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CeNS Workshop 2013

Nanosciences: Great Adventures on Small Scales

September 16 - 20, 2013
Venice International University (VIU), San Servolo, Italy

Content

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Invited Talks

Beyond Electronics: Abandoning Perfection for Quantum Technologies

David Awschalom
The University of Chicago, Institute for Molecular Engineering, Chicago, Illinois 60637T (USA)

Quantitative biology: there's plenty of room at the top

Stanislas Leibler
Laboratory of Living Matter, The Rockefeller University, New York, NY 10065 (USA)

Photo- and electroactive nanomaterials. Properties and applications

Luisa De Cola
Institute de Science et d'Ingénierie Supramoléculaires (I.S.I.S.), Université de Strasbourg (France) and KIT (Germany)

The creation of nano/microstructures based on molecular components possessing defined functionalities is a very fascinating field at the cross point of different disciplines. Our effort, in the last few years has been in controlling emission and electrical properties in confined space or in self- assembled structures. In the first part of my talk I will focus on metal complexes able to aggregate in fibers, gels and soft mechanochromic materials [1]. The use of platinum complexes as building block for luminescent devices will be illustrated. The emission of the compounds can be tuned by an appropriate choice oft he coordinated ligands as well as of their aggregation in different structures. The formation of soft assemblies allows the tuning of the emission color, by pressure and temperature leading to a new class of materials. In the second part of the presentation microporous silica based nanoparticles will be discussed as potential probes for biomedical applications [2]. Also it will be shown how the molecules entrapped in the ordered channels can become active components [3]. The alignment of electroactive molecules inside the narrow channels of a zeolite L, resulted in the formation of molecular wires. The molecular wire length is tunable between 30 and 100 nm and electrical measurements on the 1D assemblies were performed. Finally an ultra-high (> 2000%) room-temperature magnetoresistance was observed applying only a few mT.

[1] C. A. Strassert, L. De Cola et al. Angew. Chem. Int. Ed., 2011, 50, 946. M. Mauro, L. De Cola et al. manuscript in preparation.

[2] C. A. Strassert, L. De Cola et al. Angew. Chem. Int. Ed., 2009, 48, 7928-7931. R. Corradini, L. De Cola et al. submitted.

[3] L. De Cola, W.G. van der Wiel et al. Science, 2013, 341, 257.

Monday, September 16 (afternoon session)

Synthesizing Life from the Bottom Up

Steven Benner

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Synthetic biologists, in their more "chemical" activities, seek to create molecules that reproduce the more complicated behaviors of living system, including replication, adaptation, and evolution. The ultimate goal is to create, from the bottom up, "synthetic life", a grand challenge that cannot help but teach us about the intimate connection between chemical reactivity and the living state. This talk will present our most recent results creating artificial genetic systems, where organic chemistry has delivered non-standard DNA-like molecules that support replication, adaptation, and evolution.

Using nanotechnology for single-DNA and single-cell biophysics studies

Cees Dekker

Kavli Institute of Nanoscience Delft, Delft University of Technology (The Netherlands)

I will provide a number of highlights from our recent single-molecule and single-cell research:

1. Dynamics of DNA supercoils [1]
DNA in cells exhibits a supercoiled state where the double helix is additionally twisted to form extended intertwined loops known as plectonemes. Although supercoiling is vital to many cellular processes, its dynamics remain elusive. We have recently managed to directly visualize the dynamics of individual plectonemes. We observe that multiple plectonemes can be present and that their number depends on applied stretching force and ionic strength. Plectonemes are found to move along DNA by diffusion or, unexpectedly, by a fast hopping process which facilitates very rapid (< 20 ms) long-range plectoneme displacement by nucleating a new plectoneme at a distant position. The observations directly reveal the dynamics of plectonemes and identify a new mode of movement that allows long-distance reorganization of the conformation of the genome on a millisecond timescale. Follow up experiments now concentrate on the elucidating the effects of local pinning due to DNA sequence and bound proteins.

2. DNA and protein translocation through solid-state nanopores [2]
Solid-state nanopores have proven to be a surprisingly versatile probe for single-molecule analysis of DNA. I will describe some of our recent efforts to expand the capabilities of solid-state nanopores even further, in the direction of single-protein detection, graphene nanopores, plasmonic nanopores, and DNA origami nanopores.

3. Min oscillations in arbitrarily shaped *E. coli* cells [3]
I will show our ability to shape live *E. coli* bacteria into novel shapes such as rectangles, squares, triangles and circles. We study spatiotemporal oscillations of Min proteins – associated with cell division – in these artificial geometries.

[1] M.T.J. van Loenhout, M.V. de Grunt, C. Dekker, Dynamics of DNA supercoils, Science, 338, 94-97 (2012)

[2] C. Dekker, Solid-state nanopores, Nature Nanotechnol. 2, 209–215 (2007)

[3] F. Wu et al, to be published

Interferometric scattering microscopy: A high-speed camera for the nano-world

Philipp Kukura

Department of Chemistry, Oxford University (UK)

The primary goal of optical microscopy is to visualise and thereby understand microscopic structure and dynamics. Dramatic developments over the past decades have enabled routine studies down to the single molecule level and structural observations far beyond the limits defined by the diffraction limit through the use of fluorescence as a contrast mechanism. Despite its many advantages, one of the fundamental limitations of fluorescence detection is the frequency with which photons can be emitted and thus detected. As a consequence, although images and even movies of single molecules have become commonplace, imaging speed remains limited to few to tens of frames per second by the quantum nature of single emitters. The result is a considerable gap between the rate at which dynamics can be recorded and the underlying speed of motion on the nanoscale. A classic example is the diffusion of proteins and lipids in lipid bilayers, such as the plasma membrane, that is several orders of magnitude faster than currently available nanoscopic imaging methodologies. I will introduce an alternative approach to optical microscopy that relies on the ultra-efficient detection of light scattering, rather than fluorescence, called interferometric scattering microscopy (iSCAT). I will show that iSCAT is capable of following the motion of nanoscopic labels comparable in size to semiconductor quantum dots with true nm accuracy down to the microsecond regime, the relevant timescale for a majority of nanoscopic dynamics. Thereby, we are able to address a surprising variety of fundamental questions in molecular biophysics ranging from the mechanical properties of DNA to the existence and formation of lipid rafts in membranes. I will close with examples of the potential use of iSCAT for ultra-sensitive and super-resolved imaging of nanoscopic structure, assembly and disassembly at high-speeds, but with a sensitivity only known from scanning probe microscopies, such as AFM.

Enabling quantum technologies with micromechanical oscillators

Konrad W. Lehnert

JILA, University of Colorado, Boulder, CO 80309-0440 (USA)

Should micro-electromechanical (MEMS) devices play any role in a future quantum information processing technology? Although these structures are ubiquitous in modern electronics, their use in a future quantum information processor is not widely anticipated. In this talk, I will argue that MEMS devices may impact quantum information processing in two important areas. First, they provide a general platform for creating interactions between two otherwise non-interacting systems and thereby create hybrid quantum devices. In particular, I will describe our progress in using mechanical oscillators to build quantum coherent interfaces between the microwave and optical domains. Second, they are long lived, compact structures that can be integrated with superconducting qubits. As such they may provide local memory elements to that quantum computing architecture. I will also discuss our recent progress in this endeavor.

Tuesday, September 17 (morning session)

Nano-Optical Probes: Opening Doors to Previously-Inaccessible Parameter Spaces

P. James Schuck

The Molecular Foundry, Lawrence Berkeley National Laboratory, Berkeley, CA 94720 (USA)

In this presentation, I will discuss two types of nano-optical probes. The first type are near-field optical scanning probes, which are used to investigate materials by combining the best aspects of optical characterization and scan-probe microscopy techniques. In principle, this provides access to chemical, morphological, physical and dynamical information at nanometer length scales that is impossible to access by other means. But a number of challenges, particularly on the scan-probe front, have limited the widespread application of near-field investigations. The specific example of the "campanile" probe geometry will be discussed in detail, where it has recently been used for hyperspectral mapping of luminescence heterogeneity along InP nanowires, providing spectral information distinct from that obtained with other methods.

The second class of probes I will discuss are a type of luminescent nanocrystal – upconverting nanoparticles (UCNPs). While there has been significant progress in building microscopes able to image single molecules with increasing sensitivity and resolution, an ongoing critical challenge is the development of luminescent probes with the photostability, brightness, and continuous emission necessary for single-molecule imaging. Lanthanide-doped upconverting nanoparticles (UCNPs) overcome problems of photostability and continuous emission, but their brightness has been limited by a poor understanding of energy transfer within the nanocrystal and an unavoidable trade-off between brightness and size. Here, I will demonstrate a novel design paradigm that has resulted in UCNPs that are an order of magnitude brighter under single-particle imaging conditions than the brightest existing compositions, allowing us to visualize single UCNPs as small as fluorescent proteins. Through a combination of sub-10-nm single-particle characterization and theoretical modeling to find that surface effects and saturations effects fundamentally change the dominant factors that determine nanocrystal brightness. I will show that factors known to increase brightness in ensemble experiments are unimportant at higher excitation powers, and that, paradoxically, the brightest probes under single-molecule excitation are barely luminescent at the ensemble level.

Quantum back-action in recent cavity-optomechanics experiments

Oskar Painter[1,2]

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2 Thomas J. Watson, Sr., Laboratory of Applied Physics, California Institute of Technology, Pasadena CA 91125 (USA)

Quantum limits to precision measurement of an object's displacement, and correspondingly the forces acting on the object, have been well studied since the 1970's [1]. In the case of laser interferometers, quantum fluctuations of the probe laser field set the level of imprecision for displacement sensitivity and also give rise to quantum back-action via radiation pressure shot noise. Recent experiments with much smaller chip-scale devices have for the first time measured the effects of quantum back-action in the context of cavity-optomechanics [2-4]. I will describe two of these experiments that have been performed at Caltech. The first involves measurement of the relative amplitude of the Stokes and anti-Stokes motional sidebands created on a probe laser field by a mechanical resonator near its quantum ground-state of motion. An asymmetry in the generated motional sidebands, as has been utilized in experiments with trapped ions and atoms, provides a self-calibrated means of measuring the mechanical oscillator's quantum occupancy. An alternative view of such experiments [5], one from the perspective of continuous position measurement of the mechanical oscillator, provides an interesting twist in interpreting the source of the measured sideband asymmetry. A second experiment, involves the use of strong measurement by a probe laser field to generate, via quantum back-action, squeezed light from a silicon micromechanical resonator.

[1] Carlton M. Caves, Kip S. Thorne, Ronald W. P. Drever t Vernon D. Sandberg, and Mark Zimmermann, "On the measurement of a weak classical force coupled to a quantum-mechanical oscillator. I. Issues of principle," Rev. Mod. Phys. 52, 341 (1980).

[2] Amir H. Safavi-Naeini, Jasper Chan, Jeff T. Hill, T. P. Mayer Alegre, Alex Krause, and Oskar Painter, "Observation of quantum motion of a nanomechanical resonator," Phys. Rev. Lett., art. 033602, (Jan. 17 2012).

[3] Daniel W. C. Brooks, Thierry Botter, Sydney Schreppler, Thomas P. Purdy, Nathan Brahms, and Dan M. Stamper-Kurn, "Non-classical light generated by quantum-noise-driven cavity optomechanics," Nature 488, 476–480 (23 August 2012).

[4] T. P. Purdy, R. W. Peterson, and C. A. Regal, "Observation of Radiation Pressure Shot Noise," arXiv:1209.6334 (September 27, 2012).

[5] Farid Ya. Khalili, Haixing Miao, Huan Yang, Amir H. Safavi-Naeini, Oskar Painter, and Yanbei Chen, "Quantum back-action in measurements of zero-point mechanical oscillations," PHYSICAL REVIEW A, v86, art. 033840, (September 25, 2012).

Geometric and Mechanical Material Constraints Guide Collective Cell Migration

S. Rausch, T. Das, T.W. Hofmann, C.H.J. Boehm, H. Boehm, and J.P. Spatz

Max Planck Institute for Intelligent Systems, Dept. New Materials and Biosystems & University of Heidelberg, Dept. Biophysical Chemistry (Germany)

The collective migration of cells is fundamental to epithelial biology. One of the hallmarks of collective behavior in migrating cohesive epithelial cell sheets is the emergence of so called leader cells. These cells exhibit a distinct morphology with a large and highly active lamellipodium. Although it is generally accepted that they play a crucial part in collective migration, the environmental and biophysical factors that regulate their formation remain unknown.

Here we discuss that a geometry-based cue imposed by the matrix environment like local curvature of the collective's perimeter is capable of triggering leader cell formation and promoting enhanced motility at defined positions. Remarkably, the extent of this effect scales with the magnitude of the curvature.

Cytoskeletal tension was found to be important for geometry induced leader cell formation, as cells treated with tension reducing agents appeared less sensitive to local curvature. Accordingly, traction force microscopy revealed an increased level of shear stress at highly curved positions even before the cell migration had actually started, indicating the presence of a collective polarization induced by the geometry of the confinement.

Together our findings suggest that high curvature leads to locally increased stress accumulation, mediated via cell-substrate interaction as well as via cytoskeleton tension. The stress accumulation in turn enhances the probability of leader cell formation as well as cell motility. This work defines the importance of geometric cue such as local curvature in the collective migration dynamics of epithelial cells and thus shows implications for the material and biophysical regulation of epithelium during wound healing, embryonic development, and oncogenesis.

Fluorescence Enhancement at Docking Sites of DNA-Directed Self-Assembled Nanoantennas

F.M. Möller[1], G.P. Acuna[2], P. Holzmeister[2], S. Beater[2], B. Lalkens[2], P. Tinnefeld[2]

1 Faculty of Physics, Ludwig-Maximilians-University München (Germany)

2 Institut für Physikalische und Technische Chemie,Technische Universität Braunschweig (Germany)

Single-Molecule fluorescence spectroscopy is an important tool to learn about (bio-)molecular interactions, which are the base of all processes within living systems. However, until now it suffers from bad signal to noise ratios and a very low concentration range of pico- to nanomolar, far off the biologically relevant regime. Here we present a comparably simple and cheap, new technique to overcome these limitations. Fluorescence is locally enhanced by two metal nanoparticles, working as a plasmonic nanoantenna. Upon excitation at the metal's plasmon frequency excitation light is concentrated in a hotspot, leading to an observation volume reduction and strong fluorescence enhancement. A DNA origami arranges the nanoparticles and the fluorophore with respect to each other and to the excitation field with nanometer precision. We measured the dependence of the fluorescence enhancement on nanoparticle size and number, as well as on excitation polarization. The results are in accordance with numerical simulations. A maximum of 117-fold fluorescence enhancement was obtained for a dye positioned in the 23 nm gap between 100 nm gold nanoparticles at circular excitation polarization.[1] This allowed first measurements at µM concentrations.[2] Slow rotation of the excitation polarization lead to a strong fluorescence modulation and an additional enhancement factor of two.[3] Direct visualization of the binding and unbinding of short DNA strands, as well as the conformational dynamics of a DNA Holliday junction in the hotspot of the nanoantenna, assure the compatibility with single-molecule assays.[1] Thus the presented nanoantenna system can extend the concentration range of single-molecule measurements to the biologically relevant micro- to millimolar regime and paves the way towards an inexpensive plasmonic device which can widely be applied for ultra-sensitive sensing and nanoscale light control.

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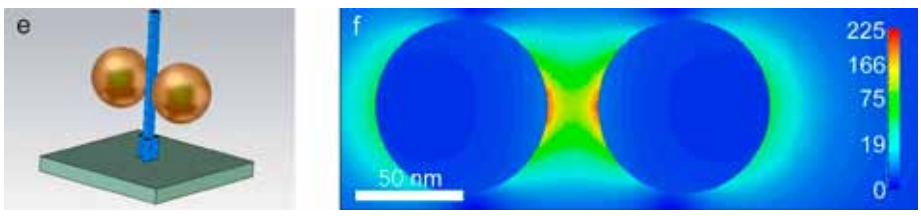
[2] G.P. Acuna, P. Holzmeister, F.M. Möller, S. Beater, B. Lalkens, P. Tinnefeld. DNA-Templated Nanoantennas for Single-Molecule Detection at Elevated Concentrations. J.Biomed.Opt., 18(6): 065001.1-5, 2013.

[3] F.M. Möller, P. Holzmeister, T.Sen, G.P. Acuna, P. Tinnefeld. Polarization Dependent Fluorescence of a Single Dye near a Gold Nanoparticle Arranged on DNA Origami. Nanophotonics, 2(3): 167-172, 2013.



Left: A pillar shaped DNA origami (blue) on a glass cover slip (grey) aligns two gold nanoparticles and a fluorophore with respect to each other and the incident field. Right: Numerical simulation of the electric field intensity around two 80 nm gold nanoparticles. The scale bar represents 50 nm.

Tuesday, September 17 (afternoon session)

Spatial organization of cells via phase separation in the cytoplasm

Frank Jülicher

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Cells exhibit a complex spatial organization, often involving organelles that are surrounded by a membrane. However there exist many structures that are not membrane bounded. Examples are the centrosome, meiotic and mitotoc spindles as well as germ granules. How can such structures be assembled in space inside the cytoplasm which is essentially a fluid where all components usually mix? I will highlight the importance of phase coexistence and phase separation of fluid phases in the cell cytoplasm as a basic mechanism of the spatial organization of cells. Droplets in the cytoplasm can represent microreactors with different composition and chemistry as compared to the surrounding cytoplasm. I will discuss how such concepts shed light on the structure and organization of centrosomes and of meiotic spindles.

On-chip transduction and coherent control of nanomechanical resonators

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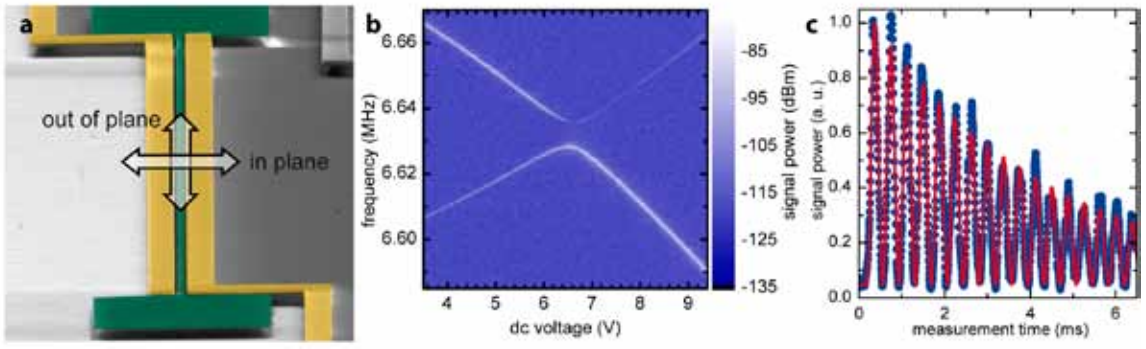
Fakultät für Physik and Center for NanoScience (CeNS), Ludwig-Maximilians-Universität München, München (Germany)

The study of nanomechanical resonant motion is a rapidly advancing field of science with prospects in fundamental studies and sensor elements. For all these applications, a versatile, integrated transduction system compatible with high quality factor nanomechanics and room temperature operation is an elemental prerequisite. We present a heterodyne approach based on a room temperature microwave cavity dielectrically coupled to a doubly clamped high-stress silicon nitride resonator. Using this technique, the motion of both fundamental flexural modes of the string resonator vibrating in and out of the sample plane can be monitored, actuated and their resonance frequencies can be tuned with respect to each other. The oscillation directions of the two modes are illustrated in the SEM micrograph of the 55µm long resonator between the two adjacent gold electrodes depicted in panel a of the figure below.

Using these control techniques, we are able to observe a pronounced avoided crossing and thus strong coupling between the two modes (see panel b of the figure below). Sweeping the previously initialized system through the coupling region with different velocities, classical Landau-Zener transitions can be studied anywhere between the diabatic and adiabatic limit.

Furthermore, the transitions between the two modes at the point of maximum coupling can be pumped by an electrical signal, thus making the system perform Rabi oscillations (see panel c of the figure). Via Ramsey and Hahn echo experiments, the energy and phase relaxation rates of the coherent superposition states are extracted, revealing that the coherence is solely limited by energy relaxation.



Visualizing protein-DNA interactions with DNA curtains

Eric Greene

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Our group uses single-molecule optical microscopy to study fundamental interactions between proteins and nucleic acids. Our overall goal is to reveal the molecular mechanisms that cells use to repair, maintain, and decode their genetic information. This research combines aspects of biochemistry, physics, and nanoscale technology to answer questions about complex biological problems that simply can not be addressed through traditional biochemical approaches. The advantages of our approaches are that we can actually see what proteins are bound to DNA, where they are bound, how they move, and how they influence other components of the system - all in real-time, at the level of a single reaction. We are particularly interested in determining the physical basis for the mechanisms that proteins use to survey DNA molecules for damage and initiate repair processes, and how these initial steps are coordinated with downstream events that lead to completion of repair. As part of our work, we are also actively pursuing the development of novel experimental tools that can be used to facilitate the study of single biochemical reactions. We are applying techniques derived from nanotechnology to our biological research, and using nano- and micro-scale engineering to facilitate the development of new, robust experimental platforms that enable "high throughput" single molecule imaging.

Wednesday, September 18 (morning session)

Photocatalytic solar fuel generation with colloidal nanocrystal

Frank Jäckel

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Solar fuels represent an attractive way of storing solar energy in high energy chemical bonds for later use. This is important to overcome the challenges posed by the intermittent nature of most renewable energy sources. The most promising solar fuels are hydrogen (obtained from water splitting or reduction) and reduction products of carbon dioxide.

In my talk, I will first outline the basic approaches and principles of photocatalytic hydrogen generation. Subsequently, I will discuss highlights of our recent research on photocatalytic hydrogen generation employing Pt decorated CdS nanorods.[1,2] In particular, I will focus on the role of hole scavengers[3] and the importance of the atomic-scale details of the catalyst clusters.[4,5]

[1] M. Berr, A. Vaneski, A.S. Susha, J. Rodríguez-Fernández, M. Döblinger, F. Jäckel, A.L. Rogach, J. Feldmann, Appl. Phys. Lett. 2010, 97, 093108.

[2] M. Berr, A. Vaneski, C. Mauser, S. Fischbach, A.S. Susha, A.L. Rogach, F. Jäckel, J. Feldmann, Small 2012, 8, 291–297.

[3] M. Berr, P. Wagner, S. Fischbach, A. Vaneski, J. Schneider, A.S. Susha, A.L. Rogach, F. Jäckel, J. Feldmann, Appl. Phys. Lett. 2012, 100, 223903.

[4] M. Berr, F.F. Schweinberger, M. Döblinger, K.E. Sanwald, C. Wolff, J. Breimeier, A.S. Crampton, C.J. Ridge, M. Tschurl, U. Heiz, Nano Lett. 2012, 12, 5903–5906.

[5] F.F. Schweinberger, M.J. Berr, M. Döblinger, C. Wolff, K.E. Sanwald, A.S. Crampton, C.J. Ridge, F. Jäckel, J. Feldmann, J. Am. Chem. Soc. 2013 DOI: 10.1021/ja406070q.

Modal coupling in GaAs-based mechanical resonators and phonon lasing operation

Hiroshi Yamaguchi,[1,2] Hajime Okamoto,[1] Takayuki Watanabe,[1,2] and Yuma Okazaki[1]

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The use of compound semiconductor heterostructures allows us to fabricate micro/nanomechanical systems with novel functionalities [1-7]. In this talk, we present examples of experimental results that we have recently demonstrated in our investigations of electromechanical resonators made of semiconductor-based low-dimensional quantum structures.

The mechanical motion can be coupled to the photo-excited carriers in compound semiconductors by piezoelectricity. Through the optomechanical effects, the thermal motion can be optically controlled in similar way as that in cavity optomechanics. The amplification and the damping of thermo-mechanical vibration have been demonstrated by simply applying the laser light with a near-bandgap wavelength [3,4]. We proposed to utilize the carrier-mediated optomechanical interaction for characterizing the properties of semiconductors [5]. Optical absorption properties and carrier dynamics are studied through the mechanical resonance characteristic.

We also investigate the coupling between carriers and mechanical degrees of freedom in low-dimensional electron systems. The back-action on the mechanical motion mediated by electron systems is studied. In high mobility two-dimensional electron systems, electron localization induced by quantum Hall effects strongly suppresses the damping of mechanical motion, showing the electron-induced mechanical friction [6]. The carrier-medicated back-action is also confirmed in quantum dots systems, where both damping and amplification were observed depending on the relative position of Fermi level to the quantized electron energy in QD [7].

We are grateful to H. Goto, I. Mahboob, K. Onomitsu, H. Sanada, S. Sasaki, and T. Sogawa, for their kind cooperation in this study. This work was partly supported by Grants-in-Aid for Scientific Research from the Japan Society for the Promotion of Science.

[1] I. Mahboob and H. Yamaguchi, Nature Nanotech. 3, 275 (2008).

[2] H. Okamoto, A. Gourgout, C.-Y. Chang, K. Onomitsu, I. Mahboob, E. Y. Chang and H. Yamaguchi, Nature Phys. 9, 480 (2013).

[3] H. Okamoto, D. Ito, K. Onomitsu, H. Sanada, H. Gotoh, T. Sogawa, and H. Yamaguchi, Phys. Rev. Lett. 106, 036801 (2011).

[4] T.Watanabe, H. Okamoto, K. Onomitsu, H. Gotoh, T. Sogawa, and H. Yamaguchi, unpublished.

[5] T.Watanabe, H. Okamoto, K. Onomitsu, H. Gotoh, T. Sogawa, and H. Yamaguchi, Appl. Phys. Lett. 101, 082107 (2012).

[6] H. Yamaguchi, H. Okamoto, S. Ishihara, and Y. Hirayama, Appl. Phys. Lett. 100, 012106 (2012).

[7] Y. Okazaki, I. Mahboob, K. Onomitsu, S. Sasaki, and H. Yamaguchi, unpublished.

Active 3D DNA Plasmonics

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We utilize structural DNA technology to achieve intelligent plasmonic nanomachines with engineerable optical response and active functionalities. Plasmonic metal particles are assembled at specific locations on an active 3D DNA origami template with nanometer scale accuracy. The plasmonic system constitutes a well-defined 3D configuration with unique optical response. Due to the intrinsic programmability and excellent functionalities of DNA, the plasmonic nanomachine can respond to external stimulus upon recognition of biochemical events or stimulated movements of the DNA template. Any conformational changes of the plasmonic nanomachine will lead to the near-field interaction changes of the metal particles in the 3D assembly and therefore give rise to immediate optical signal changes in the spectrum, providing an active optical response to external stimulus. Due to the native biocompatibility of DNA, this will enable a new generation of 3D plasmon rulers.

Voltage sensing inorganic nanoparticles

Shimon Weiss

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We will report on efforts to develop voltage sensing inorganic nanoparticles that self-insert into the cell membrane and optically record, non-invasively, action potential on the single particle level. Bandgap-engineered colloidal semiconductor nanoparticles, dubbed voltage-sensing nanoparticles (vsNPs) that display large quantum-confined Stark effect (QCSE) at room temperature and on the single particle level were developed. QCSE measurements of several types of fluorescent colloidal semiconductor quantum dots (QDs) and nanorods (NRs) were performed. It was shown that charge separation across one (or more) heterostructure interface(s) with type-II band alignment (and the associated induced dipole) is crucial for an enhanced QCSE. Surface functionalization that impart membrane-protein like properties was developed. We will discuss the possible utility of these nanoparticles for voltage sensing on the nanoscale, and in particular, their suitability for action potential recording.

Thursday, September 19 (morning session)

Plasmonics in the sub-nanometre and quantum domains

Jeremy Baumberg
FRS, University of Cambridge (UK)

Coupling between plasmonic nano-components generates strongly red-shifted resonances combined with intense local field amplification on the nanoscale. In recent years we have explored plasmonic coupling combined with soft materials to tune this interaction dynamically, and to work in the strong coupling domain for gaps below 1nm which can be formed reliably by bottom-up self-assembly. At these distances, coupled dipoles are not sufficient to describe the response, and the system is described in terms of gap plasmons. The crucial aspect of these systems is the extreme sensitivity to separation, and how quantum tunneling starts to play an influence that can be directly seen at room temperature in ambient conditions. We recently demonstrated how quantum plasmonics controls the very smallest space that light can be squeezed into.

[1] Nature 491, 574 (2012); Revealing the quantum regime in tunnelling plasmonics.

[2] Nano Letters 10, 1787 (2010); Actively-Tuned Plasmons on Elastomeric Au NP Dimers.

[3] ACS Nano 5, 3878 (2011); Precise sub-nm plasmonic junctions within Au NP assemblies.

Ultrafast polarization control of topological photocurrents

Alexander W. Holleitner
Walter Schottky Institut and Physik-Department, Technische Universität München, Am Coulombwall 4a, 85748 Garching (Germany)

In recent years, a new class of quantum solid state materials, called topological insulators, has emerged. In the bulk, a topological insulator behaves like an ordinary insulator exhibiting states with a band gap. At the surface, gapless states exist showing remarkable properties such as helical Dirac dispersion near zero energy and suppression of backscattering of spin-polarized charge carriers. The characterization of the surface states via transport experiments is often hindered by a large residual bulk charge carrier density. Here, I will demonstrate that polarization-dependent photocurrents can be controlled and read-out in Bi2Se3 on a time-scale of a picosecond with a near-unity fidelity even at room temperature [1]. We reveal the temporal interplay of such ultrafast spin currents with photo-induced thermoelectric and drift currents in the optoelectronic circuits. Our results may prove essential for an ultrafast off/on-chip communication of an information technology based on topological insulators.

In my lecture, I will introduce the underlying, essential ultrafast photocurrent spectroscopy to measure topological currents in the picosecond regime [2], and I will guide through further experimental challenges in nanoscale optoelectronics [3].

I gratefully acknowledge the fruitful work and collaboration with C. Kastl, C. Karnetzky, and H. Karl. This work was supported by the DFG via SPP 1666 (grant HO 3324/8), ERC Grant NanoREAL (n°306754), the DFG excellence cluster Nanosystems Initiative Munich (NIM), and the Center for NanoScience (CeNS) in Munich.

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Dislocation Mediated Elongation of Bacteria via Nanomachines

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Recent experiments have revealed a remarkable growth mechanism for rod-shaped bacteria: specialized proteins associated with cell wall elongation move at constant velocity in clockwise and counterclockwise directions on circles around the cell circumference. We argue that this machinery attaches to dislocations in the ordered peptidoglycan cell wall, and study theoretically the dynamics of these interacting nanomachines on the surface of a cylinder. Unlike the dislocations typical in materials science, the motion is predominantly climb (glycan strand extension) instead of glide. The activated motion of these dislocations and the resulting dynamics within a simple kinetic model show surprising effects arising from the cylindrical geometry, with important implications for bacterial growth. Recent experiments revealing plastic deformation of bacterial cell walls in a hydrodynamic flow will be presented as well.

Ultrasmall nanoparticles for energy applications

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One of the most demanding fields of research in this century is the development of sustainable and high performance energy conversion and storage technologies. This goal is closely connected to the development of suitable materials. In addition to the design of completely new materials, the properties of already existing materials can be improved and modified by nanostructuring. Nanostructuring has the potential for greatly enhancing the performance of materials in many applications, for example due to an increased surface area and short diffusion pathways in porous systems. Hence, green, non-toxic and low-temperature bottom-up syntheses of nanomaterials and their building blocks with defined properties are of great interest.

In this talk, the synthesis of nanomaterials for energy storage and conversion applications, such as lithium ion batteries, dye-sensitized solar cells and photoelectrochemical water splitting will be presented. In order to achieve this, we have developed a novel synthesis approach based on solvothermal reactions in tert-butanol to obtain ultra-small, crystalline metal-oxide nanoparticles. The nanoparticles obtained in this way exhibit a very good dispersibility and extremely small sizes down to about 3 nm. These features make them promising building blocks for low-temperature bottom-up syntheses of porous nanomaterials via surfactant templated evaporation-induced self-assembly. Additionally, due to the small size and the good dispersibility, the nanoparticles can be homogeneously distributed on the surface of pre-formed porous nanostructures for catalytic applications. The absence of aromatic ligands on the nanoparticle surface enables a very good electrical accessibility in the above-mentioned electronic applications.

Successful nanoparticle syntheses in tert-butanol were accomplished for ultrasmall crystalline TiO_2, Nb-doped TiO_2, $Li_4Ti_5O_{12}$, NiO and Co_3O_4. The advantages of these nanoparticles will be demonstrated in two examples: The fully crystalline interconnected mesoporous frameworks assembled from $Li_4Ti_5O_{12}$ by surfactant templating led to the fastest insertion of lithium in lithium ion batteries ever reported. This can be explained by extremely thin nanocrystalline walls drastically decreasing the lithium ion diffusion pathways. The second example will show the application of Co_3O_4 nanoparticles as an efficient surface treatment on mesoporous hematite electrodes for photoelectrochemical water splitting.

Thursday, September 19 (afternoon session)

Chemical warfare and survival strategies in bacterial range expansions

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Spreading of species into uncolonized territory is a fundamental ecological process in the evolution and maintenance of biological diversity. Although interactions between species have experimentally been identified as major determinants of species coexistence in spatially extended populations, their role in spatially expanding populations is largely unknown. Here, we address the roles of resource and interference competition by genetically tuning a bacterial model system of three *Escherichia coli* strains: a toxin (colicin) producing strain (C), a sensitive strain (S), and a resistant strain (R). We show that maintenance of biodiversity is determined by three strongly interdependent ecological factors: the relative ratio of the competing strains, their growth rates and the strength of toxicity. Range expansion experiments with equal initial ratios do not lead to three-strain coexistence. However, exploring the impact of the initial C strain ratio with a mathematical model predicts the presence of a biodiversity window. This prediction is fully confirmed by experiments. The robust agreement between experiments and theory enables us to study parameter regimes beyond the experimental reach. These studies allow us to quantify the correlations between the ecological factors promoting biodiversity. Our mathematical analysis suggests that, despite general expectations, a non-hierarchical interaction network is not a necessary prerequisite for biological diversity. Moreover, we find that robust three-strain coexistence requires a balance between growth rates and a small enough toxicity range or, alternatively, a reduced initial ratio of the colicin-producing strain. We expect that the approach presented in this study will be useful to identify further mechanisms for the maintenance of biodiversity in microbial communities.

Spin-photon entanglement in quantum dots

Weibo Gao, Aymeric Delteil, Parisa Fallahi, Emre Togan and Atac Imamoglu

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Realization of a quantum interface between flying photonic qubits and stationary spin qubits is expected to play a key role, both in quantum repeaters and realization of quantum networks. Thanks to their superior optical properties and the possibility of integration in photonic nanostructures, semiconductor quantum dots confining a single spin are particularly well suited for this purpose. In this work, we will describe our recent observation of spin-photon entanglement and demonstration of quantum teleportation from a propagating photonic qubit to a stationary spin qubit.

[1] W. B. Gao, P. Fallahi, E. Togan, J. Miguel-Sanchez & A. Imamoglu, Nature 491, 426–430 (2012)

Accessibility of telomeric G-quadruplex DNA studied by single molecule fluorescence

Helen Hwang[1,2], Alex Kreig[1], Jacob Calvert[1], Justin Lormand[3], Yongho Kwon[4], James M. Daley[4], Patrick Sung[4], Patricia L. Opresko[3], Sua Myong[1,5,6]

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The G-rich single stranded DNA at the 3' end of human telomeres can self-fold into G-quaduplex (GQ). However, telomere lengthening by telomerase or recombination-based alternative lengthening of telomere (ALT) mechanism requires protein loading on the overhang. We report here that telomeric overhangs exhibit dynamic properties when the length exceeds four TTAGGG repeats. Overhangs with four and eight repeats that can fold into one GQ and two GQs, respectively, show limited accessibility to telomerase loading and extension activity, and to loading of the ALT-associated proteins RAD51, RPA, WRN and BLM. However, overhangs with five to seven repeats showed much higher accessibility to these proteins. In contrast, POT1, the telomere-specific single-stranded DNA binding protein, binds independently of repeat number. Our results suggest that the telomeric overhang repeat length and dynamics may contribute to telomere extension via telomerase action and the ALT mechanism.

Nanomachines in the innate immune sensing of viral nucleic acids

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The innate immune system is a first line of defense of our cells against invading viruses and bacteria. Cells sense viruses and bacteria in the cytosol predominantly via their RNA and DNA molecules. We study the molecular mechanism of the detection of cytosolic DNA and cytosolic RNA by receptors of the innate immune system. An important question is how these receptors can robustly distinguish pathogenic nucleic acids from the large amount and diversity of host nucleic acids. The receptors turn out to be molecular machines that use the energy of ATP hydrolysis to robustly detect specific features of viral RNA that are mostly absent in host RNA.

Probing the response of double-stranded RNA to force and torque at the single-molecule level

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Double-stranded RNA (dsRNA) plays a number of roles in biological processes in which it often encounters mechanical strain; examples include the packaging of double-stranded RNA (dsRNA) viral genomes into capsids, deformations of the ribosome during translation, and more generally conformational changes of functional RNAs while folding or due to interactions with proteins. While the response of dsDNA to applied forces and torques has been measured with exquisite precision, much less is known about dsRNA.

We have developed a "polymerase-stall" labeling method that allows us to generate fully double-stranded RNA constructs carrying multiple biotin and digoxigenin labels at opposite ends. Using the functionalized dsRNA constructs in a range of a complementary magnetic tweezers assays (1-3), we have probed the elastic properties of dsRNA and, in addition, determined force and torque induced structural transitions that go beyond linear response behavior.

From the force-extension response, we have determined the bending persistence length and the stretch (or Young's) modulus of dsRNA and find values in agreement with previous measurements (4,5) and overall similar to dsDNA. Employing our novel magnetic torque tweezers assays, we have probed the torsional response of dsRNA and again find a behavior that is generally similar to dsDNA. Surprisingly, measurements of the twist-stretch coupling reveal a striking difference between dsRNA and dsDNA. While DNA lengthens when overwound, RNA shortens. In addition, we have studied the dynamics of the buckling transition under positive twist (6) and discovered that the characteristic time scale of the transition is about two orders of magnitude slower for RNA than for DNA.

We expect that these measurements of the fundamental properties of dsRNA can help refine our models for twist-storing polymers and inform quantitative models of RNA function in vivo.

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Poster Abstracts - Session I (A-Mai)

Poster Abstracts - Session II (Mal-Z; Barth)

Elucidating the roles of Notch signaling and contact morphology in sprouting angiogenesis

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During blood vessel formation Notch signaling determines which cell guides a new capillary sprout (tip cell) and which cells stay behind to form the vessel lumen (stalk cells). Tip and stalk cells dynamically change their fate and their position within the growing sprout. Thereby, cells must frequently break down cellular junctions and form new ones. Notch receptors and ligands are enriched at endothelial cell contacts and this allows cell-to-cell signaling. It is however still unknown, which factors affect the localization of Notch ligands and receptors at endothelial junctions and how dynamic this process is. Furthermore, little is known regarding how junctional integrity and contact area affect Notch signaling. We would like to understand how Notch receptors and ligands are dynamically distributed and how this distribution depends on the contact morphology between cells. To address this, we look at the cell-cell interactions and the contact area morphology using Murine R1 ES cells in witch we insert fluorescent probes into the coding sequences of the ligands and receptors of the cells using genome editing tools such as TALENs or CRISPR/Cas9 and advanced microscopy techniques such as live cell imaging, FRAP-TIRF and STORM super resolution imaging. Most methods used to examine parameters such as cell morphology and contact area are restrained by their limited ability to manipulate these interactions without influencing additional aspects of the cell's microenvironment. In an attempt to moderate these restraints, we employ micro-patterning devices that make it possible to easily manipulate the geometry of the boundary between cells, thus isolating and studying the effects of the contact morphology in these systems.

The role of endocytosis in the modulation of BMP receptors signaling

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The plasma membrane is the site where trans-membrane receptors encounter their respective ligands and initiate signaling cascades. Endocytosis of cell-surface receptors regulates the levels of the receptors at the plasma membrane and may be involved both in signal transduction and signal termination. Bone morphogenetic proteins (BMPs) are members of the TGF-β cytokines superfamily. They signal via two receptor Ser/Thr kinases, type I (BRI) and type II (BRII). BRII have two splice variants, the long form (BRII-LF) that contains a long C-terminal tail after the kinase domain which is absent in other TGF-β-family type II receptors, and the short form (BRII-SF), terminating shortly after the kinase domain. Although both forms induce BMP responses, it appears that the long C-terminal tail can modulate signaling. Here, we explored the influence of this C-terminal extension on the internalization of BRII. We find marked differences between the endocytosis rates of BRII-SF and BRII-LF, with BRII-LF endocytosis being much faster and achieving higher percentages of internalization. The differences between the endocytosis rates of BRII-SF and BRII-LF map the endocytosis-targeting signals to the unique C-terminal extension present in BRII-LF. To narrow in on the endocytosis motifs in this region, we measured the endocytosis rates of several serial truncations of BRII-LF, expressed in cells which do not express caveolin-1 (allowing to follow exclusively clathrin-mediated endocytosis, CME). These studies revealed that the enhanced endocytosis of BRII-LF is dependent on a region encompassed between amino acid residues 746-982. This region contains a potential di-leucine endocytosis motif (amino acid residues 869-870), whose replacement by di-alanine (BRII-LFaa) nearly abolished BRII-LF endocytosis. This identifies the CME endocytosis signal of BRII-LF as $Leu^{869}Leu^{870}$.

In-phase and anti-phase synchronization in noisy Hodgkin–Huxley neurons

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We numerically investigate the influence of intrinsic channel noise on the dynamical response of delay-coupling in neuronal systems. The stochastic dynamics of the spiking is modeled within a stochastic modification of the standard Hodgkin–Huxley model wherein the delay-coupling accounts for the finite propagation time of an action potential along the neuronal axon. We quantify this delay-coupling of the Pyragas-type in terms of the difference between corresponding pre-synaptic and postsynaptic membrane potentials. For an elementary neuronal network consisting of two coupled neurons we detect characteristic stochastic synchronization patterns which exhibit multiple phase-flip bifurcations: The phase-flip bifurcations occur in form of alternate transitions from an in-phase spiking activity towards an anti-phase spiking activity. Interestingly, these phase-flips remain robust for strong channel noise and in turn cause a striking stabilization of the spiking frequency.

Nanopore force spectroscopy on nucleic acid structures and their target complexes using biological and synthetic ion channels

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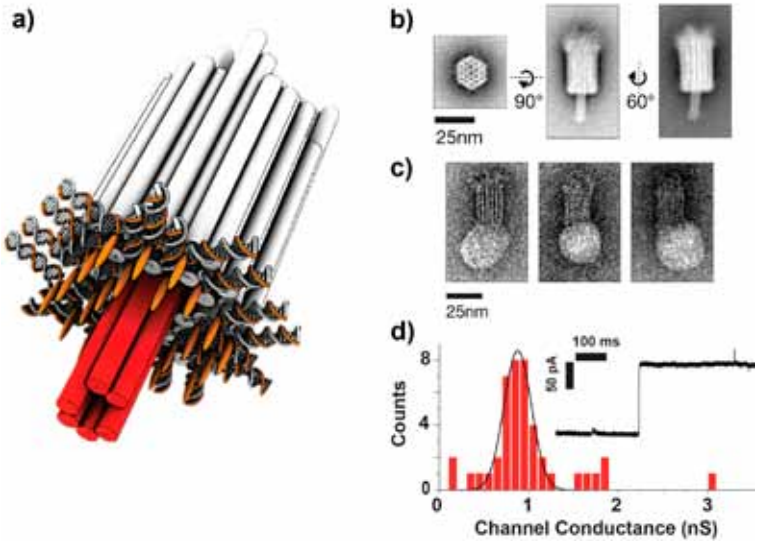
2 WSI, Physics Department, Technische Universität München, Garching (Germany)
3 Department of Biomedical Engineering, University of Michigan, Ann Arbor (USA)

Nanopore force spectroscopy (NFS) is a versatile tool for the investigation of single molecule interactions with high throughput, sensitivity and accuracy. In our experiments, we study the binding of the ATP aptamer to its target in terms of complex stability as well as binding affinity. From these experiments, the distribution of bound and unbound complexes is determined, which in turn allows determination of the dissociation constant Kd≈0.1 mM of the aptamer and of voltage-dependent unfolding rates. The experiments also reveal differences in binding of the aptamer to AMP, ADP, or ATP ligands [1]. Previous NFS studies were based on naturally occurring membrane channels like α-hemolysin or solid-state nanopores. Tailoring these systems to specific applications remains a challenging task, when altering the channels' geometry or chemical modification becomes necessary. We report a new type of synthetic lipid bilayer membrane channel with user-defined geometric specifications that is constructed entirely from DNA. Scaffolded DNA origami was used to create a stem that penetrates and spans a lipid membrane, and a barrel-shaped cap that adheres to the membrane in part via 26 cholesterol moieties. The electrical conductivity of the resulting membrane pores was studied by means of single-channel electrophysiological experiments. We find remarkable similarities to the behavior of biological ion channels such as "gating" caused by molecular fluctuations within the channel structure. Geometry and chemical properties of synthetic DNA channels can be tailored for custom nanopore sensing applications. We show that synthetic DNA channels can be used for single molecule studies on DNA structures [2]. Synthetic DNA channels introduced here open up broad perspectives for further applications as antimicrobial agents and interference with cellular homeostasis.



(a) Synthetic DNA membrane channels. b) Averaged negative-stain TEM images obtained from purified DNA channel structures. (c) Example TEM images of DNA channels adhering to small unilamellar vesicles (SUVs). (d) Stepwise increase in ionic current during an incorporation event at V = 200 mV. Histogram of channel conductances obtained from 43 incorporation events. The black line depicts a Gaussian fit.

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Cotransfection of three different SNIM RNAs to the PMEF cells with and without magnetofection

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Induced pluripotent stem cells (iPS) are a type of pluripotent stem celsl artificially derived from a non-pluripotent cell by inducing a "forced" expression of specific genes, which named Yamanaka factors (Oct3/4, Sox2, Klf4, c-Myc). In other words, for iPS production Cotransfection of four different genes to the somatic cells is required. In this experiment, cotransfection of three different marker SNIM RNAs (Luciferase, RFP and GFP), with and without the help of magnetofection, was examined to investigate the effect of cotransfection on transfection of every single mRNA. MTT test also was done to show the toxicity effect. The results showed that cotransfection of different mRNAs not only does not inhibit the transfection of every single mRNA, but also improves the transfection of genes which are easy to transfect. Also, MTT results indicated that toxicity with cotransfection does not significantly increase, and cells can tolerate this higher amount of nucleotides and enhancers. In addition, magnetofection improves cotransfection as well as transfection of mRNAs. According to this results, producing iPS with cotransfection of Yamanaka SNIM RNAs is possible. Also it is clear that, using magnetic nano particles and magnetofection methods considerably improves transfection and cotransfection as well.

Quantum dot-carbon nanotube photo responsive surfaces for optical stimulation of neurons

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3 School of Chemistry, Hebrew University, Jerusalem (Israel)

Retinal prosthetic devices aim to restore vision following blindness caused by degenerative diseases of the retina, such as retinitis pigmentosa. In these diseases, the photoreceptor layer of the retina degenerates, while the rest of the retinal layers remain functional. Thus, an artificial system capable of locally stimulating remaining inner neurons will allow vision restoration. Clearly, wiring-free optical stimulation of the retina is an ideal platform for such vision restoration. Here we present a novel approach for light induced neuronal stimulation based on the conjugation of quantum dots (QDs) with high density carbon nanotubes (CNTs). These conjugates form photo-responsive electrodes where the QDs supply light induced charge separation and the CNT films provide superior electrochemical properties and support excellent neuronal cell adhesion. Plasma polymerized acrylic acid coating was used as a platform for covalently binding amine functionalized QDs directly on the porous surface. Through plasma polymerization robust thin films with good controllability of the surface composition were formed and used for efficient QD binding. The effectiveness of the presented method is demonstrated by photocurrent and photovoltage measurements of the QD decorated CNT films. These photo responsive surfaces are currently being investigated in vitro for optical stimulation of a blind retina model.

Short Peptide Nucleic Acid (PNA) as Novel Building Blocks for Supramolecular Assemblies

Or Berger, Lihi Adler-Abramovich and Ehud Gazit

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Peptide nucleic acid (PNA) is an artificially-synthesized polymer. It is similar to nucleic acids except of the phosphate ribose ring of DNA which is replaced by a peptide-like polyamide backbone. Due to its flexible and neutral backbone, PNA displays very good hybridization properties with either DNA or RNA with high affinity and specificity, even at low ion concentration. Furthermore, PNA shows high chemical stability and resistance to both nuclease and protease degradation. Subsequently, this unique molecule has attracted large interest both in biotechnology and biomedicine. PNA has been previously used in the formation of ordered nano- and micro-sized self-assembled architectures, but only as a template or as a conjugate to the self-assembled structure in order to gain specific recognition properties. To date, no work has been done on PNA as a material able to form assemblies by itself. Since PNA shares common attributes with both peptides and DNA, it can converge the two worlds of peptide self-assembly and DNA nanotechnology. The nucleic acid nature of the PNA may give it the potential to form typical DNA assemblies such as DNA origami and G-quadruplex. On the other hand, the peptide backbone decorated with aromatic moieties makes it similar to the self-assembled diphenylalanine motif of the Alzheimer's β-amyloid peptide. Here we employed the chemical method of solid-phase peptide synthesis and synthesized the 16 different di-PNAs, which were screened for the ability to form ordered assemblies. Indeed, several different structures of nano- and micro-metric scales were identified, exclusively for guanine containing PNAs. Owing to the remarkable properties of the PNA, such as durability, high thermal stability and synthetic versatility, the nanostructures hold great potential that could be exploited in various biotechnology and biomedicine applications such as highly sensitive biosensors and drug delivery vehicles able to target specific genes.

EM and single particle image processing of Myosin-XXI

Dario Brack, Claudia Veigel

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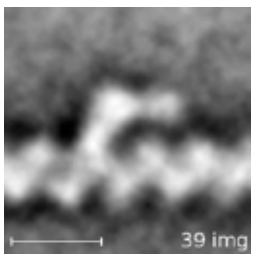

Figure 1: Class average of 39 myosin-XXI monomers bound to F-actin. Scale: 10nm

Myosins are actin activated ATPase motor proteins. Due to their functional properties and specialization in various roles such as membrane anchorage, longer range directed movements of cargo and cell signalling, they are divided into 47 different classes. The Leishmania parasite genome comprises only two myosin genes, one myosin class XXI and one of class I. In contrast to other eukaryotic cells that express at least 13 different classes, the parasite apparently expresses only one class, myosin-XXI. Consequently this myosin has to perform a wide range of motile functions in this system, making it unique and interesting to study. One way to investigate the structural adaption and variability of this molecule is to apply single particle image analysis on negatively stained samples. This analysis includes the acquisition of electron micrographs followed by the application of image processing and classification methods, which can be done by using the SPIDER & WEB software. In this work, structural details of myosin-XXI monomers bound to F-actin could be revealed. Compared to the well-studied myosin class V, myosin-XXI-tails seem to be more flexible. When bound to actin, the tails were found to be in partly extended

states as well as in compact structures (see Fig. 1). Further analysis suggests backfolding on the myosin motor domain. Myosin-XXI molecules also seem to form dimers and are presumably able to connect actin filaments. Whether these cross-links are parallel, antiparallel or both has to be studied further. Single particle analysis was also applied to myosin-XXI molecules in the absence of F-actin. Images of free molecules suggest an adoption of a wide range of structural conformations (see Fig. 2). The fitting of crystal structures to the EM-maps may reveal more details whether these conformations are physiological and which functional states they represent.

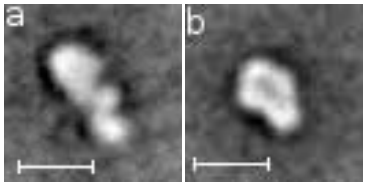

Figure 2: Class averages representing nucleotide free myosin-XXI monomers with no actin present either in an extended (a) or in a compact conformation (b). Scale: 10nm

Energy transfer processes in graphene-based hybrid circuits

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The near-field interaction between fluorescent emitters and graphene exhibits rich physics associated with local dipole-induced electromagnetic fields that are strongly enhanced due to the unique properties of graphene [1]. The near-field interaction between an emitter and a purely two-dimensional material is particularly interesting because it allows for the exploration of new limits of light-matter interactions. Recent fluorescent experiments have demonstrated that the fluorescence of nitrogen vacancy centers in diamond is quenched by the presence of graphene. We present corresponding optoelectronic measurements on Förster Resonant Energy Transfer (FRET) processes in graphene-based hybrid devices.

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Mechanical susceptibility of vascular protein vWF depends strongly on extension – from a globule to single strands

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One of the world's most common hereditary diseases is von Willebrand Disease which is caused by a lack of functionality or insufficient concentration of von Willebrand Factor (vWF) in blood. VWF is a large protein, which can be mechanically activated and it plays an essential role in initializing blood clotting in the primary hemostasis. VWF can be highly polymerized by dimer units with a size of 520 kDa and is in shape of a coiled globule while inactive. During its activation it is stretched to an uncoiled, several microns long strands, where it exhibits specific binding sites to other parts of the primary hemostasis (e.g. platelets, collagen). This shape transition and activation can be driven by a wide range of thermodynamic forces such as pH, shear velocities and external mechanical forces. For a mechanical investigation force spectroscopy via an AFM is used and several different approaches for gaining a mechanical susceptibility are presented. As large data sets of numerous force-distance curves are needed for a statistical approach automatic analysis by fitting the worm-like chain (WLC) model to all appropriate parts of the data set is used, which leads to parameters (i.e. persistence length and contour length) depending on extension. Calculating a mechanical susceptibility based on these parameters one can compare it to susceptibilities derived by approaches of direct data analysis. The comparison of these approaches and the general development of the mechanical susceptibility leads to the insight of a coincidence of the different approaches and to an depper understanding for the activation of vWF. Moreover the developing persistence length can be interpreted as a system parameter describing an evolution from a globule shape to single molecular strands. In summary, we can show, that different approaches show common but distinct features, that are preserved in promising approaches. Moreover they indicate a global development of elastic properties of vWF from smaller to higher susceptibility and a changing persistence length.

Therapeutical nanoparticles – how specific do they bind to their target?

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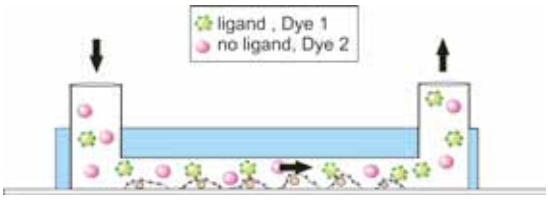
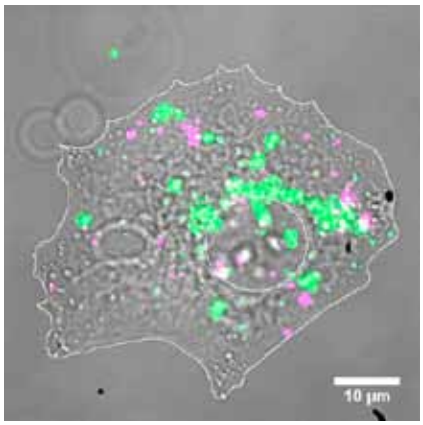
Drug delivery and gene therapy are developing strategies to treat diseases, for example cancer, neurological disorders, infectious and cardiovascular diseases. First of all suitable nanocarriers have to be synthesized which are able to transport the therapeutic cargo into the target cells and release it at the right place. After extensive characterization, in vitro studies on cell monolayers as well as in vivo studies with lab animals have to be performed before clinical tri-

als can take place and the "nanodrug" could be approved. In our experiments we focus on one crucial step during the nanocarrier development: the specific binding to target cells, the targeting. As many diseased cells e.g. cancer cells overexpress certain receptors on their cell surface, a complementary small molecule, peptide or protein which binds specifically can be incorporated on the nanocarrier. We mounted such a ligand - the transferrin receptor (TfR) binding peptide B6 - on model beads which mimic the surface of therapeutical nanocarriers. The cellular binding of these targeted beads was compared to the adhesion of non-targeted beads, beads carrying a scrambled B6 peptide (same amino acids, but different order) and modified B6 peptide (all positively charged amino acids are exchanged by neutral ones). To reduce sedimentation and include dynamics, the binding study was performed under laminar flow conditions. For a direct comparison we labeled targeted and control beads with two different dyes and flushed them over a cell monolayer within a flow channel. After fixation of the cells, we measured the fluorescence of adhered beads with widefield microscopy at a single cell level. With this approach we are able to directly obtain the ratio of targeted and non-targeted beads. In addition, the influence of electrostatics on cellular binding of nanoparticles under flow conditions has been investigated.



(a) Schematic drawing of flow channel experiments: two different bead types, with and without ligand are labeled with ATTO488 and Cy5 respectively, and floated over a cell monolayer within a flow channel. The number of adhered beads is counted at a single cell level after 40 min of flow.



(b) Merged image of targeted (fluorescence, green) and non-targeted (fluorescence, magenta) beads on a HuH7 cell (transmitted light, grey) after flow application and fixation.

DNA binding kinetics in an optical trap by plasmonic nanoparticle heating

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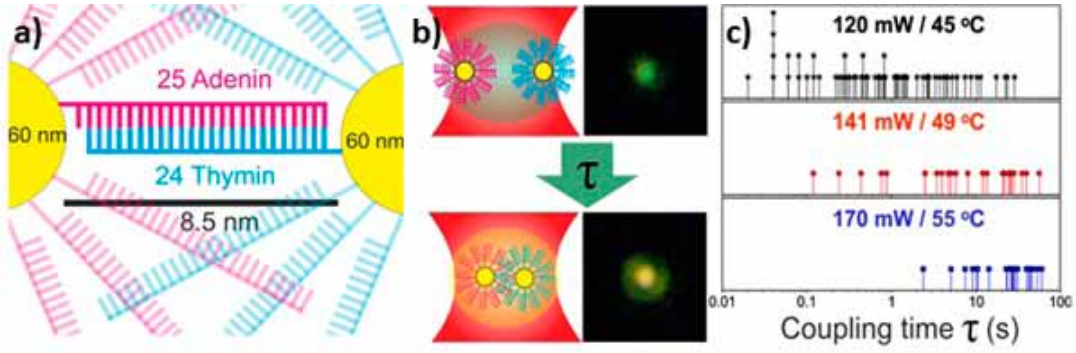
Optical trapping is a well established technique that has been widely used to noninvasively manipulate micro- and nano-sized objects [1], including plasmonic nanoparticles [2,3]. Plasmonic nanostructures are known to provide strongly enhanced and highly localized electromagnetic fields due to their localized surface plasmon resonances. In addition, their large absorption cross sections render them attractive nano-sized heat sources. This allows for manipulating local temperature, which can be used, for instance, to induce local cell membrane melting or to engineer colloidal chemistry. Optical trapping enables taking advantage of these properties in free solution at the individual particle level. Here, we demonstrate a novel application of optically trapped lasmonic nanoparticles. We show that plasmonic heating of individual nanoparticle dimers in an optical trap enables the tuning of the hybridization kinetics of DNA molecules attached to the nanoparticles [4]. DNA hybridization events are detected optically by the change in the plasmon resonance frequency due to plasmonic coupling of the nanoparticles. We find that at larger trapping powers (i.e. larger temperatures and stiffer traps), the hybridization of complementary DNA strands slows down. The corresponding rates decrease by more than an order of magnitude. We show that this effect is the result of higher temperatures preventing the formation of dimers with lower binding energies. Our results demonstrate that plasmonic heating can be used to fine-tune the kinetics of biomolecular binding events.



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Pore Filling of Spiro-OMeTAD in Solid-State Dye-Sensitized Solar Cells Determined Via Optical Reflectometry

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A simple strategy is presented to determine the pore-filling fraction of the hole-conductor 2,2-7,7-tetrakis-N,N-di-pmethoxyphenylamine-9,9-spirobifluorene (spiro-OMeTAD) into mesoporous photoanodes in solid-state dye-sensitized solar cells (ss-DSCs). Based on refractive index determination by the film's reflectance spectra and using effective medium approximations the volume fractions of the constituent materials can be extracted, hence the pore-filling fraction quantified. This non-destructive method can be used with complete films and does not require detailed model assumptions. Pore-filling fractions of up to 80% are estimated for optimized solid-state DSC photoanodes, which is higher than that previously estimated by indirect methods. Additionally, transport and recombination lifetimes as a function of the pore-filling fraction are determined using photovoltage and photocurrent decay measurements. While extended electron lifetimes are observed with increasing pore-filling fractions, no trend is found in the transport kinetics. The data suggest that a pore-filling fraction of greater than 60% is necessary to achieve optimized performance in ss-DSCs. This degree of pore-filling is even achieved in 5 µm thick mesoporous photoanodes. It is concluded that pore-filling is not a limiting factor in the fabrication of "thick" ss-DSCs with spiro-OMeTAD as the hole-conductor.

Picosecond photocurrents in single-walled carbon nanotubes

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The exciton dynamics in carbon nanotubes are typically detected in a time-resolved way by optical techniques such as the transient absorption technique and the time-resolved photoluminescence spectroscopy. Both methods focus mainly on the dynamics of localized charge carriers within the carbon nanotubes. Many questions remain concerning the separation and the transport of photogenerated charge carriers to source and drain leads in an optoelectronic device structure. We address these questions by a novel ultrafast photocurrent spectroscopy, which is based on an on-chip THz time domain spectroscopy [1]. We find a combination of an optically induced ultra-fast displacement current, transport of photogenerated charge carriers at the Fermi velocity to the electrodes, and interband charge-carrier recombination processes to dominate the ultrafast photocurrent of the single-walled carbon nanotubes [2]. We further discuss optoelectronic effects in the carbon nanotubes which arise from an ultrafast optical excitation with a super-continuous light spectrum [3]. We acknowledge financial support from the ERC-grant "NanoREAL", the DFG excellence cluster Nanosystems Initiative Munich (NIM), and the Center for NanoScience (CeNS) in Munich

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Understanding the role of performance-enhancing surface treatments on mesoporous hematite for water oxidation

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The direct splitting of water into hydrogen and oxygen gases, with sunlight as the only input of energy, could provide a vital source of fuel in the context of a low-carbon economy. Hematite is a promising photo-anode material for the oxidation of water to oxygen (OER). Nonetheless, despite its suitable valence band position, visible light absorption, and good chemical stability, hematite is limited by rather weak absorption and poor charge transport. This trade-off between light absorption and carrier collection can be resolved by nanostructuring the material, allowing good hole-collection at the semiconductor-electrolyte interface. This, however, facilitates surface recombination, which competes with the OER. Intensity modulated photocurrent spectroscopy, IMPS, is a small amplitude frequency-resolved technique which offers insight into the kinetics of processes, such as surface recombination and charge transfer, occurring in photo-electrochemical systems.[1-3] We have developed two surface modifications for mesoporous hematite. On the one hand, the addition of a Sn-precursor to the hematite sol-gel synthesis yielded a surface Sn-enriched mesoporous structure after a 600°C heat treatment. On the other hand, well-defined Co_3O_4 nanoparticles were synthesised and applied to the Sn-enriched hematite layers. IMPS studies revealed a dramatic increase in the rate of hole transfer to the electrolyte, i.e. OER, upon surface Sn-enrichment. Application of Co_3O_4 nanoparticles to the Sn-enriched hematite films led to improved electron collection efficiency, which may be due to a reduction in the rate of surface recombination.

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Characteristics and controllability of solid-wetting Deposition of organic semiconductors

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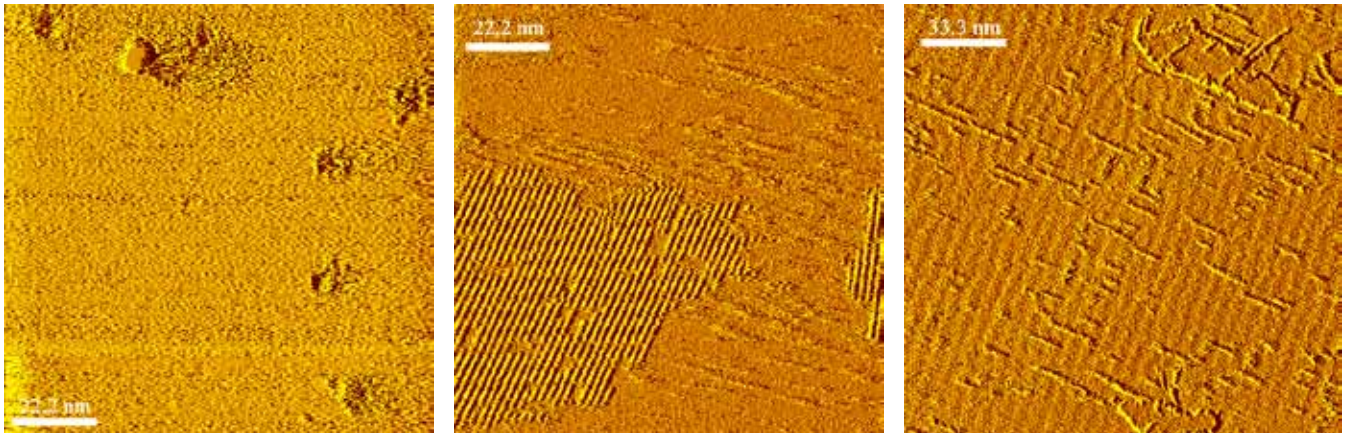

Organic Solid/Solid Wetting Deposition (OSWD) is a process which enables to deposit insoluble molecules such as organic pigments and semiconductors on substrate surfaces under ambient conditions. This process initiates supramolecular self-assembly of monolayers if organic nanocrystals, mixed with a dispersing agent, get in contact with an inorganic substrate surface. The behaviour of the nanocrystals can be described analogue to a liquid droplet wetting a surface [1].

OSWD enables various approaches to control the self-assembly of organic semiconductor molecules such as locally guided self-assembly or tip-induced coadsorption [2]. However, the exact role of the dispersing agent in the OSWD process was not well understood so far. This made a systematic exploration of additional approaches to control OSWD self-assembly difficult.

Here we show results obtained via sedimentation experiments and Scanning Tunneling Microscopy which shed light on the function of a dispersing agent for OSWD and the required properties to successfully grow and control the structure of organic semiconductor monolayers. The results indicate that the dispersing agent has to change the interface tension by modifying the cohesive and adhesive bonding energies between nanocrystals, substrate and dispersing agent. It appeared that to initiate the OSWD the nanocrystals must be colloidal dispersed. The colloid itself must be thermodynamical metastable, so that the nanocrystals can leave the colloid as soon as they get in contact to the substrate. In contrast, stable or generally instable colloids don't induce OSWD. Its stability mainly depends on its polarity (thus its dielectric constant) and the ability to accept or display hydrogen bondings.

We demonstrate that due to these relationships we are able to control the structure of the self-assembled monolayers and to change its appearance totally by the use of different dispersing agents with preselected properties. These results are highly relevant for the field of 2D crystal engineering as well as for enabling highly controlled band gap engineering of graphene [3,4].

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Metal-oxide core-shell nanostructures for applications in hybrid solar cells

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TiO_2 is widely used as electron acceptor for hybrid and dye-sensitized solar cells due to its adaptability of the structural and electronic properties. Nanostructuring of the donor-acceptor interface enables an enhanced charge carrier separation and reduces recombination, which both leads to higher power conversion efficiencies. According to various reports,[1-4] the efficiency of titania based dye-sensitized solar cells can be further increased by replacing bare titania by core-shell structures in order to optimize the band engineering of the device. This study focuses on the synthesis and electron microscopic analysis of TiO_2 based core-shell structures for hybrid solar cells. Initial investigations are performed on bilayers consisting of an about 120 nm thick TiO_2 anatase layer covered by a 10 nm thick Nb_xO_y layer. The solar cell performance of these core shell structures compared to bare anatase flat films is studied for various organic hole conductors. The most appropriative organic hole conductor is used to prove the superior performance of core shell nanostructures, e.g. rutile nanowires, for different morphologies and modifications. Scanning electron microscopy (SEM) enables the investigation of these nanoscale titania morphologies (Fig. 1). Using transmission electron microscopy (TEM) measurements, we can prove that the combination of sol gel method and spin-coating technique is suitable for a homogeneous covering of rutile nanowires by a 2 nm thick Nb_xO_y shell. The crystallization behavior of this Nb_xO_y shell is studied by additional TEM measurements, showing that an enrichment of certain impurities suppresses crystallization whereas adjacent, impurity-free areas are highly crystalline.

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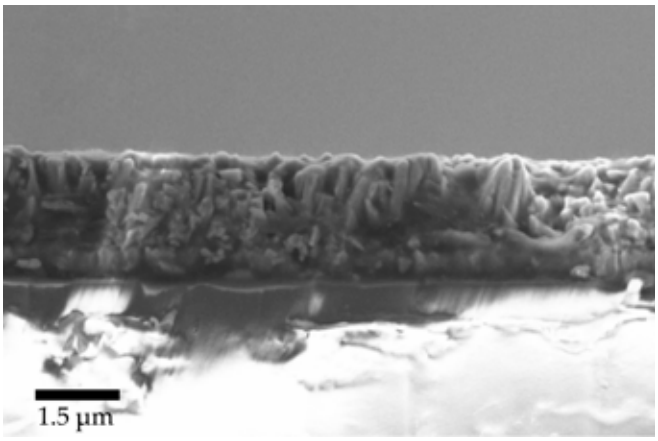

Figure 1: SEM cross-section of a solar cell composed of TiO_2/Nb_xO_y core-shell nanowires filled with an organic hole conductor.

Ultrasmall NiO, Fe-NiO and Co_3O_4 Nanoparticles for Water Splitting

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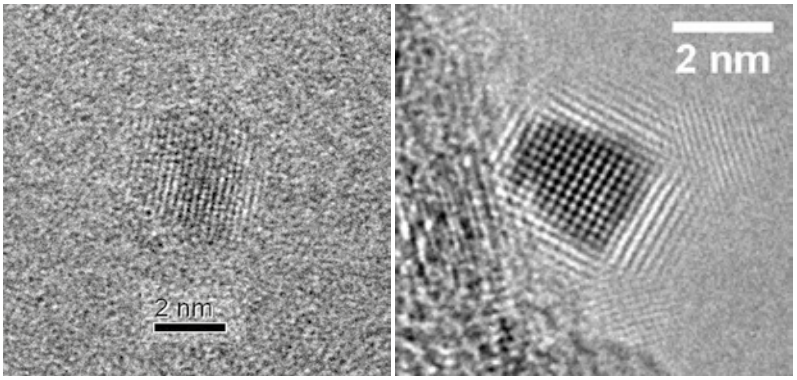
Efficient photoelectrochemical water splitting to hydrogen and oxygen may be one of the technologies to overcome our dependency on fossil fuels and to establish a carbon-neutral hydrogen economy. Although hydrogen is the desired end product, the very slow kinetics and high overpotential of the oxygen generation are the limiting factors for an efficient overall water splitting process. Therefore, searching for catalytic materials for photo/electrochemical oxygen generation is of great importance for improving the efficiency of water splitting. We present our new tert-butanol-based solvothermal synthesis route for the fabrication of ultrasmall crystalline dispersible metal oxide nanoparticles. Using this approach we have obtained extremely small crystalline nanoparticles of cobalt oxide acting as an extremely efficient co-catalyst for a photoelectrochemical water oxidation on the hematite photoanodes. In a similar way, we have prepared ultrasmall dispersible nickel oxide nanoparticles that show extremely high electrocatalytic activity for water oxidation which we attribute to a non-stoichiometric surface exhibiting oxidized nickel states. The electrocatalytic activity of nickel oxide nanoparticles is enhanced further by doping with iron atoms during the synthesis, which leads to an almost ten-fold increase in the turnover frequency.



TEM image of a crystalline Co_3O_4 (left) and NiO nanoparticle (right)

TiO_2 nanowires / $CuInS_2$ thin films for solar cell applications

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The recent progress in energy requirements tends towards the so called "green energy", hence new developments in the research area of solar cells are popular. In our study we want to grow thin $CuInS_2$ films on rutile TiO_2 nanowires. Nanostructured interfaces offer the advantage of enhanced separation of charge carriers and therefore reduced recombination what should lead to higher power conversion efficiencies. Additionally, TiO_2 nanowires have the benefit to provide a direct path for electrons towards the electrode. $CuInS_2$ offers a direct band gap which fits well to the solar spectrum as well as a high absorption coefficient.[1] TiO_2 is a wide band gap semiconductor with n-type conductivity.[2-3] Both materials are synthesized via mild solvothermal methods. In the case of TiO_2 the rutile nanowires are grown directly on fluorine-doped tin oxide (FTO) substrates by a hydrothermal synthesis route developed by Liu et al.[4] (Figure 1(a)). The $CuInS_2$ thin films are afterwards grown onto the rutile nanowires using a solvothermal method following the description from Peng et al.[5] First investigations of $CuInS_2$ films grown directly on the rutile nanowires show a flower-like structure in the scanning electron microscope and no wires are detectable (Figure 1(b)). Transmission electron microscopic investigations reveal that the nanowires are still beneath the $CuInS_2$ layer and that the $CuInS_2$ infiltrates the structure completely. Besides a TiO_2 blocking layer, covering the substrate, is visible. Further investigations will focus on smoother $CuInS_2$ films to facilitate the attachment of the counter electrode, for example silver, and on the synthesis of a very thin $CuInS_2$ layer around the rutile nanowires to get extremely thin absorber (eta) solar cells.

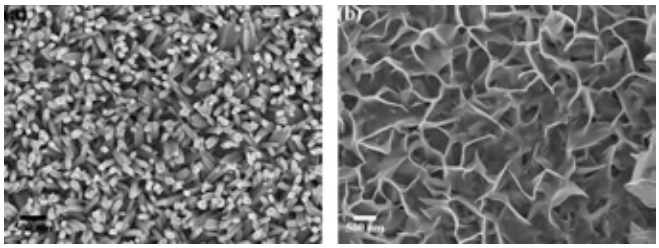

Figure 1: SEM images of the as-synthesized layers. (a) TiO_2 rutile nanowires on FTO substrate. (b) $CuInS_2$ layer on rutile nanowires.

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Investigation of high temperature polymer electrolyte membrane fuel cells by transmission electron microscopy methods

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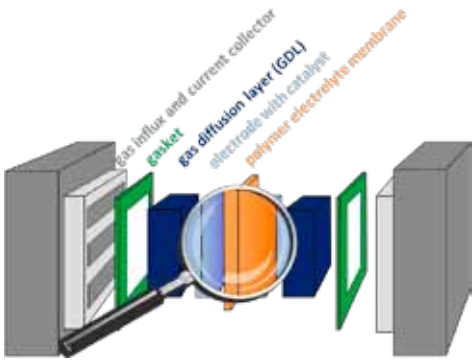
Fuel cells in general and high temperature polymer electrolyte membrane (HTPEM) fuel cells in particular are promising devices to potentially ensure the global energy supply in the near future. The key components of this fuel cell type comprise the membrane and the adjacent electrodes with the active catalyst layer (see Figure 2). This so called membrane electrode assembly (MEA) accounts for nearly 50 % of the whole production costs of HTPEM fuel cells.[1] Thus, an intensive research on these components is crucial to accelerate the comprehensive market maturity by reduction of costs. The membrane is composed of phosphoric acid doped polybenzimidazole which is enhanced by silica particles for reasons of stability.[2] In this study, we investigated membranes synthesized by varying reaction parameters and conditions using transmission electron microscopy, electron energy loss spectroscopy and energy dispersive X ray spectroscopy in order to understand the correlation between nanoscale morphology of the membranes and high efficiency. Furthermore, we want to analyze the catalytic behavior and degradation processes of the electrode material comprising platinum nanoparticles on a carbon support. By applying an exit wave reconstruction on platinum particles before and after the operation of the fuel cell we want to determine their crystal morphology including the indexing of the catalyst facets.



Schematic illustration of the construction of a HTPEM fuel cell. The MEA is highlighted with a magnifier

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Optical mapping of genetic and epigenetic properties of DNA Molecules

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Optical mapping techniques offer accesses to new information in genomic research, information that is unavailable using traditional DNA sequencing methods. The basic principle of optical mapping is fluorescent labeling of various features of DNA molecules, stretching the molecules and finally imaging them and analyzing the labels locations. Optical mapping enables studies at the single molecule level, providing data about genetic variations between different cells. Moreover, this field allows direct visualization of DNA molecules, giving the opportunity to simultaneously obtain several types of information from the same molecule, including epi-genetic information. My research is focused on combining new techniques to establish an optical mapping platform. In order to generate a fluorescent "finger print" of each DNA molecule, short and known sequence motifs are used. These labeled motifs exhibit a known and unique pattern which can be used for identification. Currently we use two enzymatic based methods for labeling of these motifs. One is based on nicking enzymes and the other on DNA methyltrasferase enzymes. Another method, based on the enzyme β-glucosyltrasferase is used to label hydroxy methyl cytosine, an important epi-genetic modification. Stretching the DNA into a linear form, to address the labels to specific locations along the DNA, is critical prior to imaging. Two DNA stretching methods are used: in the first we flow the DNA over glass surfaces that were modified with amines and vinyls, these modifications unravel the DNA and anchor it to the surface. In the second method we use an electrical force to drive the DNA into silicon fabricated nano channels. The width of these nano channels is 45 nanometers, this is smaller the persistence length of DNA and therefore the DNA is extended into a linear form while in these channels. After imaging labels locations are analyzed and by combining data from a few types of labels, the distribution of hydroxymethylcytosyne residues may be studied.

In situ photopolymerization of C_{60}

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Much effort has been put into the synthesis of matched donor/acceptor pairs for organic photovoltaic devices. The most well-known of which is PCBM/P3HT, in which excitons generated in the P3HT dissociate at the interface by electron transfer to the PCBM. Recent studies showed that the charge transfer efficiency strongly depends on the relative position of the HOMO and LUMO levels of the fullerene material and the polymer.[1]

Here we present the effect of a photoinduced [2+2]-cycloaddition[2] of C_{60} on the HOMO/LUMO levels and the bandgap of the resulting polymer. A thin film of C_{60} was deposited on a glassy carbon electrode, and cyclic voltammograms were recorded while simultaneously irradiating the sample with UV light (left figure). The reduction potential, which corresponds to the LUMO level of the acceptor material, shifted by about -0.4 V. In this way, it is possible to finely adjust the properties of the acceptor material to suit a given donor.

Additionally, the stability afforded by the increased crosslinking leads to a stable polymer network, which opens the way to structuring the polymer with a template material. For example, free-standing fullerene nanowires were obtained by polymerizing C_{60} in alumina membranes (right figure).

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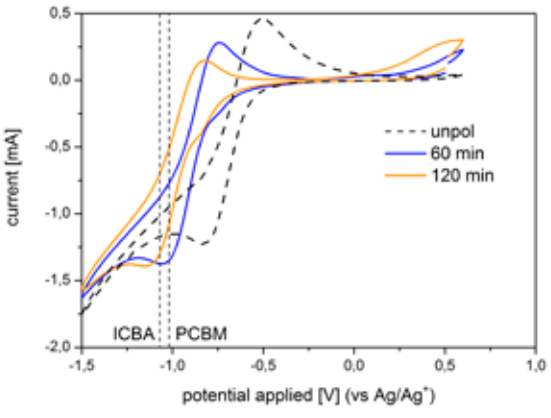

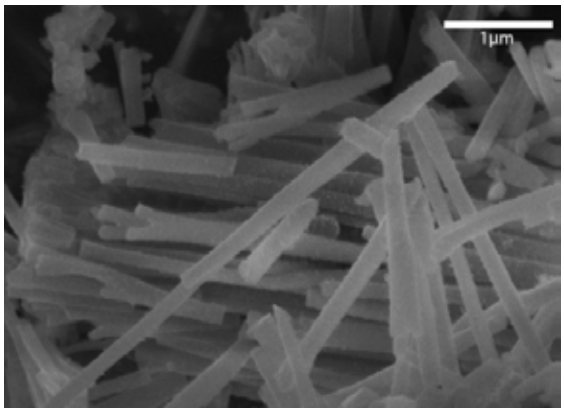

MicroRNA responsive switches via chemically modified microRNA target sequence conjugates

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Pharmaceutical Biotechnology, Faculty of Chemistry and Pharmacy, Ludwig-Maximilians-Universität Munich, SFB 1023, CeNS, München (Germany)

Every human tissue or tumor cell type has a unique expression profile of a subset of >1500 microRNA (miRNA) genes, which by RISC formation inactivate their natural mRNA targets. Nanoagents consisting of oligonucleotides conjugated with nanoparticles are designed as artificial RISC targets. While partial complementarity leads to translational repression by binding to 3´UTRs of the gene of interest, perfect complementarity provides miRNA target cleavage. This feature can be utilized to control the on and off switching of intracellular processes with tumor cell lines displaying different cancer progression-associated miRNA profiles as test systems. The artificial RISC targets have to be designed to provide sufficient stability towards single-strand specific RNases, but still be prone to microRNA dependent cleavage by the RISC complex. Fluorescence cross correlation spectroscopy is used for selection of a suitable modification pattern. Tracking of the degradation can be accomplished by monitoring the RISC cleavage dependent separation of two dyes attached to each end of the target sequence.

Electron microscopy characterization of platinum on WO_x support material in high-temperature polymer electrolyte membrane fuel cells

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Fuel cells provide a promising possibility for generating energy with high effectiveness. Their active principle is based on the combination of combustion engines and batteries. Like in combustion engines, a fuel cell only operates when a fuel is supplied and like in batteries a direct conversion of chemical energy into electrical energy occurs. Due to the omission of combustion processes, a fuel cell stack can operate with 40 – 60% efficiency and with up to 90% efficiency if the utilization of the waste heat is also taken into account.[1] Conventional combustion engines only show efficiencies of 20% (petrol engine) to 25% (diesel engine).[2]

In our research we focus on the optimization of tungsten oxide (WO_x) based electrodes in high-temperature polymer electrolyte membrane fuel cells (HTPEM-FCs) and the degradation of the platinum catalyst on the WO_x support material. WO_x, combined with platinum, are frequently reported as promising candidates in fuel cell applications. Once the oxidation of hydrogen on the surface of the platinum catalyst has taken place, a hydrogen spill-over from platinum to WO_x occurs. Due to the formation of tungsten bronzes $HyWO_x$, catalytic active sites on platinum are set free comparatively fast so that the oxidation process on platinum can proceed.[3]

The characterization of the platinum catalyst on the WOx support material was performed using scanning electron microscopy (SEM) and various methods of transmission electron microscopy (TEM) like electron diffraction, conventional TEM (CTEM), high-resolution TEM (HRTEM) and scanning TEM (STEM). The analysis of the chemical composition was performed in TEM and SEM by energy dispersive X-Ray spectroscopy. The TEM samples were prepared using focused ion beam (FIB) methods.

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A new low temperature near-field optical scanning microscope

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The characterisation of nanostructures with high spatial resolution and detection sensitivity can be achieved by tip-enhanced near-field optical microscopy (TENOM) [1]. Up to now nearly all TENOM measurements were performed at room temperature. Low temperature measurements on the other hand would reveal even more detailed information about material properties, for example due to reduced spectral broadening. We describe a new scheme for implementing TENOM at low temperatures. For initial experiments and testing well known quasi 1D semiconducting model systems such as single-walled carbon nanotubes (SWCNT) and cadmium selenide (CdSe) nanowires were used [2]. Here we describe our efforts and first results on our way towards low temperature near-field optical microscopy.

We acknowledge financial support by NIM and the ERC (NewNanoSpec).

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Extremly thin Absorber Layer Solar Cells with in situ grown lead Sulfide Quantum Dots

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Interest in ETA (extremely thin absorber layer) cells has increased steadily, but although performance values have improved progressively, they are still well below the values that would be interesting for industrial production.[1-3] One of the main performance-limiting factors in ETA cells originates from the difficulty in finding suitable hole transporting materials (HTMs) that can provide complete pore filling and good charge transport. Key issues for further development of ETA cells include: 1) control of metal oxide structure in terms of pore size, surface area and crystallinity, 2) improvement of light harvesting, 3) improvement of HTM infiltration into the pores, 4) reduction of charge recombination and (5) enhancement of hole transport.

Here we report the use of the structure-directing block-copolymer (BCP), poly(styrene-b-ethylene oxide) (PS-b-PEO), in preparation of porous TiO_2 films for integration into ETA cells to enhance the porosity, crystallinity and structural regularity of the metal oxide layer. The porous TiO_2 was obtained by mixing the BCP with a non-hydrolytic sol-gel, followed by annealing in air to remove the polymer and to transform the sol-gel into the pure crystalline anatase phase of TiO_2. The porous TiO_2 films obtained by this route were used in the fabrication of ETA solar cells in which a thin PbS absorber layer was deposited by the SILAR (successive ion layer adsorption and reaction) method, and the CuSCN HTM was infiltrated from solution phase by doctor blading. The performance of ETA cells was tested by recording current-voltage characteristics (I-V) and external quantum efficiencies (EQE). Calculation of the short circuit current from the EQE spectrum and the AM1.5 solar spectrum yielded a value which is in a good agreement with the value obtained from I-V measurement. The ETA cells were also analyzed with impedance spectroscopy (IS) and physical parameters such as electron lifetime, diffusion constant and electron diffusion length were determined by fitting the experimental IS spectra with an equivalent circuit.[4]

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Hierarchical assembly of DNA origami

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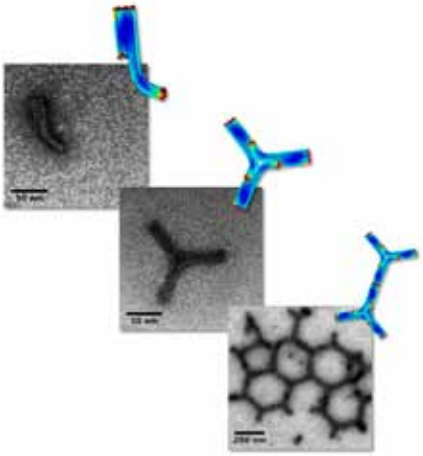
DNA Nanotechnology evolved over the last years into a powerful tool to build structures that self-assemble at high yields and that are addressable with nanometer precision. DNA-assembled structures are expected to be of high potential for examining and influencing biological processes on the nanometer scale [1,2]. In order to advance drug delivery concepts, we aimed to mimic clathrin-mediated cellular transmembrane trafficking with DNA origami [3,4]. Clathrin is a well-studied example of how cells manage transport of molecules through the cellular membrane [5]. The clathrin protein is a triskelian super-molecule, which forms higher-order lattices and buckyball-like cages. During the assembly process of clathrin molecules, the associated membrane is bent and finally a clathrin-coated pit is released into the cytosol. We assembled DNA origami structure with the form of a truncated Y and an average armlength of 71 nm. By controlling the association properties of the structure's ends, we were able to form two-dimensional lattices of micrometer size. The resulting lattices contain mostly hexagonal arrangements but also pentamers can be observed, as the flexibility of the joints allow the formation of both pentagonal and hexagonal geometries. In recent experiments, we intended to form three-dimensional buckyballs out of up to 120 individual DNA origami structures. Future work will combine these DNA constructs with artificial lipid bilayers.



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Mechanics of Bacterial Biofilms

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Bacteria embed themselves with secreted biopolymers forming a community that is referred to as a biofilm. Due to their high mechanical resilience and their resistance to antibiotic treatment, such biofilms constitute a significant problem both in industry and health care. It is important to understand at which stage of biofilm formation this high resistance is established and what molecular components are responsible for this behavior. Using a cantilever array sensor system, we quantify the mechanical stability of *B. subtilis* biofilms in their early developmental stage as well as the maturation kinetics of the biofilm. We use several wild-type strains that differ in the composition of their biofilm matrix as well as mutant strains lacking specific matrix components. We compare attachment and growth rates of these biofilm formers with a strain unable to form biofilms in order to understand the importance of basal production of matrix elements for the initial phases of biofilm formation. To quantify the mechanical stability, bacterial biofilms are grown on carbohydrate-coated cantilevers. Such fully grown biofilms are then exposed to shear-forces and the detachment of the biofilm from the single cantilevers is quantified over time. We want to quantify the force generation during bacterial biofilm formation by following the deflection of an AFM cantilever that rests on the surface of a growing biofilm. The change of the mechanical properties of the biofilm during maturation and the force generation during biofilm development will be monitored.

Direct observation of acousto-electric charge conveyance in high-purity GaAs/AlGaAs core-shell nanowires

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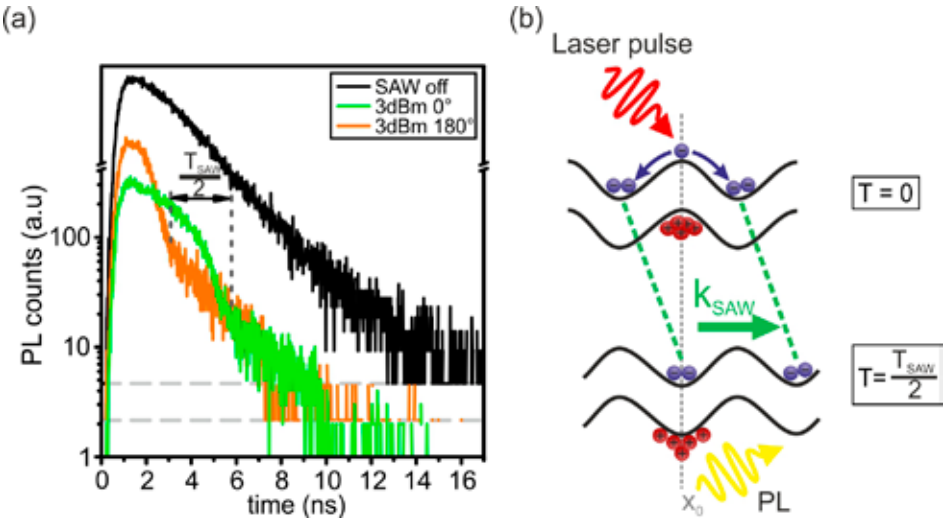
Radio frequency (RF) surface acoustic waves (SAW) are versatile tool to control and manipulate charge and spin excitations in semiconductor structures. This unique, fast control mechanism has recently been applied to dynamically modulate the optical emission of single semiconductor nanowires (NWs) [1]. Here, we present direct experimental evidence of acousto-electric exciton dissociation and subsequent transport of spatially separated electrons and holes along the axis of single, surface-passivated GaAs/AlGaAs core-shell NWs. To resolve the underlying dynamics, we performed stroboscopic time-correlated single photon counting (s-TCSPC) of the photoluminescence (PL) emission of individual NWs. A typical unperturbed PL transient is plotted in red in Fig. (a) showing a mono-exponential decay with a time constant of τ_{PL}= 1.3 ns. When subject to a SAW (f_{SAW} = 194 MHz, P_{SAW} = 3 dBm), we observe a characteristic beating in the PL transient (blue), matching T_{SAW} = 5.1 ns. As expected, this beating shifts in time by $T_{SAW}/2$=2.55ns when the SAW phase is tuned by 180° (green). This observation is a direct fingerprint of charge conveyance within the SAW-induced type-II band edge modulation. As sketched in Fig.(b) electrons drifts away from the point of excitation χ_0 into the stable points at the minimum of the conduction band whereas the less mobile holes remain stationary. $T_{SAW}/2$ later these electrons are conveyed to the position of the holes giving rise to the observed beating. By further increasing the acoustic power and thus electric field the conveyance of holes accrues, leading to an abrupt quenching of the NW emission. The recorded time transients can be reproduced nicely by numerically solving the semi-classical drift and diffusion equation. By comparing characteristic points in the transients we can determine the mobilities of electrons and holes μ_e=500 cm²/Vs and μ_h=25-50 cm²/Vs.



a) PL transient a a single GaAs/AlGaAs core-shell NW without SAW (black) and with SAW applied with defined phase shifts (orange, green).

b) Dissociation and acoustic transport of electrons in the SAW-induced type-II bandedge modulation. Spatial overlap of transported electrons and stationary holes gives rise to the observed time-delayed PL emission.

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Stability of Zero-Sum Games in Evolutionary Game Theory

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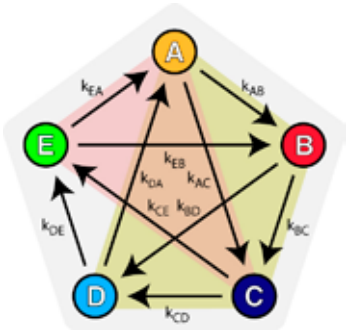
Evolutionary game theory (EGT) has become one of the most successful theoretical concepts to study mechanisms that govern the evolution of biological ecosystems. At the heart of EGT stands the idea that different phenotypes or traits can be considered as interacting strategies in a population of players. On a mathematical level, this approach has been formalized in the framework of the celebrated replicator equations (REs). In our work, we analyze the long-time behavior of the REs for zero-sum games in which the payoff of the winner equals the loss of the defeated. We investigate generalized versions of the children's game Rock-Paper-Scissors (where paper wraps rock, scissors cuts paper, and rock crushes scissors). Here, we demonstrate that it is possible to determine the strategies that survive and the strategies that go extinct without resorting to a numerical integration of the REs. We do so by reducing the nonlinear dynamics problem to an algebraic problem from linear programming theory. We show that the extinction of strategies is generically exponentially fast. Our general results are illustrated for a noncyclic zero-sum game with four strategies in which all of the strategies can coexist. Furthermore, we determine the survival scenarios that are possible for the general zero-sum game with five competing strategies. Our results show that the class of zero-sum replicator equations can serve as a reference model for the analysis of other models in evolutionary game theory.



Given an arbitrary zero-sum game in the context of evolutionary game theory, we determine which strategies survive and which strategies go extinct.

Targeted Sequence-Defined Oligomers of Different Topologies for pDNA and siRNA Delivery Synthesized via Native Chemical Ligation

Petra Kos, Katharina Müller, Canyang Zhang, Christina Troiber, Ulrich Lächelt, Ernst Wagner

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Targeted and shielded sequence-defined oligomers of different topologies have been assembled via native chemical ligation (NCL) as polymeric carriers for pDNA and siRNA therapy. For this purpose, existing potent non-targeted N-terminal cysteines containing oligomers synthesized via solid-phase synthesis were selected as precise cationic (oligoethanamino)amide cores to which a monodisperse polyethylene glycol (PEG) chain coupled to a folic acid targeting ligand or terminal alanine as negative control was attached by NCL reaction. The resulting topological structures were evaluated for the suitability of the NCL reaction for the ligation with the shielded and targeted oligomer by gel shift assay, dynamic light scattering, cellular binding and in vitro luciferase gene expression or down-regulation. The folic acid modified conjugates displayed an improved cellular binding and in vitro gene transfer as compared to the alanine control analogs. Increasing the complexity of the topological structure such as increasing the number of polycationic arms or adding the tyrosines as stabilizing or histidines as endosomal escape facilitating moieties resulted in beneficial gene transfer characteristics. The results indicated that NCL reaction can be a useful method to easily modify various oligomers in order to synthesize precise multifunctional polymeric carriers.

Plasmonic Nanotriangle Arrays for Surface Enhanced Raman Spectroscopy of Supported Lipid Membranes

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Faculty of Physics and Center for NanoScience (CeNS), Ludwig-Maximilians-Universität München (LMU), München (Germany)

We utilize plasmonically coupled gold triangles for Surface Enhanced Raman Scattering (SERS) measurements of a fluid lipid bilayer. First, large arrays of plasmonic nanoantennas made of gold triangles are prepared on a glass substrate by an improved colloidal lithography technique. Plasma treatment of the colloid monolayer allows for adjusting structural parameters such as the triangle side length and the distance between individual triangle tips at the nanoscale which has a substantial impact on the overall SERS performance. Then, a fluid supported membrane is formed on the intervening glass substrate by vesicle fusion. We demonstrate the applicability of this platform for spectroscopic investigations by performing SERS measurements of molecules that are constituents of a fluid supported phospholipid membrane. Our method offers a novel tool to analyze lipid membranes and membrane components under physiological conditions without fluorescent labeling or static entrapment of the membrane molecules.

Mass selective deposition of radical-cations as building blocks for surface-supported covalent organic nanostructures

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1 TUM School of Education, 2 Deutsches Museum, 3 Center for NanoScience (CeNS), München (Germany)

Covalent organic frameworks (COF) are porous and crystalline networks of covalently interlinked organic molecules. Two-dimensional surface-supported COFs can be synthesized by polymerization through radical recombination. Radicals are generated by deposition of monomers on metal surfaces through homolysis of weakly bonded substituents (e.g. halogen atoms). This dehalogenation is promoted by the catalytic activity of the typically used coinage metals, and the radicals subsequently recombine into covalent networks interlinked through strong C-C σ–bonds. This method, however, typically yields poorly ordered covalent networks. To improve the structural quality of 2D COFs and to become independent of catalytic surfaces, we propose the deposition of pre-generated radicals as building blocks under ultra-high vacuum. Halogenated molecules are used as precursors, and the dehalogenation is accomplished in the gas phase by electron irradiation. This process is highly unspecific and yields different fragments, therefore prior to deposition defined radical fragments are mass selected by a quadrupole mass filter. For testing and parameter optimization, the proposed setup is additionally equipped with a secondary electron multiplier and can be operated as a conventional mass spectrometer. The sample is positioned perpendicular to the mass filter, i.e. out of line-of-sight, in order to avoid sample contamination. The ions are electrostatically deflected and focused by an einzel lens onto the sample in order to maximize the flux. Soft landing is accomplished by a retarding electrostatic field and the ion current at the sample position is measured by an integrated Faraday cup. The setup is used for deposition of benzene triradicals and the resulting nanostructures are characterized by high-resolution scanning tunneling microscopy.

Hydrophobic actuation of a DNA origami bilayer structure

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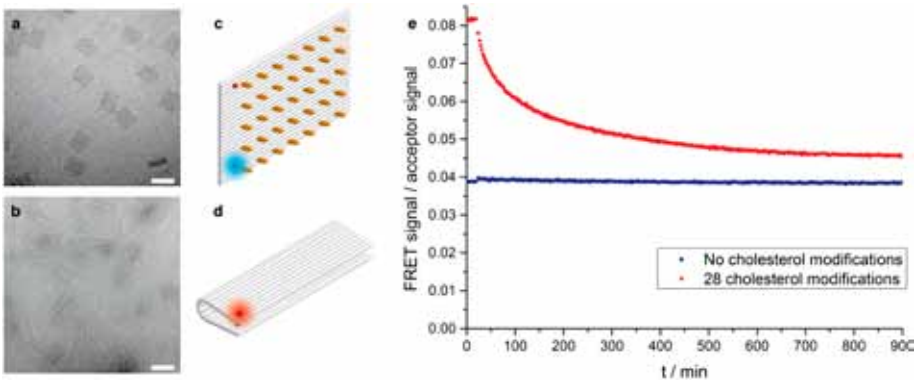
Supramolecular nanostructures, capable of large conformational changes upon varying environmental conditions are highly desirable for nanotechnology and biomedicine. In this context, switchable containers for controlled drug release represent a major research objective of nanomedicine. Such containers can be realized using the DNA origami technique [1] and have been shown to bind to cell membranes [2] in order to facilitate targeted drug delivery. In another approach, DNA origami structures were bound to lipid membranes via cholesterol moieties in order to create an artificial ion channel spanning across the membrane [3]. Here we present a DNA based envelope - like container, which opens in the presence of surfactants or lipid membranes. Cholesterol modified oligonucleotides were hybridized to one side of an initially flat, rectangular DNA origami structure. Hydrophobic interaction in between these amphiphilic cholesterol moieties induced folding of the structure along its central axis into a closed state. A strong dependency of this effect at varying numbers of cholesterol moieties was found. In presence of hydrophobic agents, the structure opened up again. We studied the opening kinetics in presence of lipid vesicles or by addition of surfactants in FRET – based fluorescence spectroscopy measurements. Two fluorophores were attached to the structure to serve as a FRET pair. In the native unfolded state, the dyes were separated and a low FRET signal was observed. Closing of the structure lead to a reduction of the distance between the dyes and therefore to an increase of the FRET signal. The described confirmation change was also observed in TEM studies. Additional locking mechanisms, for controlling the conformational changes, can be added to the system, for example microRNA recognition sequences or aptamers for signaling molecules.



a) Positive stain transmission electron micrograph of the unfolded origami structures of approx. 90 x 60 nm. Scale bars 100 nm. b) Negative stain TEM image of the folded structures, exhibiting half the width of the unfolded structures. c, d) Schematic illustrations of the folded and unfolded state, donor and acceptor of the incorporated FRET pair are shown in blue and red e) FRET signal induced by conformational change of structures in the presence of small unilamellar vesicles. The blue graph shows a control experiment performed with a cholesterol free structure, showing no interactions with vesicles.

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A Novel Imine-based Covalent Organic Framework for Postsynthetic Modification

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Covalent organic frameworks (COFs) are crystalline, highly porous and light materials exclusively made of light elements. Different linkers can be used as building blocks to vary the pore size or to incorporate functional groups in the network. In the reaction of planar building blocks two-dimensional sheets with hexagonal or tetragonal pores are formed. The sheets stack in the third dimension by π-interactions. A possible synthesis pathway for COFs is the reaction of amines with aldehydes to imines. Recently, imine-based COFs have been reported which can undergo a keto-enol tautomerization [1]. These networks show a remarkable chemical stability towards acids and bases. Here we present a novel imine-based COF with nitro-functionalized building blocks. Infrared spectroscopy indicates that this material also undergoes a tautomerization and its final state is the keto-form. The COF is stable in different organic solvents as well as in water and under acidic and basic conditions. This stability makes it an interesting candidate for postsynthetic modifications. To demonstrate the applicability of this compound, the nitro groups decorating the COF pores were reduced to amines in a postmodification reaction.

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DNA-based micro- and nano-swimmer

Alexander Mario Maier, Sophia Kronthaler, Robert Schreiber, Anastasiya Puchkova, Eva-Maria Roller, Tao Zhang and Tim Liedl

Faculty of Physics and Center for NanoScience (CeNS), Ludwig-Maximilians-Universität München (LMU), München (Germany)

DNA-based bottom-up molecular self-assembly presents a promising new route for the construction of artificial micro- and nano-swimmers [1, 2] as it offers the advantage of a systematic design, large scale production and straightforward functionalization [3]. DNA structures coupled with magnetic particles allow for distant and fuel-free control by an external magnetic field. Such swimmer systems can be used in biomedical healthcare and lab-on-a-chip applications, as well as for the study of collective behavior in non-equilibrium physics.

We built DNA micro- and nano-swimmers by conjugating single and polymerized DNA origami [4] and DNA tile tube [5] structures with a superparamagnetic nanoparticle via the hybridization of complementary DNA strands. A setup consisting of a fluorescence microscope with integrated 2-dimensional Helmholtz coil pairs was built to allow for the observation of the swimmers under the influence of an alternating homogeneous magnetic field. In recent experiments we focus on achieving actuation of our DNA-based swimmers by the external magnetic field. Optimization and functionalization of the swimmer structure to improve velocity and utility will be the tasks of future work.

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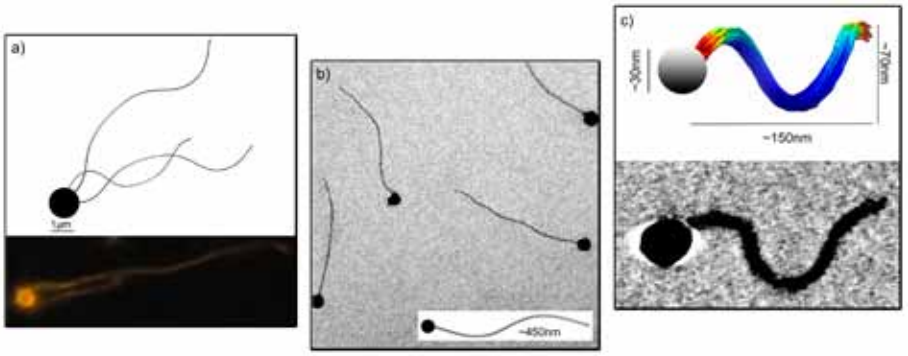

Micro- and nano-swimmer consisting of a magnetic head and a DNA-based tail structure that was built using a) DNA tile tube assembly and b-c) the DNA Origami technique.

Nanolithography by Optothermal Manipulation of Gold Nanoparticles

C. Maier, M. Fedoruk, M. Meixner, S. Carretero-Palacios, T. Lohmüller, and J. Feldmann

Faculty of Physics and Center for NanoScience (CeNS), Ludwig-Maximilians-Universität München (Germany)

Noble metal nanoparticles feature intriguing optical properties, which can be utilized for sensing or manipulating their direct molecular vicinity. Light absorbed by gold nanoparticles is very efficiently converted into heat on a picosecond timescale. A single nanoparticle can thus be used as a tool to apply heat to a nanoscopic area within a short time interval. In addition, gold nanoparticles are subject to optical forces, namely scattering and gradient forces, upon irradiation by light. Such forces can be used to optically push or trap them in two or three dimensions.

Based on these properties, we demonstrate how gold nanoparticles can be used to control the heat-induced polymerization reaction of polydimethylsiloxane (PDMS) at the nanoscale. The creation of polymer nanoparticles and nanowires represent first examples for this novel nanolithography methodology.

Overall, this approach represents an all-optical analogue to conventional scanning probe lithography in the sense that only optical forces are used to move a heated nanoparticle and no mechanical connection between the particle and the microscope is required.

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Force spectroscopy on cohesin-dockerin complexes

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Cellulosomes are discrete multi-enzyme complexes used by a subset of anaerobic bacteria and fungi to digest lignocellulosic substrates. Cellulolytic enzymes are assembled onto a non-catalytic scaffold protein via interacting protein receptor-ligand pairs, namely cohesin and dockerin modules. The binding between those modules is among the strongest protein-protein interactions known to date.

Single-molecule force spectroscopy (SMFS) with the atomic force microscope measures the response of individual biomolecules to force. We used it to study cohesin-dockerin interactions because of its ability to probe the high-force regime (>100 pN) where complex unbinding is likely to occur. Using engineered fusion proteins derived from native cellulosomes, we were able to measure unfolding of three distinct types of cohesin-dickerin pairs, and observe subpopulations impossible to resolve in bulk experiments. This provided the insight into single sub-domain unfolding characteristics, complex rupture forces and structure-function relationships of the cellulosomal subdomains.

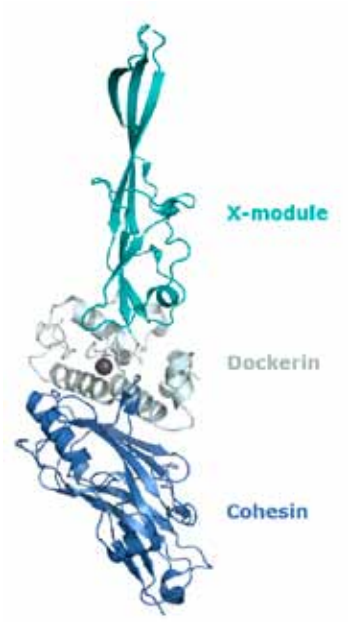

Fig 1: Crystal structure of the Cohesin-Dockerin type III complex.

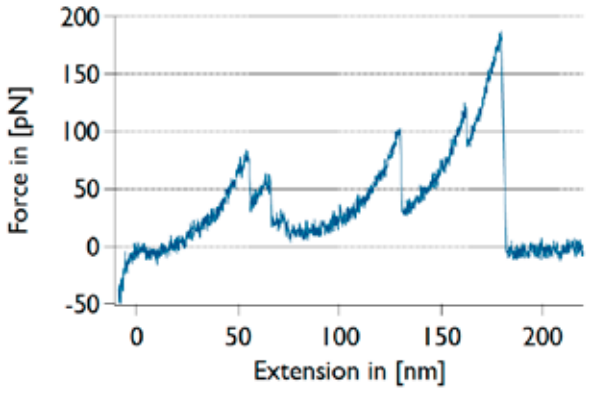

Fig 2: Example of the force-extension trace of the Cohesin-Dockerin complex obtained by SMFS.

High Resolution Optical Characterization and Lifetime Imaging of Nanomaterials

Tobia Mancabelli[1], Julia Janik[1], Nina Mauser[1], Amit Nag[2], Ritun Chakraborty[3], Dawid Piatkowski[4], Roman Krahne[3], Achim Hartschuh[1]

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We present different applications of Tip-Enhanced Near-field Optical Microscopy (TENOM) performed through a sharp gold antenna tip. First we show zero-bias tip-enhanced photocurrent [1] and electroluminescence measurements of isolated Single-Walled Carbon Nanotubes (SWCNs) on glass substrate with a spatial resolution of below 30 nm. Besides photocurrent and electroluminescence the Raman signal can be simultaneously measured within the same measurement with similar spatial resolution. Moreover we combined TENOM and Fluorescence Lifetime Imaging Spectroscopy (FLIM) to resolve lifetime variations along single Cadmium Selenide Nanowires (CdSe NWs) and to investigate the influence of the tip on the excited state decay. The comparison between the enhanced photoluminescence intensity and the lifetime variation caused by tip is used to identify the different contributions to the signal enhancement and to distinguish excitation and radiative rate modifications. TENOM-FLIM is applied also to other systems such as rare-earth doped nanocrystals and CdSe NWs decorated with gold nanoparticles.

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Towards Molecular Evolution Driven by Thermal Traps

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Biopolymers like RNA, DNA and proteins are the fundamental actors in all life on earth. It is however unclear, how the first RNA polymers with enzymatic activity could arise in a prebiotic scenario: Even in millimolar concentrations, ribonucleic acids only build short polymers with a length of 20 bases. We demonstrate how a reversible polymerization process can be enhanced with the help of a simple thermal gradient [1]. Situated in an elongated compartment comparable to a hydrothermal pore it will create a convective fluid flow and also push biomolecules along the thermal gradient due to thermophoresis. The physical non-equilibrium setting of this so-called thermal trap is able to selectively accumulate longer polymers exponentially better than shorter polymers. Since the formation of longer polymers is coupled to higher local monomer concentrations, polymerization and thermal trapping are mutually self-enhancing. This process is described by a theory of trapped polymerization which we experimentally validated with the reversible polymerization of sticky-ended dsDNA blocks (monomers) in a laser-driven thermal trap. The extrapolation of the theory toward the RNA-world scenario shows that a pore height of 5 cm and a temperature difference of 10 K are sufficient to form RNA polymers longer than the shortest RNA based replicator.

In the experimental setting, the superposition of two perpendicular convection flows and thermophoresis also supported the formation of large (~100µm) and specific DNA aggregates made of polymerizing DNA monomers: The melting temperature of the aggregates and the sticky ends of the DNA monomers match. No aggregates were found using non-polymerizing monomers with randomized sticky-ends. Such specific aggregation of genetic material could have lead to the selection of sequences by their structural stabilization.

The replication of genetic molecules is central to Darwinian evolution. We demonstrate how a laser-driven thermal trap is able to drive an exponential replication reaction via thermal cycling and at the same time protects the replication products against outward diffusion into the diluted reservoir [2]. In a proxy replication reaction, DNA replicating polymerase is able to double the amount of a 143mer product each 50 s, while the time constant for accumulation is 92 s. Thermal traps could therefore represent a possible non-equilibrium environment for the formation and replication of the first biopolymers - essential ingredients for the start of molecular evolution.

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Electroactive Covalent Organic Frameworks for Organic Photovoltaics

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Covalent Organic Frameworks (COFs) are a novel class of organic crystalline frameworks linked by covalent boronate ester formation.[1] Physical and chemical properties, such as thermal stability, absorbance spectrum and conductivity can be tailored by the choice of the appropriate building blocks. Due to the high and accessible internal surface area combined with the well-defined crystalline structure these materials can be used as model systems to investigate ordered and interpenetrated networks of donor-acceptor systems at the nanoscale providing a control over all structural and electronic features. Here we present our resent research on the growth of photoactive thiophene based-COFs on different solid supports. Benzodithiophene-based COF, BDT-COF, is synthesized as an oriented thin film on conductive transparent substrates such as ITO. PCBM derivatives, serving as electron-acceptor molecules, were infiltrated into the thin BDT-COF films to obtain an interpenetrated electron-donor, electron-acceptor system. Light-induced charge transfer from the BDT-COF to PCBM acceptor molecules is demonstrated by efficient photoluminescence quenching.[2] As an outlook a COF based on large chromophor with an excellent absorbance property is presented.

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Regulative Potential of Membrane Protein Glycosylation

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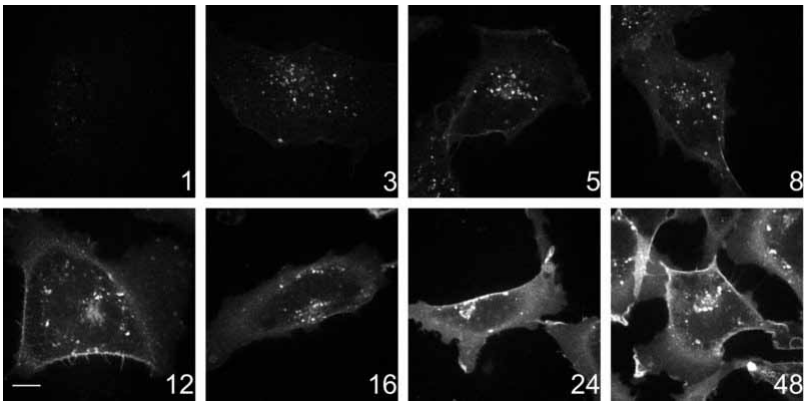
Proteins on the membrane of eukaryotic cells carry large, often very complex sugar structures. Besides their commonly known functions like participation in the quality control during protein folding there is growing evidence that membrane protein glycosylation fulfills also regulation purposes. For example, it was shown that the membrane localization of the EGF receptor depends strongly on its glycosylation which is in turn contingent upon the nutrition state of the cell. In our work, we use highly sensitive live-cell fluorescence microscopy combined with in-cellulo click-chemistry to enlighten the spatio-temporal dynamics of glycosylated membrane proteins on different cell types. We found out that the turnover and internalization rate as well as the mobility of membrane proteins is dependent on the glycosylation type. This strongly indicates that the glycosylation of a membrane protein can be employed to tune its residence time. We suggest that these finding are closely connected to the influence of the galectin lattice, a mesh-like network that is built by glycan-binding proteins. From our findings we state that the behavior of membrane proteins is highly influenced by glycosylation which constitutes a new possibility for the cell to control key processes.



Turnover of Sialic Acid Bearing Proteins on HMEC Cells

Probing non-equilibrium carbon fixation at a microfluidically defined, prebiotic rock membrane

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Faculty of Physics and Center for NanoScience (CeNS), Ludwig-Maximilians-Universität, Munich (Germany)

Here we perform non-equilibrium chemistry on a nanoporous membrane consisting of catalytic metal-sulfide nanoparticles. Similar membrane systems naturally occur in hydrothermal vents and exhibit sharp redox and pH gradients, which can lead to the formation of small organic molecules from inorganic precursors.[1] An experimental realization of this hypothesis will be a major step for origin of life research and might also reach into the field of biofuel research. Furthermore, the variety of effects involved in this system will allow a deeper understanding of the fundamental physics of non-equilibrium settings. Upon contact of sulfurous, alkaline hydrothermal fluid with iron-bearing, acidic seawater a micrometer thin iron-sulfide rock membrane precipitates.[2] The strong non-equilibria across this membrane might naturally lead to a first biological carbon fixation pathway and the emergence of first organic molecules. Strikingly, the catalytic metal-sulfide centers within the rocky membrane are highly reminiscent of clusters in modern metalloproteins.[3] Do these merely mimic a natural geological situation? Using a custom made setup we implement the anoxic, high pressure conditions of early earth hydrothermal vents. Persisting physical and chemical non-equilibria are attained by a

high pressure microflow system under laminar flow conditions. By means of mass-spectroscopy we try to detect signatures of carbon fixation, such as formate, methanol, formaldehyde and methane thiol, or even small peptides and aminoacids. To understand the non-equilibrium effects in more depth optical methods are applied.

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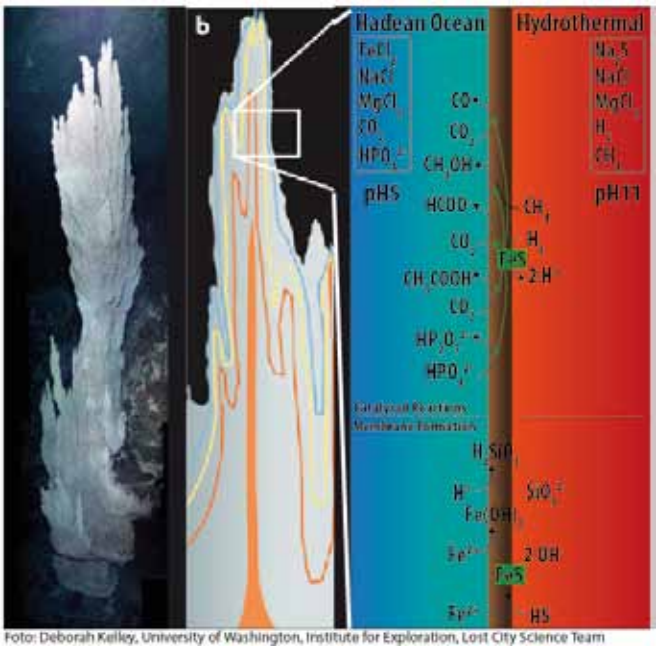

Foto: Deborah Kelley, University of Washington, Institute for Exploration, Lost City Science Team

Single Molecule FRET Study of RNA Degradation by Rrp44

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The eucaryotic exosome is a macromolecular protein complex and essential for RNA degradation. Rrp44 is a catalytic subunit of the exosome and has been shown to act as a 3'-5' exoribonuclease. Upon binding to an accessible 3'-end of RNA, Rrp44 processively cleaves the body of an RNA substrate one nucleotide at a time to completion, thereby powering its own processive motor function. To elucidate the mechanism of RNA degradation by the exosome, we apply single molecule FRET (Förster Resonance Energy Transfer) in combination with objective-based TIRFM (total internal reflection microscopy). This is a promising approach to enable the observation of individual Rrp44 molecules acting on immobilized dsRNA. Such observations may provide access to dynamics, which may be not accessible in conventional bulk measurements, thereby enhancing the understanding of the mechanism of enzyme action. Here, we present a protocol for sample preparation and analysis of such measurements. Furthermore, we show preliminary results on the interaction of Rrp44 with immobilized dsRNA. It is intended to apply this approach for the investigation of the complete exosome and of other proteins involved in RNA degradation.

Modulation of cell migration in 3-dimensional hydrogels using nanoparticles

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The development of nanoparticles (NPs) is a promising approach for advanced drug delivery, since NPs are expected to have fewer side effects due to their higher target specificity. Previous diffusion studies with charged liposomes in collagen type I and Matrigel, a model system for basal lamina, showed that these NPs can bind and accumulate in hydrogels depending on their surface charge and therefore might have an effect on cells and their migration behaviour. Leukocytes, for example, have to be able to access the blood stream and transmigrate through hydrogels such as the basal lamina and the extracellular matrix - which is critical for an effective immune response. By means of time laps video microscopy analysis of HL-60 cells within collagen type I and Matrigel gels, we found that liposomes only influenced 3D cell migration in Matrigel and that this effect depends on the charge of the NPs. Only liposomes with a negative zeta potential altered the cell migration behaviour, however cell proliferation or metabolism was unaffected. To mimic the physiological situation we designed a microfluidic device that allows to test the entry of cells into hydrogels covered with NPs at the liquid-hydrogel interface. The design of the microfluidic device offers the feature to build up a chemoattractant gradient which remains stable for hours enabling the attraction of cells towards the hydrogel. This study will help designing NPs to locally control cell migration. Such an approach might be of interest as a new strategy for implant functionalization to prevent unwanted immune reactions.

Realization of a Low-Drift Ultra-High Vacuum Scanning-Tunneling-Microscope with an Integrated Nano-Positioner

Oliver Ochs[1,2,3,4], Stephan Kloft[3,4], Johanna Eichhorn[2,3,4], Wolfgang Heckl[2,3,4] and Markus Lackinger[2,3,4]

1 Hochschule München, 2 Technische Universität München, 3 Deutsches Museum, 4 CeNS, München (Germany)

The design of the new Scanning-Tunneling-Microscope (STM) was optimized for high-resolution experiments at room temperature under UHV conditions. The instrument replaces a less-stable predecessor microscope, whereby the existing vacuum system, the sample holders, the preparation facilities, and the vibration isolation of the pre-existent STM are further used.

The new STM features a compact and rigid design with an integrated single axis nano-positioner for an efficient coarse approach. The high clamping force of the nano-positioner lends the microscope a very high mechanical stability and makes it less prone to external disturbances. Crucial parts of the microscope are made out of super invar, a special steel alloy with extremely low thermal expansion coefficient. This choice of material in combination with a symmetric design are efficient means to minimize thermal drift. Additionally, the tunneling voltage and tunneling current signals are electromagnetically shielded by a multi-stage concept. In summary, the rigidity of the microscopy, the vibration isolation, and the shielding all contribute to an excellent signal-to-noise ratio.

The performance of the STM was tested by various experiments. For instance, atomic resolution of metal surfaces is routinely obtained at room temperature. In addition, the lateral drift is extremely low, as deduced from subsequent images. Moreover, the high efficiency of the nano-positioner facilitates a quick coarse approach in typically less than three minutes. This highly stable and easy to use STM is employed as a reliable tool to study surface chemistry and self-assembly.

Cellulosomes: Nature's toolkit for Nanoscientists

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The native cellulosome offers a versatile toolkit for scientists. The cellulosomal network is composed of two main units. One fundamental part is a scaffolding protein, which is a framework for enzymes to dock onto. For that matter it contains several binding domains called cohesins. The enzymes are the second essential component of the cellulosome. They incorporate a catalytic site and a cohesin-binding domain called dockerin. To locate the cellulosome near its substrate the scaffolding is featured with a carbohydrate-binding molecule (CBM), which is able to bind cellulose [1]. In nature microorganisms secrete cellulosomes to reduce the cellulose-polymer to glucose. Cellulose is the most abundant resource around, and therefore a very attractive basis for renewable biofuels. Glucose generated bioethanol, an alternative to fossil fuels, can provide further generations with energy [2]. Scientists of different fields can examine a broad variety of actions happen at one cellulosomal complex. For example there is receptor substrate interactions between the CBM and cellulose. It is furthermore possible to learn about protein-protein interactions among cohesins and dockerins. The cellulosome shares in addition the possibility to study enzymatic networks degrading cellulose. Thereby synergistic effects occur, which are very attractive for industrial applications. One could even try to improve the enzymatic digestion of cellulose through integrating new non-cellulolytic enzymes [3]. This work reports about a novel approach developing designer cellulosomes. With the help of synthetic biology new proteins were modeled and produced.

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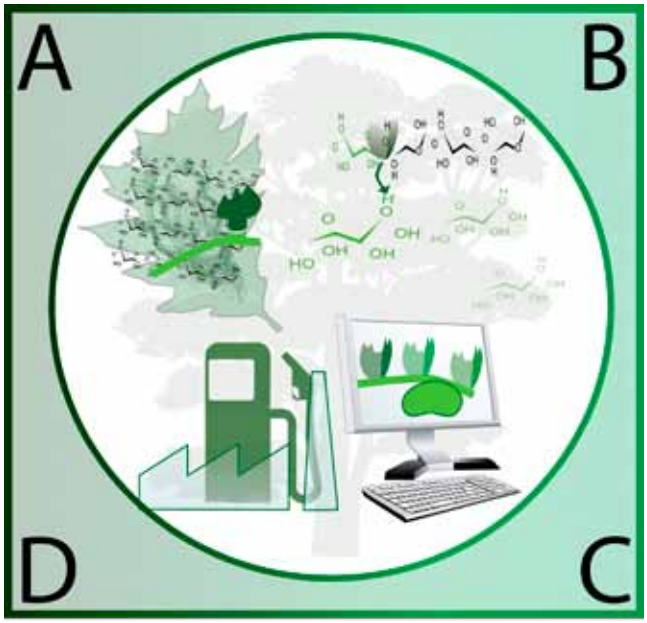

Scheme of the cellulosomal toolkit. It enables scientists to study protein-protein /-substrate interactions (A) and enzymatic activities (B) within one multimeric complex. Gained insights could be used to develop designer cellulosomes (C) for industrial applications (D).

Single Molecule Studies Based on Lithographically Arranged DNA Origami Structures

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Self-assembly of DNA molecules into arbitrary shapes facilitated by the DNA origami technique has been utilized for the fabrication of a large variety of complex and functional structures in the past few years. One of the most important features for the generation of functional structures is the possibility to address individual positions on a nanoobject with nanometer scale precision [1]. Currently, the size of origami structures is limited to structures of a few hundred nanometers. With the goal to create structures of higher order several groups have investigated strategies for up-scaling DNA origami, among these the formation of one- or two-dimensional origami 'crystals' [2][3] or the lithographic arrangement of origami structures [4]. We here demonstrate the utility of such lithographically arranged origami structures for single molecule studies in TIRF microscopy. Using electron beam lithography, arrays of gold spots with a spacing of 1 µm are fabricated on glass cover slides coated with hydrophobic hexamethyldisilazane (Fig. 1 a). As adhesion of origami structures to the hydrophobic surface is low, the attachment of origami structures modified with thiolated single-stranded DNA extensions is constrained to the gold spots. In TIRF microscopy the DNA-PAINT technique, which relies on the transient binding of short fluorescently labeled oligonucleotides, was utilized for the characterization of the origami array (Fig. 1 b-d) [5]. Furthermore DNA-PAINT served as a model experiment for testing parallelized signal readout. The detection of only a few positions of the array and the utilization of the basis vectors are sufficient to reliably read out the fluorescence intensity traces of a few hundred individual DNA origami structures for further analysis. Applications using single molecule fluorescence comprise the determination of binding kinetics for DNA hybridization events or the readout of DNA-based molecular circuits precisely arranged at the micro- and nano-scale.

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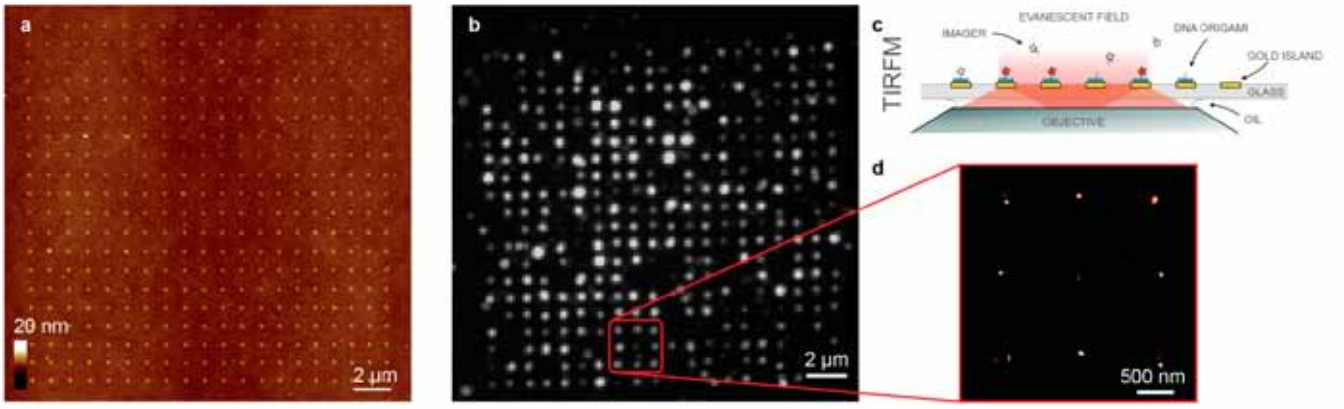

Fig. 1 a) AFM image of an array of gold spots with a spacing of 1 µm. b) Standard deviation image of DNA origami using DNA-PAINT in TIRF microscopy. c) TIRFM scheme illustrating the imaging of a DNA origami array using DNA-PAINT. d) Super-resolution image reconstructed from DNA-PAINT with one bright spot corresponding to one origami structure.

MFU-4@SAW: Metal–Organic Framework-Coated Surface Acoustic Wave Substrates as Chemical Sensors

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Metal–organic frameworks (MOFs) thin films are grown on a lithium niobate substrate with interdigital transducers (IDTs), to generate a surface acoustic wave (SAW). The combination of a SAW chip and a MOF layer yields a very sensitive sensor for the detection of various gases [1]. Depending on the pore size(s) of the MOF the sensor is specific for different gases. MFU-4 [2], with a smallest pore aperture of 2.5 Å, shows a highly sensitive response which is specific to CO_2 (Fig. b), H_2, He, NH_3 and H_2O. The selectivity of the sensor can be rationalized in terms of porosity characteristics and gas transport mechanism characteristic of this material. Larger gas sorbates are detected with MFU-4*large* [3] -coated chips (smallest pore aperture: 9.1 Å). Up to 200 nm wide cubic MOF crystals were grown directly from solution on the sensitive chip area (Fig. 1a). Investigations show that a tight bonding of the MOFs on the $LiNbO_3$ crystal surface is a crucial requirement for sensing. In vacuum and at high temperature the solvent is removed from the MOF pores to activate the stable MOF. Measurements are performed in a gas flow reactor employing gas mixtures at different ratios (sample gas to reference gas). The sensor response curve shows a very high sensitivity up to 3 ppmv, limited by the gas mixing system. Gas detection proceeds in relation to a reference measurement on the same chip, while the relative phase shift of both SAWs is measured [4]. SAWs are generated from the center IDT to both outer IDTs (cf. Fig. 1a) and phase shift is induced by mass loading of the MOF. This sensor responds within milliseconds to gas loading of MOFs and is set to a very sensitive level by the electrical construction. Also such a sensor type is manufactured very simply and economically, thus reducing manufacturing costs. With their tunable pore sizes and adjustable internal surface properties, MOFs offer a new sensor technology with an enormous application potential.

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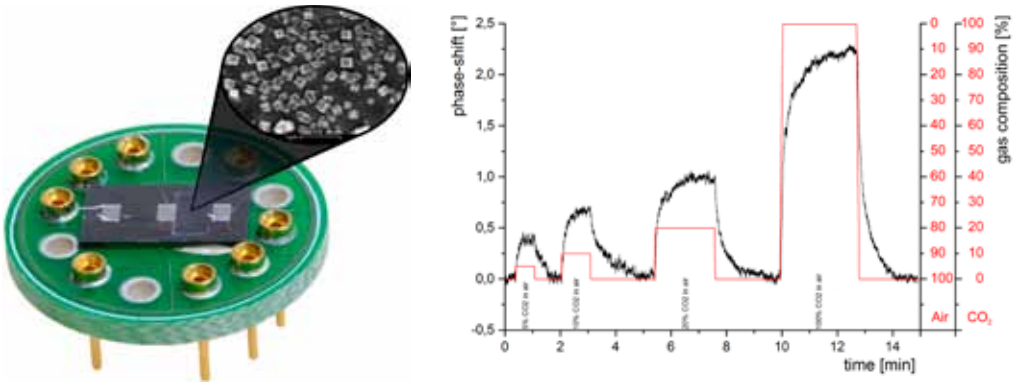

Fig. 1 (a) Triple-IDT-Device with MFU-4 on SAW in one of the active areas for selective gas uptake and reference measurement on one and the same chip. (inset: SEM of MOF crystals grown on top of a $LiNbO_3$ single crystal); (b) Response curve to CO_2 gas, detected in air by a reference measurement of the phase shift.

Visualization of SAW and thin fluidic films and Standing surface acoustic waves (SSAW) in microfluidic channels

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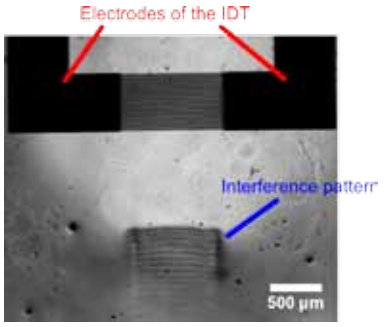
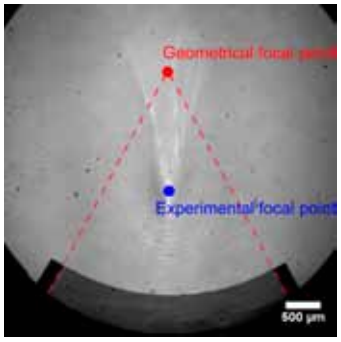
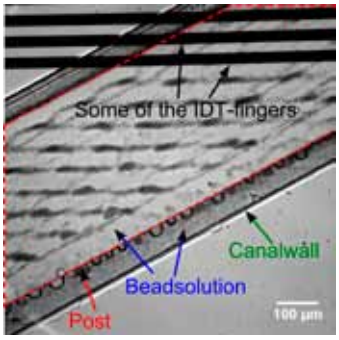
One fast-growing field of research in nano-biotechnology is the development of µ-TAS (micro total analysis systems) and accordingly the development of lab-on-a-chip-systems. Those mini-labs utilize the principles of microfluidics and are offering a huge amount of applications. Important building blocks of such systems are the transportation, manipulation, mixing or even sorting of particles in fluids. For experiments, acoustic methods are most important. Hereby we use waves which are propagating along a surface, so called SAW's (surface acoustic waves). Those high frequency waves (MHz-order) are generated by IDTs (interdigital transducers) on a $LiNbO_3$-substrate. The microchannels are cheap, disposable PDMS devices which are made by lithographical processes. For better aligning the IDT with other fluidic components, such as a PDMS channel, testing the functionality of an IDT and probing completely new IDT-designs, it is often necessary to visualize IDT's acoustic path or the focal point of a focused IDT. However this visualization still remains elusive and requires expensive equipment such an AFM, SEM or a vibrometer. We show a simple and quick way to visualize the IDT's sound path. Thereby other interesting effects (boundary layer streaming and fluidic layer formation) in thin fluidic films have been revealed. Another interesting point in this field of research is the ability of a controlled movement of particles inside a microchannel device. This can be done by standing waves which are generated with opposed IDTs. Both IDTs are operating again on a high frequency level in MHz-order and the beads are accumulating in the nodes of the standing waves. If the frequency of one IDT is lightly shifted (Hz-order), the nodes, with the trapped beads inside, start to propagate along the surface. Further we use posts for a local injection of the SAW into the microchannel device. Reflections at the post's borders can also induce standing waves so that we gain an opportunity to manipulate the form of standing wave within our PDMS devices simply by the design of different post structures.



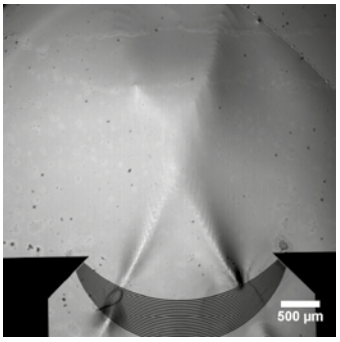
Visualization of the acoustic path of a straight IDT. An interference pattern of the SAW can be seen.



Demonstrating the visualization of the focused IDT's acoustic path. Depending on the material's anisotropy the focal point is shifted towards or away from the IDT.



Standing surface acoustic waves in a microchannel focusing the latex-beads into the nodes.



Visualization of a focused tapered IDT's acoustic paths at 90MHz. The two sound paths converge at the focal point.

Mucin hybrid gels as antiviral/antibacterial wound dressings

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Mucin glycoproteins are the key constituents of mucus, a biopolymer-based hydrogel that lines most of the inner surface in humans and animals and serves as a first layer of protection against pathogenic microorganisms. Recently, it has been shown in vitro that purified porcine gastric mucin biopolymers can efficiently protect a cell layer from a broad range of viruses and also reduce bacterial adhesion. Yet, the low viscosity of reconstituted mucin solutions hampers their direct application for wound treatment. Here, we aim at developing a novel mucin-based gel for wound dressings. This novel material is supposed to maintain the antiviral/antibacterial properties of mucins while allowing for in situ gelation for easy application on inner wounds, e.g. after surgery. Therefore we developed composites of porcine gastric mucin and methylcellulose so that gelation of the mixed polymer system can be induced by temperature. The characterization of this biopolymer hybrid system is performed using macrorheological measurements and optical microscopy. Live/dead cell viability assays with fibroblasts and endothelial cells demonstrate the good biocompatibility of the hybrid material. In a last step, we aim at optimizing the adhesion strength of the gel on native tissue samples.

Nanoscale mechanical impedance mismatch imaging with a mechanical point contact

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For nanoelectromechanical (NEM) resonators, control of vibrational energy exchange between the resonator and its supports is highly desirable: High Q-factor resonators are attained by suppressing this energy transfer, which allows realization of ultrasensitive devices. Conversely, the energy transfer can be engineered to realize integrated resonator devices communicating through phononic waveguides.

It is convenient to think of the vibrational modes as localized standing waves caused by the mismatch in mechanical impedance between the resonator's support and the suspended region. A large impedance mismatch gives rise to a large wave reflection and a correspondingly highly localized vibrational mode with a large Q-factor (limited by intrinsic losses only).

Here we employ an atomic force microscope (AFM) tip as a local perturbation of a high-Q silicon nitride string resonator, modifying the mechanical impedance mismatch to its environment. Thereby the dissipation of the resonator's flexural modes changes greatly. Thus, this method of spectroscopy through local mechanical impedance mismatch imaging yields fundamental insights into damping of NEM resonators.

Kinetic Studies of Nanotoxicity and Cellular Self-Organization on Microstructured Surfaces

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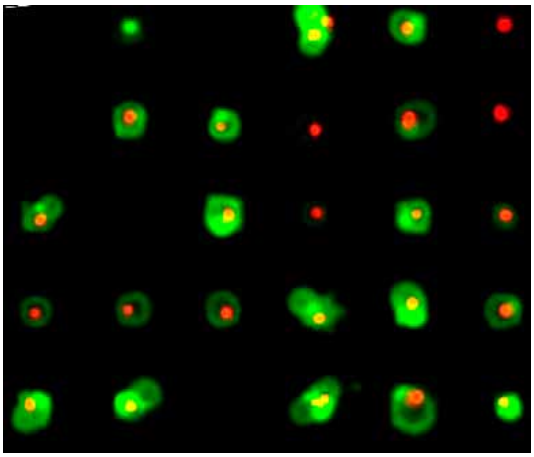
Dynamics of molecular processes in living cells appears to be heterogeneous at the single-cell level. Hence time-lapse microscopy becomes increasingly important as it allows measurement of e.g. cell fate decisions and cellular responses in general. Micropatterned surfaces can help to achieve high-throughput cell fate microscopy as they allow to direct cells to defined adhesion sites. For this purpose, a new micro-structured surface has been developed whose surface chemistry and geometry has been optimized to allow self-organization of cells after seeding. By varying the distance of the lattice cells need different finite times to find the adhesion sites. Small lattice distances cells are dominated by directed motion; for bigger distances the system can be described by a diffusive search process. A first application has been used for on automated single cell image analysis of cell death (induced by nanoparticles and staurosporine). Time resolved dose response curves of amid polystyrene nanoparticles have been measured. Moreover, time dependencies between different cell death events have been shown. The knowledge about the timing can be used for mapping various signal pathways of apoptosis (programmed cell death).



Cells on a single cell lattice which have been exposed to amid functionalized nanoparticles. The two fluorescent colors are an indication of different events in cell death (green: membrane change detected by pSIVA-IANBD, red: nucleus staining (loss of membrane integrity) detected with propidium iodide).

High-resolution live-cell imaging of cascaded photoinduced drug delivery from lipid bilayer coated multifunctional mesoporous silica nanoparticles[1]

Alexandra Schmidt[a], Veronika Weiss[b], Stephan A. Mackowiak[b], Christian Argyo[a], Constantin von Schirnding[a], Christoph Bräuchle[b], Thomas Bein[a]

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Colloidal mesoporous silica core-shell nanoparticles (MSN) have attracted great attention in recent years as versatile vehicles for drug delivery. These MSN offer a high pore volume, a defined and tunable pore size, and various functionalization possibilities.[2] After uptake of the silica nanoparticles by cancer cells, a major bottle-neck for efficient drug delivery is the endosomal entrapment of the MSN, which can be overcome by employing photosensitizers. Previous work has taken advantage of this approach by combining MSN, surrounded by a supported lipid bilayer (SLB), with photosensitizers.[3,4] Recently, we improved this system by developing a MSN system with surface-bound PEG and covalently attached red-light sensitive phthalocyanine photosensitizer $AlPcS_{2a}$ surrounded by a biocompatible DOPC/DOTAP-SLB (SLB@MSN). We synthesized highly uniform spherical multifunctional core-shell MSN with particle sizes of 70 nm and pores of 5 nm. The MSN are surrounded by a supported DOPC/DOTAP lipid bilayer (SLB) for efficient encapsulation of the guests (calcein and

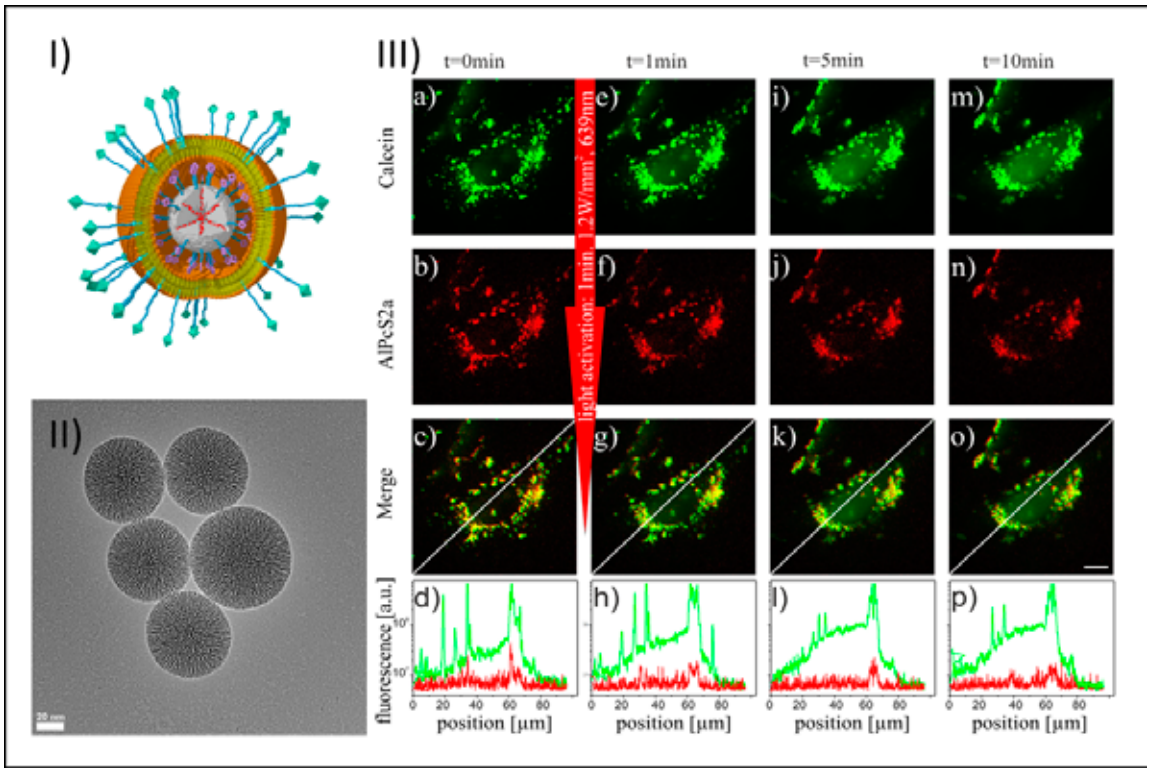
rhodamine derivative) and folate or the epidermal growth factor (EGF) is employed as targeting ligand for specific uptake of the nanoparticles. Singlet oxygen is generated by photoactivation and leads to endosomal membrane rupture in cells causing cargo release from the mesopores. The successful intracellular release of the encapsulated guests was monitored by fluorescent live-cell imaging. The functionality of the targeting ligands on our nanoparticle system was evaluated by performing competition experiments.

[1] S. A. Mackowiak, A. Schmidt, V. Weiss, C. Argyo, C. von Schirnding, T. Bein, C. Bräuchle, Nano Lett. 2013, 13, 2576.

[2] V. Cauda, A. Schlossbauer, J. Kecht, A. Zuerner, T. Bein, J. Am. Chem. Soc. 2009, 131, 11361.

[3] A.M. Sauer, A. Schlossbauer, N. Ruthardt, V. Cauda, T. Bein, C. Bräuchle, Nano Lett. 2010, 10, 3684.[

[4] A. Schlossbauer, A.M. Sauer, V. Cauda, A. Schmidt, H. Engelke, U. Rothbauer, K. Zolghadr, H. Leonhardt, C. Bräuchle, T. Bein, Adv. Healthcare Mater. 2012, 3, 316.



I) Schematic representation of the MSN; II) The TEM image shows spherical core-shell MSN with a size of 70 nm, illustrating radial growth. III) Fluorescence microscopy of MSN-PS-SLB-FA nanoparticles loaded with calcein inside HeLa cells, after an incubation time of 16 h. (a–c) Calcein (green) and $AlPcS_{2a}$ (red) are colocalized (yellow) prior to photoactivation. (d) Intensity profile along the white line in the merged image for both. (e–h) 1 min, (i–l) 5 min, and (m–p) 10 min after photoactivation. The scale bar represents10 µm.

Towards a Numerical Renormalization Group description of the steady-state nonequilibrium single-impurity Anderson model using Lindblad driving

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2 Institute of Physics, Adam Mickiewicz University, Poznań (Poland)

Wilson's Numerical Renormalization Group (NRG) allows to describe the single-impurity Anderson model (SIAM) in equilibrium in a nonperturbative way. However, it remains a challenge for NRG to treat situations of steady-state nonequilibrium, such as transport through a quantum dot at finite source-drain bias, or to describe the dynamics of relaxation processes. To model such situations, we envisage considering additional baths, which are coupled to the leads. The effect of these baths on the leads can be described by using Lindblad operators [1] in the Liouville equation for the density matrix of the dot and the leads. The action of these operators can, in principle, be chosen such that the leads are effectively held in thermal equilibrium. An efficient way of solving this Liouville equation is to use the stochastic quantum trajectory method [1]. The intermediate time evolution needed to generate such trajectories can be done with time-dependent NRG (tNRG) based on complete basis sets. Here we present our preliminary results illustrating the above ideas.

[1] C.W. Gardiner, P. Zoller, Quantum Noise (Springer, Berlin, 2000)

Synthesis of Free-standing Carbon Nanofibrous Films Utilizing a Fast Microwave-assisted Process

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Carbon nanofibrous (CNF) films are of great interest for various applications, e.g., as substrates for electrodes, sensors or catalysts. Here we present a fast microwave-assisted synthesis process to fabricate free-standing carbon nanofibrous films. The major advantages of the microwave-assisted synthesis of CNFs are the simple set-up without hazardous reactants, a low overall temperature in the reaction chamber and short reaction times.[1,2]

Irradiation with 250 W for 1 min turned out to be sufficient to synthesize CNF coatings. As precursors for the reaction, nickel-based catalysts on silicon substrates and ethanol were used. When just a small amount of catalyst was applied, loosely bound, powder-like CNF coatings were obtained. With an optimized amount of catalyst, entangled CNFs were grown, which formed stable films. These films could be detached from the substrate simply by utilizing tweezers and without the need of further treatment. Thereby, square centimeter large, approximately 10 µm thin free-standing carbon nanofibrous films were obtained. Their detachment from the substrate was facilitated by a partially uparching and self-delamination of the film during the synthesis process. Morphology investigations were carried out by scanning electron microscopy and a growth model was developed.

Those films potentially find application as electrode material or for catalytic devices where they could, e.g., be used as a lightweight, conductive basis upon which a device can be built.

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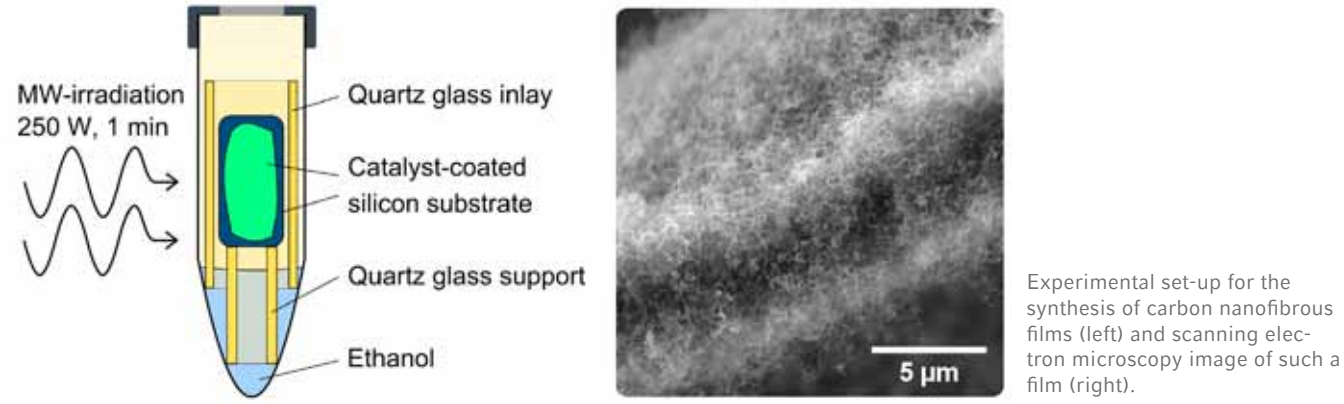
[2] T. Druzhinina, W. Weltjens, S. Hoeppener, U. S. Schubert, Adv. Funct. Mater. 2009, 19, 1287–1292.



Experimental set-up for the synthesis of carbon nanofibrous films (left) and scanning electron microscopy image of such a film (right).

Response of a Complex Fluid at Intermediate Distances

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The viscoelastic response of complex fluids is length- and time-scale dependent, encoding information on intrinsic dynamic correlations and mesoscopic structure. We derive the subdominant response of such fluids at intermediate distances and show that it governs their dynamics over surprisingly large length scales. Generalizing the framework of microrheology to include this response, we experimentally confirm the theory, thereby measuring the dynamic correlation length of F-actin networks, as well as their bulk and local viscoelastic properties.

Exploiting non-abelian symmetries in the Dynamical Mean-Field Theory using the Numerical Renormalization Group

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The realistic description of strongly correlated materials is a huge challenge in condensed-matter physics. As the strength of electron-electron interactions is comparable to or larger than the kinetic energy, intriguing quantum many-body phenomena like the transition from a metallic to an insulating phase arise, but cannot be investigated by perturbative methods.

The Dynamical Mean-Field Theory (DMFT) provides a non-perturbative many-body approach to describe the local dynamics of strongly correlated systems by mapping a lattice model self-consistently onto an effective (single-site) quantum impurity model, which is then solved by a non-perturbative method, such as Quantum Monte Carlo simulations (QMC) or the Numerical Renormalization Group (NRG) approach. QMC codes are widely used and have been highly refined over the last few decades. However, the data is obtained on the imaginary (Matsubara) frequency axis and has to be analytically continued to the real axis, a procedure that is mathematically ill-conditioned. Furthermore, possible limitations are very low temperatures and also the so called "sign problem" for fermionic systems.

In my work, I exploit one of the most evolved codes in the field of NRG as an alternative to QMC impurity solvers within DMFT. The NRG method allows to calculate physical quantities directly on the real frequency axis. Using the full density matrix approach (fdm-NRG, A. Weichselbaum et al., PRL 99, 2007) within the framework of complete many-body basis sets (F. B. Anders et al., PRL 95, 2005), our NRG solver can handle arbitrary temperatures in a clean, systematic and thus optimal manner. Moreover, our code is, to date, the only NRG framework, that is able to exploit arbitrary abelian and non-abelian symmetries (A. Weichselbaum, Ann.Phys. (N.Y.) 327, 2012), which leads to a significant reduction of numerical effort and makes it highly suitable for the investigation of multi-band models in the presence of intrinsic symmetries.

A novel tool for cell adhesion studies - the DeAdhesion Number Investigator

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Studying cell adhesion and properties of different cell-material combinations is crucial not only for scientific interests but also for a medical purpose. Where a strong cell adhesion in osseointegration of hip implants is necessary, adhesion on stents should be prevented completely.

For an optimal implementation of materials in living environments, a thorough characterization of cell adhesion properties, both kinetics and strength, is required. Here we present a miniaturized (~ 100 µl) lab-on-a-chip implant hybrid system which allows it to quantify cell (de-)adhesion under dynamic conditions mimicking those of physiological relevance. Surface acoustic waves on optical transparent chips are used to create a microfluidic shear spectrum ranging from 0 - 400 s-1 which the cells are exposed to. We demonstrate its applicability with a model of an osseointegration study using SAOS-2 cells on titanium implant material samples. The great advantage of DANI compared to present-state cell adhesion probing systems is that it requires only very few lab consumables and allows live observation of the cells as well as arbitrary material-cell combinations. Further more, the measurement chamber allows temperature and pH-value control (e.g. to generate physiological conditions).

Control of ion transport across lipid membranes by plasmonic heating of gold nanoparticles

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In our work, we study heating effects on the physical properties of phospholipid membranes. In living cells, lipid membranes play an important role as a natural barrier between the sensitive cell interior and the cell's environment. Transport across a membrane is facilitated by ion channel proteins, while the membrane itself is considered to be almost impermeable for ions. We demonstrate that the permeability of a pure lipid bilayer can be altered reversibly by heat which is generated by the non-radiative plasmon decay in gold nanoparticles.

The lipid diphytanoylphosphatidylcholine (DPhPC) is used to prepare giant unilamellar vesicles (GUVs) by electroformation. Vesicles are functionalized with gold nanoparticles and laser light tuned to the plasmon resonance frequency is used to heat the particles. Effects of local heating on the lipid membrane are investigated by using the planar patch-clamp technique. Simulated heat profiles of gold nanoparticles in water help to interpret the results of the conducted optothermal experiments.

Game Theory on the Nanoscale

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Game theory can be applied to many distinctive fields, ranging from economics to psychology and also biology. Evolutionary game theory has been used to describe populations of bacteria or yeast cells [1], but we investigate a coexistence game on the nanoscale, using DNA and polymerase chain reaction (PCR) as replication mechanism. To copy the sequence information with PCR, short snippets of DNA, so called primers are added. They will bind to a specific site and will be elongated by the polymerase according to the DNA template. The templates we use are designed to form a hairpin, a secondary structure of polynucleotides often found in nature. This will prevent primers from binding to the primer binding sites, thus suppress the replication. This self-inhibition can be overcome, if hairpins are able to cooperate, therefor at least two distinct hairpin species have to be involved. They are designed, such that their loop sequences are able to bind to each other, but the primer binding sites are not. If this happens, they can't fold into the hairpin conformation and this allows the PCR to take place (see image). Our results show, that for a hairpin population, the presence of a cooperating species is very favorable. The composition of the total population changes with every cycle, leading to a fixed point, where the efficiencies of the species become equal. To observe another aspect of game theory, we built an inverted fluorescence microscope which allows us to perform spatially resolved real-time PCR in PAA-Gels [2]. The important role of diffusion in such an environment can be considered a game changer, which leads to results which differ strongly from a well-mixed environment [3]. For cooperative hairpins like those mentioned above, slow diffusion might be favorable, since the locally higher concentration of cooperators should enhance their growth rates.

[1] Gore, J., Youk, H., & van Oudenaarden, A. (2009). Snowdrift game dynamics and facultative cheating in yeast. Nature, 459(7244), 253-256.

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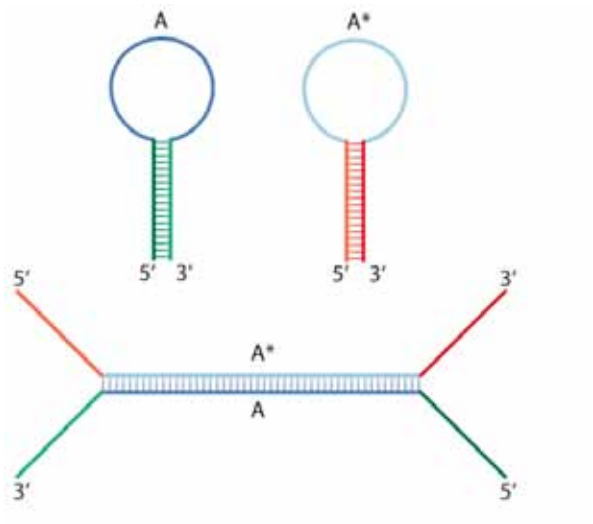
[3] Reichenbach, T., Mobilia, M., & Frey, E. (2007). Mobility promotes and jeopardizes biodiversity in rock–paper–scissors games. Nature, 448(7157), 1046-1049.



The two hairpins in the top of the image are self-inhibiting due to blocking of their primer binding sites. Their complementary loop sequences allow them to bind to each other, which makes it possible for primers to bind and thus replication can start.

Pitfalls and artifacts in two-focus fluorescence fluctuation spectroscopy

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Fluorescence fluctuation spectroscopy is a powerful technique to quantify intracellular transport on the almost single-molecule scale. Going beyond a single observation volume, temporally cross-correlating the fluorescence from two separated foci can be exploited to obtain large-scale transport coefficients, and to detect transport barriers. Using mean-field theory and simulations in combination with experiments on a laser scanning microscope (LSM), we have investigated which artifacts and pitfalls may hamper this promising approach. We find that the unavoidable bleaching of fluorophores only has a minor influence on the results, whereas the typically poor statistics in commercial LSMs severely limits the applicability of the approach to in vitro systems.

Myosin Driven Actin Fragmentation and Lipid/Protein Diffusion Studied in a Minimal Actin Cortex

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In eukaryotic systems the actomyosin cortex is involved in fundamental processes such as cytokinesis and cell polarization and is proposed to control lipid/protein diffusion within the membrane. Only little is known about the interaction between individual myofilaments and membrane-bound actin and the role of the membrane during actin cortex reorganization. We therefore developed minimal actin cortices (MACs), consisting of membrane bound actin and myosin motors, that allow performing well-defined quantitative experiments, which are difficult to realize in living cells. We visualized individual myofilaments on membrane-bound actin using TIRF microscopy and found that myosins fragment and compact membrane-bound actin while processively moving along actin filaments (Vogel et al., eLife 2013). We propose a mechanism by which tension builds up between the ends of myofilaments, resulting in compressive stress exerted on single actin filaments, causing their buckling and breakage. Modeling of this mechanism revealed that indeed sufficient force can be generated by single myofilaments to buckle and break actin filaments. This mechanism of filament fragmentation and compaction may contribute to actin turnover and cortex reorganization during cytokinesis. To test the impact of the actin meshwork on the lipid/protein diffusion behavior within the membrane we measured the lateral diffusion of lipids/proteins with FCS. We found that actin slows down the diffusion of lipids and proteins pointing to a direct role of actin in controlling the mobility of lipids/proteins within the membrane of the MAC (Heinemann et al., Biophysical Journal 2013). The reduction of mobility for both, the lipid and the protein probes depends on the density of the actin mesh, the size of the probes, and is much more pronounced for the larger protein than compared to the smaller lipid. The observed modulation of the lateral diffusion behavior of the lipid/protein content in membranes by the actin meshwork may play an important role in protein sorting and signaling events in cell membranes.

Conformational dynamics of proteins involved in RNA maturation and protein folding

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Foerster Resonance Energy Transfer (FRET) is an ideal tool to study properties of objects on the nanoscale, as the distance range of the energy transfer lies in the regime of interest. It is thus well suited for the observation of subpopulations and conformational changes or dynamics of proteins on the single molecule level. In this project, both solution based confocal microscopy and total internal reflection microscopy (TIRF) on immobilized molecules were applied to investigate conformations of proteins involved in RNA maturation and in protein folding. Maximum information including FRET efficiency, anisotropy, and lifetime can be collected by multi-parameter fluorescence detection (MFD) on a confocal microscope with polarized, pulsed interleaved excitation. However observation times of individual molecules are in this case limited, while TIRF microscopy offers extended measurement times up to several hundred seconds with immobilized proteins without the advantage of detecting several parameters simultaneously. Single pair FRET measurements on the above mentioned instruments were performed on the spliceosomal subunit U2 snRNP auxiliary factor (U2AF65). The RNA recognition motives of this polypyrimidine tract RNA binding factor are involved in the recognition of the 3' end of introns during pre-mRNA splicing. FRET efficiency histograms show large conformational changes of these motives upon RNA binding. Furthermore the conformational cycle of the chaperone BiP (binding immunoglobulin protein) from murine endoplasmic reticulum was investigated using three-color FRET. Incorporation of three fluorescent labels required expression of the heat shock 70 protein with an unnatural amino acid and site-specific attachment of the dye. Correlated motions between its domains (nucleotide binding, substrate binding, lid) were investigated by simultaneously monitoring the FRET efficiencies between each of the domains.

Acousto-electric control of quantum dots in GaAs/AlGaAs core-shell nanowires containing a single radial GaAs quantum well

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Radio frequency (RF) surface acoustic waves (SAW) represent a versatile tool to control and manipulate charge and spin excitations in semiconductor quantum structures. Here, we analyze the influence of the dynamic electric field induced by a SAW on the optical emission of single semiconductor nanowires. The investigated NWs consist of a GaAs core and an AlGaAs shell containing a single 5nm wide radial GaAs quantum well (QW). We study the optical emission by means of conventional, low-temperature micro- photoluminescence (μ-PL) spectroscopy in combination with a stroboscopic excitation scheme. In addition to the emission of core and QW of the NWs additional sharp emission lines can be observed at higher energies. These lines are attributed to local alloy fluctuations within the AlGaAs shell leading to the formation of quantum dot (QD)-like emission centers. The QD emission lines exhibit dynamic spectral shifts, due to the periodically modulated electric fields and mechanical deformation induced by the SAW. Moreover, we observe intensity oscillations being connected to the local acoustic phase, similar to observations on embedded, planar QD structures [1,2]. These intensity oscillations are attributed to a SAW induced tunneling process of charge carriers from the QD into the continuum states of either the two dimensional QW or the Core of the NWs.

[1] F. J. R. Schülein et al., Phys. Rev. B 88, 085307 (2013)

[2] S. Völk et al., Appl. Phys. Lett. 98, 023109 (2011)

Micro Patterned Organic Field Effect Transistors for Biosensors

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Biosensors for medical applications are a thrust of organic electronics. In this emerging field we have demonstrated a transducer based on the organic semiconductor pentacene [1]. However, the support of this device has still been a silicon chip. To benefit from the advantages of organic electronics, like mechanical flexibility, we replaced it with a biocompatible dielectric, parylene [2]. Thin foils of this material can also serve as the substrate for the Organic Thin Film Transistor (OTFT), resulting in flexible devices. The electrode structures can be micro patterned by photolithography. A distorted growth of the parylene on Au electrodes is observed, which can be eliminated by capping the Au with a thin Al layer. Operation of such OTFTs fabricated on glass in liquids is demonstrated. We will integrate these devices in cell cultures and functionalize the sensor's surface with specific binding sites.

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Optimization of Sugar utilization strategies employing regulated phenotypic heterogeneity

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Bacterial gene regulation at the molecular level exhibits stochastic fluctuations that can subsequently lead to heterogeneity in the phenotype. This phenotypic heterogeneity is not only reflected by a statistical distribution of phenotypes at a given point in time, but also by a significant cell-to-cell variability in the timing of changes of the phenotype. We have previously studied in experiment and theory the „heterogeneous timing" of gene expression in the arabinose utilization system of Escherichia coli and have identified the small number of transporter proteins as the key source of variability [1]. Here, we investigate the time-distributed response of sugar utilization systems in the light of evolutionary optimization. We study the situation of two competing sugar utilization systems part of a system with "flux-limited competition". We are specially interested in the switching mechanism underlying the regulation of such competing sugar utilization systems. As example systems, we concentrate on systems within the Phosphotransferase System (PTS), which catalyzes the uptake and phosphorylation of several different sugars and plays a major role in carbon catabolite repression [2]. When two different sugars are present at the same time, it is assumed that their utilization systems will compete for the phosphor available inside the cell [3]. Using microfluidic set-ups we will expose bacterial cultures to well-defined stable and systematically variable environments and use time-lapse microscopy and single cell tracking to acquire single-cell expression kinetics. In mathematical models using cost-benefit analysis and game theory we compare metabolic networks in their performance as regulatory strategies in such variable environments.

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[2] Deutscher J.; Francke C.; Postma P.W., 2006, Microbiology and Molecular Biology Reviews, 70(4):939-1031.

[3] Thattai M.; Shraiman B.I., 2003, Biophys. Journ. 85(2):744-754.

Thermophoresis of Nonionic Polymers and Lipids

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The movement of molecules in thermal gradients recently gained importance in bioanalytics (1). Whereas the basic effect has been measured for more than 100 years, the underlying theory is fragmentary so far except for ionic contributions. Thus effort is put into the understanding of thermophoresis of uncharged polymers in dilute solution (A) and as well of lipids in a bilayer (B).

A) While a model for charged polymers was recently developed and successfully tested (2, 3), there is no uniform theory towards the nonionic contribution to the Ludwig-Soret effect. The Soret coefficient quantitatively describes the concentration gradient between hot and cold regions: $ST=-\ln(c/c0)/\Delta T$. To gain deeper insight, experiments on uncharged fluorescently labeled polyethylene glycol (PEG) molecules were performed. Adding different salt solutions shows little effect since the polymers are not influenced by ionic contributions to thermophoresis. However changes of pH or solvent alter the Soret coefficient significantly. Furthermore the crossover towards the semidilute polymer regime is clearly visible and the values increase with polymer length. Most surprisingly the Soret coefficient decreases with base temperature in stark contrast to deoxyribonucleic acid and charged beads (2, 3, 4). These results indicate that swelling of polymers and the connected free energy of the system may play an important role for the underlying theory.

B) Thermophoresis cannot only be observed in dissolved polymers, but also in a completely different system of a supported lipid bilayer (SLB). The typical thermophoretic movement of labeled lipids in a SLB was observed for the first time. The preliminary results imply that this system is dominated by a different mechanism than swelling. Interesting applications may rise up in novel lipid based binding assays, since it is presumably possible to detect binding affinities of proteins to SLBs (1).

[1] S.A.I. Seidel et al., Methods 59 (2013) ;P. Baaske, C. Wienken, P. Reineck, S. Duhr and D. Braun, Angewandte Chemie 49 (2010)

[2] M. Reichl, M. Herzog, A. Götz and D. Braun (to be submitted)

[3] S. Duhr and D. Braun, PNAS (2006)

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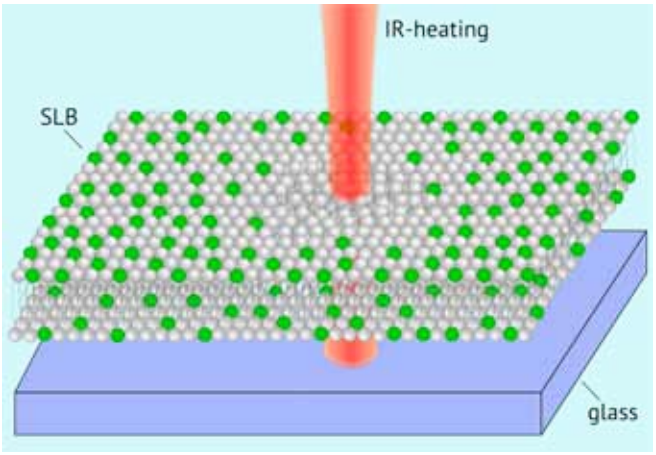

Thermophoresis of fluorescent labeled lipids (green) in a supported lipid bilayer (SLB) is observed when the temperature is locally raised by infrared heating. This observation might be the cornerstone for novel lipid based binding assays

Resonant Inelastic Light Scattering on Two-Dimensional Systems

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The low energy excitation spectrum is a unique fingerprint of the properties of materials and quantum states. We utilize inelastic light scattering – a contactless and extremely versatile tool – to study phonon excitation spectra of the purely two-dimensional semiconductor MoS_2 as well as of collective charge and spin excitation of two-dimensional charge carrier systems. Whereas phonons provide insight in e.g. number of layer, defects, strain, doping, etc., collective charge and spin excitations provide fundamental understanding of carrier dynamics as well as interaction phenomena. Due to the low scattering cross section, the observation of electronic excitation and some processes involving electron-phonon interaction is only feasible under resonant conditions, where the incoming or outgoing light meets the energy of a fundamental optical transition of the system. We present results on resonant inelastic light scattering on mono- and multilayer MoS_2, where a clear dependence of the phonon spectra from the exciting photon energy occurs. This observation points towards the contribution of electron-phonon interaction in the underlying scattering process. Furthermore, lowest collective charge and spin excitation of a two-dimensional electron system will be exemplarily shown for the exotic 5/2 fractional Quantum Hall effect state caused by strong electron-electron interaction. Our results corroborate an interpretation that this quantum state exhibits non-Abelian particle statistics making it a candidate for fault tolerant quantum information processing.

We acknowledge financial support by the DFG excellence cluster Nanosystems Initiative Munich (NIM), the Center for Nano-Science (CeNS) in Munich, and the DFG project HO 3324/4-3.

DNA-mediated Arrangement of Gold Nanoparticles on Lipid Bilayers

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The lipid bilayer membrane serves not only as a barrier for both cell and intracellular compartments to their environments, but also as a functional interface for the biological activities of living cells, based on its unique properties, such as selective permeability, fluidity and its ability for phase transitions. Herein, we try to utilize the special properties of membranes and the power of DNA self-assembly to investigate the effects of the collective distribution of gold nanoparticles upon membrane behavior with the aim to realize patterning of nanoparticles on the membrane.

In our system, we use giant unilamellar vesicles (GUVs) as membrane templates. After incubation with DNA-cholesterol conjugates whose cholesterol moieties can insert into the membrane, the GUVs are modified with DNA-anchoring sites and can thus bind AuNPs that are modified with complementary DNA sequences. The spacing of the hybridized DNA duplex structure can protect the membrane from being contacted and affected by the nanoparticles. In our design, the phase distribution behavior of the cholesterol moieties determines the distribution of nanoparticles and allows us to study the crowding effect of nanoparticles collectively distributed on GUVs. Also, the fluidity of the membrane allows the diffusion of DNA-AuNPs on the membrane of GUVs without phase separation, and helps to reduce defects of nanoparticle patterns. Therefore, this system shows a promising platform to investigate biomembrane properties and construct novel nanomaterials.

Self-organization of spatial regulators for cell-division in micro-engineered PDMS compartments

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Cell division is a highly regulated process in which the spatiotemporal localization of cell division proteins is essential. However the fundamental physical laws for spatial organization during cell division are largely unknown, because even simple model organisms, like *Escherichia coli* disclose a large number of molecular interactions. Aiming at understanding cell organization during cytokinesis on the scale of individual molecules we are reconstituting E. coli proteins, which are involved in cell division, in a bottom-up approach. Recently we engineered a biomimetic synthetic system in which spatial regulators for bacterial cell division (Min proteins) were reconstituted. In a device composed of micro-engineered compartments and lipid membranes the Min proteins self-organize and form dynamic protein patterns which can be modulated by the geometry of the compartment [1]. This biomimetic system enables us to investigate how cellular geometry influences spatiotemporal pattern formation and in future studies it will provide a platform to study further cell division proteins on single molecule level in a well-defined environment.

[1] Zieske, K. and Schwille, P. (2013), Reconstitution of Pole-to-Pole Oscillations of Min Proteins in Microengineered Polydimethylsiloxane Compartments. Angew Chem Int Ed Engl. 52: 459-462.

Three-color Multiparameter Fluorescence Detection: Doing more with FRET

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Single-pair FRET (spFRET) has become a standard tool to monitor conformational changes in biomolecules in vitro, due to the strong distance dependence of the FRET efficiency in the nanometer range. In solution-based burst analysis, the burst of photons emanating from molecules diffusing through the confocal volume gives access to the underlying distribution of the FRET efficiency and other parameters of interest. Extension of spFRET with multiparameter fluorescence detection (MFD) to three colors enables the simultaneous observation of three distances. Application of pulsed interleaved excitation (PIE) additionally grants access to dye stoichiometries on the single molecule level. The increased complexity of the multi-color FRET system and multiple dimensions measured leads to severe shot-noise broadening of the measured spectra. To maintain high accuracy, we have optimized the excitation pulse sequence to spend more time probing the donor fluorophores. The capabilities of three-color MFD are demonstrated using selected examples. Firstly, a mixture of double and triple labeled DNA molecules can be separated based on stoichiometries and FRET efficiencies. Secondly, domain motions within a protein are correlated with the presence or absence of a binding partner. Finally, correlated domain motions within a single protein are investigated by monitoring three distances with three-color FRET.

Notes

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Weiß	Veronika	LMU Munich

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Wurstbauer	Ursula	TU Munich
Xing	Yongzheng	LMU Munich
Yamaguchi	Hiroshi	NTT Basic Research Kanagawa
Zieske	Katja	MPI of Biochemistry

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DOMUS CILIOTA
Calle delle Muneghe - S. Marco, 2976
Tel: +39.041.5204888
Fax: +39.041.5212730
info@ciliota.it
http://www.ciliota.it

Directions from hotel to workshop location:
Walk to the boat stop "S. Zaccaria" (~ 15 min) or take boat No. 1 from "S. Angelo" to "S. Zaccaria" (~19 min, every 10 min) and take boat No. 20 to San Servolo (10 min).

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www.donorione-venezia.it

Directions from hotel to workshop location:
Walk to the boat stop "S. Zaccaria" (~20 min) and take boat No. 20 to San Servolo. **OR**
Take boat No. 2 (~15 min) or 51 (~7 min) from stop "Zattere" to "S. Zaccaria". Then take boat No. 20 to San Servolo.

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info@romite1323.com
http://www.romite1323.com/english/contacts-of-canossiano-college-venice.htm
The Institute closes at midnight and opens at 6 a.m.

Directions from hotel to workshop location:
Walk to the boat stop "Cà Rezzonico" and take boat No. 1 (~14 min, every 10 min) to "S. Zaccaria", then change to boat No. 20 to San Servolo.
OR
Walk to the boat stop "Zattere" and take boat No. 2 (~14 min, every 10 min) or No. 51 (~7 min, every 20 min) to "S. Zaccaria". Then take boat No. 20 to San Servolo.

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info@pietavenezia.org
http://www.pietavenezia.org

Directions from hotel to workshop location:
Walk to the boat stop "S. Zaccaria" and take boat No. 20 to San Servolo (boat trip: 10 min).

Lunch

Lunch will be available between 12:30 and 2:30 pm at the cafeteria located on the ground floor of Building 15. A lunch menu costs about € 10.00 (pasta course, main course, side order of vegetables or salad, yoghurt, bread and water). There are also reduced menus for € 7.00 (pasta course, side order of vegetables or salad, water and bread) and € 8.00 (main course, side order of vegetables or salad, water and bread). A coffee bar is located on the ground floor of Area 6 in the main building.

Internet

WLAN Network San Servolo: UNIVIU
Username: censworkshop2013
Password: censworkshop2013

Two PC rooms with internet connection are accessible for the participants located next to the conference hall. Please ask for the keys in the conference office next to the lecture hall.

Internet activity will be monitored and recorded as required by Italian law.

Timetables

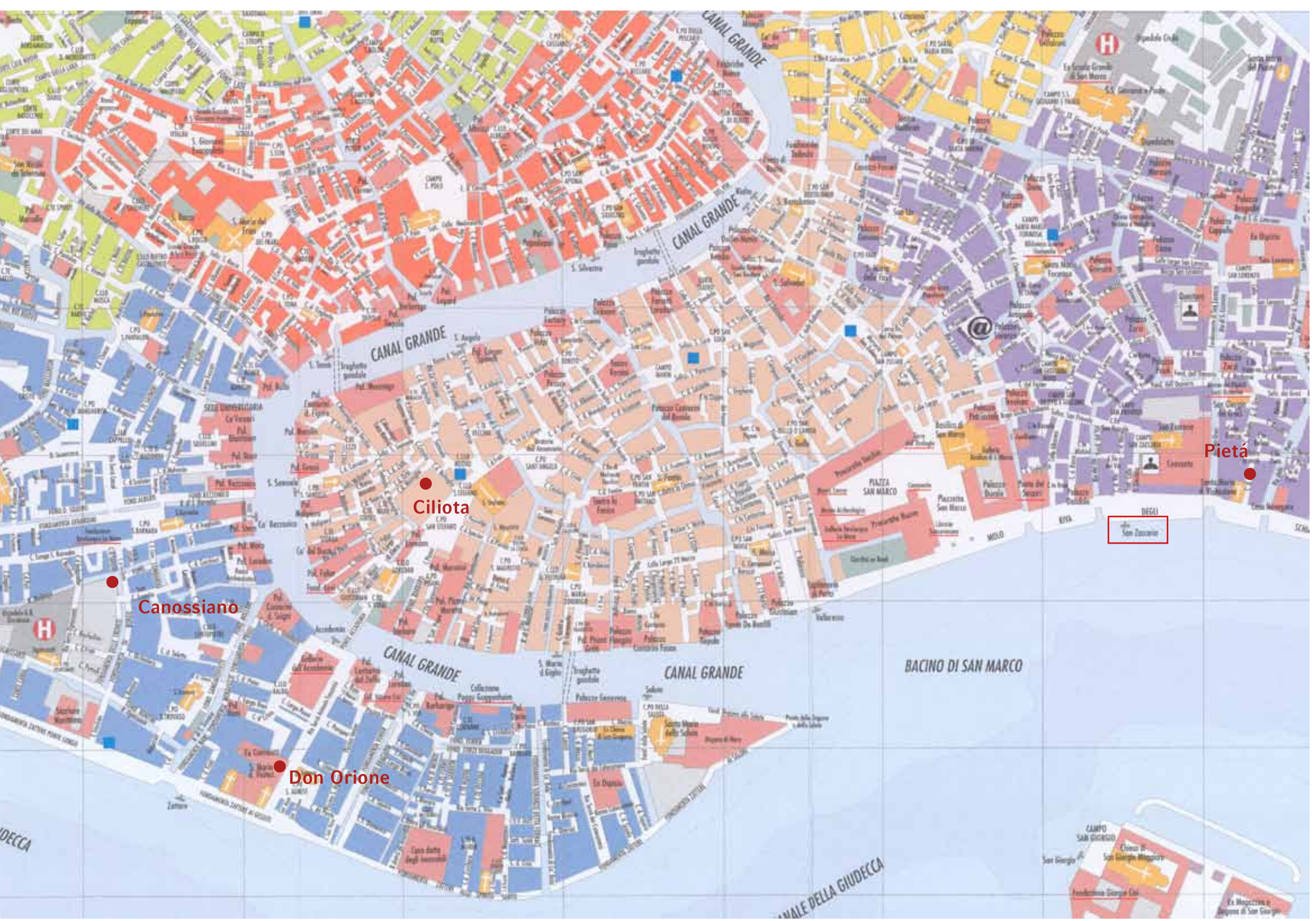
TRAIN TO VENICE AND BACK TO MUNICH

To Venice (15.09.)		Back to Munich (20.09.)	
Munich Main station	**Venezia Santa Lucia**	**Venezia Santa Lucia**	**Munich Main station**
11:31	18:10	13:34	20:25

BOAT LINE 20 TO WORKSHOP LOCATION (SAN SERVOLO)

The boat from Venice to San Servolo leaves from the Riva degli Schiavoni at San Marco; the stop is in front of the Londra Palace Hotel. Boat number 20 goes to San Servolo.

To San Servolo		Back to Venice	
S. Zaccaria	**S. Servolo**	**S. Servolo**	**S. Zaccaria**
6:55	*7:05*	*8:35*	*8:45*
7:15	*7:25*	*8:45*	*8:55*
8:10	*8:20*	*9:10*	*9:20*
8:40	*8:50*	*9:40*	*9:50*
9:00	*9:10*	*10:00*	*10:10*
9:20	*9:30*	*10:50*	*11:00*
9:50	*10:00*	*11:20*	*11:30*
10:30	*10:40*	*12:10*	*12:20*
11:10	*11:20*	*12:40*	*12:50*
11:50	*12:00*	*13:30*	*13:40*
12:30	*12:40*	*14:00*	*14:10*
13:10	*13:20*	*14:50*	*15:00*
13:50	*14:00*	*15:30*	*15:40*
14:30	*14:40*	*16:00*	*16:10*
15:10	*15:20*	*16:50*	*17:00*
15:50	*16:00*	*17:30*	*17:40*
every 40 min until		*18:00*	*18:10*
		18:50	*19:00*
		19:20	*19:30*
20:30	*20:40*	*20:10*	*20:20*
every hour until		*20:40*	*20:50*
23:30	*23:40*	*21:50*	*22:00*
0:25	*0:35*	*22.40*	*22.50*


CANAL GRANDE
CANAL GRANDE
CANAL GRANDE
CANAL GRANDE
CANAL GRANDE
BACINO DI SAN MARCO
PIAZZA SAN MARCO
Ciliota
Canossiano
Don Orione
Pietá
DEGLI SCHIAVONI
CAMPO SAN GIORGIO
CANALE DELLA GIUDECCA

Time	Monday, September 16
	Boat departing at 9:00
09:20	**Welcome**
09:30	**David Awschalom** Beyond Electronics: Abandoning Perfection for Quantum Technologies
10:15	**Stan Leibler** Quantitative biology: there's plenty of room at the top
11:00	**Coffee break**
11:30	**Luisa De Cola** Photo- and electroactive nanomaterials. Properties & applications
	Lunch (12:15-14:30)
14:30	**Steven Benner** Synthesizing life from the bottom up
15:15	**Cees Dekker** Using nanotechnology for single-DNA & single-cell biophysics studies
16:00	**Coffee break**
16:30	**Philipp Kukura** Interferometric scattering microscopy: A high-speed camera for the nanoworld
17:15	**Konrad Lehnert** Enabling quantum technologies with micromechanical oscillators
18:00	**Welcome Reception**

Time	Tuesday, September 17
	Boat departing at 9:00
09:20	**James Schuck** Nano-optical probes: Opening doors to previously-inaccessible parameter spaces
10:05	**Oskar Painter** Quantum back-action in recent cavity-optomechanics experiments
10:50	**Coffee break**
11:15	**Joachim Spatz** Geometric & mechanical material constraints guide collective cell migration
12:00	**Friederike Möller** Fluorescence enhancement at docking sites of DNA-directed self-assembled nanoantennas
	Lunch (12:20-14:15)
14:15	**Frank Jülicher** Spatial organization of cells via phase separation in the cytoplasm
15:00	**Thomas Faust** On-chip transduction and coherent control of nanomechanical resonators
	Posters session I & coffee (15:20-17:30)
17:30	**Eric Greene** Visualizing protein-DNA interactions with DNA curtains

Time	Wednesday, September 18
	Boat departing at 9:00
09:20	**Frank Jäckel** Photocatalytic solar fuel generation with colloidal nanocrystal
10:05	**Hiroshi Yamaguchi** Modal coupling in GaAs-based mechanical resonators & phonon lasing operation
10:50	**Coffee break**
11:15	**Laura Na Liu** Active 3D DNA plasmonics
12:00	**Shimon Weiss** Voltage sensing inorganic nanoparticles
	Lunch (from 12:45)
	Informal discussions

Time	Thursday, September 19
	Boat departing at 9:00
09:20	**Jeremy Baumberg** Plasmonics in the sub-nanometre & quantum domains
10:05	**Alexander Holleitner** Ultrafast polarization control of topological photocurrents
10:50	**Coffee break**
11:15	**David Nelson** Dislocation mediated elongation of bacteria via nanomachines
12:00	**Johann Feckl** Ultrasmall nanoparticles for energy applications
	Lunch (12:20-14:15)
14:15	**Madeleine Leisner** Chemical warfare & survival strategies in bacterial range expansions
	Posters session II & coffee (15:00-17:30)
17:30	**Atac Imamoglu** Spin-photon entanglement in quantum dots
18:15	**Sua Myong** Accessibility of telomeric G-quadruplex DNA studied by single molecule fluorescence

Time	Friday, September 20
	Boat departing at 9:00
09:20	**Karl-Peter Hopfner** Nanomachines in the innate immune sensing of viral nucleic acids
10:05	**Jan Lipfert** Probing the response of double-stranded RNA to force & torque at the single-molecule level
10:50	**Closing remarks**
	Boat leaves at 11:20 / 12:10 **Train to Munich leaves at 13:34 h from Santa Lucia train station**