5th Erwin Schrödinger Symposium 2023
of the Erwin Schrödinger Society for Nanosciences

„Challenges in Nanoscience & Application"

March 13-15, 2023
Mauterndorf Castle, Mauterndorf
Salzburg, Austria
https://esg-nano.ac.at/

Committee: Oskar Armbruster, Fadi Dohnal, Eva-Kathrin Ehmoser, Wolfgang Kautek, Aida Naghilou, Sandra Stroj

Foreword

The **5th Erwin Schrödinger Symposium 2023** of the Erwin Schrödinger Society for Nanosciences **"Challenges in Nanoscience & Application"** aims to stimulate vivid scientific communication and discussion in synthetic, biogenetic, and biomimetic interfacial nanosciences in relation to their fabrication methods, characterization properties, size effects, applications, and modeling of features and structures.

This symposium is organized by the Erwin Schrödinger Society for Nanosciences in a series of successful predecessor events, the **1st Erwin Schrödinger Symposium 2014 "Two Dimensional Nanostructures"** (November 2014, Vienna, Austria), the **2nd Erwin Schrödinger Symposium 2016 "Zero Dimensional Nanostructures: Science and Technology of Nanoparticles"** (May 2016, Vienna, Austria), the 3rd Erwin Schrödinger Symposium 2018 "Progress in Interfacial Nanosciences" (July 2018, Dornbirn, Austria), and the **4th Erwin Schrödinger Symposium 2021 "Advanced Materials"** (January 2021, online).

International invited experts will illustrate the importance of interfacial nanosciences in future applications. Scientists can contribute their recent research in poster sessions. The conference features active discussions in oral and poster sessions. Due to the coherent theme of the conference, no parallel sessions are planned so that full participation is possible.

Vienna, Dornbirn; March 2023

The Organizing Committee

Oskar Armbruster
Fadi Dohnal
Eva-Kathrin Ehmoser
Wolfgang Kautek
Aida Naghilou
Sandra Stroj

Sponsors

Erwin Schrödinger Society for Nanosciences
c/o University of Natural Resources and Life Sciences, Vienna
Institute for Synthetic Bioarchitectures
Muthgasse 11/II
1190 Wien, Austria
https://esg-nano.ac.at/

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1030 Wien, Austria
https://www.bmk.gv.at/

University of Natural Resources and Life Sciences, Vienna
Institute for Synthetic Bioarchitectures
Muthgasse 11/II
1190 Wien, Austria
https://boku.ac.at/nano/synthbio/

University of Vienna
Department of Physical Chemistry
Währinger Straße 42
1090 Wien, Austria
https://pchem.univie.ac.at/

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Hochschulstraße 1
6850 Dornbirn, Austria
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Program

Monday, March 13, 2023

08:30 – 09:00 **Registration**
09:00 – 09:15 **Opening and greetings**
09:15 – 09:45 **L01** Armin Gölzhäuser (Bielefeld University, DE)
Carbon nanomembranes (CNMs): 2D materials for osmosis and water purification
09:45 – 10:15 **L02** Peer Fischer (Ruprecht Karl University of Heidelberg and Max Planck Institute for Medical Research, DE)
Nanostructures in motion
10:15 – 11:45 **Posters:** Short lectures and session (with coffee)
11:45 – 12:15 **L03** Ille C. Gebeshuber (TU Wien, AT)
Biomimetic nanotechnology insights for growing technical devices in functional shape

12:15 – 17:00 **Free discussion**

17:00 – 17:15 **Coffee**
17:15 – 17:45 **L04** Thomas Klar (Johannes Kepler University Linz, AT)
Sub-diffractional optical lithography beyond acrylates
17:45 – 18:15 **L05** Christian Zafiu (University of Natural Resources and Life Sciences, Vienna, AT)
Challenges in nanoscience & application
18:15 – 18:45 **L06** Ueli Heiz (Technical University of Munich, DE)
Photochemistry and photocatalysis of alcohols on bare and metal cluster-loaded TiO_2(110)

Tuesday, March 14, 2023

09:00 – 09:30	**L07**	Joris van Slageren (University of Stuttgart, DE) *Molecular nanomagnets for data storage and quantum technology*
09:30 – 10:00	**L08**	Armando Rastelli (Johannes Kepler University Linz, AT) *Semiconductor nanostructures for quantum science and technology*
10:00 – 10:30	**L09**	Alois Lugstein (TU Wien, AT) *Silicon and Germanium nanostructures for electrical, optical and plasmonic applications*
10:30 – 10:45	**Coffee**	
10:45 – 11:15	**L10**	Thomas Werzer (imd BIOTECH GmbH, AT) *From structure to function: S-layers as novel diagnostic tools*
11:15 – 11:45	**L11**	Aida Naghilou (Medical University of Vienna, AT) *Crystallinity and stiffness of spider silk affect the migration of Schwann cells*
11:45 – 12:15	**L12**	Eva-Kathrin Ehmoser (University of Natural Resources and Life Sciences, Vienna, AT) *Colloidal stabilized core-shell particles for preservation of bioactive compounds*
12:15 – 17:00	**Free discussion**	
17:00 – 17:15	**Coffee**	
17:15 – 15:45	**L13**	Nadezhda M. Bulgakova (HiLASE Centre, CZ) *Selective ultrashort laser annealing of amorphous Ge/Si multilayer stacks: experiment and theory*
17:45 – 18:15	**L14**	Wolfgang Kautek (University of Vienna, AT) *Physicochemical issues in cultural heritage science*
18:15 – 18:45	**L15**	Josef Freudenstein (University of Regensburg, DE) *Attosecond clocking of correlations in quantum materials*

Wednesday, March 15, 2023

09:00 – 09:30	**L16**	Thomas Lippert (Paul Scherrer Institute, CH) *Ablation plume analysis to understand problems of pulsed laser deposition*
09:30 – 10:00	**L17**	Thomas Bein (Ludwig Maximilian University of Munich, DE) *Controlling optoelectronic processes in covalent organic frameworks*
10:00 – 10:30	**L18**	Sarah Skoff (TU Wien, AT) *Nanophotonics for sensing applications*
10:30 – 10:45	**Coffee**	
10:45 – 11:15	**L19**	Johannes Heitz (Johannes Kepler University Linz, AT) *Antiadhesive bionic combs for handling of nanofibers*
11:15 – 11:45	**L20**	Nikita Vashistha (Friedrich Schiller University Jena, DE) *Wavelength and decay time tuning of intraband transitions in low spatial frequency laser-induced periodic surface structures*
11:45 – 12:15	**L21**	André Gazso (Austrian Academy of Sciences, AT) *The role of technology assessment and foresight in governing emerging technologies. The case of nanomaterials.*
12:15 – 12:30	**Closing remarks**	

Lecture Abstracts

L01

Carbon nanomembranes (CNMs): 2D materials for osmosis and water purification

Armin Gölzhäuser

Bielefeld University

To achieve osmotic water transport, nature utilizes membrane proteins (aquaporins) with only 0.3 nm wide channels that efficiently transport water molecules in a “single-file” motion across cell membranes but block all ionic species. This has inspired the creation of artificial membranes with similar “sub-nanometer” channels that combine rapid water flow with superior ion rejection. We show that 1.2 nm thick carbon nanomembranes (CNMs) made from cross-linking of terphenylthiol (TPT) self-assembled monolayers possess an extremely high pore density of one sub-nm channel per square nanometer [1]. It will be demonstrated that TPT CNMs efficiently hinder the translocation of ions, including protons, while they let water molecules rapidly pass through [2]. Their membrane resistance reaches ~10000 Ω cm^2 in 1 M Cl^- solutions, comparable to lipid bilayers of a cell membrane. Consequently, a single CNM channel yields a much higher resistance than pores in lipid membrane channels and carbon nanotubes. The ultra-high ionic exclusion by CNMs is likely dominated by a steric hindrance mechanism, coupled with electrostatic repulsion, surface functional groups and entrance effects. We demonstrate the operation of TPT CNMs as semipermeable membranes in forward osmosis, and discuss possible applications. Our observations highlight the potential of utilizing CNMs for water treatment and open up avenues to create 2D membranes through molecular self-assembly for highly selective and fast separations.

[1] Y. Yang, P. Dementyev, N. Biere, D. Emmrich, P. Stohmann, R. Korzetz, X. Zhang, A. Beyer, S. Koch, D. Anselmetti, A. Gölzhäuser, ACS Nano 2018, 12, 4695.

[2] Y. Yang, R. Hillmann, Y. Qi, R. Korzetz, N. Biere, D. Emmrich, M. Westphal, B. Büker, A. Hütten, A. Beyer, D. Anselmetti, A. Gölzhäuser, Adv. Mater. 2020, 1907850.

L02

Nanostructures in motion

Peer Fischer

Heidelberg Univ. and Max Planck Institute for Medical Research

Microorganisms can move in complex media, respond to the environment and self-organize. The field of nano- and microrobotics takes inspiration from nature and strives to achieve these functions in synthetic systems. However, building synthetic motors and machines ‘bottom up’, such that they can mimick biological matter and function autonomously or such that they can be controlled externally, is challenging. Symmetry-breaking appears to be a pre-requisite for achieving many interesting functions including locomotion, but is difficult to realize with most colloidal and molecular systems. I will discuss how one can nevertheless obtain motion in micro- and nanocolloidal systems. A physical vapor deposition process is described that permits us to obtain large numbers of designer micro- and nanostructures with defined shape and material composition. These enable a number of applications, including as nanopropellers that can penetrate biological tissue, and as self-propelled autonomous chemical nanomotors. Whether these ideas can be extended to the molecular scale is currently being debated and I will discuss recent diffusion measurements that address this question.

L03

Biomimetic nanotechnology insights for growing technical devices in functional shape

Ille C. Gebeshuber, R. W. van Nieuwenhoven

Institute of Applied Physics, TU Wien

Currently, there is a huge difference between growth in organisms on the one hand and the production of technical devices, buildings, textiles and further human produce on the other hand. Growing man-made devices in functional shape, with locally available materials and using water-based chemistry at ambient conditions, that additionally serve as food or fertilizer at the end of their lifetime, is still a challenge for nanoscientists. Plants, animals and microorganisms, on the other hand, excel in this realm - the natural nanoscience of growth is still unsurpassed.

Multiple non-plant organisms have developed ways to manipulate the growth of plants to their advantage. Gall wasps for example chemically and locally reprogram plant cells that then grow into shapes that are based on functional nanostructures providing shelter and food for the galls offspring. Biomimetic transfer of such approaches from gall wasps to the human sphere shall pave our way to a new type of growth-based nanoscience.

The invited lecture gives an overview of the related biological control of growth in plants by parasites and introduces plant growth simulation algorithms and computer-based approaches that simulate the growth of leaves into the development of gall-like structures - a first and important step in the direction of controlled growth of technical devices in functional shape.

L04

Sub-diffractional optical lithography beyond acrylates

Sourav Islam, Georgii Gvindzhiliia, Clemens Schwaiger, Thomas A. Klar

Institute for Applied Physics, Johannes Kepler University Linz, 4040 Linz, Austria

Stimulated emission depletion (STED) microscopy proved to break the diffraction limit of resolution. Besides, it was proposed already in the early experimental reports that the STED-confined excitation volume should be applicable to spatially control chemical reactions on the nanometre scale [1]. Meanwhile, this prediction has been experimentally realized in optical nanolithography using radical polymerization of negative tone resists, most of them (meth)acrylates [2-4]. To the best of our knowledge, this concept has not been transferred to optical nanolithography applying cationic polymerization, so far. This is a great pity, because, for instance, epoxy-based resins define todays clean-room standard. Our most current work focusses on this topic. We have managed to find a formulation of cationic epoxy resins which allow for STED-inspired super-resolution in optical lithography using visible and near-IR wavelengths [5]. Besides, we also found a formulation for the class of poly-thiophenes with which we wrote substantially sub-diffractional lines [6].

[1] Klar, T. A.; Hell, S. W., Subdiffraction resolution in far-field fluorescence microscopy. Opt. Lett. 1999, 24 (14), 954-956.
[2] Li, L.; Gattass, R. R.; Gershgoren, E.; Hwang, H.; Fourkas, J. T., Achieving l/20 Resolution by One-Color Initiation and Deactivation of Polymerization. Science 2009, 324 (5929), 910-913.
[3] Fischer, J.; Wegener, M., Three-dimensional direct laser writing inspired by stimulated-emission-depletion microscopy. Opt. Mat. Exp. 2011, 1 (4), 614-624.
[4] Wollhofen, R.; Katzmann, J.; Hrelescu, C.; Jacak, J.; Klar, T. A., 120 nm resolution and 55 nm structure size in STED-lithography. Opt. Exp. 2013, 21 (9), 10831-10840.
[5] Islam, S.; Sangermano, M.; Klar, T. A., unpublished. 2023.
[6] Gvindzhiliia, G.; Schwaiger, C.; Klar, T. A., unpublished 2023.

L05

Challenges in nanoscience & application

Christian Zafiu

University for Natural Resources and Life Sciences, Vienna; Department of Water, Atmosphere and Environment (WAU); Institute of Waste Management and Circularity

Nanotechnology has attracted much attention over the past two decades and enabled new and exciting technologies that found their way into consumers products. Despite the clearly useful properties of nanomaterials, concerns were raised on the safety of such materials as they can be highly reactive and mobile in the environment. Therefore, (environmental) safety aspects must be taken into account, that are accompanied by toxicity and fate studies. In both (toxicity and fate studies) the complex transformation pathways of nanomaterials must be considered too, which depend on properties of the nanomaterial as well as the environment. For the analysis of such materials, the situation becomes even more complex due to the presence of natural nanoparticles and the expected low environmental concentrations of nanoparticles.

This talk will provide an overview of challenges and solutions in understanding the fate of nanoparticles in environmental studies and their impact towards environment and health. It will cover the field of nano-analytics and provide insight into environmental transport and risks.

L06

Photochemistry and photocatalysis of alcohols on bare and metal cluster-loaded TiO_2(110)

Martin Tschurl, Moritz M.J. Eder, Philip Petzoldt, Ueli Heiz

Technische Universität München - School of Natural Sciences - Lehrstuhl für Physikalische Chemie

The energy transported as sunlight to the earth's surface is hardly utilized anywhere near its full potential by mankind, even though the total amount of energy reaching earth exceeds the demands of modern civilization by orders of magnitude. In this regard, heterogeneous photocatalysis is a potential key methodology for energy storage. For example, photocatalytic CO_2 reduction, water splitting, or decomposition of toxic organic compounds have been shown to be well feasible. However, a major drawback lies in the fact that the photocatalysts developed to this day lack efficiency, independent of the reaction they have been designed for. Their improvement is therefore strictly necessary for applicability, and potentially very rewarding given the possibilities. For example, hydrogen evolution by photo(electro)catalytic methods would be an economically competitive technology if the catalytic efficiency was sufficiently high.

Here we report on mechanistic investigations of the alcohol photo-oxidation on Pt and Ni cluster-loaded TiO_2(110) [1,2]. The photoreforming of alcohols is particularly interesting. Not only are alcohols hydrogen carriers and precursors for biomass; they also provide a rich chemistry due to a variety of different bonds, and their oxidation products are of considerable chemical and economical value.

[1] Courtois, Carla; Eder, Moritz; Kollmannsberger, Sebastian L.; Tschurl, Martin; Walenta, Constantin A.; Heiz, Ueli: Origin of Poisoning in Methanol Photoreforming on TiO2(110): The Importance of Thermal Back-Reaction Steps in Photocatalysis. ACS Catalysis 10 (14), 2020, 7747-7752

[2] Courtois, Carla; Eder, Moritz; Schnabl, Kordula; Walenta, Constantin A.; Tschurl, Martin; Heiz, Ulrich: Reactions in the Photocatalytic Conversion of Tertiary Alcohols on Rutile TiO2(110). Angewandte Chemie International Edition, 2019

L07

Molecular nanomagnets for data storage and quantum technology

Joris van Slageren

University of Stuttgart

Molecular nanomagnets can display bistable magnetization of purely molecular origin due to large magnetic anisotropy. In addition, rational chemical design has allowed quantum coherence times approaching the millisecond regime. Beyond their synthetic adaptibility, molecular qubits have an advantage in being easily ordered in arrays. Furthermore, few-qubit systems can be made with finely tunable interaction strengths.

I will present the state of the art, as well as aims and challenges of the field. I will highlight our own work in improving magnetic bistability and coherence times guided by acquiring detailed understanding of the origin of the relevant properties. Furthermore, I will discuss recent work on the spin dynamics of strongly coupled hybrid systems of spin ensembles and microwave resonators, on the study of the interaction of molecular qubits with mobile charge carriers, and on self-assembled monolayers of molecular quantum bits. Finally, I will present first efforts to develop and utilize two-qubit systems.

L08

Semiconductor nanostructures for quantum science and technology

Armando Rastelli

Johannes Kepler Universität Linz

Semiconductor quantum dots (QDs) are nanostructures capable of confining the motion of electrons and holes in all spatial directions, giving rise to light emission spectra similar to those of atoms. Similar to atoms and other quantum systems, QDs can be employed as hosts and sources of quantum information. Compared to single atoms, however, single quantum dots are easily integrated into optoelectronic devices and are characterized by stronger interaction with light. These features, together with the potential for scalability, make QDs very attractive as sources of quantum states of light to be employed in tasks such as quantum key distribution and possible future quantum networks. In this talk, I will discuss the properties of QDs obtained by epitaxial methods and present recent results relevant to their application in quantum communication, i.e. entanglement-based quantum key distribution, as well as challenges to be faced to use them as scalable quantum hardware.

L09

Silicon and Germanium nanostructures for electrical, optical and plasmonic applications

Alois Lugstein

Institute for Solid State Electronics, Technische Universität Wien, Floragasse 7, 1040 Vienna, Austria

Due to physical limits and short channel effects a shift towards the adoption of new materials and novel design architectures is predicted to insure further improvement of modern ICs technology with respect to integration densities, power dissipation and performance. Nanowires and sheets are predicted to be one of the most promising building blocks for future ultra-scaled high-speed nano- and opto-electronics.

I will address the controlled formation of monolithic metal–semiconductor nanowire and nanosheet heterostructures. The main obstacles facing towards reliable synthesis of such hybrid systems are related to lateral strain relaxation, mitigating the limitations of material lattice compatibility and allow arbitrarily combined dissimilar materials unattainable in layered structures. Out of the wide range of nanowires, Ge combines a high carrier mobility, with a more than five times larger exciton Bohr radius compared to Si. Hence, Ge is of particular interest especially for the development of high speed and novel quantum devices.

The formation of axial Al-Ge-Al nanowire heterostructures with atomically sharp interfaces and monocrystalline aluminum leads by using a thermally initiated exchange reaction will be presented. This enables the fabrication of an in line contacted quantum dot without requiring precise lithographic alignment of the contacts, which is one of the most challenging issues of fabricating quantum dot based devices. Unambiguous signatures of quantum ballistic transport and electrostatically tunable negative differential resistance even at room temperature will be demonstrated and attributed to intervalley electron transfer.

Together with the wafer-scale accessibility, the proposed fabrication scheme may give rise to the development of key components for a broad spectrum of emerging Si and Ge-based devices requiring monolithic metal-semiconductor−metal heterostructures with high-quality interfaces for electrical, optical and plasmonic applications.

L10

From structure to function: S-layers as novel diagnostic tools

Thomas Werzer[1,2], Andreas Breitwieser[1], Christian Zafiu[3], Wolfgang Kautek[4], Uwe B. Sleytr[1], Eva-Kathrin Ehmoser[1]

[1] Institute of Synthetic Bioarchitectures, University of Natural Resources and Life Sciences, 1190 Vienna, Austria.
[2] imd BIOTECH GmbH, 1190 Vienna, Austria.
[3] Institute of Waste Management and Circularity, University of Natural Resources and Life Sciences, 1190 Vienna, Austria.
[4] Department of Physical Chemistry, University of Vienna, 1090 Vienna, Austria.

Crystalline bacterial cell surface layers (S-layers) consist of single (glyco)protein units and represent one of the simplest biological membranes. They are commonly found on the outer cell membrane of many eubacteria and archaea. Over the last few decades, S-layers have been object of intensive research to study the self-assembly behavior in vivo, in vitro, in solution and at various interfaces and substrates. More recently, S-layers have proven to be ideal candidates for the design of synthetic bio-architectures. It is due to their repetitive surface properties down the nanometer-scale that S-layers allow for the patterning and functionalization of all sorts of surfaces. Furthermore, genetic engineering enables the fusion of various protein motifs (e.g., receptor binding domain of SARS-CoV-2) to S-layer proteins, which makes them attractive for a multitude of unique applications.

This presentation will provide an overview of S-layer technology and address their potential for novel applications in the field of diagnostics.

L11

Crystallinity and stiffness of spider silk affect the migration of Schwann cells

Aida Naghilou[1], Karolina Peter[2], Flavia Millesi[1], Anda Mann[1], Leon Ploszczanski[2], Paul Supper[1], Lorenz Semmler[1], Tamara Weiss[1], Ellen H. G. Backus[3], Helga Lichtenegger[2], Christine Radtke[1]

[1] Department of Plastic, Reconstructive, and Aesthetic Surgery, Medical University of Vienna, Vienna, Austria
[2] Institute of Physics and Materials Science, University of Natural Resources and Life Sciences, Vienna, Austria
[3] Department of Physical Chemistry, University of Vienna, Vienna, Austria

Nerve guidance conduits are a promising alternative to autologous nerve transplantation and conduits filled with fibrous materials have shown great potential in bridging nerve gaps. The application of spider silk as a filament material has led to results comparable to nerve autograft [1]. However, the use of spider silk has been phenomenological so far and the reasons for its success are still not identified. The aim of this study is to elucidate the material properties of spider silk leading to its unique medical performance. This knowledge enables a targeted production of synthetic alternatives such as recombinant silk.

In this work, various silk types were investigated [2]. Schwann cells were seeded on the spider silks and monitored by live cell imaging and immunofluorescent staining. In addition, the silk fibers were inspected with an electron microscopy, Raman spectroscopy, wide angle X-ray scattering, and tensile tests to determine morphology, secondary protein structure, crystallinity and stiffness, respectively. It was found that the secondary protein structure and specifically the high content of β-sheets in the direction of silk's axis gives the fiber its ability to act as a guiding element for Schwann cells. In addition, the results show that the crystallinity of the silk does not affect the proliferation of Schwann cells, while the directed movement of cells is affected by this material property.

This direct comparison demonstrated the crucial role of the secondary protein structures and crystallinity of spider silk for the guidance properties of fibers during nerve regeneration. The crystalline structure of silk affects its stiffness, which in turn influences the directed migration of Schwann cells. These results should be considered during the targeted production of synthetic fibrous materials for nerve regeneration.

[1] T. Kornfeld, et al., Biomaterials, 271, 120692 (2021)
[2] A. Naghilou, et al., Materials Science and Engineering: C, 116, 111219 (2020)

L12

Colloidal stabilized core-shell particles for preservation of bioactive compounds

Seta Kuepcue, Andreas Breitwieser, Eva-Kathrin Ehmoser

University of Natural Resources and Life sciences, BOKU, Institute for Synthetic Bioarchitectures, Department for BioNanoSciences, Vienna, Austria

Since thousands of years, humans are aware of bees wax as a surprisingly helpful material in the context of food, energy and medicine and health care [1]. Bees Wax reveal not only extremely interesting material properties, but additionally, reveal substantial help to prevent oxidation despite the fundamental permeability. In addition to honey, royal jelly and propolis, beeswax is the most important product of bees in terms of weight.

Beeswax is a natural product and secreted by special glands for the purpose of building honeycombs. It is produced for example, by honeybees of the species Apis mellifera and Apis cereana and consists mainly of hydrocarbons, free fatty acids, esters of fatty acids and fatty alcohols, diesters, and exogenous substances [2]. The wax is insoluble in water and cold alcohol and has a density of 0.96 kg/cm^3 at 15°C with a melting point between 40° and 64.5°C, depending on its origin. Beeswax is highly hydrophobic and has protective properties, which have aroused interest in the medical field, but also in cosmetic and food industries as a bio-preserving material [3,4].

Nano- and microspheres have been widely used as carrier systems for controlled drug release in the human body. Biodegradable particles composed of wax, called solid lipid microspheres, and their preparation without the use of any organic solvents have attracted increasing interest over the years. The therapeutic application potential of beeswax microspheres has been studied, intensively. On the one hand, biocompatible particles for controlled drug release [5,6] could be generated; on the other hand, the poor aqueous solubility of these particles was considered to be a major drawback. Therefore, great efforts have been made to overcome the hydrophobic properties, allowing a higher systemic bioavailability, leading to promising results in the field of cancer treatment, dental implants, and bone growth simulation [7].

Based on our concept to generate quantum dot nanoparticles with functional core-shell architecture via a solvent exchange process [8], we have successfully generated core-shell beeswax particles. I will present a fluorescence-based strategy to characterize the core-shell nature of bees wax particles and the ability of tree's resin to effectively preserve their cargo and therefore, qualify as carrier systems for (bio) active compounds, such as odors and other subtle materials [9].

[1] Roffet-Salque, M. et al. Widespread exploitation of the honeybee by early Neolithic farmers. Nature 527, 226-230, doi:10.1038/nature15757 (2015).
[2] Fratini, F., Cilia, G., Turchi, B. & Felicioli, A. Beeswax: A minireview of its antimicrobial activity and its application in medicine. Asian Pac J Trop Med 9, 839-843, doi:10.1016/j.apjt
[3] Buchwald, R., Breed, M. D. & Greenberg, A. R. The thermal properties of beeswaxes: unexpected findings. J Exp Biol 211, 121-127, doi:10.1242/jeb.007583 (2008).
[4] Youssef, D. M., Alshubaily, F. A., Tayel, A. A., Alghuthaymi, M. A. & Al-Saman, M. A. Application of Nanocomposites from Bees Products and Nano-Selenium in Edible Coating for Catfish Fillets Biopreservation. Polymers (Basel) 14, doi:10.3390/polym14122378 (2022).
[5] Zambrano-Zaragoza, M. L. et al. Effect of Nano-Edible Coating Based on Beeswax Solid Lipid Nanoparticles on Strawberry's Preservation. Coatings 10, doi:10.3390/coatings10030253 (2020).
[6] Souza, C., de Freitas, L. A. P. & Maia Campos, P. Topical Formulation Containing Beeswax-Based Nanoparticles Improved In Vivo Skin Barrier Function. AAPS PharmSciTech 18, 2505-2516 (2017).
[7] D.V.Gowda, M. M., Balmurlidhara V., Mohammed S. Khan. Study on encapsulation of Ranolazine in bees wax microspheres: Preparation, characterization and release kinetics of microspheres. Der Pharmacia Lettre 2, 232-243 (2010).
[8] Mobility and fate of ligand stabilized semiconductor nanoparticles in landfill leachates. Part F, Zaba C, et al., Ehmoser EK. J Hazard Mater. 2020,15;394:122477.doi:10.1016/j.jhazmat.2020. 122477 PMID: 32240897.
[9] Novel Insect Repellent Composition, Ehmoser, E.-K., Sperl, I., European Patent Application No. 22177456.5, 2022

L13

Selective ultrashort laser annealing of amorphous Ge/Si multilayer stacks: Experiment and theory

Nadezhda M. Bulgakova[1], Vladimir A. Volodin[2,3], Yuzhu Cheng[3], Yoann Levy[1], Jiří Beránek[1,4], Siva S. Nagisetty[1,5], Martin Zukerstein[1], Alexander A. Popov[6], Alexander V. Bulgakov[1]

[1] HiLASE Centre, Institute of Physics of the Czech Academy of Sciences, 25241 Dolní Břežany, Czech Republic
[2] Rzhanov Institute of Semiconductor Physics SB RAS, 630090 Novosibirsk, Russia
[3] Novosibirsk State University, 630090 Novosibirsk, Russia
[4] Czech Technical University, Faculty of Nuclear Sciences and Physical Engineering, 11519 Prague, Czech Republic
[5] Coherent LaserSystems GmbH & Co. KG, 37079 Göttingen, Germany
[6] Valiev Institute of Physics and Technology, Yaroslavl Branch, Russian Academy of Sciences, 150007 Yaroslavl, Russia

We report on single-short laser crystallization of Ge/Si multilayer stacks consisting of alternating amorphous nanosized films of silicon and germanium using near- and mid-infrared femtosecond and picosecond laser pulses. The phase composition of the irradiated stacks was investigated by the Raman scattering technique. Several non-ablative regimes of crystallization were found, from partial crystallization of germanium without intermixing the Ge/Si layers to complete intermixing of the layers with formation of GexSi1-x solid alloys. The roles of one- and two-photon absorption, thermal and non-thermal (ultrafast) melting processes, and laser-induced stresses in selective pico- and femtosecond laser annealing are analysed based on theoretical estimations and comparison with experimental data. It is concluded that, due to a mismatch of the thermal expansion coefficients between the adjacent stack layers, efficient explosive solid-phase crystallization of the Ge layers is possible at relatively low temperatures, well below the melting point. The possibility of ultrafast non-thermal phase transition in germanium in the studied regimes is also discussed.

L14

Physicochemical Issues in cultural heritage science

Wolfgang Kautek

University of Vienna, Department of Physical Chemistry, Währinger Strasse 42, A-1090 Vienna, Austria

Cultural Heritage Science (CHS) is a multidisciplinary science which bridges sectors as physics, chemistry, biology, and engineering with art conservation and archaeology.

Preservation of cultural heritage artefacts involves increasingly laser techniques for e.g. phase separations down to the nanoscale, cleaning and also diagnostics [1,2]. Particulate removal from fibrous, polymer [2-5] or painted substrates [6] has been studied systematically. The treatment of organic materials such as paper is characterized by the limitation of photochemical and photothermal destruction. This is minimized when visible laser wavelengths are chosen such as the second harmonic (532 nm) of a Nd:YAG lasers [7-9]. Ultraviolet laser radiation, on the other hand, can serve as a quasi ultra-precise non-contact scalpel [10]. Fundamental investigations combining laser pulse interactions with atomic force measurements support thermomechanical models [11,12]. Laser-induced breakdown spectroscopy may be used for depth profiling needed in the restoration praxis [13].

Nano-scale photochemical processes are encountered particularly in the project “The impact of early photography and electrotyping media on the creation of images and contemporary art"" (PHELETYPIA) [14]. There, daguerreotypes and photomechanical prints from the crown lands of the former Habsburg monarchy are being systematically examined. In 1839 Louis Jacques Mandé Daguerre published the first photo-graphic process [15]. Due to the insufficient sensitivity of the silver-plated substrates, the process could not be used to produce images of moving scenes. Decisive steps in further development, increasing the sensitivity of daguerreotype plates, and developing the first mathematically calculated portrait lens with a specially designed cam-era were already taken in Vienna around 1840 [16-18]. Collections throughout Austria and abroad are contacted and a selection of daguerreotypes are examined for their special surface properties. The surface morphology and surface chemistry of daguerreotypes are the most important sources of information related to their production methods and the corrosion and aging processes affecting their long-term preservation [19-20]. Three non-destructive and non-contact examination methods were identified to be the standard for analyzing the daguerreotypes in this project: digital optical microscopy, scanning electron microscopy with an atomic force microscope, and micro-X-Ray fluorescence. Thus, corrosion states, surface features due to various production steps, possible conservation interventions and storage conditions, have been observed.

Recently, an etched daguerreotype from the early 1840s depicting the Emperor Joseph Monument in Vienna was discovered in the legacy of the first galvanoplastic-artistic laboratory in Austria from the collection of the Technisches Museum Wien [19-20]. This possibly is the only preserved etched daguerreotype plate from the early days of photography that was intended for photomechanical reproduction. This involved electrodeposited printing plates in so-called electrotyping processes also developed in the first half of the 19th century [21-23].

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L15

Attosecond clocking of correlations in quantum materials

Josef Freudenstein[1], Markus Borsch[2], Manuel Meierhofer[1], Dmytro Afanasiev[1], Christoph P. Schmid[1], Fabian Sandner[1], Marlene Liebich[1], Anna Girnghuber[1], Matthias Knorr[1], Mackillo Kira[2], Rupert Huber[1]

[1] Department of Physics, University of Regensburg, 93040 Regensburg, Germany
[2] Department of Electrical Engineering and Computer Science, University of Michigan, Ann Arbor, Michigan 48109, USA

Correlations between delocalized electrons near the Fermi energy are the driving force behind key electronic and optical properties of solids as well as intriguing phase transitions. To directly track how these many-body interactions affect electronic dynamics, attosecond (1 as = 10^{-18} s) temporal resolution [1,2] is advantageous. Yet, the photon energy of attosecond extreme ultraviolet probe pulses of typically tens to hundreds of electronvolts do not match well with the energetics of many-body excitations. Conversely, multi-terahertz (THz) photon energies are perfectly suited to resonantly probe millielectronvolt (meV) correlation-induced excitations. Although lightwaves have been routinely employed to drive electron currents [3], dynamical Bloch oscillations [4], and to reconstruct Bloch waves [5], it has remained an open challenge to resolve the influence of correlation effects on the trajectories of delocalized Bloch electrons in the time domain.

We will show how many-body correlations modify the dynamics of charge carriers on the attosecond time scale [6]. This is achieved by combining sub-fs resolution with meV energy selectivity. Coherent excitons are injected in bulk and monolayer tungsten diselenide (WSe_2) at a precise point in time by a 9-fs pulse resonant with the band gap of the semiconductors. Subsequently, an intense THz light field with actively stabilized carrier-envelope-phase [7] accelerates the electron-hole pairs. First, the oscillating electric field component of the intense THz pulse will separate the charge carriers. As soon as the sign of the electric field switches its sign, electrons and holes are driven towards each other again, resulting in quasiparticle collisions. The energy of the system – consisting of the band gap energy and the kinetic energy of the electron-hole pairs upon recollision – is emitted as high-energy light, so-called high-order sidebands (HSB). This radiation contains key information about the ballistic dynamics of the charge carriers. In particular, only certain injection times of the excitons during the oscillating THz field will lead to a strong HSB emission, that is if the separating half-cycle can accelerate the charge carriers sufficiently to gain high kinetic energy while still keeping the excitonic coherence intact. By comparing monolayer and bulk WSe_2, we see how the strongly enhanced Coulombic correlations in the monolayer modify the lightwave dynamics of the charge carriers, resulting in attosecond shifts of the optimal injection time. Additionally, we observe how increasing the strength of the driving field destroys the excitonic coherence faster and how the valley polarization and Pauli blocking can be exploited to further alter the dynamics of charge carriers on the attosecond time scale. The newly developed attosecond chronoscopy of Bloch electrons could open a new pathway to understanding emergent quantum dynamics and phases and set a corner stone for future optoelectronics and quantum-information processing.

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L16

Ablation plume analysis to understand problems of pulsed laser deposition

Thomas Lippert

Division for Research with Neutrons and Muons, Paul Scherrer Institute, 5232 Villigen, Switzerland
Laboratory of Inorganic Chemistry, Department of Chemistry and Applied Biosciences, ETH Zürich, 8093 Zürich, Switzerland
International Institute for Carbon-Neutral Energy Research (WPI-I2CNER), Kyushu University, Fukuoka 819-0395, Japan

The expansion dynamics of laser induced plasmas has received considerable attention in the last 30 years due to its importance for the basic understanding of materials removal by laser ablation as well as laser-materials processing and thin film deposition. Thin film deposition by pulsed laser deposition (PLD) is on the verge or is already an established tool for industry, e.g. for X-ray mirrors and high T_c superconducting tapes, but for a wider application several shortcoming must to be overcome. These problems, e.g. differences in composition between targets and thin films, non-homogenous composition of the thin films, and deviation of the film thickness for substrates greater than around 1 cm^2, are most likely related to the ablation plume. A detailed study of the ablation plume can therefore help to understand whether and how these problems can be overcome. We apply space-, angle-, and energy-resolved plasma mass spectrometry, space- and angle-resolved ion probe measurements, and spectral- and time-resolved plasma imaging in the same PLD chamber, that is equipped with a special designed substrate system to analyse the thin films composition for various deposition angles. To analyse the influence of the applied elements, a variety of different target compositions are utilized. We would like to highlight here some of the most important findings related to the film composition, while the thickness related variations are mostly related to the well-known forward peaked nature of the ablation plume:

- Deviations in composition, mainly of light elements, are most pronounced when the mass differences in the target are high, e.g. Li vs. Mn (with deviations in composition of up to 80%). These deviations are additionally angle dependent (related to a charged dynamic double layer), resulting in composition variations for larger substrates.

- The stability of metal oxygen species vs. the stability of O_2, which are formed especially in the commonly used oxygen backgrounds, are important.

- Light elements arrive in vacuum prior to heavy elements at the substrate and may experience a pronounced bouncing, i.e. backward movement to the target, and coating of the target with a different composition than the original composition, which is additionally background gas dependent.

I will also show some selected application of PLD prepared films for fundamental studies in the area of photoelectrochemical water splitting using the large facilities at PSI (synchrotron and neutron spallation source)

In summary, ablation plume analysis showed that the most important problems of PLD, i.e. complex deviations of the film composition are clearly related to the properties of the ablation plume. The variation of the deposition conditions combined with plume analysis suggests also certain approaches how to overcome these problems, e.g. by varying background gases and pressures, but also when more drastic approaches must be used, e.g. an enrichment of certain elements in the target.

L17

Controlling optoelectronic processes in covalent organic frameworks

Thomas Bein

Department of Chemistry, University of Munich (LMU)

Photoactive molecular building blocks can be spatially integrated into the crystalline lattice of covalent organic frameworks (COFs), allowing us to create models for organic bulk heterojunctions, chemical sensors and porous electrodes for photoelectrochemical systems. In this presentation, we will address means of controlling the morphology and packing order of COFs in thin films [1] and with spatially locked-in building blocks [2].

We will discuss different strategies aimed at creating electroactive networks capable of light-induced charge transfer. For example, we have developed a COF containing stacked thienothiophene-based building blocks acting as electron donors with a 3 nm open pore system, which show light-induced charge transfer to an intercalated fullerene acceptor phase [3]. Contrasting this approach, we have designed a COF integrated heterojunction consisting of alternating columns of stacked donor and acceptor molecules, promoting the photo-induced generation of mobile charge carriers inside the COF network [4]. Additional synthetic efforts have led to several COFs integrating extended chromophores capable of efficient harvesting of visible and near infrared light, for example [5].

Extending newly developed thin film growth methodology to a solvent-stable oriented 2D COF photoabsorber structure, we have established the capability of COF films to serve in photoelectrochemical water splitting systems [6]. The detailed mechanism of excited state dynamics in light-harvesting conjugated COFs has been revealed by means of transient absorption spectroscopy [7]. Many optoelectronic applications of COFs depend on significant electrical conductivity. Here, Wurster-type structural motifs are attractive building blocks for imparting high conductivity in the corresponding COFs [8]. Finally, COF films can also act as ultrafast solvatochromic chemical sensors [9], as photodetectors [10], and show very efficient electrochromic response [11]. Ongoing work focuses on the design of ultra-large pore donor-acceptor COFs with extended light-harvesting abilities, and extends the structural paradigm of COFs to novel 3D conjugated frameworks. The great structural diversity and morphological precision that can be achieved with COFs make these materials intriguing model systems for organic optoelectronic materials.

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L18

Nanophotonics for sensing applications

Sarah M. Skoff

TU Wien

With the rise of quantum technology, the quest for nonlinear interactions at low signal levels, eventually down to a single quanta of light has gained increasing importance. This requires strong light-matter interactions where even a single molecule, atom or quantum emitter can have a strong effect on the probing light field. Such interactions can be implemented by the aid of nanophotonics.

On the other hand, this means that such well-engineered platforms lend themselves for sensing applications. In my lecture, I will present results on a number of nanophotonic platforms that allow the detection of single molecules or impurities in 2D materials. I will then discuss how nanophotonics can also help in the detection and identification of nanoplastics. Such particles present a widespread pollution in our environment but are thus far very difficult to monitor as adequate detection methods are still sought after. I will show that we are now able to detect and identify single nanoplastic particles and agglomerates down to sizes of 100 nm in a facile and fast fashion, which presents an important step towards development of future sensors.

L19

Antiadhesive bionic combs for handling of nanofibers

Johannes Heitz

Johannes Kepler University, AT

Nanofibers are constantly drawing the attention of material scientists and engineers as their surface-to-used-material-ratio is beneficial for, e.g., medical applications. However, technical nanofiber processing, transportation or even simple things as spooling is inhibited by their attraction to any surface by van der Waals forces, the adhesive forces also enabling geckos to stick to the wall. Recent research aims for scale-up of the controllable production of nanofibers though have not enabled an easier handling and thus their application is still limited. A specific kind of nanofibers are nanofibrous protrusions of adherent cells and microorganisms. The interaction of these fibers with nanostructures is a key feature for their controlled adhesion at natural or artificial surfaces.

One major problem for handling of nanofibers is their stickiness to almost any surface due to van der Waals forces. However, there is a biological example to show how to tackle this problem in the future: cribellate spiders bear a specialized comb, the calamistrum, to handle and process nanofibers, which are assembled to their structural complex capture threads. These 10 – 30 nm thick fibers do not stick to the calamistrum due to a special fingerprint-like nanostructure. This structure causes the nanofibers to not smoothly adapt to the surface of the calamistrum, but rather minimizes contact and thus reduce the adhesive forces between the nanofibers and the calamistrum.

We were able to demonstrate that the transfer of these bionic comb structures to a technical surface is feasible, for instance by short-pulsed and ultrashort-pulsed laser processing. This could enable that future tools for nanofiber handling (covered with such a nanostructure) are antiadhesive towards nanofibers. We could also show that similar nanostructures can hinder the adhesion of nanofibrous protrusions of bacterial microorganisms, which is very promising to realize cell-repellent or antiseptic areas on medical devices or in biotechnology in future.

L20

Wavelength and decay time tuning of intraband transitions in low spatial frequency laser-induced periodic surface structures

Nikita Vashistha, Amit Kumar, Rajiv K. Singh, Mahesh Kumar

CSIR-National Physical Laboratory, Dr. K.S. Krishnan Marg, New Delhi 110012, India

We present the study of the alteration of wavelength and decay time of intraband transitions in the laser-induced periodic surface structures (LIPSS) of silver formed by varying the incident laser peak fluence. The studies are performed using a femtosecond laser (λ_0 = 800 nm) based ultrafast transient absorption spectroscopy (UFTS)setup. Using the same laser, an array (~2 mm size) of laser-induced periodic surface structures were obtained in a single step fabrication process in the open air without translating the sample. Each unit cell of the array comprises low spatial frequency LIPSS (LSFL) near the center with nanoparticles/clusters around the edges. As obtained from 2D Fast Fourier Transform, the overall periodicity(Λ) of LSFL is within 0.714 λ_0 - 0.723 λ_0 range. The nanoparticles/clusters show a random size distribution that varies from 50 nm to 300 nm. In UFTS measurement, the LIPSS was excited by a 3.3 eV laser. The SPP/SPR dip in the data is an indication of intraband transition or hot electron generation. The effect of change in structuring due to varying laser fluence on these intraband transitions is also analyzed. It is observed that there is a non-linear redshift (~16 nm) in the SPR peak wavelength with a significant enhancement in the relaxation times of the hot electrons due to localized annealing of shallow defects. Therefore, a large tunability in wavelength of SPP/SPR and lifetime of hot electrons was achieved by varying the laser fluence. The study highlights the suitability of LIPSS in applications requiring efficient energy transfer, enhanced photocatalytic action, and tunable sensors.

L21

The role of technology assessment and foresight in governing emerging technologies. The case of nanomaterials.

André Gazso

Austrian Academy of Sciences

Technology Assessment (TA) can play a key role, as an evidence-based, interactive process which aims to bring to light the societal, economic, environmental and legal aspects and consequences of new and emerging science technologies. TA is a process that informs public opinion, helps direct research and development, and acts as a source of strategic intelligence to shape policies that both promote and govern new and emerging technologies.

Poster Abstracts

P01

CuCr catalysts for ammonia electro-oxidation - A study on activity and selectivity

Annie Cleetus, Hanan Teller, Alex Schechter

Ariel University

Ammonia is considered as one of the most efficient hydrogen carrier, as it contains 17% of H_2 by weight. Being carbon free at the end use energy generation from ammonia (NH_3) has become a matter of interest in the past years. In the efficient conversion of ammonia to electricity in fuel cell technologies, such as portable power sources, a major challenge is the identification of a suitable catalyst that can selectively oxidize NH_3 to N_2 at low over potentials, and ambient pressure and temperature, at high rates. In this work, low cost bimetallic carbon supported CuCr catalysts which were found to be more active than elemental Cu and Cr were prepared by a simple sodium borohydride reduction method. The formation of alloy was confirmed through PXRD. AFM and HR-SEM was used for further characterization of the nano-particles. The CuCr activity was found to increase with Cu content, however it was higher than pure Cu, which reveals a synergistic effect between Cu and Cr in the oxidation of NH_3, due to electronic interactions between Cr and Cu.

Cyclic voltammetry on stable catalysts with 90% Cu in 0.1 M KOH and 0.1 M NH_3 revealed a peak current density of 22 mA/mg at a scan rate of 20 mV/s compared with 0.04 mA/mg for Cr and 6.9 mA/mg for Cu under the same conditions. PXRD measurements have revealed the presence of oxides and hydroxides of Cu and oxides of Cr along with the metallic phases on the electrode surface that contributes to the activity of the catalyst. Mass spectrometry measurements have identified N_2 as the major product of oxidation along with trace amounts of N_2O and N_2H_4. Subsequent LSV coupled with chronamperometry at 1.1 V (vs RHE) in 0.1 M KOH and 0.1 M NH_3 for 1 hr has shown an increase in peak current density for the initial 3 hrs followed by a decrease suggesting the saturation of the active sites in the first 3 hrs of oxidation. Pre-oxidation in KOH was found to improve the activity and stability of the catalyst over time. Dissolution of Cu and Cr (CrO_4^{2-}) into the solution has also been identified through ICP and UV-Vis spectroscopy. 90% Cu catalyst of CuCr in similar conditions show higher peak current density compared to commercial Pt catalyst (14.8 mA/mg) thus corroborating the potential of CuCr based catalysts for ammonia oxidation in fuel cells in the future.

P02

A special example for advanced materials: Nanocarriers

Anna Pavlicek[1], Eva-Kathrin Ehmoser[1], Florian Part[2], Christian Zafiu[2], Sabine Greßler[2], Christina Hipfinger[3], Bernd Giese[3]

[1] Institute of Synthetic Bioarchitectures
[2] Institute of Waste Management and Circularity
[3] Institute of Safety and Risk Sciences

Nanoparticles are the focus of attention because they can solve many of our societal issues in a sustainable, material-saving, and most-effective way.

In medicine, for example, nanoparticles, such as drug delivery particles, are expected to provide radical new solutions for diagnostics and therapeutics. Such cargo-carrying vehicles are the so-called “Nanocarriers”, often designed to release active ingredients in a controlled manner by induced structural changes. Such responsive structures influence carriers' functional properties, such as cargo's controlled release or spatiotemporally controlled interactions. Thus, nanocarriers can outrun conventional delivery systems regarding transport activity, site of action, the amount of active drug released, and duration of exposure. These novel properties can also include altered degradability or durability in the environment. At the Institute of Synthetic Bioarchitectures in Vienna, we deal with synthesis aspects and integrate such structures into a safety assessment matrix by involving the Sustainable by design principle. Essential factors for a risk assessment of nanocarriers are persistence and behavior in the environment.

Together with the Institute of Safety and Risk Sciences and the Institute of Waste Management and Circularity, we are investigating the state of development of nanocarriers in different application fields. We experimentally analyze their risk potential and their mobility in the environment, the possible unintended release of the active ingredient and their degradability in aquatic systems.

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P03

Managing insect feet: Biomimetics of plant wax based non-toxic micro- and nanostructural insect repellents

Florian Gisinger, Ille C. Gebeshuber

Institute of Applied Physics, TU Wien

Insects play a crucial role in our lives. They act as pollinators and sources of nutrition for people and animals alike, thus forming a backbone of virtually all ecosystems on land. However, they can also transmit diseases and destroy farm crop yields, necessitating management and control of the behaviour of certain species. Current ways of dealing with insect pests mostly rely on chemical insecticides, affecting not only the target species with intended consequences, but often also further life forms with unintended consequences: In recent years, the use of chemical insecticides has been linked to global pollinator decline [Mit+17] and decline of populations of other non-target organisms such as birds [LMK20]. In humans, the use of insecticides has been associated with elevated risks for developing cancer [Ler+15].

Physical mechanisms that merely repel the target species without interruptions to other organisms could provide a non-toxic alternative to chemical insecticides. Various plants produce insect repellents based on wax micro- and nanostructures that exhibit specific mechanical and structural properties, such as finely tuned fracture behavior, thereby preventing insect attachment [BGG10]. As England and co-workers showed in 2016, surface roughness rather than surface chemistry essentially affects insect adhesion [Eng+16]. This exemplifies the fact that for certain functionalities in living Nature, structure (physics) is often more important than specific materials (chemistry).

This study aims to investigate the interaction between insects and wax structures found on a selection of plants common in Austria and whether the processes involved could be utilized to develop sustainable non-toxic insect repellents based on natural micro- and nanostructures.

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P04

Towards biomimetics of superhydrophobic water strider feet

Lukas Hageneder[1], Harald Plank[1], Karin Wewerka[1], Ille C. Gebeshuber[2]

[1] Institute of Electron Microscopy, Graz University of Technology, Graz, Austria.
hageneder@student.tugraz.at, harald.plank@felmi-zfe.at, karin.wewerka@felmi-zfe.at
[2] Institute of Applied Physics, Technical University Vienna, Vienna, Austria.
gebeshuber@iap.tuwien.ac.at

This contribution summarizes first characterization results of superhydrophobic water strider feet with the vision to understand the interplay of morphology and chemistry to ultimately mimic such unique functionalities for future applications. The study started with chemical aspects to validate the likely existence of a wax layer. For that, separated legs were exposed to $CHCl_3$ under controlled conditions, followed by the chemical analyses of the solution. Fourier Transformed - Infrared Spectroscopy (FT-IR) confirmed the expected wax layer as first element for the superhydrophobic functionality. In a second step, individual feet were studied via Environmental Scanning Electron Microscopy (ESEM). For nanoscale studies, we prepared ultrathin cross sections via Ultramicrotomy (UM) and subjected them to Transmission Electron Microscopy (TEM). Together with Atomic Force Microscopy (AFM) studies on UM-prepared block-faces, we could confirm a partial wax coverage by a direct comparison of native and $CHCl_3$ treated feet. In a next step, we conducted ESEM-based, dynamic in situ studies, which directly revealed the hydrophobic H_2O condensation on native legs. Currently, we work on a mechanical setup to access friction coefficients of differently treated legs, inspired by the Cavendish method. By that, we will be able to separate between morphology- and chemistry-related contributions to understand the origin of superhydrophobic water strider legs.

P05

Insight into response of a thin Mo film to short laser pulse using a Lagrangian hydrodynamic model

K. Hlinomaz[1,2], A. S. Fedotov[3], I. Timoshchenko[3], A. Kozlovski[3], Y. Levy[1], T.J.-Y. Derrien[1], V. P. Zhukov[1,4,5], O. G. Romanov[3], N. M. Bulgakova[1]

[1] HiLASE Centre, Institute of Physics of the Czech Academy of Sciences, Za Radnicí 828, 25241 Dolní Břežany, Czech Republic
[2] Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering, Břehová 7, 115 19 Praha 1, Czech Republic
[3] Belarusian State University, 4 Nezavisimosti Ave., Minsk 220030, Belarus
[4] Institute of Computational Technologies SB RAS, 6 Lavrentyev Ave., Novosibirsk 630090, Russia
[5] Novosibirsk State Technical University, 20 Karl Marx Ave., Novosibirsk 630073, Russia

A physico-chemical elucidation of the world-wide first photographic technology allowing manifold reproduction around 1840 in Vienna is presented. An etched daguerreotype from the Technisches Museum Wien served as a case-example. Surface analysis showed that the photographic process did not include Hg but led to the formation of colloidal Ag nanoparticles (AgNPs) with sizes between 30 nm and 120 nm with shell layers consisting of Ag_2O, Ag_2S, and some AgCl. The breakthrough photographic technique provided a hitherto unachieved high sensitivity due to various halogenide mixtures without Hg. The image development consisted in the reduction of the Ag halides by H_2SO_3 created by the hydrolysis of S_2Cl_2 leading to AgNPs around the latent image Ag nuclei. The fixation of the image was performed either by KCN or by $Na_2S_2O_3$. The investigated plate exhibits etched areas with Ag_2O conversion layers and no Cl or S. In parallel, a first etching method for daguerreotype images applying a gum arabic solution on the fixed image surface before the etching step was invented. The gum arabic preferentially wetted the exposed AgNP regions so that unexposed areas could be etched by HNO_3.

P06

High photosensitivity daguerreotypes and their reproduction: Physico-chemical elucidation of innovative processes developed around 1840 in Vienna

Valentina Ljubić Tobisch, Wolfgang Kautek

University of Vienna, Department of Physical Chemistry, A-1090 Vienna

A physico-chemical elucidation of the world-wide first photographic technology allowing manifold reproduction around 1840 in Vienna is presented. An etched daguerreotype from the Technisches Museum Wien served as a case-example. Surface analysis showed that the photographic process did not include Hg but led to the formation of colloidal Ag nanoparticles (AgNPs) with sizes between 30 nm and 120 nm with shell layers consisting of Ag_2O, Ag_2S, and some AgCl. The breakthrough photographic technique provided a hitherto unachieved high sensitivity due to various halogenide mixtures without Hg. The image development consisted in the reduction of the Ag halides by H_2SO_3 created by the hydrolysis of S_2Cl_2 leading to AgNPs around the latent image Ag nuclei. The fixation of the image was performed either by KCN or by $Na_2S_2O_3$. The investigated plate exhibits etched areas with Ag_2O conversion layers and no Cl or S. In parallel, a first etching method for daguerreotype images applying a gum arabic solution on the fixed image surface before the etching step was invented. The gum arabic preferentially wetted the exposed AgNP regions so that unexposed areas could be etched by HNO_3.

P07

Surface characterization of Austrian dagueretypes

Valentina Ljubić Tobisch[1], Klaudia Hradil[1], Karin Whitmore[2], Christina Streli[3], Wolfgang Kautek[4]

[1] Technische Universität Wien, X-Ray Center, Getreidemarkt 9, 1060 Vienna
[2] Technische Universität Wien, USTEM, Wiedner Hauptstraße 8-10/E057B, 1040 Vienna
[3] Technische Universität Wien, Atominstitut, Stadionallee 2, 1020 Vienna
[4] University of Vienna, Department of Physical Chemistry, Währinger Strasse 42, 1090 Vienna

The surface properties of daguerreotypes are the most important source of information in connection with its production and its long-term preservation [1-6]. The surface morphology and surface chemistry provide information about the production methods, and also the corrosion and ageing processes. The PHELETYPIA project, "The impact of early photography and electrotyping media on the creation of images and contemporary art", funded by the Austrian Academy of Sciences, is researching original daguerreotypes with the aim to gain detailed information about the special Viennese methods from the early 1840s.

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P08

Investigation of the effect of the spot size on the regularity of LIPSS produced on c-Si by femtosecond laser scanning

Yoann Levy[1], Juraj Sládek[1,2], Thibault J.-Y. Derrien[1], Nadezhda M. Bulgakova[1]

[1] HiLASE Centre, FZU - Institute of Physics of the Czech Academy of Sciences, Czech Republic
[2] Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering, Czech Republic

Texturing of surfaces by laser-induced periodic surface structures (LIPSS) is a simple single-step process that can be used for tailoring various surface properties [1,2]. The quality of the LIPSS generated on large surfaces by laser scanning can be very diverse, depending on the irradiation conditions while their regularity is of interest to better control these properties.

Beside laser fluence and overlap between spots during scans, the wavefront [3] was demonstrated to have a strong influence on the structures regularity. In this work we have investigated the influence of the spot size on the quality of the low spatial frequency LIPSS. The Gaussian beam of a 1030-nm 250-fs laser was scanned over the surface of crystalline silicon with fluences from ~0.2 to ~0.6 J/cm^2 with spot overlaps between 50% and 97% and with 3 different spot sizes. Under the conditions at which scanned area exhibit a homogeneous structuring, the regularity of the LIPSS is characterized by the dispersion in the LIPSS orientation angle [4].

In the overlap-fluence parametric space investigated the results reveal at least 2 regions of high regularities. The first is located in the domain of overlaps higher than 90% with fluence close to the single-shot damage threshold. The second spans over a wider range of overlaps and fluences. In this second region, the smallest spot size employed in this study (~12.6 µm) yields the best regularities of this preliminary study.

Since the processing time is driven by the scanning velocity, directly related to the overlap and spot size, the results are of interest for assessing the possible speedup in the large-scale production of regular structures.

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P09

Ultrastructural + mechanical investigations of spider silk

Leon Ploszczanski[1], Aida Naghilou[2], Lorenz Semmler[2], Gerhard Sinn[1], Sarah Stadlmayr[2], Helga Lichtenegger[1], Christine Radtke[2]

[1] Inst. f. Physik u. Materialwissenschaften der Boku Wien, Peter-Jordan-Straße 82, 1190 Wien
[2] Medizinische Universität Wien, Universitätsklinik für Plastische Rekonstruktive und Ästhetische Chirurgie, Währinger Gürtel 18-20, 1090 Wien

The unique properties of Spider silk (SPSI) make it one of nature's most fascinating materials due to its unique properties. A remarkable application of the SPSI is its use in reconstructive medicine as nerve guidance structure [1,2]. A crucial part of the nerve regeneration process are the Schwann cells (SCs), which adhere to SPSI and migrate along it to support axonal elongation [3]. SPSI degrades without inflammatory response or physiological pH changes. However, the interaction at the interface of the SCs and the silk and by that the SPSI properties, that promote SC adhesion are still unclear. To clarify the interaction at the interface, is the goal of our FWF project. Not all spider silks show the same medical success, and we believe that properties such as composition, ultrastructure, and mechanical behaviour have a pronounced influence on the acceptance of SPSI by SCs. Therefore, by combining experiments consisting of in vitro studies and the material characterization of various SPSIs, the properties, which are responsible for the success of SPSI in nerve regeneration, will be investigated.

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[2] Semmler L, et al., Silk-in-Silk Nerve Guidance Conduits Enhance Regeneration in a Rat Sciatic Nerve Injury Model, https://doi.org/10.1002/adhm.202203237
[3] Kornfeld T, et al., Spider silk nerve graft promotes axonal regeneration on long distance nerve defect in a sheep model, https://doi.org/10.1016/j.biomaterials.2021.120692

P10

Pulsed laser ablation synthesis of composite nanoparticles with plasmonic properties for multimodal applications

Yury V. Ryabchikov

HiLASE Center, Scientific Laser Application Department, Institute of Physics of the Czech Academy of Sciences, Dolní Břežany, Czech Republic

Ultrafast laser processing using laser sources with an ultrashort pulse duration is a promising approach to both surface and volumetric structural materials modifications leading to considerable changes of their properties. Among them, pulsed laser ablation in liquids (PLALs) is a versatile method to direct synthesis of colloidal solutions of both semiconductor and metallic nanoparticles. Moreover, recently it has been shown that this approach can also be employed for the fast synthesis of composite nanoparticles with controlled chemical compositions combining both semiconductor and metallic specific features.

In this work, various composite nanoparticles based on silicon or carbon nanostructures with variable plasmonic properties were synthesized using pulsed laser ablation approach. It is demonstrated that optical properties of semiconductor nanostructures can easily be modified by ablation a noble metal target immersed in colloidal solutions of silicon or carbon nanoparticles leading to the appearance of plasmonic properties, which efficiency can easily be varied by laser ablation time. Additionally, the spectral position of the absorption maximum can be adapted by choosing an appropriate target for the laser ablation purpose. This laser-induced structural modification also leads to the change of the structural properties of semiconductor nanostructures studied by X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS) and electron paramagnetic resonance (EPR). In particular, the chemical content also affect the amount of paramagnetic defects of semiconductor nanocomposites decreasing the amount of unpaired electrons due to laser-induced structural modifications. At the same time, the presence of plasmonic properties opens up new perspectives of the application of semiconductor nanostructures in the field of plasmonic biosensing such as surface-enhanced Raman scattering (SERS) due to the laser-affected plasmonic properties that can be combined with semiconductor-related properties.

P11

Homogeneous stripes of LIPSS on silicon

J. Sládek[1,2], Y. Levy[1], T. J.-Y. Derrien[1], N. M Bulgakova[1]

[1] HiLASE Centre, Institute of Physics of the Czech Academy of Sciences, Dolní Břežany, Czech Republic
[2] Czech Technical University in Prague, Prague, Czech Republic

Surface nano-/micro-structuring of materials by laser-induced periodic surface structures (LIPSS) with femtosecond pulses is a flexible, relatively fast and single step approach applicable for a broad range of materials. Such structuring finds applications in control of tribological and wettability properties, optical properties tuning, anti-bacterial surfaces, engineering of tissue adhesion and functionalization of 2D materials. In most cases it is desirable to produce LIPSS on relatively large areas with a high level of homogeneity and controlled periodicity.

This poster presents a study of large-area LIPSS formation on a surface of monocrystalline silicon in a specific fabrication regime [1]. A range of processing parameters where LIPSS are formed in a pattern of periodic stripes is investigated. These stripes consist of LIPSS parallel to the scanning direction, as shown in the figure below. The stripes of LIPSS are regularly spaced with a period of the laser pulses and, interestingly, are located in between regions where the fluence of the Gaussian laser beam peaks. A formation mechanism is explained by analyzing a connection between local accumulated fluence [2], N-on-1 pulse damage geometry and thresholds of modifications. Within the processes at play in the generation of such structures, specific pattern of surface amorphization seems to play a key role.

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P12

Simulations of SERS enhancement

Fritz Steiner, Ambika Shorny, Helmut Hörner, Sarah M. Skoff

TU Wien

Following the experimental work on the detection of single nanoplastic particles down to the scale of 100 nm by utilising commercially available SERS targets we demonstrate with numerical simulations the connection between the enhancement of the electric field near metallic nanostructures and the experimentally observed increased Raman scattering rate. The simulations are performed with the Ansys Optics software package by using two distinct solver units, Frequency Dependent Time Domain and Discontinuous Garlekin Time Domain, to solve Maxwell's equations in three dimensions explicitly in the time domain. We record the electric field distribution around the SERS target to calculate the enhancement factor of the field amplitude via the $|E|^4$-approximation and compare it to the experimentally acquired data. With the possibility to support the numerical data with experimental measurements we may tailor the SERS target to the particle type of interest further enhancing our capabilities for detection of small particles. Therefore, these results pave the way for a more streamlined development for future nanoplastic detection devices.

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P13

Femtosecond laser processing of piezoelectric actuator devices for quantum-optic applications

Sandra Stroj[1], Barbara Ursula Lehner[2], Julia Freund[3], Rinaldo Trotta[4], Javier Martín-Sánchez[5], Armando Rastelli[2], Fadi Dohnal[1]

[1] Research Center for Microtechnology, FH Vorarlberg, Hochschulstraße 1, 6850 Dornbirn, Austria
[2] Institute of Semiconductor and Solid State Physics, Johannes Kepler University, Altenbergerstraße 69, 4040 Linz, Austria
[3] Institut für Theoretische Physik, Universität Innsbruck, Technikerstraße 21a, 6020 Innsbruck, Austria
[4] Dipartimento di Fisica, Sapienza Universitá di Roma, Piazzale A. Moro 5, 00185 Roma, Italy
[5] Departamento de Física, Universidad de Oviedo, C/Calvo Sotelo, s/n, Oviedo 33007, Spain

Femtosecond laser ablation as a process step in the field of microtechnology shows its main advantages in its flexibility and the possibility of structuring a wide variety of material classes. Due to its high piezoelectric coefficient and high ductility, lead magnesium niobate lead titanate (PMN-PT) has proven to be an excellent material for the realization of actuators. The fabrication of novel PMN-PT based actuators depends on the availability of suitable micromachining processes for PMN-PT thin films or volume substrates. Various approaches such as chemical etching, UV laser ablation or reactive ion etching are discussed in the literature with their respective advantages and disadvantages. In general, however, it is essential for maximum device performance that the crystalline quality of the substrates is preserved as much as possible. Consequently, the fabrication process must cause minimal damage to the material in the form of cracks and other defects. In this work, we demonstrate a relatively fast and flexible method for fabricating high-quality PMN-PT actuators with femtosecond laser pulses. Due to the high peak intensities and short laser-material interaction time of the femtosecond laser, a cutting process is available that causes minimal thermal stress and enables high cutting precision. For this reason, components produced with this laser are characterized by the absence of extensive cracks and well-defined edges with relatively low roughness. In addition to the cutting process, the same laser source can be used to structure a previously vapour-deposited metallic contact layer. In this way, it is possible to produce the complete actuator chip with one machining process.

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P14

Mechanical bactericide by biomimetics of the nanopillars on cicada wings

Richard W. van Nieuwenhoven, Alexander M. Bürger, Ille C. Gebeshuber

Institute of Applied Physics, TU Wien, Vienna, Austria

The nanopillar structures on cicada wings exhibit unique antibacterial properties with species-specific heights. These structures are also superhydrophobic and self-cleaning, making them promising candidates for biomimetic materials with multifunctional properties. In this study, we investigate the cicada wings of three species (Amphipsalta cingulata, Kikihia scutellaris, and Magicicada septendecim) using Atomic Force Microscopy, Scanning Electron Microscopy and bacterial tests with live-dead staining. Our primary focus is developing low-cost bio-replication methods to transfer these unique properties to manufactured surfaces, such as hospital surfaces, medical instruments, smartphone displays, and door handles.

Our findings highlight the challenges associated with verifying the antibacterial properties of these nanostructures, such as determining the bacteria concentration needed to confirm the antibacterial effect. These challenges will have implications for the practical implementation of antibacterial nanostructures and support the findings of recent critical publications.

P15

A toroidal topology of top-hat laser pulses tightly focused inside silica glass: insight through modeling

Vladimir P. Zhukov[1,2], Nadezhda M. Bulgakova[1]

[1] HiLASE Centre, Institute of Physics of the Czech Academy of Sciences, Dolni Brezany, Czech Republic
[2] Federal Research Center for Information and Computational Technologies, Novosibirsk, Russia

Ultrashort pulse laser writing of optical structures inside bulk of transparent materials has been proven to be a powerful tool for fabrication of integrated photonic devices. The main challenge in this field is a control over localization of absorbed laser energy into desired micro/nanovolumes that can be achieved by spatial and/or temporal beam shaping. For instance, Gaussian and doughnut-shaped laser pulses tightly focused inside fused silica were shown to induce significantly different level of modification [1]. Here we analyze theoretically a possibility of using top-hat laser beam profiles for volumetric modification of glass materials. Large-scale numerical modeling of propagation of femtosecond top-hat laser pulses are performed based on the nonlinear Maxwell equations supplemented by the hydrodynamic-type equations for generation of free electron plasma and its oscillations in the laser wave. For tightly focused laser beams, widely used boundary conditions for the incident laser wave based on the paraxial approach lose their validity. To describe realistically the focusing optics, we apply a computational technique based on a parabolic mirror as a focusing element. A series of simulations have been performed for typical irradiation conditions used in experiments. Surprisingly, it has been found that, under certain irradiation conditions, the top-hat laser beam can behave as a doughnut-shaped, thus converting to a toroidal geometry. The dynamics and mechanism of such conversion will be discussed.

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P16

Time-resolved volumetric modification in fused silica reveals ultrafast electron dynamics and shielding

Martin Zukerstein[1], Vladimir P. Zhukov[1,2,3], Nadezhda M. Bulgakova[1]

[1] HiLASE Centre, Institute of Physics ASCR, Za Radnici 828, Dolni Brezany, Czech Republic
[2] Federal Research Center for Information and Computational Technologies, 6 Lavrentyev Ave., Novosibirsk, Russia
[3] Novosibirsk State Technical University, 20 Karl Marx Ave., Novosibirsk, Russia

Time-resolved experiments of two successive laser pulses acting on a material open a new way to investigate the dynamics of volumetric modification in fused silica. Fast free electron plasma shielding and long-lasting states of self-trapped excitons strongly influence the modification of material which can be controlled by the time delay of the applied laser pulses.

The time-resolved experiments allow us to follow the evolution of laser-generated electron plasma, which causes shielding and delocalization of the absorbed energy. At the same time, we can observe the influence of long-lived electronic states (self-trapped excitons) on the investigated modification level of the material. The experimental results were compared with numerical simulations describing the effect of energy density distribution and plasma shielding in the focal region based on the propagation of laser pulses in a nonlinear media by axially symmetric Maxwell's equations [1].

We show that two almost overlapping pulses in time cause a significantly smaller volumetric modification than the two time-separated pulses (two pulses with a large time delay). We estimate the duration of the electron plasma shielding effect of $\tau_{plasma} \approx 600$ fs. We also show that, for larger volumetric modification, it is advantageous to use a weak pre-pulse followed by a stronger pulse. This can be explained by screening of the focus by self-trapped exciton population in the focal area [2].

[1] N. M. Bulgakova, V. P. Zhukov, S. V. Sonina, and Y. P. Meshcheryakov. “Modification of transparent materials with ultrashort laser pulses: What is energetically and mechanically meaningful?,” J. Appl. Phys., Vol. 118, 233108, 2015.
[2] N. M. Bulgakova, V. P. Zhukov, Y. P. Meshcheryakov, L. Gemini, J. Brajer, D. Rostohar, and T. Mocek. “Pulsed laser modification of transparent dielectrics: what can be foreseen and predicted by numerical simulations,” J. Opt. Soc. Am. B, Vol. 31(11), C8-C14, 2014.

	Monday, March 13	**Tuesday, March 14**	**Wednesday, March 15**
8^{30} - 8^{45}	**Registration**		
8^{45} - 9^{00}			
9^{00} - 9^{15}	**Opening and greetings**	Lecture 7	Lecture 16
9^{15} - 9^{30}	Lecture 1	**J. van Slageren**	**T. Lippert**
9^{30} - 9^{45}	**A. Gölzhäuser**	Lecture 8	Lecture 17
9^{45} - 10^{00}	Lecture 2	**A. Rastelli**	**T. Bein**
10^{00} - 10^{15}	**P. Fischer**	Lecture 9	Lecture 18
10^{15} - 10^{30}	**Posters:** **Short lectures and session** with coffee	**A. Lugstein**	**S. Skoff**
10^{30} - 10^{45}		Coffee	Coffee
10^{45} - 11^{00}		Lecture 10	Lecture 19
11^{00} - 11^{15}		**T. Werzer**	**J. Heitz**
11^{15} - 11^{30}		Lecture 11	Lecture 20
11^{30} - 11^{45}		**A. Naghilou**	**N. Vashistha**
11^{45} - 12^{00}	Lecture 3	Lecture 12	Lecture 21
12^{00} - 12^{15}	**I.C. Gebeshuber**	**E. Ehmoser**	**A. Gazso**
	Free discussion	Free discussion	**Closing Remarks**
17^{00} - 17^{15}	Coffee	Coffee	
17^{15} - 17^{30}	Lecture 4	Lecture 13	
17^{30} - 17^{45}	**T. Klar**	**N.M. Bulgakova**	
17^{45} - 18^{00}	Lecture 5	Lecture 14	
18^{00} - 18^{15}	**C. Zafiu**	**W. Kautek**	
18^{15} - 18^{30}	Lecture 6	Lecture 15	
18^{30} - 18^{45}	**U. Heiz**	**J. Freudenstein**	