[1] modelling

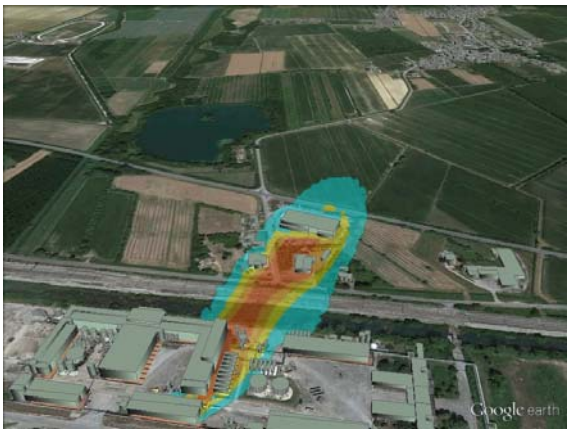


Figure 1. Chlorine ground level concentrations estimated by the MSS modelling system 10 minutes after an accident involving a chlorine leakage in an industrial area.

system about 10 minutes after an accident in an industrial area involving a chlorine leakage. From this map it is evident that the set-up of alert systems, based on dispersion models and low-cost sensors deployed around hazardous facilities, would provide important information regarding the danger to public safety in case of accidents. With CTMs it is also possible to estimate the impact on secondary pollutants of precursors emitted by both natural and anthropogenic sources. As an example, in the following Figure 2 is shown the potential impact on $PM_{2.5}$ levels of ammonia emitted from natural landscapes during a summer period. In the following Figure 3 are presented, for the year 2012, a map showing the PM_{10} emissions from open burning in Puglia region (Southern Italy) and a graph reporting the monthly modulation of such emissions. These data have been obtained from an elaboration of the FINN inventory[2] and can be easily included in AQ simulations in order to estimate the impact of such emissions on predicted concentrations. Also at these scales the contribution of the information provided by low-cost sensors could be relevant not only in terms of model evaluation but also to better understand the processes involved by such emissions (impacted areas, checks on the emissions, health effects assessment, etc.).

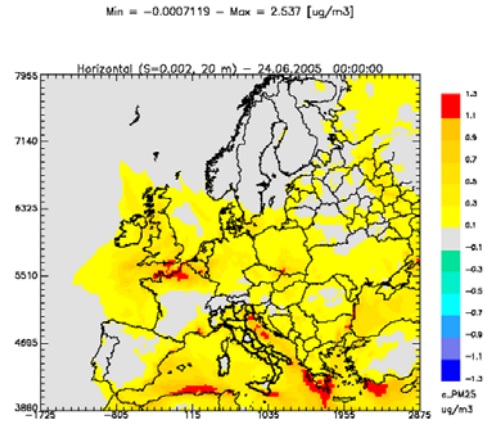
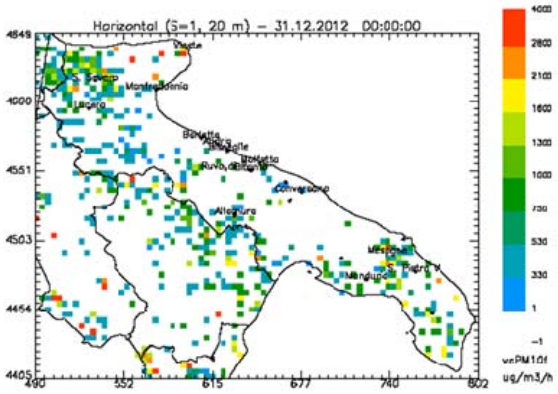


Figure 2. Potential impact on $PM_{2.5}$ levels of ammonia from natural landscapes at the European scale (one week period during summer season).



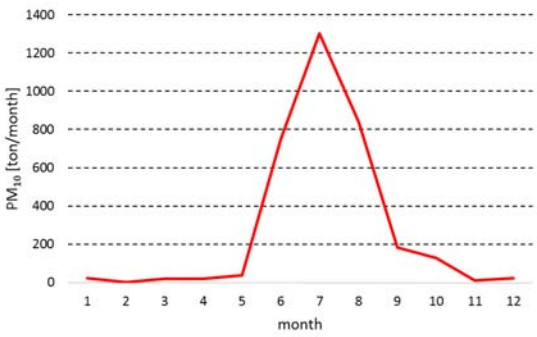


Figure 3. PM_{10} from open burning in Puglia region (Southern Italy) and monthly modulation (year 2012)

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Oral Presentation

CHALLENGES FOR ENVIRONMENTAL INFORMATION SERVICES RESULTING FROM SENSORS INTEGRATED TO SMARTPHONES

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Abstract

We study the "behaviour" of atmospheric environonment microsensors that are intergated in smartphones in order to access their ability to be used for developing personalised environmental information services. Their measurements are made available via an appropriate Android API [1]. Sensor data stream characteristics in terms of sensor correlations are investigated (Fig. 1), taking into account previously published results [2]. The ability to use embedded sensor data in order to estimate ambient environment conditions is discussed with the aid of actual temperature, relative humidity and pressure readings. As an outcome, information services that have an impact on quality of life are presented via the example of the discomfort index based on temperature and relative humidity measurements (Fig. 2). Results show that data coming from smartphones with embedded sensors can be used as "raw material" for the creation of personalised, quality of life information services. As a next step, data coming from AQ sensors that have been integrated to smartphones should be used to evaluate their potential as constituents of information services that may create and support a new market of environmental information services.

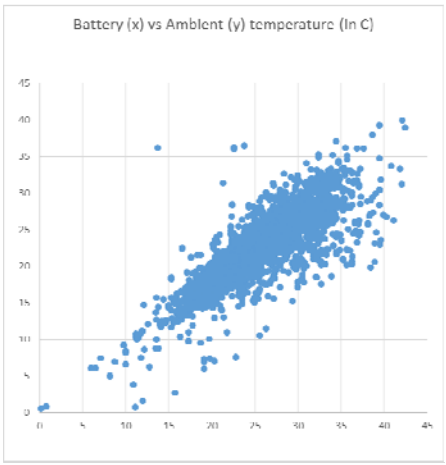

Figure 1: Scatter plot of battery vs ambient environment temperature readings resulting from embedded smartphone sensors.

Oral Presentation

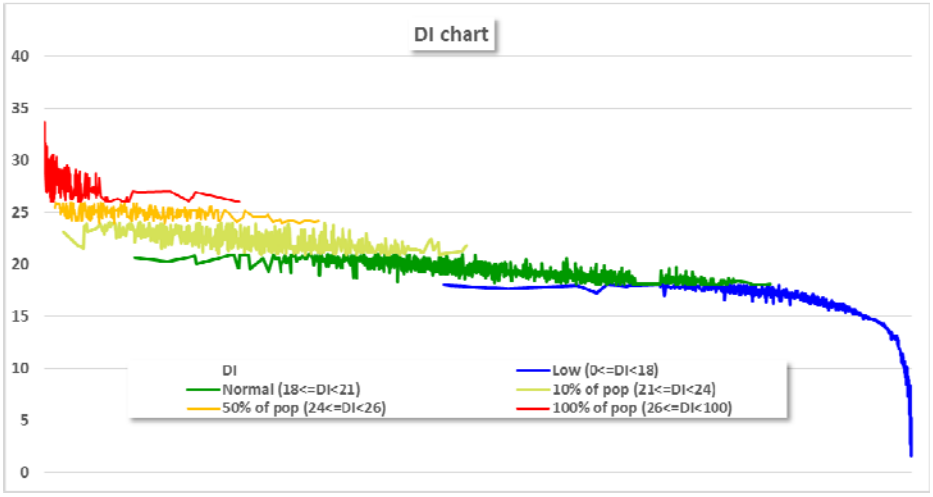

Figure 2: A discomfort index chart based on ambient environment and relative humidity readings coming from microsensors embedded in smartphones [1].

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Oral Presentation

A NEW APPROACH FOR ON-SITE CALIBRATION AND CALIBRATED QUANTIFICATION OF VOCS WITH LOW-COST SENSORS

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Motivation and Introduction

Semiconductor gas sensors are highly sensitive and inexpensive devices but suffer from drift and poisoning [1]. For most applications such as air quality control stable VOC quantification also under ambient conditions in the ppb-range and traceable calibration are required. For gas sensor calibration typically several large gas cylinders and complex gas mixing systems are used [2]. Since this is not suitable for on-site calibration, we present a method for preparing calibration standards based on the thermodynamic equilibrium between liquid and gaseous phases. The approach described here also includes the model-based temperature cycled operation (TCO) for SnO_2-based semiconductor gas sensors, where the chemical reaction between reducing compounds (VOCs) and surface adsorbed oxygen are measured after temperature step changes.

Theoretical and Experimental Background

Measurements were performed with an AS-MLV sensor, which is able to perform fast temperature changes. After a high temperature plateau (300 ms at $T_h = 450$ °C) to clean the sensor surface and achieve high oxygen coverage the sensor is cooled (200 ms at $T_l = 200,\ 220,\ \ldots,\ 380$ °C). During this time the oxygen coverage is reduced, which raises the sensor conductance because of the decreasing energy barrier at grain boundaries. The slope of this increase in conductivity is linked to the concentration of reducing compounds. The calculation of the reaction rate k is shown in Fig. 1 using the following equations [3]:

$$k = \frac{k_B T}{2 \cdot E_B} \frac{dln(G)}{dt} \quad \& \quad E_B = k_B \ln\left(\frac{G_h}{G_l}\right) \frac{T_h T_l}{T_h - T_l}$$

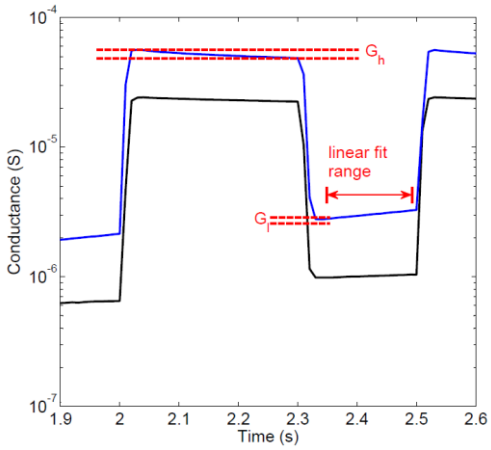

Figure 1: Calculation of the reaction rate of reducing compounds from sensor conductance after a temperature step change (in this example from 450 °C to 280 °C).

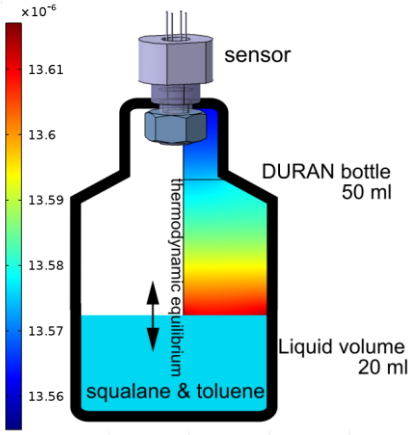

Figure 2: Calibration standard and the concentration distribution after 1000 seconds (FEM simulation).

Calibration samples (see Fig. 2) were produced using toluene as a representative VOC solved in squalane, a very long-chained alkane with negligible vapour pressure. According to Henry's law vapour pressure and, hence, headspace concentration are proportional to the mole fraction. The Henry constant for toluene in squalane can be estimated with the UNIFAC model (1.9 kPa at 20 °C) [4]. Thus, on-site calibration can be realised by exposing the sensor to the headspace. Since any VOCs contained in the calibration sample equilibrate, i.e. dissolve in squalane, their concentration is reduced by least 3 orders of magnitude. This allows background measurements ("zero air") under the same ambient conditions.

Oral Presentation

Results and Discussion

To verify the estimated Henry's constant and to realise a traceable calibration, the headspace of four samples was measured with a GC-MS system. Aside from smaller deviations the Henry adsorption constant of 1.9 kPa at 20 °C was confirmed. Nevertheless adaptions always have to be made according to the temperature dependency of toluene's vapour pressure.

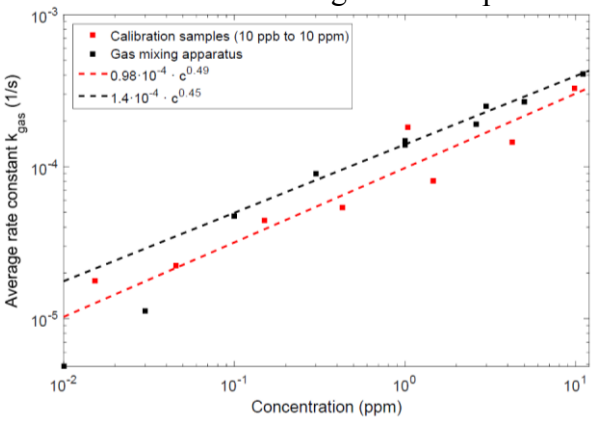

Figure 3: Sensor signal obtained from gas mixing system measurements with zero air background (black) and from calibration standards under ambient conditions (red) on a double logarithmic scale. Both follow a power law and show good agreement based on the extremely different background conditions.

The quantification method was tested using a gas mixing system and a permeation oven to produce toluene concentrations ranging from 10 ppb to 10 ppm. Calibration was performed under normal ambient conditions. The reaction rates measured inside an empty calibration standard (pure squalane) were subtracted to obtain a background independent signal. Results show very good agreement between both methods, cf. Fig. 3. The functional relation between concentration and sensor signal follows a power law. Although both measurements were conducted under very different ambient conditions, which normally implies that gas sensor data are hardly comparable at all, the recorded differences are below 50 %.

To test the overall approach a demonstrator was set up to simulate a small room (glass box, volume 180 l). The sensor and a septum are included so that known gas concentrations can be injected. The measurement (see Fig. 4) was performed as follows: first, ambient air was measured; after approx. 0.3 h toluene was injected, which theoretically should result in a concentration of 1 ppm inside the chamber. After 0.8 h an empty calibration standard was exposed to the sensor to obtain a background signal. The recorded sensor signal shows an injected toluene concentration of 0.92 ppm and an ambient toluene equivalent pollution level of 1.12 ppm based on the calibration (Fig. 3).

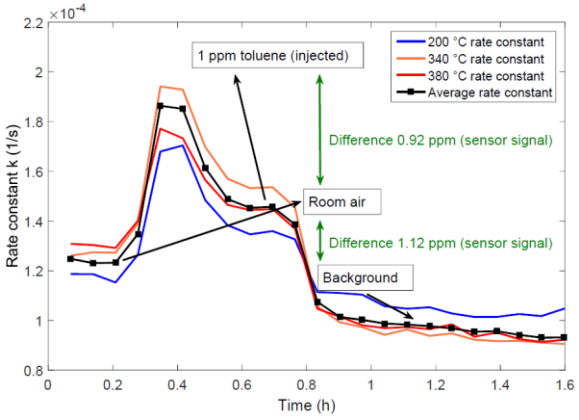

Figure 4: Measurement inside the room demonstrator. Accordance between injected concentration and sensor signal is quite good.

Conclusion and Outlook

The presented experimental results show the ability of this approach to quantify VOCs and to calibrate background independently. Further optimisation and experimental investigations are needed to achieve better performance (lower uncertainty) as well as practical handling.

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Oral Presentation

NOISE-BASED TECHNIQUES FOR GAS SENSING

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Random fluctuations or noise determine sensitivity of different kind of sensors. In particular, in nano-devices, which are promising due to their high surface to volume ratio, the relative noise (e. g. standard deviation of current fluctuations to mean current) increases with reduction of device dimensions. This is because less and less carriers participate in transport and thus small imperfections or low number of active surface sites modulate the current tremendously. Fluctuations in carrier number and/or carrier mobility can be considered. Noise is usually considered as detrimental factor in sensors as it decreases signal to noise ratio [1-3]. However noise can be considered as information carrier in sensors [4] and this idea led to the development of general concept of fluctuation enhanced sensing (FES) which has been utilized in particular for gas and biological sensing [5-6]. It has been proposed that different gas species can be selectively detected thank to special spectral features in noise spectrum. This could lead to reduction of number of detecting elements in comparison to conventional electronic nose [7] concept which is based on DC or transient measurements in large array of detectors with different gas selectivity.

In frequency domain, the adsorption-desorption noise provides Lorentzian shape of power spectral density with a corner frequency determined by the time constant of adsorption-desorption process [8,9]. Lorentzian spectra attributed to adsorption-desorption noise have been measured in thin film [10-12] and graphene [13] sensors subjected to different gases and volatile species. If the relaxation/correlation time of fluctuations is broadly distributed, 1/f spectrum [14] can be observed [3,15].

In time domain, individual adsorption-desorption events result in discrete resistance switching which has been observed in graphene sheets subjected to different gas species [16]. Furthermore, higher order moment statistical analysis of fluctuations [6,17] and wavelet analysis of current waveforms [18] have also been used to find specific signatures of gases in gas sensors.

In this presentation, basics of noise, noise models and noise measurement techniques for FES will be first briefly introduced. Examples of noise studies in gas sensors, in particular FES via adsorption-desorption noise, will be shown. Finally a recent study of influence of air humidity on 1/f noise in CuO single nanowire gas sensors [15] will be presented. The observed rise in relative noise in humid atmosphere is attributed to increased surface potential fluctuations and related carrier scattering fluctuations due to random distribution of hydroxyl groups at the nanowire surface.

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Oral Presentation

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Invited Talk

NEW STRATEGIES FOR ODOR ANNOYANCE ASSESSMENT: FROM SAMPLING TO DISPERSION MODELLING

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Abstract

Exposure to odours that are perceived to be unpleasant can affect well-being at levels of exposure well below those that would lead to physiological or pathological effects. A smell that is perceived to be unpleasant is hard to ignore, and easily leads to an overall negative appraisal of the environment itself.

Methods for assessing the impacts of odours on communities can be classified according to two distinct approaches, namely: source characterization and subsequent prediction of impacts in surrounding areas, or direct measurements of impacts in the field [1]. Through use of the dilution-to-threshold approach, odour concentrations at the source can be quantified using standardized sampling and analysis techniques and instruments (e.g. European Method EN 13725:2003) [2]. Subsequently, an odour emission rate from a source may be determined by multiplying the source odour concentration by the volumetric gas emission rate. In some cases this volumetric gas emission is the foundation of the problem because it comes from diffuse sources that are difficult to characterize.

In this work, source measurements and dispersion modelling were used to quantify the odour impact of a waste water treatment facility located within an urban area. The distance between some houses and the odour sources was near 20 m. Considering the potential impacts of different source emissions a comprehensive source characterization was performed, and a new strategy was used to assess diffuse emissions, based on the application of a multizone airflow analysis software. The odour levels evaluation was performed based on German Guidelines, where odour assessment is based on the concept of the so called “odour hour” [3].
The results confirm that the odours frequency perception, from the operation of the facility, could get to the population at a level higher than the 10% of the limit. This work allows the identification of opportunities for intervention and improvement and control of diffuse emission sources. In this context, the use of new sensing technologies for odour assessment and building management could be seen as a valuable contribution to assess and minimize odour impacts from similar facilities.

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Oral Presentation

USE OF NOVEL SENSOR TECHNOLOGIES IN THE ENVIRONMENTAL HEALTH AND CLIMATE CHANGE DOMAIN: THE CITI-SENSE-MOB EXPERIENCE IN OSLO, NORWAY

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Abstract

Urban and peri-urban growth is increasing worldwide and Europe is now one of the most urbanized continents in the world. Oslo is one of the fastest growing cities in Europe. This creates pressure on its infrastructure, including traffic. Traffic is one of the main sources of air pollution in urban areas and it is a major contributor to CO_2 emissions, which affects climate change. Improving air quality and lowering carbon emissions still remains an unsolved problem in Oslo.

The main objective of Citi-Sense-MOB was to demonstrate how using innovative low-cost sensor technologies combined with innovative Information and Communication Technologies (ICT) can help to create environmental health and climate change mobile services for citizens and authorities based on the use of near real-time data on air quality and CO_2 emissions at road level.

We have identified two main challenges in the use of low-cost sensor technologies: (i) Necessary to evaluate the sensor performance, assessing error characteristics and how their measurement capability holds up over time or through a range of environmental conditions; and (ii) Necessary to develop new methodologies to work with such diverse and often highly uncertain datasets to best make use of them and provide citizens as well as other end users with a relevant value-added product.

Low-cost air quality sensor platforms from different providers were evaluated against reference equipment. The results show clearly that a good performance in laboratory is not indicative of a good performance in real-world. The correlations in laboratory are above $r^2>0.9$ for all the gases, while in field the correlations show a significant decrease, especially for NO_2 and O_3. This decrease in the performance is most probably due to interferences with temperature and relative humidity. Advances in algorithms to process the data might result in a higher performance of the sensors.

The air quality platforms were also evaluated in real-world applications. Mobile sensors were installed in two buses, in one electrical bicycle and carried by a volunteer in a backpack. The field trials in Oslo indicate that low-cost sensor technologies offer the possibility to provide end users with relevant value-added services. Services as near-real time air quality maps, personal exposure to air pollutants and green house gas emission maps at street level have been created in the framework of Citi-Sense-MOB. However the main challenges to using these technologies include precision and accuracy of the low-cost sensors measurements.

Oral Presentation

O_3 AND NO_2 SENSOR NETWORK IN ZURICH: OPERATION AND STRATEGIES FOR QA/QC

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Abstract
Inexpensive sensors capable of sensing pollutants at ambient concentrations and of being integrated within wirelessly communicating sensor units forming sensor networks have the potential to enhance air quality monitoring. Such sensor units can be deployed in a larger number than traditional monitoring sites and, in principle, can provide information about air quality at higher spatial resolution. However, the operation of low-cost sensor networks requires new concepts in order to be able to obtain data that is accurate and reliable enough to significantly expand the information obtained by traditional measurement facilities.

Empa and Decentlab GmbH jointly engineered a sensor unit consisting of two boxes: the first box contains two O_3 sensors (Aeroqual SM50) and a GSM module, the second box contains three NO_2 sensors (Alphasense B42F) and a temperature and humidity sensor. The sensor units form a small sensor network in Zurich since June 2015. The network consists of six locations that represent typical pollutant situations encountered in Zurich. All the sensors were calibrated by running in parallel with instruments at air quality monitoring sites for about three months before operation.

Municipal and federal agencies operate six air quality monitoring sites for regulatory purposes in Zurich covering similar pollutant situations than the sensor network. Moreover, the city of Zurich performs extensive NO_2 passive sampler measurements. Their measurement network includes also all the locations of the sensor network.

In this framework, we investigate the requirements for operating viable sensor networks for air quality monitoring. This includes for example strategies for optimal sensor calibration and methods for quality assurance and quality control (QA/QC) within sensor networks. In this talk we give a summary of the project and our preliminary findings.

Oral Presentation

ON FIELD STOCHASTIC CALIBRATION OF FAST INDICATIVE AIR QUALITY SENSING SYSTEMS WITH DYNAMIC APPROACHES

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Abstract

In the last few years, the interest in the development of new pervasive or mobile implementations of air quality multisensor devices has significantly grown. New application opportunities appeared together with new challenges. One of these relate with the limitations in dealing with rapid pollutants concentrations transients both for static and mobile deployments. The relatively slow response of chemical sensors can, in fact, filter out or reduce the magnitude of rapid transients affecting the precision and accuracy of real time or averaged pollutant concentration estimations. This issue has been tackled in several in-lab studies but, as far as we know, it has been never addressed in real world scenarios [1].

In this work, we propose a Dynamic Machine Learning based approach to the stochastic prediction of air pollutants concentrations by means of chemical multisensor devices. DNN (Dynamic Neural Network) architectures, have been devised and tested in order to simultaneously tackle the cross sensitivities issues and sensors inherent dynamic limitations. In particular a Tapped Delay Neural Network (TDNN) and a NARX (Non Linear Auto-Regressive network with eXogenous inputs) have been selected for this study. The first one is known for the capability to take into account the dynamic of a system's input boosting slow responsiveness [1]. Additional properties relates with the capability of limiting influences of noise on calibrated output. The NARX network take as a further input, w.r.t. the TDNN, the past values of the estimated output, in our case past estimated concentration values. This add information about concentration trends that further help to improve the network output.

Furthermore the need to obtain a stochastic evaluation of concentration estimations is now emerging in order to provide a complete information to the user of the indicative air quality multisensing device helping to correctly compute and/or estimate the personal exposure. The same uncertainty estimation is of course needed for the implementation of cooperative pervasive assessment on city air quality and data assimilation schemes. To this regard we provide a methodology to estimate uncertainty on concentration prediction for this two neural architectures that, in their base configuration, do not provide such information. Algorithms have been coded in Matlab™ for off line data processing. However the memory footprint of the complete provided solution should easily allow for on board integration.

Testing of the proposed methodology has been performed using an on-field recorded dataset from a pervasive deployment in Cambridge (UK), encompassing several weeks [2]. The results obtained with the dynamic models are compared with the response of the static neural networks (FFNN, see table 1). The performance analysis indicates the capability of the on-field dynamic multivariate calibration to ameliorate the static calibration approach performance in this real world air quality monitoring scenario (see fig 1.c). Interestingly, results analysis also suggests that the improvements are more significant when pollutants concentration changes more rapidly (see fig 1.d). This suggests that, whenever accuracy is concerned, for static and mobile settings, a dynamic approach should be preferred to the classic static multivariate one.

Oral Presentation

TABLE 1: RESULTS OF THE COMPARISON TESTS FOR ESTIMATION OF NO_2 CONCENTRATIONS (TEST SET VALUES).

NN	Input (Sensors)	Hyper Parameters	MAE (ppb)	MRE	NLPD
FFNN	NO, NO_2, O_3, Rh, T	HN=5	1.50(std=0.06)	0.25	2.15(std=0.03)
	NO, NO_2, O_3	HN=5	1.58(std=0.04)	0.28	1.98(std=0.01)
TDNN	**NO, NO_2, O_3, Rh, T**	**HN=5, TDL=0:6**	**1.27(std=0.10)**	**0.22**	**1.78(std=0.05)**
	NO, NO_2, O_3	HN=5, TDL=0:6	1.33(std=0.05)	0.24	1.78(std=0.02)
NARXNN	NO, NO_2, O_3, Rh, T	HN=5, TDL=0:6, FDL=1:5	1.30(std=0.15)	0.21	1.82(std=0.10)
	NO, NO_2, O_3	HN=5, TDL=0:6, FDL=1:5	1.40(std=0.10)	0.24	1.87(std=0.21)

Table 1: Results obtained upon 30 different executions of the proposed architectures by the use of the indicated chemical sensor array (+environmental variables). HN = Hidden Number, TDL = Tapped Delay Length and FDL = Feedback Delay Length. Bold values indicates best performance.

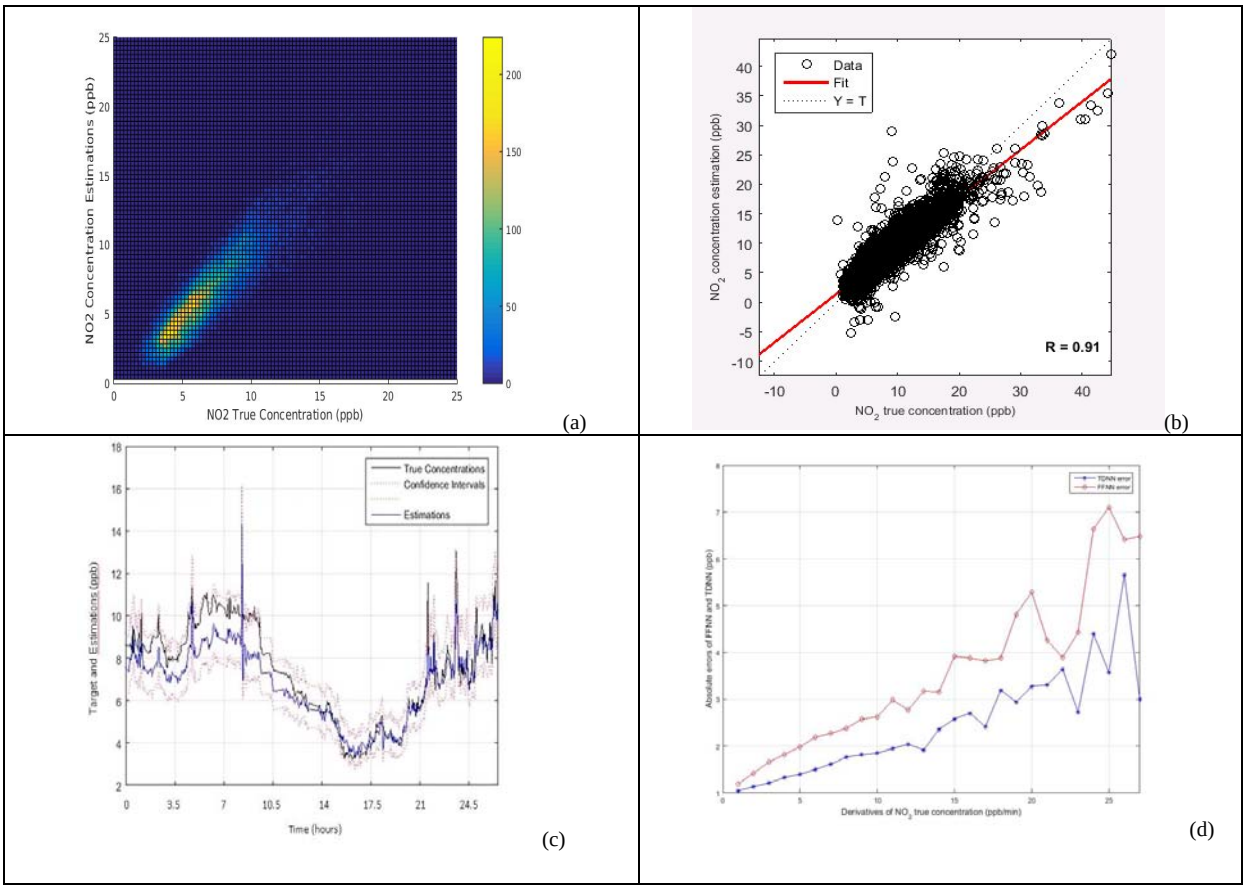

Fig. 1. (a) NO_2 concentration estimation – True Concentration joint distribution for TDNN (best results) and (b) correlation plot. Stochastic estimation for a 26 hrs period (c). Mean Absolute error value at different true concentration derivatives (d): Dynamic networks show significant advantage with respect to a static state of the art calibration network; performance advantage improves at high absolute derivative values i.e. when rapid transients occurs.

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Invited Talk

THE AIR POLLUTION IN THE CROSS-BORDER REGION TURKEY-BULGARIA: MODEL SIMULATIONS VS. MEASUREMENTS

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Introduction

The investigated region is located in the south-eastern part of the Balkan Peninsula. It includes numerous protected areas and natural parks; and for its rich biodiversity the area is treated as unique in Europe. The population density in the Districts Burgas-Kirklareli is rather low, but there is a growing urbanisation in the Turkish part and the small villages along the Bulgarian Black Sea coast accept a lot of tourists in summer.
The main goal of this study is to analyse the air pollution status and related problems in the cross border area, based on available air quality measurements, deposition data and modelling results for some months in 2014.

The modelling system

The Bulgarian Chemical Weather Forecast System (CWFS) [1, 2] has been presented at several *EuNetAir* meetings. It is based on the well-known models WRF (Meso-meteorological Model) and US EPA dispersion model CMAQ (Chemical Transport Model). The system runs operationally over several nested regions, from European to city scale (http://www.meteo.bg/en/cw). Here, the results for domain "Bulgaria" (dx = 9 km) have been analysed. The emissions are based on the Bulgarian national inventory for 2010, and on TNO emission inventory for the adjacent countries and for the bigger domains.

The observational data

Standard air quality measurements have been taken by respective environmental authorities at limited locations in the bigger urban areas. For the analysis we have selected 3 months (February, June, and October 2014) looking at PM_{10}, SO_2 and O_3 concentrations at the background type of stations in Burgas, Kirklareli and Edirne.
The wet deposition data, discussed here, have been obtained from sampling campaigns organised by NIMH-BAS at two locations - at an urban one in Burgas, and at a rural one, about 80 km southwards, near the small coastal village of Ahtopol.

Results and discussion

Monitored PM_{10} concentrations are high, especially at the Turkish stations - mean annual values for 2014 at Kirklareli and Edirne are, 62 μgm^{-3} and 67 μgm^{-3}, respectively; at the coastal city Burgas - 36 μgm^{-3}. For the months of February and October 2014 modelled concentrations are about 3-5 times lower, with rather good correlation coefficients - between 0.55 and 0.76. The time variation of observed and modelled mean daily PM_{10} values (Fig. 1) shows that pollution episodes in terms of occurrence, are well captured by the model at all sites. This indicates that the episodes are related to larger scale processes, well reproduced by the modelling system. For October this occurs with westerly flows.

Ozone concentrations, monitored at the coastal site of Burgas have mean annual values about 60 μgm^{-3}, with daily maximum values (DMAX) in summer above 100 μgm^{-3}. The model simulates well O_3 DMAX (Fig. 2), although in general the model overestimated hourly values by about 10-20%, especially during night-time (Fig. 2 right).

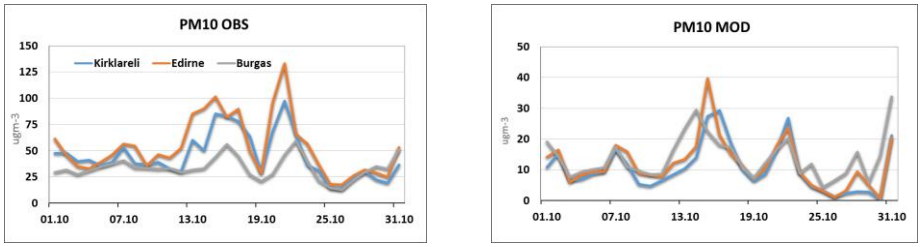

Figure 1. Daily mean PM_{10} concentration at 3 sites in October 2014 - observed (left) and modelled (right)

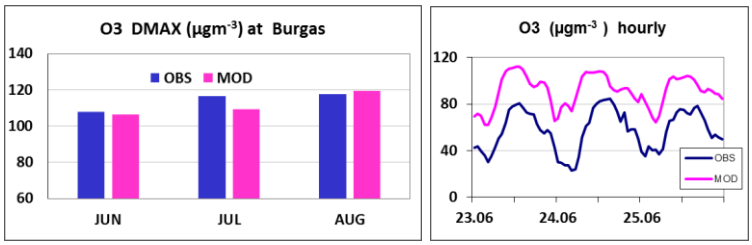

Figure 2. Ozone daily max (left) and mean hourly variation (right)

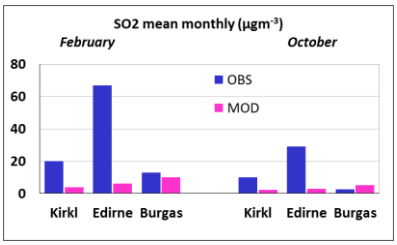

Figure 3. SO_2 mean monthly values

Observed SO_2 concentrations at Edirne are significantly higher than at Kirklareli and Burgas (Fig. 3), most probably due to the fossil fuel burning used for heating. Model results are within 10% of the ones observed for Burgas, while for the other two stations the underestimation has an order of 5 to 10 for the months February and October.
Sulphur wet deposition was compared in terms of monthly mean values for the coastal sites Burgas and Ahtopol (Fig.4). Both observations and model results show higher values at the rural site Ahtopol for the months of October and November.

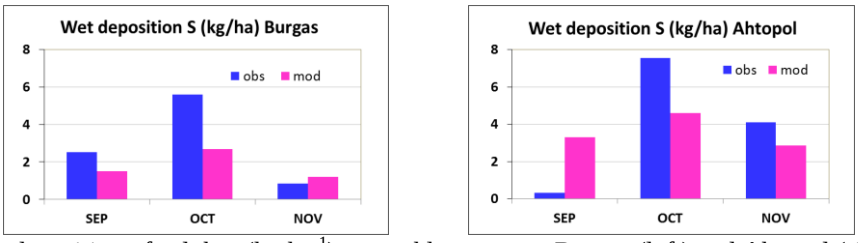

Figure 4. Wet deposition of sulphur (kg.ha^{-1}) - monthly means at Burgas (left) and Ahtopol (right).

Conclusion

Numerical modelling results indicate that the cross border area, although without significant emission sources of air pollution and assumed to be clean, may be polluted in specific meteorological situations from sources outside the region. Main problems are related to PM_{10} and SO_2 in winter, while high ozone levels at the coast are observed during summer. Simulations with finer grid resolution and better emission inventories are necessary for increasing model skills. Observations on atmospheric deposition at more locations are required for studying acidification phenomena in this region.

Acknowledgments: This study was partly supported by the IPA CBC cross-border program CCI 2007CB16IPO008 in the framework of project SAAP4FUTURE

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Oral Presentation

CHEMICAL CHARACTERIZATION OF THE SEA SURFACE AND AMBIENT MARINE AEROSOLS OF MIDDLE ADRIATIC AREA DURING SPRING AND SUMMER SEASONS

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Abstract
The current knowledge in aerosol science is still incapable of giving a real and quantitative assessment of their actual impact on the global climate and the human health. This problem arises from the insufficient understanding of aerosol sources, their formation mechanisms, chemical composition and properties.

Organic matter (OM) is an important atmospheric fraction which enters the atmosphere through biogenic and anthropogenic emissions. However, the composition of atmospheric OM and the respective source apportionment are far less known than those of the inorganic part of the atmospheric particulate matter (PM). The lack of information about atmospheric organic species lies in their complexity and low concentrations in general [1]. Many of the organics identified in the atmospheric aerosols are known to be surface active in aqueous solutions, contributing to the aerosol water soluble organic carbon (WSOC) pool [2]. Surface active substances (SAS) or surfactants present in the atmosphere influence the climate by reducing the surface tension of the air-droplet interface, affecting physical properties of aqueous droplets in the air. Being amphiphilic organic compounds, SAS are also highly enriched in the upper part of the sea surface, known as a sea surface microlayer (SML) [3], which represents the largest interface on the Earth. Therefore, the sea surface has a global role in exchanging marine OM with the atmosphere and a combined interdisciplinary SML and aerosol study could provide new knowledge on the linkage between the sea and the atmosphere.

Thus, a comprehensive physical-chemical study of both, marine aerosols and sea surface samples (SML and corresponding underlayer water (ULW) from 0.5 m depth) collected simultaneously during spring and summer 2015 at the Rogoznica Lake, central Dalmatia, Croatia, has been performed.

Water soluble organic matter of aerosol, SML and ULW samples was analysed. SAS were determined by electrochemical methods and the total organic carbon (TOC) and dissolved organic carbon (DOC) by high temperature catalytic oxidation (HTCO) technique. Ionic composition was studied by ion chromatography (IC).

Spring aerosol samples were characterized by lower PM mass, TOC, WSOC, SAS and inorganic ion concentrations (F^-, Cl^-, Br^-, NO_2^-, NO_3^-, SO_4^{2}, PO_4^{3-}, Na^+, K^+, NH_4^+) in comparison to the summer samples. At the same time, higher enrichment factors (EFs) were obtained for particulate and dissolved organic carbon, nutrients and SAS of the spring SML samples, indicating a recent phytoplankton bloom and accumulation of OM within the SML. Intense biological activity most likely influenced the atmospheric PM during the spring

season, whereas the aerosols from the summer period were highly affected by the local biomass burning events (significant correlation of PM mass with K^+ ions) as well as by secondary photo-oxidation processes (indicated by elevated WSOC/OC ratios as well as the content of dicarboxylic acids and SAS).

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Oral Presentation

EVALUATION OF MONITORING PM WITH LOW-COST MONITOR AND CONVENTIONAL DEVICES

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Abstract

Air pollution, where respirable particulate matter (RPM) components are the most dangerous, stems from both anthropogenic and natural emissions that undergo further changes in the atmosphere. It is a mixture of mixtures that is not constant in level and composition, and varies through space and time. Premature death, attributable to air pollution, happen mostly due to heart disease and stroke, followed by lung diseases and cancer [1]. In addition, air pollution is associated with increase in incidence of numerous additional diseases. The International Agency for Cancer Risk IARC designated outdoor air pollution as a Group 1 carcinogenic substance, i.e., proven human carcinogen [2]. RPM mixture, as a major component of outdoor air pollution, was evaluated separately and was also classified as carcinogenic to humans, Group 1 [2]. There is no difference in the hazardous nature of RPM in indoor environment in comparison with those at outdoor, in the presence of indoor sources of RPM, levels of RPM fractions are usually higher than the outdoor.

Real-time RPM devices are essential for accurately estimating exposure to coarse ($PM_{10-2.5}$), fine ($PM_{2.5}$) and ultrafine (PM_1) particles both outdoors and indoors. Monitoring networks at local and state level provide precise, but limited spatial coverage and not enough information for personal exposure to air pollutants including coarse, fine and ultrafine fractions of PM. Access to detailed air quality variations encountered when moving and spending time in different indoor and outdoor microenvironments is important for citizen in order to be more informed on how to minimize personal exposure to inhalable pollutants including PM fractions. For monitoring indicative levels of the ambient RPM, at a much higher spatial resolution, a network of small and cheap sensors could represent an alternative opportunity to conventional devices [3]. Such data may be used for creation of air pollution maps in near to real time. However for direct assessment of personal exposure in different microenvironments (MEs) a low-cost particle counter with integrated or external GPS receiver may be applied.

There is a number of low-cost sensors that are integrated in particulate matter monitors [3]. In this paper we review some recently published data about evaluation of characteristics of Dylos monitor in laboratory and in the field. We also present results of variability in Belgrade urban area of fine particles and coarse particles and evaluate the relationship between the level $PM_{0.5-2.5}$ fractions detected with a commercially available cheap PM counter collocated with a reference instruments at an Automatic Monitoring Station (AMS) as well as with other conventional PM devices.

In the case of the DYLOS monitor a modified device was tested in the laboratory condition by Northcross et al. [4]. In a chamber a controlled test atmosphere with a very wide range of aerosol concentrations were generated. Pearson correlation coefficient with the TSI Dust Track compared with BAIRS, modified Dylos monitor, was 0.99 for polystyrene latex spheres and NH_4NO_3 aerosol and 0.97 for wood smoke particles. Steinle et al [5] measured PNCs (particle number concentration) with the Dylos monitor and transformed into $PM_{2.5}$ mass concentration based on co-location experiments. They performed 5 days collocation studies

with TEOM-FDMS at rural (R=0.9) and urban (R=0.7) AMS. According to previously collected data in indoor, 35 profiles were summarised in average and standard deviation per ME in PNCs and calculated $PM_{2.5}$ mass concentration. For ourdoor MEs data were validated over a range of 0 - 50 $\mu g/m^3$ with a linear function. While a second order equation for indoor ME was necessary where $PM_{2.5}$ range across 0 - 1000 $\mu g/m^3$.

For measurement in source specific atmosphere in indoor environment Dacunto et al [6] tested for different scenarios DYLOS 1100 with TSI SidePak and gravimetric pump and attempted to estimate the Dylos calibration factors of $PM_{2.5}$ for emissions from 17 different common indoor sources including cigarettes, incense, fried bacon, chicken, and hamburger. They conclude that the Dylos might be used to provide a qualitative measure of near instantaneous $PM_{2.5}$ concentration indicating whether it is generally in a "high," "medium," or "low" category.

We present the work in the field of calibrations of a laser based optical particle counter DC1700 (Dylos Corp) integrated into a EB700 platform and deployed within the CITI-SENSE project pilot campaign and discuss the obtained data. Data were collected at the site of an AMS in Belgrade, Serbia, belonging to the State Network. Nine EB700 platforms with integrated DC1700 monitors for measurement of air pollutants with a resolution of 1 minute averages were available. For calibration of the low cost PM monitor data collected with reference SVEN Leckel LVS, equipped with sampling head for $PM_{2.5}$ was used. The main focus of this presentation is however to compare measurements of the low-cost PM devices with a higher resolution signal collected with more sophisticated optical instruments at the same location. Reference instrument present data according to the legislation requirements in $\mu g/m^3$ and we used conservative approximation to convert low-cost monitor counts of the fractions $PM_{0.5\text{-}2.5}$ into mass-concentration. We performed a campaign in March 2014, in duration of 15 days at the AMS Novi Beograd. To quantify and compare the strengths of correlations, we used the coefficients of correlation (R) from ordinary least-squares regression models fit between nine DC1700 monitors and between low-cost devices and reference instruments. Coefficient of correlation within the nine DC1700 was higher than 0.8 for fine PM fraction. R between each of the nine DC1700 and reference PM GRIM monitors were higher than 0.9. Next step in proving usability of DYLOS device for monitoring with higher spatial and temporal resolution and usage for personal exposure assessment is comparability of data collecting at different type of AMS e.g. traffic, residential, industrial site.

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Oral Presentation

COMPLEXITY OF SOFTCOMPUTING MODELS FOR BIG DATA PROCESSING

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Abstract

Due to large scale, high-dimensionality, incompleteness, and noisy character, sensor data sets belong to the category of so called big data. Their management is not only about storage and acces to data, but analytics plays an important role in making sense of the data and exploiting their value. However, learning from big data represents a challenge for machine learning as many popular learning algorithms cannot easily scale up with growing sizes and dimensions of processed data.

Sensor data gathered by participants of the *EuNetAir* Action contain tens of thousends of measurements of gas multi-sensor devices recording concentrations of several air pollutants. Subsets of these measurements, which are labelled with conventional air pollution monitoring stations, can be used as training sets of input-output pairs of data for supervised learning of suitable computational models (such as neural and kernel networks). These computational models can learn from samples of empirical data and when properly designed, they can generalize acquired knowledge so that they can properly process new data that were not used for training. Thus these models enable prediction and estimation of missing data. However for big data, a proper choice of computational units and their architectures has a strong impact on model complexities which are critical factors for feasibility of implementations and efficiency of computation.

In our research, we investigated posibilities of reduction of model complexities and improvement of generalization by suitable regularization techniques. These technique can improve learning based on empirical data by taking advantages of some prior informations playing roles of penalties on undesirable solutions. We proposed new measures of sparsity of networks formulated in terms of variational norms tailored to types of computational units [1,2,3] . We showed that this type of sparsity can be achieved using weight-decays regularization techniques. Our goal was to contribute to methodology of selection of types of computational units reducing model complexity requirements and thus allowing efficient performance of learning algorithms. In particular, we investigated model complexities of kernel networks [1,4]. We focused on composite kernels, which are suitable for heterogenous data. We proposed evolutionary learning algorithms for networks with units in the form of sums and tensor products of kernels operating on subsets of input variables [5]. We implemented the algorithms and tested them on real data from gas multi-sensor devices obtained by colleagues from *EuNetAir* Action [6].

Our research was partially supported by national research project COST LD13002 of the Ministry of Education of the Czech Republic.

Oral Presentation

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Invited Talk

FLAMENCO: AIR QUALITY SENSING IN FLANDERS MOBILE ENACTED CITIZEN OBSERVATORIES

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Abstract
Participatory sensing allows people-centric contextual monitoring by way of smart mobile devices. It is the driving technology behind citizen observatories, sets of ICT-tools to collect, analyse and visualise sensor data, with the aim of improving the quality of life of citizens. Today citizen observatories have to be developed from scratch for each application area, an enormous effort as witnessed by dedicated consortia for the topics of air quality, water quality, ocean monitoring and odour monitoring, under the 2012 EU-ENV-FP7 call. These first-generation citizen observatories prove the critical role of ICT in the evolution towards a sustainable society, but deploying a new citizen observatory remains extremely difficult and labour-intensive. Despite an overwhelming demand for such platforms, they are thus beyond the reach of most societal stakeholders.

The goal of FLAMENCO is to build and valorise an open reusable and reconfigurable citizen observatory platform for Flanders. Through this platform, (ICT-agnostic) stakeholders themselves can instantiate new citizen observatories for the particular application area they have in mind. Web services and mobile apps are generated accordingly. Data gathered involves sensorial data (e.g., noise levels, air quality, physical activity) as well as behavioural data (e.g., tolerance for delays in public transportation or sensitivity to public safety). In this scalable approach stakeholders see their concerns translated into procedures for successful participatory campaigning without having to rely on platform engineers.

Only in this way can we move away from research-oriented deployments to the full-fledged adoption of citizen observatories as a societally and scientifically relevant method. We situate the observatory around the notion of a campaign. A campaign is defined by a stakeholder through constraints on the data that need to be collected. Subsequently, the campaign is enacted through the stakeholder's citizen observatory, which also monitors campaign progress in terms of incoming data, and orchestrates activities in case progress is not as expected. Finally, the campaign is analysed by producing the requested output (maps, reports). Despite the fact that campaigns constitute a fairly obvious notion, there currently exists only limited support for them. In this project they are essential in bridging the gap between stakeholder usability, data quality, and the well-known intricacies of engineering reconfigurable software.

The main technological research issues are reactivity (i.e., dealing with data flows and the propagation of change) and coordination in citizen observatories as data-intensive cloud applications, and processing large amounts of heterogeneous and "dirty" data. But there is more. Acknowledging the fact that a citizen observatory only exists through its contributors, this project also investigates user engagement and motivation, studying its relation to privacy issues and the effect of game elements. Likewise, a citizen observatory's existence is only justified when it informs the domain it is designed for, and this means translating enormous quantities of data into qualitative statements about indicators, impact and costs.

Invited Talk

FLAMENCO will deliver policy-supporting tools in the domains of sustainable mobility and environmental monitoring. FLAMENCO unites specialists in software engineering, data analysis, environmental monitoring, mobility and ICT user studies. Each partner will benefit from participation in FLAMENCO to advance the state of the art in his respective academic specialisation.

FLAMENCO's valorisation strategy is to achieve six valorisation trajectories: (1) establishing the reconfigurable citizen observatory platform itself, (2) engaging citizens and creating improved awareness w.r.t. the data gathered, (3) designing successful participatory campaigns, (4) translating data into knowledge useable for policy support, (5) real-world campaigning, including campaign outcomes and unanticipated citizen observatory initiatives, and (6) paving the way for post-project activities. The sharp focus on societal valorisation can only be realised thanks to FLAMENCO's unique interdisciplinary consortium and its extensive array of contacts which has led to an extensive advisory board consisting of no less than 20 societal partners.

Oral Presentation

FUNCTIONALIZATION OF CARBON NANOMATERIALS: TOWARDS DEVICES FOR THE MOLECULAR RECOGNITION OF AROMATIC COMPOUNDS IN THE ENVIRONMENT.

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Abstract
Functionalization of carbon nanotubes and other carbon nanomaterials with complex molecules in view of tuning their gas sensing properties is a strategy that has been raising interest in the last few years. Here we will review a few examples of how this approach could help implementing molecular recognition of ambient pollutants and also will report our latest results in the field.

Introduction
Kong et al. first explored in [1] the use of carbon nanotubes as gas sensitive nanomaterials, given their remarkable intrinsic properties such as high surface area to volume ratio, carrier mobility, physicochemical stability and adsorption capacity. However, gas sensors based on pristine CNTs exhibit some disadvantages such as high inertness and, therefore, low interaction with their chemical environment. Additionally, very oxidizing gases such as NO_2 or O_3 strongly bind to carbon nanotubes, resulting in extremely long sensor recovery dynamics [2]. To overcome these drawbacks, the physical and chemical modification of CNTs has been implemented, especially by substitutional doping, by grafting functional groups to the outer wall of tubes via wet chemistry or reactive plasma routes and/ or by decorating its surface employing a wide range of materials such as metal oxide nanoparticles, polymers, non-polymeric organic materials or catalytic metal nanoparticles [3]. Metal and metal oxide nanoparticles donate or accept a significant amount of charge upon gas adsorption, so as to affect carrier transport in the carbon nanotube. Polymers or non-polymeric organic materials are often used to filter out polar or non-polar compounds, so better selectivity can be achieved and cross-sensitivity to ambient moisture is diminished. Very recently, we have employed quinoxaline-walled thioether-legged deep cavitand functionalized multiwall carbon nanotubes for the detection of benzene vapours at trace levels [4]. In this talk we will further develop this approach by producing gas sensors employing films of gold nanoparticle decorated, multiwalled carbon nanotubes (MWCNT/Au) functionalized with a self-assembled monolayer of 16 Mercaptohexadecanoic acid (MHDA. The self-assembled monolayer (SAM) technique employed here takes advantage of the good affinity between the sulphur group (thiol) present at one end of the MHDA molecule and gold, which decorates the outer wall of carbon nanotubes in the form of nanoparticles. Compositional and morphological characterisations of the resulting films will be shown and the gas sensing properties will be discussed in light of the experimental findings.

Results and discussion
Figure 1 shows a scheme of the MWCNT/Au/MHDA sensors developed. Figure 2 shows the response and recovery curves of a MWCNT/Au/MHDA sensor to different concentrations of acetone and also the calibration curves of MHDA functionalised and bare MWCNT/Au

sensors. The response is fully reversible even though the sensor is constantly operated at room temperature. Furthermore, the functionalization with MHDA, results in a significant increase in response and sensitivity towards acetone and the suppression of benzene response.

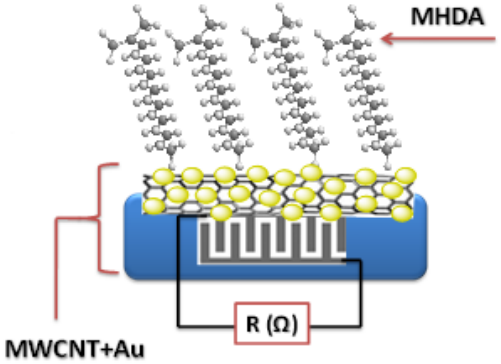

Figure 1. Synoptic sensor structure based on MHDA deposited on carbon nanotubes decorated with gold nanoparticles.

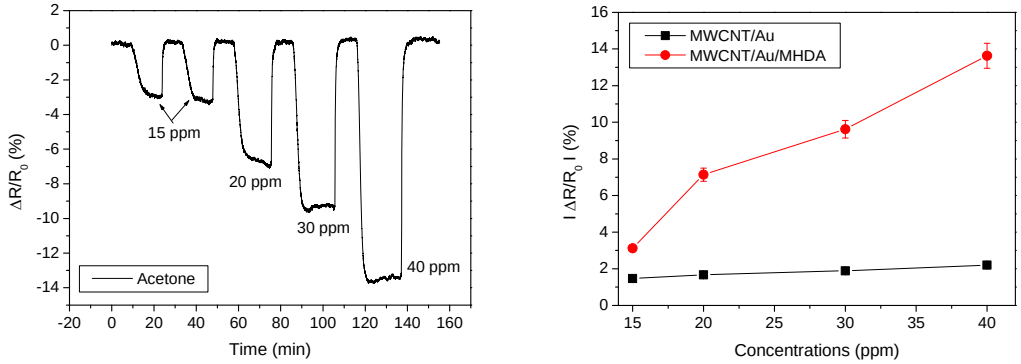

Figure 2. Response and recovery curves towards acetone for a MWCNT/Au/MHDA sensor (left) and calibration curves for a bare and MHDA functionalized sensor (right).

Upon adsorption of the non-aromatic VOCs the acidic nature of the thiol is reinforced and electronic charge is transferred from Au NPs to the S atom of the MHDA molecule. This slightly perturbs the band structure of MWCNTs causing a small shift of the Fermi level energy toward lower energies, which is equivalent to a p-doping of the tubes and their conductivity is increased. This strategy opens a simple and flexible way to fine tune the gas reactivity of carbon nanotubes, since the length of the mercaptan chain and/or the hydrophilic or hydrophobic nature of the terminal part of the molecule become parameters of the functionalization.

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Invited Talk

MSDI HETEROJUNCTIONS, HOW CONDUCTIVITY AND IMPEDANCE ALLOW FOR DISCRIMINATION BETWEEN AMMONIA AND HUMIDITY

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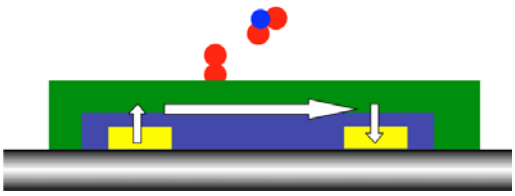
Abstract

This work is the result of collaboration between the teams of Marcel Bouvet, ICMUB – Dijon – France and this of Andreas Schütze, LMT – Saarland University – Germany, initiated in the framework of the COST action EuNetAir, through two short term scientific missions.
This work deals with the sensing response of Molecular Semiconductor – Doped Insulator heterojunctions (MSDI) [1], a new organic device combining two molecular materials with very different electronic properties (Fig. 1). We focused on understanding the phenomenon occuring at the interface between the two layers that appears to be a determining factor for the electronic transport in the device and ultimately deciding the nature of gas sensing. Conductometric measurements showed the rather good stability of the response to ammonia in the 10-100 ppm range, whatever the relative humidity (rh) in the 10%-70% range (Fig. 1,2). The impedance measurements (Fig. 3) showed that the Schottky contact between the sublayer and the electrodes plays also a key role [2]. They, furthermore, provide complementary data for the selective detection of ammonia and relative humidity in air (Fig. 4).



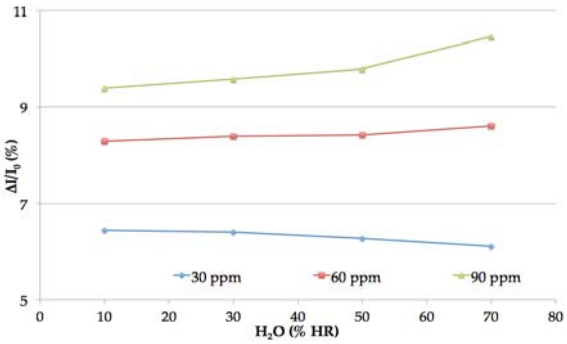


Figure 1. Scheme of a MSDI heterojunction and relative response to NH_3 of the Cu(F_{16}PcCu)/$LuPc_2$ 50 nm/50 nm n-MSDI, during exposure-recovery cycles (1 min-4 min), as a function of the relative humidity

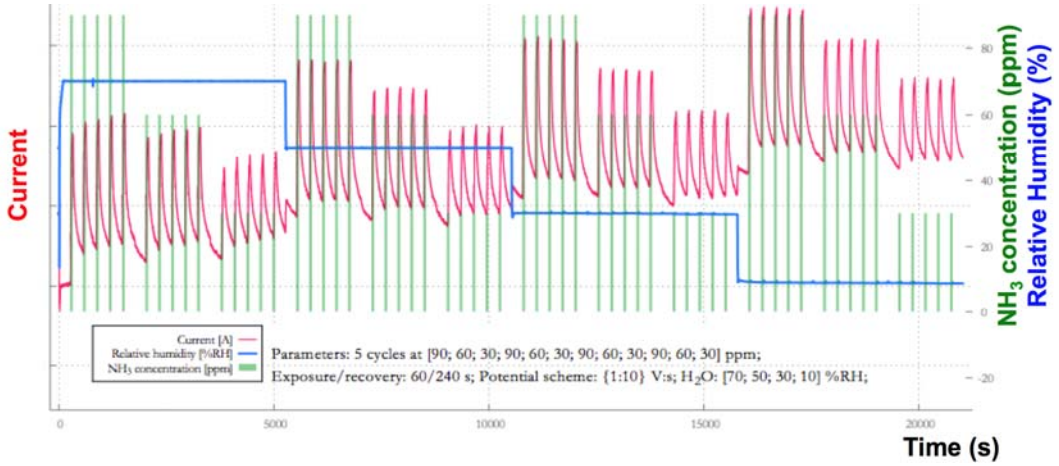


Figure 2. Variation of the current as a function of time during exposure-recovery cycles (1 min-4 min) to 90, 60 and 30 ppm NH_3, under 70, 50, 30 and 10 % rh.

Invited Talk

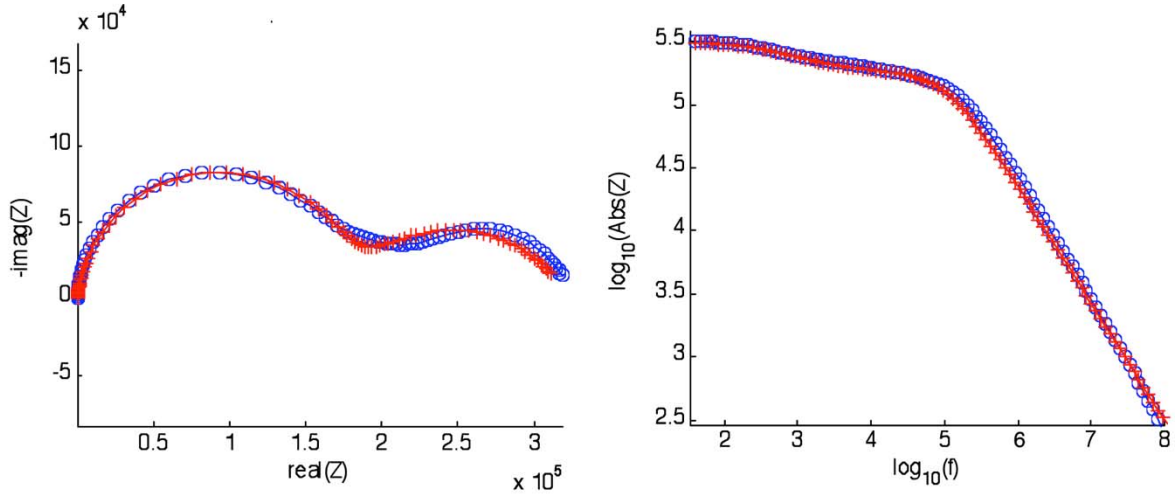


Figure 3. Nyquist (left) and Bode (right) plots of the n-MSDI $LuPc_2$/Cu(F_{16}Pc) (50 nm/50 nm); in blue the experimental curves and in red the fits.

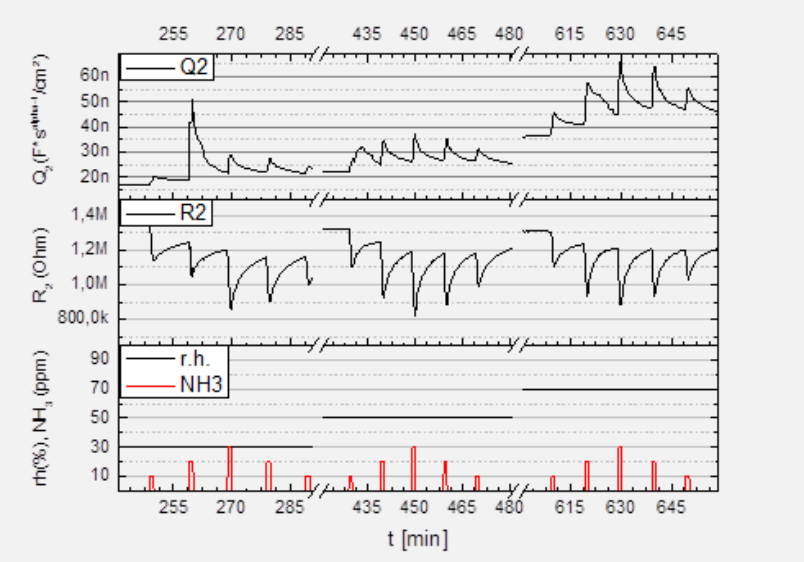


Figure 4. Variation of R and Q of the equivalent circuit of n-MSDI Cu(F_{16}PcCu)/$LuPc_2$ 50 nm/50 nm, polarized at 0.5 V, during exposure-recovery cycles (1 min-4 min) in 10, 20 and 30 ppm NH_3, under 30, 50 and 70 % rh.

From electrical impedance measurements, we proposed a model of the sensor with an equivalent circuit consisting of four elements. The individual elements are affected differently by humidity and NH_3, in a characteristic manner. Thus, the parameter Q increases under NH_3 and is shifted under increasing rh, whereas R decreases under NH_3, but remains constant whatever the rh (fig. 4).

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Oral Presentation

SITE-SELECTIVE SYNTHESIS OF SnO_2 NANOWIRES FOR AMMONIA SENSING IN THE PRESENCE OF HIGH LEVELS OF HUMIDITY

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Abstract

One-dimensional (1D) semiconductors, such as nanowires (NW), nanotubes (NT), etc., are highly interesting materials for gas sensing applications due to their high surface to volume ratio [1], which gives rise to enhanced transduction of the interaction between their surface and the surrounding gas molecules into a change in their electrical resistance. The preparation and fabrication of 1D-nanostructure based gas sensor devices usually involves transfer of the grown bottom-up nanostructures from the substrate where they grew to the final substrate for device fabrication, which is difficult, time consuming and shows low repeatability. A strategy to achieve more reliable and reproducible devices would include a change in the fabrication strategy, employing localized growth of these nanostructures directly on the final electronic device, avoiding several steps that add uncertainty factors to process fabrication.

The here-employed methodology uses a site-selectively growth of SnO_2 on top of CMOS compatible micromembranes that contain a microheater, which provides the thermal energy necessary for the growth. Synthesis of NWs is carried out by a localized vapour-liquid-solid deposition process at about 750ºC using gold nanoparticles as a catalyst, in a fast, and low power consumption process, about 30mW, and which represents an important power reduction compared to a standard CVD furnace. The network of NWs is fabricated directly on the micromembranes without employing a mask and without the need of a post-processing step. The detailed growth process is described elsewhere [2].

The response of these SnO_2 nanowires towards NH_3, NO_2, CO and other toxic gas at different concentrations and temperatures, both in the absence and presence of water vapor, has been tested. Figure 1 shows the resistance variation of the localized grown NW matt in the presence of different NH_3 pulses. The tests were carried out at a constant flux of 200 $ml \cdot min^{-1}$. The responses can be easily fitted to an exponential behavior, achieving a lowest value of 63 s for 50 ppm at a heater power supply of 30mW, corresponding to 400ºC. These sensors show a stable baseline and reach a saturation in response at around 30 ppm, which is close and slightly above the time-weighted average exposure limit for 8 h recommended by NIOSH [3] (25 ppm). Furthermore, these nanowire-based devices have shown a long operational lifetime in laboratory conditions: prototypes have been operated towards toxic gas species more than 3 months**,** demonstrating high durability and stability.

Oral Presentation

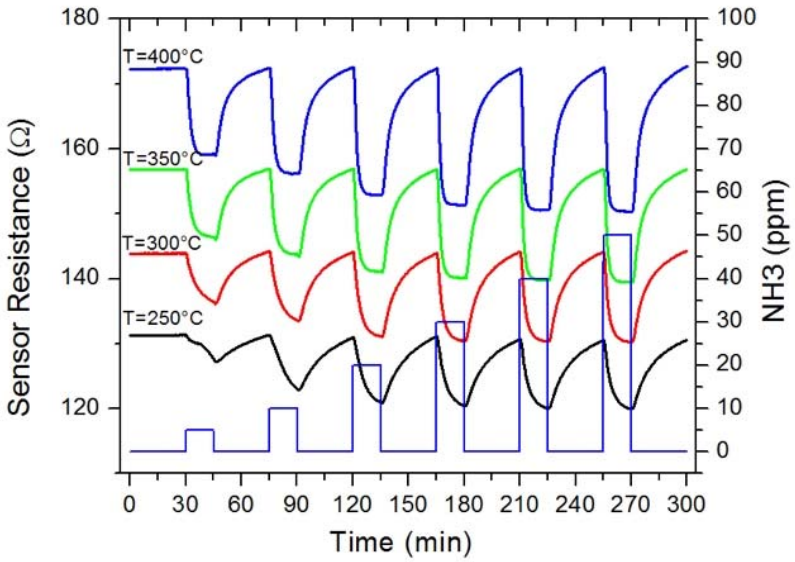

Figure 1: Resistance of SnO_2 NWs towards the presence of NH_3 in synthetic air at different temperatures.

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Oral Presentation

DEVELOPING AIR QUALITY SENSORS BY LASER DEPOSITION ON GRAPHENE

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Abstract

Graphene as 2D material can be fully exposed to environment and hence provides an ideal platform for chemical sensing [1]. However, in order to achieve the sensitivity and selectivity required for air quality sensors, additional adsorption centres have to be created at its surface e.g. by controlled formation of defects, dopants or clusters [2].

In the present work, we demonstrate the development of sensor structures based on single layer CVD-graphene, which is modified by pulsed laser deposition (PLD). PLD can be used as a precise tailoring tool for this purpose as it allows depositing virtually any material with controlled amount and kinetic energy of atoms (molecules). Typically only 1% of a monolayer is deposited by a single laser pulse with particle energies adjustable from 25 meV to 100 eV. The adsorption properties of 2D sensor material can be modified with PLD by different mechanisms: i) doping, ii) creation of point defects or iii) phase boundaries. These features can be also introduced in a combined way within a single technological process, which provides extensive possibilities for designing the structures with suitable adsorption properties for different target gases.

Different target materials - metals (Ag, Au, Pd, Ru) and oxides (NiO, ZrO_2, SnO_2, TiO_2, V_2O_3) – were used for functionalizing graphene. The amount of deposited materials was varied between 0.01 to 20 monolayers, the energy of 'landing particles' was adjusted by gas (N_2 or O_2) pressure in the deposition chamber. The magnitude of gas response, its selectivity and recovery time were further tailored by temperature and (visible or UV) optical excitation. For some tested oxide materials, the qualitative performance in case of different test gases was as follows:

Oxide/Gas	NO_2	NH_3	CO	SO_2
TiO_2	X	x	0	0
SnO_2	x	X	0	X*
V_2O_3	x	x	X	x

Table I. Qualitative scale of responses: 0 – response was (almost) absent, x – 'normal' response, X - largest response. X* - sensor made by 2-stage deposition, with significantly different energy of material pulses at each stage; sensor was stimulated by visible (546 nm) light. All other sensors were stimulated with UV (360-385 nm) light. The gas concentrations were typically at 100 ppb level for NO_2 and SO_2 and at 10 ppm level for CO and NH_3.

The sensor structures with TiO_2 deposits were optimised for NO_2 sensing in the typical range for outdoor concentrations of this gas. The sensors had Langmuir-type response [3] (Figure 1), low cross-sensitivity to humidity, and high stability over 6-month observation period. Performance benchmarking was made with sgx Sensortech (e2v) model 4514 MOX sensor (Figure 2). Whereas the response to NO_2 gas in <100 ppb range was practically same for both sensors, the influence of humidity was significantly smaller in case of graphene sensor.

Oral Presentation

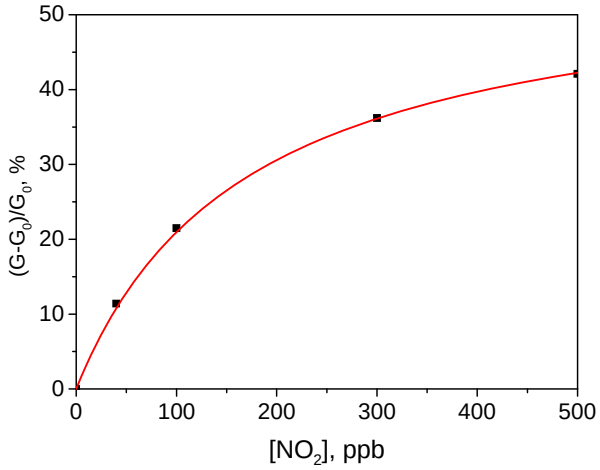

Figure 1. Response (relative change of electrical conductance) of PLD-modified single layer graphene sensor to NO_2 gas. Modifier – TiO_2 with average thickness of 0.35 nm. Measurements were made at room temperature under illumination with 385 nm LED.

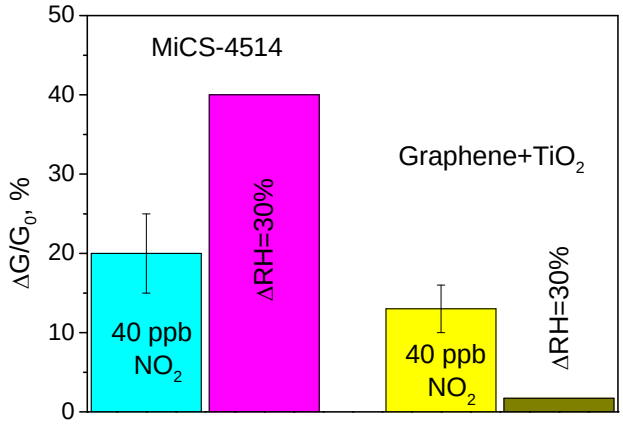

Figure 2. Comparative responses of MiCS-4514 and graphene/TiO_2 sensors to 40 ppb of NO_2 and to relative humidity change (from 20% to 50%). The absolute values of responses together with error bars are shown.

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Oral Presentation

METAL LOADED TITANIA NANOSTRUCTURES FOR AIR QUALITY SENSORS

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Abstract

Metal oxide materials can be loaded, making them more useful for any application, especially gas sensor. To improve gas sensing properties of metal oxide materials, they can be loaded with Pd [1], Au [2], Co, Cu [3], and Ag [4].

In this study, we fabricated to TiO_2 nanowires loaded by different type of catalytic materials. Hydrothermally fabricated TiO_2 nanowires were loaded Cobalt (Co), Nickel (Ni) and Palladium (Pd) via cathodization, hydrothermal and chemical vapor deposition (CVD) methods, respectively. The diameters of TiO_2 nanowires were about 60 nm. The samples were characterized by X-ray diffraction (XRD) and scanning electron microscope (SEM). After structural analysis, gas sensing properties of these nanostructures were investigated at desired temperatures. H_2 sensing properties of TiO_2 nanowires loaded by Co and Ni were given in **Figure 1**. The all results showed that Pd loaded TiO_2 nanowires were more sensitive against measured gases than Ni and Co loaded TiO_2 nanowires.

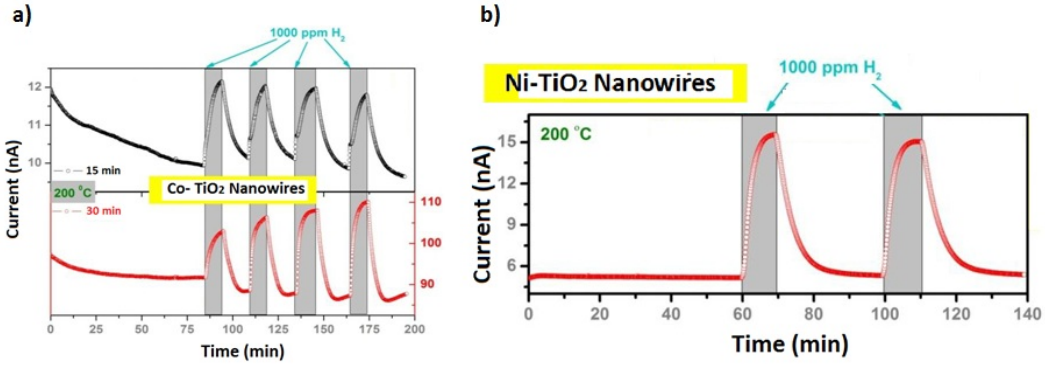

Figure 1. H_2 sensing properties of TiO_2 nanowires loaded by **a)** Co **b)** Ni.

Acknowledgement: This study was supported by The Scientific and Technological Research Council of Turkey, project numbers "111M261".

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Oral Presentation

MONITORING OF HYDROCARBON CONTAMINATION AND EMISSION FROM WATER USING PERVAPORATION MEMBRANE UNIT AND MOX SENSORS

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Abstract
Monitoring of hydrocarbon contamination of water, detection of gas leakage from underwater pipelines, and delimitation of oil and gas field in water seem to be important problems because of green-house action of hydrocarbons (methane in particular) in Earth atmosphere. This monitoring is also important for the surveillance of the state of underwater pipelines and for exact delimitation of oil and gas fields. In this work, we tried to develop an approach related with the application of tubular pervaporation membranes and metal oxide gas sensors for the detection of gases dissolved in water.

The work presented here is a continuation of the research published in [1-3]. In these previous publications we considered the properties of different types of pervaporation membranes, which served for the separation of gases dissolved in water. In that works we used two types of membranes: polymeric membranes made of polydimethylsiloxane (PDMS) and ceramic TiO_2 membranes hydrophobized by fluorinated silanes $C_6F_{13}C_2H_4Si(OEt)_3$ (C6) and $C_{12}F_{25}C_2H_4Si(OEt)_3$ (C12). The contact angle of ceramic membranes was determined as 148^0 and 135^0 for C12 and C6 materials, respectively. 75-195 micron PDMS membranes are characterized by water permeability coefficient equal to $7.34 \cdot 10^{-15}$ $mol \cdot m^{-1} \cdot Pa^{-1} \cdot s^{-1}$. The membrane is selectively permeable for hydrocarbons. The enrichment coefficients for water-hexane and water pentane mixtures are equal to 120 and 75, respectively. For the demonstration of the applicability of this approach, we designed and fabricated a set-up consisting of plain pervaporation membrane separating gas chamber with metal oxide gas sensor from water volume containing distilled water saturated with methane. It was shown that methane saturation of water leads to a decrease in sensor resistance by a factor of 6-7, the response time of the system is of 200-300 s.

However, this set-up used for the demonstration of the effect and estimation of signal levels and permeability of the membrane is not suitable for the fabrication of the real instrument. In the actual research we designed an experimental set-up consisting of tubular membrane unit and gas sensor. The scheme of the set-up is presented in Fig. 1.

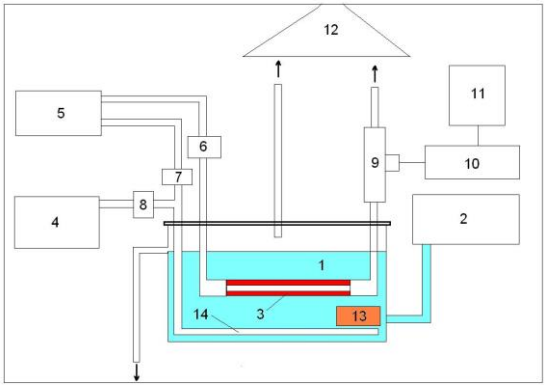

Fig. 1. The scheme of the set-up used for the study of hydrocarbon content in water. (1) cell with water; (2) water tank; (3) porous ceramic tubes with hydrophobic coating; (4) cylinder with methane; (5) generator of purified air; (6-7) air flowmeters with valves; (8) methane flowmeter; (9) gas sensor cell; (10) voltage source and ohmmeter for the measurement of MOX sensor response; (11) computer; (12) fume hood; (13) pump for water stirring; perforated tube for gas mixture bubbling through water.

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In the experiment we used two types of porous ceramic tube: ceramic tubes made of alumina ceramics with 10 μm pores and alumina tube with additional coating made of titania with pore size of 0.1 μm. These tubes were hydrophobized in two ways. The first one was an impregnation with a fluorocarbonic liquid. The molecules of this liquid contained alcoxyl head bonded to fluorocarbonic queue. The head chemically bonds with the surface of ceramics, and the queue insures hydrophobic properties of the surface. Thickness of this coating is of 2 – 3 nm. Another method of hydrophobization is the surface coating of the tube with PTFE film. Thin polymer coating was deposited onto the surface of the tube by electron-beam dispersion of PTFE powder in vacuum [4].

First question, which should to be answered is the optimization of the carrier gas (air) flow through tubular membrane unit. In the experiments, we used 60 cm long tubes with external diameter of 10 mm (wall thickness 2 mm). The plot demonstrating the gas sensor response as a function of carrier gas flow rate (gas residence time in the tube) is presented in Fig. 2.

In next experiments, we investigated how the concentration of methane bubbling through water affects the sensor response. The concentration of methane in these experiments was in a range from 0.1 to 100 % in air. An example of the plots demonstrating this dependence for the ceramic tube with titania coating is presented in Fig. 3.

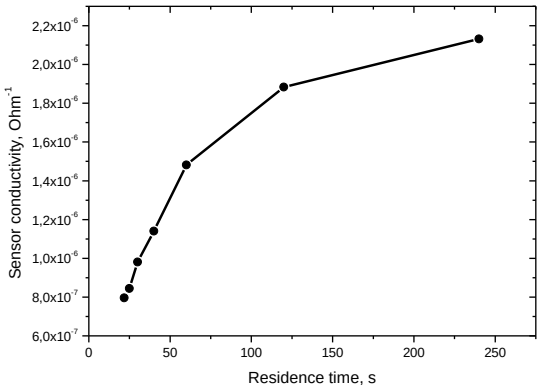

Fig. 2. MOX sensor (SnO_2+3wt.% Pd) response as a function of residence time of carrier air through tubular membrane unit. Working temperature of the sensor is of 450_0C. Methane concentration bubbling through water is of 1.26 %.

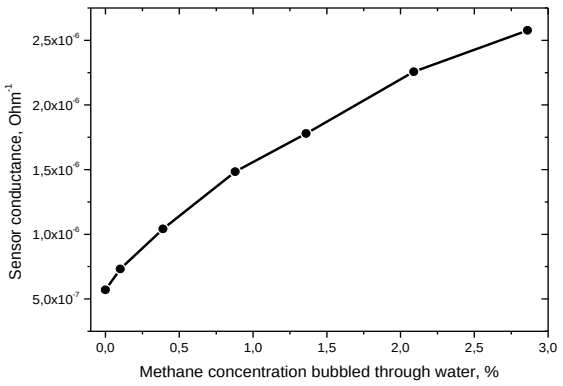

Fig. 3. Sensor response as a function of methane concentration bubbling through water. The sensor is the same as in Fig. 2. Sensor conductivity corresponding to 1 % of methane in air is equal to $6.8 \cdot 10^{-5}$ Ohm^{-1}.

The best results were obtained with the application of hydrophobized ceramic membrane with titania coating. However, even in this case, methane concentration in carrier gas differs from the concentration bubbling through water. Further optimization of the unit design is necessary to improve gas permeability of the membrane unit.

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Oral Presentation

WHAT BRINGS FORMALDEHYDE'S CONTINUOUS MONITORING TO THE ANALYSIS OF BUILDING'S AIR QUALITY AND WAYS TO MANAGE/IMPROVE IT ?

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Abstract

As air pollution becomes a visible issue, air quality has been raising in the public opinion, where before it was only an expert's topic. This was observed first for the outdoor air, but became in the last decade also a concern for public health in indoors (home, offices, buildings…).

Formaldehyde is the major indoor air pollutant. Not only is it a 1B category carcinogenic classified compound, it is also the most volatile Organic Carbon (VOC). In addition, Formaldehyde, is a specific Indoor Air Quality (IAQ) marker, as it is not present outdoor, and vastly used in the home furniture's (paints, floor covering, wood items…) and products (cleaners/disinfectants, or perfume's diffuser).

During the last decades, building's construction introduced new standards for the ventilation systems: Reducing air exchanges with the outdoor, necessarily reduces energy lost, thus optimizes the global energetic balance of the building. But in the same time it raises indoor air pollutant concentration, and the need to monitor pollutant concentration. As these systems are working differently depending on day vs night, and week days vs weekends, it becomes relevant to extend pollutant measurements, with appropriate periodicity, continuously during a full week.

Measuring Formaldehyde concentration faces 2 main issues: 1) Average concentration is bellow 50µg/m^3, and target value is below 20µg/m^3, a very low level difficult to measure accurately. 2) Most of measuring methodologies detect aldehydes and are not differentiating Formaldehyde from other aldehydes or even other VOCs, interfering in the reading.

The reference methodology (DNPH) is using an absorbent material, exposed to the air, for a fixed duration (from 15 minutes in an active flow exposure - with a pump - to a full week in the passive exposure). After the exposure, the samples have to be stored a low temperature (2-8°C) and quickly shipped to an analytical lab, where desorption is performed before chromatography analyse is done.
This method is providing only an average value of the concentration during the exposure.

Ethera is a startup that develops the applications of a technology patented by a CEA/CNRS French Academic lab, directed by Dr Thu-Hoa Tran-Thi. This technology is using the unique properties of a nanoporous materials, structured in a Silica matrix, in which a probe molecule is inserted in every nanopore, to provide specific functions. The chemical affinity of the probe molecule generate a reaction with the pollutant, and an optical density change at a specific wavelength is used to quantify the reaction, thus the pollutant concentration is calculated. The performances of this technology where demonstrated and shows excellent sensitivity, accuracy and specificity.

Oral Presentation

This technology is used for several years, in a similar mode to the DNPH method : dynamic sample using a pump (15 minutes exposure), or using a passive exposure chamber for a week exposure. Recently this nanoporous technology was adapted to allow an Optical Density reading as the material is still in the exposure module. Having the reader driven by an embedded software, allow continuous reading during all exposure period.

The sensor was calibrated for a Formaldehyde concentration range of 0 to 150µg/m^3, with a sensibility of 4µg/m^3. At 50% RH, the system is validated for 7 days, showing an error of 2% compare to the active DNPH value (Supelco) and a 12% compare to the passive DNPH value (Radiello). This mean an error that is contained within the reference method uncertainty. Influence of temperature and relative humidity were characterized and automatic correction is now performed by the equipment. The Formaldehyde sensor is associated on a chip, with other classical sensors (temperature, relative humidity, CO_2 and light VOC) and all data are recorded and transmitted to a cloud center accessible from anywhere.

Measurement campaigns have been conducted, and provide very interesting data, showing the variation of formaldehyde concentration during the days vs nights and also weekends, thus the integration of occupants presence and real exposure to the pollutant. Most of the variation can be associated with the operation and the efficacy of ventilation systems.

Indoor Air Quality campaign coupled with global building's energy consumption, will provide appropriate data to optimize the balance between energy saving and occupant's health.

Figure 1 YEMo

Oral Presentation

CMOS INFRARED EMITTERS AND DETECTORS FOR ENVIRONMENTAL MONITORING

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Abstract

Infrared (IR) method of gas sensing for environmental monitoring has long been established to be one of the most reliable ways measure the target gases with good selectivity, sensitivity, speed and stability [1]. However, to achieve such performance require complex optics and signal processing solutions, together with sophisticated compensation techniques to minimise drifts due to ambient temperature, humidity and pressure variations [2]. The IR environmental monitoring systems are therefore usually bulky and expensive when compared with other solutions such as electrochemical or metal-oxide sensor. Amongst the key components that determine the performance of an IR gas sensor are the emitters and detectors [3]. The main principle used for IR method of detecting gases is based a technique known as non-dispersive IR (NDIR) concept [4]. Here, gas sensing is achieved by measuring the absorption of molecules at a given wavelength at IR range. For most environmental gases such as CO, SF_6, CO_2, CH_4, NO, NO_x etc. typically found to have good absorptions between 2 to 12 µm wavelengths [3], thus detecting gases by IR method is considered to be a preferred alternative option where measurement accuracy is important. However, to detect such gases at low concentration level, for example NO_2, at 50 ppb level, require long path length (in excess of 10's meter, depends on the response time and sensitivity) as a result not only IR emitter with high output power is required, but also a detector (or detectors) with high responsivity and low noise is needed [5]. Furthermore, the optical path with highly reflective surface is needed to collimate and reflect light in the gas sampling cell to ensure efficient and compact overall design. There are essentially three types of IR sources and detectors that are commonly used for such applications. IR sources: Lasers; LED and heat source; and for detectors: Pyro; Thermopile and Micro-bolometers. Table 1, gives a summary of the key differentiations between state-of-the-arts IR emitter and detector technologies. In this presentation we will explore all these options and show that, CMOS, MEMS IR emitters and detectors provides a viable alternative for future environmental monitoring (see Figure 1) to enable low cost and compact solutions. It is true to state that for some applications, optical power generated by CMOS, MEMS IR emitter will not match that of QCL, however, enhancements to emissivity and absorption can be made by exploiting CMOS process layers to improve the performance of the devices [6]. Furthermore, with correct optics together with surface-mount package devices, using MEMS IR technology together with on-chip signal processing circuitries provides opportunities for innovative low power, miniature solutions in order for such sensors to be integrated within a smartphone or wearable devices in future.

Type	Power	Spectrum	Directivity	Cost	Freq	Filter
Thermal	Medium	Wide	Low	Low	Low	Yes
Mid-IR LED	Medium	Narrow	Med	Med	Medium	No
IR Laser	High	Very Narrow	High	High	High	No

(a) Types of IR Emitters

Type	Spectrum	Cost	Freq
Thermopile	Wide	Low	Low
Pyro-Detector	Narrow	Med	Medium
Microbolometers	Very Narrow	High	High

(b) Types of IR Detectors

Table 1: Comparative summary of IR emitter and detector technology options

Oral Presentation

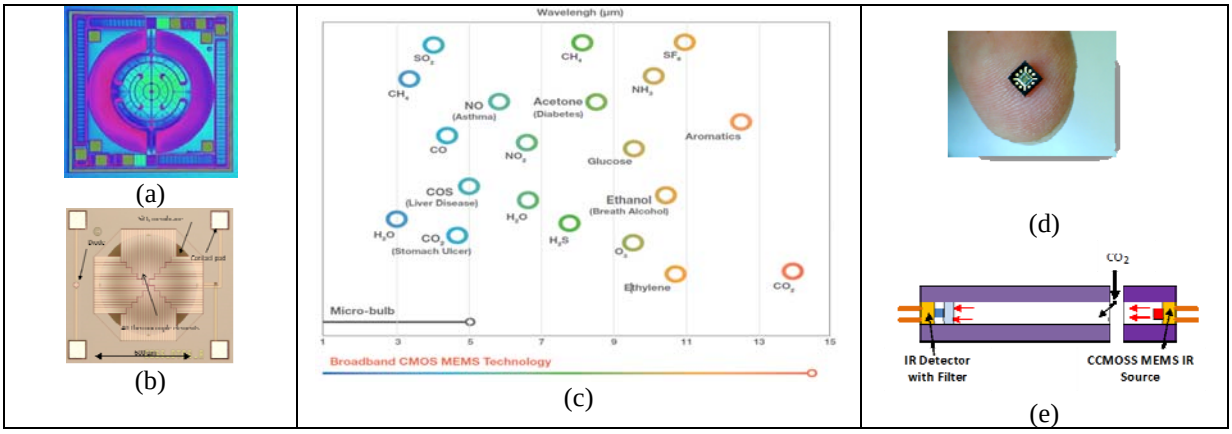

Figure 1. CMOS MEMS IR devices (a) Emitter; (b) Thermopile detector; (c) Mid-IR range applications; (d) SMD package options; (e) Typical NDIR sensor construction

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Oral Presentation

CONCEPTS FOR MOBILE SENSING OF INORGANIC NITROGENOUS POLLUTANTS IN EXHAUSTS AND THE ATMOSPHERE

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Abstract

Besides greenhouse gases and nanoparticles, nitrogenous pollutants emissions are the most critical emissions of combustions processes. Virtually any high-temperature combustion processes relying on air as one reaction component, i.e. industrial furnaces, heaters and combustion engines alike, emits nitrogen oxides NO_x (NO, NO_2 and N_2O) in varying quantities and relative compositions. The problem has been intensified in recent years by the trend towards lean combustion, i.e. the minimisation of fuel use to reduce CO_2 emissions, which in turn increases the amount of generated and subsequently emitted NO_x. Various approaches for exhaust treatment have been suggested and implemented that can effectively reduce NO_x emissions but at the same time introduce new nitrogenous compounds, in particular ammonia (NH_3). All these nitrogenous compounds are reactive, and hence more or less respiratorily toxic, and actively involved in the production of low-level ozone. Both effects call for a close monitoring at both the emission sites and in the atmosphere, creating an urgent need for portable analysers - preferably sensors - that are both selective and sensitive.

State of the art analysers (chemiluminescence detectors and absorption spectroscopy) are sensitive and selective, but typically limited to stationary applications. Consequently, a number of different sensing approaches have been researched and published in the literature, with resistive transducers equipped with metal oxide redox-layers being the predominant approach. While extensively researches worldwide, the present performance of such devices still leaves room for improvement and alternative approaches. With its partners, CTR is hence engaged in researching a number of different methods for sensing of nitrogenous substances, both within the Austrian COMET Competence Centres for Excellent Technologies Programme and beyond.

A first approach researched in a joint effort involving also two Austrian industry partners is a combination of analyte-sensitive, noble metal-doped metal oxide layer with an SAW (surface acoustic wave) element as transducer. The reasons for applying an SAW transducer are *i*) a high-temperature applicability up to 650°C, which allows varying the layer temperature over a wide temperature range and/or positioning the sensor right in an exhaust stream and *ii*) the potential of realising maintenance-free wirelessly RF interrogable sensors. Additional advantages are an integrated temperature sensing functionality of the SAW and the possibility to realise the sensors in highly compact, multiplexed form, e.g. to increase selectivity by differential response detection. The experimental evaluation of the approach yielded particularly high analyte sensitivity down to less than 0.5 ppm(v) when exploiting the effect of analyte-layer interaction on the acousto-electrical coupling. Still, a limiting factor proved the selectivity and the analytical capacity of the sensing layer. Although in particular Au-doped WO_3 thin layers yielded very interesting results, cross-sensitivities to other oxidising substances still occur. Furthermore, if exposed to oxidising substances only (as is often the case with exhaust gases from lean combustions), the layers at some point go into saturation and need to be regenerated by exposure to a reducing agent.

Oral Presentation

A second, fundamentally different approach currently under investigation aims at direct sensing of the analytes of interest by interrogating substance-specific optical properties. For the analytes of interest here, UV/short-wave VIS and the mid-IR range are of interest. Such methods are already in use for the purpose, but in stationary instruments.

One highly sensitive option of detecting nitrogen oxides optically is by their UV/VIS absorptions. The key approach to adapt the established principles to use in mobile, decentralised analysers is to adapt the instrumentation, in particular the opto-electronics. For NO_2, which features a broad absorption band in the blue – long-wave UV with little interferences, this can be conveniently achieved by using blue light / laser sources. More complex is the situation with NO. Although the analyte features three intense, narrow-band absorption bands in the UV, only few compact, robust and energy-efficient light sources exist for the respective wavelength range. Furthermore, the bands may be at least partially obscured by interferent absorptions, and the two other key analytes of interest – N_2O and NH_3 – are not directly detectable in the UV/VIS. Still, this approach is probably the optical method that is presently closest to an actual application in mobile sensing.

The highest analytical selectivity and full coverage of all four key analytes can finally be achieved when reverting to measuring fundamental vibrational transitions and thus the mid-infrared region (2.5 – 20 µm). The established methods use long-path transmission cells coupled to fully spectroscopic (FT-IR) analysers. Despite recent developments towards compact, MEMS-based FT-instruments, this approach is hardly compatible with sensing. The key points to be addressed are hence

i) the selection of optimal spectral ranges / wavelength for interference-free detection and quantification of the analytes,
ii) the identification of suitable IR radiation sources that could either be used in classical non-dispersive layouts with one measurement and one reference wavelength, or spectrally modulated across an absorption band, and
iii) the use of new interaction and/or detection layouts to minimise the interaction pathlengths required for sensitive detection at trace levels.

Regarding the use of suitable light sources, the most promising approach is the use of quantum cascade lasers (QCLs). Such devices are nowadays available for different wavelengths, including suitable wavelengths for all target analytes. A particular advantage here is the possibility to scan the lasing wavelength across a limited wavelength range, using either a tuneable external cavity or by using the inherent heat-up of the laser in pulsed mode. Either method allows scanning the interrogation wavelength across an entire gas-phase absorption band, thus detecting both the analyte and the background in one sweep. QCLs are already used in commercial products, but their more general use in portable sensors is currently limited by *i*) the price and *ii*) the power consumption of such devices. Still, QCLs are regarded as a hope market for future sensors, with some manufacturers targeting a use in mass applications like smartphones. Regarding the interaction and detection part, finally, two options are currently under investigation by CTR and its partners: *i*) the use of photonic structures to intensify the interaction of the radiation with the analyte and thus minimise the effective size of the sensor and *ii*) the use of alternative detection principles, including resonantly enhanced photo-acoustic detection.

Overall, also given the increasing public awareness of the problem, the selective and sensitive sensing of nitrogeneous pollutants remains an open and dynamic research field that is expected to see substantial further collaborative academic / industrial R&D activities in the future.

Invited Talk

AIRSENSEUR: AN OPEN-SOURCE MULTI-SENSOR PLATFORM FOR AIR QUALITY MONITORING

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Abstract
The use of low-cost sensors by laboratories in charge of ambient air monitoring for regulatory purposes or by citizens is quickly developing. At the same time, low-cost sensors raise strategic questions including the assessment of the quality of the information provided by those devices, the localization and identification of the micro-environments being sampled and the automatic reporting of this information so that it is available for all stakeholders using near to real time web services.
Although several sensor systems have appeared in the last years, generally the developers do not have the capacity to tackle the whole set of open questions regarding sensor systems. Currently air pollution using low cost sensors involves fast growing companies and/or public institutes specialized in digital technologies. Unfortunately, a great deal of effort is wasted by repeating the same research by several companies/institutes or within research projects. Moreover when a solution for one of the problem listed above is found, it is generally subjected to the control of the intellectual property rights.
In order to facilitate the use of sensors by diminishing the operational and development cost, the Joint Research Centre (JRC) is developing a multi-sensor platform, called AirSensEUR, for the monitoring of air pollution at low concentration levels. All development aspects owned by JRC about AirSensEUR are made freely available through the use of public licenses. AirSensEUR is developed as an open software/open hardware object that has the capacity to behave as a node within a network of multi sensors assuring interoperability and compliance with the INSPIRE Directive [1]. We strongly believe in such a common and participative plan for the establishment of a scientific community both of interested users and/or developers joining forces to build a validated sensor system.
The JRC objective is to build both the AirSensEUR host platform able to simultaneously control several sensor shields and to develop the first sensor shield for air pollution sensors to be connected to the host.
The host integrates functionalities shared by sensor shields including GPS positioning, Linux operating system and programming languages to control a list of I/O ports used by the shields (COM, USB, SPI, I2C, PWM …) with sufficient RAM, CPU computing capacity and a micro-SD storage up to 64Gb. Twined with the host platform we designed the 1st AirSensEUR sensor shield for air pollution monitoring based on electrochemical sensors. Figure 1 gives the flow chart of the AirSensEUR platform with the whole set of functionalities that is planned to develop.
The development of the sensor shield (block A1) and host (A2) is now completed. The shield allows testing a wide set of amperometric sensors commercially available. We are finishing designing the handling boxes, also distributed under public license. The laboratory evaluation and calibration of the sensor shield was carried out for the O_3, NO_2, CO and NO City Technology sensors (block A3). More evaluation should be carried out in particular for filtered or other more sensitive sensor brands and models.

Invited Talk

The data transfer to a server backend (blocks B1 and B2) has been developed in compliance with the requirements of the INSPIRE Directive [1] using the Sensor Observation Services SOS interface standard [2] and it is in validation stage.

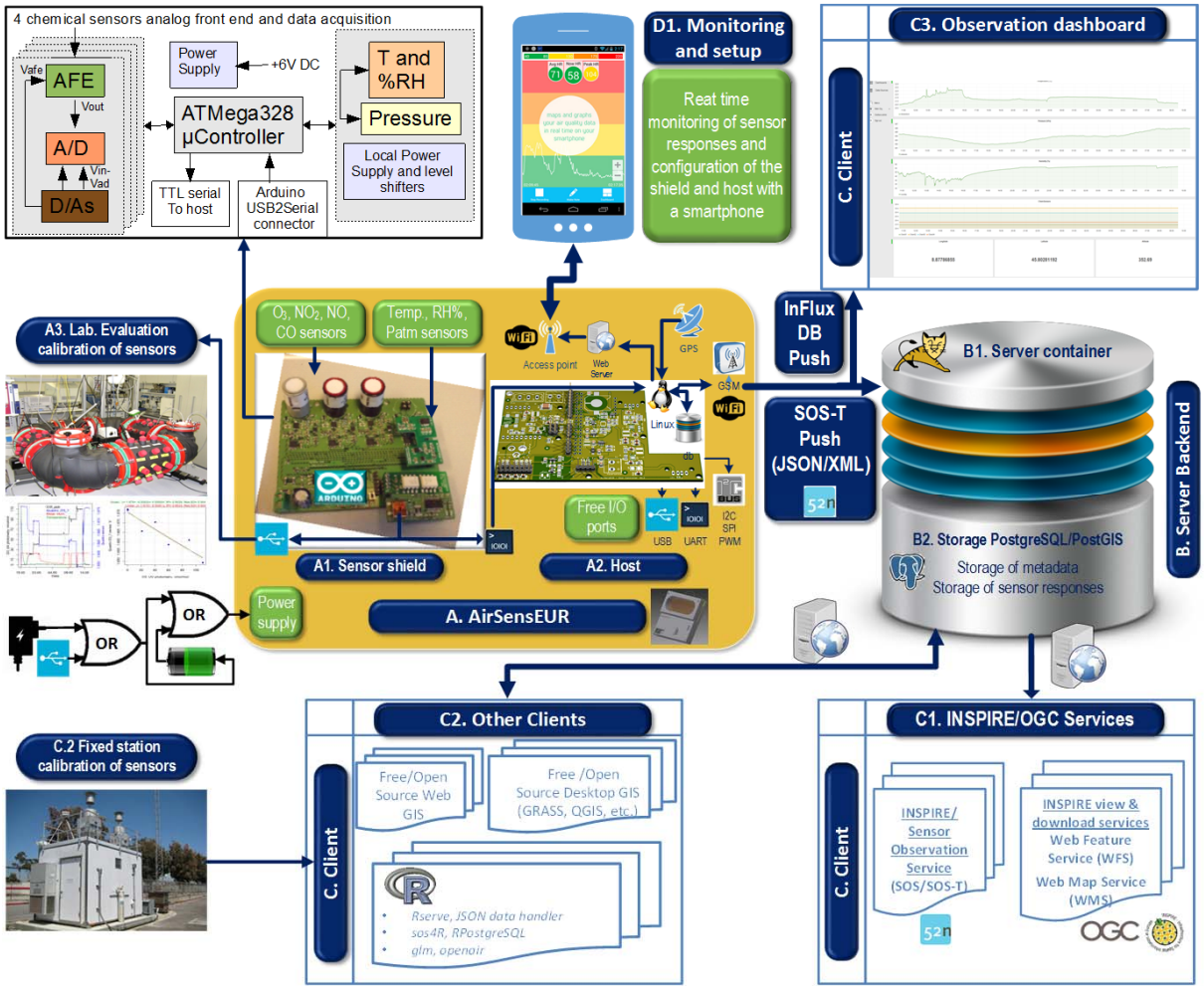

Figure 1: Schematic diagram of the AirSensEUR platform

The architecture of AirSensEUR based on well-established free and open source software, also includes an Inspire view (through a Web Map Service - WMS), download services (block C1) and the web observation dashboard (block C3) that gives the possibility to visualize time series plots of data stored in the PostgreSQL database (block B) need be developed though they should require limited effort to be set up.
The block C2 in Figure 1 is about the development of algorithms for the correction of sensor measurements based on the reference measurements of automatic stations or using the results of laboratory experiments in exposure chamber (block A3).
The host can act as an access point. A local web server allows configuring each sensor channel data acquisition and monitoring the sensor shield responses and the data stored in the host data base (block D1).

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Invited Talk

FP7 PROJECT MSP - MULTI SENSOR PLATFORM FOR SMART BUILDING MANAGEMENT: STATUS AND PROGRESS

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Abstract
The three-year FP7 project MSP - Multi Sensor Platform for Smart Building Management started on 1st September 2013. Materials Center Leoben (MCL), an Austrian COMET K2 Competence Centre, coordinates this € 18 million project that is designed to strengthen the leadership of European industries in the highly competitive area of smart sensing systems in wireless mobile and building applications.
The MSP consortium[2] comprises large and small companies, universities and public research centres from 6 European countries. The 17 partners include: Materials Center Leoben, ams AG and EV Group (EVG) from Austria; ams Sensor Solutions Germany GmbH (previous Applied Sensors), Fraunhofer Gesellschaft (IISB and IIS), Siemens AG and the University of Freiburg from Germany; Boschman Technologies B.V. and Holst Centre from the Netherlands; the University of Oxford, the University of Cambridge, the University of Warwick, Cambridge CMOS Sensors and Samsung R&D Institute UK from the United Kingdom; the University of Louvain and Vito from Belgium; and Universitá degli studi di Brescia from Italy.
The MSP project is focused on the development of sophisticated devices and sensors as elements of a "tool-box" that are required for the realization of innovative smart multi-sensor systems capable for indoor and outdoor environmental monitoring:
Gas sensors for detection of potentially harmful or toxic gases

- Sensors for particulate matter and ultrafine particles
- Development of IR sensors for presence and fire detection
- Development of highly efficient photovoltaic and piezoelectric devices for energy harvesting
- Development of light sensor and UV-A/B sensors
- Development of humidity and temperature sensors.

Major objective is the development of a powerful technology and manufacturing chain enabling flexible "plug-and play" 3D-integration of devices and sensors on CMOS electronic platform chips. The MSP concept is based on rigorous employment of Through-Silicon-Via (TSV) technology and relies wherever possible on CMOS technology being the sound foundation for cost efficient mass fabrication. The multi-sensor system will include devices providing wireless communication between MSP nodes and from MSP nodes to users. By integrating different types of devices and components from the "tool-box" the following MSP demonstrator systems will be realized:

- MSP Device for Smart Building Management
- MSP Device for Wearable Wristwatch Application
- MSP Device for Outdoor Environmental Monitoring.

The requirement specifications have been defined by the end-users Siemens and Samsung in cooperation with all other partners according to the target applications. The relevant target gases are CO, CO_2, VOCs (Volatile Organic Compounds), O_3 and NO_2; in addition particulate matter, UV-A/B radiation as well as IR emission from humans will be detected.

Invited Talk

Lot of progress has been achieved in the development of components and sensors. Gas sensors ranging from commercially available products and demonstrator systems to highly sophisticated devices based on graphene and nanowires (NWs) have been developed. Particular emphasis has been put on CO_2 sensing, which is of essential importance for SBM applications.

Most important achievments are:

- Development of portable data logger including MOx sensors
- ZnO-NW-gas sensor array integrated on CMOS-fabricated µhp-chips
- High response of CuO-NWs/$BaTiO_3$-NPs hybrid sensor to CO_2 almost independent of the humidity level
- High response of CexZryO2 oxide based Kelvin Probe gas sensor to CO_2 at different levels of humidity
- Development of AlGaN/GaN-gas sensors for low ppb NO_2 detection
- Graphene-based gas sensor fabricated on a µhp chip by PDMS transfer process with high sensitivity to formaldehyde
- Particle sensor based on ASIC-FBAR to form a SiP
- Fabrication of Demo-Kit infrared thermopile device for people presence detection implemented on USB stick
- The UV sensors based on SiC with very high visible-to-UV-rejection ratio (~60 dB)
- Optimization of P(VDF-TrFE-CTFE) based piezo energy harvester with enough output power for driving 44 LEDs forming the MSP-letters
- Fabrication of Demo-Kit frontside photodiode device with 6 TSVs connections to the backside, which is solder ball bonded on a PCB.

Extensive characterization and test measurements have been performed both in the test labs of the individual sensor developers as well as in the specialized test labs of Siemens and Vito. Two generations of CMOS-Platform Chip (PC) have been developed; the 1st Generation PC has been already realized and is able to communicate with all sensor devices. The PC provides pads for 3D-stacking of sensor devices and is designed to provide high flexibility, which was demonstrated by successfully operating all available sensor devices.

Lot of progress has been achieved in development of data processing and wireless communication modules. Based on the MSP requirements, a wireless system level architecture has been developed. The 2.4GHz multi-standard radio supports Bluetooth V4.0 (also known as Bluetooth Low Energy or Bluetooth Smart), as well as the IEEE802.15.4 (also known as. ZigBee) and is designed to achieve best-in-class performance at world's lowest power consumption.

The MSP team has successfully elaborated the full manufacturing chain flow including molding for D2D and D2W system integration. Due to technological restrictions several sophisticated devices such as the GaN-based gas sensors cannot be fabricated with TSVs. The 3D-integration concept thus includes both devices with TSV-based contact plugs as well as components requiring wire bonding, and enables realization of a "hybrid" 3D-integrated encapsulated MSP demonstrator system. The sensor devices, which will be finally integrated on the CMOS-Platform chip Gen2 PC2 have been fixed. A total of 12 sensor chips will be finally integrated on Gen2 PC2. This work is well in progress.

ABSTRACTS OF POSTER PRESENTATIONS

Poster Presentation

LONG-TERM TRENDS IN CONCENTRATION OF SO_2 NEAR COPPER SMELTER BOR - SERBIA

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Abstract

The SO_2 is one of the most important air polluters. Anthropogenic emission of SO_2 results from burning the fossil fuels (coal and heavy oils) or smelting of sulphide ore concentrates (most frequently Cu, Pb, and Zn ores). Monitoring the mass concentrations of SO_2 is very important having in mind that SO_2 gas has a negative effect on human health, especially to the health of childrens and older persons. Due to the certain negative effect of SO_2 in the atmosphere, European Union limits its mass contents [1, 2].
The aim of this paper is to present long-term trends in SO_2 mass concentrations (analysis of data between 2001 and 2015) in the near vicinity of the copper smelter in Bor, the Republic of Serbia. The town of Bor, with about 40,000 inhabitants is situated in eastern Serbia, 220 km away from Belgrade and about 30 km away from the Bulgarian border. The main source of air pollution with SO_2 and toxic metals and metalloids in PM is the Copper Smelter Bor, part of the RTB Bor Company (Copper Mining and Smelting Complex Bor) [3, 4].

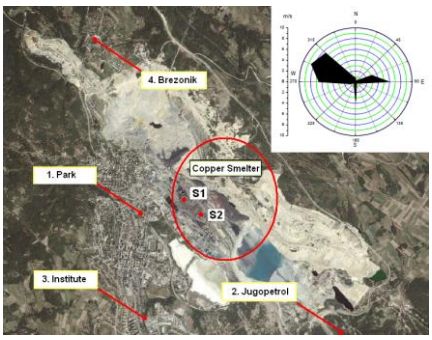

Figure 1. Map of the Bor town area together with the locations of the copper smelter, air quality monitoring stations (1.Park, 2.Jugopetrol, 3.Institute and 4.Brezonik) and the wind rose diagram (2001-2015) [5].

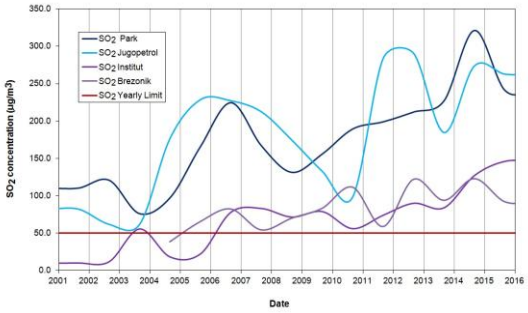

Figure 2. Yearly means of SO_2 mass concentration in the Bor town area (2001-2015)

The town was built in the near vicinity of the copper smelter, as shown in Figure 1, and represents a serious environmental hot spot in the Republic of Serbia and Europe as well. There are two tall smokestacks in the copper smelter (marked as S1 and S2 in Figure 1). In the present study, we have analyzed daily mean SO_2 concentrations and a number of days

with SO_2 concentrations over the daily limit (125 μg/m^3). The analysis includes data collected in the time interval from 2001 to 2015 from the four monitoring stations (Park, Jugopetrol, Institute, and Brezonik) that are situated in a wider town area, as shown in Figure 1. It was proved that the exceedings of daily limit for SO_2 usually occurs due to very high SO_2 concentrations in a period of several hours a day. According to data gathred in Table 1, during the period, 2001-2015 exceeding of the daily limit value of SO_2 concentrations has occurred at all monitoring stations, at some sites even over 245 days a year (3 days allowed [1]).

Table 1. Number of days with SO_2 concentrations above the daily limit value (- no data) and Cu production in the copper smelter Bor (2001-2015)

Year	SO_2 Park	SO_2 Jugopetrol	SO_2 Institute	SO_2 Brezonik	Cu production (t)
2001	142	89	-	-	32400
2002	123	40	5	-	35900
2003	39	28	28	-	14000
2004	67	84	9	-	12000
2005	119	155	21	8	31300
2006	132	144	25	32	41400
2007	109	150	20	51	31200
2008	69	126	22	36	33700
2009	36	83	-	18	27400
2010	34	77	60	44	22200
2011	163	138	68	52	28449
2012	151	201	94	109	34650
2013	172	195	74	-	35840
2014	245	245	176	-	33175
2015	204	214	169	-	44646

It could be noted that the citizens of Bor were exposed to the high concentrations of SO_2 and not so rare to the extremely high concentrations in the time interval from 2001 to 2015. The SO_2 concentration levels in the Bor town area exceeded the corresponding Serbian and European Union air quality standards. The annual average concentrations of SO_2 observed at Park and Jugopetrol are the greatest in the Republic of Serbia and in Europe as well. Therefore, Bor Municipality area is considered as one of the most polluted regions with SO_2 in Serbia and in Europe as well. The copper smelter activities, coupled with calm weather are responsible for high SO_2 concentrations in the ambient air. This situation of ambient air quality in the Bor town is serious and needs immediate measures to improve.

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Poster Presentation

INDOOR ENVIRONMENT AND RESPIRATORY HEALTH OF OLDER PEOPLE IN ELDERLY CARE CENTERS

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Abstract

Background: This cross-sectional study explored environmental variables and buildings characteristics in 22 elderly care centers (ECC) in Portugal. The influence of indoor air quality (IAQ) and contaminants on older people's respiratory health was also evaluated.
Methods: Indoor environmental parameters were measured twice for a total of 141 sampling sites. Each site was assessed for PM_{10}, $PM_{2.5}$, total volatile organic compounds (TVOC), formaldehyde, CO, CO_2, total bacteria and fungi. Thermal comfort (TC) parameters were measured according to ISO 7730:2005 and a building characterization was performed. The Portuguese version of BOLD questionnaire was administered by an interviewer to older residents able to participate (n=143). Mixed effects logistic regression models were used to study the association between the health questionnaire results and the monitored IAQ, adjusted for age, smoking habits, gender and number of years living in the ECC.
Results: The overall $PM_{2.5}$ mean concentration was above international reference levels in summer and winter seasons. TVOC, bacteria, CO and CO_2 showed significantly higher indoor levels compared to outdoor, in both seasons. Indoor PM_{10}, TVOC, bacteria and CO_2 present significant differences between seasons. TVOC, bacteria and CO2 show significant variation between ECC rooms and 4% of fungi samples were positive for pathogenic Aspergillus species. The winter predicted mean vote (PMV) index showed a 'slightly cool' thermal sensation scale which may potentiate respiratory tract infections. The predicted percent of dissatisfied people (PPD) and PMV indices show significant differences by season. Cough (23%) and sputum (12%) were the major respiratory symptoms, and allergic rhinitis (18%) the main self-reported illness. Older people exposed to PM_{10} above the reference levels demonstrated higher odds of allergic rhinitis (OR = 2.9, 95% CI: 1.1 – 7.2).
Conclusion: High levels of PM_{10} were associated with 3 fold odds of allergic rhinitis and some concern is raised by the presence of pathogenic microorganisms.

Keywords: indoor air quality, thermal comfort, older people, elderly care centers, allergic rhinitis.

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Poster Presentation

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Poster Presentation

PERYLENE - BASED MSDI HETEROJUNCTIONS FOR AMMONIA SENSING IN GENUINE ATMOSPHERE

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Abstract
New organic devices, namely Molecular Semiconductor-Doped Insulator (MSDI) heterojunctions have been proposed as new transducers for gas chemosensing. They are built around a heterojunction between the thin film of a molecular semiconductor (MS), the lutetium *bis*phthalocyanine complex ($LuPc_2$) and the thin film of a doped-insulator (DI) material, the pefluorinated copper phthalocyanine ($Cu(F_{16}Pc)$) or perylene derivatives. In contrast to resistors, the MSDI exhibit non-linear but symmetrical I(V) characteristics as a result of the energy barrier at the interface between the two layers. Even though the only material in contact with the atmosphere is a p-type material ($LuPc_2$), the current across MSDI increases when exposed to a donating species like NH_3. Due to the particular redox properties of $LuPc_2$, the MSDI are very sensitive.

Introduction
Interest in molecular materials has been driven in large part by their various and prosperous applications, especially in the domains of organic electronics and sensors. There is a huge amount of well-known and applied families of small molecular weight organic molecules that can easily form molecular materials, such as phthalocyanines, arenes or fullerenes. Nonetheless, the phthalocyanine derivatives are without doubt interesting candidates for the development of thin film sensors [1]. One of the most profitable skills is their electrical behavior, either semiconductor or doped-insulator (extrinsic semiconductors, *n* or *p*).
The lutetium derivative ($LuPc_2$), the first discovered intrinsic molecular semiconductor, exhibits an electronic conductivity at room temperature about 5.10^{-5} $(\Omega.cm)^{-1}$, an extraordinary high density of free charge carriers (5.10^{16} cm^{-3}), and an unusual small energy gap (ca. 0.5 eV). Whereas organic FETs and diodes were studied after their inorganic counterparts, the new molecular material-based devices we designed and characterized are completely original.

MSDI heterojunctions
MSDI heterojunctions are built around an heterojunction between a molecular semiconductor (MS) and a doped-insulator (DI) [3] (Fig. 1). The MS must be more conductive than the sub-layer to take advantage of the heterojunction. In most cases, the lutetium *bis*phthalocyanine ($LuPc_2$) is used as MS. DI may be an n-type-material, such as fluorinated Pc (ex.: $Cu(F_{16}Pc)$) or a perylene derivative. The energy barrier at the interface depends on the difference in energy levels of the two materials.
NH_3 is an olfactive pollutant. It is involved in many industrial applications. Any leak may lead to injury of the personnel working around installations. Its concentration must not exceed 50 ppm in air, the value corresponding to the alert threshold. To better protect the workers, we need reliable devices that perform well in real time. In the European Union, the Short-Term Exposure Limit (STEL) and the Time Weighted Average (TWA) are 50 ppm and 20 ppm, respectively.

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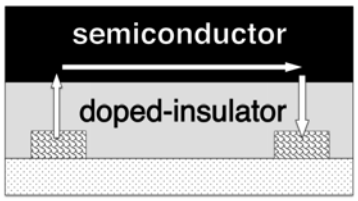

Figure 1. Schematic view of MSDI heterojunctions; the arrows indicate the conduction path of charge carriers.

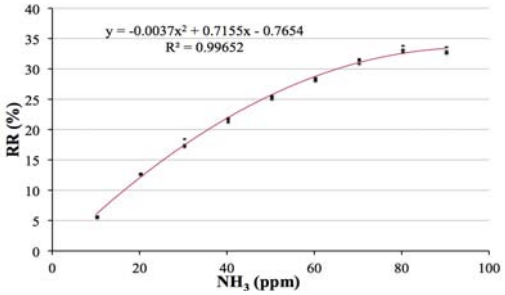

Figure 2. Relative response of MSDI C_4F_7-PTCDI / $LuPc_2$ exposed to 10 – 90 ppm of ammonia under 50 % rh

MSDI C_4F_7-PTCDI / $LuPc_2$

We studied a MSDI made of an n-type material, the 2,2,3,3,4,4,4-heptafluorobutyl-perylene-bisimide (C_4F_7-PTCDI), 50 nm, as DI and $LuPc_2$, 50 nm, as MS. We exposed the MSDI to ammonia in the 10-90 ppm range. The sensing performances were studied using 1 min / 4 min exposure / recovery cycles, with a polarization of 5 V. This MSDI exhibits an increase of I at 90 ppm from 1.53 to 2.04 µA, after 1 min-long exposure period to NH_3. This corresponds to a relative response RR = $(I_{on}-I_{off})/I_{off}$ of 33 %. At 10 ppm, the RR is of 6 %. The RR variation as a function of the NH_3 concentration is not linear but may be fitted by a polynomial of degree 2 (Fig. 2.). After several months, the RR at 90 ppm NH_3 and 50 % relative humidity (% rh) remains in the range of 15-12 % [4].

Conclusion

MSDIs with a n-type sub-layer exhibit a positive response to electron donating species like ammonia. In the case of the C_4F_7-PTCDI sub-layer, the relative response to 90 ppm ammonia is of +30 % after 1min-long exposure periods, under a relative humidity of 50 % rh .
The better stability towards humidity was obtained with $Cu(F_{16}Pc)$ as n-type sub-layer. Thus, for $Cu(F_{16}Pc)/LuPc_2$ MSDI (50 nm/50 nm), the relative response to NH_3 remains unaffected by the variation of relative humidity in the 20-80 % range.
Moreover, this response has proved to be stable over time (several years).

Acknowlegments

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Poster Presentation

THE METHODOLOGICAL APPROACH TO A HEALTH IMPACT ASSESSMENT (HIA) FOR PROMOTING A SUSTAINABLE AND HEALTHY COMMUNITY IN VAL D'AGRI (BASILICATA - ITALY)

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Abstract
Health Impact Assessment (HIA) is a practical tool, which can be used for evaluating the health impact of a proposed program, project, policy, strategy and initiative in sectors that indirectly affect health and well-being and inform decision-makers of these potential outcomes before the decision is made, supporting the identification of appropriate policy options.
HIAs:

- determine the potential effects of a proposed decision on the health of a population and the distribution of those effects within the population [1];
- consider input from stakeholders, including those impacted by the decision;
- use different types of evidence and analytical methods;
- are flexible based on available time and resources; and
- provide evidence and recommendations to decision-makers in a timely manner.

HIAs provide recommendations for maximizing the potential positive health impacts and minimizing and/or avoiding the potential negative health impacts of the decision [2].
The major steps in conducting an HIA include:

- Screening (identifying plans, projects or policies for which an HIA would be useful),
- Scoping (identifying which health effects to consider),
- Assessing risks and benefits (identifying which people may be affected and how they may be affected),
- Developing recommendations (suggesting changes to proposals to promote positive health effects or to minimize adverse health effects),
- Reporting (presenting the results to decision-makers), and
- Monitoring and evaluating (determining the effect of the HIA on the decision).

The HIA is strongly reliant on inter-sectorial collaboration, both across various sectors, but also across policymaking and practice [3].

The following 'Project for the construction of a health impact assessment in the municipalities of Grumento Nova and Viggiano in Val d'Agri' was in fact launched by a multidisciplinary research team: it has been defined and developed by the Environmental Epidemiology and disease registries Unity - Institute of Clinical Physiology, National Research Council (CNR), in collaboration with researchers from the Department of Biology of the University of Bari, the Institute for Atmospheric Sciences and Climate of the National Research Council, the Institute for the Study of Ecosystems of the CNR, the Consorzio Mario Negri Sud, and the Department of Epidemiology of the Lazio Region.
The project proposes the realization of an HIA in Val d'Agri (Basilicata – Italy); the interest for its realization in this area is due to the presence of the largest Italian gas and oil pre-treatment plant, called the "Centro Oli Val d'Agri" (COVA), which performs a first processing of the crude oil extracted from the various wells on the surrounding territory. It is located in the industrial area of Viggiano (PZ), a small village in the South of Italy and covers an area of 171 700 m^2 [4].

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Areas characterized by intense drilling activities usually have wells close enough to each other so that the risk cannot be modelled by considering a simple point source, but rather it should be considered as different risk point sources. Since the extraction of oil is carried out in populated areas without a full risk assessment, human beings and animals that live in these areas have inadvertently become organic supplements of chemicals released by this type of industrial activity [5,6].
The operation of oil refineries and petrochemical plants is associated with the emission of Volatile Organic Compounds (VOC), mainly deriving from production processes, from storage tanks, gas pipelines and exhausted areas [7].
An epidemiological approach capable of analysing the effects on human health in the vicinity of areas of petroleum extraction and processing is necessary in order to identify the potential risks on human health in these areas.
In this project the task of the research group of the University of Bari is to monitor conventional and non-conventional pollutants at the high spatial-temporal resolution, performed by standard and innovative methodological approaches and integrated technologies that are able to provide real time information about the emissive situation and the impacts on the territory.
The research group will conduct the following activities:

- determination of VOC by means of passive samplers and a network of PID sensors in order to achieve a smart network which allows us to obtain time profiles of these compounds and a mapping of the territory;
- determination of VOC by means of personal dosimeters;
- breath sampling of volunteers and determination of VOC for the early diagnosis and screening of chronic diseases and cancer;
- monitoring of PM10 and PM2,5 fractions and determination of Polycyclic aromatic hydrocarbon including benzo(a)pyrene, which is listed as a Group 1 carcinogen by the International Agency for Research on Cancer (IARC);
- odour monitoring both by means of electronic noses and dynamic olfactometry according to UNI EN 13725. The odour impact assessment will also be carried out by involving citizens by means of an experimental methodology for the detection and evaluation of olfactory annoyance.

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Poster Presentation

COMPARISON OF MULTIVARIATE LINEAR REGRESSION AND ARTIFICIAL NEURAL NETWORKS FOR CALIBRATION OF LOW COST ELECTROCHEMICAL SENSORS FOR CO AND O_3

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Abstract

In the last few years, research activities on finding alternative methods for air-pollution monitoring are significantly intensified and this field is in the focus of many research projects. This is possible due to the development of new low cost gas sensors that are characterized by their small size. Beside a significant reduction in financial costs, these sensors are enabling a high spatial and temporal coverage as opposed to the standard measurement stations. However, calibration of low cost gas sensors for air pollution monitoring remains a major challenge [1]. In general, poor stability and selectivity are the main problems of these sensors [2-4]. Therefore, it is necessary to work on the development of new algorithms for the quantification of air pollution and calibration of low-cost sensors.

This paper presents a comparison between multivariate linear regression models (MLR) and artificial neural networks (ANN) for calibration of low cost electrochemical sensors for the detection of CO and O_3 gases. In this paper we present results for B4 Alphasense sensors that are operating in amperometric mode. These sensors generate a current which is directly proportional to the fractional volume of toxic gas that needs to be detected. These sensors are systems with 3 electrodes and beside the working and counter electrode these sensors include also reference electrode. Electrodes are parallel to each other. Working electrode ensures optimum oxidation and reduction processes of toxic gas, while the other two electrodes have a similar chemical composition as well as the working electrode. The reference electrode ensures that the potential of the working electrode is always in a relevant area of current-voltage characteristics. It is imperative that the reference electrode has a stable potential, in order to maintain the proper electrochemical potential of working electrode to provide high sensitivity, good linearity and minimum sensitivity to other interfering gases.

During the implementation of the calibration procedure with MLR and ANN, it has been taken into consideration how meteorological parameters and other interfering gases such as NO_2 affect on the operation of electrochemical sensors for CO and O_3.

First we analyzed multivariate models, and then the calibration procedure has been performed using the feed-forward neural network with one hidden layer. In the hidden layer it was used 10 neurons with sigmoid transfer function, and a linear function was used at the output layer. Training of neural networks was carried out by using three different methods: 1) Levenberg-Marquardt algorithm (LM); 2) Resilient backpropagation algorithm (RB) and 3) Conjugate Gradient Powell-Beale algorithm (CG). For network training it was used 70% of the total number of measurements for validation and 15% of the total number of measurements were used for testing.

In this paper we established models that use information about the weather and other environmental conditions such as other interfering gases. We developed a larger number of models with different number of input parameters and thus we examined how this manifest on their response.

For meteorological parameters it was taken into consideration temperature (T), humidity (RH) and pressure (p), and on the basis of additional correlation analysis it was found that is suitable to take as an additional input measurements for NO_2. Correlations between the measurements between CO, O_3 and input parameters NO_2, T, RH and p are shown in Table 1.

Table 1. Pearson's correlation coefficient between the measurement of gases and meteorological parameters.

	NO_2	T	RH	p
CO	-0.49	-0.41	0.31	0.14
O_3	0.75	0.71	-0.60	0.16

From Table 1. it can be easily seen that the CO measurements correlate well with NO_2 and T. It can also be noted that CO have negative correlation with NO_2 and T, while the correlation between CO and rH is positive and slightly lower. On the other hand, based on the results in Table 1. it can be seen that the measurements for O_3 are highly correlated with measurements for NO_2 and T with positive values, while the correlation between O_3 and RH is slightly smaller with negative sign.
Based on the results of statistical analysis it was found that the models which were used a larger number of input parameters, gave better results. The results of modeling for CO were better than the results for O_3. It has been shown that ANN are more complex, but also more effective for calibration of low-cost sensors in comparison to MLR. Also, it was found that LM neural network show the best results compared to RB and CG neural networks.

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Poster Presentation

SOME PRACTICAL ASPECTS OF PREDICTOR VARIABLE LAYER CREATION FOR LUR MODELING OF AIR POLLUTION IN BELGRADE

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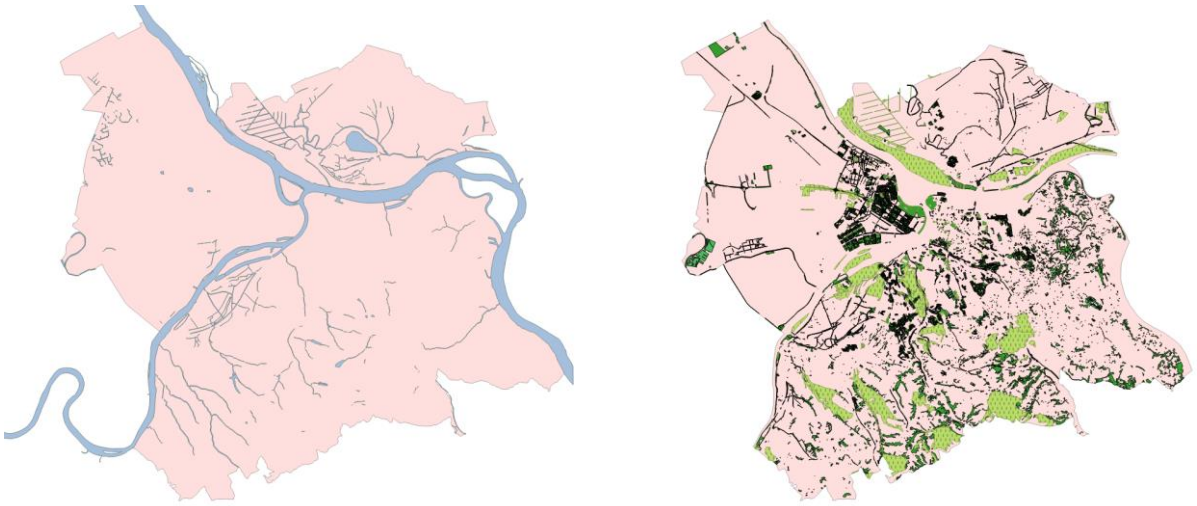
Abstract

Land use regression (LUR) modelling is a method of choice for creation of high resolution air pollution maps, and has recently been used to develop maps of NO2 and particulate matter pollutants in a number of European cities, including Belgrade [1]. Important part of land use regression (LUR) modelling is evaluation of predictor variables at points of interest. While the development of LUR model only requires value of potential predictors in limited number of points where sensor measurements were taken, process of mapping requires value of predictor variable in much larger number of points (in order to form raster layers), calling for much larger computational resources. Creation of such raster layers is not a trivial task, and presents a number of practical difficulties, some of which will be pointed out in this work, alongside possible solutions.

Process of creation of predictor variables is largely dictated by data available in local GIS databases. Example of such data is given in figure below, where detailed water surfaces and parks situated within area covered by master plan of Belgrade are shown.



(a) (b)

Fig. 1 (a) GIS layer for water surfaces (rivers, streams) (b) GIS layer for green spaces (parks, forests) in area covered by master plan of Belgrade (shown in light red)

Computational challenge lies in amount of data to be processed for production of predictor raster layers. Typical predictor variable might require calculation of amount of green and water surfaces inside circular buffer. Such task can quickly become very computationally expensive, depending on number of segments used to approximate circular buffer and number of features available in GIS layer. For example, GIS layer shown in Fig. 1b contains over 10,000 polygons. Depending on the desired map resolution and size and density of buffers, conceptually simple GIS operation can suddenly become very difficult to perform, requiring

nonstandard approaches. In our work non computationally expensive predictor layers were calculated using QGIS software and standard GUI interface while more computationally demanding operations were performed using Python wrapper libraries Fiona (for input and output) and Shapely (for 2D geometry operations), inspired by [2].

Classification of predictor variables based on physical process associated with them is crucial for the development of the LUR model. When considering traffic related air pollutants, water and green surfaces are associated to physical process of deposition, while emission related predictors include traffic counts and road network related predictors such as length of roads in a buffer, category of road etc. It should be noted that not all predictor are derived from geometry of GIS layers, but can be more complex, being the result of additional modelling efforts. Example of such variable is traffic count. City authorities usually have complex models of traffic at their disposal, which are kept up to date via costly traffic count campaigns. Traffic models can also be statistical, and even based on LUR modelling [3]. One of the problems that can be encountered when choosing the predictor variables for traffic LUR model is variability of traffic and variability of predictors. Usually, traffic exhibits much greater variability compared to predictor variables, especially for smaller urban environments. For example, one predictor variable could be number of lanes, however, in small urban environments such variable does not have enough variability. In [3] traffic network connectivity was used as a traffic predictor. This type of predictor is interesting since it does not require extensive data input and relies only on topology of road network. In [4], we used public transport as a predictor of total traffic. This model was developed based on data from automatic counters which exist on roads in wider area of Belgrade and Serbia. In this work, traffic model was updated based on additional traffic counting data, and possibilities for additional predictors such as network connectivity was explored.

Updated predictor layers resulted in updated NO2 and PM2.5 air pollution maps which can be later used as basemaps for data fusion algorithm [5] which combines and adds value to both basemap data and sensor data.

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Poster Presentation

CMOS integrated nanocrystalline SnO_2 gas sensors for air quality control

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Abstract

We report on gas sensors based on ultrathin nanocrystalline SnO2-films, which were fabricated on a CMOS microhotplate by spray pyrolysis with a thickness around 50 nm. The sensor devices show a good response to carbon monoxide at gas concentrations as low as 10 ppm. The best performance with the highest change in resistance is achieved at an operating temperature of 400 °C, where for 130 ppm CO the resistance is decreased by up to ˜ 50%.

Motivation and results

Chemiresistors based on semiconducting materials, like metal oxides (MOX), are one of the most promising gas sensing systems due to their high sensitivity to numerous gases, fast response, low weight and simple production [1-3]. Today's commercially available gas sensors are sort of bulky devices with a still quite large power consumption. The integration of nanostructured gas sensitive materials on thermally insulated microhotplates makes it possible to reduce power consumption, cost and size of gas sensors. The ability to implement the gas sensing materials on CMOS microchips is one of the most important requirements for building smart devices for consumer electronics [4-7].

We report here on a CMOS integrated metal oxide gas sensor with good sensitivity to the highly toxic gas carbon monoxide (CO). The ultrathin gas sensing film was implemented on a CMOS microhotplate (µhp) by spray pyrolysis in a post-backend process with a thickness of ~ 50 nm (see Fig.1). The µhp chips have been realized in a 0.35µm standard CMOS technology from ams AG and released in a post process MEMS-etching step. The µhp consists of an active area with dimensions of 74 x 74 μm^2 suspended in air and connected to the rest of the silicon chip by four arms (length 150 µm, width 12 µm). Tungsten plugs are used for contacting the gas sensitive layer in 4-point configuration [8].

The performances of the CMOS integrated sensor was investigated in an automated measurement setup, which enabled precise tuning of the gaseous environment. Synthetic air was employed as background gas, the response to CO concentration of 10 ppm, 40 ppm, 80 ppm and 130 ppm was measured at different operation temperatures (300 °C, 350 °C and 400 °C) and three different humidity levels (25%, 50%, 75%). The detection of the sensor's response to the test gas was done by applying a constant voltage of 100 mV and measuring the current increase. The sensor performance to the exposure to CO was evaluated at three different temperatures and humidity levels in a continuous measurement with a duration of more than 16 hours. The highest response to the different CO concentrations was achieved at 400°C with, for example, a decrease in resistance of up to 10 % at a CO concentration of only 10 ppm. The change in resistance is linear to the increasing concentration of the test gas. Unfortunately humidity also has an impact on the gas sensor response but the resistance is still decreased by up to 30 % at a relative humidity level of 75 % (see Fig.2).

The integration of gas sensitive SnO_2 thin films on a CMOS µhp with the capability of 3D-integration of different gas sensing systems gives the opportunity to building smart nanosensor devices for daily life applications.

Poster Presentation

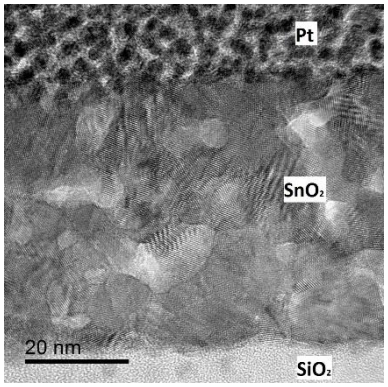

Figure 1. TEM characterization of SnO_2 thin film.

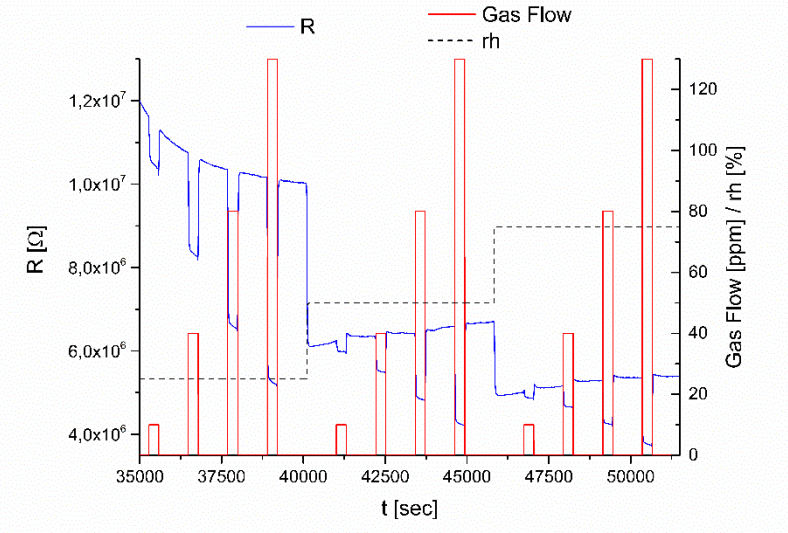

Figure 2. CO detection response of CMOS integrated SnO2 gas sensor. The measurement run shows the resistance at 400 °C of the sensor with increasing CO concentration (10 – 130 ppm) and varying humidity levels (25 %, 50 % and 75 % rH).

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Poster Presentation

CMOS INTEGRATED TUNGSTEN OXIDE NANOWIRE NETWORKS FOR PPB-LEVEL H_2S SENSING

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Abstract

In this work we report on a gas sensor device based on tungsten oxide nanowire networks, which are integrated on a CMOS fabricated microhotplate. Utilising WO_{3-x} nanowire networks as gas sensing material we could obtain extraordinary sensitivity to hydrogen sulphide: concentrations down to 10 ppb have been detected, even in the presence of 50% relative humidity.

Motivation and results

The detection of hydrogen sulphide (H_2S) is a great issue both in terms of personal safety as well as in technical applications: It is a highly toxic and flammable gas and is considered as broad-spectrum poison. The production of hydrogen for fuel cells by reformation of petroleum gas, diesel or ethanol leads to trace concentrations of H_2S, which can result in immediate damage of the fuel cell.

Semiconducting metal oxides are widely used as active materials for gas sensing devices [1]. The underlying principle of metal oxide gas sensors is based on the change of electrical resistance of the material while being exposed to the gas. In the last years metal oxide nanostructures have gained importance and have shown beneficial performances in sensing toxic and harmful gases as H_2S [2–7].

We report the implementation of a tungsten oxide (WO_{3-x}) nanowire network on a prefabricated CMOS microhotplate chip and investigated the H_2S gas sensing behaviour. Such CMOS integrated systems are promising candidates for realising smart sensor devices for consumer market applications [8]. The fabrication of the microhotplate (μHP) chip has been realised in a 0.35 μm standard CMOS technology from ams AG and released in a post process MEMS-etching step. The μHP consists of an active area with dimensions of 74 x 74 μm^2 suspended in air and connected to the rest of the silicon chip by four arms (length 150 μm, width 12 μm) (see Figure 1; left) [9]. The WO_{3-x} nanowires were synthesised by a hydrothermal process [10] and drop-coated on the CMOS μHP. TEM characterisation (see Figure 1; right) reveals a dense network of nanowires with average diameters in the order of 20 nm. The non-stoichiometric state can be confirmed by Raman spectroscopy.

In conclusion of an extensive gas measurement programme with a variation of temperature and three different humidity levels (25%, 50% and 75%) an optimum operation temperature of 250°C can be determined for the WO_{3-x} nanowire gas sensor, which is supported by literature [11]. The gas measurements were conducted toward H_2S in concentrations of 10, 30 and 60 ppb with synthetic air as background gas. Figure 2 shows a gas measurement at 250°C with 50% relative humidity where the high sensitivity is demonstrated by a noticeable resistance decrease up to almost 10% even at an ultra-low concentration of 10 ppb H_2S.

Poster Presentation

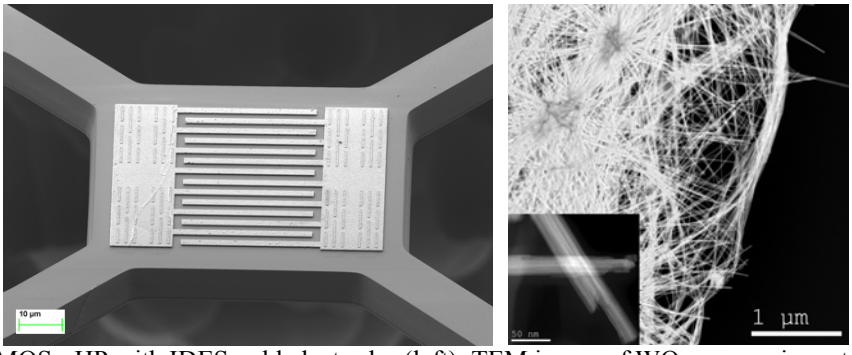

Figure 1. CMOS µHP with IDES gold electrodes (left); TEM image of WO_{3-x} nanowire network (right).

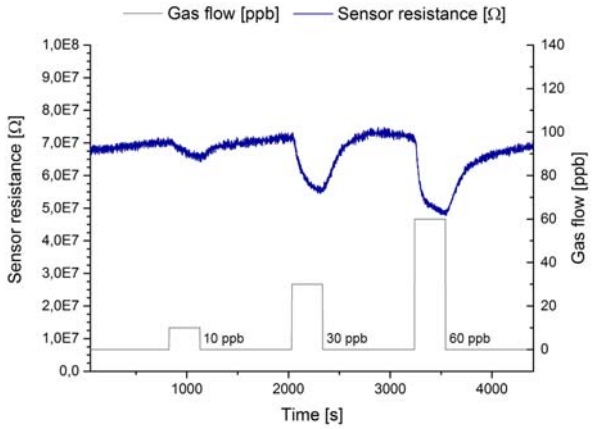

Figure 2. H_2S response of WO_{3-x} nanowire network sensor in 50% rh at 250°C operation temperature.

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Poster Presentation

OPTO-CHEMICAL SENSOR SYSTEMS BASED ON ELECTROSPUN NANOFIBERS FOR ULTRA-FAST OXYGEN DETECTION AND THEIR APPLICATION IN EXHALED BREATH GAS ANALYSIS

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Abstract
In general opto-chemical oxygen sensors consist of a luminescent dye embedded in a compact polymeric matrix. Luminescence intensity and decay times are a function of oxygen concentration and can be evaluated by appropriate equipment. The response dynamics of such sensors are limited by the diffusion kinetics of oxygen in the polymer matrix. Traditionally, the sensor formulation is cast onto a substrate as a compact layer. The thicker the layer, the slower the response. By means of electrospinning, many polymers can be processed to nanofibers, resulting in a non-woven textile-like fleece with a high surface-tovolume ratio and outstanding analyte accessibility. Doped with fluorescent dyes, such fiber layers are well suited for fast sensing applications where the response time is a critical issue. By electrospinning of a typical oxygen sensor formulation, the response time t_{90} can be accelerated from several seconds to approx. 20ms without loss of signal quality. The optical and electronic equipment was also optimized achieving a sampling rate of 10ms.

One application of fast oxygen sensing is the detection of the O_2-concentration in exhaled breath gas. The overall oxygen concentration is an important marker concerning pulmonary and cardiovascular diseases, training optimization in professional sports and general fitness applications. During exercise the breath frequency climbs to 1 Hz or higher, resulting in breath strokes of <500 ms. For a precise scan of the O_2-profile an oxygen sensor with t_{90} lower 50ms is highly desirable.

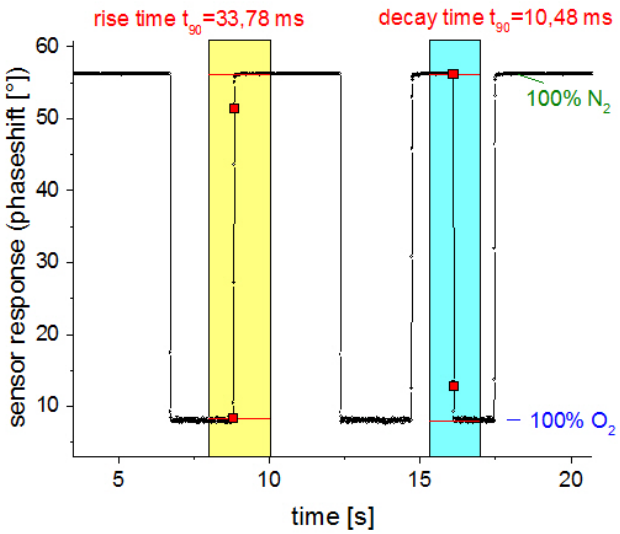

Figure 1. Sensor response to fast changes of the oxygen concentration (sampling rate: 10 ms).

Poster Presentation

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Poster Presentation

A NANOSECOND LUMINESCENCE LIFETIME MEASUREMENT SYSTEM FOR OPTICAL SENSING

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Abstract

Optical chemical sensors are of special interest in a wide range of applications including biomedical, industrial, food, and environmental monitoring [1]. In fluorescent dye based optical sensors, the signal transduction is mediated by the interaction of the fluorophore with a specific analyte, resulting in a change of luminescence properties, e.g. quantum yield or luminescence lifetime. Naphthalimides represent good candidates for sensor dyes due to their high photostability, the "off-on"-mechanism for analyte detection by photoinduced electron transfer (PET) and the variability of receptor functions. Selective naphthalimides have already been evaluated for analytes such as alkali and heavy metal ions, saccharides, thiols and for pH-changes, to name only a few. Immobilizing a pH sensitive dye system in a suitable polymer matrix, allows to construct sensors for various gaseous analytes such as CO_2 [2] or ammonia [3].

In this work, fluorescence lifetimes of a pH sensitive naphthalimide dye were measured using a compact and portable LED-based detector. Measurements were made using the method first proposed in 2008 and modified with LED light source in 2014 [4, 5]. A 405 nm LED allowed matching the absorption spectrum of a methylpiperazin functionalized naphthalimide dye [6]. The fluorescence emitted from the sample is detected by an APD, the photo current is conditioned by a sensing circuit before digitization. A gating mechanism of the APD, in combination with a time-interleaved integration window specified a delay-line, guaranteed that all segments of the fluorescence decay are integrated incrementally with a resolution of 250 ps.

The novel optical sensing system was applied for monitoring of pH change. Fluorescence lifetimes of the naphthalimide-based dye changed from 3.6 ns to 7.5 ns when pH was tuned between 9.7 and 3.3.

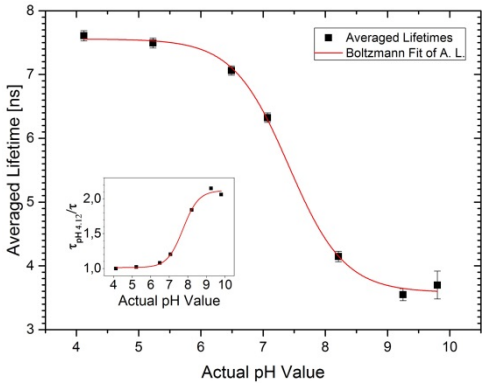

Figure 1. Dependence of fluorescence lifetimes on pH.

Poster Presentation

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Poster Presentation

THE INFLUENCE OF Nb ON SURFACE CHEMISTRY AND MORPHOLOGY OF TiO_2 NANOTUBULAR ARRAYS

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Abstract

In the last several years there is an increasing attention of the scientific community to the titanium dioxide TiO_2, an n-type wide band-gap stable nontoxic oxide semiconductor material because of its wide application among others in the chemical/gas sensing [1,2].

It is well known that the TiO_2 based gas sensors are particularly attractive for the reducing gases, as well as that larger the extended surface area materials provide higher sensitivity at low gas concentrations [3]. Especially, the hierarchical nanostructured TiO_2 seems to be a best candidate for the manufacture of gas sensors because its conductivity changes with the surface adsorption and desorption of gas molecules, what is related to the electronic transfer that occurs upon the adsorption of gas molecules over the film surface [4]. Moreover, what is also extremely important, by addition to TiO_2 nanostructures Nb atoms as the dopants cause the enhancement of their gas sensors characteristics (sensitivity, selectivity, response time, etc.) [5-9].

However, as it is well known since about 15 years, that the sensor effect for all the forms of metal oxides take place within the surface space charge layer at the depth up to the Debye length of about several nm. This is why the absolutely crucial is a new insight into the sensor properties of TiO_2 nanotubes is indispensable [10].

This is why the aim of the presented work was to obtain the fundamental information on surface chemistry as well as the surface contaminations including C species at the surface of pure and Nb-doped TiO_2 (TNO) nanotubes and morphology, by using XPS and SEM method respectively.

Fig.1 shows (left side) the XPS survey spectra of pure and Nb-doped (4% and 12%) TiO_2 nanotubes (NT) deposited on Si substrate and the SEM image (right side).

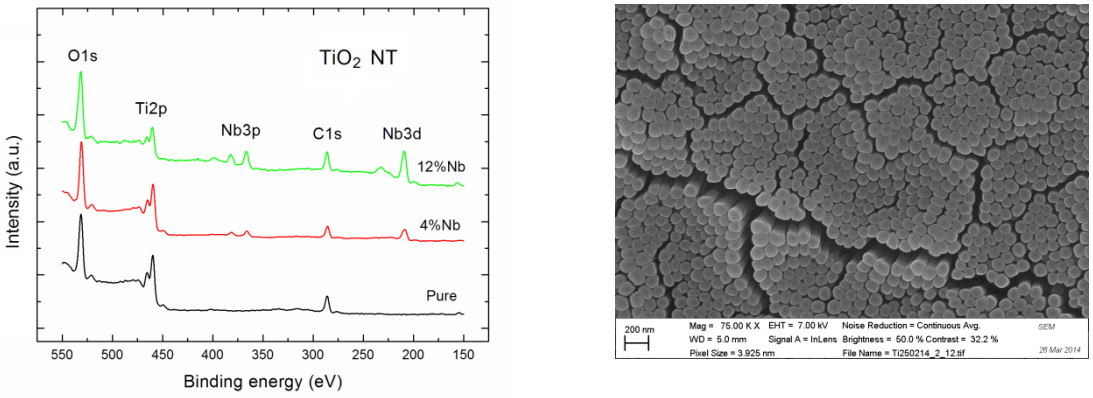

Figure 1. XPS survey spectra (left side) SEM image (right side) of pure and Nb-doped TiO_2 nanotubes .

Poster Presentation

For the pure TiO_2 NT the relative [O]/[Ti] concentration was at the level of 2.6, what means that this sample is evidently over-stoichiometric of main matrix TiO_2. For the lower Nb-doped (4%) TiO_2 NT the total relative [O]/[Ti] concentration increased to about 3.6, what means that this sample is even more over-stoichiometric with respect to the pure TiO_2 NT. For the higher Nb-doped (12%) TiO_2 NT the total relative [O]/[Ti] concentration additionally increased to the level of 3.7, what was related to the appearance of evident amount of Nb oxides.

In turn, for all the TiO_2 nanotubes a huge amount of C contaminations was observed at their surface. For the pure TiO_2 NT the relative [C]/[Ti] concentration was at the level of 1.8, and slightly decreased to the value of 1.4 for the lower Nb-doped (4%) TiO_2 NT. A completely opposite tendency was observed for the higher Nb-doped (12%) TiO_2 NT, for which the relative [C]/[Ti] concentration twice increased to the value of 2.8. What is crucial, the C contaminations at the surface of all the object are weakly bounded to the crystalline TiO_2 nanotubes, and can be easily removed from their surface.

Our experiments showed that the pure TiO_2 NT are over-stoichiometric, and a huge amount of C contaminations was observed at their surface. What is crucial, the C contaminations at the surface of all the object are weakly bounded to the crystalline TiO_2 NT confirmed by SEM image showing inner diameter of Nb-doped nanotubes of about 100 nm, and can be easily removed from their surface. The obtained results gave us insight on the interpretation of aging effect for TiO_2 NT that would be of great importance for their potential application in the development of novel type chemical nanosensors devices.

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PRACTICAL INFORMATION

WELCOME TO VIENNA

Vienna is located in the very heart of Europe and is a very green city – about half of the city is covered by forests, grassland, parks and gardens.



Vienna‘s historic city centre ranks among the most beautiful historical cities in Europe. Numerous churches, palaces and parks contribute to the imperial flair of Vienna‘s Old Town.



On the other hand, Viennese Art Nouveau (Jugendstil) has also brought forth unique places of interest. This mix of old and new, tradition and modernity is what gives Vienna its extra special flair.




Vienna is a paradise for art lovers. Over 120 museums and collections are open to the public, showcasing works of the highest calibre. They include the world's largest collection of Bruegels at the Kunsthistorisches Museum (Museum of Fine Arts) as well as the MuseumsQuartier Wien, one of the largest museum complexes in the world.
Vienna is also renowned as the world's capital of music. It has been home to "Waltz King" Johann Strauss, "Prince of Song" Franz Schubert, Haydn, Beethoven, Brahms, Schoenberg and Mahler, not to mention Wolfgang Amadeus Mozart. Enjoy an unrivalled selection of music – from opera and operettas to concerts and musicals – in Vienna, music is literally in the air!

Vienna's outskirts are also especially attractive: romantic landscapes and picturesque villages invite you for a day's outing.

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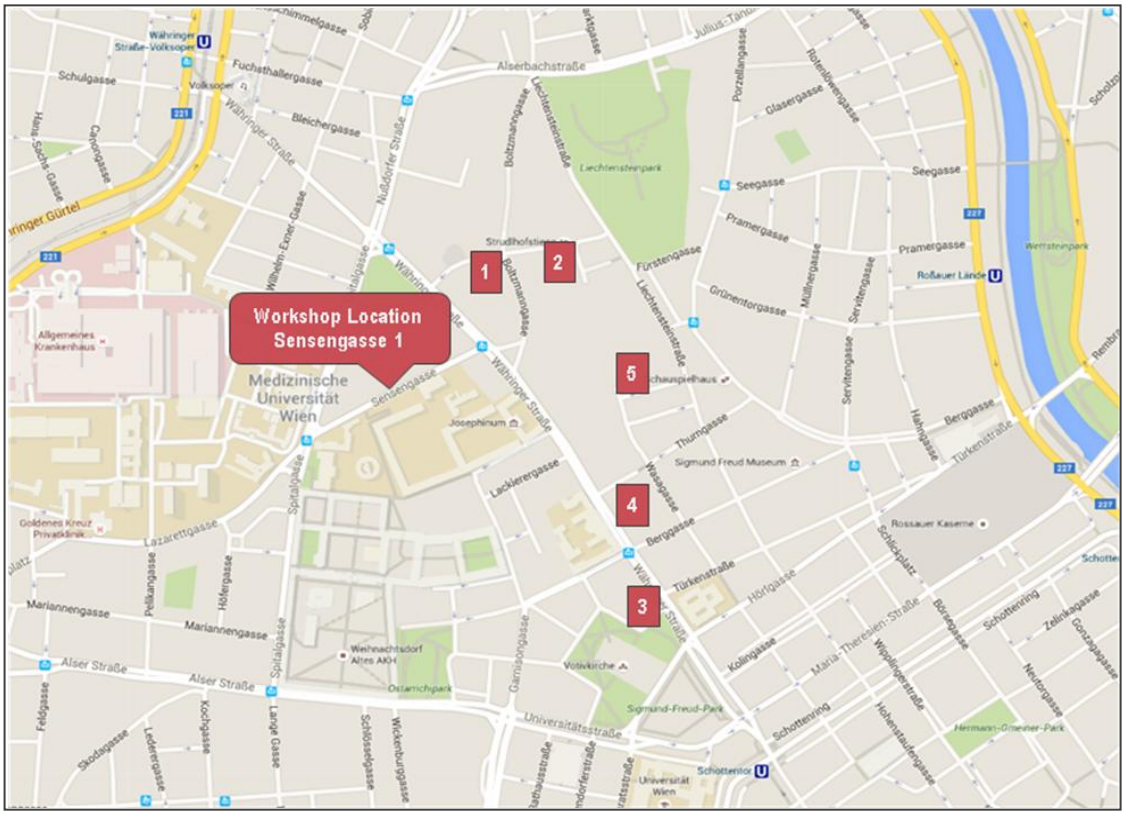

1) Hotel Boltzmann about € 68,- / single room
http://www.hotelboltzmann.at/en/home.php
Boltzmanngasse 8 | 1090 Vienna | +43 1 354 50 0 | info@hotelboltzmann.at

2) Hotel & Palais Strudlhof about € 49,-/ single room
http://www.strudlhof.at/en/hotel-strudlhof/
Pasteurgasse 1 | 1090 Wien | +43 1 319 2522 | hotel@strudlhof.at

3) Hotel Regina about € 59,-/ single room
http://www.kremslehnerhotels.at/en/hotel-regina-vienna/reservations/
Rooseveltplatz 15 | 1090 Vienna | +43 1 404 46-0 | regina@kremslehnerhotels.at

4) Hotel am Schottenpoint double room for single use from € 49,- to € 79,-
http://www.schottenpoint.at/en
Währingerstrasse 22 |1090 Wien | +43 1 310 87 87 -0 | hotel@schottenpoint.at

5) BEST WESTERN PREMIER Hotel Harmonie Vienna single room from € 124,- to € 140,-
http://www.harmonie-vienna.at/index.php/index.php/home-en.html
Harmoniegasse 5-7 | 1090 Vienna | +43 1 317 66 04 | *welcome@harmonie-vienna.at*

Please find some other hotels on booking.com
http://www.booking.com/city/at/vienna.de.html?aid=301584;label=vienna-iqgEtJnPqs24MkhHHWk1ZgS66586248061:pl:ta:p11040:p2260.000:ac:ap1t1:neg:fi:tiaud-146342137270:kwd-6071463321:lp1000900:li:dec:dm;ws=&gclid=Cj0KEQiAiNi0BRDaobaq3dKJhrwBEiQAyVThzWCpvp3L82KMUnqjWiWdWfV5qZbVzSUWQ-t7es-RKDUaArnm8P8HAQ#map_opened

HOW TO FIND FFG (Workshop Location)

The FFG is located in the ninth District of Vienna near the General Hospital (AKH) and the University campus.

How to reach by public transport

The No. 5 and 33 trams stop right in front of the House of Research ("Lazarettgasse" stop).

Arriving by train

Information about train and bus schedules: www.oebb.at

... from "Hauptbahnhof" railway station

No. 13A bus bound for Skodagasse, get off at the "Laudongasse" stop and change to No. 5 tram bound for Praterstern or No. 33 bound for Friedrich-Engels-Platz; get off at "Lazarettgasse".

Arriving by plane

... from From Vienna International Airport:

Take the **CAT (City-Airport Train*)** or the **S-Bahn**** to "Landstrasse/Wien-Mitte", change to U4 metro bound for Heiligenstadt; get off at "Friedensbrücke" and change to No. 5 tram bound for Westbahnhof; get off at "Lazarettgasse".

***CAT :** The **City Airport Train (CAT)** - 30-minute intervals from 06:05 to 23:00 daily from the airport to train station "Landstrasse/Wien Mitte"*
Fares: € 12,– one-way, € 19,- return ticket. Duration: approx. 16min. Reduced fares via online booking >> http://www.cityairporttrain.com/

****S-Bahn:** At 30-minute intervals, the Vienna Airport Lines depart between 04:48 and 00:18 daily. Fares: € 2,40,– one-way, Duration: approx. 25 min. >> http://www.schnellbahn-wien.at/web/flughafen_wien-schwechat.html*

Vienna Metro Map >> https://www.wienerlinien.at/media/files/2014/svp_139764.pdf

Local Info

Languages & Time Zone
Official language is German - Conference language is English! Timezone CET; UTC+1

Weather in Vienna in February
Vienna in February is **freezing cold**: The average maximum temperature is **4 degrees Celsius**, the **minimum averages at minus 1**. This might be better than January, but still requires you to bring very **warm** and **windproof clothing** if you plan to spend time outside. Visitors of Vienna can expect **3 hours of sunshine** on the average February day; on **seven days** they will experience rain or snowfall over the course of the month.
Please check the current weather
>> http://www.weather.com/weather/tenday/l/Vienna+Austria+AUXX0025:1:AU

Emergency numbers:
Ambulance 133, Police 144, Fire 122

Electricity & Power Station
Electricity in Austria is 230 volts. If you plan on using your own 110-volt appliances, you will need a voltage converter, unless your appliance is designed to also work with 230 volts electricity (dual voltage). It might help to get one before you leave home. Regardless of voltage, if your appliance has flat prongs, you will need a plug adapter: Austrian sockets are designed to accept round prongs.

WLAN
WLAN will be provided on site during the whole workshop.

Telecommunication & Country Code
Austrian Country Code is +43 and Vienna City Code is (0)1. At a POST office you are welcome to do phone calls, send telegrams and faxes. Post offices display the sign "POST" on a yellow background. For local calls you can buy phone cards there or in any tobacconist.

Banks - Currency
All banks in Austria exchange foreign currency and traveller's cheques. Numerous automatic teller machines and exchange offices are available! Most hotels, restaurants and shops accept major credit cards!

Persons with special needs
Should you require any specific assistance, please let us know in advance to enable to assist in making your stay at the Workshop pleasant and comfortable.

Smoking policy
Participants are requested to refrain from smoking inside the Workshop Building.