Nano and Photonics Mauterndorf 2023

15th – 17th March 2023

Mauterndorf, Salzburg
Austria

www.nanoandphotonics.at

Table of Contents

Organizers

Univ.-Prof. Dr. Franz Aussenegg

Erwin Schrödinger Institut für Nanostrukturforschung
Karl-Franzens-Universität Graz

Universitätsplatz 5, 8010 Graz, Austria

(T) + 43 (0) 316 380 5186

(E) franz.aussenegg@uni-graz.at

Prof. Dr. Wolfgang Knoll

AIT Austrian Institute of Technology GmbH

Donau-City-Str. 1, 1220 Vienna, Austria

(T) +43 (0) 50 550 0
(E) office@ait.ac.at

Prof. Dr. Emil J.W. List-Kratochvil

Humboldt-Universität zu Berlin
Institute für Physik &Chemie, IRIS Adlershof & CSMB

Helmholtz Zentrum Berlin für Materialien und Energie GmbH

Zum Großen Windkanal 2, 12489 Berlin, Germany

(T) +49 (0)30 2093 7697
(E) emil.list-kratochvil@hu-berlin.de

Conference Content

Scope of Nano and Photonics

The purpose of this conference is to organize an informal meeting for those who are interested in photonic applications of modern nanotechnology.

One goal of this event is to create a European-wide discussion platform for state of the art work in basic research done at the various universities as well as industrial-based research and development. The location, Castle Mauterndorf, provides an ideal environment to discuss the entire range of topics without any pressure of time, particulary between the morning and afternoon sessions as well as in the evening.

Another goal is to give young students the possibility to present their work in the form of talks or poster presentations. Therefore, the Nano and Photonics seminar continues with the long-standing tradition of the Mauterndorf LASERSEMINARS.

Nanotechnology as a crossover technology enables application-based product and system innovations in different industries and has obtained worldwide importance in driving the economy. Nanophotonics is an area of nanotechnology of growing importance where breakthrough results in the development of devices and material systems are reported on a day-to-day basis. The seminars are spanned acros a wide range of topics from light emitting devices based on inorganic and organic semiconductors, through theoretical aspects of photonics to photonic structures and structuring techniques.

Information and Registration

Mauterndorf

Mauterndorf is a small village about 100 km south of the city of Salzburg close to a well known ski resort (1100 m above sea level).

The closest train station is Radstadt
(on the Track Bischofshofen – Graz).

Conference Location

The sessions will take place in the festival room of the Castle Mauterndorf.

Program

The program will be in a way so that there will be enough free time for you to have informal chats and time for all kinds of winter sports (skiing, cross country skiing, hiking, etc.).

Accomodation

There are several hotels, and bed and breakfast available for you (about 5 to 10 minutes from the castle). Please book your accomodation by yourself or via the local tourism agency:

Fremdenverkehrsverein Mauterndorf
5570 Mauterndorf, Lungau
Salzburger Land

(T) +43 (0) 64 72 79 49
(F) +43 (0) 64 72 79 49 - 27
(E) info@mauterndorf.at
(W) www.mauterndorf.at

Program and Time Table

Program and Time Line

Wednesday, 15. 3. 2023 – Afternoon

14:00 – 15:00	**Registration**
15:00 – 15:15	**Welcome**
15:15 – 15:45	**A. Pogany** (Federal Ministry for Climate Change, Environment, Energy, Mobility, Innovation and Technology, Wien/AUT) *"Austrian Research Policy in Nanotechnology and Photonics"*
15:45 – 16:15	**S. Mittler** (University of Western Ontario, Ontario/CAN) *"Waveguide Evanescent Field Microscopies for Cell- and Bacteria-Biophysics"*
16:15 – 16:45	**Coffee**
16:45 – 17:15	**G. Schitter** (Technische Universität Wien, Wien/AUT) *"AFM-Based Electrical Measurements on Device- and Wafer-Level up to 90 GHz"*
17:15 – 17:45	**B. Schwarz** (Technische Universität Wien, Wien/AUT) *"Integrated mid-infrared semiconductor laser frequency combs"*

Program and Time Line

Thursday, 15. 3. 2023– Morning

08:30 – 09:00	**W. Kern** (University of Leoben, Loeben/AUT) *"Immobilization of bisacylphosphinoxides and acylgermanes: Formation and application of photoreactive surfaces and particles"*
09:00 – 09:30	**J. Krenn** (Karl-Franzens-Universität Graz, Graz/AUT) *"Gain, lasing and photocurrents of colloidal quantum dots"*
09:30 – 10:00	**C. Kleber** (Danube Private University, Krems an der Donau/AUT) *"fs-laser treatment of Ti and Ti-alloys used for medical purposes and their surface characterization"*
10:00 – 10:30	**Coffee**
10:30 – 11:00	**G. Trimmel** (Graz University of Technology Graz/AUT) *"Perylene-Aryl-Perylene non-fullerene acceptors in organic solar cells"*
11:00 – 11:30	**P. Hurdax** (JOANNEUM RESEARCH Forschungsgesellschaft mbH, Weiz/AUT) *"OptoQuant"*
11:30 – 12:00	**P. Banzer** (Karl-Franzens-Universität Graz, Graz/AUT) *"Rethinking Sensing – Towards the Development of Next Generation Camera Technology"*

12:00 - 15:30 LUNCH BREAK

Program and Time Line

Thursday, 16. 3. 2023 – Afternoon

15:30 – 16:15	**Key Note Lecture:** **N. Hüsing** (Paris Lodron University Salzburg, Salzburg/AUT) *"Hybrid Porous Materials and Nanostructures – Design of Concave and Convex Curvatures"*
16:15 – 16:45	**W. Fritzsche** (Leibniz Institute of Photonic Technology, Jena/GER) *"Bioanalytics using plasmonic nanostructures"*
16:45 – 17:15	**K. Toma** (Shibaura Institute of Technology, Tokyo/JPN) *"Surface plasmon polaritons for label-free bioimaging and continuous biosensing "*
17:15 – 17:45	**Coffee**
17:45 – open end	**Poster Session**

Program and Time Line

Friday, 17. 3. 2023 – Morning

08:30 – 09:00	**B. Mizaikoff** (Ulm University, Ulm/GER) *"Mid-Infrared Photonics: Quo Vadis?"*
09:00 – 09:30	**M. Minunni** (Università degli Studi di Firenze, Florence/ITA) *"Recent trends in Bioanalysis: from biomimetic receptors to point-of-care drugs analysis."*
09:30 – 10:00	**J. Dostalek** (AIT Austrian Institute of Technology GmbH, Wien/AUT & Czech Academy of Sciences, Prague/CZ) *"Plasmonic Nanostructures with Responsive Polymer Interfaces for Actuating and Biosensing"*
10:00 – 10:30	**Coffee**
10:30 – 11:00	**T. Rodrigues** (Univ. Lille, Lille/FRA & AIT Austrian Institute of Technology GmbH, Wien/AUT) *"Discovery of a Peptide Nucleic Acid (PNA) aptamer for cardiac troponin I: substituting DNA with neutral PNA maintains picomolar?"*
11:00 – 11:30	**S. Fortunati** (University of Parma, Parma/ITA) *"Smart Electrochemical Biosensors Based on Innovative Receptors and Nanomaterials for Application in Point-of-Care Testing?"*
11:30 – 11:45	**Closing Remarks**

Austrian Research Policy in Nanotechnology and Photonics

A. Pogany

Federal Ministry for Climate Change, Environment, Energy, Mobility, Innovation and Technology, Wien/AUT

Photonics and Nanotechnology can contribute to solve major societal challenges of Europe with regard to energy efficiency, the ageing society, safety and security as well as the European knowledge society. These technologies are Key enabling technologies and the EC makes strong efforts to address these topics under Horizon Europe. Austria is well positioned in the photonics and nanotech area. The BMK has initiated plattforms with stakeholders from Research and Industry to network and to establish R&D-roadmaps. The BMK runs a big Research programme called “Production of the Future” which includes Nanotechnology and Photonics. Within this programm R&D-projects between research and Industry can be funded. Austria is also taking part in several ERA-Nets in photonics and nanotechnology in order to help research and industry to cooperate with partners abroad. Additionally the BMK has established a strong cooperation with China with the goal to fund R&D-Projects between Austrian counterparts and the Chinese Academy of Science and the University of Shanghai.

Actually a Strategy how digital and green transformation can be established in R&D-Policy in BMK is discussed. Some ideas will be presented.

Waveguide Evanescent Field Microscopies for Cell- and Bacteria-Biophysics

S. Mittler

University of Western Ontario, Ontario/CAN

First a short introduction into the physics principles underlying the WEF microscopies is given - evanescent fields under total internal reflection and waveguiding. Both Waveguide Evanescent Field Fluorescence (WEFF) and Waveguide Evanescent Field Scattering (WEFS) Microscopies are introduced. First examples with phase-separated Langmuir-Blodgett films of lung surfactants are shown. Then qualitative and quantitative examples with cells and bacteria are discussed as applications. For example, the dye distance maps are introduced displaying the distance of the plasma membrane of cells to the substrate giving a measure for the closeness of cell adhesions. The number of cell adhesions with respect to various biodegradable poly(ester amide) coatings is shown. Dynamic investigations about triton-X100 (surfactant) triggered 3-stage solubilization of cells are discussed. The advantages of WEFS in bacteria microscopy is shown as well as the influence of UV-sterilization on bacteria.

Ref: Waveguide Evanescent Field Fluorescence and Scattering Microscopy: The Status Quo, Optics, Photonics and Laser Technology, Springer Series in Optical Sciences 218, P. Ribeiro and M. Raposo (eds.), Springer Nature Switzerland AG, 2018.

AFM-Based Electrical Measurements on Device- and Wafer-Level up to 90 GHz

T. Hackl, M. Poik, M. Schober, **G. Schitter**

Technische Universität Wien, Wien/AUT

Atomic force microscopes (AFM) enable characterization of surfaces at nanometer resolution, including the topography as well as electrical properties.

Measuring surface charges with an AFM at high-spatial resolution is known as Kelvin-Probe force microscopy (KPFM), where in a two-pass mode a feedback controller applies a DC-offset to the AFM-tip for the compensation-based charge measurement. However, this DC-bias may cause limitations for imaging in liquid due to electrolysis, and in electronic applications due to a shift of the band gap on the device under test.

Recently various novel electrical AFM measurement modes have been developed that enable measurements without bias voltage. In AC-KPFM multiple AC-signals are applied to the AFM tip that enable compensation-based surface potential measurements [1]. An extension towards simultaneous excitation of the AFM tip electrically as well as mechanically results in a heterodyne detection that renders the measurement independent of the lift-height, reduces influence of the cantilever cone structure, and results in a better spatial resolution and measurement accuracy [2]. In AC-EFM an amplitude-modulated signal in the MHz-range is applied to the AFM tip that also enables surface potential measurements at a high spatial resolution [3].

In a second step a new AFM system is developed that extend these measurements towards radio-frequency (RF) up to several GHz, which converts the AFM into a RF-probing station on the sub-micrometer scale. This enables the characterization of electronic components and circuits directly on the device during operation and is demonstrated by measurement of the voltage distribution in RF-switches.

In an ongoing project (SuRF) this AFM-based system with specialized cantilevers is combined with a vector-network-analyzer and a conventional probing station for measurements on RF-circuits during operation directly on the device and wafer-level at frequencies up to 90 GHz. This opens up new possibilities in the development and failure analysis of RF-electronics, such as radar sensors operating at 77 GHz and devices for 5G applications.

[1] Kohl, et al., Microel. Eng. (2017)
[2] Hackl et al, I2MTC (2022)
[3] Hackl et al, patent pending #A50813/2021

Oral Presentation Abstracts

Integrated mid-infrared semiconductor laser frequency combs

B. Schwarz[1,2], F. Pilat[1], N. Opacak[1,2], S. Dal Cin[1], J. Hillbrand[1,2], M. Beiser[1], G. Strasser[1], R. Weih[3], S. Höfling[4], M. Piccardo[2], F. Capasso[2]

[1] Technische Universität Wien, Wien/AUT
[2] Harvard University, Cambridge/USA
[3] Nanoplus GmbH, Gerbrunn/GER
[4] University Würzburg, Würzburg/GER

The increasing interest in mid-infrared sensing technology demands a scalable technology.Several challenges still need to be solved in order to integration of all mid-infrared photonic components on a single chip.

An overview of previously solved challenges as well as an outlook towards monolithic single-chip spectrometers will be provided. Compact infrared sensing instruments require the elimination of all moving parts, which is why optical frequency combs are moving into the spotlight of research. The practical realization of frequency combs from laser materials with detection capabilities is presented on two technology platforms, the quantum cascade lasers(QCLs) and interband cascade lasers (ICLs). An intuitive picture of the synchronization of states in frequency combs is provided by the analogy to coupled clocks, which provides an illustrative understanding of how these lasers can be tuned into either the pulsed (amplitude modulated) or the frequency modulated (FM) comb regime. This knowledge enabled the emission of picosecond pulses in the mid-infrared at 4 µm using an ICL and at 8 µm wavelength using a QCL, respectively.

After a review on the principles of FM comb states, I will briefly explain how the presented work can be connected to the well known complex Ginzburg-Landau equation, as well as to the Lugiato-Lefever equation, opening a new direction towards electrically pumped soliton sources.

[1] J. Hillbrand et al. Nature Photonics 13, 101 (2018).
[2] B. Schwarz et al. Optica 6, 890 (2019).
[3] J. Hillbrand et al. Optica 6, 890 (2019).
[4] N. Opačak et al. Physical Review Letters 123 (2019).
[5] M Piccardo et al. Nature 572 (2020).

Immobilization of bisacylphosphinoxides and acylgermanes: Formation and application of photoreactive surfaces and particles

W. Kern [1,2], M. Müller [1], Ch. Bandl [1], M. Haas [3], M. Drusgala [3]

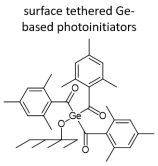
[1] University of Leoben, Leoben/AUT
[2] Polymer Competence Center Leoben GmbH, Leoben/AUT
[3] Graz University of Technology, Graz/AUT

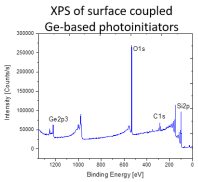
Immobilized photoinitiators are an interesting approach in surface photochemistry, providing polymerization initiating species which are employed for surface functionalization and the fabrication of nanostructured materials. Typically, photoinitiators are coupled to inorganic surfaces via trialkoxysilyl or thiol anchoring units. Employing photosensitive molecular layers, surface properties such as polarity, chemical reactivity, and optical properties can be adjusted upon light induced irradiation. Moreover, light induced trans-formations (e.g., isomerizations) are useful to confer new properties on surfaces. In combi-nation with lithographic patterning, 2D struc-tures can be generated.

In addition to planar surfaces, also inorganic particles can be functionalized with photore-active groups. Examples are (i) the addition of photoreactive fillers based on silica nano-particles bearingNorrish type I photoinitiators (e.g., tri(alkoxy)silyl functionalized acylphosphine oxides) to acrylate and thiol-ene resins as low-migration photoinitiators, and (ii) the generation of inorganic protection layers on inert polymer films and fibers (e.g., PE and PET) by attachment of azidophenyl functionalized silica particles.

The main focus of this presentation is set on recent results on a new class of photoinitia-tors based on acylgermanes. Group-14 based photoinitiators, in particular triacylhaloger-manes (X = Br and I), were prepared and equipped with different coupling units which were subsequently attached to inorganic sur-faces such as pre-activated silicon and inor-ganic particles. The generated light sensitive surfaces were then used for the polymeriza-tion of, e.g., fluorescent monomers and monomers with polar / non-polar character such as acrylamide and perfluoroalkyl acrylate. Both the surface composition and the reactivity were studied, using, e.g., FT-IR and XPS spectroscopy. Silica nanoparticles with a photoreactive shell are discussed as well. The high potential and suitable applications of this promising class of photoinitiators are highlighted.

References:
1. Sahin et al., Eur. Polym. J. **98**, 430 – 438 (2018).
2. Picu et al. Composites Sci. Technol. **183**, Article Number 107799 (2019).





Oral Presentation Abstracts

Gain, lasing and photocurrents of colloidal quantum dots

D. Grimaldi [1], M. Belitsch [1], D.N. Dirin [2], M.V. Kovalenko [2], H. Ditlbacher [1], A. Hohenau [1], **J.R. Krenn** [1]

[1] University of Graz, Graz/AUT
[2] ETH, Zürich/CH

Colloidal semiconducting quantum dots are efficient, stable and spectrally tunable emitters, but their optical gain is often limited by fast nonradiative processes. These processes are strongly suppressed in slab-shaped nanocrystals (nanoplatelets), due to relaxed exciton Coulomb interaction. We show that CdSe/CdS nanoplatelet ensembles can be shaped into simple sub-microscopic stripe waveguides that achieve lasing. We find a remarkably high gain factor of 1630 cm^{-1} and look into the details of the laser emission above threshold [1]. Our results illustrate the feasibility of geometrically simple monolithic microscale nanoplatelet lasers for a variety of photonic applications.

Besides light emission, the full understanding of charge transport in quantum dots is key to their application in photovoltaics and light detection. We investigate the photoconductance of colloidal PbS/$MAPbI_3$ quantum dots in nanoscale metal electrode gaps. By scanning photocurrent microscopy we evidence the strong localization and high reproducibility of photocurrent generation in the gap regions. With laser irradiances spanning five orders of magnitude, we find a consistent power law dependence of the photocurrent on the light intensity with an exponent of about 2/3, hinting at the charge transport dynamics. Furthermore, we probe the current dependencies on the gap bias and the exciting light wavelength, as well as the photocurrent noise levels [2].

[1] M. Belitsch, D.N. Dirin, M.V. Kovalenko, K. Pichler, S. Rotter, A. Ghalgaoui, H. Ditlbacher, A. Hohenau, J.R. Krenn, Gain and lasing from CdSe/CdS nanoplatelet stripe waveguides, Micro and Nano Engineering 17, 100167 (2022)

[2] D. Grimaldi, E. Kelderer, D.N. Dirin, M.V. Kovalenko, A. Hohenau, H. Ditlbacher, J.R. Krenn, Photoconductivity of PbS/perovskite quantum dots in gold nanogaps, Nanoscale Adv. 4, 3566 (2022)

Oral Presentation Abstracts

FS-LASER TREATMENT OF TI AND TI-ALLOYS USED FOR MEDICAL PURPOSES AND THEIR SURFACE CHARACTERIZATION

C. Kleber [1], D. Knapic [2], M. Muck [2]; J. Heitz [2], W. Baumgartner [2], A.I. Mardare [2], A.W. Hassel [1,2]

[1] Danube Private University, Krems an der Donau/AUT
[2]Johannes Kepler University Linz, Linz/AUT

Titanium and Titanium alloy (Ti6Al4V) samples were structured on a µm and nm scale by femtosecond laser treatment and subsequent electrochemical anodization in different electrolytes to influence their osseointegrational behaviour. Produced micro-cones and nano-ripples were characterized by Atomic Force Microscopy and Scanning Electron Microscopy and the composition of the formed oxide layer was analysed by XPS. In addition, the electrochemically active surface area (ECSA) was determined by CV measurements on the samples with the femtosecond laser induced structures. The osseointegrational behavior was examined using the SaOS-2 cell line which is a human osteosarcoma cell line which displays several osteoblastic features. It could be shown that the osseointegration properties of Ti and Ti alloys can be tailored by the fs-laser treatment in combination with the anodization to reach the desired properties.

Perylene-Aryl-Perylene non-fullerene acceptors in organic solar cells

G. Trimmel

Graz University of Technology, Graz/AUT

Organic solar cells are on the dawn of a new era. The change of focus towards non-fullerene acceptors has introduced an enormous amount of new organic n-type materials and has finally brought the power conversion efficiencies of organic photovoltaics into new spheres, now exceeding 19%, a value that was believed to be unreachable some years ago.

This contribution gives first an overview on the progress of organic photovoltaics and then focuses on our work on new non-fullerene acceptors (NFA)s. In the last years, we prepared a set of different perylene and perylene-aryl-perylene NFAs and, together with different conjugated polymers, applied them in organic solar cells [1]. These solar cells exhibit high open circuit voltage values well above 1.1 V. By choosing an indeno[1,2 b]fluorene moiety as aryl linker, V_{OC} values of 1.4 V could be reached in solar cells with D18 as donor polymer [2].

However, as most organic semiconductors, they typically exhibit low dielectric permittivities and are processed form halogenated solvents. Both limitations reduce their maximum efficiency as well as their attractiveness as green technology. To overcome both limitations at once, NFA molecules were modified with sulfone and sulfone-ether chains to improve the solubility in non-halogenated solvents and the permittivity via the Clausius-Mossotti relationship.

We found, that some of the new compounds show the desired combination of improved permittivity and solubility in non-halogenated solvents. This combination enabled us to fabricate solar cells in a simple bilayer setup using only non-halogenated solvents such as o-xylene and tetrahydrofuran. That way, efficiencies of over 5% were achieved together with an open-circuit voltages of around 1.3 V [3].

[1] S. Weber et al. Mater. Adv. 2020, 1, 2095 – 2106
[2] J. Hofinger et al. J. Mater. Chem. A, 2022, 10, 2888-290
[3] P. Fürk et al ACS Appl. Energy Mater. 2023, ASAP, https://doi.org/10.1021/acsaem.2c03433

OptoQuant

P. Hurdax, G. Jakpic

JOANNEUM RESEARCH Forschungsgesellschaft mbH, Weiz/AUT

According to current understanding, quantum processors should be able to solve tasks that far exceed classical computer systems in the near future.

The OptoQuant project is based on a quantum computing approach that uses trapped ions as fundamental building blocks for quantum information processing. In this approach, individual ions are trapped by electromagnetic fields and their quantum states are manipulated using laser beams. Currently, free-beam optics are typically used to perform quantum operations.

OptoQuant aims to increase the scalability of quantum computers by increasing the number of entangled ion qubits from the current 10-20 or so to 100 or more. This is to be achieved, among other things, by means of integrated optics.

The work to be reported will focus on the design and fabrication of integrated photonics, in particular the miniaturization of the required optics, using femtosecond laser lithography.

Femtosecond laser lithography is a powerful technique for creating integrated optical waveguides in the volume of transparent substrates. The process involves tightly focusing a femtosecond laser beam into the volume of substrates that are transparent to the laser wavelength used. fs lasers provide sufficient laser intensities to allow multiple photons to simultaneously cross the bandgap of the otherwise transparent material, which occurs in the process of nonlinear photoionization. As a result, these intense fs laser beams are absorbed (only) in the focal region of the laser beam, creating a free electron plasma, followed by energy transfer to the crystal lattice, leading to local structural modifications within the focal volume. The spatial resolution of this focal volume is in the µm range. Thus, moving this focal volume in 3D in the material enables the fabrication of 3D structures with high spatial resolution.

Oral Presentation Abstracts

Rethinking Sensing – Towards the Development of Next Generation Camera Technology

J. Bütow [1], J. Eismann [1,2,3], V. Sharma [1], D. Brandmüller[1], **P. Banzer** [1,2,3,4] and the SuperPixel Consortium

1University of Graz, Graz/AUT
2Max Planck Institute for the Science of Light, Erlangen/GER
3 University Erlangen-Nuremberg, Erlangen/GER
4 University of Ottawa,Ottawa/CAN

The spatial structure of light is an intriguing playground giving rise to fascinating phenomena and paving the way towards versatile applications. For instance, the polarization, phase and intensity distributions of a light field can be sculpted and engineered. Although especially phase and polarization are important information carriers storing details regarding the interactions matter of any kind and, hence, enabling a plethora of different applications, the vast majority of detectors and cameras on the market are not sensitive to these two degrees of freedom.

As part of the Horizon 2020 project 'SuperPixels' (https://www.superpixels.org/) and together with other European and international experts, we develop and apply novel all-integrated light-processing photonic circuitry. This next generation of pixels and cameras will be capable of simultaneously measuring polarization and phase distributions in addition to light's intensity. We started utilizing first prototypes of this new technology for various applications, ranging from endoscopic imaging and turbulence mitigation to nanometrology and microscopy.

In this presentation, we plan to introduce the general idea behind SuperPixels, their main building-blocks as well as their capabilities. Furthermore, we briefly highlight selected applications in the field of ultra-precise nanometrology.

Hybrid Porous Materials and Nanostructures – Design of Concave and Convex Curvatures –

N. Hüsing

Paris Lodron University Salzburg, Salzburg/AUT

The development of synthetic routes to hierarchically organized porous materials containing multiple, discrete sets of pores having disparate length scales is of high interest for a wide range of applications. One possible route towards the formation of multilevel porous architectures relies on the processing of condensable, network forming precursors (sol–gel processes) in the presence of molecular porogens, lyotropic mesophases, supramolecular architectures, emulsions, organic polymers, or ice.

In this presentation materials from sol–gel processing of non-conventional precursors with concurrently occurring microscopic and/or macroscopic phase separation for the formation of self-supporting monoliths are presented. [1,2] Starting from glycolated silanes hierarchically organized silica monoliths with isotropic macroporosity, different approaches have been applied to control the orientation of the macroporous network during gelation. One focus will be on strategies to generate mechanically flexible and functional porous structures based on organofunctional silanes as well as hybrids of silk and silica. In addition, a purely aqueous process towards deliberately shaped, hierarchically organized amorphous silica and the corresponding polycrystalline quartz analogues based on a direct ink writing process (DIW) will be presented. The resulting 3D (DIW) printed silica consists of a macroporous network of struts comprising hexagonally arranged mesopores on a 2D hexagonal lattice. Together with a printed porous superstructure on the millimeter scale, well-defined pore sizes and shapes on at least three hierarchy levels can thus be fabricated.

References

[1] A. Feinle, M.E. Elsässer, N. Hüsing, Chem. Soc. Rev. 2016, 45, 3377.

[2] F. Putz, R. Morak, M.S. Elsässer, C. Balzer, S. Braxmeier, J. Bernardi, O. Paris, G. Reichenauer,

[3] N. Hüsing, Chem. Mater., 2017, 29, 7969-7975

[4] F. Putz, S. Scherer, M. Ober, R. Morak, O. Paris, N. Hüsing, Adv. Mater. Technol. 2018, 3, 1800060.

Bioanalytics using plasmonic nanostructures

W. Fritzsche

Leibniz Institute of Photonic Technology (IPHT), Jena/GER

Today, innovative tools for diagnostics and bioanalytics are needed, to be usable outside of dedicated laboratories and with less qualified personnel, at minimal costs.

Plasmonic nanostructures promise to provide sensing capabilities with the potential for ultrasensitive and robust assays in a high parallelization and miniaturization, and without the need for markers. Upon binding of molecules, the localized surface plasmon resonance (LSPR) of these structures is changed, and can be used as sensoric readout [1]. This is possible even on a single nanostructure level, using optical darkfield detection introduced more than 100 years ago [2], as demonstrated for DNA detection [3]. In contrast to SPR, LSPR senses only in a very thin layer (on the scale of the particle diameter), resulting in an efficient background suppression [4].

In order to multiplex this approach, imaging spectrometer setups, e.g. based on a Michelson interferometer or multiple LEDs have been developed, able to readout a whole array of sensors in one step [5]. On the sensor side, microarrays of gold nanoparticle spots were fabricated using spotting of pre-synthesized gold nanoparticles [6]. Such chemically synthesized particles allow for a cost-efficient generation of highly crystalline particles as nanosensors; by using microfluidic approaches, a higher quality and reproducibility can be achieved [7]. Using this microarray approach, a multiplex DNA-based detection of fungal pathogens involved in sepsis could be demonstrated [8]. DNA-based signal amplification, e.g. by hybridization chain reaction, improves the sensitivity [9]. Beyond DNA detection, LSPR sensing is also applicable for the detection of protein targets, such as CRP [10].

References:

[1] Philosophical Transactions A 369, 3483 (2011).
[2] Angew Chem Int Ed 51, 11208 (2012)
[3] J Nanopart Res 15, 1531 (2013)
[4] Sensing and BioSensing Research 7, 62 (2016)
[5] Biosensors and Bioelectronics 81, 287 (2016), Advanced Photonics Research, in revision (2023)
[6] Analytical and Bioanalytical Chemistry 411, 1537 (2019)
[7] Chemical Engineering Journal 288 432 (2016)
[8] ACS Sensors 4, 335 (2019)
[9] Biosensors and Bioelectronics 167, 112465 (2020)
[10] Scientific Reports 12, 836 (2022)

Sugar Exposure alters the Surface Charge of Collagen Fibrils on the Nanometer Scale

K. Toma

Shibaura Institute of Technology, Tokyo/JPN

Surface plasmon polaritons (SPPs) are electromagnetic waves propagating along a metal-dielectric interface. The sensitive nature of SPPs to the refractive index near the interface has been used in imaging and sensing technologies [1-4]. In this presentation, I will introduce applications of SPPs in label-free bioimaging of cell-metal interface along with continuous biosensing of drugs.

In electrophysiology, tight and close cell adhesion to the electrode is key to attaining an electric signal with a high signal-to-noise ratio. Herein, a surface plasmon microscope (SPM) was developed to investigate the adhesion of cells to a gold surface. The developed SPM combined the lens-imaging-type SPM (LISPM) and the scanning localized SPM (SLSPM). The LISPM imaged a cell-gold interface in a large area for qualitative and real-time observation of cell adhesion, while the SLSPM allowed quantitative and local imaging of the cleft gap distance between the cell bottom membrane and a gold surface. These two SPM modes were switchable by a flipping mirror.

Since efficacy and side effects in medical treatment with drugs are two sides of the same coin, methods enabling continuous monitoring of drug concentration in the body are demanded. Here, a long-range surface plasmon (LRSP) aptasensor for vancomycin was developed for next-generation therapeutic drug monitoring. The sensor took advantage of LRSP and the aptamer: high sensitivity to changes in the refractive index and a moderate affinity to vancomycin. Combination of these unique properties of two elements, the LRSP aptasenseor achieved real-time and continuous measurement of vancomycin.

[1] B. Rothenhäusler, W. Knoll, Nature. (1988) 332.
[2] J. Homola, S.S. Yee, G. Gauglitz, Sensors Actuators B Chem. (1999) 54.
[3] K. Toma, K. Oishi, K. Iitani, T. Arakawa, K. Mitsubayashi, Sensors Actuators B Chem. (2022) 368.
[4] K. Toma, Y. Satomura, K. Iitani, T. Arakawa, K. Mitsubayashi, Biosens. Bioelectron. (2023) 222.

Oral Presentation Abstracts

Mid-Infrared Photonics: Quo Vadis?

B. Mizaikoff

Ulm University, Ulm/GER
Hahn-Schickard Institute for Microanalysis Systems, Ulm/GER

Vibrational spectroscopies - and especially infrared spectroscopy - apparently play an increasingly important role in modern biodiagnostics. This begs the question - quo vadis, where do we go from here?

With applications ranging from non-invasive exhaled breath analysis to the in-vivo assessment of cartilage damage, mid-infrared (MIR; 3-20 µm) photonics ranges among the most flexible molecular sensing platforms nowadays available. With the emergence of quantum and interband cascade laser technology, the on-chip hybridisation and/or integration of entire MIR sensing devices is on the horizon ultimately leading to IR-lab-on-chip systems. The inherent molecular selectivity of MIR signatures enables studying small molecules (e.g., volatile organic compounds; VOCs) in the gas phase, as well as biomacromolecules (e.g., proteins) in the liquid phase at unprecedented detail in a label-free and non-destructive fashion. Most importantly, the combination with advanced multivariate data evaluation algorithms facilitates analyses in real-world complex mixtures of biomedial and clinical relevance. The discussion of latest MIR photonic technologies we will be complemented by highlight applications underlining the utility of next-generation MIR photonics.

1. F. Seichter, et al., J. Breath Res. 15, 026013 (2021), DOI: 10.1088/1752-7163/ab8dcd
2. I. Vasilikos, et al., Journal of Biophotonics 13, e202000110 (2020), DOI:https://doi.org/10.1002/jbio.202000110
3. J. Glöckler, et al. ACS Sensors 5, 4, 1033–1039 (2020), DOI: 10.1021/acssensors.9b02554
4. A. Lopez-Lorente et al., Journal of Biophotonics e201800429 (2019), DOI: 10.1002/jbio.201800429
5. E. Tütüncü et al., ACS Sensors, 3, 1743-1749 (2018), DOI: 10.1021/acssensors.8b00477
6. P. Wang, et al., Analyst, 143, 5023-5029 (2018), DOI: 10.1039/c8an00924d
7. Á.I. López-Lorente et al., Microchimica Acta, 184(2), 453–462 (2017), DOI: 10.1007/s00604-016-2031-0
8. M. Sieger et al., Analytical Chemistry, 88 (11), 5562–5573 (2016), DOI: 10.1021/acs.analchem.5b04143
9. Á.I. López-Lorente et al., Analytical and Bioanalytical Chemistry, 408 (11), 2875–2889 (2016), DOI: 10.1007/s00216-016-9375-5
10. M. Sieger e al., Analytical Chemistry, 88 (5), 2558–2562 (2016), DOI: 10.1021/acs.analchem.5b04144
11. A. Wilk, et al., J. Analytical Chemistry, 85, 11205–11210 (2013), DOI: 10.1021/ac402391m
12. B. Mizaikoff, Chemical Society Reviews, 42 (22), 8683–8699 (2013), DOI: 10.1039/C3CS60173K

Oral Presentation Abstracts

Recent trends in Bioanalysis: from biomimetic receptors to point-of-care drugs analysis

Francesca Torrini [a1], Mariagrazia Lettieri [a2], Federica Battaglia [a], Simona Scarano [a], Pasquale Palladino [a], and **Maria Minunnia** [a]

[a] Università degli Studi di Firenze, Florence/ITA
[1] ETH Zurich, Zurich/CH (present address)
[2] Dublin City University, Dublin/IRE (present address)

In the last twenty years we have been witnessed to an important evolution of bioanalytical approaches moving from conventional lab bench instrumentation to simple, easy-to-use, techniques to deliver analytical responses on site, with reduced analysis times and costs. In this frame, affinity reagents production has also jointly advanced from natural receptors to animal-free produced biomimetic receptors. Among these, a new generation of sustainable receptors is gaining attention, namely neurotransmitters-derived molecular imprinted polymers (MIP), in protein affinity-based analysis thanks to their interesting and promising analytical performances. In this framework, we will discuss recent advances in plasmonic-based approaches using Surface Plasmon Resonance (SPR) spectroscopy and simple microwell-based assays. Afterwards, we will introduce a second trending line of research in bioanalysis: colorimetric assays for drugs active principles analysis. In this context, the ideation of methods for pharmaceutical products analysis in complex matrices is an important issue to address to follow the patient's health during therapies. Specifically, we will focus on innovative approaches for the detection of levodopa and carbidopa in commercial Parkinson's drugs.

Finally, novel nanomaterials, such as copper nanoclusters (CuNCs), which have shown extraordinary optical properties leading to an efficient analytical signal enhancement, will be presented.

References:

Torrini F. et al. Biosens. Bioelectron. 2023, 220, 114806;

Torrini F. et al. Biosens. Bioelectron. 2022 217, 114706;

Torrini F. et al. Anal. Bioanal. Chem 2022, 414(18), pp. 5423–5434;

Torrini F. et al. Anal. Chim. Acta. 2021, 1161, 338481;

Lettieri M. et al. Anal. Bioanal. Chem., 2022, 414(23), 6911–6918;

Lettieri M. et al. Sensor Actuators Reports, 2022, 4, 100108;

Lettieri M. et al. Anal. Bioanal. Chem. 2022, 414(4),1713–1722;

Lettieri M. et al. Mikrochim. Acta 2021,188 (4), 116,

Plasmonic Nanostructures with Responsive Polymer Interfaces for Actuating and Biosensing

S. Fossati[1], D. Cattozzo Mor[2], Y. Morozov[1], K. Schmidt[1], F. Diehl[3], U. Jonas[3], **J. Dostalek**[1,2,4]

[1]Austrian Institute of Technology GmbH, Tulln/AUT
[2]Institute of Physics of the Czech Academy of Sciences, Prague/CZ
[3]University of Siegen, Siegen/GER
[4] Danube Private University, Krems an der Donau/AUT

Metallic nanostructures support surface plasmon modes that originate from collective oscillations of charge density and are associated with increased intensity of electromagnetic field and local density of optical states. Such optical resonances increasingly find use in bioanalytical technologies for efficient probing of chemical and biological species including surface plasmon resonance–based affinity biosensors as well as surface enhanced optical spectroscopy methods. The interface of metallic nanostructures needs to then facilitate several key functionalities including the specific capture of target molecular species, resistance to fouling from other abundant molecules, and their resonances need to be tuned to desired spectral windows. The talk will cover responsive hydrogels for plasmonic biosensors and rapid actuating of plasmonic nanomaterials. [1] We will report on precise crosslinking and attachment of an open polymer network structure to the metallic surface by using UV or two-photon absorption process followed by the postmodification with desired biofunctional groups [2]. As illustrated in the Figure below, characterization of rapid swelling and collapsing of the pNIPAAm-based hydrogel thin films by the use of plasmonic heating [3], employment for dual amplification strategies [4], and reversible tuning of surface plasmon modes [5] will be discussed. In conjunction with additional rolling circle amplification, a route towards facile single molecule detection will be presented [6].

[[1] F. Diehl, et al., Chem. Soc. Rev., 2022, 51, 3926
[2] N. Quilis et al, J. Phys. Chem. C, 2020, 124, 5, 3297-3305
[3] S.K.Auer et al., J. Phys. Chem. B, 2022, 126, 16, 3170–3179
[4] S. Hageneder et al., ACS App. Mat. & Interfaces, 2021, 13, 27645-27655
[5] N. Quilis, Adv. Opt. Mat., 2019, 1900342
[6] K. Schmidt et al, ACS Applied Materials & Interfaces, 2022, in press.

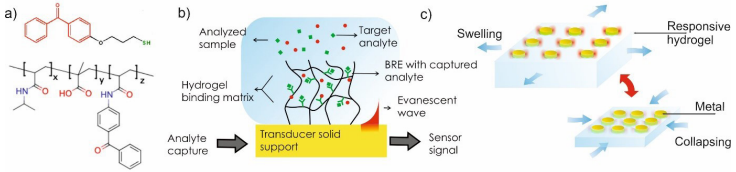


Figure: Schematics of a) polymer toolkit employed for b) construction of an affinity biding matrix and c) modulating period of gold nanoparticle arrays by external stimulus.

Oral Presentation Abstracts

Discovery of a Peptide Nucleic Acid (PNA) aptamer for cardiac troponin I: substituting DNA with neutral PNA maintains picomolar affinity and improves performances in graphene field-effect transistors (gFET)

T. Rodrigues [1,2], F. Curti [2,3], Y. R. Leroux [4], A. Barras [1], Q. Pagneux [1], H. Happy 1, C. Kleber [5], R. Boukherroub [1] S. Volpi[3], M. Careri [3], R. Corradini [3*], S. Szunerits [1,5*] and W. Knoll [2]

[1] Univ. Lille, Lille/FRA
[2] AIT Austrian Institute of Technology GmbH, Tulln/AUT
[3] University of Parma, Parma/ITA
[4] Univ. Rennes, Rennes /FRA
5 Danube Private University, Krems/Austria

Electrolyte-gated graphene field-effect transistors (EG-GFETs) to detect relevant analytes in the human body and in our surrounding environment are considered a key technology to tackle society's health and/or environmental needs [1], [2]. They expect to excel the commercialized biosensors that today require high costs, and long-assay times to achieve a proper diagnosis. DNA-based aptamers are widely employed as receptors due to their tuneable affinity and specificity toward their targets [3]. The use of peptide nucleic acids (PNAs) has instead proven challenging for this purpose, due to the absence of selection methods for the independent discovery of suitable receptors and due to the difficult mimicry of established DNA-based ones [4]. Despite PNAs exceeding homologous DNA or RNA in terms of complementary base pairing, they can fail to reproduce alternative modes of binding because of their different structural features (i.e., neutral, pseudopeptide- vs anionic, sugar-phosphate backbone) [5]. On the other hand, the remarkable stability and charge distribution of PNAs could be beneficial to produce sensing receptors, especially in the development of electronic devices such as field-effect transistor-based (FET) biosensors. We hereby report the identification of the first high-affinity PNA aptamer for a cardiac Troponin I (cTnI), a biomarker of acute myocardial infarction. The PNA aptamer was included in a graphene-based FET (gFET) transducer, and its ability in the direct detection of cTnI was compared with that of a DNA-based one having the same sequence. Similar dissociation constants were obtained for both receptors in 0.01× PBS, as well as comparable detection limits of 6.0 ± 1.0 pg mL^{-1} (PNA aptamer) and 3.3 ± 0.7 pg mL^{-1} (DNA aptamer). Apart from the non-trivial demonstration that a PNA can behave as an aptamer, the tested receptor proved to be more consistent upon working in more complex biological matrices.

References

[1] A. Gao et al., Sci. Reports 2016 61, vol. 6, no. 1, pp. 1–9, Mar. 2016, doi:10.1038/srep22554.

[2] Y. Syu et al., Devices and Clinical Applications," 2018, doi: 10.1149/2.0291807jss.

[3] B. Deng et al., Anal. Chim. Acta, vol. 837, pp. 1–15, 2014, doi: 10.1016/j.aca.2014.04.055.

[4] P. Jolly et al., Biosens. Bioelectron., vol. 123, no. June 2018, pp. 244–250, 2019, doi: 10.1016/j.bios.2018.09.006.

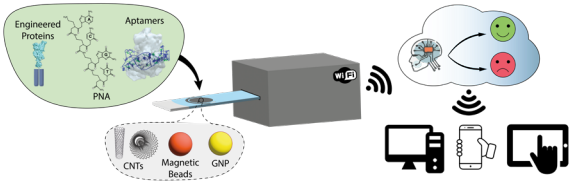
[5] R. Oliveira et al., Trends Biotechnol., vol. 40, no. 5, pp. 549–563, May 2022, doi: 10.1016/J.TIBTECH.2021.09.011.

Smart Electrochemical Biosensors Based on Innovative Receptors and Nanomaterials for

S. Fortunati, M. Giannetto, A. Bertucci, R. Corradini, V. Bianchi, A. Boni, I. De Munari, M. Careri

University of Parma, Parma/ITA

Clinical diagnostics has traditionally relied upon methods for the analysis of biological samples from patients, which consist of several steps, ranging from the collection of biological fluids or tissues to analysis in a dedicated laboratory, where the samples can be further subjected to different treatments and analysis steps. As a result, the whole process is not only expensive but also time-consuming, which is a critical issue especially for the diagnosis of severe diseases that require timely intervention. Taking into account these limitations, it is evident that Point-of-Care (PoC) tests represent a valuable tool for the development of innovative diagnostics technologies. In fact, PoC devices are generally cheap, rapid, robust and allow diagnosis to be performed directly at the point of need, i.e. at hospital facilities or, in some cases, even at the patient's home. In this context, electrochemical genosensors and immunosensors find numerous applications by integrating the possibility of using innovative receptors, such as DNA mimics, aptamers, antibodies and engineered proteins, with micro- and nano-substrates for immobilization, such as carbon nanotubes, gold nanoparticles and micromagnetic particles. Thanks to their compactness and portability, these devices can also feature on-board wireless connection that allows integration into smart environments, such as the Internet of Things (IoT). Through these protocols, data is encrypted and transferred to a cloud service for storage and/or further processing through advanced data treatments (e.g., Machine Learning). Finally, from the cloud the results can then be transferred to the device of the selected user or physician. This represents a great advantage for clinical applications since it allows to build a repository of patients' data for long-term monitoring of specific markers and to share analysis results in real time Furthermore, IoT also has a major impact on reducing healthcare costs significantly and improving treatment outcomes.



Poster Abstracts

List of Posters

Mechatronic Lock-In Amplifier for Dynamic Atomic Force Microscopy Measurement Modes

M. Poik, T. Hackl and G. Schitter

TU Wien, Wien/AUS

Dynamic Atomic Force Microscopy (AFM) imaging modes are widely used for the characterization of surfaces with sub-nanometer resolution. The AFM cantilever is excited close to one of its mechanical resonance frequencies and the interaction forces with the sample lead to a modulation, i.e. a low-frequency variation of amplitude and phase shift, of the cantilever oscillation. The measurement of amplitude and phase, which requires the demodulation of the cantilever oscillation, is therefore a crucial part of the control structure in dynamic AFM imaging modes. The demodulation is typically performed with digital lock-in amplifiers, which require high resolution ADCs with sampling frequencies of up to hundreds of MHz.

In this work, dynamic AFM measurement modes are implemented using self-sensing cantilevers with integrated piezoresistive elements and a mechatronic lock-in amplifier, which enables a simplified measurement and demodulation of the cantilever oscillation. To this end, two piezoresistive elements are configured in separate bridge circuits which are supplied by in-phase and quadrature sinusoidal signals, thus integrating the lock-in technique in the sensor electronics [1].

The mechatronic lock-in amplifier is integrated with a commercial AFM system and the imaging performance is compared to the results obtained using a conventional lock-in amplifier for demodulation. To verify the applicability of the method for AFM imaging, topography and phase measurements are performed using Amplitude Modulation AFM (Tapping Mode) with simultaneous phase imaging. The results show that that the mechatronic demodulation method enables a reduction of the sampling frequency by a factor of 100 without loss of imaging performance [2].

[1] M. Poik et al., IEEE Trans. on Instr. and Meas. 70 (2020)
[2] M. Poik et al., I2MTC (2022)

AC Kelvin Probe Force Microscopy Enables Charge Mapping in Water

T. Hackl [1], P. Mesquida [1,2], M. Poik [1], G. Schitter[1]

[1] TU Wien, Wien/AUS
[2] King's College London, London/UK

Kelvin probe force microscopy (KPFM) is an atomic force microscope (AFM) measurement mode for the determination of the local electric surface potential distribution. Surface potentials and charge distributions at the nanoscale are a very important surface properties, as they greatly affect the physical and chemical interaction of the carrier with its environment. KPFM has therefore been used in a wide variety of scientific fields, such as corrosion studies, analysis of dopant profiles on semiconductors or even biological applications.

Measuring the surface potential is achieved by modulating the electrostatic interaction of the scanning probe to the sample by the application of an ac voltage. The electrostatic force on the probe is nullified by controlling an additional dc voltage between the conducting cantilever (=probe) and the sample, which directly leads to the surface potential.

However, in some applications such a dc bias can deteriorate the measurements or can even have a negative impact on the sample. Semiconductors, often examined by KPFM, show a dependence on the dc voltage as it induces band bending and leads to an invasive measurement. Biological samples often need to be studied in an aqueous solution, where the application of a dc bias leads to electrochemical reactions or gas formation due to electrolysis, making any controlled measurement impossible.

To address this issue a new AFM measurement mode is discussed [1], which removes the need for a dc bias while keeping the advantages of closed-loop operation. Recent development focuses on adopting the mode for measurements in water with a specific ionic concentration [2] and to increase its spatial resolution [3], which is important when measuring on sub-micrometer samples such as nanoparticles or biomolecules.

[1] D. Kohl, et al., Microel. Engineering 176 (2017) 28-32
[2] T. Hackl, et al., ACS Nano 16 (2022) 17982-17990
[3] T. Hackl, et al., IEEE Trans. Instrum. Meas. (2022)

Poster Abstracts

Gold-Mediated Exfoliation of millimeter-scale MoS2 Monolayers and their use in high transconductance Electrolyte Gated Field Effect

M. Heyl[1], D. S. Rühl[1], S. Grützmacher[1], F. Gärisch[1], S. Blumstengel[1], G. Ligorio[1], E. J. W. List-Kratochvil[1,2]

[1] Humboldt-Universität zu Berlin, Berlin/GER
[2] Helmholtz-Zentrum für Materialien und Energie GmbH, Berlin/GER

The efforts to reach the monolayer limit of transition metal dichalcogenides (TMDCs), are motivated by a whole set of interesting properties accompanying two-dimensional TMDCs, e.g., rich exciton physics, and the “only-surface-no-bulk” character. This extreme surface-to-volume ratio makes devices from monolayers exceptionally sensitive to changes in their surroundings, giving potential for applications in sensing devices. However, the isolation of high-quality, large-area TMDC monolayers still poses a key challenge. On this note, scalable gold-mediated exfoliations attracted broad attention to supersede the traditional scotch tape method. Herein, a gold-mediated exfoliation based on a low-temperature annealing is presented. The exfoliation achieves scaling with parent crystal areas, placing it on par with previously reported methods. The process is benchmarked using MoS2 as prototypical TMDC and millimeter-scale monolayers are successfully exfoliated and transferred. With large-scale high-quality monolayers unlocked, we show that electrolyte gated devices operated in an aqueous environment provide for promising transducing elements for (bio)sensor applications. Looking forward, these results pave the way for additional neuromorphic functions co-implemented in the sensing platform, enabled by the tuneability of the stimuli response by simply modifying the monolayer interface.

Poster Abstracts

ORGANIC SYNAPTIC DIODES BASED ON POLYMERIC MIXED IONIC-ELECTRONIC CONDUCTORS

F. Gärisch [1], G. Ligorio [1], P. Klein [2], M. Forster [2], U. Scherf [2], E. J. W. List-Kratochvil [1,3]

[1] Humboldt-Universität zu Berlin,Berlin/GER
[2] Wuppertal Center for Smart Materials and Systems CM@S, Wuppertal/GER
[3] Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin/GER

Neuromorphic devices are likely to be the next evolution of computing, allowing to implement machine learning within hardware components. In biological neural systems, learning and signal processing are achieved by communication between neurons through time-dependent ion flux in the synapses. Integrating such ion-mediated operating principles in neuromorphic devices could deliver an energy efficient and powerful technology. Here we revisit and modify a device known as a light-emitting electrochemical cell, exploiting its ability to modulate current through ion accumulation/depletion at the electrodes and turn it into an organic synaptic diode. This two-terminal device is based on an organic mixed ionic-electronic conducting polymer that serves as active layer for conduction of lithium ions as well as charge carriers. The ionic conduction properties are modified by cryptand molecules, able to reversibly capture ions. The device can be reliably switched between states for at least 100 cycles and displays state retention for multiple minutes. The applicability for neuromorphic applications is further demonstrated by exploring frequency-dependent plasticity and paired-pulse facilitation behaviour in the millisecond range. The polymeric nature, combined with the simple two-terminal architecture of the presented neuromorphic device opens up a range of possibilities regarding the fabrication of artificial neural networks..

Coherent & Incoherent Energy transfer in ML-WS_2-metal and ML-WS_2-organic heterostructures

N. Zorn Morales [1], N. Severin [1], S. Rühl [1], S. Sadofev [2], E. J. W. List-Kratochvil [1,3], S. Kirstein [1], S. Blumstengel [1]

[1] Humboldt-Universität zu Berlin, Berlin/GER
[2] Leibniz-Institut für Kristallzüchtung (IKZ), Berlin/GER
[3] Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin/GER

Van der Waals heterostructures consisting of a 2D transition metal dichalcogenide (TMDC), organic molecules and metallic films/ nanostructures hold the promise to benefit from synergy effects that enhance optoelectronic properties of such systems e.g. to manipulate and enhance light emission. Studies on energy transfer (ET) in such systems have until now mostly focused using a TMDC as an acceptor. In this contribution, we discuss an incoherent ET from monolayer (ML) WS2 to an organic dye molecule (ATTO 725) as well as a coherent ET between a ML WS2 and a surface plasmon polariton (SPP) of a thin silver film.

The ET from WS2 to ATTO 725 was confirmed by time correlated single photon counting (TCSPC), photoluminescence (PL) micro-spectroscopy, and PL excitation (PLE) spectroscopy. TCSPC shows a reduced PL lifetime of the A exciton of WS2 after deposition of the organic dye suggesting an ET efficiency of about 70%. The PLE spectrum of the WS2/ATTO 725 hybrid sample recorded at the emission energy of the dye molecule reproduces clearly the absorption spectrum of the WS2 monolayer proving that the exciton energy is transferred to the dye as an acceptor. Since any type of energy transfer happens on length scales of less than 10 nm, these results suggest that the ET to the molecule could serve to locally probe the optical response of TMDCs beyond the optical resolution limit as well as a route to fabricate single photon sources.

Coupling of excitons of ML-WS2 with propagating SPPs of a thin Ag film is studied by spectroscopic ellipsometry in total internal reflection geometry. Anti-crossing and Rabi splitting provide evidence for strong coupling between the A exciton of ML-WS2 and the SPP while B and C excitons couple only weakly. In such planar configuration, electric field tuning of the optical response of TMDCs could be employed to actively control of the exciton-plasmon coupling strength for the construction of novel plasmonic devices.

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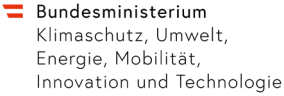

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