I3S 2015

4th International Symposium on Sensor Science

13 – 15 July 2015

Pharmacenter, University of Basel
Basel, Switzerland

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I3S2015 is the 4th edition of the *International Symposium on Sensor Science*.

Three previous editions have already taken place:
Paris (France) in 2003, Nanjing (China) in 2004, and Juelich (Germany) in 2005.

Links to the websites of the previous editions:
I3S2003: http://www.mdpi.org/sensors/I3S/
I3S2004: http://www.mdpi.org/sensors/I3S2004/
I3S2005: http://www.mdpi.org/sensors/i3s2005/

Welcome by Prof. Dr. Peter Seitz

Dear authors and attendees,

We are delighted to have you here in Basel to participate and share in the *4th International Symposium on Sensor Science*. Thank you for coming, for reporting the results of your research work, and for joining your peers in building together the future of sensing. We are proud and honored that so many of you have joined your peers in Basel, and we are pleased that you have submitted such a large number of excellent contributions. This has allowed us to select the very best for an outstanding three-day symposium program on sensor science which you can all now enjoy.

In effect, sensor science is the basis for the next big technological wave, the "Internet of Things" (IoT). According to a recent market study, the impending IoT revolution will bring huge business opportunities: The total market size for integrated IoT sensors is estimated to be €342b in 2024, with a CAGR of 165% during the period 2014–2024 [1]. And it is you who are creating the foundations for this revolution with your research efforts and your exciting results, some of which you will be sharing with us during this conference.

On behalf of the organizers of this symposium, I want to welcome you warmly to Basel, and we would like to wish you three days of outstanding scientific presentations and discussions.

Prepare yourself to be amazed, challenged and inspired—and enjoy your stay in Basel!

Peter Seitz
Conference Chair

[1] "Sensors and Technologies for the Internet of Things—Business and Market Trends 2014-2024", Yole Development, June 2014

Welcome by Prof. Dr. Antonio Loprieno

Dear colleagues,

In the name of the University of Basel, it is my distinct pleasure to welcome to our university and to our city all the participants of the *4th International Symposium on Sensor Science*, sponsored by the MDPI journal *Sensors*. If our 555-year-old university, firmly rooted in the values of Humanism as much as of scientific excellence in Life, Natural and Exact Sciences, has accepted the kind offer to hold this conference under its patronage, it is because our institutional strategy for the years 2014–2021 attributes the highest importance to translational domains of research such as yours. Thanks to our century-old intellectual tradition, but also to the presence of a pharmaceutical industry of global importance, of major clusters in the field of nanoscience, and of an active net of spin-offs and start-ups, we are confident to be an ideal venue for your scientific discussions and are proud to host you on our campus.

May your stay at the University of Basel be pleasant and productive!

With all best wishes,

Professor Antonio Loprieno
Rector

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1 General Information

The *4th International Symposium on Sensor Science* (*I3S2015*) will be held from the 13th to the 15th of July 2015 in Basel, Switzerland. It will comprise five plenary sessions and one afternoon with three parallel sessions to cover the most exciting aspects and the latest developments in sensor science.

1.1 Conference Topics

- Sensor technology and new sensor principles
- Electrochemical sensors/biosensors
- Electrical and thermal-based sensors
- Mass-sensitive and fiber-optic sensors
- Optoelectronic and photonic sensors
- Gas sensors
- Sensor applications for food industry, medicine, pharmacy, environmental monitoring, corrosion, *etc.*
- Sensor devices and sensor arrays/nanosensors
- Analytical methods, modeling, readout and software for sensors
- Neurosensors
- Sensor networks

1.2 Conference Venue

Biocenter/PharmaCenter
Universität Basel
Klingelbergstrasse 50, CH-4056 Basel, Switzerland

1.3 Registration Desk

Sunday, 12 July 2015
12:00–17:00

13 July–15 July 2015
07:30–17:30

Direct Telephone Line: +41 61 267 20 06

1.4 Wireless Internet Access

WLAN: unibas-event
Login: eventbzpz
Password: 4isSS-2015!

1.5 Directions and Map

1.6 Switzerland and the Tri-Region

Basel lies in the heart of Europe, on both banks of the Rhine. The city is the center of the idyllic border triangle of France, Germany and Switzerland—lying between the Swiss Jura, Germany's Black Forest and the Vosges in Alsace.

Basel is so easy to get to. Only a 10-minute drive from the city center, Basel's EuroAirport is served by a number of international airlines. Together with neighbouring Zürich Airport, it enjoys connections to all European airports and to more than 200 intercontinental destinations.

Located in the center of Europe, Basel is a major transportation hub. Its three railway stations not only offer excellent connections to far and wide but are also all situated in the very heart of the city. Source: www.basel.com

1.7 Basel

Where the Rhine, one of Europe's most important waterways, bends north and flows out of Switzerland towards the North Sea lies the charming city of Basel. This exceptional location at the heart of the three-country-triangle that joins Germany, France and Switzerland is what lends Basel its openness, economic strength and cultural diversity. Source: www.bs.ch

1.8 Best Connections

As far back as the Middle Ages, Basel became a major transportation hub thanks to its location on the Rhine and in the center of Europe. And still today, there is no way around Basel: The city lies at the intersection of the German and French rail and road networks. The trinational EuroAirport Basel-Mulhouse-Freiburg and the Rhine port connect Basel with the world. Source: www.bs.ch

1.9 Dynamic Economy

Again thanks to the Rhine, Basel developed into a prosperous center for commerce and trade fairs early on. Today, this city with a total area of only 37 square kilometres, inhabited by 200,000 people from 160 countries, is at the heart of the most dynamic economic region in Switzerland. Source: www.bs.ch

1.10 Fair Weather City

Next to the rich cultural offerings (museums with a global reputation, theater and concert halls, renowned architecture), the weather adds to the high quality of life: Nestled comfortably in the Rhine valley, Basel enjoys many more days of sunshine than the towns in central Switzerland. Source: www.bs.ch

1.11 The University of Basel

The University of Basel has an international reputation of outstanding achievements in research and teaching. Founded in 1460, the University of Basel is the oldest university in Switzerland and has a history of success going back over 550 years.

As a comprehensive university offering a wide range of high-quality educational opportunities, the University of Basel attracts students from Switzerland and the entire world, offering them outstanding studying conditions as they work towards their bachelor's, master's or PhD degrees. Today, the University of Basel has around 13,000 students from over a hundred nations, including 2,700 PhD students. The University of Basel has seven faculties covering a wide spectrum of academic disciplines. At the same time, the university has positioned itself amidst the international competition in the form of five strategic focal areas: Life Sciences, Visual Studies, Nanosciences, Sustainability and Energy Research and European and Global Studies. In international rankings, the University of Basel is regularly placed among the 100 top universities in the world thanks to its research achievements. Source: www.unibas.ch

1.12 Biocenter/PharmaCenter

The Biozentrum (Biocenter), is the largest department at the University of Basel's Faculty of Science. The primary focus of this interdisciplinary institute is basic molecular and biomedical research and teaching. The Biozentrum holds a leading position nationally and internationally and closely networks with partners from the academic world and industry.

In 1971, at the time when the Biozentrum was founded, the visionary concept of developing an interdisciplinary research facility was unique. Today, some 40 years later, the success of this interdisciplinary approach to molecular and biomedical research remains evident. It continues to be the Biozentrum's greatest strength, along with its excellent facilities providing leading technologies and its highly motivated staff.

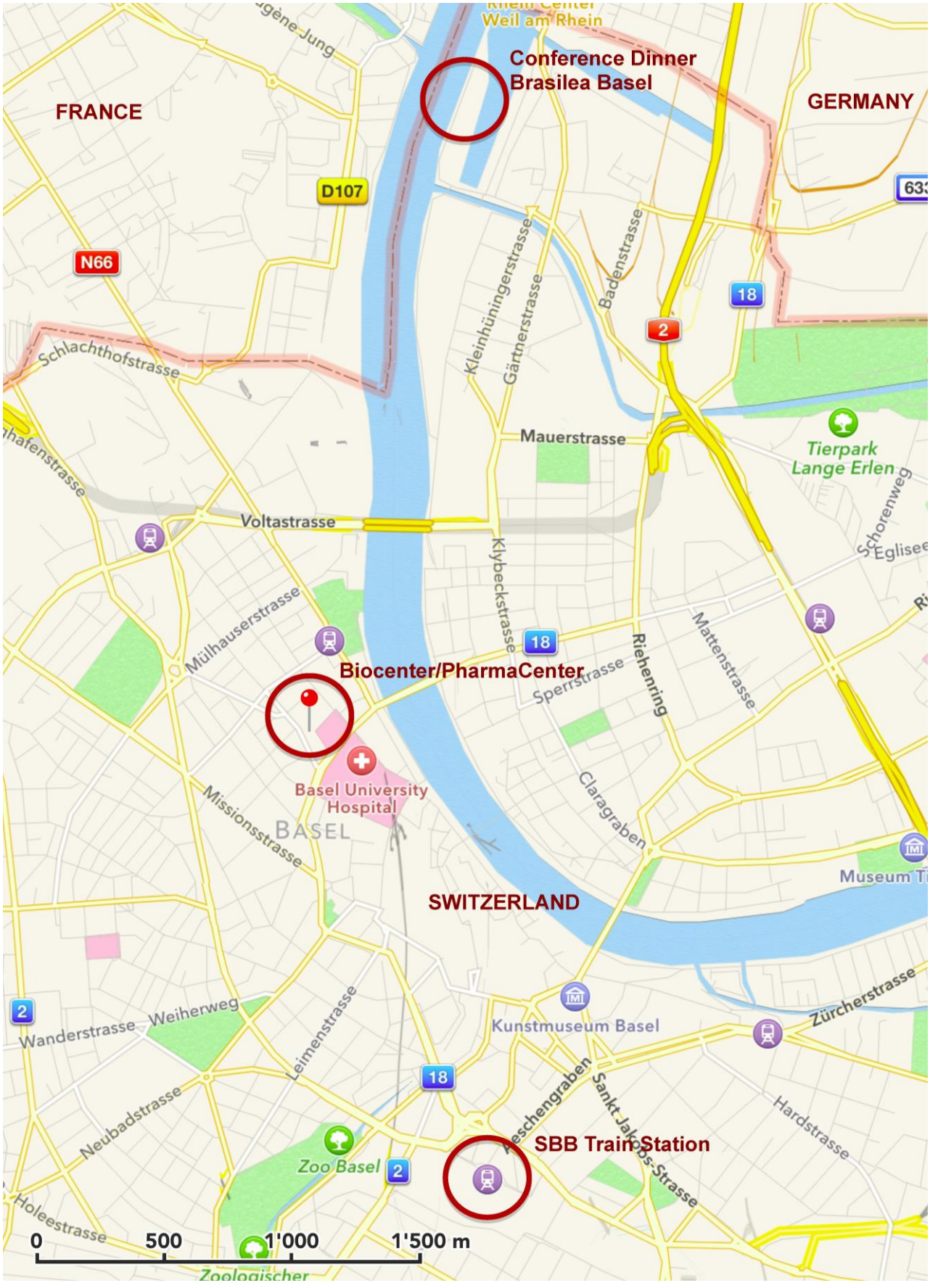
The Biozentrum is home to 30 research groups. These scientists, representing more than 40 nations, are engaged in investigating the molecular basis of biological processes. Their work covers a broad spectrum of activities, the scientific research is wide-ranging: How does a cell develop, how does it function and how are all its vital processes regulated? Can we make computer assisted models of these processes? How does a stem cell know what to become? How does a blood vessel form or the nervous system develop and how does the body defend itself against bacterial infections? Could

the findings lead to new approaches in the treatment of serious diseases such as muscular diseases, Alzheimer's disease or cancer? Producing more than 200 scientific publications each year, the Biozentrum is regularly rated in the top 25% of the world rankings. Research at the Biozentrum is grouped into five major focal areas: Growth and Development, Infection Biology, Neurobiology, Structural Biology and Biophysics, as well as Computational and Systems Biology. These research areas, however, are not strictly separated from each other; new and relevant questions often arise at the overlap between the research fields, while the collaboration between teams and the expertise of each respective area leads to innovative solutions. This has contributed greatly to the scientific success of the Biozentrum. Both its funding and infrastructure make the Biozentrum internationally highly competitive and ensures research of the highest level.

The Biozentrum enjoys an excellent reputation for its scientific training, both nationally and internationally. Students are integrated into a research environment from the start of their academic career and gain first-hand experience of life as a scientist. Being able to link education with research makes the Bachelor's and Master's degree programs at the Biozentrum particularly attractive for many aspiring students. PhDs and postdocs, on the other hand, benefit from the Biozentrum's scientific success and the intensive, individual supervision.

The PharmaCenter Basel, The University of Basel Translational Science Platform, is the interdisciplinary center for excellence at the University of Basel. The PharmaCenter Basel aims to establish a leading research and teaching community in drug development, drug therapy and drug safety. Together with partners from the industry, the PharmaCenter Basel plans to translate increased knowledge about the molecular basis of disease into improved therapies.
Sources: www.biozentrum.unibas.ch and https://pharmacenter.unibas.ch/

1.13 Location



1.14 How to Reach the Venue

Public Transport

From **EuroAirport Basel Mulhouse Freiburg** (15 minute journey)
Take the airport bus (No. 50) to the Kannenfeldplatz stop, where you have to change onto a No. 31, 36 or 38 bus going in the direction of Schifflände/Habermatten or Wyhlen Siedlung. Get off at the next stop, Metzerstrasse, and cross the road to the Biocenter/PharmaCenter.

From the **Basel SBB** (Swiss) and SNCF (French) train station (15 minute journey)
Take a No. 30 bus to the Kinderspital UKBB (children's hospital) stop and cross the road to the Biocenter/PharmaCenter–see Google Maps.

From the **Badischer Bahnhof** (German) train station: (10 minute journey)
Take a No. 30 bus to the Kinderspital UKBB (children's hospital) stop, and then walk to the Biocenter/PharmaCenter–see Google Maps.

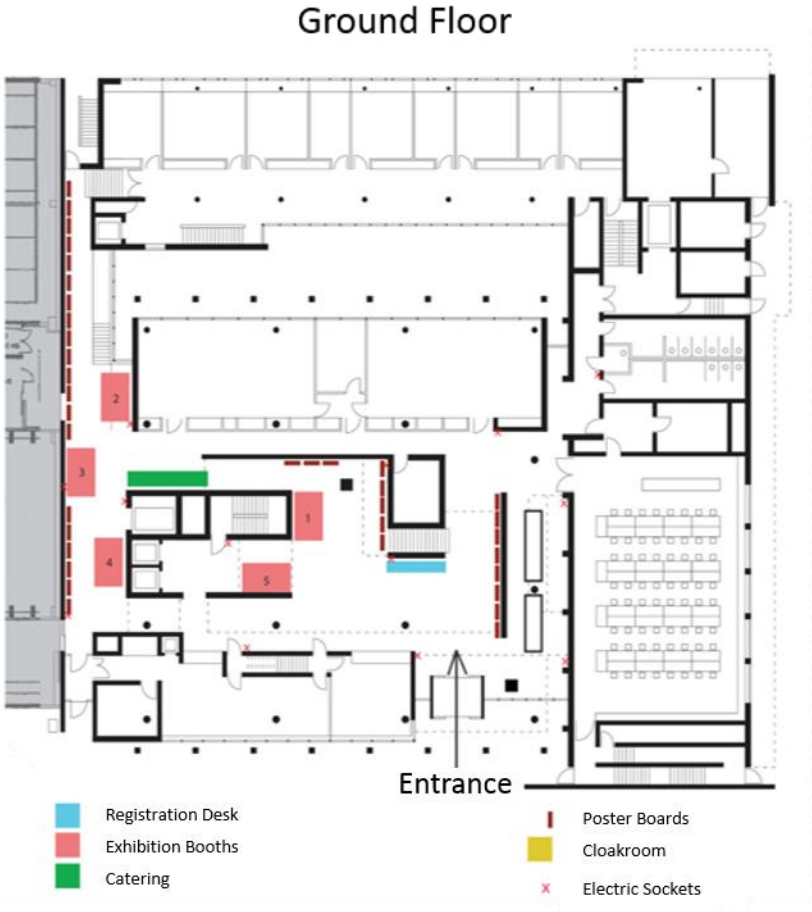
By Car

Within Switzerland
Leave the expressway in the direction of the Unispital, drive through the tunnel and then across the viaduct. Keep on the main road, passing Spalentor, and carry straight on over the traffic lights. Turn left after about 500 m. The Biocenter/PharmaCenter is then on the right-hand side.

From France
After driving over the border in Saint-Louis, drive towards Basel-Kannenfeld as indicated. Stay on the main road (direction city), go straight on around the roundabout (direction city) and, after about 500 m, take the left-hand lane at Kannenfeldplatz. After only a few meters, take the right-hand lane and turn into Metzerstrasse. The Biocenter/PharmaCenter is then about 300 m ahead.

From Germany
Leave the expressway at exit Basel-St. Johann. After the tunnel, carry straight on for about 150 m. Turn left into Elsässerstrasse (direction city) and then, after 550 m, right onto St. Johanns-Ring (direction Augenspital). 300 m farther on, turn left into Klingelbergstrasse. The Biocenter/PharmaCenter is then on the left-hand side. Source: www.biozentrum.unibas.ch

1.15 Inside the Biocenter/PharmaCenter



1.16 Conference Dinner

Tuesday, 14 July 2015, 18:00

The conference dinner will take place at the Kunst- und Kulturhaus BRASILEA in the middle of the three border triangle. After the conference you will be guided to a nearby dock and transported by a boat taxi on the Rhine.

Kunst- und Kulturhaus BRASILEA

The ship engine factory was built in the middle of the border triangle with France and Germany in 1963. Its position is inside a green corridor parallel to the Rhine river. The far overhanging crane works as a significant time-witness and as a landmark of the building and the harbour. The building is solely orientated and open towards the river through horizontally rows of windows. Two materials arrange and assign the appearance: Reinforced concrete is used for the ground floor and translucent fibreglass is used for the build-up of the facade cover. The new dress glimmers, glitters and reflects due to light intension and position. The locations abrasive industrial character keeps on conserved. Raw materials were used consciously for renovation to do justice to primary use as well as to new cultural and art needs. Simplicity and robustness are part of our concept credo to understand architecture as a daily article of use. The esthetic effect is a sensible staging who distributes an industrial elegance to the premises and simultaneously demonstrates the changing port area. Source: www.brasilea.com

Returning to the Hotel

After the Conference Dinner, a private shuttle will take you back to the city center.

1.17 Visiting Basel and Dining Out

It is not easy to describe Basel in a few words. Descriptions for example such as “cultural city of Switzerland” or “University town” are merely an attempt to give some sort of impression of the wealth of culture, history, relaxation and enjoyment to be found in the city. Whether it is a visit to one of the numerous museums, a dip in the Rhine or an evening at the theater, allow yourself to be inspired by the joys that await you in Basel. We hope you have a fantastic time here in Basel.

Art and Culture

Fondation Beyeler—www.fondationbeyeler.ch

In building Renzo Piano’s museum in 1997, the Fondation Beyeler made its collection accessible to the public. The 250-odd works of classic modernism reflect the views of Hildy and Ernst Beyeler on 20th-century art and highlight features typical of the period: from Monet, Cézanne and van Gogh to Picasso, Warhol, Lichtenstein and Bacon. The paintings appear alongside tribal art from Africa, Oceania and Alaska.

Museum Tinguely—www.tinguely.ch

Situated directly on the Rhine, the Museum Tinguely, built according to plans by the Ticinese architect Mario Botta, houses the greatest collection of works by Jean Tinguely (1925–1991), one of the most innovative and important Swiss artists of the 20th century. The permanent exhibition presents a survey of his oeuvre spanning four decades. Special exhibitions show a wide range of artists and subjects including Marcel Duchamp and Kurt Schwitters who influenced Tinguely significantly, companions such as Arman, Niki de Saint Phalle, Yves Klein as well as current art trends along Tinguely’s ideas.

Vitra Design Museum—www.design-museum.de

The Vitra Design Museum numbers among the world’s most prominent museums of design. It is dedicated to the research and presentation of design, past and present, and examines its relationship to architecture, art and everyday culture. In the main museum building by Frank Gehry, the museum annually mounts two major temporary exhibitions. In conjunction with our alternating exhibitions, the Vitra Design Museum offers a variety of workshops and guided tours. Source: www.basel.com/en

Suggestions of Restaurants in Basel—www.basel.com

***Kohlmanns*–www.kohlmanns.ch**

It smells of fire, wood and freshly baked goods. The restaurant with its modern oak furniture is extremely cosy and is situated right at the Barfüsserplatz. *Kohlmanns* offers hearty Swiss and surprising regional specialities.

***Brasserie au Violon*–www.au-violon.com**

Lively brasserie with traditional and seasonal French cuisine served in a former prison.

***Zum Braunen Mutz*–www.braunermutz.ch**

The traditional tavern with bar and restaurant. Here you will meet original Basel locals of all generations.

***Der vierte König*–www.weinwirtschaft.ch**

In the restaurant *Der vierte König* you will find freshly cooked meals and a fine selection of bottled wines from all over the world–also available by the glass.

***Kunsthalle*–www.restaurant-kunsthalle.ch**

The traditional restaurant *Kunsthalle*, where "Tout Bâle" feels at home serves seasonal delicacies.

***Käfer Stube* cuisine des alpes–www.kaefer-schweiz.ch**

Gourmet restaurant with regional products from all the alpine countries.

***Cheval Blanc*–www.lestroisrois.ch**

Refined seasonal cuisine and a selected wine list. Awarded with 19 points Gault-Millau and two Michelin stars. Summer terrace with a great view of the Rhine.

***Chez Donati*–www.lestroisrois.com**

For more than 50 years, the *Chez Donati* is an esteemed institution and the essence of fine Italian table culture in Basel.

***Brasserie Les Trois Rois*–www.lestroisrois.com**

The relaxed atmosphere and Swiss and French brasserie specialities make the city restaurant in the *Les Trois Rois*, a 5-star-superior deluxe hotel, a popular all-day rendezvous.

***Atelier* (*Der Teufelhof*)–www.teufelhof.com**

The restaurant charms by its modern and inspiring ambience. Enjoy a modern international cuisine with predominatly Swiss and regional products.

***Les Quatre Saisons*–www.lesquatresaisons.ch**

Treat yourself to some culinary delights in the newly renovated Restaurant *Les Quatre Saisons.* Head chef Peter Moser and his team apply a fresh sense of inspiration and a high level of commitment to their dishes, bringing together all of the elements necessary to create their unique cuisine–ingredients fresh from the market, original recipes and a great deal of passion.

Suggested Events

Disney The Lion King–www.thelionking.ch

Be transfixed by powerful African rhythms, the warm glow of the Serengeti and timeless hits including «Circle of Life» and «Can You Feel the Love Tonight» by Sir Elton John and Sir Tim Rice. Experience the magnificent musical about Simba and his adventurous journey from innocent lion cub to King of the Pridelands in its English original production.

Holbein. Cranach. Grünewald. Masterpieces from the Kunstmuseum Basel – www.kunstmuseumbasel.ch/en

If the Kunstmuseum Basel enjoys global renown today, this is essentially due to its collection of works by Hans Holbein the Younger, the world's largest in a single museum. It was in Basel that Holbein's genius achieved full realization. The treasure of pictures he left behind also inspired the city's residents who successively enlarged the collection with masterpieces of the late Middle Ages and the Renaissance.

Cézanne to Richter. Masterpieces of the Kunstmuseum Basel–www.kunstmuseumbasel.ch/en

Basel's public art collection is of outstanding importance, especially in terms of the late 19th century and classical modernism.
The large Oberlichtsaal and adjacent rooms of the Museum für Gegenwartskunst (Museum of Contemporary Art) is staging masterpieces from Paul Cézanne to Gerhard Richter. This wide-ranging overview vividly illustrates the main artistic developments in European painting up to the 1970s. The chronology serves as a guide to the 70 or so works which are less a didactic sequence of artistic movements and more a simultaneity of otherness that characterizes the modern period. The first works are by French artists who were seeking new visual languages beyond academic painting. The work by Paul Cézanne stands as an example of dogged artistic research.

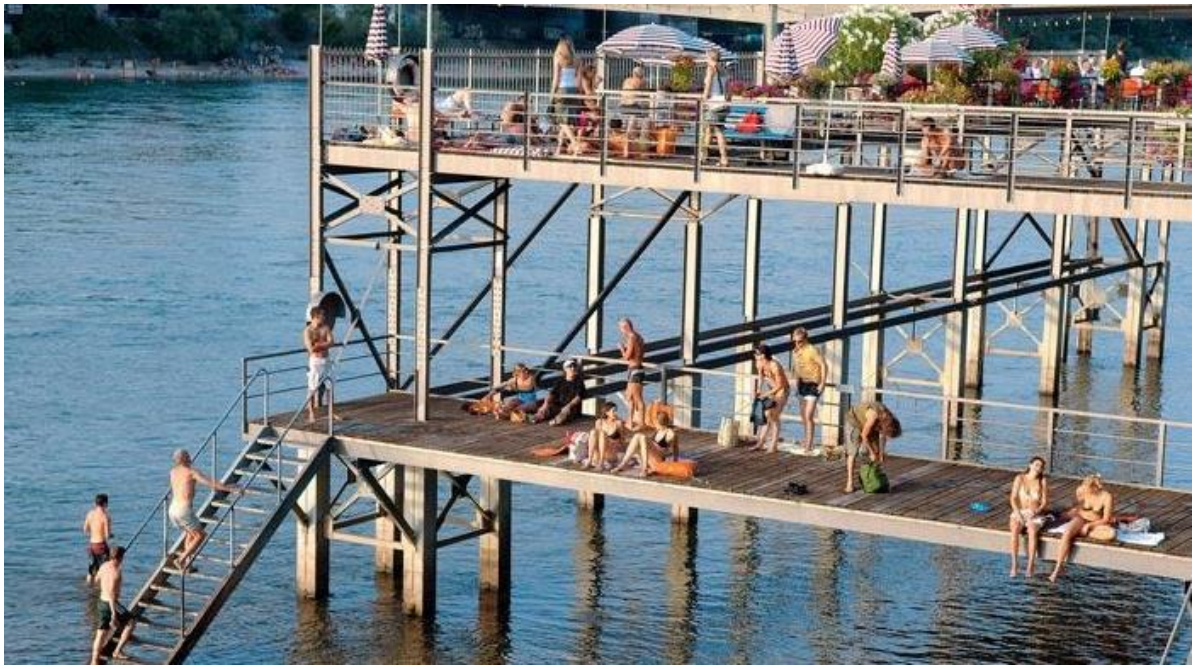
... and if you intend to stay longer

Basel Tattoo–www.baseltattoo.ch

This top-quality musical event features bagpipes, brass bands and traditional folk dancing with top dance troupes from around the world and delights both young and old in equal measure. The Basel Tattoo guarantees a sensational and perfect show with the best formations, which will thrill the audience into standing ovations.
Source: https://ueber.basel.com/en/event/basel-tattoo-0

Summer in Basel

Summer Bars in Basel–www.basel.com/en/summer-openings-basel
The Rhine is Life–www.basel.com/en/portrait/rhine-life
Parks and Gardens - www.basel.com/en/sommer_in_basel/park_und_gaerten



1.18 Emergency Information

Other useful numbers

Medical Emergency Center	+41 (0) 61 261 15 15
REGA air rescue service	1414

2 Scientific Program

2.1 Program at a Glance

<table>
<tr><td></td><td>Monday, 13th July</td><td>Tuesday, 14th July</td><td colspan="3">Wednesday, 15th July</td></tr>
<tr><td rowspan="3">Morning</td><td>Check-in
Conference Opening
Sensors Breakthroughs</td><td rowspan="2">Chemical Sensors</td><td rowspan="2">Photonic Sensing</td><td rowspan="2">Remote & Micropower Sensors</td><td rowspan="2">Neurosensors</td></tr>
<tr><td>Coffee Break</td><td>Coffee Break</td></tr>
<tr><td>Sensors Breakthroughs</td><td>Chemical Sensors</td><td>Photonic Sensing</td><td>Remote & Micropower Sensors</td><td>Neurosensors</td></tr>
<tr><td></td><td>Lunch & Poster Session (odd)</td><td>Lunch & Poster Session (odd)</td><td colspan="3">Lunch & Poster Session (even)</td></tr>
<tr><td rowspan="4">Afternoon</td><td>Biosensors</td><td>Extreme Sensing</td><td colspan="2">Single Chip Sensors and Sensor Networks</td><td>i-net Technology Workshop</td></tr>
<tr><td>Coffee Break</td><td>Coffee Break</td><td colspan="3">Coffee Break</td></tr>
<tr><td>Biosensors</td><td>Extreme Sensing</td><td colspan="2">Single Chip Sensors and Sensor Networks</td><td>i-net Technology Workshop</td></tr>
<tr><td>Poster Session (even)</td><td>Conference Dinner</td><td colspan="3">Closing Remarks</td></tr>
</table>

2.2 Detailed Program

Monday, 13 July 2015	
07:00–09:00	Check-in & Welcome Coffee
09:00–09:05	Welcome by Guy Morin–President of the Government of the Canton of Basel-Stadt
09:05–09:10	Welcome by Huangxian Ju–*I3S2004* Conference Chair
09:10–09:15	Conference Opening by Peter Seitz–*I3S2015* Conference Chair
09:15–12:30	**Session 1: Sensors Breakthroughs**
Session Chair:	**Debbie G. Senesky**
09:15–10:00	Roland Horisberger–*Supreme Sensing to Answer the Ultimate Questions of Physics*
10:00–10:30	Christof Fattinger–*Focal Molography: The Coherent Detection of Biomolecular Interactions*
10:30–11:00	Coffee Break & Networking
11:00–11:30	Vladimir M. Mirsky–*Ultrasensitive SPR-Sensors*
11:30–11:45	Logan S. Marcus–*Photoacoustic Spectroscopy-Based Sensor Platforms: Trace Gas Sensing and Standoff Detection of Solid Materials* (selected from abstracts)
11:45–12:00	Torsten Wagner–*From the Light-Addressable Potentiometric Sensor towards a Fully Integrated (Bio)chemical Sensor Platform* (selected from abstracts)
12:00–12:30	Evgeny Katz–*Binary Operating Biosensors Based on Biocomputing Systems*
12:30–14:15	Lunch & Poster Session (odd numbers)
14:15–18:00	**Session 2: Biosensors**
Session Chair:	**Michael J. Schöning**
14:15–15:00	Huangxian Ju–*Signal Amplification Strategies for Biosensing*
15:00–15:15	Tal Yoetz-Kopelman–*Amperometric Bacterial Biosensor for Screening of Cytochrome P450 Inhibitors* (selected from abstracts)
15:15–15:30	Laurent A. Francis - *An Integrated Capacitive Array Biosensor for the Selective and Real-Time Detection of Whole Bacterial Cells* (selected from abstracts)
15:30–16:00	Spas Dimitrov Kolev–*Paper-based Microfluidic Sensors for Environmental Monitoring and Analysis*
16:00–16:30	Coffee Break & Networking
16:30–17:00	Gary Zabow–*Dynamically Morphing Magnetic Complexes as new RF-Based Nanosensors* (selected from abstracts)
17:00–17:15	Arshak Poghossian–*Label-Free Detection of DNA Molecules by their Intrinsic Molecular Charge using Field-Effect Sensors Modified with a Positively Charged Weak-Polyelectrolyte Layer* (selected from abstracts)
17:15–17:30	Alexander Star–*Chemical and Biological Sensing with Carbon Nanostructures*
17:30–18:00	Muthukumaran Packirisamy–*Nanostructures Integrated Optofluids Chips for the Detection of Proteins* (selected from abstracts)
18:00–19:30	Poster Session (Even Numbers)

Tuesday, 14 July 2015	
08:15–12:30	**Session 3: Chemical Sensors**
Session Chair:	**Peter Hauser**
08:15–09:00	Tatsuo Yoshinobu–*Recent Developments and Applications of the Chemical Imaging Sensor Systems*
09:00–09:15	Karine Bonnot–*The Sensitive Detection and Identification of RDX and PETN Explosives Vapors by Measuring Their Thermal Signature When Desorbing or Decomposing the Explosive Inside a Porous Material* (selected from abstracts)
09.15–09.30	Kohji Mitsubayashi–*Sniff-Camera For Imaging of Gazeous Ethanol From Palm Skin After Drinking* (selected from abstracts)
09:30–10:00	Dermot Diamond–*Chemical Sensing Based on Biomimetic Principles*
10:00–10:30	Coffee Break & Networking
10:30–11:00	W. Rudolf Seitz–*Ratiometric Fluorescent Indicators for Metal Ions and Polar Organics based on the Poly-N-isopropylacrylamide Thermal Phase Transition*
11:00–11:15	Johan Stiens - *Change Detection in (Bio)chemical Liquids with Ultrasensitive Label-Free and Immobilization-Free Sensors Operating the GHz-THz Range* (selected from abstracts)
11:15–11:30	Eloisa Gallegos-Arellano–*Simultaneous CO and CO_2 Gas Sensor based on a Single Fabry-Perot Interferometer* (selected from abstracts)
11:30–12:00	Fabien Josse–*Design of Sensor Coatings with High Sensitivity to Benzene and Long-Term Stability for Groundwater Monitoring Applications* (selected from abstracts)
12:00–13:45	Lunch & Poster Session (odd numbers)
13:45–17:30	**Session 4: Extreme Sensing**
Session Chair:	**Roland Moser**
13:45–14:30	Debbie G. Senesky–*Micro- and Nano-scale Sensors for Extreme Harsh Environments*
14:30–15:00	Michael J. Schöning–*Thin-Film Sensors for Monitoring Aseptic Food Processes*
15:00–15:15	Yacine Halfaya–*High Sensitivity NO, NO_2 and NH_3 HEMT Based Sensor for Diesel Exhaust Systems* (selected from abstracts)
15:15–15:30	Thierry Laroche–*Surface Acoustic Waves Sensors on Langasite Substrates for High Temperature Measurements* (selected from abstracts)
15:30–16:00	Xueji Zhang–*New Strategy for microRNA Detection*
16:00–16:30	Coffee Break & Networking
16:30–17:00	Adrian M. Ionescu–*Tunnel FET Sensors: Breaking Sensitivity and Energy Efficiency Limits for Integrated Transducers*
17:00–17:30	Juerg Leuthold–*Photonic Probing with Memresistive Devices*
18:00	Conference Dinner

Wednesday, 15 July 2015	
08:15–12:00	**Session 5.1: Photonic Sensing**
Session Chair:	**Hans Peter Herzig**
08:15–09:00	Christian Pedersen–*Room-Temperature Mid-Infrared Single Photon Spectral Imaging*
09:00–09:30	Vittorio M.N. Passaro–*Silicon on Insulator Vernier Devices for High Performance Photonic Sensing in the Near-IR and Mid-IR*
09:30–10:00	Vanessa Wood–*Infrared Wavelength Quantum Dot-based Sensing*
10:00–10:30	Coffee Break & Networking
10:30–11:00	Markus Werner Sigrist–*Mid-Infrared Laser Spectroscopic Chemical Sensing*
11.00–11.15	Raphael Florin Tiefenauer–*Simultaneous Electrical and Plasmonic Sensing with Gold Nanostructures: Device Fabrication and Applications* (selected from abstracts)
11:15–11:30	Simas Rackauskas–*Flexible and transparent UV sensor from ZnO tetrapods* (selected from abstracts)
11:30–12:00	Andrea Fiore - *Light Sensing at the Quantum Limit: Measuring from One to Twenty Photons*
12:00–13:45	Lunch & Poster Session (Even numbers)

08:15–12:00	**Session 5.2: Remote and Micropower Sensors**
Session Chair:	**Assefa Melesse**
08:15–09:00	Leonhard Reindl–*Power Supply for Wireless Sensor or Actuator Systems*
09:00–09:30	Assefa M. Melesse–*Sensors and Role of Remote Sensing in Coastal and Wetland Studies*
09:30–10:00	Marcin Kafarski–*Porous Corundum Plate Sensor for Atmospheric Water Deposits' TDR Measurements* (selected from abstracts)
10:00–10:30	Coffee Break & Networking
10:30–11:00	Agnieszka Szypłowska–*Determination of Complex Dielectric Permittivity Spectra from the Analysis of Electrical Signal Reflection in Transmission Lines of Various Lengths* (selected from abstracts)
11:00–11:30	Mehran Safdar–*A Mobile Vehicle Weight Sensor and its Application in Transportation (Case Study: Municipal Solid Waste Collection Vehicles)* (selected from abstracts)
11:30–12:00	Andrzej Wilczek–*Impact of the TDR Pulse Width on the Reflection Amplitude and its Dependence on Soil Dielectric Loss and Electrical Conductivity* (selected from aAbstracts)
12:00–13:45	Lunch & Poster Session (Even numbers)

08:15–12:00	**Session 5.3: Neurosensors**
Session Chair:	**Patricia A. Broderick**
08:15–09:00	Stéphanie P. Lacour–*Soft Transducers to Communicate with the Nervous System*
09:00–10:00	Patricia A. Broderick–*Nanobioimaging: Personalized Medicine in Real Life is Here. Nanotechnology Meets the Brain.*
10:00–10:30	Coffee Break & Networking
10:30–11:00	Christian Peter Brändli–*Neuro-Inspired, Event-Based Vision Sensors*
11:00–11:30	Federico Picollo–*Diamond-Based Electrochemical Sensor: A Multi Electrode Array for Simultaneous Detection of Quantal Exocytic Events from Neuroendocrine Cells* (selected from abstracts)
11:30–12:00	Yusuf Leblebici–*3D Microelectrode Arrays for Neuro-Sensing: Read-Out Circuit Design and Hybrid 3D Integration*
12:00-13:45	Lunch & Poster Session (Even numbers)

13:45–18:15	**Session 6: Single Chip Sensors and Sensor Networks**
Session Chair:	**Patrick Thomas Eugster**
13:45–14:30	Andrew J. de Mello–*Droplet-Based Microfluidics: Towards Ultra-High Throughput Experimentation*
14:30–15:00	Christian Schönenberger–*Silicon Nanowire Ion Sensitive Field Effect Transistor*
15:00–15:15	Denis Sallin–*A CMOS Compatible Photodetector with Intrinsic Light-to-Time Conversion for Low Light Applications* (selected from abstracts)
15:15–15:45	Eduardo Franzi–*Smart Image Sensors for Metrology Applications*
15:45–16:15	Coffee Break & Networking
16:15–16:45	Patrick Thomas Eugster–*Towards a Robust Internet of Things: the Case of Wireless Sensor Networks*
16:45–17:15	Thomas Watteyne–*From Smart Dust to 6TiSCH: Building the Industrial Internet of Things*
17:15–17:30	Chih-Yu Wen–*Energy-Efficient Scheduling with Compressed Sensing for Distributed Target Tracking* (selected from abstracts)
17:30–18:00	Jean-Dominique Decotignie–*Wireless Sensor Networks, Real-Time and Low Consumption: Lessons Learned*
18:00–18:15	Closing Remarks–Announcement of the “Best Poster“

14:15–17:30	**Session 7: i-net Technology Workshop**
	«Sensors - Trends, Exchanges and Collaborations»
14:15–14:25	Welcome & Introduction: Dr. Ralf Dümpelmann, i-net
14:25–14:50	Highlights of the Symposium: Prof. Dr. Peter Seitz, Conference Chair
14:50–16:30	Interactive Working Groups “Introduction and Exchange in a Dynamic and Changing Atmosphere”
16:30–17:00	Harvesting: Collecting and presenting conclusions, project ideas or collaborations. Proposals of follow-up actions.
17:00–17:30	End of i-net Workshop

Oral Presentation Abstracts

Session 1: Sensors Breakthroughs

Session Chair: Debbie G. Senesky


SWISS PHOTONICS


HAMAMATSU

Supreme Sensing to Answer the Ultimate Questions of Physics

Roland Horisberger

Paul Scherrer Institute (PSI) / ETH Zürich, Switzerland.

The quest to understand the fundamental physical behavior of matter requires the observation of newly created elementary particles by colliding protons at the highest energies possible. The Large Hadron Collider (LHC) at CERN is designed to collide protons at the world's highest achieved energy of 13 TeV. The induced physics processes allow to observe and test on a fundamental level, the currently best available theoretical description, the Standard Model (SM) of particles and forces. The experimental observations of the induced particle reactions require the development and construction of sensing detectors that are able to measure precisely the position and momentum of the emerging particles under extreme conditions and unprecedented data rates. The Compact Muon Solenoid Experiment (CMS) at LHC has at its innermost radius a pixel particle detector that is crucial to the reconstruction of the induced particle physics reactions. The design and conception of the CMS pixel detector is described as well as its performance that has been crucial in the observation of the newly discovered Higgs Boson. The successful application of this new and supreme detector technology in the field of protein crystallography has been an outstanding success story on how fundamental physics research can cross-fertilize into the field of molecular biology.

Focal Molography: The Coherent Detection of Biomolecular Interactions

Christof Fattinger

Roche Innovation Center Basel, Basel, Switzerland.

Focal molography is based on the scattering of coherent light by coherently assembled molecules that are linked to a biocompatible monolithic layer on the surface of a chip [1, 2]. Because only coherently arranged molecules contribute to the molographic signal, focal molography is much less affected by nonspecific bindings, medium composition, and solvent exchanges than refractometric label-free detection methods (e.g., surface plasmon resonance (SPR), interferometric detection schemes) are. Background scattering by randomly attached molecules can be easily separated from the detected coherent signal. Submicron photolithography is well-suited for the preparation of molograms on the surface of a chip. A mologram represents a phase object with minuscule phase contrast. The optical detection of loosely packed biomolecules in the mologram is accomplished through the dark-field illumination of the mologram with coherent light, which yields a diffraction-limited focal spot, the focus of the mologram. From all other observation points, the mologram is perfectly transparent. Focal molography is applicable to all assays in which molecular recognition and binding are of prime interest. The coherent detection principle enables the analysis of biomolecular recognition and binding processes at low receptor occupancy in a complex biological environment. This opens up new perspectives and possibilities in the analysis of non-covalent interactions involving known or unknown biomolecules. The talk introduces the fundamentals of focal molography and describes the light-controlled synthesis of the modulated molographic binding pattern on a monolithic brushed-polymer layer. The talk discusses promising applications of the new analytical method, e.g., novel ways of performing sensitive real-time immunoassays, proteomics, transcriptomics on a chip, and the development of diagnostic tests at the point of care.

Ultrasensitive SPR-Sensors

Vladimir M. Mirsky

Brandenburgische Technische Universität Cottbus, Senftenberg, Germany.

Surface plasmon resonance (SPR) is currently the mostly used transducing technology applied in label-free biosensing. It belongs to refractometry: analyte adsorption onto immobilized receptor molecules leads to an increase of refractive index which is detected as a shift of resonance conditions of surface plasmons. An important task of the improvement of SPR technique is a separation of a signal corresponding to the changes in the surface layer from an undesired contribution caused by volume phase (for example due to fluctuations of temperature, concentrations of solutes or pressure) and a suppression of the contribution of the volume effects. A number of different approaches of self-referencing SPR measurements, mainly the ones developed in our group, will be discussed and compared. One approach ("distributed referencing") is based on SPR-microscopy of a surface with microstructured sensing and referencing spots: instead of single macroscopic reference spots, numerous miniaturized reference spots placed between miniaturized sensing spots are used. During the signal processing, the signals from numerous reference and sensor spots are taken into account. This leads to a decrease of fluctuations of temperature (as well as of the pressure, reagent concentrations) to the level of these fluctuations between two miniaturized sensing and reference spots while the total area of the spots remains macroscopic thus suppressing noise sources caused by miniaturization of the sensor surface. Another approach (Penetration Difference Self Referencing Surface Plasmon Resonance - PDSR-SPR) is based on the sharp decay of evanescent field and on its strong dependence on the wavelength of the incident light. This technology was realized as an integral technique and as an SPR-imaging. The third approach is based on application of integral SPR measurements to specially designed microstructured surfaces. The measurement is performed at the incidence angle corresponding resonance conditions for the patterned surface. The intensity of the reflected light measured at such conditions corresponds to the difference of signals coming from sensing and referencing areas. This self-referencing approach is applicable in a wide range of existing SPR devices with Kretschmann configuration.Theoretical analysis and subsequent computer simulation and optimization of this technique indicate a possibility of over 20-times suppression of the contribution of the volume effect. Experimental tests result in some smaller values - about 10-15 times suppression was obtained. Finally, an application of surface plasmon microscopy for detection and analysis of single nanoparticles will be discussed. This new technology was developed within FP7 project “NANODETECTOR”. A number of the nanoparticle–surface binding events per time unit characterizes volume concentration of nanoparticles. A large value of the resonant surface allows us to detect many hundreds events in each frame, this leads to a very high dynamic range of counting and correspondingly to a high dynamic range in the concentration scale. Depending on the type of nanoparticles and experimental conditions, the detection limit for aqueous samples can be so low as 10 - 1000 nanoparticles per microliter. Characteristic SPR images of nanoparticles allows

us to study heterogeneity of nanoparticles and can be used as a finger prints for identification of different types of nanomaterials. Chemical modification of the plasmonic surface as well as changes of pH or ionic strength influence on the interaction of nanoparticles with surface and can be used as additional parameters to evaluate this interaction and to distinguish between different types of nanoparticles.

Photoacoustic Spectroscopy-Based Sensor Platforms: Trace Gas Sensing and Standoff Detection of Solid Materials

Logan S. Marcus, Ellen L. Holthoff, Paul M. Pellegrino.

U.S. Army Research Laboratory, USA

Photoacoustic spectroscopy (PAS) is a versatile and sensitive chemical sensing method. This versatility allows for the construction of focused sensors that are optimized for specific sensing tasks. Current research underway at the U.S. Army Research Laboratory (ARL) is directed towards two fronts; gaseous hazard detection and ranged interrogation of layered solid samples. The common point of the two sensing tasks is the excitation source. Commercial quantum cascade lasers (QCLs) offer broad wavelength tuning ranges in ever decreasing package sizes, and operate in the appropriate modes of modulation needed to drive PAS. We discuss QCL technology in relation to the construction of a compact gaseous sensor platform based on microelectromechanical (MEMS)-scale photoacoustic (PA) cells. The use of MEMS-scale cells allows for the miniaturization of the PA sensor, which leads to greater sensor portability and flexibility while maintaining detection sensitivity. We also discuss standoff PA investigation of layered solid samples comprised of a thick substrate topped with a thin layer of energetic material. The current sensing paradigm uses an interferometer to measure the PA signal, and that signal lends insight into the mechanical and optical properties of the sample. Finally, the different operating modes (*i.e.*, pulsed or continuous wave (CW) modulated) of the excitation laser source (QCL) will be examined.

From the Light-Addressable Potentiometric Sensor towards a Fully Integrated (Bio)chemical Sensor Platform

Torsten Wagner [1,2], Frederik Carl Werner [3], Ko-ichiro Miyamoto [3], Tatsuo Yoshinobu [3, 4], Michael J. Schöning [1, 2]

[1] Institute of Nano- and Biotechnologies, FH Aachen, Germany. [2] Peter Grünberg Institut PGI-8, Research Center Jülich GmbH, Germany. [3] Department of Electronic Engineering, Tohoku University, Japan. [4] Department of Biomedical Engineering, Tohoku University, Japan.

With the release of small, affordable and powerful enough system-on-chip (SoC)-designs, current research and development trends towards the design of fully integrated miniaturised sensor systems. Such units contain the sensor itself and an analogue front-end for the sensor supply and read-out. Furthermore, they include a SoC-based digital unit to control measurement sequences and to analyse the obtained sensor raw data. Finally, they hold a digital back-end to link up the sensor unit, enabling communication within a network of other devices. As a semiconductor-based (bio-)chemical sensor, the light-addressable potentiometric sensor (LAPS) is suited to the design of miniaturised and microelectronic compatible sensor systems. The read-out mechanism relies on a spatially resolved current, induced by a light beam. The amplitude of this photo-current depends eventually on the ion concentration at the sensor surface of the illuminated region. Thereby, moving the light source or changing the light beam geometry enables the user to address individual parts of the sensor surface, or to adjust the measurement spot geometry easily. It was demonstrated that this unique feature can be utilised to create arrays of measurement sport arrangements for a set of different analytes. Moreover, one can scan the entire sensor surface to compose chemical images of the ion concentration distributions at the sensor surface. Nevertheless, until recently, the complex read-out sequence, the recording of a photo-current in the nano-ampere range and the handling of a LAPS-chips required a good amount of experience and theoretical knowledge. Furthermore, a set of expensive laboratory equipment was needed to build-up a suitable measurement environment for LAPS research. Thus, within the last years, the authors focused on the design of fully integrated and miniaturised LAPS-based (bio-)chemical sensor units. These include SoC-based automated measurement procedures and data evaluation, which enables users of different disciplines to perform LAPS-based measurements easily and in a straightforward manner. This work will present the last ten years of the authors' LAPS investigations. It will provide an insight into how to come from a general bench-scale sensor principle to constructing a fully integrated measurement platform, for a wide range of possible (bio)chemical sensing applications.

Binary Operating Biosensors Based on Biocomputing Systems

Evgeny Katz

Clarkson University, Department of Chemistry and Biomolecular Science, USA.

This talk overviews recent advances in biomedical applications of enzyme-based logic systems, particularly for the analysis of pathophysiological conditions associated with various injuries. Novel biosensors digitally processing multiple biomarker signals produce a final output in the form of YES/NO responses through Boolean logic networks composed of biomolecular systems. The biocomputing approach applied to biosensors leads to high-fidelity biosensing compared to traditional single-analyte sensing devices. By processing complex patterns of multiple physiological biomarkers, such multi-signal digital biosensors should have a profound impact on the rapid diagnosis and treatment of diseases, and particularly can provide timely detection and alert of medical emergencies (along with immediate therapeutic intervention). The novel biosensing concept has been exemplified with the systems for logic analysis of various injuries, including soft tissue injury, traumatic brain injury, liver injury, abdominal trauma, hemorrhagic shock, and oxidative stress.

Session 2: Biosensors

Session Chair: Michael J. Schöning

Biosensors (ISSN 2079-6374) provides an advanced forum for studies related to the science and technology of biosensors and biosensing. It publishes original research papers, comprehensive reviews and communications. Our aim is to encourage scientists to publish their experimental and theoretical results in as much detail as possible. There is no restriction on the length of the papers. The full experimental details must be provided so that the results can be reproduced. Electronic files and software regarding the full details of the calculation or experimental procedure, if unable to be published in a normal way, can be deposited as supplementary electronic material. It is indexed in MEDLINE (NLM), PubMed (NLM) and Scopus (Elsevier).

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Signal Amplification for Biosensing

Huangxian Ju

State Key Laboratory of Analytical Chemistry for Life Science, Department of Chemistry, Nanjing University, China.

To detect biomolecules with low abundance and extract the ultra weak biological signals, our group brings nanotechnology and biotechnology into analytical methodologies and designs a series of signal amplification strategies. Nanotechnologies for signal amplification involve five methods: (1) accelerating the electron transfer or obtaining a sensitized optical signal; (2) realizing optical, electrical or visual analysis by applying the catalytic functions of the nanomaterials; (3) using nanomaterials as a signal tag; (4) using nanomaterials as the carriers of signal molecules; and (5) selective concentration of biomolecules. The molecular biological technologies for signal amplification are to use PCR, rolling circle amplification, target-induced repeated primer extension, hybridization chain reaction, loop-mediated amplification and target DNA recycling amplification, including endonuclease-, exonuclease- and polymerase-based circular strand-replacement polymerization, DNA nanostructure assembly and proximity hybridization regulated DNA biogate or signal switch to amplify the electrochemical, optical and visual signals. These novel signal amplification strategies have been used for electrochemical, electrochemiluminescent, and photoelectrochemical detections; optical analysis methods, such as chemiluminescent, fluorescent, Raman, infrared and ultraviolet analysis; and mass spectrometric analysis and the development of imaging technologies such as grayscale scanning imaging, scanning electrochemical microscopic imaging, chemiluminescence imaging, fluorescence imaging and Raman spectral imaging. The established methods can conveniently be used in the detection of small biomolecules, DNA, proteins, cells, carbohydrate sites on cell surfaces, intracellular microRNA as well as pre-microRNA, intracellular telomerase and sialyltransferase activity. The designed probes have also recently been used for precise near-infrared cancer therapy and therapeutic monitoring. Some methods can even realize quasi-single-molecule detection.

Amperometric Bacterial Biosensor for Screening of Cytochrome P450 Inhibitors

Tal Yoetz-Kopelman [1], Carmit Porat-Ophir [1], Yosi Shacham-Diamand [2], Amihay Freeman [1]

[1] Department of Molecular Microbiology and Biotechnology, Faculty of Life Science; Tel Aviv University, Tel Aviv, Israel. [2] Department of Physical Electronics, Faculty of Engineering; Tel Aviv University, Tel Aviv, Israel.

A fast and cost-effective whole-cell electrochemical biosensor for screening of potential inhibitors of cytochrome P450 is proposed and its feasibility demonstrated. Two approaches were established: suspended cells in a continuous stirred system, and an immobilized cells-on-beads (COB) stagnant system. Sensing was performed by monitoring the decrease in the electrochemical signal generated by enzymatic oxidation of aniline by cytochrome P450 BM3 expressed in E. coli cells to the electroactive product p-aminophenol (pAP) and its subsequent oxidation on the electrode's surface. The system is self-maintained and does not require external addition of NADPH or other cofactors. Measurements were performed simultaneously at eight self-fabricated chips, applying low positive potential of 100 mV vs Ag/AgCl quasi reference electrode. Signals were received within less than a minute following substrate addition. Kinetics of the whole-cell intracellular enzymatic activity on aniline was analyzed and the system's linear concentration range and detection limit were determined, and aniline concentration for the inhibition studies was selected accordingly. Three known inhibitors - imidazole, metyrapone and 1-aminobenzotriazole (ABT) - were tested and their inhibition profiles characterized. Imidazole was found to be the most potent inhibitor under the experimental conditions employed, with 50% (IC_{50}) inhibition achieved at 0.3 mM, followed by ABT with IC_{50} of 0.5 mM. The weakest inhibitor was metyrapone with IC_{50} of 3.1 mM. To the best of our knowledge, the system developed offers for the first time a rapid and cheap cytochrome P450 inhibitors screening by a disposable whole-cell electrochemical chip, providing the advantages of a whole-cell system without neither enzyme purification nor NADPH addition. In addition, our COB approach provides a fast and simple cells immobilization technique, enabling recording of high and sensitive amperometric signal.

An Integrated Capacitive Array Biosensor for the Selective and Real-Time Detection of Whole Bacterial Cells

Numa Couniot, Laurent A. Francis, Denis Flandre

ICTEAM Institute, Université catholique de Louvain, Belgium.

The rapid and selective detection of whole bacterial cells is of interest for the development of Point-of-Care (PoC) diagnosis tools. We present here an integrated capacitive array biosensor based on the AC impedance spectroscopy of interdigitated microelectrodes. The microelectrodes are integrated with a 0.25 µm CMOS process as the pixel element of a capacitive array. A capacitive-to-voltage conversion was designed below each pixel and the sensitivity is boosted by a subthreshold gain stage. The microelectrodes are coated by an ultrathin passivation layer and operated in electrolytes with bacterial cells adherent to the surface. Analytical models and two-dimensional simulations accurately assessed the device's sensitivity. The simulations include the modeling of the sensor topology, the dielectric properties of multi-shell bacteria, the various ionic transports, and surface and space charges. The selectivity is provided by involving lysostaphin for genus-specific bacterial detection. The sample matrix is then directly flown on the polydopamine-covered sensor surface without any pre-treatment. The capacitive biosensor array performs dielectric measurement of the electrolytes and the real-time detection of *Staphylococcus epidermidis* binding events with a detection limit of about five bacteria per pixel.

Paper-based Microfluidic Sensors for Environmental Monitoring and Analysis

Spas Dimitrov Kolev

School of Chemistry, The University of Melbourne, Victoria 3010, Australia.

Paper-based microfluidic sensors have gained considerable popularity in recent years as a new type of disposable analytical sensing devices which meet the increasing needs of rapid, accurate and low-cost monitoring and analysis for environmental protection and healthcare. They utilize the capabilities of cellulose fibres in paper, which form a hydrophilic porous matrix, to transport liquids by capillary force only. The present paper describes the development and application of paper-based microfluidic sensors for environmental monitoring of nutrients such as phosphate, nitrite, nitrate and ammonia, and toxic heavy metal ions such as copper(II). The hydrophilic liquid penetration channels and detection zones in these sensors were ink-jet printed using a paper-sizing agent. Colour analytical reactions were utilized for analyte detection with the colour intensity being measured with a conventional flatbed scanner. Complex on-line sample pre-treatment steps such as reduction of nitrate to nitrite and membrane-based gas-diffusion separation of ammonia have been successfully implemented for the first time in the proposed paper-based sensors, thus further expanding their analytical capabilities. The paper-based sensors, mentioned above, were successfully applied to natural samples and very good agreement with the corresponding reference methods was observed.

Dynamically Morphing Magnetic Complexes as new RF-Based Nanosensors

Gary Zabow [1,2], Stephen Dodd [2], Alan Koretsky [2]

[1] National Institute of Standards and Technology (NIST), Boulder, CO, USA. [2] National Institutes of Health (NIH), Bethesda, MD, USA.

The minimally invasive nature of nanoscale optically-based sensors has led to their ever-increasing use in many areas. Notable among these are the biomedical fields, where plasmonic and fluorescence-based sensors have dramatically advanced biomolecular research, enabling sensing and visualization of countless cellular and biomolecular processes. However, whether based on plasmonic nanoparticles, fluorescent proteins, quantum dots, or, more recently, nanodiamonds, their common need for optical access limits potential applications. Much work is currently directed towards shifting such probes resonances further into the near-infrared where light propagation through biological tissue improves, but optical penetration distances remain limited. Here, we introduce a new form of micro- to nanoscale sensor that offers sensing opportunities similar to those of fluorescence-based sensors, but which operates at radio-frequency wavelengths, allowing use in optically occluded regions. The sensors are based on microfabricated magnetic complexes that rapidly change shape in response to a chosen stimulus. In the process, associated changing magnetic field profiles around the structures dynamically modify the NMR frequency of water surrounding the structure, transducing the detected stimulus into a quantitative NMR frequency shift measurement. Thus sensors can be remotely probed using regular NMR or magnetic resonance imaging (MRI) equipment. Being small, and not requiring either optical or electrical access, these new sensor types may find application in not only medical fields, but also in other areas where access for traditional sensors may be difficult. In this presentation, we will explain the operating principles of these new sensors, provide some demonstrations of their use as pH sensors, and discuss how inherent adaptability of the sensor platform should enable such sensors to measure a wide variety of physiological and environmental variables.

Label-Free Detection of DNA Molecules by their Intrinsic Molecular Charge using Field-Effect Sensors Modified with a Positively Charged Weak-Polyelectrolyte Layer

Arshak Poghossian [1,2], Thomas Bronder [1], Sabrina Scheja [1], Chunsheng Wu [1,3], Michael J. Schöning [1, 2]

[1] Institute of Nano- and Biotechnologies, FH Aachen, Germany. [2] Research Center Jülich GmbH, Jülich, Germany. [3] Biosensor National Special Laboratory, Key Laboratory for Biomedical Engineering of Ministry of Education, Department of Biomedical Engineering, Zhejiang University, Hangzhou, China.

A capacitive field-effect electrolyte-insulator-semiconductor (EIS) sensor, consisting of an Al–p-Si–SiO_2 structure modified with a positively-charged weak-polyelectrolyte layer of PAH (poly(allylamine hydrochloride), was applied for the label-free electrical detection of DNA (deoxyribonucleic acid) immobilization and hybridization by the intrinsic molecular charge. To achieve a preferentially flat orientation of DNA strands and thus, to reduce the distance between the DNA charge and EIS surface, the negatively charged probe single-stranded DNA molecules were electrostatically adsorbed onto the positively charged PAH layer using a simple layer-by-layer (LbL) technique. In this way, more DNA charge can be positioned within the Debye length, yielding in a higher sensor signal. The surface potential changes induced after each surface modification step (PAH adsorption, probe DNA immobilization, hybridization with complementary target DNA, non-specific adsorption of mismatched DNA) were directly recorded using constant-capacitance mode measurements. Dependence of the EIS signal on the DNA length as well as detection limit has been studied. Atomic force microscopy and fluorescence microscopy have been applied as reference methods to control the surface modification steps and to verify the DNA immobilization and hybridization events. An electrostatic model for potential changes at the gate surface of the polyelectrolyte-modified EIS sensor induced by the DNA immobilization and hybridization will be presented. The obtained results demonstrate the potential of the EIS sensors in combination with the simple and rapid LbL immobilization technique as a promising platform for a future development of label-free DNA chips with direct electrical readout.

Chemical and Biological Sensing with Carbon Nanostructures

Alexander Star

Department of Chemistry, University of Pittsburgh, Pittsburgh, Pennsylvania, USA.

Field-effect transistor (FET) devices based on one dimensional (1D) materials are of interest in biosensing due to their scalability and high sensitivity to changes in surface potential [1]. Single-walled carbon nanotubes (SWNTs) are of particular importance due to their excellent inherent electrical and mechanical properties, chemical stability, versatile surface chemistry, and dimensions on the size order of important biomolecules [2]. For sensor fabrication, devices are functionalized for specific interactions with peptides, proteins, DNA, or other targets. This can be accomplished noncovalently, through polymer wrapping or π-π stacking on the sp2 carbon structure with pyrene or porphyrin-based conjugates, or covalently through chemical reactions with the SWNT sidewall or tips. Covalent chemistry necessitates destroying the sp2 structure of SWNTs, leading to a partial or total loss of electrical properties. To circumvent this issue, holey graphene may be used to accomplish covalent chemistry via coupling with carboxylic acid moieties. While pristine graphene is a zero bandgap semiconductor, holey graphene mimics graphene nanoribbons, producing a bandgap at neck widths less than 10 nm. The resulting structure is analogous to an interconnected network of SWNTs on a device surface. We have previously demonstrated the synthesis of such a holey graphene material by enzyme catalyzed oxidation of graphene oxide (GO), produced via a modified Hummer's method, with a mixture of horseradish peroxidase and H_2O_2 [3]. By controlling the length of time GO is exposed to HRP/H_2O_2, the size of holes and neck widths between holes can be controlled as the material is degraded, resulting in an interconnected nanoribbon-like structure that, when reduced by hydrazine, mimics the electronic properties of a network of carbon nanotubes [4]. In one example of biosensors based on holey reduced graphene oxide (hRGO), covalent functionalization of the oxygen moieties on hRGO with the antimicrobial peptide, Magainin I, produced a broad-spectrum bacterial probe for the detection of gram-negative bacteria [5].

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Nanostructures Integrated Optofluids Chips for the Detection of Proteins

Muthukumaran Packirisamy

Concordia University, Montréal, Canada.

Photonics integrated microsystems are attractive to perform chemical and biological analysis using minute amounts of samples with high throughputs. Micromachined fluidics and optical devices are integral components of Lab-on-a-chip (LOC) devices, which are fabricated monolithically or by hybrid integration in order to perform various analytical process in a single chip. In this paper, novel micro-nano integration techniques for developing optical lab-on-chips (LOCs) devices on integrated optical and polymer platforms are presented. LOCs were developed for detecting proteins in optical microfluidics chips through the integration of gold nano-islands and polymer nanocomposites. In order to further enhance the detection sensitivity to few ng/mL, it was required to integrate nanostructures having plasmonic properties into the microfluidics devices. This is achieved by a novel process development for the synthesis of nano-islands on various material platfroms. The process was simple, low cost and compatible with the fabrication process of microfluidics chip by using silicon, glass and PDMS. Numerical modelling was carried out using Finite-difference time-domain (FDTD) method in order to analyse the change of optical properties during the formation of god nanoislands and their interaction with the biological species having various size and optical properties. This talk also covers the developments of a novel evanescent based cascaded waveguide coupler (CWC) and nano-island integrated Silica-on-silicon-PDMS microfluidics device for the detection of growth hormone in milk.

Session 3: Chemical Sensors

Session Chair: Peter Hauser

Chemosensors (ISSN 2227-9040) provides an advanced forum for the science and technology of chemical sensors. It publishes reviews, regular research papers and communications. Our aim is to encourage scientists to publish their experimental and theoretical results in as much detail as possible. All aspects of chemosensing are welcomed from theoretical concepts to education and training. We also welcome manuscripts on classic chemical sensing–be it wet chemistry or biological sensing using enzymes or cells and other model organisms. Drug testing and medical/diagnostic testing are also included under this umbrella. We welcome results of field testing or assay validation as well, whether it be at the research level or from commercial pretesting. We also ask for perspectives from people working in the field or editorials that concern prominent issues related to chemosensing. There is no restriction on the length of the papers. The full experimental details must be provided so that the results can be reproduced.

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Recent Developments and Applications of Chemical Imaging Sensor Systems

Tatsuo Yoshinobu

Department of Biomedical Engineering, Tohoku University, Japan.

The chemical imaging sensor [1] is a semiconductor-based chemical sensor that can visualize the two-dimensional distribution of pH or the concentration of specific ions in the solution in contact with the sensing surface. It is based on the principle of the light-addressable potentiometric sensor (LAPS) [2], in which a light beam scans the sensor plate to read out the photocurrent signal determined by the local capacitance of the depletion layer responding to the Nernst potential. A chemical image is obtained by measuring the photocurrent signal in a pixel-by-pixel manner. The sensor plate is made of a silicon wafer with an insulating layer on the front surface and an ohmic contact on the back surface. The locations of pixels are not pre-defined by device structures but are defined by illumination at the time of use. This method, on one hand, facilitates flexible zoom-in/out, low-cost production and long life of sensor plates and large (wafer-scale) area of measurement. On the other hand, the total time required to complete a scan of a chemical image tends to be long, due to the sequential readout of the photocurrent signal. In addition, lateral diffusion of photocarriers inside the semiconductor layer limits the spatial resolution. In recent years, the measurement speed has been greatly enhanced by employing a plurality of light beams simultaneously illuminating different locations of the sensor plate, which realized movie recording and real-time display of pH distribution. Efforts have also been made to improve the spatial resolution and precision, to miniaturize the system and to apply the method in various fields. Developments and applications of the chemical imaging sensor systems will be discussed.

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The Sensitive Detection and Identification of RDX and PETN Explosives Vapors by Measuring Their Thermal Signature When Desorbing or Decomposing the Explosive Inside a Porous Material

Karine Bonnot, David Doblas, Laurent Schlur, Spitzer Denis

NS3E, Nanomatériaux pour les Systèmes Sous Sollicitations Extrêmes - UMR 3208 CNRS-UNISTRA-ISL (French German Research Institute of St Louis), Saint-Louis, 68301, France.

Detecting explosives in air is challenging for homeland security applications due to the increasing threat of terrorists exploding bombs against populations. There is a crucial need for detecting explosive vapor traces and sub-traces at the ppt level and lower. To develop sensing devices that have high sensitivity and selectivity towards numbers of energetic compounds, it is necessary to simultaneously develop novel materials that are highly specific for identification and innovative technology for rapidly detecting trace concentrations with high selectivity. We recently developed two innovative technologies for (i) identifying explosives within a few seconds on the scale of femtograms and a single microcrystal with nanocalorimetry [1] and (ii) sensing explosive vapor down to the ppt level within three minutes of employing nanostructured cantilevers [2]. Despite the fact that both techniques are very sensitive, we note that cantilevers achieve detection whereas nanocalorimetry permits selective identification. We used microthermal analysis to discriminate RDX and PETN. Once an explosive vapor is trapped in a material, fast heating at 3000 K/s up to 350 °C leads to a thermal pattern specific to the explosive and its interaction with the porous material. The obtained signatures permit the simultaneous detection and identification of vapors in just a few milliseconds. Our method also allows for the development of devices that can address multiple targets using just one unspecific material for capturing the vapor, combined with microthermal analysis for fast detection and identification. This is the first time that microthermal analysis has been used to characterize and detect explosives in the vapor state.

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Sniff-Camera for Imaging of Gazeous Ethanol From Palm Skin After Drinking

Takahiro Arakawa, Kenta Iitani, Toshiyuki Sato, Koji Toma, Kohji Mitsubayashi

Tokyo Medical and Dental University, Japan.

A sniff-camera (2-dimensional visualization system) for gaseous ethanol was constructed and tested in visualization of transdermal alcohol. This visualization system measures ethanol concentrations as intensities of chemiluminescence (CL) by luminol reaction induced by alcohol oxidase and horseradish peroxidase-luminol-hydrogen peroxide system. Conversion of ethanol distribution and concentration to 2-dimensional CL was conducted on an enzyme-immobilized mesh which contained luminol solution. This was done in order to visualize ethanol emission from palm skin, which concentration is typically at sub ppm-level. Thus, luminol HG was employed as high-purity luminol solution in the visualization system. The detection limit was improved by this solution. Owing to high sensitivity, transdermal ethanol was successfully visualized and the intensity of each pixel was the reflection of ethanol concentrations. Therefore, the system was sufficiency useful for assessment of ethanol measurement of the palmar skin.

Chemical Sensing Based on Biomimetic Principles

Dermot Diamond, Larissa Florea, Francis Wayne

National Center for Sensor Research, Dublin City University, Dublin, Ireland.

Our ability to sense chemistry and biology in challenging scenarios, such as implantable devices for monitoring our health, or the quality of water in rivers and lakes has not advanced significantly since the fundamental breakthroughs in chem/bio-sensors of the 1970's and 1980's. It is becoming clear that in order to meet challenging performance specifications in terms of price and performance, these devices will have to be much more sophisticated, and in particular, adopt bio-inspired strategies to deliver platforms that can function autonomously for years. For example, many sensing platforms employ fluidic systems, and increasingly microfluidic systems to integrate functions such as sample transport, reagent addition, filtering, and detection. In the future, these fluidic systems will have a more active role in monitoring, reporting and maintaining the overall functionality of the platform. Like our own blood circulation system, fluidics in chem/bio-sensing devices will contain micro/nano-vessels and in-channel active components (e.g., integrated soft-polymer valves) capable of detecting damage, leaks, fouling, channel blockage etc., and furthermore, undertake appropriate remedial action (detect leak location & perform repairs, open blocked channels or provide alternative fluidic pathway) in order to dramatically extend the functional lifetime of the platform. Access to 3D additive technologies, in combination with directed polymer self-assembly, now enables such soft polymer actuators to be created with nano-scale resolution inside microfluidic channels for fluid control, or to provide channels with switchable characteristics such as surface roughness [1], or controlled uptake and release of molecular guests. In addition, fluidic coatings can optically report their condition (e.g., whether they are in binding or passive form, or molecular guests are bound) reflecting the chemical status along the entire length of the fluidic system, rather than at a localised detector [2]. The same characteristics can be integrated into micro-vehicles such as droplets, beads and vesicles, or microrobots that can also move spontaneously or be externally directed to specific locations, where they can perform these and other tasks [3, 4]. In this paper, we will present routes through which these exciting concepts can be practically realized.

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Ratiometric Fluorescent Indicators for Metal Ions and Polar Organics Based on the Poly-N-isopropylacrylamide Thermal Phase Transition

W. Rudolf Seitz

Department of Chemistry, University of New Hampshire, Durham, NH, USA.

Indicators consist of a recognition agent incorporated into poly(N-isopropylacrylamide) (polyNIPAM), labeled with donor and acceptor fluorophores. They are designed so that analyte binding causes polyNIPAM to go from a collapsed to an extended configuration (or visa versa) resulting in a change to the extent of fluorescence resonance energy transfer (FRET) from donor to acceptor. Analyte concentration is related to the ratio of acceptor to donor fluorescence. One type of recognition agent is a ligand. Metal ion binding changes the amount of charge on polyNIPAM, causing it change configuration. Using this approach with bipyridine as a ligand, we get a ratiometric fluorescent response to Cu(II), a metal ion that normally quenches fluorescence. These indicators measure metal ion activity rather than total metal concentration, which determines metal ion effects in biological and environmental systems.The other type of indicator is prepared by molecular imprinting using a lightly crosslinked copolymer of N-isopropylacrylamide and a recognition monomer. This results in a material that remains suspended in solution as tiny particles and can be processed as a solution.

Change Detection in (Bio)chemical Liquids with Ultrasensitive Label-Free and Immobilization-Free Sensors Operating the GHz-THz Range

Johan Stiens [1], Vladimir Matvejev [1], Yuchen Zhang [1], Cathleen De Tandt [1], Guoqiang He [1], Dominique Maes [2], Debby Mangelings [3], Sven Declerck [3], Maria Alexandra Mernea [4], Dan Mihailescu [4]

[1] ETRO-IR, VUB, Brussels, Belgium. [2] DBIT, VUB, Brussels, Belgium. [3] FABY-GF, VUB, Brussels, Belgium. [4] Faculty of Biology, University of Bucharest, Bucharest, Romania.

In a solution comprised of a solvent (predominantly water), buffers, and solvated biomolecules, complex biophysical and biochemical interactions can take place due to the existence of permanent and induced charges and dipoles, hydrogen bonds, hydrophilic and hydrophobic species, and phonon vibrations, which depend on the conformations and rigidity of the components. The dielectric response of this solution to EM waves in the (sub)-THz waves will be dependent on the relative concentration of the individual components, but also on their hydration shells and their interaction strengths. Any (tiny) change in the concentrations or interaction strength due to an external perturbation can be monitored with sub-THz waves, when one disposes over an ultra-sensitive biosensor, which can cope with the high absorption properties of water in this frequency range. In this paper, we will discuss the operation principle and the technological implementation of a novel generic, label-free, immobilization-free (bio)chemical sensor with world-record sensitivities in the sub-THz range for the characterization of micro and nano-liter liquids. Benchmarking of alcohol-water mixtures yields a dynamic signal change of +100 dB. A multitude of biological, pharmaceutical and biochemical applications will be discussed ranging from monitoring antibody-antigen interactions, PCR reactions, protein denaturation and crystallization, quality control of suspensions. Some of the experimental results will be backed with molecular dynamics simulations. We will compare this novel measurement technology with commercial analytical instruments such a SPR, UV-spectroscopy, etc. Some future tracks towards high throughput screening will be discussed.

Simultaneous CO and CO_2 Gas Sensor based on a Single Fabry-Perot Interferometer

Eloisa Gallegos-Arellano [1], Everardo Vargas-Rodriguez [1], Juan Manuel Sierra-Hernandez [1], Ana Dinora Guzman-Chavez [1], Ruth Ivonne Mata-Chavez [1], Alejandro Jurado-Paramo [2]

[1] Departamento de Estudios Multidisciplinarios, Campus Irapuato-Salamanca, Universidad de Guanajuato, Col. Yacatitas, Yuriria Guanajuato, México. [2] Universidad Tecnológica de Salamanca, Col. Ciudad Bajío, Salamanca Guanajuato, México.

A dual gas sensor design based on cross correlation spectroscopy principle is presented. This sensor is based on a single Fabry-Perot interferometer (FPI), which acts as an optical modulator. Hence, due to characteristics of the FPI transmission spectrum, it can be used to detect molecules with very well defined ro-vibrational lines such as those produced by diatomic and linear molecules. In this work, the FPI was rotated over, to shift the spectral transmission fringe pattern, inducing the modulation. Moreover, the Fabry-Perot interferometer was achieved by using only a silicon wafer, which has a specific thickness to modulate the ro-vibrational abortion lines of both CO and CO_2. Here, it is important to point out that the design of this FPI is illuminated with a collimated beam and it is placed just in front of the pyroelectric detector. Furthermore, the principle of operation of the sensor setup is presented. Finally, some experimental measurements are provided to support the simulation and to show that is possible to use a single silicon wafer, such as FPI, to detect two gases at same time.

Design of Sensor Coatings with High Sensitivity to Benzene and Long-Term Stability for Groundwater Monitoring Applications

Laura J. Alderson [1], Shamitha Dissanayake [1], Florian Bender [1], Fabien Josse [1], Antonio J. Ricco [2], Rachel E. Mohler [3]

[1] Department of Electrical and Computer Engineering, Marquette University, Milwaukee, WI, USA. [2] Department of Electrical Engineering, Center for Integrated Systems, Stanford University, Stanford, CA, USA. [3] Chevron Energy Technology Company, Richmond, CA, USA.

Benzene is one of the volatile organic compounds present in crude oil and gasoline. Accidental releases from sources like underground storage tanks or hazardous waste sites can result in the presence of benzene in nearby groundwater. Benzene is a known carcinogen and its exposure is limited by the US Environmental Protection Agency to 5 parts per billion (ppb) in groundwater. Early, accurate monitoring of the presence of benzene in groundwater supplies is therefore important. Shear horizontal surface acoustic wave (SH-SAW) sensors with suitable sorbent polymer coatings can be used to detect benzene in the liquid phase. At concentrations in the parts-per-billion range, this task becomes difficult due to the generally low partition coefficients for benzene in most polymers (relative to water). In addition, not all polymers that are chemically suitable to absorb benzene are able to do so in a reasonable time due to their glassy nature. A plasticizer can be added to the selected polymer to lower the glass transition temperature thus allowing for rapid analyte absorption. In previous investigations, the addition of dioctyl phthalate (DOP) to polystyrene resulted in coatings showing higher sensitivity to benzene than many commercially available polymers. However, most plasticizers leach out of the polymer over time. Investigation of various plasticizers in poly(vinyl chloride) (PVC) has shown that DOP has a small but non-negligible leach rate into water. The leaching of the plasticizer into the surrounding environment results in limited long-term stability of the coating, rendering reliable, repeatable measurements impossible. The plasticizer DINCH (1,2-cyclohexane dicarboxylic acid diisononyl ester) has been shown to have an undetectable leach rate into water due to its chemical structure. It has also shown promise as a plasticizer to increase the sensitivity to benzene in polystyrene-coated sensors. The plasticizer percentage plays a crucial role in optimizing the sensitivity to the analyte. If the percentage of the plasticizer is too small, the polymer will be too glassy for rapid analyte sorption. This higher rigidity of the coating will also result in low analyte sensitivity. On the other hand, if the plasticizer percentage is too high, the polymer becomes too rubbery. This causes high acoustic wave attenuation, which will interfere with the signal-to-noise ratio of the SH-SAW sensor. This work demonstrates the successful design of sensor coatings with long-term stability and high sensitivity to benzene in liquid-phase sensing for the example of DINCH-polystyrene coatings. Preliminary results indicate that plasticizer concentrations around 24% - 26% with coating thicknesses of about 0.03 λ (λ = acoustic wavelength) are near the optimum for polystyrene-based coatings for liquid-phase applications. Sub-ppm (down to 100 ppb) detection of benzene and other hydrocarbon compounds in water is demonstrated, and data on long-term stability of sensor coatings is also presented.

Session 4: Extreme Sensing

Session Chair: Roland Moser


MDPI


sensors

Micro- and Nano-scale Sensors for Extreme Harsh Environments

Debbie G. Senesky

Stanford University, CA, USA.

Wide bandgap semiconductor materials are inherently temperature-tolerant, radiation-hardened and biocompatible which can extend the operation regime of micro- and nano-scale devices to extreme harsh environments (e.g., deep space, hypersonic structures, subsurface environments, combustion environments, and the human body). In addition, wide bandgap semiconductor materials are often simultaneously piezoelectric, piezoresistive and pyroelectric, which can be leveraged in the design of a multitude of micro- and nano-scale devices such as inertial sensors, bolometers, dosimeters, micromechanical resonators and energy harvesters in a single material layer. In this talk, a review of the advancements in manufacturing technology for polycrystalline thin film, epitaxial thin film and nanowire growth of wide bandgap semiconductor materials are presented. In addition, the compelling results of silicon carbide (SiC), gallium nitride (GaN), and aluminum nitride (AlN) device operation at temperatures as high as 600 °C and under gamma irradiation will be reviewed. These robust material sets can serve as a platform for the realization of sensor, actuator and electronic systems that can operate and collect data under the most hostile conditions.

Thin-Film Sensors for Monitoring Aseptic Food Processes

Jan Oberländer [1,2], Patrick Kirchner [1], Michael Keusgen [3], Michael. J. Schöning [1,2]

[1] Institute of Nano- and Biotechnologies (INB), FH Aachen, Campus Jülich, Jülich, Germany. [2] Peter Grünberg Institute (PGI-8), Forschungszentrum Jülich, Jülich, Germany. [3] Institute of Pharmaceutical Chemistry, Philipps-University Marburg, Marburg, Germany.

Nowadays, gaseous hydrogen peroxide (H_2O_2) serves as a common sterilization agent for beverage cartons in aseptic filling machines. H_2O_2 possesses different advantages over conventional chemical sterilization media (e.g., chlorine or peracetic acid): (i) high microbicidal and sporicidal activity in a short exposure time (due to radical formation, especially at elevated temperatures) and (ii) H_2O_2 decomposes into environmental-friendly end products, such as water vapor and oxygen [1]. Recently, several types of calorimetric gas sensors have been developed in our laboratory to monitor the sterilization process of beverage cartons in real time [2, 3]. For these calorimetric gas sensors, the sensing principle relies on the determination of the decomposition energy (exothermic heat reaction) when H_2O_2 is decomposed on the catalytically active sensor surface. For our sensors to operate, a differential set-up of two temperature sensors is applied: one of the sensors is passivated with an H_2O_2-resistant polymer, whereas the second temperature sensor is covered with a catalyst to force the decomposition of H_2O_2. Various catalytic materials have been investigated, such as manganese(IV)-oxide, platinum, and palladium. During operation, the temperature difference between both sensors shows a linear correlation to H_2O_2 volume ranging from 0-8% v/v. In the case of the polymer-based thin-film sensor, the flexible substrate enables us to position the sensor chip inside of the beverage packages. In combination with a wireless readout system, online monitoring of the sterilization processes can be demonstrated. Moreover, due to the lower thermal conductivity, compared to silicon, the sensor characteristics, in terms of sensitivity and response time, were improved.

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High Sensitivity NO, NO_2 and NH_3 HEMT Based Sensor for Diesel Exhaust Systems

Yacine Halfaya [1,2], Chris Bishop [1,3,], Jean-Paul Salvestrini [1,4], Ali Soltani [5], Suresh Sundaram [1], Xin Li [3], Youssef El Gmili [1], Vincent Aubry [2], Paul Voss [3], Abdallah Ouggazzaden [3]

[1] Georgia Tech - CNRS, UMI 2958, Metz, France. [2] PSA Peugeot Citroën, Paris, France. [3] School of Electrical and Computer Engineering, Georgia Institute of Technology, GT-Lorraine, Metz, France. [4] Université de Lorraine, LMOPS, EA4423, Metz, France. [5] Université des Sciences et Technologies, IEMN, UMR 8520, Lille, France.

The need to meet upcoming EURO7 emissions standards for diesel engines provides motivation for improved sensor technologies. Anti-pollution systems that limit NO_x emissions require the injection of NH_3 into the catalytic converter in order to reduce NO and NO_2 emissions. One may meet the upcoming standards with better measurement of NO_x pollutants. One may further improve the anti-pollution system by means of selective detection of NH_3, NO, and NO_2, which will allow more precise control of the anti-pollution system and better fuel efficiency while meeting the new regulations. Our approach consists of using High Electron Mobility Transistor (HEMT) devices based on group III-nitride materials which have high resistance to corrosion, humidity, and high temperatures. This makes them an ideal solution for automotive exhaust gas sensors. The use of catalytically active gate materials yields gas sensors with high sensitivity towards both reducing and oxidizing gases. The adsorption of the gaseous molecules leads to changes in the surface depletion layer, which has a direct effect on device sensitivity and the selectivity. This can be improved by the material and structure of the functional layer. We report improved sensitivity to NO_2, NO, and NH_3 with AlGaN/GaN HEMTs as compared to previous reports [1–3]. Our measured sensitivity to 450 ppm-NO_2 and to 450 ppm-NO is 17% and 6.5%, respectively at 400 °C. We also detect concentrations of NH3 in the 150 ppb–15 ppm range, with dynamic time response for these three gases of 1 to 4 seconds at 300 °C. Additionally, we have achieved NO_2 and NO selectivity for the first time using this type of sensors. We show that these responses can be conveniently modeled analytically. Together, these results demonstrate the potential use of AlGaN/GaN structures as high-performance sensors for automotive exhaust applications due to their selectivity and high sensitivity.

Surface Acoustic Waves Sensors on Langasite Substrates for High Temperature Measurements

Thierry Laroche [1], Sylvain Ballandras [1], Émilie Courjon [1], Bruno François [2], Sergey Sakharov [3], Zachary Davis [4], Denny Richter [5], William Daniau [1,2], Jean-Michel Friedt [2,6]

[1] frecn|n|sys SAS, Besançon, France. [2] FEMTO-ST, UMR 6174 CNRS-UFC-ENSMM-UTBM, Besançon, France. [3] OAO FOMOS Material, Moscow, Russia. [4] DTI, Lyngby, Denmark. [5] TUC–Clausthal/TDK-EPCOS. [6] SENSeOR SAS, Mougins, France.

Temperature sensors built on Langasite (LGS) stand for good candidate to withstand temperature in excess of 700 °C. Surface Acoustic Waves (SAW) resonators designed with a high level of confidence require the effective coefficient for this kind of materials and robust tools for the prediction of electrical response and more of this temperarature coefficients of frequency (TCF). A comprehensive model for computing the electrical response of SAW devices is proposed in this paper. Based on a mixed-matrix analysis, it allows for the prediction of any SAW device admittance/impedance at any temperature. For that purpose, the temperature dependences of the wave velocity of course but also of the reflexion coefficient, directivity, conductance and capacitance are established using polynomial developments. In the proposed paper, the accuracy of the published data sets for LGS and more specifically their capability to predict measured TCF for several crystal cuts supporting Rayleigh and surface transverse waves is assessed. Data from Kaminskii (1983), Ilyaev (1986), Silvestrova (1993), Sakharov (1995) and Bungo (1999) have been used to systematically evaluate their capability to predict first and second order TCF. Considering the experimental data set used to asses the tested coefficients, the authors propose a combination of data set allowing for accurate prediction of the device behavior at room and elevated temperature. This set are finally dedicated to demonstrate the capability of this kind of sensors to adress a measure from the room conditions to temperarture up to 700 °C.

New Strategies for miRNA Detection

Xueji Zhang

Research Center for Bioengineering and Sensing Technology, University of Science & Technology, Beijing, China.

MicroRNAs (miRNAs) are a class of endogenous non-coding RNAs (18-23 nucleotides) that act as post transcriptional regulators of gene expression in a broad range of humans, animals, and plants, and play key roles in many biological and pathological processes, such as proliferation, apoptosis, growth, development, differentiation and reproduction, etc. MiRNA is believed to be involved in the regulation of nearly 30% of all human genes and its expression level is closely related to some major human diseases. Since miRNA concentration is very low in physiological condition and its small size, low abundance and sequence similarity among family members, it is challenge for detection of miRNA in real samples. We describe the latest research progress of detection methods of miRNAs in our lab. A highly sensitive and selective microRNA detection strategy using DNA-bio-bar-code amplification (BCA) and Nb·BbvCI nicking enzyme-assisted strand cycle for exponential signal amplification was designed. Second, label-free method for microRNA biosensing was described using oligonucleotide encapsulated silver nanoclusters (Ag-NCs) as effective electrochemical probes. The functional oligonucleotide probe integrates both recognition sequence for hybridization and template sequence for in situ synthesis of Ag-NCs, which appears to possess exceptional metal mimic enzyme properties for catalyzing H_2O_2 reduction. Furthermore, a multiple microRNA detection method based on the graphene oxide (GO) fluorescence quenching and isothermal strand-displacement polymerase reaction (ISDPR) was developed.

Tunnel FET Sensors: Breaking Sensitivity and Energy Efficiency Limits for Integrated Transducers

Adrian M. Ionescu

Ecole Polytechnique Fédérale de Lausanne, Switzerland.

We report on a new class of sensors exploiting Tunnel FETs with extreme electrostatic sensitivity of their quantum mechanical band-to-band-tunneling current to enable future generation of biosensors, gas sensors and imagers operating at voltages as low as 100 mV with unprecedented energy efficiency. These devices are expected to form a unique technology for future autonomous smart systems and the Internet-Of-Everything. Tunnel FETs form today one of the privileged device candidates for aggressive scaling of both size and operation voltage, offering with their sub-thermal swing (below the 60 mV/decade limit of conventional MOSFETs) a credible alternative for voltage scaling and mitigation power issue in advanced technological node. With the steep slope and high sensitivity to small gate voltage variation, they offer a unique alternative to break sensitivity limits of integrated on-chip sensors exploiting MOS principles. The Lieber group at Harvard and our group clearly demonstrated that the sensitivity of nanowire FET sensors can be exponentially enhanced in the subthreshold regime being directly related to the value of the subthreshold slope (the output sensitivity of an ISFET sensor being inversely proportional to the transistor subthreshold slope). Here, the fundamental limit of ~39 V^{-1} of g_m/I_d, which impose a limit on the transducer sensitivity exploiting a gated three-terminal device, can be overcome by the slope reduction. Steep slope sensors based on tunnel FETs can achieve sensitivities up to 100x higher that their FET counterparts. We will detail theoretical projects for biosensors and gas sensors benefitting from the tunnel FET unique properties.

We will report experimental demonstrations of some of the first one transistor (1T) Active Pixel Sensor exploiting the physics of tunnel FETs in a partially overlapped gate ultra-thin body SOI architecture, which amplifies into the BTBT the potential modulation induced by the light generated carries in the visible spectrum. An APS based on a Tunnel FET pixel has the potential of high sensitivity with high compactness and ultra low power consumption for vision sensors, beyond what CMOS imagers can acheive today. Overall, this paper will highlight how future on-chip integrated transducers could greatly benefit from an ultra-low voltage and steep slope switch technology in terms of opening an unexplored design space below 100 mV.

Photonic Probing with Memresistive Devices

Juerg Leuthold

Institute of Electromagnetic Fields, ETH Zürich, Basel, Switzerland.

Plasmonic memristors are electrically activated optical switches with a memory effect. Memresistive devices are known in electronics for many years where they are supposed to play an important role as e.g., so-called “resistive random access memories (RRAMs)”. So far it was not possible to probe the state of a RRAM optically. We introduce a novel plasmonic memristor that allows to probe the state of a RRAM. More precicely, we probe the Memresistive switching with extinction ratios of 12 dB (6 dB) with up to 1 MHz sampling rates. The underlying operation principle is more fundamental and might be of interest for other sensing schemes.

Session 5.1: Photonic Sensing

Session Chair: Hans Peter Herzig

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Room-Temperature Mid-Infrared Single Photon Spectral Imaging

Christian Pedersen, Peter Tidemand Lichtenberg, Jeppe Seidelin Dam

DTU Fotonik, Lyngby, Denmark.

The mid-infrared (mid-IR) wavelength range is an emerging and important new topic for frontier research. Its importance relates to a multitude of mid-IR industrial and biomedical sensor applications. Most complex molecules such as those found in food, tissue or catalytic compounds have vibrational spectra in the mid-IR, thus identifiable through mid-IR spectroscopy. Incidentally also the fundamental absorption bands of gas molecules are located in the mid-IR enabling novel instrumentation for mid-IR gas spectroscopy. Therefor the mid-IR is also referred to as the “finger print region”. A main obstacle for the exploitation of the mid-IR optical window has been a historical lack of sensitive mid-IR detectors/imaging devices working at room temperature. Upconversion technology suggest a route to circumvent the unavoidable “dark noise” associated with standard mid-IR detectors when operating at finite temperature, thus opening a door to mid-IR, room temperature single photon spectral imaging and hyper spectral imaging. Different examples will be presented.

Silicon on Insulator Vernier Devices for High Performance Photonic Sensing in the Near-IR and Mid-IR

Vittorio M.N. Passaro, Benedetto Troia

Photonics Research Group, Department of Electrical and Information Engineering, Politecnico di Bari, Italy.

The Vernier effect has been widely used in photonic refractive index sensors and demonstrated to be particularly suitable for enhancing optical sensing performance. It can be achieved by cascading two coupled ring resonators, two Mach-Zehnder interferometers or a mixed combination of such devices. In this context, we propose a sophisticated, flexible and reliable design flow based on a rigorous mathematical modelling for the design of integrated photonic devices working in the second regime of the Vernier effect for ultra-high performance sensing. The applications of the design procedure have been tested on cascade-coupled racetrack resonators at the near- and mid-infrared wavelength ranges of 1520–1580 nm and 3700–3900 nm, respectively. In particular, Vernier gains as high as 30, minimum and maximum overall Vernier FSRs of roughly 8 nm and 35 nm as well as insertion losses ranging from 2.1 dB up to 5.7 dB have been achieved in silicon-on-insulator Vernier devices based on rib waveguides and operating around 1550 nm. Furthermore, single and cascade-coupled racetrack resonators based on silicon-on-insulator rib and strip waveguides operating in the 3700–3900 nm wavelength range with insertion loss lower than 1 dB, extinction ration up to 25 dB as well as Vernier gains of about 20 have been characterized, resulting in the first experimental demonstration of the Vernier effect in the mid-infrared wavelength range, where a number of harmful gases as well as chemical and biochemical specie exhibit typical very strong fingerprints. Finally, the reproducibility and reliability of the implemented design tool is demonstrated by means of relative errors even lower than 1% for the most important Vernier device figures of merit and by a graphical comparison among experimental and theoretical Vernier spectra. In conclusion, a wavelength sensitivity higher than 1000 μm/RIU (refractive index unit) and limit of detection down to 10^{-6} RIU have been estimated theoretically in SOI Vernier devices characterized by a ring resonator coupled to a Mach-Zehnder interferometer, resulting in the detection of 5000 ppm of carbon dioxide and 2 ppm of ammonia in aqueous solution. Moreover, wavelength sensitivities as high as 224 μm/RIU and a limit of detection as low as 2×10^{-5} RIU have been estimated theoretically in Vernier devices characterized by cascade-coupled ring resonators and operating at 3.39 μm, resulting in the detection of minimum percentages of methane and ethane in air volume, equal to 2% and 1 %, respectively.

Infrared Wavelength Quantum Dot-based Sensing

Vanessa Wood

Deptartment of Information Technology and Electrical Engineering, ETH Zürich, Switzerland.

Composite semiconductors manufactured by the low cost, solution-based deposition of colloidally synthesized semiconductor quantum dots (QDs) are of growing interest for a variety of optoelectronic devices, including infrared photodectectors for sensing applications. In this talk, I will first present advances in QD synthesis, which make it possible to transition away from infrared-active compounds that contain the most toxic elements, such as lead-sulfide (PbS) and mercury telluride (HgTe). Then, I will discuss new findings concerning recombination in QD-based semiconductors, which can guide the rational optimization of these hybrid materials. I will discuss a simple, high-yield synthesis for ternary and quaternary I-III-VI and I-II-III-VI chalcopyrite QDs (e.g., Ag-In-Se or Cu-Zn-In-Se), which are candidates for infrared sensing [1]. The approach differs from the conventional hot-injection syntheses of QDs by the presence of (silyl)amide-anions in the reaction mixture, which create super-basic conditions, thus speeding up the reaction and enabling precise composition and size control. In the second part of the talk, I will focus on the opportunities and challenges of making high efficiency devices from semiconductor QDs. In particular, I will discuss the open question related to trap states and recombination in QDs. While in bulk semiconductors, it is well established that device performance is limited by the presence of electronic states within the band gap, in the case of QD-based semiconductors, relationships between traps states and performance are still being understood [2,3]. I will discuss a multi-technique approach for characterizing trap states in QD-semiconductors and relate the findings to device performance.

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Mid-Infrared Laser Spectroscopic Chemical Sensing

Markus Werner Sigrist

Institute for Quantum Electronics, ETH Zürich, Zürich, Switzerland.

Laser-based sensing has attracted great interest recently due to several advantages such as high sensitivity and specificity, large dynamic range, multi-component capability, and lack of pretreatment or preconcentration requirements. The availability of broadly tunable sources like difference frequency generation (DFG) and external cavity quantum cascade lasers (EC-QCLs) or the most recent development of diode-pumped lead salt vertical external cavity surface emitting lasers (VECSELs) has certainly eased the implementation of laser-based sensing devices. I shall discuss the basic principles, present various experimental setups and illustrate the performance of systems developed in our laboratory. The multi-component capability is demonstrated with a very recent mid-IR VECSEL which enables the fast analysis of C1-C4 alkanes at sub-ppm concentrations in gas mixtures which is of interest for the petrochemical industry. Another important study concerns measurements of short-lived species like nitrous acid (HONO) which was detected at ppb concentrations with an EC-QCL combined with quartz-enhanced photoacoustic spectrocopy (QEPAS). In human breath, the D/H ratio has been determined after intake of a small amount of D2O as a tracer. An enhanced deuterium content in the breath could be recorded during a month. Such data can be used to determine the total body water, energy expenditure, glucose or cholesterol synthesis rates. Spectra of surgical smoke–produced and collected during minimal-invasive surgery with an electro-knife in the University hospital in Zürich–have been recorded with a broadly tunable DFG system and analysed with a principal component analysis. Besides water vapor, mainly traces of methane, ethane, ethylene, CO and the anesthetic gas sevoflurane were found. Finally, studies in the area of medical diagnosis were performed with a fiber-coupled EC-QCL photoacoustic system to measure glucose in human skin. During in vivo oral glucose tolerance tests with volunteers, comparisons were made with conventional blood glucose measurements with a glucometer. Although first results of the non-invasive laser-photoacoustic method look promising further developments are still needed.

Simultaneous Electrical and Plasmonic Sensing with Gold Nanostructures: Device Fabrication and Applications

Raphael Florin Tiefenauer, Bernd Dielacher, Juliane Junesch, Klas Tybrandt, János Vörös

Laboratory of Biosensors and Bioelectronics, ETH Zürich, Switzerland.

Simultaneous LSPR and electrical detection using ultrathin gold films with incorporated nanoholes is presented. The sensor is electrochemically accessible and enables label-free sensing in a controlled fashion. Films with dimensions smaller than the electron mean free path are essential to measure large resistance changes due to small alterations in thickness or close proximity of charged species [1]. Additionally, nanoholes within thin films enable optical sensing based on localized surface plasmon resonance. Our sensor combines both phenomena and can be controlled electrochemically. The chip is fully integrated into a custom-made flow cell. The design of both the flow cell and the chip allows for reproducible and accurate measurements with ideal fluid exchange behavior. Iodide sensing is one of the possible applications for this device [2]. Most current detection methods are costly and require both a sample pretreatment and a long analysis time [3,4]. However, for determining iodide concentrations of human samples in developing countries or for comprehensive and long-term studies in environmental waters, low cost and simplicity are becoming increasingly important. Our device takes up on these issues with sensing based on iodide induced electrochemical etching of ultrathin gold films. Iodide anions can be attracted using voltage. The resulting etching can be measured by a change in the impedance of the thin film. As sensing methodology, an amperometric multistep method is presented in buffer as well as in an environmentally relevant fluid (lake water) with limits of detection in the range of 1 µM and 2 µM, respectively. The versatility of this sensing platform is also shown with binding studies. Attachment of thiolated single-stranded DNA demonstrates this concept. Iodide etching can thereby be used as a controlled cleaning step, enabling the reuse of the device. As a further development, the use of periodic gold nanowire arrays are a promising approach for higher sensitivity. However, Extreme Ultraviolet Interference Lithography (EUV-IL) is essential for parallel fabrication with high resolution [5,6]. A transfer technique was developed to limit this step to mold making and thus multiplying the number of structures. We believe this sensor not only enables low cost measurements of iodide concentrations and binding events, but also opens up opportunities for a variety of biosensing applications. This work is supported by the Swiss National Science Foundation as part of the NCCR Molecular Systems Engineering.

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A Flexible and Transparent UV Sensor from ZnO Tetrapods

Simas Rackauskas [1,2], Hua Jiang [2], Kimmo Mustonen [2], Marco Mattila [3], Harri Lipsanen [3], Esko Kauppinen [2], Albert Nasibulin [2,4]

[1] CCS - UNICAMP, 13083-870, Campinas, SP, Brazil. [2] Aalto University School of Science, Puumiehenkuja 2, Espoo, Finland. [3] Department of Micro and Nanosciences, Micronova, Espoo, Finland. [4] Skolkovo Institute of Science and Technology, Skolkovo, Russia 143025.

Zinc oxide nanostructures have received broad attention due to their distinguished performance in electronics, optics, gas sensing and piezoelectronics. Zinc oxide tetrapod (ZnO-T) is one of these structures, which consists of four nanowires, and is especially interesting for its simple synthesis; however, the growth mechanism is not thoroughly understood. Here, we propose a simple non-catalytic one-step process method for an efficient and rapid synthesis of ZnO tetrapods by Zn vapor oxidation under an air environment. ZnO-Ts were fabricated in a vertical quartz tube furnace from Zn powder mixture at temperature range of 500–750 °C. The temperature has the highest impact on ZnO-T morphology. We were able to control the tetrapods “legs” diameter and length in the range 10–200 nm and 100–1000 nm respectively. The structure change, relative to temperature was also investigated. ZnO-T is an excellent material for UV sensors. UV sensing phenomenon originates from variation of charge carrier density. Under irradiation of UV-light with higher energy than band gap of ZnO, charge carrier density is increased and this reduces the resistance of ZnO tetrapod. UV-responses of single tetrapod devices has been measured under air (oxygen) atmosphere and it is has been suggested that oxygen molecules absorbed on the ZnO surface play a decisive role in UV-detection. Oxygen molecules capture free electrons from the ZnO surface and become oxygen ions, forming a low conductivity depletion region on the surface of ZnO-T. A UV sensor was fabricated by simple filtering process. ZnO-T were suspended between two carbon nanotube electrodes. The obtained layered structure showed excellent UV sensing properties.

Light Sensing at the Quantum Limit: Measuring From One to Twenty Photons

Andrea Fiore [1], Francesco Mattioli [2], Zili Zhou [1], Alessandro Gaggero [2], Rosalinda Gaudio [1], Saedeeh Jahanmirinejad [1], Roberto Leoni [2]

[1] Eindhoven University of Technology, The Netherlands. [2] Istituto di Fotonica e Nanotecnologie (IFN), CNR, Roma, Italy.

For many optical sensing and communication applications, including LIDAR, single-molecule spectroscopy and quantum cryptography, detectors with sensitivity at the single-photon level are required. In order to achieve this sensitivity, single-photon detectors (e.g., avalanche photodiodes) usually employ a strongly nonlinear internal gain process and a quenching circuit, which makes their response nearly independent of the number of absorbed photons. In contrast, a linear detector, with a response proportional to the photon number, would enable a direct mapping of optical to electrical signals at the few-photon level. In this paper, I will present detector technology which allows the measurement of the photon number in a pulse in the 1–24 photon range. It is based on arrays of superconducting nanowires. After reviewing the detection principle in superconducting nanowire detectors, I will present the concept of photon-number-resolving detectors based on series arrays of nanowires and our latest experimental results.

Session 5.2: Remote and Micropower Sensors

Session Chair: Assefa Melesse

Remote Sensing (ISSN 2072-4292) publishes regular research papers, reviews, letters and communications covering all aspects of the remote sensing process, from instrument design and signal processing to the retrieval of geophysical parameters and their application in geosciences. Our aim is to encourage scientists to publish experimental, theoretical and computational results in as much detail as possible so that results can be easily reproduced. There is no restriction on the length of the papers.

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Power Supply for Wireless Sensor or Actuator Systems

Leonhard Reindl

Institute of Microsystems Technology (IMTEK), University of Freiburg, Germany.

Portable wireless sensor or actuator systems, like portable phones, remote control, or ID cards play an ever-growing role in our industrialized environment. Those systems and many more were enabled due to the steady decreasing power consumption of high-integrated ICs. Most such systems are powered by batteries or inductive coupling. In this presentation, several concepts for an alternative power supply of wireless sensor or actuator systems are discussed in detail. Batteries, although used in most situations, suffer from a limited storage capacity, which induce a labour and sometimes cost-intensive periodic maintenance, and a problematic ecological impact. The operating range of inductive coupling systems is due to the near field limited to the aperture of the coupling coil. UHF systems operate in the far field and reach higher distances. Their operating range is limited by the distance where the voltage at the feeding point of the antenna becomes too low to drive the rectifier circuit. Larger read out ranges become feasible by omitting the rectifier stage. In this case, we need either a passive frequency-modulating device to shift the read out signal to a side band, or a resonator with a high quality factor, like a SAW or BAW device, to store the energy until all environmental echoes are feed away. For many applications, both indoor and outdoor, energy harvesting system become feasible which convert ambient power densities like light, RF fields, special or temporal thermal gradients, or mechanical vibrations into electrical supply power of the wireless system. All those systems strongly suffer from a lack of energy. Thus new concepts for lowering the power consumption of a wireless sensor or actuator system by keeping their features remain extreme important. Herby, a new wake up receiver is presented which operates on a current requirement as low as 3 µA.

Sensors and Role of Remote Sensing in Coastal and Wetland Studies

Assefa M. Melesse

Florida International University, FL, USA.

Coastal zones and wetlands are among the most important ecosystems of the world with varied functions and structures. Humans have drained coastal areas and wetlands and altered the structure and functions for various uses. Restoration efforts of these areas require assessment of the level of ecohydrological restoration for the intended functions. The role of remote sensing in mapping, change detection and estimation of various model parameters to study the spatiotemporal changes in the structure, cover and, hence, functions of coastal wetlands, is receiving great attention. Sensors from the optical, thermal and microwave spectra have been employed in studying coastal zones and wetlands. Coastal eutrophication, nutrient and sediment loading, tropical storm wetland vegetation damages, wetland drainage and destruction, urbanization and saltwater intrusion are among the various challenges faced by the coastal and wetland management professionals. The role of remotely-sensed data in providing useful information for mapping and modeling of the different processes governing the fluxes of water, energy and nutrients is substantial. Landsat and Moderate Resolution Imaging Spectroradiometer (MODIS) data for understanding dynamics of vegetation cover, imperviousness, urban heat island, energy fluxes and vegetation cover have proven to be promising. SeaWIFIS and MODIS data for mapping and estimating Chl-a in coastal waters has been gaining popularity. The impact of hurricanes on algal blooms in coastal water bodies and pre- and post-hurricane wetland vegetation cover can be studied using selected sensors. Results of various studies using remote sensors of various spatial, temporal and radiometric resolutions in modeling wetland latent heat fluxes, estimating coastal algal blooms, vegetation dynamics, pre- and post-tropical storm coastal eutrophication, mapping fractional vegetation and impervious areas, modeling lake evapotranspiration and other important applications, will be presented and discussed.

Porous Corundum Plate Sensor for Atmospheric Water Deposits' TDR Measurements

Marcin Kafarski [1,2], Anna Nakonieczna [2], Andrzej Wilczek [2], Agnieszka Szypłowska [2], Grzegorz Janik [3], Małgorzata Albert [3], Wojciech Skierucha [2]

[1] The State School of Higher Education in Chełm, Chełm, Poland. [2] Institute of Agrophysics, Polish Academy of Sciences, Lublin, Poland. [3] Institute of Environmental Protection and Development, Wrocław University of Environmental and Life Sciences, Wrocław, Poland.

In some regions the amount of water supplied to the soil due to the existence of fog, dew, hoarfrost and direct water adsorption from the atmosphere can exceed that of rainfall. For this reason, the atmospheric water deposits can be the main source of liquid water for living organisms. On this account, the measurements of the amount of water thus added to the soil are of crucial importance from the ecological perspective. For measuring the atmospheric water deposits intensity, the TDR (Time Domain Reflectometry) sensor was designed and produced. The sensor was equipped with a water collector in the form of a corundum ceramics plate. The plate was placed between a flat surface made of laminate covered with copper, which was impermeable to water, and a copper wire. The metallic layer and the wire formed a transmission line. The properties of the porous material used for manufacturing the plates do not change in time, which ensures high measurement repeatability. The results are obtained immediately. Moreover, the TDR technique allows to achieve the desirable resolution and accuracy of the atmospheric water deposits measurements. The aim of the research was to test the sensor for the atmospheric water deposits intensity measurements and to define its measuring range and detection level. In order to achieve this goal, sensors with ceramic plates were tested in the laboratory. The performance of the produced sensors was also examined during field measurements. The outdoor readings taken simultaneously with a set of six sensors with different porous plates thicknesses allowed obtaining a wide measuring range while maintaining a high level of detection. Additionally, the conducted field measurements revealed that the designed sensor is also capable of measuring the rainfall of very low intensity.

Determination of Complex Dielectric Permittivity Spectra from the Analysis of Electrical Signal Reflection in Transmission Lines of Various Lengths

Agnieszka Szypłowska [1], Marcin Kafarski [1,2], Andrzej Wilczek [1], Anna Nakonieczna [1], Bartosz Paszkowski [1], Wojciech Skierucha [1]

[1] Institute of Agrophysics, Polish Academy of Sciences, Lublin, Poland. [2] The State School of Higher Education in Chełm, Chełm, Poland.

Time-domain reflectometry (TDR) sensors enable the determination of electromagnetic wave propagation velocity in a given medium by analysis of the reflected electrical signals. The signal propagation velocity is determined by bulk dielectric permittivity of a given medium. This principle is used in TDR soil moisture meters, because soil dielectric permittivity is primarily determined by the water content. The value of soil complex dielectric permittivity depends on the frequency of the electrical field. In the frequency range of the TDR signals, several dielectric relaxation mechanisms could overlap and influence the bulk dielectric permittivity of a given soil. For this reason, the relationship between water content and bulk dielectric permittivity can differ for various soils. Determination of the complex dielectric permittivity frequency spectrum should increase the accuracy of in-situ soil moisture measurements, as well as provide information about other soil properties (e.g., clay content). The obtained data could be used e.g., in environmental studies and interpretation of remote sensing images acquired for the purpose of soil moisture monitoring. Complex dielectric permittivity spectra can be obtained from TDR waveforms using Fourier analysis. The aim of the presented research is to develop and evaluate a methodology of complex dielectric permittivity determination using Fourier analysis of TDR pulses reflected from the ends of the probe rods of various lengths. In this approach, the distorting effects of the cable, connectors and the surface irregularity of a tested material can be largely neglected. The measurements of several reference materials as well as examples of target materials will be presented. The results will be discussed in terms of measurement accuracy and optimal frequency ranges and compared to standard frequency-domain testing.

A Mobile Vehicle Weight Sensor and its Application in Transportation (Case Study: Municipal Solid Waste Collection Vehicles)

Mehran Safdar

Isfahan Science and Technology Town, Iran.

In recent years, due to the expansion of the vehicles' transportation system and concerns about the lack of accurate calculations of vehicle weight, a system that is able to calculate the vehicle's weight at any moment, it seems necessary. Given that the transportation electronic management is related to the location and movement data of vehicles, information about movement, speed and time, traveled path, the weight sensors and fuel for the quick and timely decisions are required. Therefore, the design and implementation of modern systems for monitoring and control of these devices to make quick decisions and plan codified is essential. In this paper firstly, the different ways of measuring the vehicle weight and the problems of each them has been described then the weight sensor device which is equipped with an AVL system, and its application in urban management (waste collection) has been described- Finally, the advantages of this device have been proposed.

Impact of the TDR Pulse Width on the Reflection Amplitude and its Dependence on Soil Dielectric Loss and Electrical Conductivity

Andrzej Wilczek [1], Agnieszka Szypłowska [1], Marcin Kafarski [1,2], Wojciech Skierucha [1], Anna Nakonieczna [1], Bartosz Paszkowski [1]

[1] *Institute of Agrophysics, Polish Academy of Sciences, Lublin Poland*. [2] *The State School of Higher Education in Chełm, Chełm, Poland.*

Soil dielectric permittivity is a complex quantity. Its real part is mainly related to water content, density and dielectric permittivity of the solid phase. Dissolved salts determine soil electrical conductivity EC. Dielectric properties of water in contact with the solid phase particles affect dielectric loss of soil. This quantity is also strongly dependent on the clay fraction and is associated with the presence of bound water. Furthermore, dielectric loss depends on the wavelength and it determines the penetration depth of electromagnetic waves in a material. Knowledge of this parameter is important in the interpretation of satellite measurements. Moreover, it can be used for calibration of contactless methods of soil moisture measurement, such as GPR or microwave reflection methods. The presented research describes the application of a needle TDR pulse of variable width to measure soil dielectric properties. The aim of the research was to determine the relationship between the dielectric relaxation time and amplitude of the TDR pulse with variable spectral parameters. The S11 parameter was measured using a multi-rod probe placed in dry and nearly saturated soil. In addition, S11 was determined by FDTD simulations and calculated based on mathematical formulas describing the impedance transformation for lossy transmission line. Then transient simulations were carried out to give the response in the time domain for a given needle pulse of variable width. The results obtained for nearly saturated soil allow to observe that the reflected signal amplitude increases with increasing pulse width. For dry soil the reflected signal amplitude remains almost constant. Based on these results the parametric model was developed for the simultaneous determination of EC and soil relaxation time. The model was verified by performing measurements of water with different EC. The results show that the described method allows for the selective determination of soil dielectric loss.

Session 5.3: Neurosensors

Session Chair: Patricia A. Broderick

Editor-in-Chief: Prof. Dr. Miko Elwenspoek - MESA+ Institute, University of Twente, PO box 217, NL 7500 AE Enschede, The Netherlands.

Micromachines (ISSN 2072-666X) is an international, peer-reviewed open access journal which provides an advanced forum for studies related to micro-scaled machines and micromachinery. It publishes reviews, regular research papers and short communications. Our aim is to encourage scientists to publish their experimental and theoretical results in as much detail as possible. There is no restriction on the length of the papers. The full experimental details must be provided so that the results can be reproduced.

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Soft Transducers to Communicate with the Nervous System

Stephanie P. Lacour

Laboratory for Soft Bioelectronic Interfaces, School of Engineering, Center for Neuroprosthetics, EPFL, Lausanne, Switzerland.

A crucial component of a neuroprosthesis is the implanted microelectrode array (MEA) that is positioned at the surface or within the neural tissues. Most “research” neural MEAs are prepared today with materials and technological know-how borrowed from the microelectronics and MEMS industry. This results in well-defined, batch-processed transducing arrays but often ill-chosen materials and designs when considering the biological tissue. To ensure reliable long-term performance in vivo, the MEA should also possess physical characteristics close to those of the tissue itself. In this paper, I will focus on the mechanical and structural aspects of biocompatibility, and the desired physical properties of the materials used to fabricate implantable neural electrodes. Low modulus elastic materials in conjunction with stretchable conductors enable the evolution of neural electrode arrays towards conformal bioinspired interfaces. These ultra-compliant devices are engineered to establish a synergy with living tissue to reactivate, repair, restore, or replace diminished/lost physiological functions due to disease or injury of the nervous system. Using examples from our research, I will highlight recent progress on chronic, soft neural implants.

Nanobioimaging: Personalized Medicine in Real Life is Here. Nanotechnology Meets the Brain.

Patricia A. Broderick

Sophie Davis School of Biomedical Education City College of New York - City University of New York (CUNY), Graduate Center NYU, Langone Medical Center - NYU Comprehensive Medical Center.

"*It is more important to know what sort of person has a disease than to know what sort of disease a person has*". Hippocrates said this, a long time ago, in the age of Pericles. What Hippocrates was talking about was and is "personalized medicine". Each brain with its billions of neurons, connecting one to the other in spider web fashion, in seemingly pseudo-order, needs peraonal attention to detail. Nanobioimaging/Neuromolecular Imaging (NMI) with the BRODERICK PROBE® can and will provide it. Nanobioimaging actually studies neuropathology and compares neuropathology with normal neuronal activiey in the same subject. This is the "Trade Secret". We avoid the scenario wherein one subject is studied for its neuropathogy and an entirely different set of neuropathologic nuances in a different subject is studied. To this author's knowledge, no other technology enables living imaging in live subjects in real time. To do this, we have pioneered the development of a nanobiosensor which is smaller than a human hair, which images several chemical and biologic substances separately within a temporal resolution as low as nanoseconds in real time, in vivo, in vitro and in situ in the intact living brain as a subject is moving about freely? This nanobiosensor provides imaging of specific neurotransmitters at specific oxidation (half wave) potentials enabling characteristic analog signal processing in the intact living organism using a current resolution range as low as nanoamperes. In controlled studies, this nanbiosensor has been shown to be free of bacterial infection. This nanobiosensor encompasses hundreds of tested patented formulas for use in selectively imaging a myriad of substances capable of diagnostic use in ameliorating brain disease. This nanobiosensor is amenable to regenerative, preconcentrative and conditioning processes with or without performing genetic engineering. This nanobiosensor does not produce scarring (glial) formation after its placement in the human patient as reported in blind studies by NYU Langone pathologists. The nanobiosensor is already available for scientific use in humans and animals. The lecture presents such a unique nanobiosensor technology and presents the tools needed for Neuromolecular Imaging (NMI) as well as the applications and use of the BRODERICK PROBE®. This nanbiosensor has already met with success in the clinic in the operating room and the images are recorded on line, in vivo, in real time, within the neocortical brain of the epileptic patient during intraoperative surgery. Nanotechnology meets neurodegenetive disorders, epilepsy, stroke and Parkinkson's disease for personalized medicine and point of care diagnostics and treatment will be discussed. The terminology, NMI, was recently introduced into the literature (Broderick and Pacia, 2005) and is based on, but is different from conventional electrochemistry and conventional voltammetry. NMI allows inventive new formulations for biosensors; these include biochemical classes of lipids, glycolipids, lipoproteins, cerebrosides, ceramides and fatty acids, whether saturated or unsaturated. Detection capabilities include, among others, dopamine (DA), serotonin

(5-HT), homovanillic acid (HVA), l-tryptophan (L-TP), norepinephrine, (NE), ascorbic acid (AA), uric acid (UA) as well as neurotransmitter peptides such as dynorphin and somatostatin. The BRODERICK PROBE® nanobiosensor is further useful for diagnosis and treatment of brain and peripheral diseases due to its molecular recognition imprinting properties. This lecture will delve into this patented, proprietary versatile tool for nanobioimaging.

Neuro-Inspired, Event-Based Vision Sensors

Christian Peter Brändli, Tobi Delbrück

Institute of Neuroinformatics, UZH/ETH Zürich, Zürich, Switzerland.

The success of Moore's law resulted in an abundace of digital, synchronous computation and this had a severe impact on how we sense the world: information is as early as possible digitized and synchronized. However, sampling an imput with a constant sampling rate is not very efficient and often produces redundant data which has to be converted, communicated, and processed. The brain has a much more elegant way to sense the world: analog, asynchronous computation allows to focus the computational resources on the relevant data.
The talk will introduce a neuro-inspired, event-based sensing principle, introduce the dynamic and active pixel vision sensor (DAVIS), give a demonstration, highlight its advantages and show possible applications.

Diamond-Based Electrochemical Sensor: A Multi Electrode Array for Simultaneous Detection of Quantal Exocytic Events from Neuroendocrine Cells

Federico Picollo [1], Alfio Battiato [2], Ettore Bernardi [2], Emilio Carbone [3], Sara Gosso [3], Paolo Olivero [2], Alberto Pasquarelli [4], Valentina Carabelli [3]

[1] INFN sect. Torino, Physics Department & NIS inter-departmental Center - University of Torino, Torino, Italy. [2] Physics Department & NIS inter-departmental Center - University of Torino, INFN sect. Torino, Torino, Italy. [3] Department of Drug Science and Technology & NIS inter-departmental Center -University of Torino, Torino, Italy. [4] Institute of Electron Devices and Circuits, Ulm University, Ulm, Germany.

The study of the mechanism involved in observed catecholamine (*i.e.*, adrenaline) secretion is of paramount importance in neuroscience research in order to achieve a better understanding of signal transmission among neurons. New technologies allow for overcoming the limitations of current standard approaches. Diamond-based sensors, which take advantage of the extreme properties of this material (biocompatibility, chemical inertness, single defects quantum properties), represent the next generation of devices. In the present work, we report on a systematic investigation of quantal exocytic events from cultured bovine chromaffin cells carried out by a diamond-based Multi Electrode Array (MEA) sensor. The biosensor was fabricated using an opportunely masked broad 1.3 MeV He^+ ion beam on a IIa monocrystalline diamond sample (4.5×4.5×0.5 mm^3). This process provides us with buried highly conductive graphitic channels (resistivity ~mΩ·cm) embedded in a highly insulating and chemically inert diamond matrix, which can act as electrochemical sensors for excitable cells, as already demonstrated by amperometric measurement of exocityc events on single-electrode device [1] and by a preliminary characterization of the multi electrode sensors [2]. Taking advantage of the biocompatibility of diamond, cultures of chromaffin cells were incubated over the surface of the device. Quantal secretory responses were simultaneously measured from stimulated cells positioned on the sixteen graphitic microelectrodes. The proposed diamond based sensor exhibits sensitivities toward oxidazable molecules similar to that of standard commercial techniques, as demonstrated by the full compatibility of the presented results with those obtained using carbon fibre microelectrodes. However, our new device offers faster data harvesting due to the multi electrode integration and the possibility of recordings from cell populations, thus using the microchip for fast drug screening of a large number of biological samples.

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3D Microelectrode Arrays for Neuro-Sensing: Read-Out Circuit Design and Hybrid 3D Integration

Yusuf Leblebici

Institut de génie électrique et électronique, EPFL, Lausanne, Switzerland.

This talk will review the hybrid 3D integration technologies based on through-silicon-via (TSV) arrays that are being developed at EPFL, and their potential applications for the integration of microelectrode arrays for neuro-sensing. We will also review the key challenges and innovative solutions for the design of ultra-low-power, low noise and high precision readout circuitry that are used in such applications.

Session 6: Single Chip Sensors and Sensor Networks

Session Chair: Patrick Thomas Eugster

Journal of
Sensor and Actuator Networks

Journal of Sensor and Actuator Networks (ISSN 2224-2708) is an international open access journal on the science and technology of sensor and actuator networks. It publishes regular research papers, reviews (including comprehensive reviews on complete sensor and actuator networks), and short communications. Our aim is to encourage scientists to publish their experimental and theoretical results in as much detail as possible. There is no restriction on the length of the papers. The full experimental details must be provided so that the results can be reproduced.

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Droplet-Based Microfluidics: Towards Ultra-High Throughput Experimentation

Andrew J. de Mello

ETH Zürich, Zürich, Switzerland.

The past two decades have seen enormous progress in the development and realization of microfabricated systems for use in the chemical and biological sciences. Interest in microfluidic or lab-on-a-chip technology has in large part been driven by concomitant advances in the areas of genomics, proteomics, cellomics, drug discovery, high- throughput screening and diagnostics with a clearly defined need to perform rapid measurements on ultra small sample volumes. At a fundamental level, microfluidic activities have been stimulated by the fact that physical processes can be more easily controlled when instrumental dimensions are reduced to the micron scale. The relevance of such technology is significant and characterized by a range of fundamental features that accompany system miniaturization. Such features include the ability to process and handle small volumes of fluid, enhanced analytical performance when compared to macroscale analogues, reduced instrumental footprints, low unit costs, facile integration of functional components within monolithic substrates and the capacity to exploit atypical fluid behaviour to control chemical and biological entities in both time and space. Based on these advantageous characteristics, microfluidic systems have been used to good effect in a wide variety of applications including nucleic acid separations, protein analysis, process control, small-molecule organic synthesis, DNA amplification, immunoassays, DNA sequencing, cell manipulations, nanomaterial synthesis and medical diagnostics. My lecture will describe recent studies in my group that are focused on exploiting the spontaneous formation of droplets in microfluidic systems [1] to perform a variety of analytical processes, including cell-based assays [2] and DNA amplification[3], the intelligent synthesis of nanomaterials [4,5]. Key to all these investigations is the development of high-sensitivity detection methods for probing the small-volumes encounted within microfluidic environments.[6] Accordingly, the application of fluorescence lifetime imaging and stroboscopic fluorescence detection to both continuous and segmented-flows will also be introduced.

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A Silicon Nanowire Ion Sensitive Field Effect Transistor

Christian Schönenberger

Department of Physics, University of Basel, Basel, Switzerland.

Contributors:
L. Stoop, M. Wipf, A. Tarasov, O. Knopfmacher, Wangyang Fu, M. Calame. C. Schönenberger. Department of Physics, University of Basel, Basel, Switzerland

J. Martin, I. A. Wright, E.C. Constable.
Department of Chemistry, University of Basel, Basel, Switzerland

Navarra, S. Rabbani, B. Ernst,
Department of Pharmaceutical Science, University of Basel, Basel, Switzerland

Bedner, V. A. Guzenko, J. Gobrecht.
Paul Scherrer Institut, Villigen PSI, Switzerland

Rigante, A. Ionescu
EPFL STI IEL NANOLAB, ELB 335 (Bâtiment ELB), Lausanne, Switzerland

We summarize our work on the use of chip based Si-nanowire and nanoribbon ion sensitive field effect transistors. Nanowires covered with an oxide layer, such as Al_2O_3 or HfO_2, are highly pH-sensitive, due to the large number of surface hydroxyl groups, which yield a conversion from pH to threshold swing that is close to the maximum of 60 mV/pH (as given by Nernst's law). The accuracy in pH sensing is limited by low frequency 1/f noise, which can be traced back to gate-induced noise, which is likely caused by trap states in one of the gate interfaces. A measurement accuracy of 0.017% of pH can be reached for a wire of 1 µm. Without any further functionalization, these sensors can, in practice, only probe proton concentrations. However, we have shown that one can passivate the surface with a layer tight enough that the proton signal can almost fully be suppressed, thus yielding a reference electrode. To detect other species, for example other ions, the nanowires were coated with molecules that can specifically complex with a certain ion. This functionalization was done on Au-coated nanowires. By using a set of wires, we demonstrate that a platform consisting of differently functionalized wires can be realized, which is capable of sensing different ions (H^+, K^+, Cl^-, Ca^{2+}) with some selectivity. Since these sensors inherently measure a potential change, different surface reactions can compete, yielding some degree of feedback that we demonstrate with an example. Finally, we show the first results of the label-free detection of FimH proteins.

A CMOS Compatible Photodetector with Intrinsic Light-to-Time Conversion for Low Light Applications

Denis Sallin, Adil Koukab, Maher Kayal

Electronics Laboratory (ELab), Institute of Electrical Engineering (IEL), École polytechnique fédérale de Lausanne (EPFL), Switzerland.

A new type of silicon photodetector displaying an intrinsic Light-to-Time conversion effect is presented. The device is CMOS compatible and consists of a Hybrid MOS-PN structure, with a gate surrounding a P+ diffusion. The device can be seen as a charge integrator and comparator, switching on after a certain amount of charge has been accumulated. The operation of the detector starts by generating a reference charge (Qref) in its MOS part (depletion) which blocks the conduction of the forward-based PN diode. The charge Qref is controlled by the gate voltage and geometry. After a certain illumination time, photo-generated electrons, accumulated under the oxide (integration), counter-balance Qref (comparison), and change the state of the MOS part from deep depletion to inversion. This mechanism eventually switches on the forward-based PN diode and a high magnitude current flows. The time necessary to switch the device on is inversely proportional to light intensity. The turn-on delay is thus inversely proportional to light intensity, which bring interesting properties in term of SNR. Moreover, such a “digital” operation has several advantages in terms of readout circuit complexity and noise. The read-out circuit only detects when current flows in the device, without the need for comparator nor amplification. This leads to an extremely low read noise as well as a small readout circuit area and low complexity. It is also possible forward-bias the device with short voltage pulses and take advantage of its behavior in order to operate it as a direct light-to-digital converter. As a positive side effect, pulsed operation also reduces the dark current. Devices were fabricated, along with read-out circuitry, on a 180 nm CMOS process. Measurements show good performance and suitability for low-light applications, such as bioluminescence. Measurements demonstrate good performances down to an intensity of 10^{-8} W/cm^2 and below.

Smart Image Sensors for Metrology Applications

Eduardo Franzi

CSEM S.A., Neuchâtel, Switzerland.

This talk presents a VLSI implementation of the CSEM spaceCoder technology; a completevision-based chip specifically tailored for metrology applications. This optical VLSIimplementation system is capable of measuring 2D nanometric quasi-absolute displacementsat 200 KHz. We will first recall the necessary computing steps to achieve thesebeyond-state-of-the-art performances. Then, we will describe the methods used to integratethese computing steps, taking advantage of the micro-electronics resources (*i.e.*, massively parallel computing).

Towards a Robust Internet of Things: The Case of Wireless Sensor Networks

Patrick Thomas Eugster

Purdue University, TU Darmstadt, and SensorHound Inc., IN, USA.

The Internet of Things (IoT) has strong potential for supporting a human society interacting more symbiotically with its physical environment. Indeed, the emergence of tiny devices capable of sensing environmental cues and triggering actuators after consulting logic and human preferences promises for a more environmentally aware and promiscuous society. However, the intrinsic nature of the IoT challenges existing software development processes and, in particular, techniques for ensuring software reliability and security. This talk covers our experiences in the development of debugging and monitoring solutions for a reliable and secure IoT, including techniques for gathering runtime information on individual sensor nodes' executions and interactions among nodes, as well as for efficiently compressing such information.

From Smart Dust to 6TiSCH: Building the Industrial Internet of Things

Thomas Watteyne

Inria, EVA team, Paris-Rocquencourt, France.

The 1997 Smart Dust project and its millimeter-sized wireless sensors resonated with a whole community of academic and industrial researchers. The concepts of low-power wireless mesh networks of tiny sensor and actuators devices was born. Still to this day, people often refer to these devices as "motes", defined as a "speck of dust". In the nearly two decades that followed, tremendous energy has been put in researching, standardizing and commercializing these networks, labeled Wireless Sensor Networks (WSN), Machine to Machine communication (M2M) or Internet of Things (IoT). With this effort, the focus has moved away from miniaturization, and into building highly reliable and ultra low-power solutions. Off-the-shelf commercial solutions exist today which offer >99.999% end-to-end reliability and a decade of battery lifetime. Current standardization and research activities aim at applying these networks for industrial application, which are hugely demanding in terms of reliability, latency bounds, throughput and energy consumption. A new class of mesh networks, known as Time Synchronized Channel Hopping (TSCH), has brought with it a flurry of applications ranging from monitoring oil refineries to city-wide parking solutions and controlling smart buildings. This presentation will take us through the almost 20 years of development of low-power wireless mesh technology. After presenting the vision, we will discuss the different constraints put on these networks, and detail current technology and standardization trends. Particular attention will be given to IETF 6TiSCH, the working group which combines the performance of industrial low-power wireless with the ease of use of IPv6.

Energy-Efficient Scheduling with Compressed Sensing for Distributed Target Tracking

Shi-Kuan Liao, Kai-Jay Lai, Chih-Yu Wen

Department of Electrical Engineering, National Chung Hsing University, China.

In wireless sensor networks, target tracking is an important application. This paper proposes a distributed method for cooperative target tracking in hierarchical wireless sensor networks. The concept of leader-based information processing is conducted to achieve object positioning, considering a cluster-based network topology. In this work, we use the target tracking problem as an example to investigate several major issues, such as how to organize the network with the limited resources, how to make the sensors perform the tracking task cooperatively with each other, and how to compress the sensing information in order to conserve the energy. A two-level hierarchical wireless sensor network is designed for cooperative target tracking via compressing information. The simulation results show that compared with the conventional approaches, the proposed data processing scheme has a balanced system performance in terms of localization accuracy, data size for transmission, and energy consumption.

Wireless Sensor Networks, Real-Time and Low Consumption: Lessons Learned

Jean-Dominique Decotignie

CSEM S.A. -Center Suisse d'Electronique et de Microtechnique, Neuchâtel, Switzerland.

Networking at the sensory level is now very common. Fieldbusses like CAN, FIP or Profibus have been around for more than three decades. Establishing their real-time properties and guarantees has been the subject of a number of papers in scientific conferences. Using wireless transmission at the sensory level is very attractive. It has been employed for years to link mobile robots or automated guided vehicles to control and supervision computers. The first attempts to wirelessly connect sensors with temporal constraints date from the early 1990's. Since then, the subject, under the name of real-time wireless sensor networks, has generated a large body of research and development. A number of researchers have reused protocols and algorithms designed for wireline networks or made assumptions that ease the design and the analysis. As a result, in many cases, real-time analysis is based on assumptions that are quite far from reality leading to purely academic solutions. The first part of the talk will show a few examples of WSN deployments done by CSEM on glaciers, buildings, trains or planes and explain the main lessons learned from these experiments. The validity of some of the often assumed models will be questioned in the light of experience. Given the fact that we have to revise these assumptions, the second part will show a few "real" problems of real-time WSNs and the possible change of paradigm that results.

Session 7: i-net Technology Workshop “Sensors - Trends, Exchanges and Collaborations”

I3S2015 in cooperation with i-net–explore entrepreneurial ideas

I3S2015 and i-net cooperate on this event with a special network session to facilitate an interdisciplinary exchange and promote innovation and entrepreneurial ideas.

Sensors combine nano- and microtechnologies and enable new applications in Medtech, Life Sciences and the Internet-of-Things. In addition, data are collected, transmitted and communicated to user interfaces. Sensors are not only a highly interdisciplinary technology, they are often a starting point of new products and business services.

The mission of i-net innovation networks Switzerland is to promote innovation in Northwestern Switzerland. As a public private partnership between the cantons of Baselland, Basel-Stadt, Jura and leading companies from the region, i-net supports companies in the technology fields of ICT, Life Sciences, Medtech, Cleantech and Nanotechnology. i-net offers companies and innovating entrepreneurs free advisory services and a wide range of opportunities to network and foster knowledge and technology transfer. With about 60 events per year i-net addresses a network of over 7000 people—from start-ups to global companies.

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Poster Presentation Abstracts

The Poster Award will be determined by votation of all participants.

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1 In Situ Annealing Mitigation Technique for Neutrons and Gamma rays Irradiated Silicon-on-Insulator Thermodiode

Laurent A. Francis [1], Nicolas André [1], Pierre Gérard [1], Zeeshan Ali [2], Florin Udrea [3], Denis Flandre [1]

[1] ICTEAM Institute, Université catholique de Louvain, Belgium. [2] Cambridge CMOS Sensors Ltd., Cambridge, United Kingdom. [3] Department of Engineering, Electrical Engineering Division, University of Cambridge, Cambridge, United Kingdom.

In this work, we present a low-power and in situ mitigation technique based on micro- hotplates. These are micro-electromechanical (MEMS) structures primarily of interest for low-power gas sensing, lab-on-chips and space applications. They consist of a Joule heater suspended on a thin-film membrane while thermopiles or thermodiodes are added as temperature sensors and for feedback control. Experimental results and initial properties recovery are obtained from electrical tests on thermodiodes integrated to a micro-hotplates during and after their irradiations by fast neutrons with total doses about 2.97±0.08 kGy and by Cobalt-60 gamma rays with total doses up to 18.90 kGy.

2 Safirinuim Q - a New Platform for Fluorescent Probing and Labeling Based on the Click Tandem Mannich–Electrophilic Amination Reaction

Joanna Fedorowicz, Jarosław Sączewski

Department of Organic Chemistry, Faculty of Pharmacy, Medical University of Gdańsk, Gdańsk, Poland.

Development of optical probe technology requires the design of new fluorogenic reactions that result in the formation of fluorophores with advantageous physicochemical and photophysical properties, such as good water solubility when applied in medical research, high photostability as well as large Stokes shifts [1].We have found that non-fluorescent isoxazolo[3,4-b]quinolin-3(1H)-one derivatives, when treated with secondary aliphatic amines and formaldehyde, undergo a tandem Mannich–electrophilic amination reaction, giving rise to the formation of fluorescent 1,2,4-triazolo[4,3-a]quinolin-2-ium-4-carboxylates (Safirinium Q), which are stable in aqueous solution, redox-stable, exhibit high quantum yields, large Stokes shift, lack of solvatochromism, remarkable water solubility and adjustable polarity achieved by introducing alkyl chain of various size. Moreover, the excitation and emission spectra of the dyes can be tuned in the range of 350 to 400 nm and 465 to 515 nm, respectively, by introduction of electron-donating substituents into positions 5, 6, 7 and 8 of the quinolinium moiety. The above reaction proceeds quantitatively at room temperature yielding a fluorescent product which can be isolated by non-chromatographic methods. Therefore, it fulfills the criteria of click chemistry and can be used as a versatile platform for fast and highly sensitive detection and environmental monitoring of formaldehyde and secondary aliphatic amines [2,3]. In turn, dyes Safirinium Q upon esterification with N-hydroxysuccinimide (NHS) provide amine-reactive probes useful for fluorescent labeling of lysine-containing peptides and proteins, as exemplified by labeling of bacterial spores [3].

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3 An Intensity-Based Fiber Optic Vibration Sensor using a Mass-Spring Structure

Hyeon Ho Kim [1,], Hao Yi [2], Sang-Jin Choi [1], Jae-Kyung Pan [1]

[1] Chonbuk National University, Republic of Korea. [2] Beijing oriental rayzer technology Ltd., Beijing, China. [3] Chonbuk National University, Republic of Korea.

An intensity-based fiber optic vibration sensor using a mass-spring structure, which consists of a rectangular aperture within a proof mass, is proposed and its feasibility test is experimentally demonstrated. An optical collimator is used to broaden the beam, which is modulated by the displacement of the rectangular aperture within the proof mass. The proposed fiber optic vibration sensor has been analyzed and designed in terms of the optical and mechanical parts. The mechanical structure has been designed using theoretical analysis and mathematical modelling. The relative aperture displacement according to the base vibration is given, while the output beam power according to the relative displacement is measured by experiment. By using reference signal, the output signal with 0.75% relative error shows a good stability. Experimental results for the implemented intensity-based fiber optic vibration sensor are acquired using an electrodynamic shaker (ET-126) which is controlled by a function generator. Experimental results show the sensitivity of the proposed fiber optic vibration sensor of 135.4 μW/mm for the linear range of 0.65∼1.5 mm aperture displacement over a dynamic bandwidth of about 2k Hz. By comparing with a commercial accelerator, the feasibility proposed sensor is confirmed. Results show a good performance and feasibility of the proposed sensor. The proposed vibration sensor structure has the advantages of a simple structure, low cost, and multi-point sensing characteristic. It also has the potential to be made by MEMS (Micro-Electro-Mechanical System) technology.

4 Distributed Optical Fiber Sensing System Based on a Bidirectional Chaotic Fiber Ring Laser and a Time Difference Location Method

Nian Fang, Lutang Wang, Zhaoming Huang

Key Laboratory of Specialty Fiber Optics and Optical Access Networks; School of Communication and Information Engineering, Shanghai University, Shanghai, China.

In order to detect and locate accurately external disturbances along the optical fiber, a novel distributed optical fiber sensing system based on a bidirectional chaotic fiber ring laser and a time difference location method are proposed. The system structure, principles of detection and location method, as well as experimental results are presented. The system is consisted of a ring-type fiber laser or called fiber ring laser, a two-port polarization receiver, as well as a data acquisition (DAQ) and processing unit. The fiber ring laser is constituted with a semiconductor optical amplifier (SOA), a 2x2 optical coupler (OC), and a polarization controller (PC) as well as a long-scale, single-mode (SM) fiber as sensing element. The lights of the laser are output through the OC, received by the polarization receiver at two output ports, A and B, respectively. The corresponding output electrical signals are collected and processed by the DAQ unit. However, only the signal received at port A is used for locating disturbances, while the signal at port B is used only as a reference signal. The fiber ring laser can work in a chaotic state by adjusting current of the SOA and the PC state. Therefore, the light beams of clockwise and counter-clockwise propagating in the fiber ring both are chaotic in intensity and polarization state. Due to the sensitivity of chaotic system to initial conditions, the two counter light beams in the ring will change if an external disturbance acts on the sensing fiber. Therefore, the disturbance can be detected by monitoring the changes in signal waveforms at each port. After the chaotic laser is disturbed the light beams will evolve on the basis of the new conditions and continue to counter propagate in the ring. When they meet in the SOA, they will interact with each other through the nonlinear effects in the SOA. Therefore the output waveforms will change again, the waveforms in the period between the twice changes in signal waveforms will be obviously different to those in other time. This period represents a propagating time difference between two counter-propagating beams arriving at the SOA from the disturbance point. Therefore it can be utilized for the disturbance location. Since the chaotic waveform is quasi-stochastic, it is difficult to distinguish the differences directly within the continuous signal waveform. In this paper we also propose a method to identify the differences based on the framing structure and adjacent-frame similarity of the chaotic waveform. Through calculating the cross-correlation of the waveform data obtained in current frame and in previous frame a similarity degree can be obtained. According to the value change of the calculated similarity degree, one can know if a disturbance event has occurred in current frame or not. The propagating time difference mentioned above also can be obtained via comparing the distributed similarity degrees of adjacent-frame waveforms calculated by subtracting one frame waveform from another one. The experiments of disturbance detection and location were carried out with a 3.7 km long fiber on which 10 different disturbance points were

set previously. Experimental data show that the average location error is lower than a few tens of meters across whole fiber. This result demonstrates that the proposed sensing system and location method are feasible.

5 Effect of Film Thickness of NASICON and Electrode Configuration on Electrical Properties

Steven Mudenda, Girish M Kale

Institute for Materials Research, Faculty of Engineering, University of Leeds, Leeds, UK.

NASICON ($Na_{1+x}Zr_2Si_xP_{3-x}O_{12}$ for $0 \leq x \leq 3$) is a ceramic sodium (Na^+) superionic conductor having ionic conductivity at elevated temperatures comparable to that of liquids. It has potential use in planar functional materials or devices such as separation membranes, batteries, fuel cells and gas sensors. The need for miniaturising devices, including sensors, has seen the emergence of planar devices printed by screen printing technology for cost effective mass production. Despite the fact that the conductivity bulk NASICON is well explored, the spectral studies are scanty and not well understood in light of thick films configurations. Both the conductivity and spectral measurements of NASICON thick films employing AC impedance spectroscopy as a function of film thickness will be presented. Furthermore, different electrode configurations that resemble commonly used configurations in planar gas sensors, so that they can reflect closely the electrical behaviour of material during sensing, will be presented.

6 Long Period Grating Response to Gamma Radiation

Dan Sporea [1], Andrei Stăncalie [1,2], Daniel Neguţ [3], Sylvie Delepine-Lesoille [4], Laurent Lablonde [5]

[1] National Institute for Laser, Plasma and Radiation Physics, Magurele, Romania. [2] University 'Politehnica' of Bucharest, Faculty of Applied Sciences, Romania. [3] "Horia Hulubei" National Institute of Physics and Nuclear Engineering, Romania. [4] Andra - Agence nationale pour la gestion des déchets radioactifs, Châtenay-Malabry, France. [5] iXFiber, Lannion, France.

We report the evaluation of two long period gratings (LPGs) and one fiber Bragg grating (FBG) under gamma irradiation. The LPGs were produced by a melt-drawing technique; we use an electric arc to change the fiber characteristics, to fuse silica with a controlled pitch so as to create a fringe which presents a very thin section of the fiber that has a different refractive index. The first sensor (LPG1) consists was engraved in a commercial single mode fiber SMF28 from Corning®. This reference optical fiber is commonly used in cable sensors and represents our evaluation reference for the radiation tolerance of this technology. The second grating (LPG2) was written in a prototype SMF developed by iXFiber with a fluorine (F)-doped core of 8.5 µm diameter. The fluorine concentration is about 0.2 wt% in the core and 1.8 wt% in the cladding. This fiber was chosen as we previously demonstrated that such an F-doped optical fiber presents interesting radiation hardness at high doses in terms of radiation induced attenuation (RIA). After the manufacturing of the gratings, the fibers are re-coated with acrylated and the gratings were inserted into special cases transparent to gamma radiation: in ceramic (LPG1) or metal (LPG2) case. The irradiation was performed with the IRASM irradiator of the "Horia Hulubei" National Institute for Physics and Nuclear Engineering, Magurele. The Irradiator includes a 60Co gamma source (Institute of Isotopes Co. Ltd. Budapest), class IV (source storage in a pool, automatic transport system). The dose rate of 0.34 kGy/h was evaluated with an uncertainty of 2.28%, by an Alanine-EPR dosimetry system. The total irradiation duration was 78.5 h, but within this time interval some irradiation stops took place as the facility is an industrial irradiator. The tests were performed on-line, using a wavelength multiplexing technique. The on-line measurements along with the on-off switching of the irradiation process made possible the investigation of the recovery of the irradiation induced wavelength shift, at room temperature. For the first time, different types of optical fiber gratings were investigated by using an optical fiber interrogator. During the irradiation the sensors were packed into a thermally insulated box, and the temperature was monitored both inside and outside of the box, so that the wavelength and optical attenuation measurements were corrected, post irradiation, against the temperature changes. This investigation reviled the radiation sensitivity of the LPG1 and proved the radiation resistance of LPG2 and FBG. The increase of the central wavelength of LPG1 for the entire gamma ray expose was about 1.45 nm, with a slight recovery of about 0.2 nm. The wavelength change of the FBG was of the order of 20 pm under similar irradiation conditions. The change of LPG2 wavelength was about 200 pm. This work was supported by the Romanian Executive Agency for Higher Education, Research, Development and Innovation Funding (UEFISCDI), under Grant

8/2012, the project “Sensor Systems for Secure Operation of Critical Installations”. The investigation was done as part of the COST Action TD1001 “Novel and Reliable Optical Fibre Sensor Systems for Future Security and Safety Applications (OFSeSa)”. A. Stăncalie acknowledges the partial support by a grant from “Politehnica” University of Bucharest, under the project POSDRU cod 132397.

7 Real-Time Fusion of Infrared and Visible Images using Geometric Calibration

Hwan Hur, Dong Uk Kim, Ki Soo Chang

Korea Basic Science Institute, Republic of Korea.

A methodology for overlaying infrared and visible images has received much attention for human and machine perception, medical imaging, diagnosis and therapy, and biological color vision. In the existing study, the overlay image is projected onto a 2D space and needs two visible cameras with an infrared camera to obtain 3D information. Because a 3D thermogram corresponding to spatial information can provide valuable information, our study is focused on overlaying infrared and visible images in a 3D structure while minimizing the number of cameras required. We propose a calibration method to obtain the intrinsic and extrinsic parameters of an infrared camera. A calibration board is designed by the radiation difference between the two kinds of patterns. Experimental tests are performed by the real-time processing system.

8 A Distributed Routing Approach using a Markov Model Mobility Prediction based on RSSI Measurements in a Mobile Wireless Sensor Network

German Montoya, Yezid Donoso

Universidad de Los Andes, Bogotá, Colombia.

Low network performance caused by mobility in wireless sensor networks is a current difficult problem, when considering that MWSN must operate with efficient energy consumption, reduced computational complexity and a reliable network performance. To overcome the negative effects caused by mobility, we propose to use a mobility method to predict future network disconnections in order to maintain network connectivity avoiding transmission interruptions. In this sense, the valuable information from the mobility prediction method is provided to our distributed routing algorithm in order to make the best network decisions considering future states of network resources. In each network node, the mobility method employed is based on a Markov model to forecast future RSSI states of neighboring nodes for determining if it will do an approximation or separation within the next steps. The approach is evaluated considering different mobility models such as: the Gauss-Markov Mobility Model, Reference Point Group Mobility model, and Nottingham cattle mobility traces taken from CRAWDAD Dartmouth traces website. Due to the fact that the mobility pattern can change at any time because of the uncertainty nature proper of the mobile entities, our approach adapts to these mobility changes by using a machine learning technique based on a batch learning approach, in order to avoid excessive computational costs in each node. Our results show an increasing network performance in terms of end-to-end delay, RSSI prediction accuracy and energy consumption against an approach without using a mobility prediction method. Additionally, we compare our algorithm results against a mathematical model optimization which minimizes energy consumption considering delay and network resources constraints.

9 A Feasibility Study of a Dual-Mode Intravascular Ultrasound (IVUS) Transducer with the Inversion Layer Technique

Jin Ho Sung, Sung Min Kim, Jong Seob Jeong

Department of Medical Biotechnology, Dongguk University, Republic of Korea.

In recent years, the inversion layer method has been shown to be important in ultrasound transducer because it can provide high frequency, broad bandwidth, and suitable characteristics especially for harmonic imaging. By controlling location and ratio of the inversion layer, two types of inversion layer methods exist, called front- and back-side inversion. When the inversion ratio is 0.3, the front-side inversion can generate 1.5 times higher center frequency and broad bandwidth compared with conventional active material. In the case of back-side inversion, it has high conversion loss between the fundamental and the second harmonic frequencies resulting in two peaks suitable for harmonic imaging. Through aforementioned characteristics, it can increase center frequency of ultrasonic transducer without reducing thickness of active material. In this study, we applied this technique to the novel design of intravascular ultrasound (IVUS) transducer and finite element method (FEM) simulation was conducted for performance demonstration. Two elements were arranged in serial in the single IVUS transducer and each element had 0.6 x 0.6 mm size. Note that individual element was modelled by front- and back-side inversion structure, respectively, to achieve both inversion features. Two different active materials, PMN-PT and PZT-5H, were used and the inversion ratio was 0.3. Two matching layers (7.3 and 2.6 MRayl) with 1.5 f0 thickness were employed and 9.5 MRayl backing layer was added. The fundamental frequency over the total thickness of active materials was 40 MHz. We evaluated the performance of the proposed transducer by exciting individual element independently or simultaneously. The results show that the front-side inversion layer had a center frequency of 62 MHz and -6 dB fractional bandwidth of 90%. In the case of backside inversion, there were two peaks at the fundamental and the second harmonic frequency. The center frequencies were 40 MHz and 85 MHz, and -6 dB fractional bandwidths were 39% and 26%, respectively. When the both elements were excited simultaneously, the center frequency was 81 MHz and -6 dB fractional bandwidth was 35%. The -6 dB bandwidth can be optimized by changing design parameters. In this study, we demonstrated the feasibility of inversion layer method especially for IVUS application and verified that very high frequency was obtained without reducing thickness of active material. We will experimentally demonstrate its performance in the future.

10 A Fully Encapsulated Palladium-Based Hydrogen MEMS Sensor for Highly Selective and Fast Detection

Thomas Walewyns, Nicolas André, Pierre Gérard, Laurent A. Francis

ICTEAM Institute, Université catholique de Louvain, Belgium.

We report the fabrication and the microsystem integration of a MEMS hydrogen sensor based on palladium-functionalization and capacitive transduction performing ultra-low power sensing (< 100 µW), high selectivity and high dynamics up to the Lower Explosive Limit, *i.e.*, 4% H_2 in dry air. The transducer response time is below 4 s for 0.2 % H_2 in dry air. The full system includes the MEMS capacitive sensor and its electronic interface, associated with a microcontroller for signal processing and data transmitting. Each sub-component is integrated in a dedicated housing including filters for both humidity effect removal and standards compliance.

11 A Novel Magnetolectric Mechanism for Sensing Angular Velocity with Ultra-High Resolution

Bintang Yang [1], Yikun Yang [1], Hui Liu [2]

[1] Shanghai Jiaotong University, State Key Laboratory of Mechanical Systems and Vibration, Shanghai, China. [2] Department of Mechanical and electrical engieering, Shandong Weihai vocational college, Weihai, Shandong province, China.

This paper presents a novel angular sensing mechanism that uses the magnetoelectric effect to detect permanent magnetic reciprocating motion, under the Coriolis force. To determine the relationship between the input angular velocity and the output voltage, a general mathematical model was developed with the accepted assumptions. We found the optimal excitation frequency of vibration for detecting the Coriolis force with maximum sensitivity. In the current research, according to simulation analysis, the achieved rotating resolution of the new mechanism may reach up to 0.001 ”/s; the new mechanism has remarkable potential for measuring rotations of ultra-low angular velocity. Finally, the sensing mechanism has been validated via experimental tests. A permanent magnet (PM) and an electromagnetic coil interact with each other, which leads the PM to vibrate along the y-axis, thus generating a linear reciprocating motion, *i.e.*, a vibration motion velocity (v). According to the principle of the Coriolis force (Fc), the Coriolis force can be produced as the object rotates. Therefore, the Coriolis force makes the PM reciprocate along x-axis, thereby producing a changing magnetic field derived from the reciprocating movement of the permanent magnet that acts on the magnetoelectric (ME) material, which can finally produce a detectable corresponding voltage via the ME effect. The ME effect is a phenomenon involving the induction of electric polarization through the application of an external magnetic field on an object. In this research, we realize the ME effect based upon the combination of a giant magnetostrictive material (GM) and a piezoelectric material (PE). Using the interaction between the PM and the coil, we can configure v, on the one hand, by adjusting the excitation in terms of the magnitude and the frequency of the applied current into the coil, and on the other hand, by deriving the maximum velocity from a state of resonant vibration at the natural frequency of a designed structure. Consequently, a wide range of measurements of ω can be obtained by tuning v at a given Fc. In particular, through this method, ultra-low velocities of rotation, which are conventionally very difficult to measure, can be measured. The proposed mechanism features fewer components, more satisfactory precision, and convenient operation and adaptation to harsh environments. These attributes are due to the mechanism's robustness to external transient disturbance and the rigidity of the structure. Moreover, more than one such sensor can be easily assembled to be a multidimensional rotation sensor.

12 A Stepwise Formation of Biosensor Microsystems based on the ISFET and its Application in Pesticide Detection

Mariia Andrianova, Oksana Gubanova, Natalia Komarova, Alexander Kusnetsov

SMC "Technological Center", Moscow, Zelenograd, Russia.

The proposed microsystem is the combination of the ion-sensitive field transistors as a detector, a microfluidic system for reagents delivery and a bio-recognition component. Each step of the microsystem formation is discussed with emphasis on application of the ready-made biosensor. The proposed technology of the microsystem production supports a modular design approach, both on the stage of microfluidic system formation and in the modification step of the ISFET sensitive surface with different bio-recognition components. This approach allows obtaining the desired configuration of the microsystem depending on its application. Using this technology, the biosensor microsystem for detection of organophosphorus pesticides was fabricated. This biosensor microsystem was based on a phosphotriesterase as a highly specific and efficient catalyst for a wide variety of organophosphorus compounds. As detectors different ISFET with varying channel width and length were used. The possibility of using the biosensor for determination of pesticides in an open system and isolated system (microfluidic) was demonstrated. In addition, the mechanism of the ISFET signal formation during the enzymatic hydrolysis of pesticides was proposed. Further, a modular design approach of the biosensor microsystems production was applied by using different bio-recognition components for determination of nitroaromatic explosives and exonucleatic cleavage of ssDNA.

13 A FRET Biosensor Platform Based on a Peptide Nanostructure for the Multiplex Detection of Protease Cancer Markers

Sevin Yoon, Namhun Lee, Taeuk An, Sang-Myung Lee

Department of Chemical Engineering, Kangwon National University, Chuncheon-si, Republic of Korea.

Various combinations of diagnostic tools with nanotechnology have helped expand the number of applications in the biomedical field. Recently, the fluorescence resonance energy transfer (FRET) phenomenon that was applied to nanomaterials has become one of the most common biosensor platforms for detecting biomolecules. For accurate disease detection, two more disease makers are simultaneously used in biological assays; this is referred to as multiplex diagnoses. This method can increase the predictive accuracy of an assay, but can also lead to serious problems, such as those concerning the cross-reactivity of markers, signal overlaps, and sensitivity decrease. Thus, it is very important to choose markers that are not cross-reactive with each other and a multiple fluorescence signal strategy for separated FRET analysis. To achieve the aforesaid, specific peptide substrates for matrix metalloproteinase-2 (MMP-2) and urokinase-type plasminogen activator (uPA) were immobilized on the PEPAu platform, and two kinds of carboxy quantum dots (QD-COOH), with different fluorescence emissions, were coupled on the N-terminals of substrate peptides. The fluorescence signals were efficiently quenched with gold nanoparticles (AuNPs) on the PEPAu because the absorption band of AuNPs overlapped with the emission bands of the QDs. After that, MMP-2 and uPA proteases were applied to the PEPAu-QD sensor platforms. Through specific cleavages of the peptides, the fluorescence signals that respectively corresponded with MMP-2 and uPA were revealed. Moreover, the following studies include the correlations between protease concentration and fluorescence signal, the time-dependant signal changes of the assays, and assays in human samples. Finally, our findings were evaluated in cancer cells that express MMP-2 and uPA markers.

14 A Nitric Oxide Electrochemical Sensor Based on a Decorated Multi Walled Carbon Nanotube with Chromium (III) Oxide

Liridon Berisha, Epir Qeriqi, Seninda Rexhepi, Blerina Hoxha, Arsim Maloku, Tahir Arbneshi

Departament of Chemistry, Faculty of Mathematical and Natural Science, University of Prishtina, Prishtina, Kosovo.

A multi-walled carbon nanotube (MWCNT) decorated with chromium (III) oxide was used as mediator to improve the performance of carbon electrodes for the detection of nitric oxide in comparison with unmodified electrodes. Electrochemical investigation of new modifier behaviour was done with cyclic voltammetry and hydrodynamic amperometry. Sensor operating parameters were optimized using hydrodynamic amperometry at different pHs, and using the operating potential. The amperometric response of the sensor at 0.80 V (vs.Ag/AgCl) showed good linearity up to 200 µM with sensitivity of about 0.01 µA/µM with a detection limit (3σ) 4.7 µM. The effect of all investigated interferences was not fatal at the operating potential of new electrochemical sensor. The sensor was successfully applied to determine NO in mice liver, homogenate in PBS, after the addition of L-arginine.

15 A Specific Fluorescent Probe based on Rhodamine B for Sensitive Selective Detection of Hypochlorite Ions

Jiyeon Ohm, Juyoung Yoon

Ewha Womans University, Republic of Korea.

A hypochlorite ion is one of the Reactive oxgen species (ROS), which are prevalent and important mediators in many biological pocesses. Many researches have been conducted to detect those species. The brain is sensitive to ROS induced stress, which results from an imbalance between abnormal formation of ROS and defense against these substances provided by antioxidants. Hypochlorous acid (HOCl) is an important ROS that partially dissociates with the hypochlorite ion (OCl^-) at a physiological pH. We can see the HOCl in the oxidative burst of phagocytes. Regulated production of microbicidal HOCl is beneficial for innate immunity during microbial invasion. Uncotrolled production of HOCl could casuse many diseases, so it is important to develop the OCl^- probe. We can make aprobe that opreates through specific reactions with OCl^- by using rhodamine B and a coumarine derivative. This probe could be a useful tool for the study of HOCl production.

16 Analysis of RFID-based Distributed Urban Parking Systems

Alba Martinez [1], Erik Aguirre [1], Leire Azpilicueta [1,2], Peio Lopez-Iturri [1], Jose Javier Astrain [1,2], Jesus Villadangos [1,2], Francisco Falcone [1,2]

[1] Universidad Publica de Navarra, Pamplona, Navarra, Spain. [2] Institute of Smart Cities, Universidad Publica de Navarra, Pamplona, Navarra, Spain.

Since cars are one of the most used transport systems and most families all over the world are in possession of at least one vehicle, the organization of parking zones in dense urban areas can be a challenge. To organize those zones and also to obtain an economic return, authorities of different cities fit out Monitored Parking Areas (MPAs) where in exchange for a payment, cars can be placed for a defined period of time. Nowadays the MPAs payment system is very inefficient since it needs to be done manually by the car owner and the verification of the parking time expiration must be done by a worker periodically. As it has previously been done with Electronic Toll Collection (ETC) in highways, we can take advantage from modern communication systems and automate MPAs using RFID tags placed inside cars. However, the implementation of these kinds of technologies in this environment must be studied to place readers in right places and save money creating an efficient payment system. In this context, electromagnetic simulation tools are helpful to carry out adequate planning of the communication system and therefore, in this work, an in-house developed 3D Ray Launching method is used. Thanks to this tool the topology and dielectric characteristics of an entire street with buildings, streetlights, cars or pavement can be considered and choose consequently the best distribution for all the antennas. Besides, a car model has been developed to take into account its complexity when a communication link vehicle to infrastructure (V2I) is simulated. This model is essential since the V2I link will be established between a tag inside the car and the receiver placed in the street and therefore the influence of the vehicle morphology will be critical. Received power distribution, power delay profiles or delay spread results are obtained to carry out an accurate characterization of the RFID system. The overall result is the proposal and analysis of a distributed parking and location application devoted to handling private car parking in urban areas.

17 Broadband Dielectric Measurements of Apple Fruits using Open-Ended Dielectric Probes

Wojciech Skierucha, Andrzej Wilczek, Agnieszka Szypłowska, Marcin Kafarski

Institute of Agrophysics, Polish Academy of Science, Lublin, Poland.

Broadband dielectric measurements in 103–1011 Hz frequency ranges enable us to differentiate between various dielectric dispersion mechanisms associated with the molecular characteristics of tested materials. Currently, the agricultural applications of dielectric spectroscopy are concentrated in heating effects, quality tests and dielectric sensors constructions specific for the tested material for fast and nondestructive measurements. The paper compares the performance of two constructions of Open-Ended dielectric probes, the typical one (coax OE probe) and the one with prolonged central conductor in a form of an antenna (coax OE-A probe). A standard coax OE probe is characterized by small measuring volume, which limits its application to homogeneous materials, mainly liquids. The tested coaxial open-ended probe with an antenna (coax OE-A probe) increases the measurement volume and consequently the range of applications other materials like granulated agricultural products, soils or liquid suspensions. However, the working frequency range of the OE probe is wider than OE-A probe, which is attributed to the generation of higher modes of electromagnetic wave propagation beside TEM mode. The tests are made on apples during their storage in room temperature conditions (temperature 20±1 °C, air humidity 50±10%) for the period of 21 days. The measurements did not show significant changes of dielectric properties and soluble solid content of apples, although their firmness decreased significantly. The coax OE probe worked correctly in the full measured frequency range (10 MHz–20 GHz) but the coax OE-A probe measurement frequency range was limited to 1.5 GHz. The applied calibration algorithm was based on air-water-methanol calibration. The performance of the tested probes as applied to apple material was in agreement with the FEM simulations. The observed dielectric spectrum was analyzed using a generalized fractional dielectric relaxation model, which assumes three active relaxation processes: primary a-process (water relaxation) and two secondary processes caused by solid-water-ion interactions a (bound water relaxations) as well as b (the superposing of counter ion relaxation and the Maxwell-Wagner effect). Further test of the probes are in progress with soil material.

18 Calibration Method of a Redundant Gyro System

Kunpeng He, Yuping Shao

Measurement and Control Technology and Inertial Navigation Laboratory, Automation, Harbin Engineering University, China.

For the error coefficient calibration problem of AUV redundant gyros, a model replacement method with simple structure was used to establish a calibration model in case of redundancy, and it can take full advantage of the gyro measurement information. A Kalman filter was applied to estimate the error parameters for a new 3 IMUs redundant configuration, and the simulation results showed that the estimation accuracy of each filter was very impressive. Finally, the piecewise linear systems theory and singular value decomposition were used to analyze degree of observability of the filter, and the simulation results validated the filter of all 36 state variables can be observed. On the basis of the gyro scale factors and constant value error were nominal, the method proposed in this paper, not only could separate the error parameters effectively, but also had some versatility and provided a reference for calibration of different redundant gyros configures.

19 Calibration of Humidity Sensors for Upper-Air Measurements

Sang-Wook Lee, Jong Chul Kim, Byung-Il Choi, Sang Bong Woo, Yong-Gyoo Kim

Center for Thermometry, Korea Research Institute of Standards and Science, Republic of Korea.

Precise measurements of atmospheric temperature and relative humidity are of paramount importance in relation to prediction of weather and climate change as well as securing safety. The measurement on temperature and humidity in upper air relies on flying disposable radiosondes from the ground to lower stratosphere (~ 35 km). Most radiosondes use polymer thin-film capacitors as humidity sensors because they show an excellent price-performance. However, the performance of polymeric humidity sensors inevitably presents a temperature dependency. Since radiosondes experience extreme air temperature down to -80°C or lower, the temperature effect on humidity sensors of radiosondes should be compensated in the temperature range from -80°C to room temperature. Here, we have developed a calibration system for humidity sensors of radiosondes in order to obtain a temperature-compensation formula. The calibration system consists of a two-temperature two-pressure (2T2P) type humidity generator, a 2T type humidity generator, a test chamber in which sensors are located, and a dew point hygrometer. The 2T2P and 2T type humidity generators are national standard equipments covering the frost point down to -105 °C. Using these humidity generators, relative humidity in the test chamber is varied and humidity sensors are calibrated at different test chamber temperatures from -80 °C to 25 °C. Consequently, it is found that the deviation of humidity sensors from the reference becomes larger as the test temperature goes down. By analyzing these deviations at each temperature, a proper temperature-compensation formula for relative humidity is obtained. We anticipate that this work will be helpful for improving the reliability of humidity measurements in upper air using radiosondes.

20 Can Photonic Thermometry Compete with Resistance Thermometry Based Approaches?

Zeeshan Ahmed

NIST, Thermodynamic Metrology Group, Gaithersburg, MD, USA.

For the past century, industrial temperature measurements have relied on resistance measurement of a thin metal wire or filament whose resistance varies with temperature. Though resistance thermometers can routinely measure industrial temperatures with uncertainties of 10 mK, they are sensitive to mechanical shock, which causes the sensor resistance to drift over time requiring frequent off-line, expensive, and time consuming calibrations. These fundamental limitations of resistance thermometry have produced considerable interest in developing photonic temperature sensors to leverage advances in frequency metrology and to achieve greater mechanical and environmental stability. We are developing a suite of photonic devices such as Fiber Bragg grating, on-chip Bragg waveguides, ring resonators and photonic crystal cavities that leverage advances in microwave and C-band light sources to fabricate cost-effective photonic temperature sensors. Our preliminary results indicate that using photonic devices such as the ring resonator we can measure short term temperature fluctuations of >~100 μK at room temperature. Photonic sensor technology provides a low cost, lightweight, portable and EMI resistant solution which can be deployed in a wide variety of settings ranging from controlled laboratory conditions, a noisy factory floor, advanced manufacturing, to the variable environment of a residential setting.

21 Characterization of a Fiber-Optic Cerenkov Radiation Sensor for Detecting Thermal Neutrons in High Temperature Conditions

Kyoung Won Jang [1], Jae Seok Kim [1], Sang Hun Shin [1], Wook Jae Yoo [1], Jong-Yun Kim [2], Jei-Won Yeon [2], Bongsoo Lee [1]

[1] School of Biomedical Engineering, BK21 Plus Research Institute of Biomedical Engineering, Konkuk University, Chungju, Republic of Korea. [2] Nuclear Chemistry Research Division, Korea Atomic Energy Research Institute, Daejeon, Republic of Korea.

When a charged particle passes through a dielectric medium with a phase velocity greater than that of light, the electromagnetic field close to the particle polarizes the medium along its path, and then the electrons in the atoms follow the waveform of the pulse. Here, the waveform and the medium are called Cerenkov radiation and a Cerenkov radiator, respectively. The Cerenkov radiation produced from the radiator can be exploited at high temperatures and in high ionization density conditions. In a high temperature tokamak, electron fluxes can be obtained by measuring the Cerenkov radiation generated from some crystals. In addition, the Cerenkov radiation generated in optical fibers allows us to measure relative depth doses without the quenching effect induced by heavy charged particles in a radiotherapy dosimetry. In this research, we proposed a novel method for detecting thermal neutrons with Cerenkov effect in high temperature conditions. In order to detect thermal neutrons, the fiber-optic Cerenkov radiation sensor (FOCRS) is fabricated using a Gd-foil and an optical fiber. A reference sensor is also fabricated with only the optical fiber for measuring background gamma-rays. To clarify the relationship between electron fluxes and intensities of Cerenkov radiation, electron fluxes inducing Cerenkov radiation in the FOCRS are calculated by using the Monte Carlo N-particle transport (MCNPX) simulations. Finally, relative fluxes of thermal neutrons in a polyethylene generated by a Cf-252 neutron source are obtained using the FOCRS in high-temperature conditions.

22 Chemical Immobilization of Aflatoxins to Immunosensor Surface for Improved Regeneration and Reproducibility

Özlem Ertekin [1,2], Selma Öztürk [1], Zafer Ziya Öztürk [3]

[1] TÜBİTAK, The Scientific and Technological Research Council of Turkey, Marmara Research Center, Genetic Engineering and Biotechnology Institute, Gebze, Kocaeli, Turkey. [2] Gebze Technical University, Department of Molecular Biology and Genetics, Gebze, Kocaeli, Turkey. [3] Gebze Technical University, Department of Physics, Gebze, Kocaeli, Turkey.

Aflatoxins (AF) are hepatotoxic mycotoxins that are produced by *Aspergilus* spp. High level exposure to AF results in acute toxicity which may lead to death, and chronic exposure often leads to liver diseases including liver cancer in humans. Several laboratory based methods are devised in order to control AF levels in food and feedstuff, however, development of biosensors for on-site detection is of crucial importance. The efforts for the development of aflatoxin biosensors often include sensor surface activation with proteins; either antibodies, or AF-protein conjugates. However, this approach leads to low reproducibility due to protein aggregation and short shelf life for the produced chips caused by protein instability. In this study, the gold coated sensor surface is functionalized by the chemical immobilization of AF via Self Assembled Monolayers (SAM). Two different AF specific monoclonal antibodies were successfully used with the developed surface for the development of QCM based immunosensors. This method not only increased the reproducibility and shelf life of the chips, but also allowed the application of effective regeneration strategies involving strong detergents up to nine times, which otherwise would disrupt the activity of protein immobilized surface.

23 Chemical Sensors based on the same Transducer Material: High-k Perovskite Oxide of Barium Strontium Titanate

Michael J. Schöning [1,2], Christina Huck [1], Matthias Bäcker [1], Vahe Buniatyan [3], Arshak Poghossian [1,2]

[1] Institute of Nano- and Biotechnologies, FH Aachen, Germany. [2] Research Center Jülich GmbH, Jülich, Germany. [3] Department of Microelectronics and Biomedical Devices, State Engineering, University of Armenia, Yerevan, Armenia.

Due to its multifunctional material properties, high catalytic activity and its high dielectric constant, perovskite oxide of barium strontium titanate (BST) has recently aroused great interest as a transducer material for the development of chemical sensors and biosensors for liquids. In the present work, two Si-based sensor chips covered with a high-k BST layer have been developed for a multiparameter detection of pH, charged macromolecules (polyelectrolytes), hydrogen-peroxide (H_2O_2) vapour, electrolyte conductivity and temperature. The chips combine two- and four-electrode capacitively-coupled contactless electrolyte-conductivity sensors, a capacitive field-effect electrolyte-insulator-semiconductor pH sensor, an interdigitated impedimetric sensor and a thin-film Pt temperature sensor. The BST films of $Ba_{0.25}Sr_{0.75}TiO_3$ composition (with different thicknesses of 100 and 485 nm and dielectric constants of ~190 and ~265, respectively) were prepared with the pulsed-laser deposition technique. The role of the BST layer is of multi-purpose: it serves as a sensitive transducer material for the field-effect pH sensor, impedimetric polyelectrolyte and H_2O_2 sensors, as an insulator layer for the contactless electrolyte-conductivity sensor, and as passivation layer, which protects the metal electrodes of the sensors from corrosion, contamination and fouling. The experimental results of characterization of individual sensors as well as combined testing of the sensor chip in buffer solutions with different pH value and electrolyte conductivity are presented. The mechanism of the sensitivity of BST to charged polyelectrolytes and H_2O_2 vapour will be discussed.The obtained results demonstrate the potential of the BST films as multifunctional material for the creation of high-order sensor systems, in which the same transducer material can be applied for the detection of various quantities in liquids.

24 Communication Protocol between Wireless Sensor Networks and Vehicular Networks in a Hybrid Network

Taha Bensiradj, Samira Moussaoui

Laboratoire RIIMA, équipe informatique mobile, USTHB Alger, Algeria.

Hybrid Sensor and Vehicular Networks (HSVN) represent a new concept of network used for improving road safety. It allows or use of the Wireless sensor networks (WSN) deployed on the border of the road working in collaboration with vehicle networks (VANET). This collaboration is represented by the exchange of road messages carried between the two networks. Moreover, this collaboration helps solve a problem of the network by using the other network. For example, to save energy consumption of the sensors, we can use the vehicles that do not have the problem of energy to disseminate the information over long distances. In addition, to solve the problem of disconnection in VANET, the sensors can be used as gateways that transmit the messages of one vehicle to the other vehicles. The exchange between the two networks allows drivers to avoid the actions that typically lead to accidents. However, the communication between the two types of networks poses several problems, because of the properties of each network (limited communication range of the sensor, the high mobility of vehicles, the sensor energy consumption and limited capacity for processing and storage of sensors). To ensure reliable communication between the two networks, we proposed a communication protocol. This last step ensures the exchange of messages between the two networks in the available time. This time is the time where the vehicle is in communication range of the sensor.

25 Controlled Synthesis and Functionalization of AuTTF Micro- and Nanowire Sensors

Mario Lenz [1], Yanlong Xing [1,2], Petra Stephanie Dittrich [1]

[1] Department of Biosystems Science and Engineering, ETH Zürich, Switzerland. [2] SALSA graduate school, Humboldt-Universität zu Berlin, Germany.

Conductive nano- and microwires are very promising sensing elements. In the past years, various approaches to form such wires have been presented. However, most of them are based on reactions in bulk with little control on the reaction conditions of individual wires, and require post-processing such as purification. In addition, it is still challenging to integrate the created structures into a functional analytical device. Recently, we showed the advantage of microfluidic devices for the creation of nanowires made of metal organic compounds or coordination polymers [1-3]. We exploited the laminar flow conditions providing a well-defined interface between two streams [1], or used small reaction volumes to allow defined diffusion of the precursors [2]. Here, we demonstrate an improved microchip design for the site-specific formation of single nano- and microwires. The geometry of the channels provides physical constraints with respect to number, orientation and localization of the created wires. We utilized such wires before for sensing gases [2], In addition, we successfully achieved the functionalization of nanowires for label-free sensing of biomolecules. Binding of dopamine to the functionalized wires could be detected by using Raman spectroscopy. Moreover, we showed in a proof-of-concept experiment that we could immobilize antibodies on the nanowires to enable the binding and detection of analytes with a high specificity. Future work focuses on the realization of conductivity measurements for sensing biomolecules.

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26 Delay/Disruption Tolerant Network Based Message Forwarding for a River Pollution Monitoring Wireless Sensor Network Application

Carlos Velásquez-Villada, Yezid Donoso

Universidad de los Andes, Bogotá, Colombia.

River pollution monitoring is a difficult task. Due to rivers' changing conditions, it is important to have several pollution measurement points along their courses. We propose a WSN deployed along a downstream river's course for pollution monitoring. This WSN has several sensor node barriers grouped together as sensor clusters. Each cluster has sensors at different heights from the river's bed, in order to detect the pollutant as it disperses along the river's course. Each cluster also has wireless communications capabilities through a WiFi antenna that floats on the river. Sensor clusters can communicate with neighboring clusters and serve as relays to send messages to a gateway installed on the riverbank. This gateway can store sensor messages and send them, through a backhaul technology, to an Internet server where data is aggregated over a map. The communication challenge in this scenario is produced by the antennas' movement and network backhaul availability. Since antennas are floating on the river and our solution utilizes microwaves for communications, communications can be disrupted at any time when the river's discharge changes and covers the antennas or when the antennas are no longer in an upright or near upright position. For non-real-time applications, we propose a DTN-based solution where all nodes will have persistent storage capabilities and DTN protocols in order to be able to wait minutes or hours to transmit through an available channel. For the gateway, we propose a mechanical backhaul that can periodically visit the river bank where the gateway is installed and automatically collect sensor data to be carried to an Internet covered spot, where they can be sent to the server. We present a message forwarding mathematical model and a decentralized heuristic implementation where it can be seen that most messages are delivered, thus maximizing network use and saving the nodes' energy in comparison with epidemic routing.

27 Design and Analytical Modeling of Advanced AlGaN/GaN Heterostructures for Device and Sensor Applications

Nitin Goyal [1,2], Tor A. Fjeldly [2]

[1] CTR Carinthian Tech Research AG, Villach, Austria. [2] Electronics and Communication Department, Norwegian University of Science and Technology, Trondheim, Norway.

GaN based High Electron Mobility Transistors (HEMT) are considered to be promising devices for next generation high-frequency (HF) and high-power applications, due to their wide band gap and high electron mobility. GaN HEMTs also possess excellent thermal properties that make them suitable candidates for high-temperature applications. The most interesting feature of these devices is the presence of a two-dimensional electron gas (2DEG) density of the order of 1013 cm^{-2} at the AlGaN/GaN interface even in the absence of both doping in the AlGaN barrier layer and a gate metal (bare surface). This is attributed to the presence of strong piezoelectric as well as spontaneous polarization effects. In the last few years, it has been shown using experiments and numerical simulations, that the presence of donor states at the AlGaN surface is the main source of the electrons in the 2DEG. Any perturbation in the distribution of these surface donor states or polarization affects the 2DEG density, and therefore the resulting device properties. This surface/strain sensitive property of 2DEG can be utilized for different sensor applications, especially for harsh environment applications. Exposure to external physical (pressure, strain) or chemical (gas, soot particles with absorbing layers) ambient can lead to the change in effective polarization or surface properties, thus affecting 2DEG. This change in 2DEG can be sensed by piezo-resistive/piezo-capacitive mechanism. Mathematical modeling is required for device design and understanding of the formation of the 2DEG and the surface barrier height in different GaN based material stacks such as AlGaN/GaN, AlGaN/AlN/GaN, SiN/AlGaN/GaN and SiN/AlGaN/AlN/GaN. In this abstract, we present a brief review of the developed mathematical framework for these material stacks. The detailed relationships between the surface properties and the observable electrical quantities are obtained by accounting precisely for the electrostatics throughout the structure. Assuming charge conservation and solution of Poisson's equation with appropriate boundary conditions gives self-consistent solutions for the above mentioned structures. The presented modeling is able to predict the experimental observations in GaN heterostructures and can be used for optimized device design.

28 Design of an Integrated Sensor System for the Detection of Traces of Different Molecules in the Air

Drago Strle [1], Bogdan Stefane [2], Igor Musevic [3]

[1] University of Ljubljana, Electrical engineering department, Ljubljana, Slovenia. [2] University of Ljubljana, Department of Chemistry and Chemical Technology, Ljubljana, Slovenia. [3] Institute Josef Stefan, Ljubljana, Slovenia.

Detecting vapor traces of different molecules in the atmosphere with simple and cheap instrument can be very useful in different application fields: security, medicine, environmental control, food production, science, military, etc. Detection is difficult, because the number of molecules in the air is usually very small, and different molecules have similar adsorption characteristics; therefore, the detection is difficult and not reliable. Different bulky and expensive instruments exist for vapor trace detection with the following main characteristics: the systems are very expensive, measurements take a lot of time and a trained operator is needed. In addition, false detections are very likely because the number of target molecules in the atmosphere is usually much smaller than to the number of other molecules. We developed a new kind of sensor system, which is capable of detecting different target molecules in the air with very high sensitivity and good selectivity, thus improving the detection level by several orders of magnitude compared to the available commercial systems. Our detection system is based on the array of differently functionalized differential COMB capacitive sensors implemented in modified MEMS process and extremely sensitive electronic detection system implemented in 0.18 BCD process. The detection is based on the adsorption of target molecules to the functionalized surface of the COMB capacitive sensors, which changes the relative dielectric constant of one capacitor in a differential pair. The surface of differently functionalized capacitors will selectively adsorb different molecules; after short time, the molecules will desorb. Adsorbed target molecules will change the relative dielectric constant of modified capacitor in the space between the plates and thus the capacitance will change. The capacitive change is extremely small and is measured using a very sensitive electronic detection system. The method is very robust, inherently insensitive to the environmental influences like temperature and mechanical noise, and has a great potential because of its CMOS compatibility. We plan to improve the inherent problem of poor chemical selectivity of individual sensors by introducing an integrated array of up to 64 chemically differently functionalized capacitive sensors (for now only four are integrated), thus mimicking the architecture of a dog's nose, which is of course much more complex and one of the best molecular detection systems in nature. Different molecules will adsorb differently on differently functionalized surfaces, changing its dielectric constants, and this will imprint a unique signal fingerprint to the measurement results from the array of the COMB micro-sensors. Currently we have integrated small array (four sensors) of differently functionalized capacitive COMB sensors and one channel of low-noise analog integrated electronic circuit in SIP (System in Package). The DSP (digital signal processing) part of the electronics is currently

implemented on the FPGA (Field Programmable Gate Array) but can easily be integrated. The sensitivity of the electronic measurement system is better than 0.3aF in 1 Hz bandwidth (1aF is 10-18F), which leads to the detection limit of 3 ppt for TNT in laboratory environment (3 molecules of TNT in 1012 molecules of N_2) and even to 0.3 ppt for the RDX at room temperature and at normal pressure. In addition, we have proved that differently functionalized sensors react differently to the same target molecules. Up to now, we have measured the response to TNT and RDX vapors in the controlled atmosphere of N_2 gas and in the air on four differently modified sensors. Currently, the measurements of the responses to other molecules are ongoing.

29 Detection of Impact Traces on Composites using a Fiber Optic BOCDA Sensor with an Al-Packaged Optical Fiber

Il-Bum Kwon [1], Bo-Hun Choi [2]

[1] Center for Safety Measurement, Korea Research Institute of Standards and Science, Daejeon, Republic of Korea. [2] Department of Materials Physics, Dong-A University, Hadan2-dong, Saha-gu, Busan, Republic of Korea.

We propose a distributed residual strain sensor that uses an Al-packaged optical fiber for the first time. The residual strain, which causes Brillouin frequency shifts in the optical fiber, was measured using Brillouin optical correlation domain analysis with 2 cm spatial resolution to detect the impact traces on composite plates. We quantified the Brillouin frequency shifts in the Al-packaged optical fiber by the tensile stress and compared them for a varying number of Al layers in the optical fiber. The Brillouin frequency shift of an optical fiber with one Al layer had a slope of 0.038 MHz/me with respect to tensile stress, which corresponds to 78% of that for an optical fiber without Al layers. After removal of the stress, 87% of the strain remained as residual strain. When different tensile stresses were randomly applied, the strain caused by the highest stress was the only one detected as residual strain. The residual strain was repeatedly measured for a time span of nine months for the purpose of reliability testing, and there was no change in the strain except for a 4 % reduction, which is within the error tolerance of the experiment. A composite material plate equipped with our proposed Al-packaged optical fiber sensor was hammered for an impact experiment and the residual strain in the plate was successfully detected. We suggest that the Al-packaged optical fiber can be adapted as a distributed strain sensor for smart structures, including aerospace structures.

30 Development of Dual-Piezoelectric Transducer for High Frequency Ultrasound Imaging

Jong Seob Jeong, Sung Min Kim

Department of Medical Biotechnology, Dongguk University, Republic of Korea.

In recent years, high frequency ultrasound capable of providing high resolution imaging has been widely used for ophthalmology, dermatology, intravascular imaging, and small animal imaging. It has been well known that the resolution is proportional to a frequency while the sensitivity related to the penetration depth is inversely proportional to a frequency. In order to improve the sensitivity, single crystals and piezoceramic material with high electromechanical coefficients should be employed, However, they have been suffered from narrow bandwidths of the transducer resulting in low resolution. As another piezoelectric materials, PVDF and P(VDF-TrFE) copolymer have been developed and provided wide bandwidth more than 100%. However, they also have low electromechanical coefficients resulting in low sensitivity. In order to achieve high sensitivity and broad bandwidth simultaneously, some researchers developed a dual layer scheme in which piezoelectric material was used for transmission and P(VDF-TrFE) was used for reception. One of the problems in this method is that the performance is affected by the thickness of the multiple bonding layers between two piezoelectric layers. Additionally, the optimal thicknesses of a matching layer and two piezoelectric layers are in conflict with each other depending on materials. In this paper, we proposed a modified transducer with dual-piezoelectric material to improve sensitivity and bandwidth. It was composed of a disc type element inside and an annular type element outside. The inner disk element was made of P(VDF-TrFE) for reception, and the outer element was made of $LiNbO_3$ for transmission. Because $LiNbO_3$ and P(VDF-TrFE) have good performances to transmit and receive ultrasounds, respectively, the proposed transducer can take an advantage of each piezoelectric material. The performance was experimentally demonstrated by a prototype dual-element $LiNbO_3$/P(VDF-TrFE) transducer and compared with stand-alone $LiNbO_3$ and P(VDF-TrFE) elements. The -6 dB bandwidth was 37% broader than ring-type $LiNbO_3$ element and the sensitivity was 8.2 times improved compared with disk-type P(VDF-TrFE) element. Thus, the dual-piezoelectric transducer may be one of the potential methods to achieve both high sensitivity and broad bandwidth at the same time.

31 Excitation of Surface Plasmons in Single Nanoparticle-Nanoelectrode Systems

Silvia Karthäuser

Peter Grünberg Institut (PGI-7) and JARA-FIT, Forschungszentrum Jülich GmbH, Germany.

Understanding light mediated electron transport through molecular capped nanoparticles (NP) is one of the key factors for their implementation as functional units in optoelectronic nanoscale devices. Here, we demonstrate the influence of the excitation of localized surface plasmons on the charge transport through a nanoparticle-nanoelectrode system. First, a single, molecule capped gold nanparticle (AuNP) was immobilized between AuPd nanoelectrodes. In the next step, this device was irradiated with visible light of different wavelength with an intensity of 0.1 $\mu W/cm^2$, while the sourc-drain current was measured. Current changes of 11% at room temperature and up to 100% at 4 K were found due to the on/off switching of the irradiation. Interestingly, the conductivity changes depend on the nature of the molecular capping layer stabilizing the nanoparticle.

32 Fabrication of Porphyrin-bound ZnO Nanowires as a Potent Phototheragnosis Agent of Cancer Cells

Jooran Lee [1,2], Sunyoung Choi [1], Ki Soo Chang [2], Minjoong Yoon [1]

[1] Department of Chemistry, Chungnam National University, Republic of Korea. [2] Optical Instrumentation Development Team, Korea Basic Science Institute (KBSI), Republic of Korea.

Nanoscale cell injection techniques combined with nanoscopic photoluminescence (PL) spectroscopy have been important issues in high-resolution optical biosensing, gene and drug delivery and single cell endoscopy for medical diagnostics and therapeutics. The visible light-sensitive ZnO nanowires (NWs) had been previously synthesized and can be inserted into the subcellular region of living cells. In this work, to develop phototheragnosis agents for cancer cells, protoporphyrin ix-bound ZnO NWs (PpIX-ZnO NWs) were fabricated using a hydrothermal sol-gel method and their structures were characterized by using techniques such as X-ray diffraction (XRD), FT-IR, X-ray photoelectron spectrometer (XPS), scanning electron microscopy (SEM) and transmitting electron microscopy (TEM) analysis. Synthesized PpIX-ZnO NWs can exhibit strong emission even after being penetrated into living cells under visible light-excitation at 405 nm. They also can damage cancer cells by irradiation at 633 nm. Therefore, the PpIX-ZnO NWs are promising nanomaterials for phototheragnosis.

33 Fabrication of Ultrathin Suspended Nanopores Fabricated by Combined Colloidal Lithography and Film Transfer

Juliane Junesch [1], Stephanie Hwu [1], Takumi Sannomiya [2], János Vörös [1]

[1] Institute for Biomedical Engineering, ETH Zürich, Switzerland. [2] Tokyo Institute of Technology, Tokyo, Japan.

A simple method of fabricating suspended nanopores in ultrathin films was previously demonstrated [1]. These nanopores can allow an analyte to flow through the pores by pressure or force, therefore enhancing the sensing time. Although solid state nanopores are widely used as sensing device, its fabrication processes are expensive and time-consuming. By combining colloidal lithography and thin film transfer, suspended nanopores in ultrathin film layers were fabricated, with gives the possibility to mass produce short-range ordered nanopore arrays. This method is mechanically stable and can produce nanopore membranes with a thickness of 15–30 nm. The trilayer AlN/Au/AlN nanopore membrane has a unique property, confirmed by the resonance shift and by comparison with numerical stimulation, to support water on one side of the membrane and gas on the other. The presented method of fabricating nanopores would give rise to application such as nanopore sensing or filtering devices.

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34 Fault Isolation of a Heat Source Chip using an Infrared Microscope

Ghiseok Kim [1], Hwan Hur [2], Kyesung Lee [2], Geon-Hee Kim [2], Haksun Lee [3], Hyun-Cheol Bae [3], Kwang-Seong Choi [3]

[1] Department of Biosystems Engineering, Seoul National University, 599 Gwanak-ro, Gwanak-gu, Seoul, Republic of Korea. [2] Center for Analytical Instrumentation Development, Korea Basic Science Institute, 169-148 Gwahak-ro, Yuseong-gu, Daejeon, Republic of Korea. [3] IT Materials and Components Laboratory, Electronics and Telecommunications Research Institute, 218 Gajeong-ro, Yuseong-gu, Daejeon, Republic of Korea.

Measurement and depth estimation of a thermally active buried heating source in stacked die architectures were performed by using the phase image obtained from infrared microscopic sensor. Highly sensitive infrared images were measured and post-processed using a lock-in method. By applying the lock-in method to infrared images, the detection sensitivity and signal to noise ratio were enhanced by the phase-sensitive narrow-band filtering effect. The operational principle of the lock-in method, as concerns the thermal wave propagation through different material multi-layers, was discussed and it was demonstrated that the phase information of thermal emission from silicon wafer sample can provide good metrics about the depth of a heat source. In addition, a photothermal model was implemented to evaluate the behavior of thermal waves from multi stacked silicon wafer sample by comparing a calculated depth with a real one. Results showed that the infrared microscopic sensor technique with lock-in method and resultant phase information have a good potential in the application of the fault isolation and its depth estimation for the stacked die devices, especially in the packaged semiconductor.

35 Feasibility Study on Development of a Stack Phantom-Dosimeter to Measure Transverse and Depth Dose Distributions of X-ray Beams

Wook Jae Yoo [1], Hyesu Jeon [1], Sang Hun Shin [1], Jae Seok Jang [1], Jae Seok Kim [1], Guwon Kwon [1], Dong Eun Lee [1], Kyoung Won Jang [1], Seunghyun Cho [2], Bongsoo Lee [1]

[1] School of Biomedical Engineering, College of Biomedical & Health Science, BK21 Plus Research Institute of Biomedical Engineering, Konkuk University, Chungju, Republic of Korea.[2] Department of Organic Materials & Fiber Engineering, College of Engineering, Soongsil University, Dongjak-gu, Seoul-si, Republic of Korea.

To measure real-time transverse and depth dose distributions of an X-ray beam, we constructed an all-in-one stack phantom-dosimeter system, which is composed of a stack phantom, a scintillating fiber ribbon detector (SFRD), transmitting optical fibers, an image intensifier, a lens system, and a complementary metal-oxide semiconductor (CMOS) image camera. In developing the SFRD, a sensing probe was fabricated by the coupling of a plastic scintillating fiber (PSF) and a plastic optical fiber (POF) and its outer surface was covered by a black polyethylene jacket to intercept the ambient light noise. The fabricated nine sensing probes, each with an identical structure, were then connected to a polymethylmethacrylate (PMMA) panel. Although the completed SFRD can measure real-time transverse dose distribution, it is difficult to use for the measurement of depth dose distribution because of its structural limitations. Therefore, we additionally fabricated a stack phantom using PMMA blocks to easily measure depth dose distribution. The stack phantom makes it possible to switch the location of SFRD up and down and provides a tissue- or water-equivalent characteristic. In this study, we measured the cross-beam profile as well as the relative depth dose of an X-ray beam using the stack phantom-dosimeter system to apply in the quality assurance (QA) of the clinical X-ray system. The proposed stack phantom-dosimeter system has many favorable dosimetric characteristics, such as multichannel and real-time monitoring, remote operation, linear response to dose rate, and water equivalence. Particularly, the multichannel and real-time measurements capability can reduce the measurement time of the beam quality during the QA of clinical X-ray systems.

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36 Fluorescent Oligomeric Dopamine for Metal-Mediated Detection of ATP

Taeuk An, Namhun Lee, Jiin Ryu, Sevin Yoon, Sang-Myung Lee

Department of Chemical Engineering, Kangwon National University, Chuncheon-si, Republic of Korea.

Dopamine, which is one of the neurotransmitters, is oxidized in the basic condition and polymerized to polydopamine (PDA). It has been used as surface coating materials, hybrid materials for biological uses, sensing applications and photothermal therapeutic agents. Polydopamine is known as a fluorescent molecule, however, it is not certain which polymeric structure emits fluorescence and which molecular weight of PDA is efficient as a fluorescent emitter. Here, we report on metal ion-mediated ATP (adenosine triphosphate) detection based on fluorescent oligomeric dopamine (F-ODA). F-ODAs are in situ synthesized by oxidation and polymerization in basic aqueous phase. They are generated together with PDA, but they can be easily separated from each other by centrifugation because F-ODAs exist in supernatant while non-fluorescent PDAs exist in the precipitated one. After that, various metal ions were applied to the separated F-ODAs to evaluate the binding affinity between F-ODA and metal ions which can be observed by decrease of fluorescence intensity after chelation of F-ODA with metal ions. Ferrous ions (Fe^{2+}) showed dramatic decrease of fluorescence intensity meanwhile other metal ions did not work well. After successful metal screening, the Fe^{2+}-mediated fluorescence quenching model was applied to detect ATP as an authentic indicator of microorganisms including bacteria. ATP molecules disturb the binding of Fe^{2+} with F-ODA, so the fluorescence of F-ODA reduces less. This means that the more ATP molecules were added, the more intensive the fluorescence is. From the finding, the correlation between ATP concentration and fluorescence intensity was determined, while the Fe^{2+} concentration was fixed. Nanomolar ATP molecules were definitely detected within 40 minutes assaying time. In addition, we performed ATP assays using real samples including hands before and after washing, cell phones, door knobs, keyboards and so on, in order to observe bacterial contamination.

37 Focal Molography: Investigation of MAPL Process for Creation of Molographic Structures

Andreas Frutiger [1], Volker Gatterdam [1], László Demkó [1], Christof Fattinger [2], János Vörös [1]

[1] ETH Zürich, Switzerland. [2] Roche Pharmaceutical Research and Early Development, Switzerland.

State-of-the-art refractometric biosensors (e.g. surface plasmon resonance, SPR) are an established and useful technology for label-free sensing and biomolecular interaction analysis [1]. However, despite being the gold-standard in the field, several impediments remain. Refractometric biosensors measure any change in the refractive index on the sensor surface and thus are prone to fluctuations of temperature, medium composition and non-specific binding. Nevertheless, with appropriate temperature stabilization (1/100°C), referencing and a steady flow of buffer they reach detection limits for label-free sensing down to 1 pg/mm^2 [1]. Diffractometric biosensors based on binding modulated diffraction gratings on monolithic surfaces are less established, despite their insensitivity to temperature fluctuations, medium composition and non-specific binding [2,3]. We present focal molography [3], a novel diffractometric sensor concept that has the potential for sensitive and robust label-free detection of biomolecular interactions in real time without the precautions for stabilization that are required by SPR and all other refractometric techniques. Focal molography enhances the sensitivity of detection by a diffraction grating that is situated on a tantalum pentoxide waveguide and focuses all diffracted light into a diffraction limited focal spot–the focus of the mologram. Here we describe and investigate the creation of molographic structures as a modulation in binding affinity for streptavidin functionalized gold nanoparticles by a surface modification technique known as molecular assembly patterning by liftoff (MAPL) [4].

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38 Gas Sensing Properties of Graphene-SnO_2 Composites Prepared with the Microwave-assisted Method

Wang Mengyun, Zhu Lianfeng, Yao Youwei

Graduate School at Shenzhen, Tsinghua University, China.

Tin oxide (SnO_2), an n-type semiconductor, is a key functional material for chemi-resistor type gas sensors. Compared with bulk SnO_2, nanosized SnO_2 has especially good properties, such as high sensitivity for gas-sensing applications. Meanwhile, graphene is a promising gas-sensing material owing to its super electronic mobility and high specific surface area. In this work, sensor based on Graphene/ SnO_2 quantum dots (QDs) nanocomposites have been fabricated and tested with ethanol vapor. The Graphene- SnO_2 composites were prepared by microwave-assisted method at 160°C for 2 min. X-ray diffraction (XRD), Scanning electron microscopy (SEM), Transmission electron microscopy (TEM), Fourier transform infrared spectra (FT-IR) and Raman spectroscopy were used to investigated the characteristic of the Graphene- SnO_2 composites, respectively. The SnO_2 quantum dots with typical size of 2~4 nm were distributed evenly on the graphene sheets. The as-prepared composites were wrapped by surface organics and can be removed by annealing in air at 400°C for 4 hours. However, the annealed composites has good crystallinity and the size can still be controlled in the range of 5~10 nm without any further growth; meanwhile, the graphene was not oxidized even after high temperature annealing. The gas sensing property of graphene- SnO_2 composite towards ethanol vapor were carried out. The results revealed that the sensor based on graphene-SnO_2 composites exhibited significant sensing response at 250 °C, good stability and fast response(60 s) and recovery time(60 s). The sensitivity (Rg/Ra) of this sensor to 1000 ppm ethanol vapor was 35, while the sensitivity of pure SnO_2 QDs was 14.

39 Gold Microelectrode Arrays Modified with Polypyrrole/Carbon Nanotube/Glucose Oxidase Nanocomposite for the Determination of Glucose

Pin-Cheng Lin [1], F. Javier Del Campo [2], Yu-Chen Tsai [1]

[1] Department of Chemical Engineering, National Chung Hsing University, Taichung 402, Taiwan. [2] Centro Nacional de Microelectrónica (CNM-IMB), CSIC Campus Universidad Autónoma de Barcelona, Bellaterra, Spain.

The determination of glucose is very important in blood sugar monitoring, food industry, and bio-processing. There are many advantages of the microelectrodes when employed in electrochemical applications such as small sample volume, fast mass transport rate, and low interfacial capacitance. The morphology of the microelectrode arrays were characterized by scanning electron microscope. It showed that the gold microelectrode arrays have a cubic arrangement where the individual microelectrodes are 20 µm in diameter separated from their nearest neighbor by 100 µm (Center-to-Center). The electrochemical behavior of the polypyrrole/carbon nanotube/glucose oxidase (PPy/cMWCNTs/GOD) modified gold microelectrode arrays was demonstrated by cyclic voltammetry. Upon addition of glucose, the oxidation current increased obviously at the PPy/cMWCNTs/GOD modified gold microelectrode arrays in 0.1 M phosphate buffer solution at a scan rate of 50 $mV.s^{-1}$. The PPy/cMWCNTs/GOD modified gold microelectrode arrays exhibited a sensitivity of 633 $\mu A.mM^{-1}.cm^{-2}$ with a linear range up to 6 mM. The prepared PPy/cMWCNTs/GOD modified gold microelectrode arrays are suitable for the development of electrochemical glucose biosensors.

40 Harsh Environment Water Vapor Sensing Platforms in SOI Technology

Nicolas André [1], Guillaume Pollissard-Quatremère [1], Numa Couniot [1], Olivier Poncelet [1], Pierre Gérard [1], Zeeshan Ali [2], Florin Udrea [3], Laurent A. Francis [1], Denis Flandre [1]

[1] ICTEAM Institute, Université catholique de Louvain, Belgium. [2] Cambridge CMOS Sensors Ltd., Cambridge, UK. [3] Department of Engineering, Electrical Engineering Division, University of Cambridge, Cambridge, UK.

In this paper, we are reporting on the performances of a micro-machined gas sensor designed to monitor the water vapor concentration at a low cost, with low power and a reliable sensor with integrated electronics interface for applications above 200 °C. The sensor is a Silicon-on-Insulator (SOI) micro-hotplate with an Al2O3 ALD-passivated impedimetric transducer. The sensor is hybrid integrated with a SOI read-out interface to convert the measured impedance to frequency. At 25 °C, the sensitivity to %RH is equal to ~2.5%/%RH for ALD-coated sensors while ~80 ppm/%RH for uncoated ones. The frequency output shows ±2% %RH level accuracy and achieves a very low power consumption of ~200 µW.

41 Highly Sensitive Curvature Sensor Based on an All-Fiber F-P Interferometer with a Tapered Fiber

Martin Cano-Contreras [1], Ana Dinora Guzman-Chavez [1], Everardo Vargas-Rodriguez [1], Ruth Ivonne Mata-Chavez [1], Daniel Jauregui-Vazquez [2], Julian Moises Estudillo-Ayala [2], Roberto Rojas-Laguna [2], Carlos Rodriguez-Donate [1]

[1] Division de Ingenierias Campus Irapuato-Salamanca, Departamento de Estudios Multidisciplinarios, Universidad de Guanajuato, León, Mexico. [2] Division de Ingenierias Campus Irapuato-Salamanca, Departamento de Electronica, Universidad de Guanajuato, León, Mexico.

In this work, a highly sensitive curvature sensing scheme, which is based on an abrupt tapered fiber concatenated to a micro Fabry-Perot interferometer, is presented. Here, the MFPI interferometer is an air microbubble which was fabricated by applying electric discharges to a hollow core photonic crystal fiber (HCPCF) with a conventional fusion splicer. Moreover, to enhance the curvature sensitivity an abrupt tapered fiber (ATF) was concatenated to the MFPI in order to modify the modal field diameter (MFD), which decreases the guided light confined into the fiber. In this way, when the ATF is bent, the interference fringes contrast, produced by the MFPI, is decreased. This effect was used to implement our sensing arrangement which is able to detect curvature changes with high sensitivity and resolution of 11.27 dB/m^{-1} and 8.87 x 10^{-3} m^{-1} respectively, at the wavelength of 1530 nm and within the measurement range from 0 - 3.5 m^{-1}. Finally, our sensing arrangement has an excellent repeatability and a practically negligible hysteresis.

42 Hybrid Single-Walled Carbon Nanotubes–Quantum Dot Photosensors

Simas Rackauskas [1,2], Andrei Alaferdov [1], Yulia Gromova [3], Raluca Savu [1], Tatiana Rackauskas [1], Esko Kauppinen [2], Albert Nasibulin [2,4], Stanislav Moshkalev [1]

[1] CCS - UNICAMP, 13083-870, Campinas, SP, Brazil. [2] Aalto University School of Science, Espoo, Finland. [3] ITMO University, Saint Petersburg, Russia. [4] Skolkovo Institute of Science and Technology, Skolkovo, Russia.

Recently, semiconductor quantum dots (QDs), such as PbS, PbSe, and CdSe, have become the subject of intense research due to their ability to absorb or emit light with high efficiency, with widely tunable bandgaps that depend on the QD dimensions. These unique optical properties make colloidal QDs very attractive for applications in many areas, including effective infrared photodetectors, organic light-emitting diodes, and photovoltaic devices, as well as in solar cell technology. In this work, hybrid photosensors fabricated using Single-Walled Carbon Nanotubes (SWCNTs) with CdSe/ZnS QDs were investigated. SWCNTs were deposited by press transfer, metal contacts were sputter deposited, and QDs deposited via the Langmuir-Blodgett method, thus controlling layer thickness. Devices were made in a phototransistor configuration, which gives the ability to apply a gate voltage on the channel and therefore tailor the photoresponse intensity. To get high performing hybrid phototransistors, the thickness of the QD layer should be optimized. SWCNT-QD phototransistor performance can be further increased by improving the process of charge transfer in the QD layer. For the preparation of QDs, as well as for their deposition, different long-chain organics, such as TOPO or oleic acid, are used and remain partially in the fabricated device. TOPO cannot be removed before the deposition process. Otherwise, QDs tend to agglomerate. Therefore, TOPO can be removed only after the QDs' deposition. In this work, we demonstrate a preparation technique for hybrid SWCNT-QD photosensors, how the photoresponse of the device depends on the thickness of QDs and gate voltage, and how the photoresponse can be further increased by heat treatment. We also investigated the photogating effect, fast and slow photoresponse mechanisms observed in the response, and processes of charge transfer between SWCNTs and QDs.

43 Hyperspectral Imaging Techniques for Rapid Detection of Fumonisin B1 in Maize

Hyun Jung Min, Byoung-Kwan Cho

Chungnam National University, Republic of Korea.

Mycotoxins are formed by fungus, which occurs depending on the conditions of temperature, moisture and insect damage. Fumonisin B1 contamination is found in maize worldwide. Fumonisin B1, which can cause liver and kidney toxicity is strongly regulated by law. To protect the health of humans and animals, many methods have attempted to precisely detect the contamination of mycotoxins. The conventional measurement methods for detecting mycotoxins, such as high-performance liquid chromatography (HPLC), thin layer chromatography (TLC) and enzyme-linked immunosorbent assays (ELISA) are laborious, time-consuming and destructive methods. It is necessary to detect the contaminants rapidly, simply and non-destructively. Hyperspectral imaging techniques have proven to be potential tools for nondestructive analysis of mycotoxins on grains. In this study, inoculated maize kernels were measured with a hyperspectral imaging system. The feasibility of diverse hyperspectral imaging techniques was investigated for the detection of the different concentrations of fumonisin B1 in maize. Results showed that hyperspectral short wave infrared imaging with partial least square discriminant analysis (PLS-DA) model has the potential for distinguishing maize contaminated by the fumonisin B1 from uncontaminated ones. Since it is possible to efficiently detect contaminants using the purposed methods, this technique could be further automated to on-line for industrial use.

44 Imino Coumarin Derivative for the Selective Detection of Homocysteine and Cysteine

Jina Kim, Juyoung Yoon

Ewha Womans University Science, Science building D, Seoul, Republic of Korea.

There are three major mercapto biomolecules, cysteine (Cys), homocysteine (Hcy) and glutathione (GSH). In general, the cellular level of these biothiols can be used for disease diagnosis in various diseases, such as, cancer, AIDS, leucocyte loss, etc. Especially, Cys and Hcy are relative in many syndromes and diseases. Abnormal concentrations of Cys and Hcy are considered as risk factors of Alzheimer's, inflammatory bowel, cardiovascular diseases, slow growth in children, hair depigmentation, edema, lethargy and liver damage. Accordingly, detection of these species has been actively studied. Especially, fluorescent probes have shown their strong applications compared to other detection methods, which is to monitor levels of intracellular thiols. Even though Michael type nucleophilic addition of thiols is one of the common approaches to design chemodosimeters for thiols due to the high nucleophilicity of SH group, direct addition of thiols to imine is less explored so far. As far as we are aware of, ortho-hydroxy imines were complexed firstly with Cu^{2+}, then the resulting Cu^{2+} complexes were utilized to sense thiols via displacement approaches. In a continuation of progress on fluorescent chemosensors, we report a bis-coumarin imine derivative 1 as a fluorescent probes for Hcy and Cys. Probe 1 consists of two coumarins bearing OH groups linked via imines. On the other hand, probe 1 did not show any significant fluorescence change with GSH and other amino acids.

45 Implementation of Wireless Sensor Networks for Photovoltaic Energy Farm Applications

David Abajo [1], Leire Azpilicueta [1,2], Erik Aguirre [1], Peio Lopez-Iturri [1], Jesus Villadangos [1,2], Jose Javier Astrain [1,2], Francisco Falcone [1,2]

[1] Universidad Publica de Navarra, Pamplona, Navarra, Spain. [2] Institute of Smart Cities, Universidad Publica de Navarra, Pamplona, Navarra, Spain.

Over the last 20 years, the world has suffered a radical change in global energy generation with the increase of renewable energy. In several countries, renewable energy already provides more than 10% of total energy generation. This changing of energy generation methods on a large scale has led to different environment-related issues, such as additional monitoring, fault detection and diagnostics in future power grids. Wireless sensor nodes bring great opportunities to replace large and expensive monitoring equipment and provide the different parameters for monitoring, with low-costs and miniaturized motes. However, before the deployment of a Wireless Sensor Network (WSN), it is highly important to consider the topology and morphology of the surrounding environment, because it has a lot of influence on radio wave propagation. The location of the sensors has a great impact on the decadence of the signal, and because of that, it is necessary to assess the radio wave propagation in this complex environment. In this work, the radio channel characterization for ISM 2.4 GHz WSN in a farm filled with photovoltaic panels has been analyzed by means of an in-house 3D Ray Launching code, to emulate the realistic operation in the framework of the scenario. Experimental results gathered from a measurements campaign conducted by deploying a ZigBee WSN, are analyzed and compared with simulations in this paper. To gain insight in the effects of radio propagation, a simplified solar panel model has been developed, considering the material parameters and simplified geometry embedded in the simulation scenario. The use of deterministic tools can aid in knowing the impact of the topological influence in the deployment of the optimal WSN in terms of capacity, coverage and energy consumption, making the use of these systems attractive for multiple applications in solar panels farms, including optimized maintenance, telemetry and telecontrol.

46 Improved Microcantilever Biosensing through Succinic Anhydride Functionalization

Gianluca Palmara, Alessandro Chiadò, Roberta Calmo, Simone Luigi Marasso, Carlo Ricciardi

Politecnico di Torino, DISAT, Torino, DISAT, Italy.

The controlled immobilization on a surface of biomolecules used as recognition element, such as enzyme, antibodies or nucleic acids, is fundamental in order to realize a highly specific and sensible biosensor. This is particularly true for label-free devices, such as silicon microcantilevers (MCs). MCs are nanomechanical sensors able of outstanding mass resolution on the verge of single atoms that can be used as micro-sized mechanical transducers whose vibration is sensitively modified upon molecules adsorption. A widely used approach for the immobilization of biorecognition elements on silicon-based biosensor consists in the deposition of 3-aminopropyl-triethoxysilane (APTES) followed by the incubation with glutaraldehyde (GA) as a crosslinking agent. These derivatization processes produce a variable chemical functionalization because of GA spontaneous polymerization in aqueous solutions. With the aim of producing a reliable chemical functionalization for protein immobilization, the deposition of a thin film of APTES by self-assembly, followed by the modification of its terminal amino groups into carboxyl groups by incubating the silicon substrate in succinic anhydride (SA), is proposed. Subsequently, the carboxyl groups were activated with (3-dimethylaminopropyl)-carbodiimide and sulfo-N-hydroxy-succinimide in order to make them more reactive toward primary amines of proteins by promoting a covalent bond. This method, rarely applied for this aim, was applied to a MC-based system. Data acquired from the characterization of MCs flexural mode of vibration showed a highly reproducible deposition of the APTES+SA functionalization when compared with the one established on APTES+GA. Afterwards, these MC arrays where incubated with Protein G and frequency shifts showed a protein immobilization that was close to the monolayer arrangement. In order to test the effectiveness of this method for a biosensing application, the APTES+SA chemical functionalization was used for the production of a MC-based biosensor for Aflatoxin B1 detection, by the immobilization of an Aflatoxin B1 specific antibody by means of Protein G. Finally, this biosensor was exerted with corn extracts containing different concentrations of Aflatoxin B1, showing a better response in the presence of the analyte in a ppb range, if compared with previous results.

47 Improving the Deadband Characteristics of Fiber Optic Gyroscopes by Analyzing the Output Sensitivity in Relation to the Amplitude of the Dithering Signal

Woo-Seok Choi, Kyoung-Ho Chong

Agency for Defense Development, Daejeon, Republic of Korea.

A region, the so-called deadband or deadzone, where gyroscopes cannot detect any angular rate at low rotation, is a significant area of research in closed-loop Interferometric Fiber Optic Gyroscopes (IFOGs). In this study, the variant feature of the IFOG output was measured and analyzed in terms of the dithering amplitude, which is a very important factor in eliminating the deadband due to electrical cross-coupling between modulation and detection. The analyzed results indicate that: (1) the output sensitivity of IFOGs in terms of the dithering amplitude is strongly related to the deadband characteristic and (2) the possible secondary cross-coupling mechanism can be a major source of deterioration in the dithering effect. The required conditions were analyzed for both the electrical and optical signals, so as to deal with the deadband problem in the presence of such a limitation.

48 Integrated Sensor Configuration Method based on Satisfying the Requirements of Autonomous Control and Condition-Based Maintenance for UAVs

Yaoming Zhou

Beihang University, Beijing, China.

Sensors form important constituent parts of UAVs (Unmanned Aerial Vehicles). The altitude, position and speed control, as well as the ground telemetry monitoring requirement of UAVs, should be taken into consideration when configuring the sensors of UAV in the conventional manner. With technological development, autonomous control of UAVs has gradually improved. Autonomous control technology, which could adapt tp sensor faults, has now become a research focus. However, research is mainly focused on fault diagnosis and strategies employed to repair faults. Little research has focused on the configuration of sensors. Research concerning condition based maintenance (timely and accurate maintenance) mainly focuses on prognostics and maintenance decisions after sensor data are acquired. Based on the analysis of airborne autonomously controlled UAVs and ground condition based maintenance, this paper presents a sensor configuration method which meets the requirements of both. Three main sections in this paper describe the sensor configuration method which meets the requirements of autonomously controlled UAVs and their condition based maintenance. These chapters cover the independent sensor configuration method, integrated sensor configuration method and lastly provide an application example. The section on the independent sensor configuration method describes the following aspects: the sensor configuration method adapted for autonomously controlled requirements, the sensor configuration method which adapts to condition based maintenance requirements, and the mapping spaces established between fault modes and sensors which meet the fault repair strategy and maintenance strategy, respectively. The section on the integrated sensor configuration method describes the interactive relationship between the fault repair strategy, maintenance strategy and the general requirements of UAVs. A trade-off matrix is acquired and the mapping space between fault modes and sensors is exported. The section giving an application example describes how the sensor configuration method must be applied to UAV sensor configuration. Finally, the application value and the major R&D of sensor configuration methods which meet the requirements of autonomously controlled UAVs, and their condition based maintenance, are summarised.

49 Label Free QCM Based Immunobiosensor for On-Site Detection of Fumonisin B1

Seyda Serife Pirincci [1,2], özlem Ertekin [1], Sevecen Tuğlu Gürpınar [1], Esin Akcael [1], Selma Ozturk [1], Zafer Ziya özturk [3]

[1] TÜBİTAK, The Scientific and Technological Research Council of Turkey, Marmara Research Center, Genetic Engineering and Biotechnology Institute, Gebze, Kocaeli, Turkey. [2] Kocaeli University, Department of Medical Genetics and Molecular Biology, Umuttepe, Kocaeli, Turkey. [3] Gebze Technical University, Department of Physics, Gebze, Kocaeli, Turkey.

Fumonisin B1 is a mycotoxin that is produced by certain Fusarium species in corn as well as wheat and rice. Epidemiological studies show that Fumonisin B1 plays a role in developing neural tube defects, food poisoning and esophageal cancer. Due to these potential effects, maximum allowed amount of Fumonisin B1 is determined by regulations. Allowed limits for fumonisin B1 according to EU regulations is 0,2–4 ppm. Currently, fumonisin B1 contamination is analyzed by using HPLC and LC/MS. However these methods are time consuming, require experienced operators and need concentration of the mycotoxin prior to analysis. Immunobiosensors can eliminate these disadvantages by enabling on-site and quick determination of the contaminants with high specificity. Previously reported Fumonisin B1 immunobiosensor involve conjugation of Fumonisin B1 with BSA and immobilization of anti-fumonisin B1 to gold surface. Both of these strategies may result in instable sensor surfaces and requires labelling of the toxin with a protein. In this study, we eliminated these problems by immobilizing the toxin directly to sensor surface and developed a label free QCM based Fumonisin B1 immunobiosensor for on-site and straightforward detection. As the name implies, recognition with QCM depends on the mass change. Due to low molecular weight of the toxin, a competitive assay format was used. In this competitive assay, Fumonisin B1 is immobilized on the gold surface and competes with the free toxin found in the sample to be identified for binding of anti-fumonisin B1 antibody. To be able to immobilize Fumonisin B1, the gold surface was functionalized with 11-mercaptoundecanoic acid in the first place and then amine groups were generated for conjugation of the toxin. This strategy confers stability to sensor surface, enables reuse of surface by regeneration up to 10 times and high reproducibility. Anti-fumonisin antibody 8F4, the key element of system to generate mass, is produced in our laboratory. The antibody was mixed with the sample and the frequency change (ΔF) due to the binding of antibody to fumonisin B1 immobilized surface was measured to assess the amount of Fumonisin B1 found in the sample. This system enables on-site detection of Fumonisin B1 below and above the limits thus may reduce the workload and dependence on highly equipped laboratories for Fumonisin B1 detection.

50 Miniaturized Catheter-Tip Based Fiber Optic Tactile Sensor for Minimally Invasive Surgery (MIS)

Jayan Ozhikandathil, Arvind Vyas, Muthukumaran Packirisamy

Concordia University, Montréal, Canada.

Miniaturized tactile sensors are very useful tools for performing minimally invasive surgical tasks. MEMS based tactile sensors can provide accurate sensory information for the surgeon, which helps to precisely characterize and diagnose abnormal tissue, tumors, and blood vessels. As of now, various techniques used for tactile sensing applications include strain gauge, piezoelectric, capacitive, and optical methods. The optical technique has several benefits, such as compatibility with magnetic resonance imaging, higher sensitivity, and electrical passivity. The optical techniques demonstrated for tactile sensing are capable of measuring only the force acting on the tissue; they cannot measure the actual hardness of the tissue. The hardness of the tissue can be predicted only by measuring the force and the displacement of the tissue simultaneously. In this work, a high sensitive tactile sensor that mimics the finger-tip perception of a surgeon was developed. The proposed tactile sensor is composed of a fiber-optic probe with a specially designed force sensitive resistor (FSR) film and a thin glass membrane. The glass membrane was sputter-coated with gold film and used as a moving membrane for measuring the displacement of tissue against the force acting on the tissue. The force acting on the tissue was measured by using the force sensitive resistor film integrated with the catheter probe. The sensor was characterized with artificial tissue.

51 Nanostencil Lithography for Plasmonic Biosensors and Applications in Vibrational Spectroscopy

Serap Aksu

Department of Biosystem Science and Engineering, ETH Zürich, Switzerland.

This research investigates a novel lithography approach for the fabrication of engineered plasmonic biosensors operating at visible and infrared wavelengths. The technique is called Nanostencil Lithography (NSL) and relies on direct deposition of materials through nanoapertures on a stencil. NSL enables high throughput fabrication of engineered antenna arrays with optical qualities similar to the ones fabricated by standard electron beam lithography. Moreover, nanostencils can be reused multiple times to fabricate series of plasmonic nanoantenna arrays with identical optical responses enabling high throughput manufacturing. Using nanostencils, very precise nanostructures could be fabricated with 10 nm accuracy. Furthermore, this technique has the flexibility and resolution to create complex plasmonic nanostructure arrays on the substrates that are difficult to work with using e-beam and ion beam lithography tools. Combining plasmonics with polymeric materials, biocompatible surfaces or curvilinear and non-planar objects enable unique optical applications since they can preserve normal device operation under large strain. In this work, mechanically tunable flexible optical materials and spectroscopy probes integrated on fiber surfaces that could be used for a wide range of applications are demonstrated. Finally, the first application of NSL fabricated low cost infrared nanoantenna arrays for plasmonically enhanced vibrational biospectroscopy is presented. Detection of immunologically important protein monolayers with thickness as small as 3 nm, and antibody assays are demonstrated using nanoantenna arrays fabricated with reusable nanostencils. The results presented indicate that nanostencil lithography is a promising method for reducing the nanomanufacturing cost while enhancing the performance of biospectroscopy tools for biology and medicine. As a single-step and low cost nanofabrication technique, NSL could facilitate the manufacturing of biophotonic technologies for real-world applications.

52 Novel Capacitive Devices for Sensing Studies of Volatile Organic Compounds (VOCs) with Metal Organic Frameworks and Polymer Composites

Sumit Sachdeva [1,2], Dimitri Soccol [3], Beatriz Seoane [2], Dirk Gravesteijn [3], Freek Kapteijn [2], Ernst J.R. Sudhölter [1], Jorge Gascon [2], Louis C.P.M de Smet [1]

[1] Organic Materials and Interfaces, Department of Chemical Engineering, Delft University of Technology, Delft, The Netherlands. [2] Catalysis Engineering, Department of Chemical Engineering, Delft University of Technology, Delft, The Netherlands. [3] NXP Semiconductors, Leuven, Belgium.

Recently, Metal-Organic Frameworks (MOFs) have been explored as filler particles in polymer matrices to selectively enhance gas permeation and separation [1]. The addition of MOF fillers results in composites with a superior separation performance [2] that may offer several advantages for polymer-based sensor devices. Herein, we report the first investigation of MOF-polymer composite systems for capacitive sensor devices. In this study, we used NH_2-MIL-53(Al) and Matrimid® polyimide as MOF and polymer, respectively. Nanoparticles of NH_2-MIL-53(Al) were successfully synthesized by solvothermal method and characterized using powder X-ray diffraction (PXRD), Scanning Electron Microscopy (SEM) and gas adsorption studies. The MOF particles were then incorporated in the polymer layer, both as a free-standing membrane and supported thin films over planar electrode devices. The length of the electrodes in the devices was 0.35 m in a meander-type structure, while the electrode width and spacing was 0.52 µm and 1 µm, respectively. Sensing studies were carried out by measuring changes in capacitance using Impedance Spectroscopy [3]. The coated devices were exposed to different concentrations of humidity, methanol, ethanol and isopropanol in dry nitrogen. Ability of these analytes to penetrate the polymer and selectivity towards the low molecular weight molecules in the polymer allowed a comparative study for sensitivity, reproducibility and response time. It was concluded that the presence of MOF enhances the overall response and hence the detection limit compared to the MOF-free polymer. Further, it was found to be possible to distinguish between these analytes kinetically. Possibilities of integration within CMOS technology allows these materials to be used for both qualitative and quantitative fingerprinting of these alcohols and humidity.

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53 Performance Evaluation of an Insertable Gamma Imaging Probe System to Measure Gamma-Ray Distribution in Inaccessible Locations

Wook Jae Yoo [1], Mingeon Kim [1], Sang Hun Shin [1], Hyesu Jeon [1], Jae Seok Jang [1], Jae Seok Kim [1], Guwon Kwon [1], Dong Eun Lee [1], Kyoung Won Jang [1], Jongguk Kim [2], Bongsoo Lee [1]

[1] School of Biomedical Engineering, College of Biomedical & Health Science, BK21 Plus Research Institute of Biomedical Engineering, Konkuk University, Chungju, Republic of Korea. [2] Molecular Imaging Research Center, Korea Institute of Radiological & Medical Science, Seoul, Republic of Korea.

Abstract In this study, we constructed an insertable gamma imaging probe (GIP) system, which is composed of a scintillation image guide, an image intensifier, and a complementary metal-oxide semiconductor (CMOS) image camera, to measure gamma-ray distribution. To develop a scintillation image guide, a replaceable collimator, an inorganic scintillator, a fiber-optic image guide, a fiber-optic taper are connected in the order named. As an inorganic scintillator, a cerium-doped lutetium yttrium orthosilicate (LYSO:Ce) crystal is employed to convert gamma-ray to scintillating light. The generated scintillation image signal due to the interactions between gamma-ray and LYSO:Ce crystal is guided through the fiber-optic image guide and then magnified by the fiber-optic taper. The scintillation image transmitted from the scintillation image guide is intensified by the image intensifier because the scintillation image signal normally has a very low light intensity. Finally, the intensified scintillation image is measured by the CMOS camera module and displayed through the software program. In order to evaluate the performance of the fabricated GIP system, we measured scintillation images with information regarding gamma-ray distribution emitted from the various gamma-ray emitters with different radioactivities and energies. From the experimental results, we demonstrated that the proposed GIP system can measure the scintillation image due to gamma-ray emitter with low-radioactivity less than 0.5 μCi. The relationship between the light intensity at the region of interest (ROI) in the scintillation image and the radioactivity of gamma-ray emitter is also obtained. Based on the results of this study, it is anticipated that a portable and insertable GIP system can be developed to accurately measure gamma-ray distribution in the inaccessible locations, such as narrow places, pipes, and holes.

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54 Performance of a Multilayered Screen Printed CO_2 Sensor Using NASICON as a Solid Electrolyte

Girish M Kale, Steven Mudenda

Institute for Materials Research, Faculty of Engineering, University of Leeds, Leeds, UK.

Two planar solid state potentiometric CO_2 sensors of the type Na-Ba or Na-Li-Ba (CO_3)| NASICON | $Na_2Ti_6\ O_{13}$ -TiO_2 ($Na_2Ti_6\ O_{13}$-$Na_2Ti_3\ O_7$)| buffer were fully fabricated. One of the sensors was a multilayered structure printed from the bottom-up starting with the buffer on the alumina substrate. The other architecture was a planar sensor fabricated by printing Nasicon paste on an alumina substrate and then the sensing electrodes were printed side by side. Finally, buffer material was then printed on top of the reference electrode. Sintering was done in between layer printing. Long-term stability is one of the major issues in the ongoing development of screen-printed potentiometric CO_2 sensors, hence the scope of the research was to investigate the feasibility of using three carbonate materials and buffer to improve the stability of the sensor. Sensor performance in terms of stability, sensisitivity and humidity cross-sensitivity was thus investigated and will be presented. Use of three carbonate materials in the sensing electrode significantly reduced the operating temperature to <= 300 °C. Also reported are the challenges during the printing and firing of NASICON on the alumina substrate. Scanning electron microscopy (SEM) analysis using EDS shows that the films achieved good densification, bar the reactions that occur between Nasicon and alumina substrate, leading to lower conductivity of the thick film than that of bulk Nasicon.

55 Photoacoustic Sensors for short-chained Hydrocarbon Isotopologues based on a cw-OPO

Alain Chee Khoon Loh, Marcus Wolff

Hamburg University of Applied Sciences, Heinrich Blasius Institute for Physical Technologies, Hamburg, Germany.

The measurement of short-chained hydrocarbon concentrations and their isotopic composition is essential to many applications from environmental research to natural gas exploration. For instance, the isotopic signature of methane ($^{13}CH_4$: $^{12}CH_4$) allows tracing the outflow to its various ecological and anthropogenic sources and can help constrain atmospheric models [1]. Concerning natural gas exploration the stable carbon isotope ratio ($^{13}C_XH_Y$: $^{12}C_XH_Y$) allows the identification of petroleum families, the detection of seals and overpressure, as well as indicates thermal maturity of the gas and productivity of the well. The isotopic composition is also used as a proxy for shale porosity and permeability [2]. We report, to our knowledge, first time photoacoustic (PA) measurements of the main methane and ethane isotopologues using a continuous-wave optical-parametric oscillator (cw-OPO). In functional interaction with a custom-made control unit, the OPO offers a wide range of emission wavelengths between 3.2 and 3.9 µm which cover the strong fundamental ν3 and ν7 absorption band of methane and ethane, respectively in the 3.3 µm spectral region. The PA signal is detected by a MEMS Microphone and processed using the Goertzel algorithm [3]. The isotopologue concentrations were determined with a simple multivariate analysis. Detection limits are in the ppb range. As a preliminary line position investigation, the infrared spectra of high-purity (99%) ^{13}C-enriched methane ($^{13}CH_4$) and ethane ($^{13}C_{12}CH_6$) were recorded using an FTIR spectrometer.

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56 Plastic Optical Fiber Temperature Sensor with an In-Fiber Microhole Filled with Reversible Thermochromic Material

Jaehee Park [1], Young June Park [1], Dohwi Jung [1], Jong-Dug Shin [2], KiRyong Ha [3]

[1] Keimyung University, Department of Electronic Engineering, Daegu, Republic of Korea. [2] Soongsil University, School of Electronic Engineering, Seoul, Republic of Korea. [3] Keimyung University, Department of Chemical Engineering, Daegu, Republic of Korea.

In this paper, a new plastic optical fiber (POF) temperature sensor, with the configuration of the POF with an in-fiber microhole filled with reversible thermochromic material whose transmittance depends on temperature, is investigated. An in-fiber microhole in the POF was fabricated by drilling after the POF was held in a vise and placed under a micro-drilling machine. The reversible thermochromic material was gel type cobalt chloride/polyvinyl butyral. Cobalt chloride solution was made using 10 volume % water and 90 volume % ethanol solvent and was gelled by dissolving polyvinyl butyral in this solution. The POF temperature sensor was fabricated by inserting the thermochromic material into the in-fiber microhole using a micropipette and then by sealing the microhole with epoxy. The experimental setup was composed of a 670 nm laser diode, a powermeter, and a POF temperature sensor placed on a hot plate. The output optical power of the POF temperature sensor was measured as temperature increased from 25 °C to 75°C. The optical power tended to decrease as temperature increased. The optical power tended to decrease as temperature increased. In addition, the optical power was inversely proportional to the diameter of the in-fiber microhole. The sensitivity was measured to be about 0.17 μW/°C for the 0.5 mm diameter hole and 4.12 μW/°C for 1.1 mm diameter hole, respectively. The experiment results indicate that the POF sensor with the in-fiber microhole filled with gel type cobalt chloride/polyvinyl butyral can be used effectively for measuring low temperature below 75 °C.

57 Power-Frequency AC Electric Field Sensor Utilizing Polyimide Film Coating in a Twin-FBG Based Fiber Fabry-Perot Interferometer

Lutang Wang, Nian Fang

School of Communication and Information Engineering, Shanghai University, China.

In this conference, we report a novel, twin-FBG based fiber-optic vibration sensor, driven by the alternative electric-field force for the power-frequency AC electric-field sensing. This sensor concept came from our previous experimental observations: when we placed a piece of optical fiber with polyimide (PI) film coating into in a high-voltage (HV), power-frequency AC electric field, it started to vibrate in the frequency and amplitude corresponding to the frequency and strength of the applied AC electric field, respectively. This kind of phenomenon can be observed usually in high electric-field environments near the HV equipment in which, for example, one can see that insulator papers constantly sway. According to our investigations, this kind of fiber vibration, driven by the alternative electric-field force, probably originates from two mechanisms in physics: one is from the electrostatic force produced by free charges which are trapped by the PI film (a dielectric material) coating on the fiber surface, and another is from the dielectric relaxation effect. In high electric-field environments, the ionized particles existing surrounding the power equipment, generated by corona discharges, are easily trapped by the dielectrics such as the PI film and keep on dielectric surfaces for a long time over almost hundreds of seconds, which generate an electrostatic force to act on the fiber. On the other hand, usually, the dielectric polarization induced by the external electric field is in an opposite direction of the electric field, which can form an attracting force to pull the dielectric body. When the external electric field is time varying and alters its polarity periodically, e.g. in a 50 Hz, or 60 Hz power frequency, the induced dielectric polarization changes its orientation following the external electric field changes. Owing to the dielectric relaxation effect, however, during the polarity exchange process, there is a delay or lag in the dielectric response to the external electric field changes. It temporally changes the action direction of electric-field force from pulling to pushing. In this way, when the fiber is placed in a non-uniform AC electric-field environment, a net pull-push electric-field force arises to shake the fiber. In the study, we designed a fiber-optic accelerometer using light-weight fiber itself as the cantilever with a resonant frequency at or close to the frequency of AC electric field in order to amplify this weak mechanical vibration. The fiber cantilever was coated with the multiple-layer polyimide film in order to enhance the mechanical strength of the fiber cantilever and obtain sufficient electric-field force to shake the fiber as well. As an optical detection method, we adopted a twin-FBG based Fabry-Perot interferometer with a 10 mm long cavity, embedded into the fiber cantilever. Basic technical backgrounds including our experimental observations done before as well as the sensor principle will be introduced. Experimental results used for evaluating sensor performances as well as for proving the sensor concept through our actual electric field measurements with a hand-made sensor prototype will be presented.

58 Radio Propagation Analysis for Wireless Sensor Network Deployment in Urban Train Transportation Environments

Aitor Redondo [1], Leire Azpilicueta [1,2], Peio Lopez-Iturri [1], Erik Aguirre [1], Jose Javier Astrain [1,2], Jesus Villadangos [1,2], Francisco Falcone [1,2]

[1] Universidad Publica de Navarra, Pamplona, Navarra, Spain. [2] Institute of Smart Cities, Universidad Publica de Navarra, Pamplona, Navarra, Spain.

The growth of deployed wireless communication networks, due to the improvement of wireless technologies and devices in terms of battery life, cost and computational capacity, has led to intelligent environments and the so called Smart Cities. In Smart Cities, a great variety of wireless systems will be present, making the coexistence and the optimal deployment of these systems a real challenge. In this work, framed by Smart Cities environments, the characterization of the radio channel for the deployment of ISM 2.4 GHz Wireless Sensor Networks (WSN) in Urban Train Transportation environments is presented. Urban Train Transportation environments are complex scenarios in terms of radio propagation, as the topology and morphology of the environment change dynamically, the effect of high density of persons within the scenario, the presence of moving vehicles (trains) and the electromagnetic interference generated by personal portable devices or other wireless communication systems. In order to assess the impact that the complexity of the environment has on the electromagnetic propagation and to emulate the realistic operation of WSNs in the framework of Urban Train Transportation environments, an in-house developed 3D Ray Launching software has been used, which considers the material properties and the real dimensions of the objects embedded in the simulation scenario. The scenario where the study has been carried out is one of the urban train stations in the city of Bilbao, with indoor and outdoor profiles. Estimations of received power as well as time domain results, such as Power Delay Profiles, have been obtained for the complete volume of the presented scenario. To gain insight into the radio propagation effects, the analysis has been completed with the inclusion of in-house developed human body computational models. The simulation results have been validated by comparing them with measurements. The presented analysis can aid in the design of optimal WSN deployments in terms of energy consumption, coverage and capacity, making the use of WSNs attractive for multiple applications in Urban Train Transportation environments.

59 Real-Time Electrochemical Detection of Proteolytic Enzyme Activity in Thrombus Model

Zsófia Keresztes [1], Eszter Orosz [1], Imre Varjú [2], Gábor Mészáros [1], Zoltán Fekete [3], Gábor Mező [4], Antal Csámpai [5], Lajos Nyikos [1], Krasimir Kolev [2]

[1] Research Center for Natural Sciences, Hungarian Academy of Sciences, Budapest, Hungary. [2] Semmelweis University, Department of Medical Biochemistry, Budapest, Hungary. [3] Center for Energy Research, Institute of Technical Physics and Materials Science, Budapest, Hungary. [4] MTA-ELTE Research Group of Peptide Chemistry, Eötvös L. University, Budapest, Hungary. [5] Institute of Chemistry, Eötvös L. University, Budapest, Hungary.

Multichannel electrochemical analytical device has been constructed to follow enzymatic reactions in a three dimensional thrombus model. Mapping of enzymatic activity in heterogenous turbid media, inaccessible for optical assays, offers the possibility of improved efficiency of currently used agents in thrombolytic therapy. Activity of the thrombolytic enzyme has been followed by electrochemical signal generated by electroactive tag modified substrate analogues. The rate of electrochemically measured cleavage can be used for the homogenous phase reaction analogue determination of enzymatic constants. Different model fibrin gel structures have been used to assess the effect of fiber thickness on the progression of lytic reaction front. The results are giving a real time follow-up of the gradual lysis of the fibrin clot, tracing the basis of whole blood clot lysis events.

60 Selective Detection of Fluorescence Singal without Spectral Filtering using Wide-Field Fluorescence Microscopy

Kwan Seob Park [1], Woo June Choi [2], Joo Beom Eom [3], Byeong Ha Lee [4], Ki Soo Chang [1]

[1] Optical Instrumentation Development Team, Korea Basic Science Institute (KBSI), Republic of Korea. [2] University of Washington, Department of Bioengineering, Seattle, WA, USA. [3] Korea Photonics Technology Institute, Republic of Korea. [4] School of Information and Communications, Gwangju Institute of Science and Technology (GIST), Gwangju, Republic of Korea.

Wide-field fluorescence microscopy has many advantages in its simple configuration for the selective imaging of targeted material by using spectral filtering. However, spectral filtering of a fluorescence signal by using a spectral filter may cause unwanted spectral cut-off to fluorescence emission, which disturbs the signal to background ratio (SBR) of the microscope. To solve this problem, we propose the use of an optical lock-in detection scheme as a SBR enhancement method for wide-field fluorescence microscopy. This method, called four-integrating bucket, uses four CCD frames captured by integrating the time-varying fluorescence intensity signal that is excited by the sinusoidally modulated illumination light, which is simpler than the technique using a fast Fourier transform method. To verify our proposed method, we compared the spectral filtering and digital filtering (four-bucket) of fluorescence signal through the experiments. A capability of the proposed method is demonstrated using a fluorescent bead solution and labelled cells fixed on a slide glass. The result shows that a background-free fluorescence image with an approximately 4-10 higher signal contrast compared to conventional fluorescence microscopy can be simply extracted within a sub-second.

61 Sensing of Biomarkers in Wound Healing Processes

Dagmara Anna Jankowska [1], Greta Faccio [1], Cindy Schulenburg [1], Markus Bannwarth [2], Luciano Boesel [2], Michael Richter [1]

[1] Empa, Swiss Federal Laboratories for Materials Science and Technology, Laboratory for Biointerfaces, St. Gallen, Switzerland. [2] Empa, Swiss Federal Laboratories for Materials Science and Technology, Laboratory for Protection and Physiology, St. Gallen, Switzerland.

Chronic wounds are one of the most common diseases of elderly people. Usually, the monitoring of the wound healing status requires removal of the wound pad, which is invasive and may extend the healing time or increase the risk of infection. To avoid constant removal of the dressing, novel non-invasive monitoring systems have to be developed. The wound liquid of chronic wound offers multiple options for monitoring because many metabolites and proteins are secreted by the damaged tissue. Changes in their concentration are characteristic for a certain stage of the healing process and thus biomarker monitoring would provide information for the current wound status. Here, we show that the selected biomarkers can be detected in artificial wound liquids. Metabolite sensing was achieved by a coupled enzyme assay. Therein, enzymes react sequentially, to transform the molecular situation within the wound liquid into an optical signal, allowing for highly sensitive detection. To detect the existence of enzymes in wound liquids and to thus receive additional information on the wound healing status, we designed fluorescent substrates that are converted with high specificity by the enzymes. For continuous operation, the two systems for metabolite and protease detection will be immobilized.

62 Sensitivity-Enhanced Thermoreflectance Imaging for Thermal Analysis of Microelectronic Devices

Dong Uk Kim, Kwan Seob Park, Hwan Hur, Ki Soo Chang

Optical Instrumentation Development Team, Korea Basic Science Institute, Daejeon, Republic of Korea.

Recently, localized heat generation has become a hot issue for performance and reliability analysis in miniaturized and highly integrated electronic and optoelectronic devices. Themoreflectance microscopy, as a high resolution and non-contact imaging technique to measure the microscale thermal profile, has begun to arouse considerable attention. In this study, we have developed a spectroscopic thermoreflectance microscopy system, which has a systematic approach, from the thermoreflectance calibration to the sensitivity-enhanced thermal imaging. Image acquisition in this thermography is based on measuring the thermoreflectance signals that result from the reflectivity variation induced by the change of temperature. The thermoreflectance effect is significantly dependent on illumination wavelength and is dramatically modified due to optical interference on the transparent or encapsulation layers existing inside modern microelectronic devices. The thermoreflectance calibration in our system can give access to an optimized thermoreflectance measurement because the sensitive wavelength for the thermoreflectance response can be found by measuring thermoreflectance coefficient spectra for the devices being tested. Besides, by employing a tunable optical filter with a broad illumination source, we have demonstrated that high quality thermoreflectance (thermal) image for each different material in the device can be achieved through the continuously selectable probe illumination without any changing part in the system.

63 Short-Wave Infrared (SWIR) Hyperspectral Imaging for Online Evaluation of the Viability of Watermelon Seeds

Hyungjin Bae, Byoung-Kwan Cho

Chungnam National University, Republic of Korea.

Seed viability assessment is considered as one of the major tasks in the seed industry, which is closely associated to the price and acceptance rate of seeds to consumers. Various methods have been developed to evaluate seed viability and vigor, such as a germination test using wet paper, a tetrazolium test and electric conductivity measurement. However, these techniques are invasive, time consuming, and laborious. To improve the quality of seeds by sorting out the nonviable ones, seed viability needs to be evaluated nondestructively before entering the market. In this study, we have constructed an online seed sorting system with hyperspectral short wave infrared (SWIR) imagery for rapid detection of seed viability. The sorting system consists of the MCT sensor combined with an imaging spectrograph, conveyer belt, air-jet nozzle and control unit. Artificially aged and untreated watermelon seeds were used to investigate the performance of the system. Reflectance spectra from normal and aged seeds were collected by scanning the seeds under the hyperspectral SWIR imaging system in the range of 1000–2500 nm. A prediction model based on partial least square discriminant analysis (PLS-DA) method was developed for real-time evaluation of viable and nonviable seeds. The SWIR hyperspectral imaging could achieve high accuracy to distinguish between viable and nonviable seeds. The result shows that SWIR hyperspectral imaging has good potential for online evaluation of viable and nonviable watermelon seeds.

64 Skill Evaluation of a Badminton Player Based on Arm Movement

Muhammad Ilhamdi Rusydi [1], Minoru Sasaki [2]

[1] Andalas University, Padang, Indonesia. [2] Gifu University, Japan.

Badminton is the most popular sport in Indonesia. Since elementary school, or earlier, children play badminton in a formal class or in informal training. Therefore, there are many kinds of styles in playing badminton. In this research, the pattern of arm kinesiology while playing badminton was studied, especially smash and serve. The right arm of the human was segmented into four parts: shoulder, elbow, wrist and back of hand. The direction of angular velocity from each part was recorded by using gyro sensor made by MotionNode. The result shows that there was a clear pattern caused by the movement of four parts of arm while performing smash or serve. This pattern can be used to evaluate a process of arm movement while performing smash or serve in badminton.

65 Smart Tactile Sensor Fingerpad for Robotic Hand Based on Direct Connection to FPGA

Óscar Oballe-Peinado [1], José Antonio Hidalgo-López [1], Jaime Herrán [2], Fernando Vidal-Verdú [1]

[1] Departamento de Electrónica. Universidad de Málaga. Málaga, Spain. [2] Unidad de Sensores. CIDETEC. San Sebastián, Spain.

This paper shows a concrete realization of a smart tactile sensor and its integration in the finger of a Barret robotic hand. It is based on a direct connection tactile sensor-FPGA proposed by the authors [1]. A previous large size complete tactile sensor suite prototype for an artificial hand was presented in [2]. We show here an advanced prototype implemented in a semi-rigid printed circuit board that has a rigid part where the electronic components are located, and a flexible part that adapts to the fingertip curved surface and contains the tactile sensitive area. The circuitry implemented to acquire and process the tactile data is based on direct connection of general purpose I/O pins of an FPGA to the resistive array [1]. The sensitive conductive polymer layer [3] is treated with a laser to isolate the areas associated with each tactel. The proposal has only a few discrete external components and results in a very compact smart sensor. This sensor has 5 rows and 11 columns plus two rows of calibration resistors. The FPGA is a Xilinx Spartan 6 (6SLX16-CSG225). A small connector is used to program the device with JTAG protocol and also to communicate with the palm sensor and communication electronics through SPI. The sensor adapts to the curved surface of the fingertip and has been mounted on the fingertip of a dummy robotic hand. The sensor is scanned and parameters to build the ellipsoid that fits the tactile image are provided at a rate of 200 Hz to the central processing unit. Figure 3 shows an example of the ellipsoid computed from a tactile image. The parallel data acquisition and also parallel processing in the FPGA allow a powerful real time pre-processing capability.

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66 Stochastic Modeling of Optical Fiber Sensing Systems

Satyan Bhongale [1], David Barfoot [1], Kwang Suh [2]

[1] Halliburton, USA. [2] Pinnacle, a Halliburton Service, USA.

An accurate model of light propagation is essential for developing a high-fidelity distributed or point-sensor optical-fiber-based system. While light propagation in optical fibers can be understood by means of the standard textbook treatment based on the nonlinear Schrodinger equation, it is limited to the inclusion of only deterministic effects, such as dispersion and nonlinearity. However, in an actual optical- fiber-based sensor system, several dynamic and stochastic effects are at play simultaneously. A practical example that is applied to the current model is distributed acoustic sensing (DAS) based on Rayleigh backscatter, where stochastic noise arising from Rayleigh scattering is inherently present in both the forward and backward propagating optical signals. Furthermore, the optical sensing system can involve active and passive components, such as a laser, amplifiers, filters, and modulators. All of these components, while providing the desired effect on the optical interrogation signal, also introduce undesired noise that limits the sensing ability of the complete system. This paper demonstrates the ability of such modeling to study the modulation instability arising in typical telecom fibers with positive dispersion (e.g., Corning SMF 28). By using this model and simulation, the contribution to optical sensing performance from each component in the system, including the fiber design parameters, can be studied and quantified. Thus, it allows for the determination of the best path forward for future research and development for improving these optical sensing systems.

67 Surface Plasmon Resonance Biosensor for Enterovirus 71 Viral Detection

Muhammad Khari Secario [1], Chia-Jung Liu [1], Briliant Adhi Prabowo [1,2], Robert Yung-Liang Wang [3,4], Kou-Chen Liu [1,5]

[1] Department of Electronic Engineering, Chang Gung University, Taoyuan, Taiwan. [2] Research Center for Informatics, Indonesian Institute of Sciences, Bandung, Indonesia. [3] Graduate Institute of Biomedical Sciences, Chang Gung University, Taoyuan, Taiwan. [4] Research Center for Emerging Viral Infections, Taoyuan, Taiwan. [5] Center for Biomedical Engineering, Chang Gung University, Taoyuan, Taiwan.

In the need to encounter enterovirus 71 (EV 71) outbreak, surface plasmon resonance (SPR) offer fast and rapid detection. Using common used Kretschmann configuration, we attempt to design a SPR sensor for early detection of EV 71 infection. Simulation was performed to obtain SPR biosensor optimum parameters. From sucrose water trial we can obtain sensitivity and limit of detection (LOD) around 3991 RIU^{-1} and $1.63x10^{-5}$ RIU respectively. While in EV measurement our sensor LOD successfully achieved up to 104 EV 71 viral particles.

68 Target-driven DNA Proximity Assembly for One-step Sensitive Biosensing of Protein Biomarkers

Jie Wu, Huangxian Ju

State Key Laboratory of Analytical Chemistry for Life Science, Department of Chemistry, Nanjing University, China.

As the levels of tumor biomarkers in serum/tissue are positively correlated with the stages of tumors, accurate tumor marker detection with a simple operation is very important in early cancer screening and evaluation. The development of rapid, easy-to-use, low-cost point-of-care methods for the quantitative detection of tumor markers has resulted in great efforts of scientific organizations. Currently, our group developed a series of one-step sensitive bioassays based on the target-driven DNA proximity assembly along with enzymatic amplifications, for example, we developed 1) two ratiometric electrochemical proximity assays by using target-triggered DNA displacement to change the distances of electrode and two electroactive molecules[1,2]; 2) a homogeneous electrochemical immunoassay by designing a target-driven proximity hybridization to regulate the electrochemical DNA biogate [3]; 3) an amplified electrochemical immunosensing by target-driven triple-blinder assembly of MNAzyme[4]; 4) an homogeneous chemiluminescent bioanalysis based on proximity hybridization-triggered signal switch [5]; 5) an array-based chemiluminescence imaging assay via proximity-dependent DNAzyme in situ formation [6]; 6) an high-throughput imaging assay by integrating target-induced DNA assembly and cleavage on a DNA chip[7]. These assays showed advantages of simplicity (one-step), fast detection, washing-free, high selectively and sensitivity, and have been applied for the detection of DNA, protein biomarkers and aptamer-recognized protein with wide detection range and pg/mL sensitivity, displaying great potential for point-of-care testing and commercial application.

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69 The Roaming Climate Measuring Box: Greenhouse Climate Control based upon a Wireless Network of Temperature and Relative Humidity Sensors.

Jos Balendonck, Hans (H.J.J.) Janssen

Wageningen UR Greenhouse Horticulture, Wageningen, The Netherlands.

In greenhouses, ventilation (dehumidification) and heating are used to remove excess moisture coming from crop transpiration. In order to save energy, especially during colder nights, in modern (semi-closed) greenhouses the ventilation rate is reduced. Consequently, humidity levels in the greenhouse will rise, as well enlarging the risk for moisture borne diseases like f.i.*Botrytis*. Previous research has shown that during the night, local differences in temperature and humidity can be very large, up to 8 °C and 30%. Extreme cold or wet spots, the ones invoking diseases through condensation on leaves and stems, may occur as fixed or roaming spots. The cause of fixes extremes can often be traced back to defects or incorrect design of the greenhouse infrastructure. Growers see this is their crop because they recognize locations in the greenhouse where the crop is smaller or where diseases occur first. Roaming extremes are mainly due to changing external factors such as the climate outside (wind, solar radiation) or by enabling or disabling of internal heat sources such as forced ventilation systems (air intake). To prevent extreme spots, it is preferred to have a homogeneous climate, which makes it possible to control the climate with a safe and small vapour pressure deficit margin (VPD). Although growers do their best to alter the greenhouse infrastructure for this, it is not always possible to avoid extreme spots. In that case, growers need to control the greenhouse at a much larger safety margin, resulting in higher energy losses. In that case, it would be nice if growers would have detailed information about the climate. This, in order to be able to set the lowest safety margin for VPD, saves energy when possible, and as well prevents possible outbreaks of diseases. Normally only one standard climate measuring box is used per department (1 ha.). This is hardly enough to capture the horizontal variability of the climate, and find the extremes. Therefore more measuring locations are needed. In this research, for the first time, a greenhouse climate was controlled in real-time using a wireless sensor network. The standard monitoring box in a 250 m^2 experimental tomato greenhouse (Straelen, D) was replaced with a set of eight wireless temperature and humidity sensors (AgriSensys, NL). The approach was to connect in real-time the sensor having the lowest VPD to the climate computer (RAM Technology, D). Because of the changing climate, the sensor, and as such the actual location controlling the climate, could vary from time to time. Therefore, the system is called the “roaming climate measuring box controller”. The system was tested during summer and autumn (2014) and operated well. The new climate control approach was compared with the standard climate box controller during intervals of several weeks, by switching every day among either approach. Depending on the chosen VPD-margin (RH=3%, 5%), energy savings where obtained of 2 and 10% respectively. Further it was observed that the wireless sensor approach led to a more homogenous climate, making it possible

for growers to choose a lower VPD-margin, grow at a higher moisture level, and save energy, as well as reduce infection risks.

70 The Si-tag for Immobilizing Proteins on a Silicon Device

Akio Kuroda

Department of Molecular Biotechnology, Hiroshima University, Japan.

Targeting functional proteins to specific sites on a silicon device is essential for the development of new biosensors and supramolecular assemblies. Proteins have mainly been immobilized on silica surfaces by nonspecific adsorption or covalent bond formation between readily available functional groups on protein molecules (e.g., $-NH_2$) and complimentary coupling groups on the solid surfaces. The nonspecific nature of these usual approaches inevitably contains the following difficulties; (i) it requires chemical modification of the solid surfaces, (ii) proteins may be denatured when the interaction with the surface is too strong, (iii) it is difficult to control protein orientation. Recently, we found a silica-binding protein, designated Si-tag, which can be used to immobilize fused proteins on a silicon device. We constructed a fusion protein of Si-tag and immunoglobulin-binding staphylococcal protein A for oriented immobilization of antibodies on a silicon wafer whose surface is oxidized to silicon dioxide. The fusion protein, Si-tagged protein A, strongly bound to the silica surface with a dissociation constant of 0.31 nM. The silicon wafer coated with Si-tagged protein A bound 30–70% more Immunoglobulin G (IgG) than the uncoated silicon wafer, whereas the antigen-binding activity was 4– 5-fold higher for the former, indicating that IgG was functionally immobilized on the silicon wafer via Si-tagged protein A in an oriented manner.

71 The Development of a Sensitive and Selective Riboflavin Sensor Based on a Carbon Paste Electrode Modified with Manganese Tetra Phenyl Porphyrin

Shokooh Sadat Khaloo.

Department of Basic Sciences, School of Health, Safety and Environment. Shahid Beheshti University of Medical Sciences, Tehran, Iran.

A chemically modified electrode constructed by incorporating manganese tetraphenyl porphyrine into a carbon paste matrix was used as a sensitive electrochemical sensor for detecting riboflavin. The resulting electrode exhibits catalytic properties for the electrooxidation of riboflavin and lowers the overpotential for the oxidation of this compound. Thus, the corresponding peak current increased significantly. The faster rate of electron transfer results in a near-Nernstian behavior of the modified electrode and makes it a suitable voltammetric sensor for the fast and easy determination of riboflavin. A linear response in a concentration range from 10^{-8} M to 10^{-5} M was obtained with a detection limit of 8×10^{-9} M for the determination of riboflavin. The electrode showed long-term stability; the standard deviation of the slope obtained after repeated calibration during a period of three months was 3.5% (n=7). The modified electrode was also used for differential pulse voltammetric determinations of riboflavin in pharmaceutical and food samples.

72 Thermal Characterization of Microbolometer Focal Plane Arrays by Thermoreflectance Microscopy

Ki Soo Chang, Seon Young Ryu, Dong Uk Kim

Korea Basic Science Institute, Republic of Korea.

The performance of microbolometer focal plane array (FPA) is driven by the thermal characteristics of the individual pixels. Therefore, thermal characterization of individual pixels in microbolometer FPA is needed for optimal bolometer design and improved performance. In this work, we used thermoreflectance microscopy on uncooled microbolometer FPA to investigate the thermal characteristics of individual pixels. Two types of custom-designed microbolometer FPAs with a shared-anchor structure were fabricated, and the 2-D temperature distribution on the individual pixels of microbolometers was quantitatively measured by thermoreflectance microscopy. The measured thermal characteristics agreed closely with the results extracted by electro-thermal analysis. We also evaluated the pressure dependence of the thermal isolation characteristics of microbolometers by measuring the quantitative thermal distribution images as a function of vacuum levels. The results show that thermoreflectance microscopy can be a useful thermal characterization tool for microbolometer image sensors.

73 Towards Real-Time Health Monitoring of Flexible Structures: Optimal Development of Sensor Network, Reduced Order Modeling and Data Processing

Giovanni Capellari [1], Matteo Bruggi [1], Francesco Caimmi [1], Saeed Eftekhar Azam [2], Stefano Mariani [1]

[1] Politecnico di Milano, Milano, Italy. [2] University of Thessaly, Greece.

Lightweight composite structures have been attracting much attention, especially in aeronautical, mechanical and civil engineering, due to their enhanced properties linked to a wise coupling of different phases or materials. In terms of their specific mechanical features per unit mass, they can behave by far better than standard structural materials, and thus allow the structures to be lighter and reduce the power/fuel consumption if they have to move, or to increase the relevant sustainability in case of mass production.On the other hand, coupling phases with different physical and/or chemical properties introduces issues related to structural reliability, in case of exposure to aggressive environments or repeated loadings. Accordingly, the design of health monitoring strategies for such composite materials needs to account for the possible presence of nested, small defects able in principle to largely affect the lifespan of the structure or its load-bearing capacity. Hence, a structural health monitoring (SHM) system is to be able to detect in real-time a deviation or bias from the response of the healthy, undamaged configuration, so as to immediately send out a warning to the users.In this work, we provide an overview on some recent accomplishments of ours as for the development of smart SHM strategies, and specifically on the following topics, see [1-7]: (i) adoption of inertial micro-sensors (*i.e.*, 3-axis MEMS accelerometers and gyroscopes) to sense the current response of the structure to the external loading; (ii) optimal deployment of a network of MEMS sensors on flat plates, so as to maximize the system sensitivity to a structural damage, no matter where this is located, while keeping the sensors to a minimal amount and reduce the overall network power consumption; (iii) reduced order modeling of the structural behavior through a proper orthogonal decomposition (POD) algorithm, ad-hoc extended to the nonlinear regime to account for a slowly varying damage, typically induced by fluctuating external loads causing material fatigue; (iv) hybrid, joint system and damage identification based on an intricate Rao-Blackwellized particle filter; (v) parallel implementation of the filtering procedure, to further speedup the data processing.

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74 Validation of Biomechanical Signals Capture Platform Based Inertial Sensors for Telerehabilitation

Mauro Callejas Cuervo [1,2], Andrés Felipe Ruíz Olaya [2], Manuel Andrés Velez-Guerrero [1], Rafael M. Gutierrez [2]

[1] Universidad Pedagógica y Tecnológica de Colombia, Tunja, Colombia. [2] Universidad Antonio Nariño, Bogotá, Colombia.

This paper shows the results of a set of experiments aimed to calibrate and validate an inertial sensor based motion caption system for capturing and analyzing biomechanical signals at the upper limb level. The inertial sensor based system estimates angular displacement for a rotating joint like human elbow. An experimental validation platform was constructed which provides an accuracy angular position information for reference. Experiments include the following steps: Construction of the experimental platform, programming the Software / Firmware to collect data generated by sensors, calibration of the experimental platform, data acquisition and generation of the results. We used the root mean squared error (RMSE) to quantify the difference between the arm guided by a servo motor and inertial sensor. Obtained results has an average error of 2.14 degrees when the arm guided by a servo motor rotating at 1 radian per second. The system also has an RMSE of 3.3, 4.9, 6.4 and 7.7 degrees for speeds of 2, 3, 4 and 5 radians per second respectively. It was also possible to identify that the degree of accuracy in the angle measurement is appropriate and feasible to be used in a platform for capturing biomechanical data, focused to monitor the recovery of the motor function in the upper limbs through physical therapy.

75 Verification of an all-in-one Phantom and Scintillator Radiation Sensor for Real-Time Monitoring of a Source Position in HDR Brachytherapy

Sang Hun Shin [1], Guwon Kwon [1], Jae Seok Jang [1], Jae Seok Kim [1], Hyesu Jeon [1], Dong Eun Lee [1], Young Beom Song [1], Kyoung Won Jang [1], Wook Jae Yoo [1], Kum Bae Kim [2], Bongsoo Lee [1]

[1] School of Biomedical Engineering, College of Biomedical & Health Science, BK21 Plus Research Institute of Biomedical Engineering, Konkuk University, Chungju, Republic of Korea. [2] Research Institute of Radiological & Medical Sciences, Korea Institute of Radiological & Medical Sciences, 75, Seoul, Republic of Korea.

The main challenge in high-dose-rate (HDR) brachytherapy is to deliver a prescribed radiation dose to a tumor while limiting the dose delivered to surrounding normal organs and tissues. In HDR brachytherapy, a gamma-emitter, iridium-192 (Ir-192) source with an initial radioactivity of about 370 GBq (10 Ci) is moved and placed along catheters inserted within the treatment site during a set period of time. The positioning and displacement of the Ir-192 source are controlled by a remote after-loader. Here, the source positions and dwell times are determined to meet the requirements for the prescribed dose. Therefore, it is very important to exactly measure the real-time position and dose distribution of the Ir-192 source in after-loading HDR brachytherapy. Unfortunately, however, existing conventional methods (e.g., HDR brachytherapy dosimetry) cannot be used to measure the position of Ir-192 source in real-time. Therefore, we fabricated an all-in-one phantom and scintillator radiation sensor (PSRS), with organic scintillators, to measure the real-time position and dose distribution of an Ir-192 source. The proposed PSRS offers many dosimetric advantages, such as a fast real-time response capability, large dose response range, excellent spatial resolution, near energy independence for high-energy photons, the ability to measure dose distribution in two dimensions, and convenient usage for brachytherapy dosimetry. As experimental results, we simultaneously obtained the shape and position information of the Ir-192 source as well as the dose distribution. Further studies will be carried out to fabricate newly-designed PSRS using organic scintillators with a diameter of less than 0.5 mm for the dose measurements with high spatial resolution. Furthermore, we will evaluate the accuracy of a fabricated all-in-one PSRS system under a clinically relevant irradiation procedure prepared with a treatment planning system (TPS).

76 Wide Band Study of Silicon-on-Insulator Photodiodes on Suspended Microhotplates

Nicolas André 1, Guoli Li [1,2], Pierre Gérard [1], Olivier Poncelet [1], Yun Zeng [2], Zeeshan Ali [3], Florin Udrea [4], Laurent A. Francis [1], Denis Flandre [1]

[1] ICTEAM Institute, Université catholique de Louvain, Belgium. [2] School of Physics and Microelectronics Science, Hunan University, China. [3] Cambridge CMOS Sensors Ltd., Cambridge, UK. [4] Department of Engineering, Electrical Engineering Division, University of Cambridge, Cambridge, UK.

In this paper, the performances of a lateral thin-film PIN photodiode based on silicon-on-insulator technology are reported for applications from blue to red wavelengths. The platform consists of a micro-hotplate with a suspended heater and a photodiode. Responsivities of 0.01 to 0.05 A/W were obtained for 450–900 nm light range in reverse bias operation. Suspended photodiodes give up to 5x responsivity improvement with regard to the photodiodes on substrate. Measurements of up to 300 °C as well as electrical and optical simulations (Atlas and Matlab) will also be presented.

77 Wireless Remote Control of Cement Plug Conatainer Improves Safety and Saves Rig Time

Nicolas Rogozinski

Halliburton Energy Services, USA.

Concurrent with the increased global demand for oil and gas, the exploitation of deeper, extended-reach, horizontal, and more profound water wells continues. These environments often involve increased pressure and temperatures. Therefore, operators continually strive to identify new technologies to limit or remove personnel nearby during operations so that safety standards can be upheld while also increasing productivity and lowering costs. During normal cementing operations of a well, cement heads are used to release darts or balls to activate subsurface tools. Topdrives are used to rotate the drillstring during cementing to help facilitate the drilling process. This paper discusses the details of a successful job in which safety valves and a topdrive cement head were controlled using a wireless remote-control to dynamically launch plugs downhole while rotating casing at elevated rev/min speeds and hookload. This true wireless capability allowed cementing operations to be performed at higher speeds and hookload than normal while eliminating potential safety hazards related to personnel that can be encountered when operations are not performed remotely and wirelessly. This technology helped the operator increase productivity while also reducing cost and potential risk associated with personnel performing operations onsite in such harsh environments. Similar future jobs are planned by the operator to further employ this wireless technology.

78 Single-Diod Time-of-Flight Sensor in Low-Sensing Mode

MIhail Georgiev, Robert Bregovic, Atanas Gotchev

3D Media Group, Department of Signal Processing, Tampere University of Technology, Finland.

Recently, depth has been established as an important modality in 3D video, 3D scene reconstruction, and gesture recognition and tracking. Subsequently, design of specific depth sensors has become a trendy research topic. Time-of-flight (ToF) sensors are such active sensors, which utilize a continuously modulated harmonic wave in the near infrared range for illuminating the scene and then measuring the phase delay of the light reflected from different objects at different depth. The ToF hardware is constrained to certain levels of reflected signal sensitivity for providing accurate enough depth measurements and requires sufficient power for the emitted signal to avoid low-light conditions and corresponding noisy measurements. The requirement for good lighting makes the depth sensor bulky because of the diode matrix. On another hand, depth sensors are targeted to miniaturization and embedding in mobile devices, which impose reducing the number of such diodes. In this work, we consider the case of single-diode ToF sensor. We propose a modification of its operating mode to extend its operability while capturing distance data in low-sensing environment. In our approach, we propose to increase the number of captured frames, which are sensed for adaptively chosen shorter sensing intervals of few microseconds. This decreases the power consumption however imposes problems with the noise presence. We investigate a specific noise model for the considered mode of operation, which also takes sensor's technological imperfections into account. The availability of more temporal frames provides overcomplete representation, which is suitable for applying modern non-local denoising approaches, tailored to ToF data. We propose a specific patch similarity cost measure and efficient de-noising based on windowed 3D Fourier Transform, which is suitable for real-time GPU-based implementation with low complexity and small-memory footstep. Our analysis demonstrates that only few frames are sufficient to converge to a result that resembles a normal operating mode.

List of Participants

Aguirre Erik
Universidad Pública de Navarra, Spain
francisco.falcone@unavarra.es

Ahmed Faisal
Tallinn University of Technology, Estonia
faisal@elin.ttu.ee

Ahmed Zeeshan
National Institute of Standards and Technology, USA
zeeshan.ahmed@nist.gov

Aksu Serap
ETH Zürich, Switzerland
olimpicser@gmail.com

Alwarappan Subbiah
CSIR - Central Electrochemical Research Institute, India
salwarap@gmail.com

An Tae Uk
Kangwon National University, Korea
onlyfrieds@naver.com

Andrianova Mariia
SMC "Technological Center" MIET, Russia
smariika1987@gmail.com

Ashraf P. Muhamed
Central Institute of Fisheries Technology, India
ashrafp2008@gmail.com

Aslanoglu Mehmet
Harran University, Turkey
maslanoglu@harran.edu.tr

Astl Georg
EOSWISS Engineering Sàrl, Switzerland
georg.astl@eoswiss.ch

Athmania Djamel
University of Tébessa, Algeria
athmaniad@yahoo.fr

Bae Hyungjin
Chungnam National University, Korea
snowballgame@naver.com

Balendonck Jos
Cornell University, USA
jos.balendonck@wur.nl

Bensiradj Taha
University of Science and Technology–Houari Boumediene, Algeria
thben24@gmail.com

Berisha Liridon
University of Prishtina, Kosovo
liridon.berisha@uni-pr.edu

Bernhard Ralf
Endress+Hauser Conducta, Germany
ralf.bernhard@conducta.endress.com

Bhongale Satyan
Halliburton Energy Services, Inc., USA
satyan.bhongale@halliburton.com

Bonnot Karine
French-German Research Institute of Saint-Louis, France
karine.bonnot@isl.eu

Brandão Lúcia
Instituto Superior de Engenharia do Porto, Portugal
luciabrandao@hotmail.com

Broderick Patricia A.
City College of New York, USA
broderick@med.cuny.edu

Brändli Christian
Insightness GmbH &Institute of Neuroinformatics, Switzerland
christian@insightness.com

Callejas Cuervo Mauro
Universidad Pedagógica y Tecnológica, Colombia
maurocallejas@gmail.com

Cano-Contreras Martin
Universidad de Guanajuato, Mexico
mcano_cco@utsoe.edu.mx

Cao Anping
Delft University of Technology, the Netherlands
a.cao-1@tudelft.nl

Capellari Giovanni
Politecnico di Milano, Italy
giovanni.capellari@polimi.it

Chang Kisoo
Korea Basic Science Institute, Korea
ksc@kbsi.re.kr

Chang Wen-Teng
National Kaohsiung University, China
wtchang@nuk.edu.tw

Cheng Zhongyang
Auburn University, USA
chengzh@eng.auburn.edu

Cho Byoung-Kwan
Chungnam National University, Korea
chobk@cnu.ac.kr

Choi Sang-Jin
Chonbuk National University, Korea
sang_jin@jbnu.ac.kr

Choi Woo-Seok
Agency for Defense Development, Korea
cws@add.re.kr

Daly Colin
Corning Incorporated, USA
dalycb@corning.com

Decotignie Jean-Dominique
CSEM, Switzerland
jean-dominique.decotignie@csem.ch

De Mello Andrew J.
ETH Zürich, Switzerland
andrew.demello@chem.ethz.ch

Diamond Dermot
Dublin City University, Ireland
dermot.diamond@dcu.ie

Duempelmann Ralf
i-net innovation networks, Switzerland
ralf.duempelmann@i-net.ch

Elwenspoek Miko
University of Twente, the Netherlands
M.c.elwenspoek@utwente.nl

Enger Olivier
BASF Schweiz AG, Switzerland
olivier.enger@basf.com

Ensafi Aliasghar
Isfahan University of Technology, Iran
Aaensafi@gmail.com

Ertekin Özlem
Genetics Engineering and Biotechnology Institute, Turkey
ozlem.ertekin@tubitak.gov.tr

Eugster Patrick Thomas
Purdue University, USA
peugster@cs.purdue.edu

Ezzouine Zakaryae
University of Moulay Ismaïl, Morocco
ezzouine.Zakaryae@gmail.com

Fang Nian
Shanghai University, China
nfang@shu.edu.cn

Fattinger Christof
Roche Innovation Center Basel, Switzerland
christof.fattinger@roche.com

Fiore Andrea
Eindhoven University of Technology,
The Netherlands
a.fiore@tue.nl

Francis Laurent A.
Université catholique de Louvain, France
laurent.francis@uclouvain.be

Franzi Eduardo
CSEM, Switzerland
edo.franzi@csem.ch

Frutiger Andreas
ETH Zürich, Switzerland
afrutig@student.ethz.ch

Fu Sheng
KK Women's and Children's Hospital, Singapore
Fu.Sheng@kkh.com.sg

Gallegos-Arellano Eloisa
Universidad de Guanajuato, Mexico
e.gallegosarellano@ugto.mx

Gotchev Atanas
Tampere University of Technology, Finland
atanas.gotchev@tut.fi

Goyal Nitin
CTR Carinthian Tech Research AG, Austria
nitin.goyal@ctr.at

Guo Hongli
Tsinghua University, China
hollymasten@163.com

Gupta Banshi
Indian Institute of Technology Delhi, India
bdgupta@physics.iitd.ernet.in

Halasz Edmund
SICPA Security Solutions SA, Switzerland
edmund.halasz@sicpa.com

Hanley Tom
Newcastle University, UK
t.h.hanley@ncl.ac.uk

Hauser Peter
University of Basel, Switzerland
Peter.Hauser@unibas.ch

Hennig Stefan
Technische Universität Dresden, Germany
Stefan.Hennig1@tu-dresden.de

Herzig Hans Peter
EPFL Lausanne, Switzerland
hanspeter.herzig@epfl.ch

Horisberger Roland
Paul Scherrer Institute, Switzerland
roland.horisberger@psi.ch

Hoxha Blerine
University of Prishtina, Albania
blerinaa.hoxha@hotmail.com

Huang Limei
MDPI AG., Switzerland
limei.huang@mdpi.com

Hur Hwan
Korea Basic Science Institute, Korea
hurhwan@kbsi.re.kr

Hussain Syed Zaheer
University of Peshawar, Pakistan
syed_zaheerhussain@yahoo.com

Hwu Stephanie
ETH Zürich, Switzerland
hwu@biomed.ee.ethz.ch

Ionescu Adrian M.
EPFL Lausanne, Switzerland
adrian.ionescu@epfl.ch

Ioppolo Tindaro
Southern Methodist University, USA
ioppolo@smu.edu

Jang Kyoung Won
Konkuk University, Korea
kko988@hotmail.com

Jankowska Dagmara Anna
Empa - Swiss Federal Laboratories for Materials Science & Technology, Switzerland
dagmara.jankowska@empa.ch

Jeong Jong Seob
Dongguk University, Korea
jjsspace@gmail.com

Jeong Seong-Yong
Chonbuk National University, Korea
jsy5351054@naver.com

Josse Fabien
Marquette University, USA
fabien.josse@marquette.edu

Ju Huangxian
Nanjing University, China
hxju@nju.edu.cn

Kafarski Marcin
Institute of Agrophysics, Poland
m.kafarski@ipan.lublin.pl

Karthäuser Silvia
Forschungszentrum Jülich GmbH, Germany
s.karthaeuser@fz-juelich.de

Katz Evgeny
Clarkson University, USA
ekatz@clarkson.edu

Keresztes Zsófia
Research Center for Natural Sciences of the Hungarian Academy of Sciences, Hungary
keresztes.zsofia@ttk.mta.hu

Khaloo Shokooh Sadat
Shahid Beheshti University of Medical Sciences, Iran
sh_khaloo@yahoo.com

Kim Dong Uk
Korea Basic Science Institute, Korea
dukim2013@kbsi.re.kr

Kim Ghiseok
Seoul National University, Korea
ghiseok@snu.ac.kr

Kim Jina
Ewha Womans University, Korea
coffee163@naver.com

Kim Jong Chul
Korea Research Institute of Standards and Science, Korea
jckim@kriss.re.kr

Kolev Spas Dimitrov
University of Melbourne, Australia
s.kolev@unimelb.edu.au

Kuroda Akio
Hiroshima University, Japan
akuroda@hiroshima-u.ac.jp

Kwon Il-Bum
Korea Research Institute of Standards, South Korea
ibkwon@kriss.re.kr

Lacour Stephanie
EPFL Lausanne, Switzerland
stephanie.lacour@epfl.ch

Lang Hans Peter
University of Basel, Switzerland
Hans-Peter.Lang@unibas.ch

Laroche Thierry
frec|n|sys, France
thierry.laroche@frecnsys.fr

Leblebici Yusuf
EPFL Lausanne, Switzerland
yusuf.leblebici@epfl.ch

Lee Bongsoo
Konkuk University, Korea
bslee@kku.ac.kr

Lee Sang-Myung
Kangwon National University, Korea
sangmyung@kangwon.ac.kr

Lee Sang-Wook
Korea Research Institute of Standards and Science, Korea
sangwook@kriss.re.kr

Lenz Mario
ETH Zürich, Switzerland
mario.lenz@ethz.ch

Leonel Wiziack Nadja Karolina
Federal University of São Carlos, Brazil
nadjalw@gmail.com

Leuthold Juerg
ETH Zürich, Switzerland
juerg.leuthold@ief.ee.ethz.ch

Li Lin
MDPI, Switzerland
lin.li@mdpi.com

Lin Kuan-Jiuh
National Chung Hsing University, Taiwan
kjlin@nchu.edu.tw

Loh Alain Chee Khoon
Heinrich Blasius Institute for Physical Technologies, Germany
alain.loh@haw-hamburg.de

Lu Lucy
MDPI AG., Switzerland
lucy.lu@mdpi.com

Marcus Logan S.
US Army Research Laboratory, USA
Logan.S.Marcus.CTR@mail.mil

Melesse Assefa
Florida International University, USA
melessea@fiu.edu

Mengyun Wang
Tsinghua University, China
348751442@qq.com

Meravy Patricia A.
pmeravy@liebertpub.com

Mergl Martin
J. Heyrovsky Institute of Physical Chemistry, Czech Republic
mmergl0@gmail.com

Miao Chunyu
Zhejiang Normal University, China
cymiao@zjnu.cn

Min Hyun-Jung
Chungnam National University, South Korea
alflso92@naver.com

Mirsky Vladimir M.
BTU Cottbus–Senftenberg, Germany
mirsky@b-tu.de

Mitsubayashi Kohji
Tokyo Medical and Dental University, Japan
m.bdi@tmd.ac.jp

Montoya Germán
Universidad de los Andes, Colombia
ga.montoya44@uniandes.edu.co

Moser Roland
Alstom, Switzerland
roland.moser@power.alstom.com

Mudenda Steven
University of Leeds, UK
stevenmudenda@gmail.com

Nallon Eric
George Mason University, USA
eric.nallon@us.army.mil

Nam Ki-Hwan
Korea Basic Science Institute, Korea
namkihwan@gmail.com

Ndangili Peter
Kenyatta University, Kenya
ndangilipeter0@gmail.com,
ndangili.peter@ku.ac.ke

Nemati Mahsa
Delft University of Technology, The Netherlands
m.nemati@tudelft.nl

Nirupama Vattikunta
Sree Vidyanikethan Engineering College, India
vcnirupama@gmail.com

Ohm Jiyeon
Ewha Womans University, Korea
jiyeonohm@hanmail.net

Orosz Eszter
Research Center for Natural Sciences of the
Hungarian Academy of Sciences, Hungary
orosz.eszter@ttk.mta.hu

Oulmi Kafia
University of Batna, Algeria
k_oulmi@yahoo.com

Packirisamy Muthukumaran
Concordia University, Canada
pmuthu@alcor.concordia.ca

Pal Mrinal
CSIR - Central Glass and Ceramic Research
Institute, India
palm@cgcri.res.in

Palmara Gianluca
Politecnico di Torino, Italy
palmaragianluca@gmail.com

Pan Jae-Kyung
Chonbuk National University, Korea
pan@jbnu.ac.kr

Park Jaehee
Keimyung University, Korea
jpark@kmu.ac.kr

Park Kwan Seob
Korea Basic Science Institute, Korea
kspark@kbsi.re.kr

Passaro Vittorio M.N.
Politecnico di Bari, Italy
vittorio.passaro@poliba.it

Pedersen Christian
DTU Fotonik, Denmark
chrp@fotonik.dtu.dk

Picollo Federico
National Institute for Nuclear Physics, Italy
picollo@to.infn.it

Poghossian Arshak
Aachen University of Applied Sciences, Germany
a.poghossian@fz-juelich.de

Prajat Mukesh
Defence Laboratory, India
prajapat89@gmail.com

Rackauskas Simas
University of Campinas, Brazil
simpin@gmail.com

Rai Prabhakar
Indian Institute of Technology Kanpur, India
prkrai@iitk.ac.in

Rampoldi Stefano
CDI Centro Diagnostico Italiano, Italy
Stefano.rampoldi2@gmail.com

Rattanarat Poomrat
Chulalongkorn University, Thailand
r.poomrat@hotmail.com

Reindl Leonhard
University of Freiburg, Germany
reindl@imtek.uni-freiburg.de

Ren Xiaohua
Institute of Geodesy and Geophysics, China
renxh@whigg.ac.cn

Roux Jean
Hamamatsu Photonics, France
jroux@hamamatsu.fr

Ruch Andreas
Halliburton Company Germany GmbH, Germany
andreas.ruch@halliburton.com

Rusydi Muhammad Ilhamdi
Universitas Andalas, Indonesia
rilhamdi@ft.unand.ac.id

Sachdeva Sumit
Delft University of Technology, the Netherlands
s.sachdeva@tudelft.nl

Saczewski Jaroslaw
Medical University of Gdansk, Poland
js@gumed.edu.pl

Safdar Mehran
Isfahan Science and Technology Town, Iran
Safdar_mehran@yahoo.com

Said Awad
University of Chemical Technology and Metallurgy, Bulgaria
orgche.mawad@gmail.com

Sallin Denis
EPFL Lausanne, Switzerland
denis.sallin@epfl.ch

Scheuber Olivera
SKAN AG, Switzerland
olivera.scheuber@skan.ch

Schönenberger Christian
University of Basel, Switzerland
Christian.Schoenenberger@unibas.ch

Schöning Michael J.
Aachen University of Applied Sciences, Germany
schoening@fh-aachen.de

Secario Muhammad Khari
Chang Gung University, Taiwan
khari.secario@gmail.com

Seitz Peter
EPFL Lausanne, Switzerland
peter.seitz@sl.ethz.ch

Seitz W. Rudolf
University of New Hampshire, USA
Rudi.Seitz@unh.edu

Senesky Debbie G.
Stanford University, USA
dsenesky@stanford.edu

Shao Yuping
Harbin Engineering University, China
syp1357531@163.com

Shigihara Yoshihito
University College London, UK
y.shigihara@ucl.ac.uk

Shin Sang Hun
Konkuk University, Korea
shshin9431@gmail.com

Shinde Tukaram
Shivaji University, India
pshindetj@yahoo.co.in

Shrivastav Anand
Indian Institute of Technology Delhi, India
anand.mhn734@gmail.com

Sigrist Markus Werner
ETH Zürich, Switzerland
sigristm@phys.ethz.ch

Skierucha Wojciech
Institute of Agrophysics, Poland
w.skierucha@ipan.lublin.pl

Stăncalie Andrei
National Institute for Laser, Plasma & Radiation Physics, Romania
andrei.stancalie@inflpr.ro

Star Alexander
University of Pittsburgh, USA
astar@pitt.edu

Stiens Johan
Vrije Universiteit Brussel, Belgium
jstiens@etro.vub.ac.be

Strle Drago
University of Ljubljana, Slovenia
drago.strle@fe.uni-lj.si

Sun Xuhui
Soochow University, China
xhsun@suda.edu.cn

Sung Jin Ho
Dongguk University, Korea
madeinjinho@dongguk.edu

Szyplowska Agnieszka
Institute of Agrophysics, Poland
a.szyplowska@ipan.lublin.pl

Tabassum Rana
Indian Institute of Technology Delhi, India
ranaiitd26@gmail.com

Tan Kuoren
DSO National Laboratories, Singapore
tkuoren@dso.org.sg

Tang Jun
Tsinghua University, China
tangj_ee@mail.tsinghua.edu.cn

Tiefenauer Raphael Florin
ETH Zürich, Switzerland
tiefenauer@biomed.ee.ethz.ch

Tkacz Ewaryst
Silesian University of Technology, Poland
etkacz@polsl.pl

Tsai Yu-Chen
National Chung Hsing University, Taiwan
yctsai@dragon.nchu.edu.tw

Usha Sruthi
Indian Institute of Technology Delhi, India
sruthiprasoodu59@gmail.com

Velasquez-Villada Carlos
Universidad de los Andes, Colombia
c.velasquez@ieee.org

Vhanalkar Sharadrao
Karmaveer Hire Arts, Science, Commerce & B.C.A College, India
sharadrao.vhanalkar@gmail.com

Vidal-Verdú Fernando
Universidad de Málaga, Spain
fvidal@uma.es

Wagner Torsten
Institute of Nano- and Biotechnologies, Germany
torsten.wagner@fh-aachen.de

Walther Matthias
Cendres+Métaux SA, Switzerland
mwa@cmsa.ch

Wang Elvis
MDPI, Switzerland
elvis.wang@mdpi.com

Wang Lutang
Shanghai University, China
ltwang@mail.shu.edu.cn

Wanjiong Wu
Lanzhou University, China
wuwj2012@lzu.edu.cn

Watteyne Thomas
INRIA, France
thomas.watteyne@inria.fr

Wei Erhu
Wuhan University, China
ehwei@sgg.whu.edu.cn

Wen Chih-Yu
National Chung Hsing University, Taiwan
cwen@dragon.nchu.edu.tw

Werner Carl Frederik
Tohoku University, Japan
werner@ecei.tohoku.ac.jp

Wilczek Andrzej
Institute of Agrophysics, Poland
awilczek@ipan.lublin.pl

Wood Vanessa
ETH Zürich, Switzerland
vwood@ethz.ch

Wu Jie
Nanjing University, China
wujie@nju.edu.cn

Yacine Halfaya
Georgia Institute of Technology, France
yacine.halfaya@mpsa.com

Yang Bintang
Shanghai Jiao Tong University, China
btyang@sjtu.edu.cn

Yang Hao
Leibniz Universität Hannover, Germany
yanghao_lmu@yahoo.com

Yoetz-Kopelman Tal
Tel Aviv University, Israel
tal.yoetz@gmail.com

Yoo Wook Jae
Konkuk University, Korea
wonzip@kku.ac.kr

Yoon Sevin
Kangwon National University, Korea
sebin890723@naver.com

Yoshinobu Tatsuo
Tohoku University, Japan
nov@ecei.tohoku.ac.jp

Yuliarto Brian
Institut Teknologi Bandung, Indonesia
brian@tf.itb.ac.id

Zabow Gary
National Institute of Standards and Technology, USA
zabow@nist.gov

Zehringer Stefan
Robert Bosch GmbH, Germany
stefan.zehringer@de.bosch.com

Zhang Juan
Shanghai University, China
juanzhang@staff.shu.edu.cn

Zhang Xueji
University of Science & Technology, China
zhangxueji@ustb.edu.cn

Zhou Yaoming
Beihang University, China
zhouyaoming@buaa.edu.cn

web

WLAN:	unibas-event
Login:	eventbzpz
Password:	4isSS-2015!
Twitter Handle:	@I3S2015
Twitter Hashtag:	#I3S2015