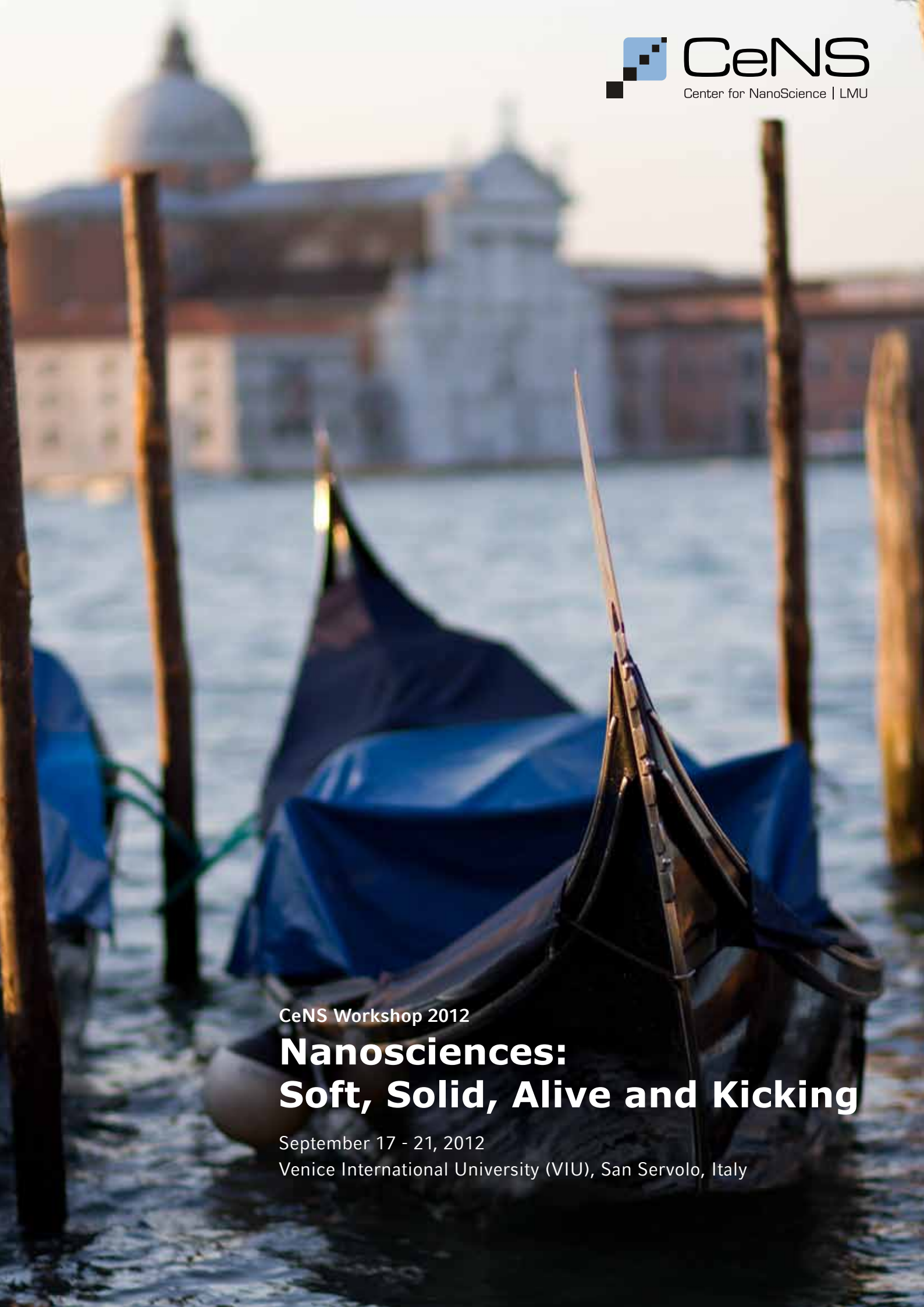

CeNS
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CeNS Workshop 2012

Nanosciences: Soft, Solid, Alive and Kicking

September 17 - 21, 2012
Venice International University (VIU), San Servolo, Italy

Content

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Invited Talks

Single Fluorophore Imaging Reveals the Abundance, Distribution, Mobility and Oligomeric State of M_2 Muscarinic Acetylcholine Receptors in Live Cardiac Muscle

Tatiana A. Nenasheva, Marianne Neary, Gregory I. Mashanov, Nigel J.M. Birdsall, Ross A. Breckenridge, Justin E. Molloy

MRC National Institute for Medical Research, Mill Hill, London NW7 1AA (U.K.)

M_2 muscarinic acetylcholine receptors modulate cardiac rhythm via regulation of the inward potassium current. To increase our understanding of M_2 receptor physiology we used Total Internal Reflection Fluorescence Microscopy to visualize individual receptors at the plasma membrane of transformed CHO^{M2} cells, a cardiac cell line (HL 1), primary cardiomyocytes and tissue slices from pre- and post-natal mice. Receptor expression levels between individual cells in dissociated cardiomyocytes and heart slices was highly variable and only 10% of murine cardiomyocytes expressed muscarinic receptors. M_2 receptors were evenly distributed across individual cells and their density in freshly isolated cardiomyocytes was ~1 receptor per μm^2, increasing at birth (to ~3 μm^{-2}) and decreasing 2-4 weeks after birth (back to ~1 μm^{-2}). M_2 receptors are primarily monomeric but can form reversible dimers. They diffused freely at the plasma membrane, moving approximately 4-times faster in heart slices than in cultured cardiomyocytes. Knowledge of receptor density and mobility has allowed receptor collision rate to be modeled by Monte Carlo simulations. Our estimated encounter rate of 5-10 collisions per second, may explain the latency between acetylcholine application and GIRK channel opening.

Symmetry Breaking and Pattern Formation in Cellular Systems

Erwin Frey

Faculty of Physics, Ludwig-Maximilians-Universität München, Munich (Germany)

Reaction-diffusion dynamics provide a versatile framework for intracellular self-organization phenomena. The Min system in *E. coli* employs such mechanisms to ensure precise cell division by its ability to dynamically adapt to cell geometry. Cell polarization, a prerequisite for processes such as stem cell differentiation and cell polarity in yeast, is also mediated by a diffusion-reaction process. Under which conditions patterns emerge, and how patterns are regulated by bio-chemical and geometrical factors are major aspects of current research. We will discuss general design principles of such cellular pattern forming systems and show how these are implemented for the respective specific biological function in cell division of *E. coli* and cell polarization in yeast.

Active Microrheology of Phospholipid Monolayers: Watching Domains Stretch, Flow, Yield and Heal

Todd Squires

University of California Santa Barbara, Santa Barbara, CA (USA)

I describe a new technique we have developed to measure the interfacial rheology - the viscous and elastic properties - of fluid-fluid interfaces that are laden with some surface-active species (molecular surfactants, copolymers, colloids, etc.). Using microfabrication techniques, we make ferromagnetic, amphiphilic microdisk probes that are ideally suited for active interfacial microrheology. By applying an oscillatory torque using electromagnets, and measuring the resulting (oscillatory) displacement, we create a small-scale Couette interfacial rheometer that is exceedingly sensitive to the rheology of the interface. A novel feature is our ability to directly visualize the interface during the measurement, which we use to explore history-dependent, visco-elastic, aging and yielding behavior of a monolayer of the phospholipid DPPC. We discuss the effects of Cholesterol upon the structure and dynamics of the monolayers, and the effects of the chirality of individual DPPC molecules upon the macroscopically measured rheology.

Single-Molecule Study of Helicases and Polymerases Using a Hairpin Substrate

Maria Manosas[1,3], Fangyuan Ding[1], Debjiani Bacchi[1], Senthil K. Perumal[2], Michelle Spierring[2], Steven Benkovic[2] and Vincent Croquette[1]

1 Laboratoire de Physique Statistique, Ecole Normale Supérieure, UPMC Univ. Paris 06 (France); 2 Department of Chemistry, The Pennsylvania State University, University Park, Pennsylvania, 16802 (USA); 3 Departament de Física Fonamental, Facultat de Física, Universitat de Barcelona, 08028, Barcelona (Spain)

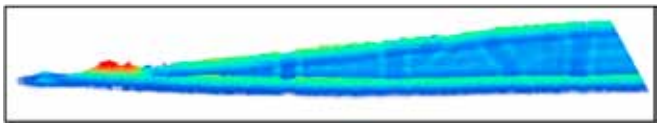
In the cell many molecular motors collaborate with other enzymes to achieve a specific task. In the T4 replisome the polymerase is coupled with the helicase to drive DNA synthesis. Whenever the replication fork encounters a lesion, a repair mechanism is triggered which might involve UvsW to correct the problem. In *E. coli* the repair helicase RecQ is known to interact with SSB to unwind the damaged DNA. Observing those multi-enzyme processes at the single molecule level is challenging since the rate of success of this multi enzyme process is usually low. Using magnetic tweezers on typically 50 beads simultaneously, we investigate these mechanisms using a hairpin substrate. We have used this substrate to investigate the coupling between helicase and polymerase in the T4 replisome but also repair mechanism by the helicase UvsW and RecQ with SSB. We shall show that it is possible to follow these collaborative processes in real time. We shall show that the replicative polymerase can go backward and is also an active helicase which couples to the replicative helicase to produce an efficient copying machine. With UvsW, we have been able to follow a complete repair mechanism in vitro involving its coupling with a polymerase in a stochastic process. With RecQ and SSB, we observe that their interaction leads to an enhanced activity but also to a fast unwinding rate absent when RecQ is working alone.

Graphene Nano-Optoelectronics for Capturing and Manipulating Light at the Nanoscale

Frank Koppens

ICFO - The Institute of Photonic Sciences, Barcelona (Spain)

Graphene, a two-dimensional sheet of carbon atoms, has recently emerged as a novel material with unique electrical and optical properties, with great potential for opto-electronic applications, such as ultrafast photo-detection and optical switches. In this talk, I will review recent experimental work on exploiting graphene as a host for guiding, switching and manipulating light and electrons at the nanoscale [1,2]. This is achieved by exploiting surface plasmons: surface waves coupled to the charge carrier excitations of the conducting sheet. Due to the unique characteristics of graphene, light can be squeezed into extremely small volumes and thus facilitate strongly enhanced light-matter interactions. I will discuss recent observations of propagating and localized optical plasmons in graphene nano-structures. The plasmon wavelength can be tuned and plasmon propagation can even be switched on and off in-situ, simply by tuning the carrier density by electrostatic gates. These results pave the way towards ultrafast modulation of nanoscale optical fields, resonantly confined in graphene nano-structures or propagating along graphene ribbons.



The second part of the talk is devoted to a novel hybrid graphene-quantum dot photodetector [3] which exhibits a gain mechanism that can generate multiple charge carriers from one incident photon. Strong and tunable light absorption in the quantum-dot layer creates electric charges that are transferred to the graphene, where they recirculate many times due to graphene's high charge mobility and long trapped-charge lifetimes in the quantum-dot layer. We demonstrate a gain of 10^8 electrons per photon and a record-high responsivity of 10^7 A/W. Our devices also benefits from gate-tunable sensitivity and speed, spectral selectivity from the short-wavelength infrared to the visible, and compatibility with current circuit technologies.

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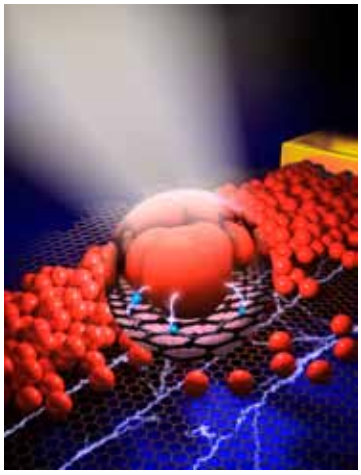

Controlling and Exploring Quantum Matter using Ultracold Quantum Gases

Immanuel Bloch

Ludwig-Maximilians Universität, Schellingstr. 4, 80799 München & Max-Planck Institut für Quantenoptik, Hans Kopfermann Str. 1, 85748 Garching (Germany)

Over the past years, ultracold quantum gases in optical lattices have offered remarkable opportunities to investigate static and dynamic properties of strongly correlated bosonic or fermionic quantum many-body systems. In this talk, I will show how it has recently not only become possible to image such quantum gases with single atom sensitivity and single site resolution, but also how it is now possible to coherently control single atoms on individual lattice sites and to reveal the presence of individual quantum fluctuations of the many-body system. I will demonstrate how 'Higgs' type excitations occur at 24 orders of magnitude lower energy scales than in high energy experiments and how they can detected in our experimental setting. Finally, I will present a new method to realize artificial gauge fields for ultracold atoms and introduce a novel method to measure the Berry-Zak phase of topological band-structures using ultracold atoms.

Optically-Active Hybrid Nanostructures: Exciton-Plasmon Interaction, Fano Effect, and Chirality

Alexander Govorov

Dept. of Physics & Astronomy, Ohio University, Athens, OH (USA)

Coulomb and electromagnetic interactions between excitons and plasmons in hybrid nanostructures lead to several interesting effects: Energy transfer between nanoparticles, plasmon enhancement, exciton energy shifts, Fano interference, and new mechanisms of optical chirality [1-6]. An interaction between a discrete state of exciton and a continuum of plasmonic states gives rise to interference effects (Fano-like asymmetric resonances and anti-resonances) [2,4]. These interference effects can strongly enhance a visibility of relatively weak exciton signals and can be used for spectroscopy of single nanoparticles and molecules. If a system includes chiral elements (chiral molecules or nanocrystals), the exciton-plasmon interaction is able to alter and enhance the circular dichroism (CD) of chiral components [5-8]. In particular, the exciton-plasmon interaction may create new chiral plasmonic lines in CD spectra of a biomolecule-nanocrystal complex [5,7]. Strong CD signals may also appear in purely plasmonic systems with a chiral geometry and a strong particle-particle interaction [6,8]. Recent experiments on the protein-nanocrystal and multi-nanocrystal complexes showed the appearance of strong plasmonic signals in CD spectra [7,8]. Potential applications of dynamic hybrid nanostructures include sensors and new optical and plasmonic materials.

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Spectral Analysis and Nanomechanics in Insect Ears

Daniel Robert

School of Biological Sciences, Woodland Road, University of Bristol (England)

Insects are small and so are their ears. Often no larger than one millimeter across, insect ears are sophisticated sensors, performing all the elementary tasks of acoustic detection known from vertebrates and mammals [1]. The most studied form of insect auditory organs are the tympanal ears, presenting an eardrum - a system peripherally analogous to that found in vertebrates, including humans. Tympanal ears display a vast diversity of forms and functions across the insects, a common feature is their extreme sensitivity to sound-induced mechanical vibrations at the nanoscale. This makes them interesting systems to investigate new ways of constructing new miniature mechanical sensors.

The ears of locusts and bush crickets ears exhibit unsuspected sophistication in their capacity to perform frequency discrimination [2, 3]. Across auditory animals tympanal membranes are invariably heterogeneous, with complicated histoarchitecture that for a large part determines their mechanical response. In locusts, vibrational travelling waves transit across the membrane; a mechanical response that reveals a method for frequency analysis without the implication of neurons. The travelling wave's topographical destination varies with frequency and determines the decomposition of waveforms into different frequencies. In other ears, such as those of bushcrickets, the mechanical response reveals a surprising case of high-level evolutionary convergence whereby the cricket's auditory system is endowed with all key steps of auditory processing in vertebrate ears. Past the tympanal membrane, this chain of events includes an impedance conversion mechanism and dispersive frequency analyser (3). Our research reveals diverse possible biomechanical solutions, honed through some 250 million years of evolution, to the problem of sound and vibration, detection and analysis.

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Nanotube Nucleation

Deborah Fygenson

University of California Santa Barbara, Santa Barbara, CA (USA)

Among nanomaterials, the tube is a prevalent and useful construct. By cyclizing one dimension, the tubular geometry enhances stiffness, allowing a material to extend thousands of times its diameter in the perpendicular dimension without buckling or breaking under ambient forces. Cyclization also provides an obvious possibility for definition of a critical nucleus. A large barrier to nucleation can be a determining factor favoring greater length and uniformity. In this talk I will compare and contrast what little is known about nucleation and growth of three different types of nanotubes made from different biomaterials: protein, DNA and lipid, and discuss strategies for designing their kinetics to favor heterogeneous nucleation.

Coupled Quantum Dots Acting as Driving Sources and Charge Monitors

Sigmund Kohler

Instituto de Ciencia de Materiales de Madrid (ICMM-CSIC), Madrid (Spain)

In recent experiments, capacitive coupling between isolated nano-circuits has been achieved, which bears a wealth of novel effects. Examples are the coupling of a quantum dot to a quantum point contact, where the latter acts as charge monitor. Most interesting is the backaction of the point contact to quantum superpositions in the measured system and the decoherence induced in this way. For example, it has been shown that, despite decoherence, a charge monitor may be used for qubit phase readout with good fidelity [1]. A point contact may act upon double or triple quantum dots not only as detector or decoherence source, but may also impose useful non-equilibrium driving and thereby induce, e.g., a pump current.

This effect leaves its fingerprints in the charging diagram of double quantum dots [2] and the full-counting statistics [3]. If the point contact is replaced by a further double quantum dot, coherent tunnel oscillations in the latter may induce phenomena known from ac-driven transport.

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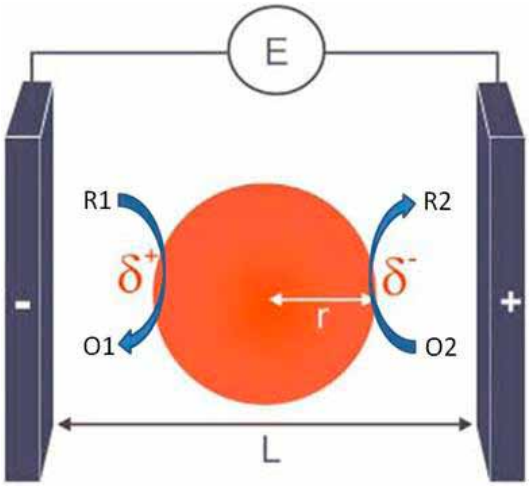
Bipolar Electrochemistry, an Emerging Tool for Micro- and Nanotechnology

Alexander Kuhn

University Bordeaux, ENSCBP, 16 avenue Pey Berland, 33607 Pessac (France)

Bipolar electrochemistry is a concept with a quite long history [1], but has only very recently revealed its virtues in the field of micro- and nanotechnology [2,3]. Among others, it allows highly controlled surface modification at the micro- and nanoscale [4-6], with original applications in different areas of chemistry [7-9]. Here we review some of the latest achievements in the field [10] and illustrate them also with examples that go beyond pure chemical aspects, such as the propulsion of small objects [11-13].



Principle of bipolar electrochemistry: a conducting object is exposed to an external electric field in solution, which leads to its polarization, that will allow an oxidation and a reduction reaction to occur simultaneously at the two opposite sides of the object.

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Optical Probes of Carbon Nanostructures

Enrico Da Como

Department of Physics, University of Bath (United Kingdom)

Carbon nanostructures in the form of zero-, one- or two-dimensional systems are gathering an increased interest because of the unique possibility to tune properties with structure. In this seminar I will address the fundamental photoexcitations in a range of material systems considering conjugated polymers [1], fullerenes [2] and graphene [3,4]. Optical spectroscopic probes reveal signatures of different excitations such as excitons, polarons and phonons as well as their interactions and correlations with structure.

I gratefully acknowledge the fruitful cooperation with Thomas Limmer, Felix Deschler, Ilka Kriegel, Raphael Tautz and Jochen Feldmann.

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Acoustic Nanoquakes Control Optically Active Nanosystems

Hubert J. Krenner

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Radio frequency control of the quantum mechanical, electronic and optical properties of nanostructures lies at the forefront of contemporary nanoscale research. Towards this challenging goal, surface acoustic waves (SAWs) provide a particularly versatile tool to manipulate and probe a broad variety of nanosystems. These "nanoquakes on a chip" promise massively parallel manipulation via acousto-mechanical and acousto-electric couplings. Here, we demonstrate that our acoustic technique can be readily applied to dynamically switch the occupancy state of semiconductor artificial atoms at nanosecond timescales. In this approach, acousto-electric charge transport regulates the injection of the two carrier species, electrons and holes into a quantum dot. In this unique preparation scheme, electrons and holes are not present at the quantum dot's position at the same time. Thus, these are injected inherently sequentially, giving rise to a well-defined exciton configuration and to precisely triggered emission of a train of single photons. In addition, we employ acousto-mechanic couplings to tune the optical resonances of different types of quantum dots. Our experiments indicate that the tuning bandwidth is highly sensitive to the quantum dot's morphology and built-in nanoscopic strain field. Finally, we discuss directions to extend our approach for advanced control schemes based on tailored acoustic strain pulses.

Quantum Dot Excitons in Carbon Nanotubes

Alexander Högele

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

Semiconducting single-walled carbon nanotubes exhibit optical transitions in the near-infrared [1] as a consequence of exciton creation and recombination pathways [2]. At room temperature nanotube excitons are highly mobile along the nanotube axis on length scales that far exceed the exciton size [3]. Here we discuss our experimental results which provide evidence for exciton localization in carbon nanotube quantum dots. Quantum dot formation at cryogenic temperatures inhibits exciton diffusion and therefore protects the exciton from exploring nonradiative quenching sites as well as from dephasing by structural or environmental inhomogeneities. In consequence, we observe ultra-narrow optical linewidths, strongly suppressed spectral wandering and long photoluminescence lifetimes in the range of nanoseconds. Our results establish a new regime for carbon nanotube optics with access to intrinsic photophysical properties, enhanced spectral resolution and prolonged exciton coherence time.

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A DNA Gel with Active, Motor-Driven Mechanics

Omar Saleh

University of California Santa Barbara, Santa Barbara, CA (USA)

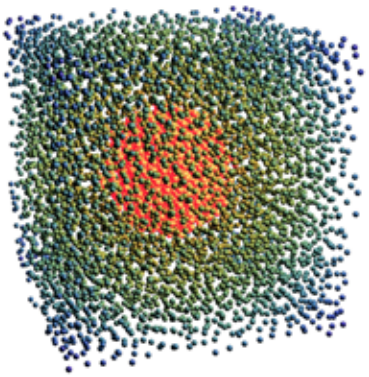
Cells are capable of a variety of dramatic stimuli-responsive mechanical behaviors. These capabilities are enabled by the pervading cytoskeletal network, an active gel composed of structural filaments (e.g. actin) that are acted upon by motor proteins (e.g. myosin). Here, we describe the synthesis and characterization of an active gel using non-cytoskeletal components. We use methods of basepair-templated DNA self assembly to create a hybrid DNA gel containing stiff tubes and flexible linkers. We then activate the gel by adding the motor FtsK50C, a construct derived from the bacterial protein FtsK that, *in vitro*, has a strong and processive DNA contraction activity. The motors stiffen the gel and create stochastic contractile events that affect the positions of attached beads. We quantify the fluctuations of the beads and show that they are comparable both to measurements of cytoskeletal systems and to theoretical predictions for active gels. Thus, we present a DNA-based active gel whose behavior highlights the universal aspects of non-equilibrium, motor-driven networks.

Hot Brownian Motion

Klaus Kroy

Institut für Theoretische Physik, Universität Leipzig, Leipzig (Germany)

Hot Brownian motion is the stochastic motion of suspendednanoparticles that are persistently heated above the solventtemperature, e.g. by absorbed laser light. I discuss a Markovian theory that maps their nonequilibrium motion onto ordinary equilibrium Brownian motion, with effective temperature and friction parameters. I show how to explicitly calculate these parameters, which are the key ingredients of a practical rational approach to emerging photothermal trapping and tracking techniques and self-thermophoretic nano-machines.



Nano-Engineering by Polymer Self-Assembly

Ullrich Steiner

University of Cambridge, Department of Physics, Cambridge (UK)

The performance of many multi-component materials depends sensitively on their detailed morphology. Structure control on the 10-nm length scale is thought to approach the physical limit of this optimisation procedure. For example, materials for photovoltaics, batteries, supercapacitors, and fuel cells rely on the detailed assembly of several components. Essential for these applications is not only the maximisation of the surface-to-volume ratio but also the inter-connectivity of the constituent phases. Random assemblies of nanoscopic building blocks, while excelling in the first property, offer very little control over the detailed structure formation on the 10-nm length scale. Organic self-assmbly, on the other hand excels in the structural control on the 10-nm length scale, but is limited to organic materials. Here, we employ polymer-self-assmbly to construct inorganic material assemblies, with the aim of optimising electronic and optical functionalities for a variety of applications.

The first part of this lecture introduces several ways in which the self-assembly of block copolymers can be used to control the structure formation on the 10-nm-scale of organic, inorganic and organic/inorganic composite materials for the manufacture of solar cells and super-capacitors. The second part employs the chiral/achiral symmetries of metal replica of self assembled block-copolymers to control the flow of light through this materials. The photonic response of these 10-nm patterned plasmonic metals are promising candidates for optical materials with a negative refractive index.

Nanomaterials in One Dimension: Exploring Mesoscopic Phenomena in Template-Grown Nanowires

Thomas E. Mallouk

Department of Chemistry, The Pennsylvania State University, University Park PA (USA)

Mesoscopic properties are those that emerge when the size of an object matches a characteristic physical length scale, such as the exciton radius in a semiconductor or the coherence length of Cooper pairs in a superconductor. Nanowires are interesting in this context as quasi-1D materials. By using anodic alumina membranes as hard templates, we have made "striped" nanowires with precise control over dimensions and composition. These structural features allow one to explore unusual electronic transport properties of single-crystal nanowires and their possible applications in nanoscale electronics. The motion of nano- and microwires in fluids is also a mesoscopic phenomenon at low Reynolds number. Bi- and trimetallic nanorods are catalytically self-propelled in fuel solutions at speeds that are comparable to those of flagellar bacteria. Despite the difference in propulsion mechanisms, catalytic motors are subject to the same external forces as natural motors such as bacteria. Therefore they follow the same scaling laws and exhibit similar emergent behavior (e.g., magnetotaxis, chemotaxis, schooling, and predator-prey behavior). Recently we have found that bimetallic nanowires also undergo autonomous motion and a range of collective behavior in fluids when excited by low power ultrasound. The acoustic propulsion mechanism may be useful for biomedical applications because it is salt-tolerant and does not involve toxic fuels.

Nanostructured Materials via Solution Phase Self-Assembly – from Batteries to Nanomagnetics

Sarah H. Tolbert

UCLA, Department of Chemistry and Biochemistry, Materials Science and Engineering, and the California NanoSystems Institute, Los Angeles, CA 90095 (USA)

Amphiphilic assembly provides a powerful method to create complex nanoscale architectures through low-cost processing routes. For example, block-copolymer templating of inorganic frameworks can be used to produce periodic nanoporous materials that combine high surface area, open porosity, and mechanical flexibility. In this talk, we examine applications of these and related solution processed nanomaterials for a variety of applications. We begin with materials for energy storage, focusing on high capacity batteries and pseducapacitors. We find that nanoporous materials built from nanoparticle building blocks can be optimized to show high levels of pseudocapacitive charge storage, producing systems that that combine high energy density with high power density. The mechanical flexibility of nanoporous materials can also be used to improve rate capability and cycle life. We next turn to magnetic materials, focusing specifically on magnetoelectric systems, which are materials that couple ferroelectricity with magnetism. We find that strain engineering of nanosystems can be used to create unique functionality. Finally, if time permits, we will move away from inorganic materials and focus on semiconducting polymer based solar cells. Here we ask how self-assembly can be used to control polymer chain conformation and optimize device architecture.

Weak Ergodicity Breaking on the Nano-Scale

Eli Barkai

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In nature the noisy signal representing a physical observable is in many cases unpredictable, though the long time average of the signal converges in statistical sense to the ensemble average (ergodicity). On the nano-scale noise levels are large and many processes exhibit ergodicity breaking. Examples include blinking nano-crystals [1] and single molecules (e.g. mRNA) subdiffusing in live cells [2]. Such processes are analyzed within the statistical framework of weak ergodicity breaking. Foundations of the theory are discussed based on random walk models. Since time averages of physical observables remain random in such systems, usual ergodic statistical mechanics cannot be applied.

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Quantitative Fluorescence Imaging of Cellular Processes During HIV-1 Budding

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A more quantitative understanding of the HIV-1 replication cycle provides detailed insight into both viral and cellular processes and contributes to reveal potential targets for therapies. Thus, we utilized quantitative fluorescence imaging techniques to analyze the kinetics of HIV-1 budding, interaction of cellular components and the mechanism of membrane scission.

The cellular ESCRT (endosomal sorting complex required for transport) machinery is involved in specific membrane scission processes like the formation of multivesicular bodies or cytokinesis. HIV hijacks this ESCRT machinery for a topologically similar membrane remodeling process, the viral budding. In combination with some modulating co-factors like LIP5, the AAA-type ATPase VPS4 acts at a late stage of ESCRT function, providing energy for the dissociation of ESCRT-III complexes.

Using fluorescence live-cell imaging, we directly visualized the assembly and disassembly of VPS4A complexes at HIV assembly sites in the presence or absence of LIP5. In cells, co-expressing eGFP-VPS4A and HIV^{mCherry}, the transient recruitment of VPS4A to viral assembly sites at the plasma membrane was visualized as fluorescent bursts. By manually tracking individual assembly sites, we could establish the timing of VPS4A-Gag interactions with respect to the three phases of HIV-1 budding. In most cases, VPS4A complexes were formed after completion of virus assembly (phase II) with a variable delay before particle release as indicated by movement or disappearance. Furthermore, co-expression of eGFP-LIP5 and mCherry-VPS4A in HIV-1 transfected cells revealed a concomitant formation of heteromeric VPS4A-LIP5 complexes. Image correlation spectroscopy revealed that VPS4A bursts consisted of 2-5 VPS4 dodecamers. The average duration of a single VPS4A burst was about 35 s. Our data suggests, in contrast to published *in vitro* studies on MVB vesicle abscission, that VPS4A is directly involved in HIV-1 budding prior to membrane scission.

Composite Fermions with a Twist

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When interacting two-dimensional (2D) electrons are placed in a large perpendicular magnetic field, to minimize their energy, they capture an even number of flux quanta and create new particles called composite fermions (CFs). These complex electron-flux-bound states offer an elegant explanation for the fractional quantum Hall effect. Furthermore, thanks to the flux attachment, the effective field vanishes at a half-filled Landau level and CFs exhibit Fermi-liquid-like properties, similar to their zero-field electron counterparts. However, being solely influenced by interactions, CFs should possess no memory whatever of the electron parameters. Here we address a fundamental question. Does an anisotropy of the electron effective mass and/or Fermi surface survive composite fermionization? We report measurements in two systems: (1) 2D electrons in AlAs quantum wells where electrons occupy an elliptical Fermi surface with large eccentricity and anisotropic effective mass, and (2) 2D holes in tilted magnetic fields where the parallel component of the field causes a sever distortion and anisotropy of the 2D holes' Fermi surface. In both systems, we find that the CFs do indeed inherit anisotropies of their constituent particles, although the degree of anisotropy is smaller for CFs.

Themoelectricity in 2DEG and Quantum Point Contacts

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Recent theoretical and experimental investigations of thermoelectricity in two dimensional electron systems are presented. The main attention is paid to unusual behavior of the thermopower in a system with strong electron-electron interaction. Electron scattering by Fridel oscillations, e.g., can drastically change the value of thermopower and even reverse voltage at fixed heat flow. The other well known effect of electron-electron interaction is increase of the effective mass at lowering of the electron density in Si-MOSFET. We show experimentally that this effect can be observed in thermopower and gives strong evidence for the critical behavior of effective mass.

Experiments with thermopower similar effects in quantum point contacts are discussed. It is shown that quantum point contacts can be used for investigation of energy transfer between edge channels under quantum Hall effect conditions.

Silicon-Germanium: From Intersubband Transitions to Nanostructure Devices

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Silicon-germanium alloys play an important role in micro- and nanoelectronics where they are used to enhance charge carrier mobility in MOS field effect transistors via appropriate strain engineering by exploiting the lattice constant difference of about 4% between Ge and Si. Furthermore considerable efforts have also been devoted to develop structures for light emission, modulation and detection with the help of the SiGe material system, driven by the strong need for Si based optoelectronic devices. To achieve lasing attempts to make Ge a direct gap semiconductor are pursued. In tensile strained Ge layers in which the energy separation between the L-valleys and the Γ-valleys decreases, enhanced light emission was observed in the near infrared and recently even lasing was claimed to occur in highly doped strained Ge by a group from MIT.

However, numerous attempts by to realize a group IV element laser for the mid-infrared, based on quantum cascade emission, have so far been unsuccessful. Mainly p-type Si/SiGe quantum cascade structures have been investigated and intersubband photocurrent spectroscopy in the femtosecond time domain has revealed rather too short intersubband hole relaxation times to achieve lasing at least for energies above the optical phonon energy.

Apart from quantum wells considerable work has been devoted to misfit-strain induced self-organized growth of SiGe islands on Si. By using patterned substrates substantial advances were made in the control of the spatial position of such quantum dots and a concomitant appreciable reduction of island size inhomogeneities was observed in comparison to nanostructures grown on flat Si wafers. Information on their structural properties combined with full 3D simulations of their electronic structure resulted in a better understanding of the photoluminescence and the excitonic features in the Si/SiGe system, in which holes are confined within the islands and electrons in the strained Si matrix surrounding them. The advantages offered by such islands for strain engineering will be demonstrated for a quantum dot based field-effect transistor device.

Coherent Optical Control of Spins in Single and Coupled Self-Assembled Quantum Dots

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Probably the first observation of carriers localized in structural or electrostatically defined three dimensional potential wells in semiconductors was published by Jörg Kotthaus et. al., for electrons confined at the interface between Si and SiO_2 nearly 40 years ago [1]. Nowadays such structures are called quantum dots. Also Coulomb coupling of gate-defined quantum dots in GaAs was first reported by the Kotthaus group already in 1990 [2]. The dots were typically occupied with many carriers in those pioneering experiments.

In this presentation I will discuss more recent experiments on the control and readout of a single spin in optically excited self-assembled InGaAs quantum dots embedded in GaAs based diode structures [3,4]. Such structures have a strong potential for solid state quantum coherent devices. As an example I will present very new results on the ultrafast preparation and manipulation of a single hole spin in coupled quantum dots [5,6].

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Bioinspired Programmable Nanotherapeutics and Organs on Chips

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Wyss Institute for Biologically Inspired Engineering at Harvard University Judah Folkman Professor of Vascular Biology, Harvard Medical School & Boston Childrens' Hospital, and Professor of Bioengineering, Harvard School of Engineering & Applied Sciences

In this presentation, I will describe work we have been carrying out in the Programmable Nanomaterials and Biomimetic Microsystems platforms at the Wyss Institute for Biologically Inspired Engineering at Harvard. The goal of the first platform is to create multi-functional nanotechnologies for regenerative medicine and drug delivery applications, with the long-term goal of developing injectable programmable devices for biomedicine. The second seeks to engineer microchips lined by living human cells that recapitulate organ-level functions as a way to replace animal testing for drug development. In this presentation, I will review recent advances we have made on development of human lung, gut and bone marrow chips and describe two new bioinspired nanotechnologies. The first is a Fluid Shear-Activated Drug Delivery System for injection of therapeutics that one desires to target to embolic or stenotic vascular lesions. The second relates to a new methodology for producing programmable nanotherapeutic devices using DNA origami as a manufacturing system.

Epitaxial Graphene on Metal Surfaces

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Graphene has originally been obtained by exfoliation from graphite, but it can also be synthesized in a relatively controlled way by expitaxial growth on certain metals, e.g., by chemical vapor deposition of hydrocarbon molecules. Of course, the metal interacts with the graphene, and the consequences of these interactions, and possible applications of these composite systems, are currently investigated with very high intensity. I will present investigations on epitaxial graphene that were mainly performed by STM, but also by several other surface science techniques, namely ARPES, LEED, and SXRD. Three aspects will be addressed. Firstly, the modified geometry and electronic structure of epitaxial graphene. Depending on the specific metal, the graphene lattice and the unique band structure of graphene are changed in a complex way, but we are beginning to understand these effects. Secondly, I will present data about the growth of the graphene layer that were obtained in situ, with a high temperature STM at temperatures of up to 1000 °C. The data show the ordering of the graphene layer and a surprising dynamic behaviour of the metal surface underneath the graphene layer. Thirdly, I will show first results from a project in which we are trying to use epitaxial graphene as basis for a large-scale synthesis of graphene.

Poster Abstracts - Session I (A-Klu)

Poster Abstracts - Session II (Ko-Z)

Characterization of magnetic viral vectors by magnet resonance imaging

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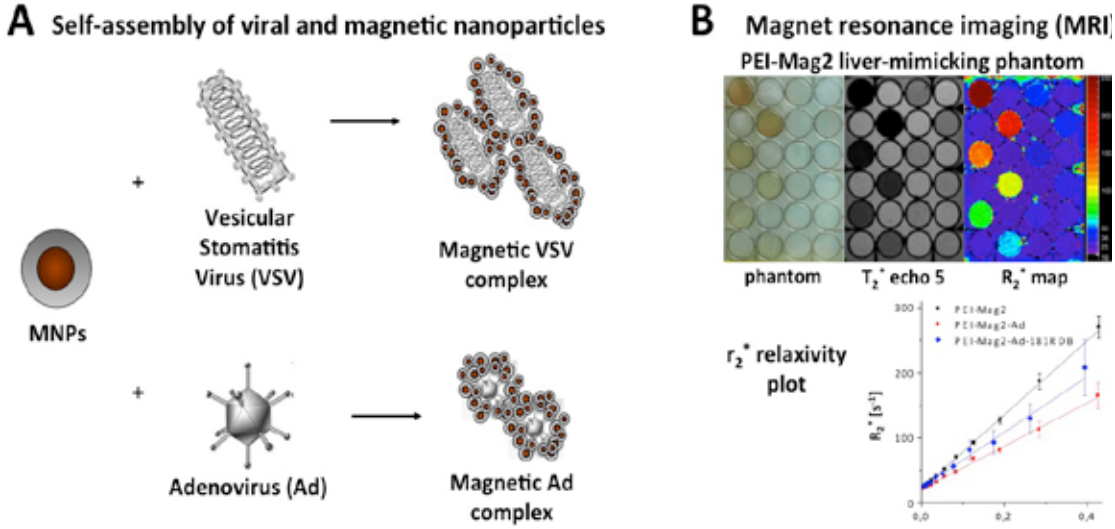
Non-invasive imaging methods such as magnet resonance imaging (MRI) are important diagnostic tools with a broad spectrum of clinical applications. Magnetic nanoparticles (MNPs) can be used as superparamagnetic MRI contrast agents reducing the transverse relaxation time T_2*. However, magnetic properties of MNPs are highly dependent on MNP interaction. Aim of this work was to quantify the effect of MNP assembly, i.e. complex formation with virus into magnetic viral vectors (MNP-V), or by internalization of MNPs or MNP-Vs into cells, on the magnetophoretic mobility and r_2 and r_2* relaxivity.

Tissue-mimicking agarose phantoms with homogeneously distributed MNPs, MNP-Vs, and cells with internalized MNPs or MNP-Vs were prepared. To evaluate the effect of cell internalization, selected cell lines were labeled with free MNPs or infected with MNP-Vs and the iron content of the labeled cells was quantified chemically. The magnetic moment of the MNPs, MNP-Vs and cells loaded with MNPs or MNP-Vs were evaluated from magnetophoretic mobility data, showing a higher magnetic moment of MNP-Vs compared to dispersed MNPs. The selected core-shell type MNPs were characterized by excellent r_2 and r_2* relaxivity values for the free and cell associated/internalized particles. Assembly of MNPs with viral particles resulted in a reduced r_2* relaxivity of these MNP-Vs compared to free MNPs. The internalization of MNP-Vs into cells increased the r_2* relaxivity compared to free MNP-Vs, but the values were still lower than those of free MNPs. The modulation of the relaxivities of internalized MNPs is presumably resulting from the intracellular compartmentalization of the associated/internalized particles.

In future in vivo studies, in particular on viral cancer therapy, such tissue-mimicking phantoms with labeled cells could be used as standard of reference for the non-invasive quantification of exogenic iron from magnetic nano-assemblies in animal tissue by MRI.



(A) Schematic of the self-assembling of the viral particles and magnetic particles into magnetic viral vectors. (B) Exemplary MNP calibration phantom and the resulting r_2* relaxivity plots. The pictures of the PEI-Mag2 phantom show from left to right a photography of the liver tissue-mimicking phantom with decreasing iron-load (brown), the T_2* weighted image (echo time 18.1 ms) and the corresponding color-coded R_2* map. The transverse relaxivity r_2* is the slope of the linear fit of the relaxation rate R_2* plotted over the iron concentration in the respective wells for the phantoms containing free particles, magnetic virus complexes and magnetotransduced cells.

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 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 presynaptic and postsynaptic membrane potentials. In case of a single neuron we analyze the spiking activity in presence of an autaptic feedback loop. With vanishing channel noise the interspike interval increases with increasing delay time. For an elementary neuronal network consisting of two coupled neurons, we detect characteristic stochastic synchronization patterns which exhibit multiple phase-flip bifurcation: 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 in strong channel noise and in turn cause a striking stabilization of the spiking frequency.

Implementing proteins into the Molecular Force Assay (MFA)

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With the technique of the Molecular Force Assay (MFA), binding strengths of molecular complexes can be determined in a fast and reliable way. Using a comparative approach, two molecular complexes are linked in series. Upon applying of a force the weaker one ruptures and a fluorophore on the linker indicates the outcome of the experiment. The fact that the force sensor is minimized to the size of a molecule renders the MFA so sensitive that a single mismatch in a 20 base pair DNA duplex can be detected. Up to 106 complexes are tested simultaneously, allowing for parallelized single-molecule experiments. Thus, the MFA is a promising candidate for the investigation of protein interactions, either with DNA or with other proteins. DNA-binding proteins play an important role in nature, as in the case of transcription factors. The binding of different DNA strands to those proteins can be compared, providing information on how the affinities are changed by the sequence. Regarding protein-protein interactions, the MFA has the advantage of measuring the interaction directly, not only the presence of a binding partner. A further miniaturization by the use of a microfluidic chip, additionally enables for on-chip expression and specific attachment of the proteins, rendering the MFA high through-put.

Polymer/metal oxide hybrid solar cells based on ultra-thin nanowires

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Hybrid solar cells comprised of a bi-continuous network of an inorganic wide-bandgap semiconductor and a light absorbing organic material have attracted much attention as possible alternatives to classical bulk heterojunction solar cells. Since the inorganic nanoarchitecture is typically synthesized first, followed by infiltration of the organic component, continuous pathways for photogenerated charge carriers are accessible without having to rely on less controllable processes like the spinodal decomposition of polymer/fullerene blends.

We have achieved the realisation of vertically oriented zinc oxide nanowire arrays with dimensions similar to those of the electron acceptors in organic bulk heterojunction cells. Reduction of the spacing between nanowires to a value that is comparable to the exciton diffusion length in the light-absorbing polymer allows for efficient harvesting of photogenerated charge carriers, while the oriented nanowire architecture enables complete pore filling with the organic component. The properties of the nanowires can be modified and further improved by post deposition treatments and modification of the inorganic-organic interface.

These strategies can lead to enhanced light harvesting and improved efficiencies in polymer/zinc oxide hybrid solar cells.

Biophysical characterization of integrin specificity at the integrin-fibronectin interaction

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Cell adhesion and motility are tightly regulated by intra- and extracellular signals which are communicated through the cell membrane among others by cell adhesion receptors. A major group of these receptors are force-transducing heterodimeric transmembrane proteins known as integrins. Although two distinct integrins, αvβ3 and α5β1, bind the same extracellular matrix (ECM) molecule fibronectin, they evoke specific cellular functions. The origin for those differences is assumably not only related to the integrins' cytoplasmatic affinity to distinct protein complexes, but also to their mechanical behaviour when conducting forces through the cellular membrane.

By single cell force microscopy (SC-AFM) we analyze the mechanical environment of the two integrins, αvβ3 and α5β1, either alone or in combination by measuring the unbinding forces of the integrin-fibronectin fragment (FNIII7-10) interaction. Fibroblasts expressing αvβ3 and/or α5β1 integrin are immobilized on a poly-L-lysine coated cantilever and probed against a FNIII7-10 coated surface. To isolate the integrin-related signals, fibroblasts without functional integrins, αvβ3 specific inhibitory peptide (cilengitide) and an inhibitory antibody against β1 integrins are used.

For αvβ3, α5β1 and αvβ3/α5β1 cell lines we report an increase in the force of individual de-adhesion steps, in peak force and in dissipated de-adhesion energy with increasing contact times. By addition of cilengitide or anti-β1 antibody peak forces are clearly reduced. The forces of individual de-adhesion steps are higher in α5β1 compared to αvβ3 cells. Highest forces are observed in αvβ3/α5β1 cells.

After identifying the integrin specific signals we want to analyze a potential crosstalk between the two fibronectin-binding integrins in αvβ3/α5β1 cell. We also want to compare our results with single molecule force measurements of the interaction of FNIII7-10 with αvβ3 or α5β1 integrins in a non-cell-based system.

A general approach for the functionalization of gold nanorods with DNA oligonucleotides

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Anisotropic nanoparticles like gold nanorods (Au NRs) are appealing building-blocks for the development of higher-order assemblies with improved plasmonic performance, and hence sensing potential.[1] In this context, DNA-directed self-assembly is one of the most powerful and versatile strategies to controllably direct the self-organization of DNA-functionalized colloidal nanoparticles by direct 'nanoparticle-nanoparticle' hybridization, or by hybridization onto soft DNA templates containing 'on-demand' complementary strands, and having pre-designed morphologies and sizes.[2] A key challenge to achieve DNA-directed self-assembly of Au NRs relies on the development of a robust strategy enabling their DNA functionalization while maintaining the colloidal stability of the dispersion, as direct replacement of the surfactant bilayer (consisting of CTAB, cetyltrimethylammonium bromide) stabilizing the Au NRs by thiolated molecules does not occur fast enough to prevent their aggregation.[3]

In this work we have developed a strategy enabling the DNA functionalization of CTAB-stabilized gold nanorods while preserving their colloidal stability.[4] Our approach consists of a careful ligand exchange process that involves a sequential phase transfer (aqueous-organic-aqueous) allowing for the careful displacement of CTAB from the Au surface by 'thiolated' helper molecules first, and by thiolated DNA strands in the last instance. We will present our results on the optimization of the different surface functionalization steps, as well as on the quantification of DNA grafting on the Au NRs' surface. Our results represent a first step towards the utilization of DNA-functionalized Au NRs as building-blocks for DNA-directed self-assembly into higher-order plasmonic assemblies of varying complexity.

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[4] V. Baumann, F. Haase, J. Rodríguez-Fernández, in preparation.

Single Cell Interaction Forces of Prostate Cancer Cells with Collagen I and Bone Marrow Derived Stem Cells

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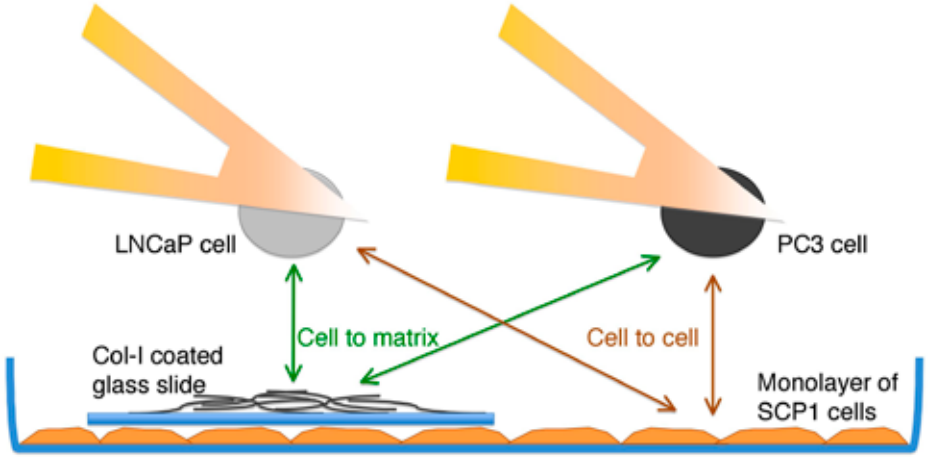
Here we quantified adhesion forces of metastasizing prostate carcinoma cells for two carcinoma model cell lines LNCaP (lymphnode-specific) and PC3 (bone marrow-specific). By single cell force microscopy (SC-AFM) we found PC3 cells to preferentially adhere to bone marrow-derived mesenchymal stem cells (SCP1 cell line).The mechanical pattern of the adhesion was characterized and compared to a substrate consisting of pure collagen type-I.

PC3 cells dissipated twice the energy (48.7 aJ) during the forced de-adhesion AFM experiments and showed significantly more adhesive and stronger bonds compared to LNCaP cells. The characteristic signatures of the de-adhesion force traces revealed that, in contrast to the LNCaP cells, PC3 cells utilize filopodia and not membrane tethers to establish adhesive bonds. Taken together PC3 cells have a superior adhesive affinity to bone marrow mesenchymal stem cells, compared to LNCaP. Integrins (α1β1, α2β1 and α11β1) are supposed key adhesion molecules for this interaction. In close collaboration with clinical researchers we aim for understanding of the mechanisms behind this phenomenon and for optimizing therapeutical applications targeting the metastatic behavior of certain prostate cancer cells towards bone tissue.



Schematic representation of the experimental setup. Single cells from two different prostate cancer cell lines (LNCaP and PC3) were immobilized to an AFM tipless cantilever in order to study their interaction forces with the apical surface of a SCP-1 monolayer (representing mesenchymal stem cells) or with Col-I (representing bone matrix).

Locked Nucleic Acid Biomolecular Handles

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University of California - Santa Barbara, USA

Single molecule manipulation (SMM) techniques are powerful because they directly quantify molecular interactions and mechanics in ways which are easily interpreted with physical theories. This work investigates the use of Locked Nucleic Acid (LNA) oligomers as handles which immobilize DNA for SMM experiments. Traditional immobilization protocols often preclude the possibility of working with native biomolecular complexes; the use of LNA handles could broaden the experimental possibilities by providing a simple, non-pertubative labeling strategy. We show that LNA probes can immobilize DNA through stable and specific bonds with one simple hybridization step. Further investigations of stability show that, although the LNA handles are stable under shear forces up to 10 pN for long times, they are up to two orders of magnitude less stable in what is called the zipper mode. We, thus, provide a set of rules for the design and use of LNA handle sin SMM applications.

Growth and analysis of rutile nanowires for applications in hybrid solar cells

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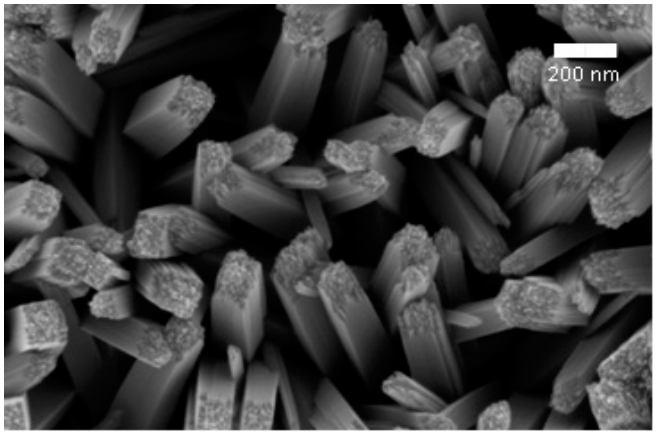
The adaptability of the electronic and structural properties of titania renders it an attractive material for the application as electron acceptor in hybrid solar cells. Nanostructuring of the donor-acceptor interface offers the potential to enhance charge carrier separation and reduces recombination, leading to higher power conversion efficiencies. This study focuses on the synthesis of rutile nanowires which provide a direct electron path towards the electrode in addition to an ordered nanostructured interface. The hydrothermal growth of rutile nanowires on fluorine-doped tin oxide depends on several parameters whose influence on the wire structure is analyzed. In this context the effect of the synthesis temperature and duration, starting material concentrations, used acid, addition of salts, gas-to-liquid ratio, and autoclave type is examined using scanning electron microscopy. Furthermore, transmission electron microscopy studies are performed in order to investigate the wire structure and composition in more detail. A focus is put on the development of the finger like structure (Fig. 1) during the nanowire growth, which might be caused by twin formation or stacking faults.

The second part of the project aims on increasing the efficiency of hybrid solar cells based on hydrothermally grown rutile nanowires as anode. For this purpose the effect of various additional oxide shell layers, such as SnO_2, Nb_2O_5, NbO_2, ZrO_2 and Ta_2O_5, on the efficiency of the solar cell will be examined. Therefore, we currently develop a sol-gel preparation method to synthesize 5 nm thick conformal layers.



Scanning electron microscope image of typical hydrothermally grown rutile nanowires.

Influence of electron scavenger redox potential on oxygen production by water oxidative Photosystem II

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Reserves of fossil energies are continuously weakening and alternative, cheap and green ways of energy production must be found. To that point, photo-catalysis is one of the most promising fields thanks to quasi-infinite source of energy: the sun. For billions of years, photosystems (PS) have produced energy from sunlight; in particular, photosystem II (PSII) splits water to produce molecular oxygen. Nevertheless, although this multi protein complex is one of the oldest of the world its functioning is not yet fully understood. In this study, we investigated the influence of electron scavenger redox potential on PSII activity. In nature, PSII is combined with PSI, which is the protein complex accepting photo-electrons from PSII to reduce NADPH. In isolated PSII, there is no acceptor for those photo-electrons and an external electron scavenger must be added to the buffer solution to generate oxygen. In this study, we investigated the influence of electron scavenger redox potential on PSII activity. The rate and amount of produced oxygen were examined using an oxygen sensitive electrode, the so-called Clark type electrode. At the same time, transient absorption spectroscopy should be further used to investigate intermediate exited-state lifetimes of the protein complex. These intermediate states are representative of electron mobility within PSII, indirectly indicating the rate of oxygen production by the PSII.

Mechanical properties of giant vascular protein VWF based on single molecule force spectroscopy

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1 University of Augsburg, Universitätsstraße 1, 86159 Augsburg; 2 Boston University, 110 Cumington Street, Boston, MA 02215

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 huge vascular protein being activated in the primary hemostasis and it plays an essential role in initializing blood clotting. VWF is a vast polymer of several thousands of kDa which is folded to a coiled shape while inactive and during its activation stretched to an uncoiled, sometimes several microns long shape. In the uncoiled shape specific binding sites are exposed to other players of the primary hemostasis. This shape transition and protein activation can be driven by a wide range of thermodynamic forces such as pH, shear velocities and external mechanical forces. Force spectroscopy via an AFM is the method of choice for the investigation of forces typically needed for proteins unfolding. Moreover, the gained force distance curves of VWF are automatically analyzed and the WLC model is fitted to the data. The fitting parameters, i.e. persistence length and contour length, show a distribution pattern which opens discussions to mechanic properties of that large, networking polymer and its functionality. In summary, it can be shown that distributions of elastic properties of single VWF polymer chains are scattered over a wide range of several magnitudes which is caused by its changing persistence length. Moreover a localized binding site for unspecific binding can be assumed due to clustering of estimated contour lengths.

Adhesion of therapeutical nanoparticles under flow conditions

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Drug delivery and gene therapy are developing strategies to treat diseases, for example cancer, neurological disorders, infectious and cardiovascular diseases. The therapeutic cargo is transported by nanocarriers reaching the target tissue via different pathways depending on the administration, which is mainly intravenously, but also can be orally, intramuscularly, subcutaneously, transdermally and pulmonary. So, the delivery systems interact with different environments within the body and come into contact with many compounds e.g. sugar molecules or serum proteins. In one of our experiments we investigate such interactions by mimicking the blood flow with a syringe driven flow system. Within a microfluidic channel we screen the specific and unspecific adhesion of therapeutic particles on different relevant surfaces, i. e. a cancer and a endothelial cell monolayer, a blood component and synthetic extracellular matrix gel, respectively. In addition, sophisticated nanocarriers are typically equipped with targeting ligands to improve the specific binding to the diseased cells. In a second experiment we quantify the targeting effect and the influence of electrostatic interactions on cellular binding at a single cell level. Thus, we use a flow channel system in which the adhesion of targeted and non-targeted model particles comprising different surface charges is compared. In this set-up, the flow conditions are used to reduce sedimentation of particles and enhance specific binding.

Fabrication and Characterization of Self-Assembled and Self-Aligned Single-Walled Carbon Nanotubes

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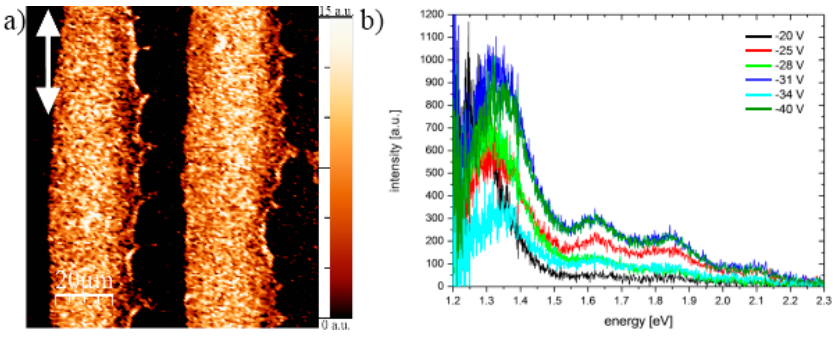
We report on the fabrication of horizontally aligned single-walled carbon nanotube arrays and their electro-optical properties. The arrays were obtained via a simple solution-based evaporation method on different substrates and were characterized by atomic force and optical microscopy [1]. Stripe formation and stripe properties depend on the concentration of the nanotube solution and the substrate surface. Other influencing factors include the surfactant concentration and nanotube shape. The nanotube alignment was determined by polarization-sensitive photoluminescence (PL) measurements. Electrically contacted arrays exhibit ohmic transport characteristics. Upon applying a bias voltage, electroluminescence (EL) from semiconducting nanotubes could be detected near electrode contacts [2]. The intensity and position varied with applied bias voltage. Four spectral contributions were observed that can be expected for phonon-assisted EL [3]. Different contributions to EL are still being investigated. Arrays of aligned nanotubes are rather robust and bright sources of broad range emission as compared to single nanotubes and could be useful for optoelectronic applications.



a) Stripes of self-aligned and self-assembled carbon nanotubes (PL image), b) Electroluminescence spectra of nanotube stripes with varying applied bias

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Optical spectroscopy of conjugated polymer films for photovoltaic applications

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Understanding and controlling carrier transport in conjugated polymer films and composites is critical to the development and application of plastic solar cells. Recent efforts have focused on "bulk heterojunction" (BHJ) structures where a conjugated polymer donor is mixed at the nanoscale with a fullerene acceptor to achieve large interfacial areas for exciton splitting. In these systems, fabrication protocols dramatically affect device efficiency and charge transport is intimately tied to film morphology through local order, domain formation, and compositional heterogeneity. We employ both far-field (absorbance, PL, Raman) and confocal/near-field optical spectroscopy to study polymer order (aggregation, π-stacking), photo-oxidation, and local morphology in conjugated polymer (PPV and polythiophene) – fullerene (PCBM) blends. Through quantitative analysis of exciton bandwidths, emission intensity, and vibronic lineshapes, we demonstrate that competition exists between the chemical "disordering" effect of photo-degradation and the physical "ordering" effect of aggregation, each of which dominate under different processing conditions. Large changes in PL and Raman show that PCBM begins to significantly hinder planarization (intra-chain) and π-overlap (inter-chain) of polymer chains over a relatively small concentration window. Mild thermal annealing of blended films was seen to restore order (i.e., vibronic PL line shapes, indicative of H-like aggregation), which result from PCBM phase segregation (lower dispersion) and growth of polymer aggregates. Spatially resolved spectral analysis of PL was used to map fullerene diffusion and agglomeration as well as detect local changes in interfacial contact between donor and acceptor domains due to thermal annealing.

Photothermal Studies of Gold Nanostructures Using a Novel Optical Thermal Sensor

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As the fields of science and technology approach smaller size scales, it becomes increasingly vital to fully understand heat transfer at the nanoscale. For the continued construction and success of nanodevices and nanostructures, thermal transport and heat dissipation must be fully characterized. Classical theory and laws associated with heating are expected to be unable to accurately model the temperature behavior of the nanostructures and the surrounding medium. Photothermal studies and nanocalorimetry measurements have already helped elucidate this information, however, these studies have largely focused on aggregates of nanoparticles and nanostructures. The aim of this research was to create a novel nanoscale temperature sensor using erbium ions in a III-V semiconductor thin-film host matrix on a silicon substrate, and use it and single-particle photothermal methods to characterize the heating effects of gold nanostructures on the surface. A technique of measuring heat transport from individual nanostructures was pioneered using a thin film of $Al_{0.94}Ga_{0.06}N$ embedded with Er^{3+} ions as an optical temperature sensor. The relative intensities from Er^{3+} photoluminescence are temperature dependent. We measure the photoluminescence spectra, extract the temperature from the relative intensities, and create a temperature image of individual nanostructures. We calibrated this procedure to yield the temperature at the nanostructure while the nanostructure is excited and use this procedure to determine the interface conductance of individual 40 nm gold nanoparticles attached to the $Al_{0.94}Ga_{0.06}N$ surface. We also show that gold nanodots optically heated in water with a continuous-wave laser do not form bubbles at the boiling point of water but can be superheated to the spinodal decomposition temperature at 594 ± 17 K. The spinodal decomposition was confirmed with the observation of critical opalescence.

Infrared nanoscopy of biomaterials

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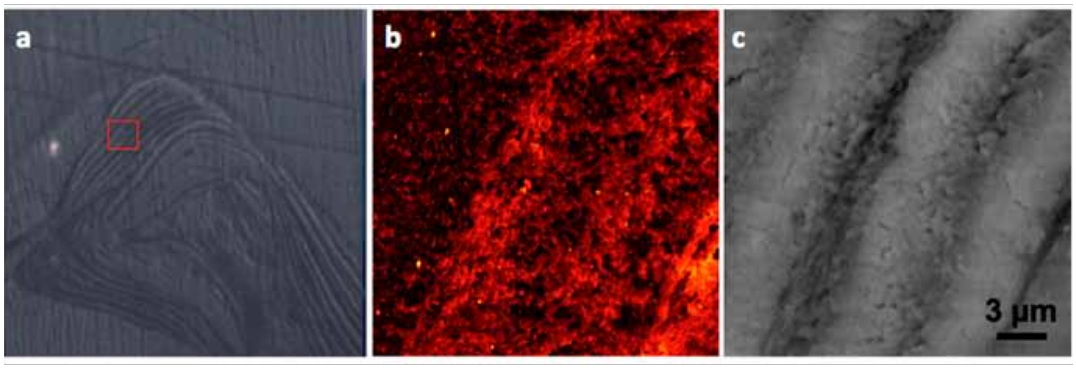
Spectroscopic near-field imaging is enabled by combining 20nm-resolving tip-scattering near-field microscopy (s-SNOM) with an infrared continuum source. Specific contrasting of biomineral components is enabled by simply choosing the appropriate "fingerprint" infrared region that as in traditional FTIR (Fourier-transform infrared spectroscopy) identifies virtually any chemical compound. Hence nano-FTIR stands for the successful realization of combining s-SNOM and FTIR [1,2].



The investigated samples are nanocomposite biomaterials, namely human bone sections, human tooth specimens and mollusk shell which contain mineral nanocrystals in organic matrices [3]. The mineral parts are highlighted by their resonantly enhanced contrast due to phonons. Here we show

bone lamellae structures in a visible microscope overview (a, image size 200x200 μm^2). The red square is mapped at high resolution and shown both in topography (b) and in near-field infrared amplitude, at fixed infrared frequency of 1054 cm^{-1} (c). In the latter, high signals indicates higher mineral concentration. Our method is surface-sensitive, probing to a depth of about 30 nm. It should be straightforwardly applicable in many fields of general mineralogy, solid state research, and materials science. In the near future, we want to extend the spectral coverage to allow specific highlighting of organic components, especially proteins.

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Mesoporous Silica Nanoparticles as Drug/Gene Delivery Carriers

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Mesoporous silica nanoparticles (MSNs) have been studied intensively for applications in modern nanomedicine over the past decade. Their unique properties such as large surface area, tunable particle size and pore dimension, flexibly tailoring of surface functionalization, and good biocompatibility and biodegradability make them a promising delivery vehicle for in vitro and in vivo applications. However, often MSNs with small pore diameters are used for drug- or gene-delivery[1][2][3]. While these are suitable for holding small drug molecules, large biomolecules (e.g. oligonucleotides such as DNA or RNA) can only attach to the surface of MSNs where they are not protected during delivery. In this work, colloidal mesoporous silica (CMS) with various particle sizes (from 50 nm to 400 nm), different pore diameters (from 4 nm to 11 nm) and ordered mesostructures have been synthesized. By further functionalization of the particle, a versatile, switchable nanodevice for controlled release of molecules can be obtained. With this synthetic approach, we provide a tailorable platform for drug- and gene-delivery.

Active pulse-shaping as a tool in ultrafast optics

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We present recent work, using taylored light pulses for studies in plasmonics and materials science. This includes the general scheme of active pulse shaping via a programmable, liquid crystal mask in the time and frequency-domain, as well as the application to the control of plasmon resonances and second harmonic generation. With the presented technique we are able to control phase, polarization and amplitude of our approximately 26fs long pulses, created by a Ti-sapphire oscillator and a single-mode fiber. Combined with a confocal microscope with high numerical aperture (NA = 1.4) we achieve precise control of the behaviour of light inside plasmonic nanostructures such as metallic nanowires and graphene on thin metal films. Second harmonic light, originating mainly from the metal surfaces, provides a valuable check for the pulse shape in the focus as it depends on the phase of the incident pulse in a sensitive way, assumed that the total pulse energy remains constant. The work is supported by numerical studies of the plasmonic systems, using the Discontinuous Galerkin method in cooperation with [2].

Resolving distinct conformations of spectrally similar silver-DNA nanoclusters using electrokinetic flows

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Silver-DNA nanoclusters (Ag:DNA) are hybrid fluorescent macromolecules in which a silver superatom is stabilized by segments of single stranded DNA in aqueous solution. Recently, electrokinetic separations in microchannels have proven useful for measuring the size and charge of different Ag:DNA emitters stabilized by the same sequence of DNA. Small (~50-100 pL) fluorescent sample plugs are electrokinetically injected down a 30 mm long, 20 μm deep silica channel in the presence of a buffered background-electrolyte. Fluorophores contained within the injected plug travel at different velocities and thus separate down the length of the channel due to their differences in electrophoretic mobility. Diffusion measurements are also performed in situ by watching the time evolution of a stationary fluorescent sample plug. In the current work, the above techniques are applied to Ag:DNA stabilized by different sequences of DNA designed to adopt similar structures: a 12 cytosine single-stranded loop. Microfluidic separation measurements reveal the presence of multiple, spectrally similar Ag:DNA for different sequences, distinguished by their electrophoretic mobilities. Our results show that both versions of the 12C hairpin motif produce multiple fluorescent species each with different electrophoretic mobilities. Electrokinetic flow measurements thus provide a means to resolve physical differences between spectrally similar Ag:DNA that can be used towards developing fluorescent mobility markers.

Light-driven water splitting on nano-structured hematite: overcoming the trade-off between light harvesting and carrier collection

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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 useful fuel in the context of a low carbon economy. Hematite is a promising photo-anode material for the oxidation of water to oxygen – the more complicated half of the overall reaction converting water to hydrogen and oxygen gases. However, despite its suitable valence band position, visible light absorption, and good chemical stability, hematite is still hindered by rather weak absorption and poor charge transport. This leads to a trade-off between light absorption and carrier collection in flat devices. Nanostructured hematite offers a solution to this issue, by decoupling light absorption from minority carrier collection. Chemical Sn-doping leads to significant improvements in photo-electrochemical activity, allowing water oxidation on mesoporous films. However, in such devices, majority carrier collection is a limiting factor, and electrons are lost to recombination. A further approach is therefore to coat the hematite absorber layer onto a macroporous scaffold, such as SnO_2.

Optical and photoelectrochemical characterization allow the efficiencies of light absorption, carrier separation and hole-transfer to be assessed. For example, analysis of photocurrent transients indicates that the optimal concentration of Sn-dopant corresponds to a trade-off between carrier separation and hole-transfer.

Tracking Image Correlation: Combining single particle tracking and image correlation spectroscopy for dynamic colocalization studies

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Every cellular process involves the interaction and coordination of different biomolecules. Fluorescence microscopy is the method of choice to understand the underlying cellular mechanisms as it allows the observation of fluorescently labeled biomolecules in living cells. The protein interactions can then be analyzed by a colocalization method in the case of a cell-wide global analysis or by single-particle tracking in the case of moving biomolecules. These two classes of methods usually don't overlap and the interactions between moving biological objects are usually not studied with quantitative colocalization analysis. There is therefore a need for a single particle dynamical colocalization analysis that can be achieved along the track of a moving particle. Here we introduce a new method to obtain a dynamical 3D colocalization analysis along single trajectories of dual-color particles. The particle is tracked in 3D and the colocalization is computed via the local 3D image cross-correlation of the two channels at the position of the tracked particle. For every particle analyzed the output consists of the 3D trajectory, the 3D colocalization information at every time point and the fluorescence intensity in both channels. In addition, the cross-correlation analysis shows the 3D relative movement of the particles in the two channels with an accuracy of 30 nm. The absolute and relative trajectories can then be further analyzed in terms of their mean-square-displacement to gain insight into the mechanistic interplay between the different labeled molecules. We applied this new method to address the entry pathway of the Prototype Foamy virus. We show that the virus can fuse with the outer cell membrane as well as from endosomes thus shedding light on the details of the fusion process.

RBC Membrane Properties Influence Shape Transition Critically

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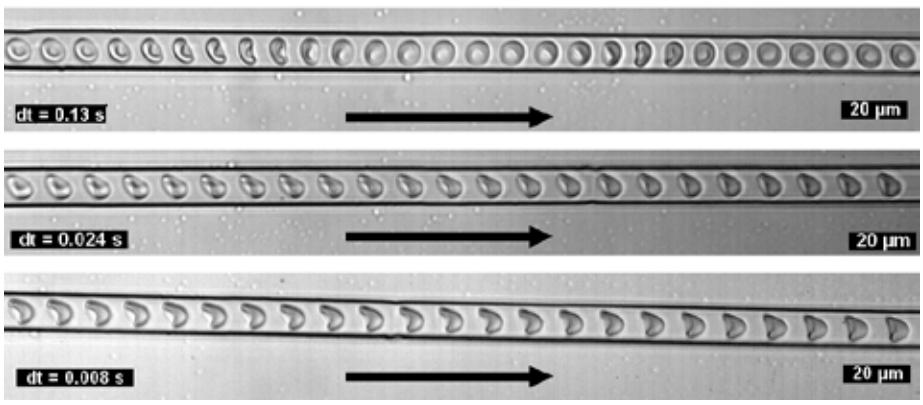
Upon moderate acceleration in capillary flow red blood cells (RBC) transit from their biconcave discocyte rest shape to an axisymmetric parachute shape with an intermediate slipper-like shape [1,2]. Those shape transitions have been described as continuous phase transitions and are governed on the one hand by membrane viscoelastic properties and on the other hand by the imposed flow forces. From a physiological point of view shape transitions reduce the slip velocity and by this lower flow resistance. In addition changing shapes supports tank-treading ability of the RBC membrane. In the experiments we identified the slipper shape as a steady and not purely transient dynamic shape and define two critical velocities to characterize the discocyte to slipper and the slipper to parachute transition, respectively. Additionally we selectively modify the RBC membrane properties by applying an oxidizing and a reducing agent, formaldehyde and diamine, respectively. The modifications affect the critical velocities by an increasing number of



cross-links in the cytoskeleton. In several widespread diseases such as diabetes mellitus, malaria, hypercholesterolemia or bacteria infection deformability is altered and causes critical symptoms because cell transportation efficiency is affected. Furthermore we investigate shape transition of RBCs by varying the cell size with two different parameters, cell volume and surface area. The volume can be controlled by applying an osmotic pressure whereas the surface area of RBC is altered with cholesterol. Other diseases like atherosclerosis or hypertension show a change in membrane cholesterol concentration. For example increased cholesterol content in RBC membranes is a clinical indicator for patients with acute coronary syndrome or chronic stable angina.

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On-Surface Polymerization of 1,4–Diethynylbenzene on Cu(111)

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The last decade has witnessed a growing interest in the use of organic materials in light-emitting diodes, batteries, and optoelectronic devices. In this context, the conjugated polymer poly(phenylene butadiynylene) (PPB) has shown promising properties like photoluminescence, electroluminescence, and nonlinear optical effects.[1] A previous study already reported that 1,4-diethynylbenzene (DEB) can be polymerized by oxidation into PPB strands within Cu^{2+}-functionalized mesoporous materials.[2] For a more facile preparation, we study polymerization of DEB on catalytically active Cu(111) surface under utmost defined conditions in ultra-high vacuum. Scanning Tunneling Microscopy was used for structural characterization.

Upon adsorption on Cu(111) at room temperature, DEB self-assembles into a densely packed structure at sub-monolayer coverage. The ethynyl groups consist of a polarized C-H bond, with the acidic hydrogen acting as a hydrogen bond donor and the triple bond as a hydrogen bond acceptor. Therefore the self-assembled structure is based on C≡C-H···C≡C interactions which are very weak hydrogen bonds. Subsequent thermal annealing of the DEB monolayer results in Y-shaped trimers and worm-like chains. The thermal stability of these surface-supported structures extends up to 450°C, thereby proofing covalent bond formation. The observed topology of the covalent networks can only be explained by at least two different reaction schemes. While trimerization of acetylene into benzene has already been observed on Cu(111),[3] other reaction schemes are unprecedented on surfaces.

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Transparent conducting electrodes with an extended 3D-nanoarchitecture

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Development of nanostructured electrode layers with defined morphology is an important challenge in modern electrochemistry, as it enables the controlled design of complex electrochemical systems. Transparent conducting oxides (TCOs) play a special role in electrochemistry, being used as transparent electrode layers for optoelectrochemical and electrochromic applications as well as spectroelectrochemistry. TCOs such as doped indium, tin or zinc oxides have been known for a long time in the form of dense flat layers, but only recently the fabrication of 3D-conducting TCO networks has been reported. The interest in such 3D-electrode architectures is based on their large interface area enabling incorporation of large amounts of functional redox guests, with the electrical conductivity of the framework providing direct electronic access to the incorporated species, and their optical transparency allowing interactions with light. We show fabrication of transparent conducting electrodes with various types and dimensions of 3D-nanostructures from different classes of TCOs, namely, antimony-doped tin oxide (ATO), niobium-doped titanium oxide (NTO) and indium tin oxide (ITO), by a directed self-assembly of corresponding nanoparticles [1-3]. Such transparent conducting matrices with defined porous architecture, high surface area and open accessible porosity can incorporate various redox moieties from small redox molecules to proteins, which show the greatly enhanced electrochemical response proportional to the electrode surface area (Figure 1).

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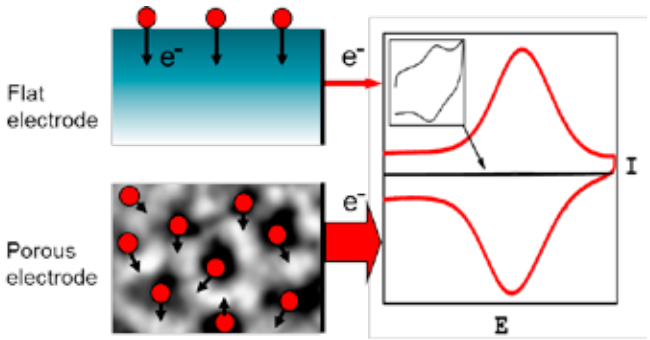

Schematic illustration of electrochemical response obtained from redox moieties immobilized on a flat electrode and on a conducting porous TCO framework.

Nonadiabatic Dynamics of Two Strongly Coupled Nanomechanical Resonator Modes

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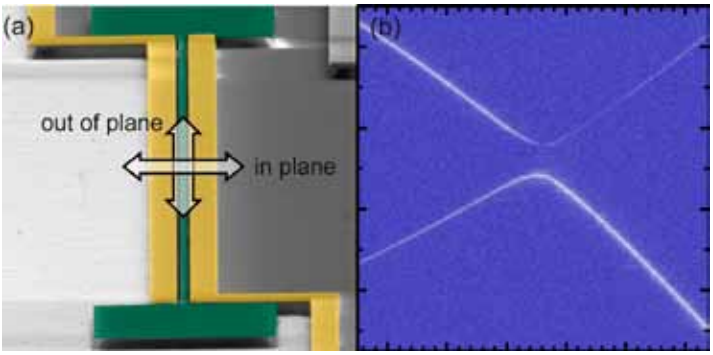
The Landau-Zener transition [1,2] is a fundamental concept for dynamical quantum systems and has been studied in numerous fields of physics. Here we present a classical nanomechanical model system exhibiting analogous behaviour [3]. A system with two tunable energy levels is realized using the two orthogonal flexural modes of a doubly clamped high stress silicon nitride beam. Dielectric coupling to a microwave readout cavity provides a sensitive detection scheme [4], the same electrodes are also used to actuate and tune the resonances via electric gradient fields. By choosing an appropriate sample geometry inverse tuning behaviour between the two modes is achieved. This allows us to bring the two modes into resonance and observe an avoided crossing. The extracted coupling strength is much larger than the linewidth of the mechanical resonances, thus the system is clearly in the strong-coupling regime. A pulsed measurement scheme is used to analyze the time-dependend evolution of a previously initialized mode as it is swept across the coupling region. At lower sweep rates, the system adiabatically follows the energy eigenstates, whereas the energy is transferred from one branch to the other during very fast sweeps. The measured transition probabilites show an excellent quantitative agreement with the Landau-Zener theory. The energy relaxation time of our system exceeds the length of the manipulation pulses, demonstrating coherent control of the system.



Panel (a) shows a SEM micrograph of the silicon nitride beam and the adjacent electrodes, the arrows denote the two flexural modes. The avoided crossing between the modes is shown in (b).

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Non-aqueous synthesis route for ultrasmall metal-oxide nanoparticles

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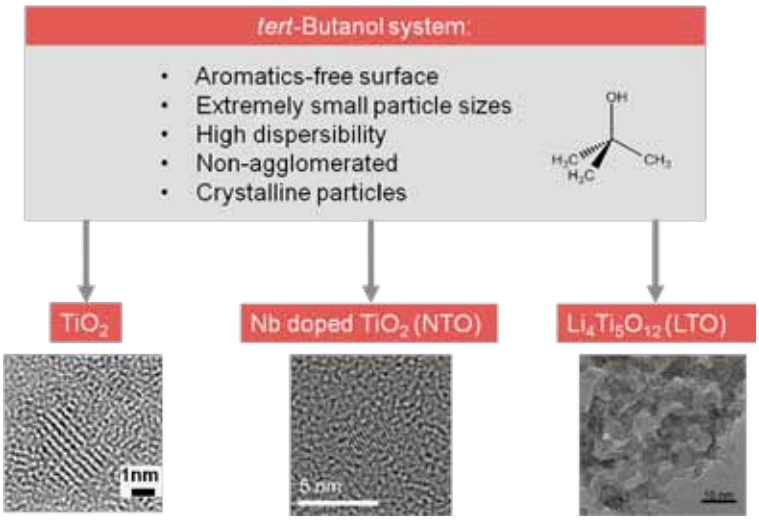
In the fast developing field of nanoscience, nanoparticles and the development of new routes for their synthesis play an important role. Reduction of the crystal size to only a few nanometers greatly modulates the electronic, optical and magnetic characteristics of the nanocrystals. The properties of the nanoparticles are strongly dependent on their size, shape, composition, surface chemistry and their crystallinity. Therefore, development of new synthesis approaches providing full control over those parameters in a broad nanoscale size range is of significant interest in nanoparticle research. We have extended the scope of the available metal oxide nanoparticles by introducing a novel non-aqueous protocol based on tert-butanol as a reaction medium. The crystalline metal oxide nanoparticles are formed already in solution by a chemical reaction with the solvent, without the need for a further high temperature treatment, which would induce undesired agglomeration and growth. The particles prepared in this way are dispersible in different solvents without additional stabilizing agents. Moreover, tert-butanol can be easily removed from the particle surface leaving an electrically "clean" interface, which is important for interfacial redox processes. Using this approach we have obtained crystalline dispersible nanoparticles of titania [1], electrically conducting Nb-doped titania [2] and lithium titanate spinel [3], whose size can be varied from ultra-small (3 nm) to relatively large (15 nm) and can be further tuned by a post-synthesis temperature treatment. The obtained nanoparticles demonstrate excellent properties in applications involving interfacial charge transfer and bulk charge transport processes such as dye-sensitized solar cells and batteries. Currently we are working on the extension of our successful tert-butanol strategy for the fabrication of nanoparticles of other functional metal oxides and mixed oxides.



Overview on the tert-butanol synthesis pathway.

The authors gratefully acknowledge financial support from the NIM cluster, Excellence Initiative (DFG) and LMUmentoring.

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Interfacial Microrheology of Phospholipid Monolayers

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Phospholipid monolayers at the air-water interface serve as model systems to study physiologically relevant films such as lung surfactant. Studying the rheological response of these relatively weak films has been complicated by the high sensitivity necessary. We have previously developed a novel technique in which a micron-scale ferromagnetic disk is placed at the air-water interface within a phospholipid monolayer in a Langmuir trough. An externally applied magnetic field induces a torque on the disk, and two small holes within the disk allow orientation tracking via bright field microscopy. The complex morphology of the monolayer phase behavior is visualized simultaneously by fluorescence microscopy. The response of the monolayer to small amplitude oscillatory shear provides linear surface viscoelastic information. We present a demonstration of this technique to measure the viscous and elastic properties of monolayers of dipalmitoylphosphatidylcholine (DPPC). Furthermore, with monolayers of DPPC and a phosphatidylglycerol (POPG) we correlate the visualized behavior of condensed domains with the measurable viscoelasticity of the monolayer and explore the lower measurable limits of this technique.

Optimization of mRNA stability and translational efficiency

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The aim of present gene therapies is to alter protein expression within a cell to gain a therapeutic or preventive effect. Very recently, an alternative platform technology has been developed, so-called transcript therapy. Here, messenger RNA is delivered instead of its counterpart DNA into the target cells. However, due to the short half-life of mRNA, repeated dosing would be necessary to achieve the desired therapeutic effect. Therefore, attempts have been made to optimize mRNA stability and its translational efficiency. Until now, several strategies have been developed and have been successful in increasing mRNA stability and reduce the immunogenic response triggered by external mRNA. One such promising strategy is the inclusion of chemically modified nucleotides in mRNA to generate stabilized non-immunogenic messenger RNAs (SNIMs). Another strategy is the insertion of untranslated regions (UTRs) into the mRNA sequence. Several UTR sequences have been shown to play pivotal roles in regulating both mRNA stability and its translation. The aim of the current project is to investigate a set of UTR sequences as "stability" and/or "translation enhancers". To achieve this, various UTRs have been selected based on mRNA stability data from published reports and cloned upstream (5' UTR) or downstream (3'UTR) of Metridia luciferase in a plasmid vector containing T7 promoter and a polyA tail of 120As. Messenger RNAs containing either 5'UTR or both 5'UTR and 3'UTR were produced and transfected into different cell systems to screen for cell-type specific effects. Preliminary results demonstrate increased expression of some tested UTRs compared to control mRNA without UTRs. The best working combination of UTRs would then be further optimized by insertion of a 3'UTR region in addition to the existing 3'UTR downstream of the gene of interest.

Towards hierarchically structured imidazolate frameworks

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Metal-organic frameworks (MOFs) are a versatile class of functional materials owing to their exceptional porosity, enabling them to act as catalysts or in gas storage and separation applications. Despite huge endeavours in the attempt to extend the pore size of MOFs from the micropore to the mesopore regime, only a limited number of MOFs with pore sizes larger than 2 nm have been reported to date. In the synthesis of materials featuring a wide range of porosities, liquid phase supramolecular templating is a known and well explored technique. Using this synthetic approach Kresge and co-workers were able to synthesize silica materials with hexagonal (MCM-41), cubic (MCM-48) and lamellar (MCM-50) mesopores and numerous silica and non-silica mesophases have been realized to date. Zeolitic imidazolate frameworks (ZIFs), which consits of metal ions (zinc or cobalt) and imidazolate linkers, exhibit zeolite-like topologies. By formal replacement of the bridging oxygen in zeolites by imidazolate units, the cage and pores in ZIFs are enlarged versions of the secondary building units in zeolites. Due to the matching local geometry including the bonding angle of the Zn-IM-Zn units, analogues of MCM type or even hierarchical porous mesophases seem highly plausible.

Following the first successful synthesis of a MCM-type ZIF, christened mesostructured imidazolate framework (MIFs), we were able to extend the range of known MIF materials by employing multi-cationic surfactants. The enhanced control over intercation distances in these surfactants compared to single-cationic surfactants enables a better control over the formed mesophases. The synthesized series of lamellar compounds with bridging imidazolate and 2-methylimidazolate linkers show high thermal stability up to 300 °C and chemical resistances even to harsch conditions such as supercritial CO_2, which is usually used for template removal.

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Dephasing of a strongly driven charge qubit: Landau-Zener-Stückelberg interference in a double quantum dot

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Quantum dots in GaAs/AlGaAs heterostructures have proven to be a powerful system to observe fundamental quantum effects of a few electrons [1]. One of these interesting quantum effects is the generation of superposition quantum states using a Landau-Zener transition of a two-level system being driven through an avoided crossing. Here, we present measurements of coherent multiple Landau-Zener transitions between the singlet (1,1) and the singlet (2,0) electron states of a double quantum dot continuously driven by a sine wave in the few GHz regime. This so called Landau-Zener-Stückelberg (LZS) interferometry is well described by theory and has already been successfully applied to determine coherence times in superconducting qubits [2,3]. By analyzing the complex interference pattern of the oscillations which is in remarkable agreement with theory, we are able to accurately extract dephasing times of our qubit system. Measurements of the LZS pattern at different temperatures up to 400 mK were performed to extract the temperature dependence of the dephasing time and facilitate conclusions about the dominating dephasing mechanisms. A deeper understanding of the underlying decoherence mechanisms is essential for improving the coherence times for applications of qubit systems.

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High frequency tuning of photonic crystal nanocavity modes using surface acoustic waves

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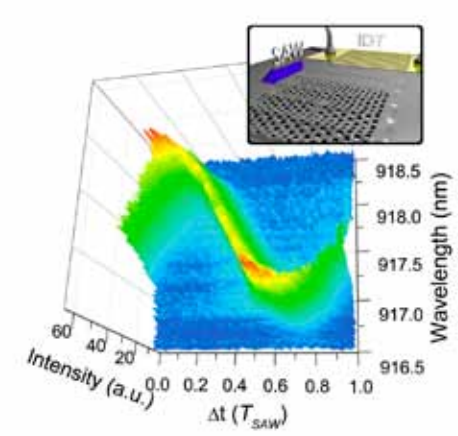
We propose and demonstrate high frequency dynamic modulation of localized optical modes of photonic crystal membrane (PCM) defect nanocavities employing surface acoustic waves (SAWs). The mechanical deformation induced by SAW distorts the PCM periodicity and gives rise to pronounced modulation of the nanocavity mode. Manipulation of the QD-Mode coupling within a SAW cycle is observed in time-resolved measurements of the QD decay characteristics. We show that this approach allows changing the coupling several times within the radiative QD lifetime. In time-integrated and SAW-phase resolved photoluminescence (PL) experiments we demonstrate tuning speeds fSAW> 1.7 GHz using this approach.

In the experimental data we observe a pronounced sinusoidal shift of the cavity resonance over one cycle of the SAW. The spectral shift of the cavity resonance increases linearly with the amplitude of the SAW and is dependent on the SAW wavelength. Shifts of more than 5 times the cavity linewidth are achieved.

In addition, a high quality factor is preserved during the SAW cycle. These experimental observations are found in excellent agreement with FDTD simulations for the same cavity design and realistic SAW amplitudes. From this comparison we can correlate the spectral shift and the local phase of the SAW at the position of the nanocavity. Remarkably, our FDTD calculations show no resolvable shift of the field distribution of the cavity mode making our technique attractive for both real-time control of solid state cQED experiments and coherent mechanical excitation of cavity optomechanical systems.



Phase resolved modulation of a nanocavity mode with a SAW frequency fSAW= 414 MHz.

Separation of Blood Cells using Hydrodynamic Lift

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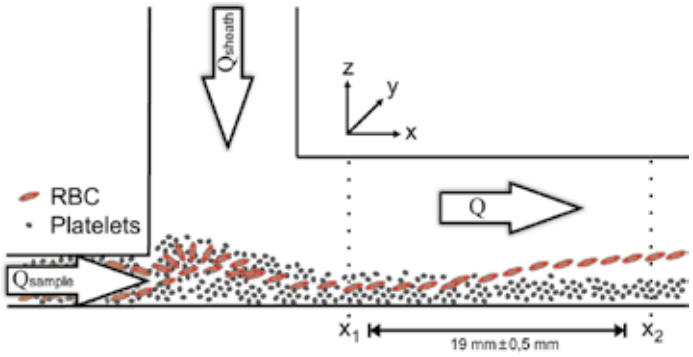
Using size and deformability as intrinsic biomarkers, we separate red blood cells (RBC) from other blood components based on a repulsive hydrodynamic cell-wall-interaction. We exploit this purely viscous lift effect at low Reynolds numbers to induce a lateral migration of soft objects perpendicular to the streamlines of the fluid which closely follows theoretical prediction by Olla. We study the effects of flow rate and fluid viscosity on the separation efficiency and demonstrate the separation of RBC, blood platelets and solid microspheres from each other. The method can be used for continuous and label-free cell classification and sorting in on-chip blood analysis.



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Polymerization of fullerene in various nanoporous hosts

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The field of fullerene chemistry has attracted increasing interest since the development of synthetic routes for multi gram scale C_{60} preparations. Due to the special physical, chemical and electronic properties of the hollow molecules, they can be used in many applications. Of these, organic solar cells represent the most prominent, but there are also examples in energy storage, bio-medical applications and optoelectronic devices. Most of these applications benefit from a specific polymeric structure of the buckyballs. Apart from specially functionalized fullerene molecules for polymerization, the pristine C_{60} molecules can also be connected via covalent bonds using [2+2]-cyclo additions. This reaction is initialized either by high pressure, high temperatures or UV-irradiation. [1] Using this addition reaction, we show the preparation of a fullerene-based mesostructured carbon polymer using a hard-templating synthesis strategy by thermopolymerization of C_{60} in a mesoporous silica host. Removal of the silica resulted in a microporous material with uniform structure and a pore size of 1.8 nm. Furthermore, thin fullerene nanowires with a width of about 150 nm and a length of 2 µm were obtained by photopolymerization of C_{60} in the pores of a nanoscale tubular host.

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

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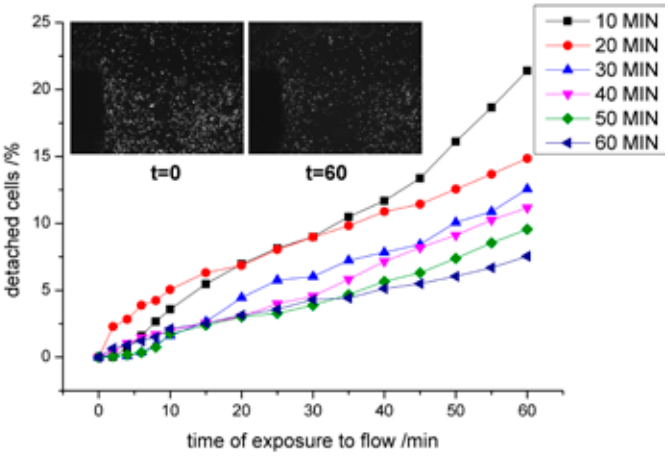
For an optimal implementation of materials in living environments a thorough characterization of cell adhesion properties, both kinetics and strength, is required. Here we present a miniaturized (~ 100 µl) lab-on-a-chip implant hybrid system which allows to quantify cell (de-) adhesion under dynamic conditions mimicing 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 cells (~60k) and lab consumables, allows a soft, non-lethal treatment of the cells, live observation of the cells and arbitrary material-cell combinations. Further on, the measurement chamber allows temperature control (e.g. to generate physiological conditions).



Percentage of detached cells depending on flow exposure time. SAOS-2 cells were grown on medical titanium for different times ranging from 10-60 minutes. Inlets show the fluorescence microscopy image of the initial and final cell distribution on the titanium samples.

Sensing single charges in the electronic environment of a quantum dot

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Self-assembled InGaAs quantum dots (QDs) exhibit a discrete set of spectrally narrow optical transitions which are sensitive to the details of the surrounding solid-state environment. This feature has been exploited recently to probe electron continuum states in spatial proximity of a QD [1,2] as well as to study charging characteristics of single impurities [3]. We present here a set of experiments which employ InGaAs QDs as sensors of their electronic environment. With resonant laser spectroscopy we study spectral shifts in the fundamental optical transition of individual QDs arising from single fluctuating charges. Based on a simple quantitative model we discuss how the spectral signatures of a QD provide insight into the quality of the sample material in terms of impurity background doping.

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Investigation of graphene as a novel substrate for near-field optical experiments

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Localized chemical analysis of surfaces at the nanoscale using light is a significant challenge because of the diffraction limit. However, tip-enhanced Raman spectroscopy (TERS) can overcome this limitation using plasmonic coupling of light with a metalized scanning probe microscopy tip (i.e., an optical antenna) to create an enhanced optical field with nanoscale dimensions. By combining this enhanced field with Raman (vibrational) spectroscopy, the chemical functionality of a surface can be identified and "imaged" with sub-λ spatial resolutions. Application of TERS to biological materials promises to improve our understanding of their complex functionality, but has thus far proven difficult due to sample fluorescence with visible light excitation and poor signal-to-noise. We seek to solve this problem using freestanding graphene membranes as substrates for TERS experiments to bias the desired "near-field" signal over the "far-field" background; for example, an optically thin graphene membrane will minimize the substrate sampling volume and quench analyte fluorescence which would otherwise overwhelm Raman signals. Toward this goal, patterned graphene on Si and suspended graphene membranes were realized using a combination of CVD growth, lithography, and polymer-based film transfer. The resulting graphene samples were characterized using AFM and confocal micro-Raman mapping to evaluate growth, patterning, and transfer procedures (e.g., optical properties, uniformity, etc.). Preliminary studies have also been done to qualitatively assess the fluorescence quenching properties of graphene and validate its potential as a novel substrate that could enable TERS on fluorescent biological materials.

Myosin XXI: a myosin with many missions

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Myosin XXI is one of only two myosins found in the parasite Leishmania. While no expression of myosin IB has been found in the organism to date, myosin XXI has been detected in both the promastigote and the amastigote stages of the Leishmania life cycle, where it is preferentially localized to the proximal region of the flagellum. The presence of only a single myosin isoform suggests that this myosin carries out a variety of functions within the protozoa, including membrane anchorage as well as longer range directed movements with cargo and possible roles in cell signalling. In this study we aim to discover how a single myosin can carry out several different tasks within the cell and to identify mechanical mechanisms that control this. To determine the directionality of myosin XXI we have performed gliding filament assays using dual labelled F-actin. Filaments were capped with gelsolin and labelled with phalloidin-TRITC at their barbed ends and phalloidin-FITC at their pointed ends. Evaluation of the direction of filament movement led to the result that myosin XXI is a plus end directed motor. Myosin XXI full length (aa 1-1051) and truncated (aa 1-800), fused with pZGreen was expressed in human cells. We observed that myosin XXI shows a range of behaviours and localisations; including a cytoplasmic and a membrane bound population, we also see accumulation at the tips of filopodia and vesicle transportation. We have further shown, in vitro, that myosin XXI binds to a variety of lipids including PIP2 and PIP3 as well as a number of other phospholipids. Myosin XXI can adopt both a monomeric and a dimeric conformation in vitro. Using a variety of tail constructs we have discovered that only the monomeric conformation has the ability to bind lipids. We have shown that the tail domain has several distinct lipid binding sites with different lipid binding specificities. We believe that Myosin XXIs ability to bind calmodulin, to be a monomer and a dimer and to bind different types of lipids depending on its conformation plays a key role in its cellular distribution and offers several distinct ways in which its behaviour can be easily modulated to perform different roles within the parasite.

Cryogenic photoluminescence spectroscopy of suspended carbon nanotubes

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Semiconducting single-walled carbon nanotubes exhibit optical transitions in the near-infrared [1]. Related studies have established basic understanding of the fundamental photophysical properties of carbon nanotubes such as chirality-dictated photoluminescence [2] or large exciton binding energy [3]. Optical response of nanotubes is highly sensitive to the details of the crystalline structure as well as the dielectric surrounding. In consequence, nanotube photoluminescence exhibits spectral blinking and wandering [4] or rapid non-radiative quenching at defect sites [5]. We report here our experimental results obtained by cryogenic photoluminescence spectroscopy on single carbon nanotubes that are detached from the substrate and have not suffered from post-synthesis processing. As key signatures we find a drastic reduction of the spectral linewidth and the spectral wandering, as well as an increase in the exciton lifetime by one order of magnitude which we interpret as a result of quantum dot exciton formation in carbon nanotubes.

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Clickable Amphiphilic Triblock Copolymers

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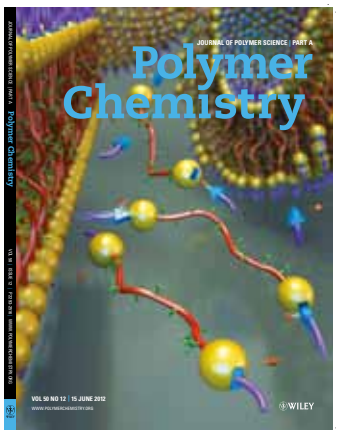
Amphiphilic polymers have recently garnered much attention due to their potential use in drug delivery and other biomedical applications. A modular synthesis of these polymers is extremely desirable, because it offers precise individual block characterization and increased yields. We present here for the first time a modular synthesis of poly(oxazoline)–poly(siloxane)–poly(oxazoline) block copolymers that have been clicked together using the copper-catalyzed azide–alkyne cycloaddition reaction. Various click methodologies for the synthesis of these polymers have been carefully evaluated and optimized. The approach using copper nanoparticles was found to be the most optimal among the methods evaluated. Furthermore, these results were extended to allow for a reactive Si-H group-based siloxane middle block to be successfully clicked. This enables the design of more complex amphiphilic block copolymers that have additional functionality, such as stimuli responsiveness, to be synthesized via a simple hydrosilylation reaction.



Large-scale measurement of the binding affinity landscape of transcription factors with fluorescence anisotropy

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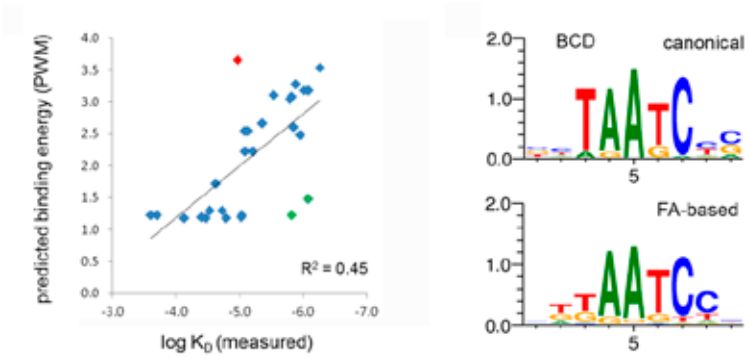
Despite longstanding efforts, our understanding of spatio-temporal transcription regulation during development remains limited. Using a previously developed thermodynamic model of the Drosophila segmentation network as a framework, we seek to address obvious deficits through a combination of experimental and computational approaches. Hence, we chose the most suitable methods to express participating transcription factors proteins and to determine their binding preferences. The binding affinity landscape of TF was measured directly with fluorescence anisotropy, an established spectroscopic method that we tuned to permit highly sensitive measurement of binding constants at large scale using a customized microscope and analysis setup. The new experimental data (position weight matrices, PWM) will be used to improve and extend our computational model to achieve more accurate predictions of expression patterns and thus deepen our understanding of the regulatory code underlying developmental pattern formation.



(Left panel) Scatter plot showing the correlation between measured KD values for all 27 single-base mutations of the Bicoid consensus sequence and the corresponding binding energies predicted by the canonical Bicoid PWM. (Right panel) A revised PWM based on the FA-measured binding constants is shown below .

Engineering Electrochemical Biosensors With Arbitrarily Edited Dynamic Range

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Recent years has seen the development of electrochemical biosensors comprising redox labeled oligonucleotide probes that are appended to an electrode surface [1,2]. This biosensor uses a binding-induced structure-switching mechanism to detect nucleic acids, proteins and small molecules. An important advantage of this class of sensors is that their structure-switching signaling mechanism is reagentless and selective enough to deploy directly in complex sample matrices. Moreover, most biological recognition element, such as proteins, RNA or DNA can be adapted into switches that can be used for building such sensors [3]. Biomolecular recognition plays an important theme in this sensing technologies. Despite their impressive performances, technologies based on biomolecular recognition suffer from the inherent limitation of single-site binding represented by its fixed response curve. That is, single-site binding is almost invariably characterized by a fixed, hyperbolic relationship between the target concentration and receptor binding for which the dynamic range spans an 81-fold range of target concentrations. It limits the utility of biosensors in applications calling for either great sensitivity or the quantification of more wide-ranging concentrations. By engineering a structure-switching mechanism to tune the affinity of a receptor molecule, we design a set of DNA probes having different affinities, but with similar target specificity [4,5]. By combining these probes, an extended dynamic response of a biosensor spanning an 1000-fold range of target concentrations was obtained. By using a different combination strategy, the useful dynamic range of an electrochemical DNA sensor was narrowed to only an 8-fold range of target concentrations [6]. We believe that these demonstration strategies can significantly improve our biosensors for the detection of disease biomarkers.

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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) with frequencies exceeding 650 MHz [1]. However, surface recombination inhibited the SAW-transport of electrons and holes along the axis of uncapped GaAs NWs. 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. 1(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} = 5 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 $T_{SAW}/2$ 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. 1(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. On selected NWs this SAW-driven beating extends over several acoustic periods. In the time transients shown in Fig. 2 the beating (blue and green) extends to more than 25 times τ_{PL} (red), only limited by the finite detection window. We attribute this to the trapping of charge carriers on intrinsic crystal defects like twin planes at the point of detection.

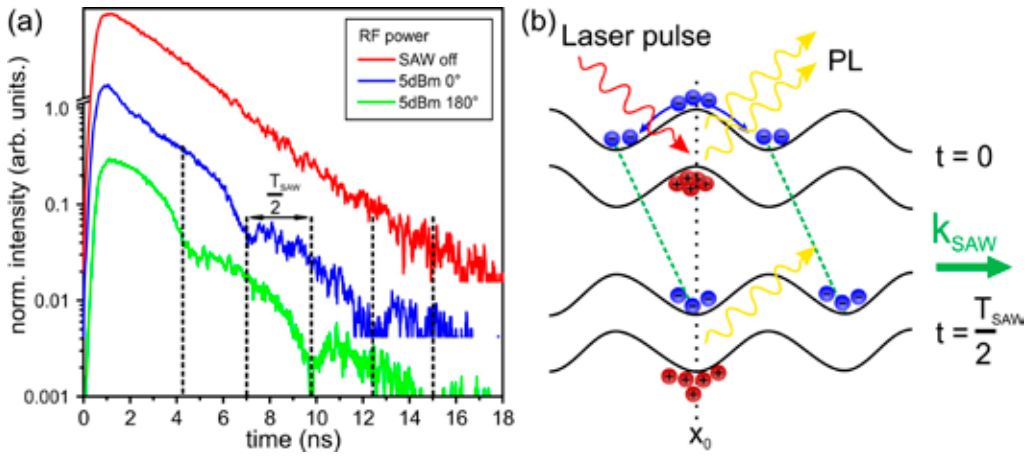

Fig. 1: a) PL transient a a single GaAs/AlGaAs core-shell NW without SAW (red) and with SAW applied with defined phase shifts (blue, green) b) Dissociation and acoustic transport of electrons in the SAW-induced type-II bandedge modulation. Spatial overlap of transported electrons and stationary holes gives rise to the observed time-delayed PL emission.

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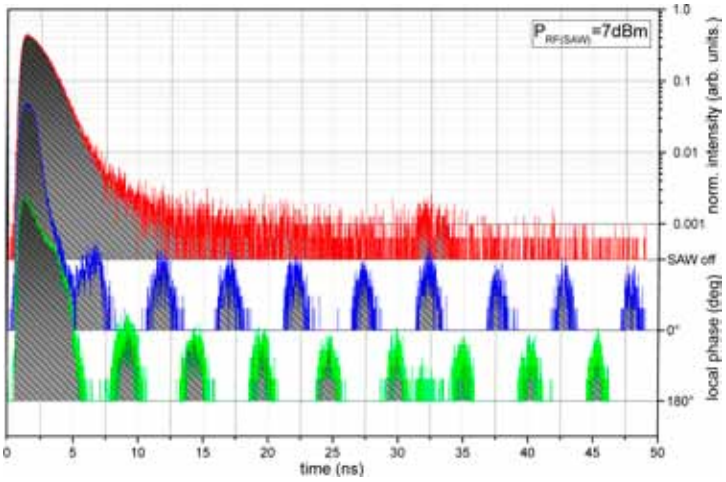

Fig. 2: Optically detected electron ratchet effect.

Protein single molecule cut & paste

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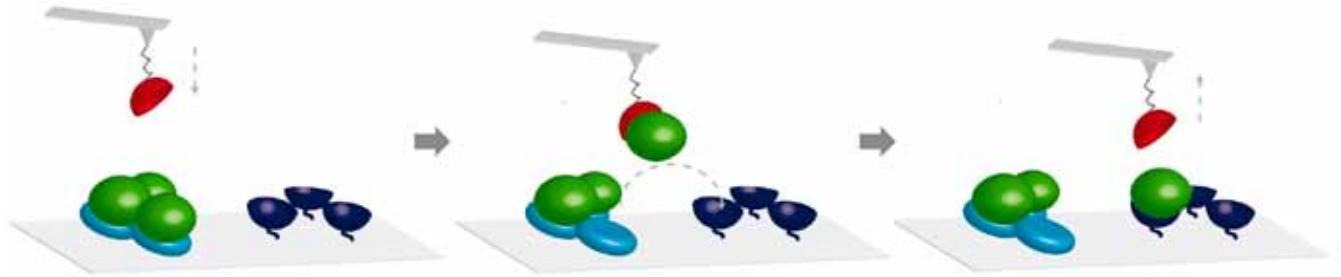
State-of-the-art technology allows for not only visualizing but also manipulating with single molecules. In our lab, Atomic Force Microscope (AFM) combined with TIRF microscope has been successfully used for Single Molecule Cut and Paste (SMC&P), a technique allowing to pick up, transfer and deposit single molecules of DNA. AFM cantilever serves here as a handle for precise manipulation with individual DNA strands. Force hierarchy is crucial to successful and efficient molecule transfer and deposition: the binding of the molecule to the handle needs to be stronger than to the depot area and at the same time weaker than that at the target area. Our aim is to expand the SMC&P technique over the world of proteins. We employ nanobodies (smallest functional antigen-binding proteins) to specifically bind GFP (Green Fluorescent Protein). With this strategy - based entirely on GFP binding and thus independent of additional protein tags or chemical modifications - transfer of virtually any GFP-fused protein will become possible. Robustness of this approach stems from the availability of such proteins in most (if not all) cell biology- and biochemistry-focused labs. This only supports the motivation of using nanobody-SMC&P to print desired patterns of protein arrays.

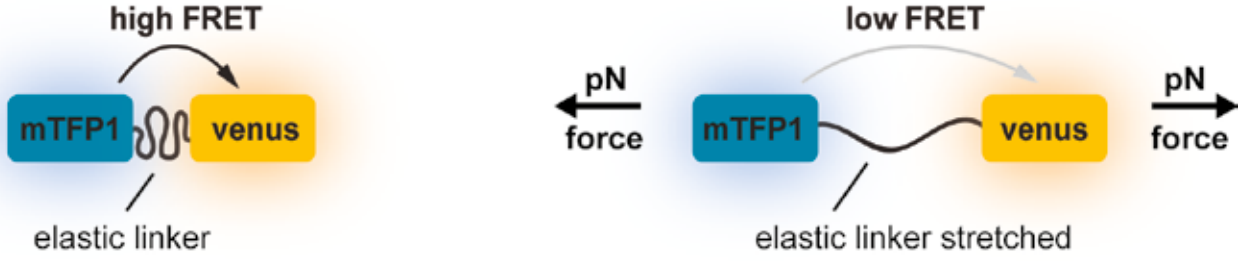


Measurement of Intracellular Force Transduction across Human Metavinculin in the Context of Cardiomyopathies

Carleen Kluger[1,2], Matthias Morasch[2], Carsten Grashoff[1]

1 Max-Planck-Institute of Biochemistry, Martinsried; 2 Faculty of Physics, Ludwig-Maximilians-Universität München

Heart muscle cells generate and bear an extensive amount of force during their lifetime. Changes in mechanical properties of the heart can lead to a very severe type of disease called cardiomyopathy, but it is unclear how they link to dysfunctions at the molecular level. Here, I propose to analyze the role of two cytoskeletal proteins, vinculin and metavinculin, which have been recently shown to be linked to the development of cardiac disorders. Vinculin is an intracellular protein known for its central role in cell adhesion and force transduction. Its splice variant metavinculin is found in mechanically active tissues such as smooth muscle and the heart, but its role in cell adhesion and mechanotransduction remains elusive. Interestingly, genetic screening revealed that some patients suffering from cardiomyopathies exhibit mutations in vinculin and metavinculin indicating a critical role of these proteins for the integrity of the heart muscle. The aim of this study is to develop a better understanding of how vinculin and metavinculin regulate cell adhesion dynamics and force transduction in cells, and furthermore to elucidate how mutations in vinculin and metavinculin affect the mechanical properties of cells on a molecular level. I propose to establish a cell culture model that allows the systematic analysis of vinculin and metavinculin in living cells. To directly measure the ability of these proteins to bear mechanical tension, I will use a novel FRET-based biosensor sensitive to forces in the pico-Newton (pN) range. Using this set-up, I will be able to measure and visualize the impact of vinculin and metavinculin mutations with high spatio-temporal resolution in living cells. Together, these experiments should not only contribute to our fundamental understanding of vinculin-dependent cell adhesion and mechanotransduction, but also have important implications for certain types of cardiomyopathies.



Tension Sensor construct: a FRET pair is connected by a flagelliform linker. As FRET efficiency if dependent on distance between fluorophores it can be used as a read-out for pN forces.

Ordered macroporous tin oxide nanostructures as an anode host scaffold for water splitting applications

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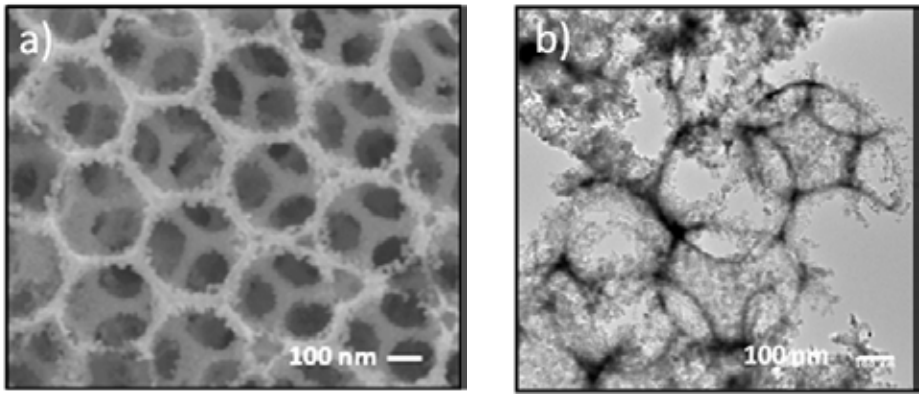
Hematite has been shown to be a promising photo-anode material for water splitting due to sufficient light absorption in the visible range and appropriate valance band position. However low light harvesting as well as poor charge transport limit the performance of the material. Host-scaffold/guest-absorber structures show enormous potential by decoupling light harvesting from charge transport, thus potentially leading to higher incident photon-to-current efficiencies (IPCE). Here we present a synthesis strategy for highly crystalline SnO_2 films with an ordered macroporous structure using PMMA spheres as a template. The PMMA particles are deposited on FTO followed by immersion in the SnO_2 precursor solution. The template removal occurs at 200°C and a highly crystalline SnO_2 film is obtained at 600°C. The SnO_2 macroporous film has a thickness of 1 µm and a pore size 20% smaller than the original diameter of the PMMA spheres caused by shrinking. The SnO_2 scaffold is further coated with hematite as an absorber layer prior to electrochemical measurements. The higher surface area of the scaffold and the resulting increase of hematite-loading on SnO_2 lead to a considerably higher photocurrent compared to a flat hematite layer. By decoupling light harvesting from electron transport, the electron transfer efficiency is increased. The macroporous architecture of the hierarchically ordered macroporous tin oxide/hematite nanostructures was studied by X-ray diffraction, scanning and transmission electron microscopy. The photo-electrochemical properties of the nanostructures were studied by voltammetry, external quantum efficiency, light harvesting and current transient measurements.



SEM (a) and TEM (b) image of a macroporous SnO_2 host-scaffold covered with an absorber layer of hematite nanoparticles.

Length sensitive accumulation of oligonucleotides in thermo-gravitational fields

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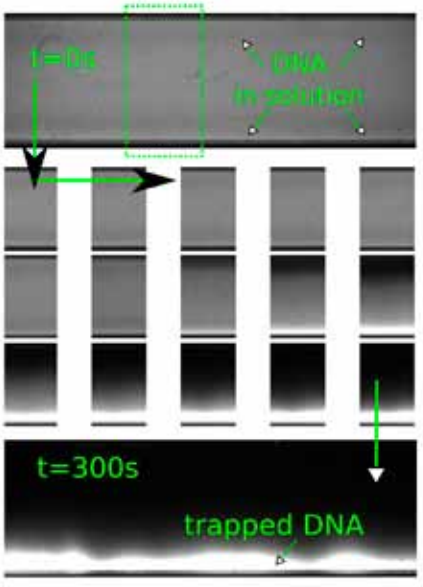
Central to most "Origin of Life" scenarios is the possibility for pre-biotic organic molecules to interact in order to form increasingly complex, catalytic molecular machinery ultimately capable of autonomous replication. While strong evidence for the spontaneous generation of single nucleotides [1] recently arose, concentrations required to allow these building blocks to polymerize [2] and gain functionality, still seem improbable for early earth conditions. Here we demonstrate experimentally that temperature gradients across vertical pores, as they occur in submarine hydrothermal vents [3], are sufficient to accumulate oligonucleotides efficiently from dilute solutions. In particular we show that, depending on the pores' dimensions, this thermo-gravitation trapping is strongest for long oligonucleotides and thus provides a length selective molecular filter. We suggest that equivalent systems could have served as meeting point for long and complex molecules, too rare to find each other in a dilute primordial ocean. Furthermore, we discuss under which conditions length sensitivity could trigger the evolutionary selection of molecular replicators driven by convective thermo-cycling.



Efficient accumulation of DNA molecules driven by the flux of heat

[1] M.W. Powner, B. Gerland, J.D. Sutherland, Synthesis of activated pyrimidine ribonucleotides in prebiotically plausible conditions, Nature 459:239-242 (2009)

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Single-cell gene expression dynamics

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A profound understanding of the cellular reaction and the kinetics of gene expression after transfection of live cells with plasmid DNA (pDNA), messenger RNA (mRNA) or small interfering RNA (siRNA) would help to advance applications in nanomedicine as well as functional assays. Transfection mediated by stabilized RNA is an attractive alternative to pDNA delivery as RNA does not require transfer into the nucleus and hence leads to earlier and less heterogeneous gene expression. The analysis of expression kinetics at the single-cell level can help to identify the cell-to-cell variability within a cell population. We studied gene expression kinetics of single cells mediated by both mRNA and pDNA constructs. Using time-lapse microscopy, fluorescence time courses were monitored and analyzed using a mathematical model for transcription and translation. While mRNA transfection compared to pDNA transfection leads to a lower GFP expression level per expressing cell, the GFP expression levels are more homogeneous than after pDNA transfection. Also, the early onset time of mRNA-induced expression is narrowly distributed, while the later onset of pDNA transfection is broadly distributed. During this work and in a previous study on the transfection kinetics of non-viral gene-transfer [1], we realised that the development of single-cell arrays would be a great step towards easy-to-analyse, high-throughput transfection studies since the regular arrangement of single cells would overcome the limitations in image-analysis that arise from whole populations of cells.

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Size distribution analysis of Von Willebrand Factor

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Von Willebrand Factor (VWF) is a multimeric protein that initiates blood coagulation, a process that highly depends on the size of VWF. However, while in recent years a general understanding of the role of VWF has emerged, its dynamic size regulation remains rather unexplored. To this end, we investigate the dynamic size distribution of recombinant EGFP-VWF with Fluorescence Correlation Spectroscopy (FCS) that allows for highly precise measurements with single molecule resolution while keeping VWF in its native environment, i.e. blood plasma. With this method, we show that the size distribution of VWF follows an exponential decay, indicating an Einstein-polymer-like polymerization behaviour. Further, we monitor the in vivo and in vitro size regulation of VWF by the protease ADAMTS13, the major factor determining VWF function. Our measurements allow for a quantification of the ADAMTS13 induced cleavage rates and enable to discriminate between physiological and pathological concentrations of the protease in patient samples. Future studies will aim for the shear-flow depend measurement of the VWF function. Therefore we currently develop a two-focus FCS as a fast flow-through setup to measure shear-induced changes of the VWF functionality.

Ordered Mesoporous Carbon for Lithium-Sulfur Batteries

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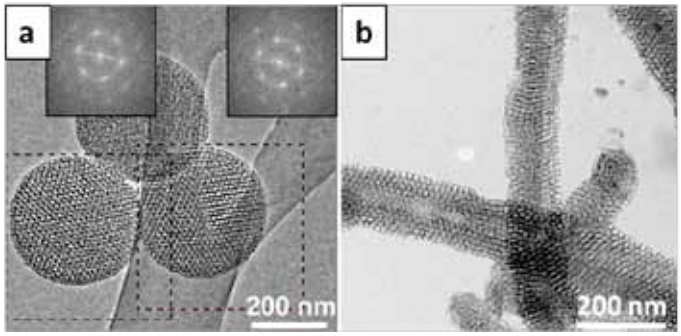
Ordered mesoporous carbon (OMC) materials feature a high chemical stability, electrical conductivity and show very high specific surface areas. Therefore OMCs can be applied in electrochemistry and used as electrodes in supercapacitors, fuel cells and batteries, such as lithium-sulfur batteries. Since the electronic conductivity of sulfur is extremely low, conductive carbon materials with high accessible porosity are essential to "wire" and host the sulfur in the positive electrode. Here, we present two novel synthetic approaches for OMC materials with spherical or fiber morphology, which were obtained by using macroporous silica as hard templates. For the synthesis of spherical OMCs a 3D ordered and in the case of the carbon fibers, a rodlike pore geometry was applied. Both porous templates were filled in the next step by casting solutions, containing a carbon precursor, a block copolymer (Pluronic family) and a silica precursor. By evaporation induced self-assembly of the precursor mixture and thermal carbonization, mesoporous carbon-silica composites were formed in the confined space of the spherical or rodlike silica templates. The silica was then removed by etching and thus spherical carbon (Fig. 1a) or carbon fibers (Fig. 1b) were obtained. The structural characterization with SEM, TEM and sorption shows the difference between these morphologies and the influence of the templates on the final structure. Finally, these two OMCs were successfully applied as active cathode materials in lithium-sulfur batteries, where their morphologies show a beneficial influence on the capacity and cycling stability.

[1] Schuster, J.; He, G.; Mandlmeier, B.; Yim, T.; Lee, K. T.; Bein, T.; Nazar, L. F. Angew. Chem. 2012, 124, 3651



TEM images of ordered mesoporous carbon spheres (a) and fibers (b).

Towards Darwinian Molecular Evolution in a Thermal Trap

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The formation of biopolymers and their replication is essential for all life forms. While modern organisms realize polymerization with a sophisticated enzyme machinery, the RNA-world hypothesis proposes the first prebiotic polymerases to be basic RNA strands of several hundred bases. The de novo formation of such long molecules is hard to imagine under highly diluted prebiotic conditions since enzyme-free polymerization shows an exponential decaying length distribution. Furthermore, replication reactions are avoided by template inhibition and the dilution of replication products. We show that thermal traps can perform both tasks:

a) Thermal traps extend the length range of prebiotic polymerization and thus significantly enlarge the available sequence space for catalytically active RNA. Temperature gradients in porous rock locally enhance the polymer concentration exponentially better for longer polymers. Since the mean length of polymers depends on its own concentration, polymerization and trapping are mutually self-enhanced: Once the monomer concentration reaches KD, our theory predicts a hyper-exponential escalation of polymerization towards exceedingly long polymers. The theory is tested experimentally with fluorescently labeled DNA. A 20-fold increase in monomer concentration was found, leading to 4-fold longer polymers within 5 hours and confirming theoretical predictions. The trap is expected to generate 100mers out of an initially dimeric starting condition after several months. We extrapolate the results to the RNA-world. Even in unfavorable conditions, such as a dilute monomer broth and small temperature gradients, a short 5 cm crack will likely generate 100mers of RNA with µM concentrations.

b) We also experimentally show that thermals traps can drive an exponential replication reaction: Convective flow drives a PCR while concurrent thermophoresis accumulates the replicated 143bp DNA. The time constant for accumulation is 92s while DNA is doubled every 50s.

Low-force single-molecule elasticity of ssDNA: sequence dependence and ion counting

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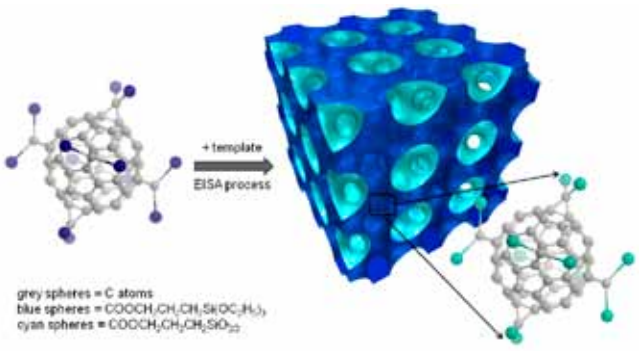
The structure of macromolecular complexes, whether entangled in a gel, densely grafted to a surface (e.g., polymer brushes), or coiled up and crowded in the cell (e.g., proteins, RNA), depends on the microscope mechanical properties of the constituent polymers. These properties include the local chain rigidity as well as the long-range monomer-monomer interaction strength. Here, we present a method for directly measuring these properties: single polymers are stretched with a known force whilst their extension is monitored. As force and extension are thermodynamic conjugate quantities, these data are easily compared to theoretical models. In applying this method to heterogeneous-sequence ssDNA molecules, we are able to reconcile our data with scaling theory for polymers in good solvent. Data on homogeneous ssDNA, particularly poly(dA), show signatures of cooperative base-stacking with sections of polymer fluctuating between flexible random coils and rigid stacked helices. By varying the sequence of the ssDNA we demonstrate an ability to control the effective rigidity of the polymer. In an application of this data, we use a thermodynamic identity to relate single molecule elasticity data to the number of ions associated with the DNA. This analysis reveals that ions are released from the DNA to the bulk as the polymer is elongated and that the quantity of released ions depends nontrivially on the polymer's rigidity, being generally larger for more flexible polymers. Based on these findings, we argue that the entropy of release of polymer-associated ions to the bulk should contribute substantially to the free energy differences between competing states of charged, flexible polymers such as RNA and proteins.

Highly Ordered Mesoporous Fullerene Polymer

Kun Hou, Norma Minar, Fabian Hanusch, Thomas Bein

Department of Chemistry and Center for NanoScience (CeNS), Ludwig-Maximilians University of Munich, Germany

Fullerenes, a family of hollow cage-shaped carbon molecules, have inspired remarkable interdisciplinary research activity in the last two decades, combining several fields of chemistry, physics and materials science. Since the fullerene C_{60} is available in macroscopic quantities, a wide variety of chemically modified derivatives has been synthesized, which exhibt unusual magnetic, superconducting, electrochemical and photophysical properties [1,2]. Due to these characteristics, a search for new applications has started, including solar cells, optical limiters, catalysts, superconductors and molecular electronics.[3] Here we report on a novel, highly ordered periodic mesoporous organosilica (PMO) that is entirely constructed from individual silane-functionalized fullerene building blocks and whose mesoporosity is controlled by cooperative self-assembly with a liquid-crystalline block-copolymer. In contrast to most of the PMO precursors reported so far, the fullerene molecules can be functionalized at many points, potentially resulting in an enormous multitude of possible fullerene adducts with different symmetry and number of functionalities. This would lead to a complicated co-selfassembly behavior between the precursor and surfactant, and likely to



limited order in the final product. To address this challenge, we surmised that a C_{60} hexakis-derivative with high Th symmetry would be beneficial for the construction of a porous framework. This new PMO material was obtained in the form of supported films by spin-coating the synthesis solution directly on glass or silicon substrates, followed by a heat treatment. The material was fully characterized by small angle X-ray diffraction (XRD), nitrogen sorption, transmission electron microscopy (TEM) and

solid state NMR.

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The Surface on the Surface – Studies on the Glycocalyx

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(1) Department of Chemistry and (2) Center for NanoScience (CeNS) Ludwig-Maximilians-Universität München, Butenandtstrasse 5-13, D-81377 München, Germany

The sugar coat found on all human cells, called glycocalyx, is a complex, very dynamic structure. Both its tasks and properties are yet poorly understood. Here, we report on our experiments that were carried out to enlighten basal characteristics of the glycocalyx. We performed shedding assays to prove its presence on cultured human endothelial cells and the recently developed technique of metabolic labeling for visualization. With this, we were able to investigate structures and assembling dynamics. We observed a variety of different structures, dependent both on the sugar type and cell line, and a strong dependence of the turnover rate of glycocalyx proteins on their glycosylation type. Glucose- and galactose-rich proteins exhibit very fast turnover rates in the range of hours, whereas mannose-rich proteins are renewed within twenty-four hours. For mannose-rich proteins, we found out that mannose is incorporated three hours after incubation at the latest, and that all mannose residues are exchanged about twenty to twenty-four hours. These results indicate a novel type of adjustment, presumably closely connected with metabolic control, and will hopefully contribute to a deeper understanding of this important cellular structure.

Transmission Electron Microscopy Studies on Domain Walls in $TbMnO_3$ Thin Films

Alexander Müller[1], Sriram Venkatesan[1], Markus Döblinger[1], Christophe Daumont[2], Beatriz Noheda[2], Christina Scheu[1]

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In recent years, the study of multiferroic materials, which exhibit more than one of the four ferroic orders at the same time, has significantly gained popularity [1]. Among them is $TbMnO_3$, in which an antiferromagnetic order leads to ferroelectricity and therefore a very strong magnetoelectric coupling [2]. Compared to the antiferromagnetic bulk material, strained thin films of $TbMnO_3$ on $SrTiO_3$ display a net magnetic moment [3]. Two theories have been developed to explain this behavior. The first proposes that the strain leads to ferromagnetic interactions, while the second assumption is that the structure of the domain walls gives rise to the magnetization [4]. In this work atomically resolved High Angle Annular Dark Field Scanning Transmission Electron Microscopy (HAADF STEM) in combination with Electron Energy Loss Spectroscopy (EELS) was used to study the structure and chemistry of the domain walls. In HAADF-STEM images, intensities are correlated to the atomic number, allowing the construction of a 2-dimensional unit cell of the domain wall (Fig. 1). An unknown atomic column X could be divided into X_1 and X_2 by signal intensity analysis. EEL spectra quantification allowed excluding Mn in these atomic columns. Further away from the $SrTiO_3/TbMnO_3$ interface, only Tb was found in the X site. The atomic number of X_1 was calculated to be approximately 43, most likely due to X_1 consisting of 2/3 Tb vacancies. X_2 could not be analyzed in this detail due to an insufficient S/N-ratio but should have an even lower Tb content. It was further found that the valence of Mn adjacent to X columns is not +III as in the bulk but higher, most likely +IV. The valence of Tb was found to be +III independent of the location. In combination with the existence of vacancies, this would lead to a neutral electric charge.

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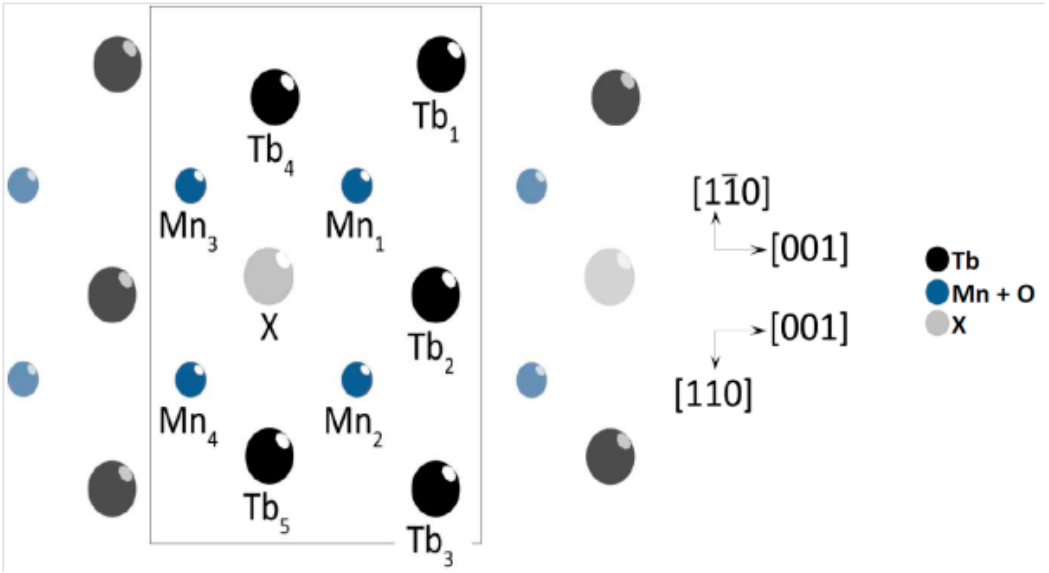


2-dimensional unit cell of the domain wall viewed in [110] direction.

DNA Origami Structures Folded Directly from Bacteriophage Lambda and M13 Particles

Philipp C. Nickels[1], Yonggang Ke[2], William M. Shih[2], Tim Liedl[1], Björn Högberg[3]

1 Physics Department and Center of NanoScience (CeNS), Ludwig-Maximilians-Universität, Munich; 2 Harvard Medical School, Dana-Farber Cancer Institute, and Wyss Institute for Biologically Inspired Engineering, Boston - MA, USA; 3 Swedish Medical Nanoscience Center, Department of Neuroscience, Karolinska Institutet, Sweden

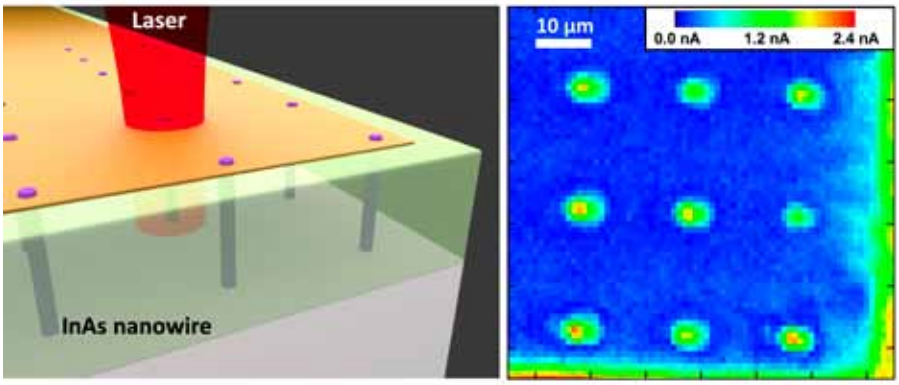
DNA origami is a widely used method for the self-assembly of nanoscale objects with addressable features of unprecedented levels of positional accuracy. This technique employs a virus-based DNA single strand as a scaffold which is brought into shape by hundreds of short oligonucleotides. The achievable size of structures built with the original origami method is limited by the size of the single-stranded scaffold molecule used. Scaling up the size of DNA origami structures remains a critical challenge that is facing the further development of DNA origami technology. Building large objects approaching the size scale of conventional photolithography techniques might be a feasible approach to combine bottom-up self-assembly with top-down lithography. Currently, the methods for the production of single-stranded DNA molcules are less efficient than those for double-stranded DNA. Here we present the use of double-stranded bacteriophage λ-DNA as a source of scaffold to fold DNA origami structures. We show that it is possible to assemble the structures directly from the bacteriophage particles without further purification methods of the scaffold material. To prove the versatility of the method we show that it is also possible to assemble conventional DNA origami structures from bacteriophage M13 particles.

Optoelectronic properties of individually positioned InAs nanowires

Jan Overbeck, Andreas Brenneis, Simon Hertenberger, Gerhard Abstreiter, Gregor Koblmüller, and Alexander Holleitner

Walter Schottky Institut and Physik-Department, TUM Garching, Germany

Small bandgap semiconducting nanowires offer a promising approach to fabricating nanoscale light-sensitive devices like broadband solar cells or mid-infrared photodetectors. We discuss the optoelectronic properties of individually positioned InAs nanowires. To this end, p-Si(111) substrates with a top layer of SiO_2 are structured via e-beam lithography creating holes in the oxide with a diameter of approximately 80 nm. The nanowires are then grown vertically on the patterned substrates by solid-source molecular beam epitaxy. To fabricate optoelectronic devices the nanowires are subsequently embedded in an insulator (BCB) and then contacted via a thin metal film evaporated on top of the insulating layer. The p-Si substrate forms the second contact of the optoelectronic two-terminal devices. Spatial resolution of individual nanowires is achieved by scanning with an IR-Laser at wavelengths both above and below the Si bandgap, which allows for selective excitation of the nanowires.



Schematic image showing the laser beam focused onto a contacted nanowire and a photocurrent map measured at excitation energy below the Si bandgap.

Towards Low-Cost Imaging Sensors: A Detection Principle Based on Tunable 1D Photonic Crystals

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Synthetic one-dimensional photonic crystals (1D PCs), alias Bragg stacks (BSs), comprise a promising class of "smart" environmentally responsive nanostructures featuring optically encoded stimuli detection. Favorably, these periodic dielectric nanostructures represent systems with an inherent response to temperature and humidity changes, and are capable of translating the chemical fingerprint of chemical and biological analytes into a visibly perceptible optical read-out. The mechanism of the optical sensing is given by the photonic stop band – a characteristic spectral region allowing for the tuning of the transmission/reflection properties of PCs. Due to the tunability of the stop band, the intensity of light propagating through the Bragg stack is modulated upon varying the environmental conditions. Herein, as a first step towards the assembly of integrated, miniature imaging sensors, we present a detection principle based on the employment of 1D PCs as tunable optical filters integrated with organic and inorganic light emitting diodes (OLEDs and LEDs, respectively). The tunable stop band lies in the visible region and can thus be detected in a straightforward and inexpensive fashion by a visible-light photodetector, such as active pixel array cameras (CCD, CMOS).[1] We demonstrate the proof of the proposed sensing concept with regard to temperature and chemical analyte detection.

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Large nuclear spin polarization in gate-defined quantum dots using a single-domain nanomagnet

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1 CeNS und Fakultät für Physik, Ludwig-Maximilians-Universität, München; 2 Institut für Angewandte und Experimentelle Physik, Universität Regensburg; 3 Solid State Physics Laboratory, ETH Zurich, Schweiz; 4 Max-Planck-Institut für Quantenoptik, Garching, Germany

Electrostatically defined double quantum dots (QD) have been shown to be a promising platform for spin based quantum information processing. One of the great challenges for GaAs/AlGaAs based QD systems is to overcome the decoherence of the information carrying electron spins due to hyperfine interaction with thermally fluctuating nuclei in the host material. Various approaches have been developed to tackle this problem, such as nuclear state narrowing [1], nuclear state squeezing [2], and nuclear spin polarization [3]. Here we present data demonstrating an unrivaled high nuclear spin polarization for lateral QDs of ~50%. This is achieved using an on-chip single-domain nanomagnet. We study the hyperfine interaction between nuclei and electrons and utilize it in dc transport measurements. In the so called Pauli spin blockade configuration, current through the double QD is suppressed. However, the spin blockade is lifted by the inhomogeneous field of the nanomagnet and hyperfine induced electron-nuclear flip-flop processes. Furthermore, the single-domain nanomagnet gives rise to an imbalance of these nuclear spin flips (up versus down), which leads to nuclear spin polarization. We are able to consistently describe this dynamic nuclear spin polarization by a semi-classical rate equation model and demonstrate a procedure for reaching high degrees of nuclear spin polarization.

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Super-Resolution Imaging of CHMP4 and ALIX at HIV-1 Assembly Sites

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Recently, it has become possible with optical microscopy to perform fluorescence imaging beyond the diffraction limit of light. This allows investigation of subviral structures and studying interactions between viral components and host factors. Here, we used super-resolution imaging to investigate recruitment of the cellular endosomal sorting complex required for transport (ESCRT) by the viral Gag protein at nascent HIV-1 budding sites at which we analyzed the localization of ESCRT components ALIX and CHMP4B. ALIX is recruited early in the assembly process and was shown to gradually accumulate together with retroviral Gag. It is also incorporated into HIV-1 particles whereas ESCRT-III protein CHMP4 forms transient membrane associated lattices mechanistically involved in virus-host membrane fission: these might either form a dome-shaped structure within the membrane neck leading to narrowing of the neck and membrane fission or CHMP4 lattices might surround the assembly site and constrict the bud neck in a lasso-like manner. To differentiate between these models, we performed Stochastical Optical Reconstruction Microscopy (STORM) on HeLa cells co-expressing fluorescently labeled HIV-Gag and HA-tagged CHMP4B that was immunostained with fluorescently labeled primary antibodies. STORM revealed closed, circular CHMP4B-HA structures with an average diameter of ~55 nm located at the center of some of the individual Gag assemblies indicating that CHMP4 assembles within the bud neck rather than forming larger structures surrounding the budding site. STORM was also performed on HeLa cells expressing fluorescently labeled HIV-Gag while endogenous ALIX was detected by immunostaining. STORM imaging of ALIX showed similar circular structures with an average size of ~60 nm. However, in contrast to CHMP4B, a cloud of individual ALIX molecules surrounded the central clusters at HIV budding sites, which represent ALIX molecules incorporated into the nascent HIV Gag shell.

Hydrogen Bonds vs. Metal-Coordination

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We report on monolayer self-assembly of 1,3,5-tris(4'-biphenyl-4''-carbonitrile)-benzene (BCNB) on the (111) surfaces of Cu and Ag single crystals. Samples were prepared by sublimation of BCNB under ultra-high vacuum conditions and analyzed by Scanning-Tunneling-Microscopy (STM). Through their carbonitrile groups BCNB can form both hydrogen bonds and metal-coordination bonds[2]. On Ag(111) the BCNB monolayer is densely packed and trigonal (a=b=1.8 nm). Molecules adsorb parallel to the surface and are interconnected by C≡N···H-C hydrogen bonds. On Cu(111) two coexisting BCNB monolayer polymorphs were found: 1) a trigonal densely packed ($4\sqrt{3}\times4\sqrt{3}$)R30° superstructure with similar lattice parameters and molecular arrangement as on Ag(111) (a=b=1.8 nm); 2) a hexagonal porous superstructure (a=b=4.9 nm). For the latter two different epitaxial relations with similar lattice parameters were found: ($11\sqrt{3}\times11\sqrt{3}$)R30° and 19×19. Here BCNB molecules are interconnected by C≡N···Cu···N≡C coordination bonds involving Cu adatoms. The polymorphism on Cu(111) can be explained by adatom availability.

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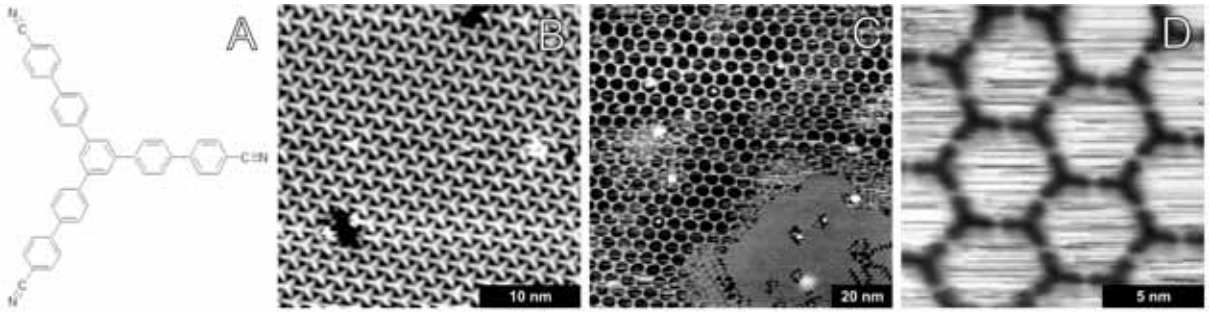

A Structure of BCNB; **B** STM topographs of Densely packed structure on Ag(111) (1.61 V, 100 pA); **C** Coexisting densely packed (lower right corner) and porous structure (rest) on Cu(111) (2.09 V, 78 pA); **D** Close-up of the porous structure on Cu(111) (1.41 V, 78 pA).

Towards thermophoresis in cells

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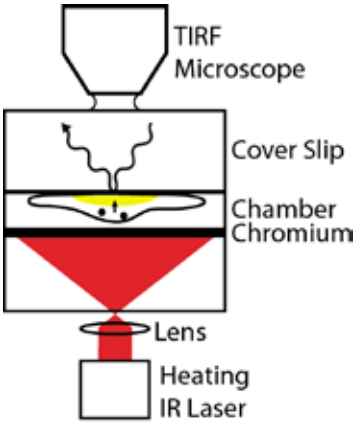

Binding constants of biomolecules in vivo are expected to differ from those measured in vitro model systems [1]. Especially interactions of competitive binding partners in complex biological fluids like blood serum or cytoplasm, which are ubiquitously encountered in biological systems, are only partially reproducible in vitro. Thus, it is necessary to develop new techniques especially for measuring directly in living cells. Thermophoresis is the motion of molecules along temperature gradients. In a vertical temperature gradient, the molecules move up and can be read out with total internal reflection fluorescence microscopy (cf. figure with our setup). A binding event will change the thermophoretic drift velocity. By a titration series binding affinities can be measured [2]. With this new technique we aim at measuring in the cytoplasm of living cells with sub-cellular resolution. This experimental setup also allows to test theories on the physical mechanism of thermophoresis. As a well characterised model system we use DNA strands of different lengths. Since we induce a temperature gradient in a thin water sheet, we can directly evaluate the influence of boundaries on thermophoresis. Following the studies by Herzog [3] we are also interested in the influence of the pH value and the salt species. Preliminary results suggest that at a given concentration the specific choice of ions has a small impact on thermophoresis, but we do not see the strong dependence on the pH-value that one would expect when classifying thermophoresis only as a consequence of Seebeck-effect induced electric fields [4].

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Coherence- and lifetime measurements of dipolar, indirect excitons

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In coupled double quantum wells, photo-generated and spatially indirect excitons can be efficiently manipulated via gate-voltage-induced control of the quantum confined Stark Effect [1,2,3]. In InGaAs-based double quantum wells, we realized electrostatically widely tunable trapping devices for dipolar indirect excitons. Resonantly excited direct excitons transform into indirect excitons and are collected via electrostatically shaped energy landscapes [3]. With their electron and hole confined to two different quantum wells, these indirect excitons exhibit a large dipole moment and long lifetimes. Employing a 3He-cooled confocal microscope with two objectives that can be independently positioned, we generate indirect excitons at a location outside the trap and measure their photoluminescence from the trap center after they have been cooled to lattice temperatures and transferred into the trap. In our experiment, we achieve a base temperature of below 250 mK. At this temperature, the thermal de Broglie wavelength exceeds the excitonic separation. Therefore many-body correlations between trapped indirect excitons can be expected [4]. We report on a novel measurement scheme based on a Mach-Zehnder-Interferometer to study both the temporal and spatial coherence of the emitted photoluminescence. First results show differences between the temporal coherence measured in our experiment and results reported in an earlier work [5]. To further characterize the temporal behavior of the cold exciton ensemble, we perform lifetime measurements of the indirect excitons. Depending on the applied bias voltage and the excitation power, the lifetime of the indirect excitons can be tuned between 50 ns and several hundred ns.

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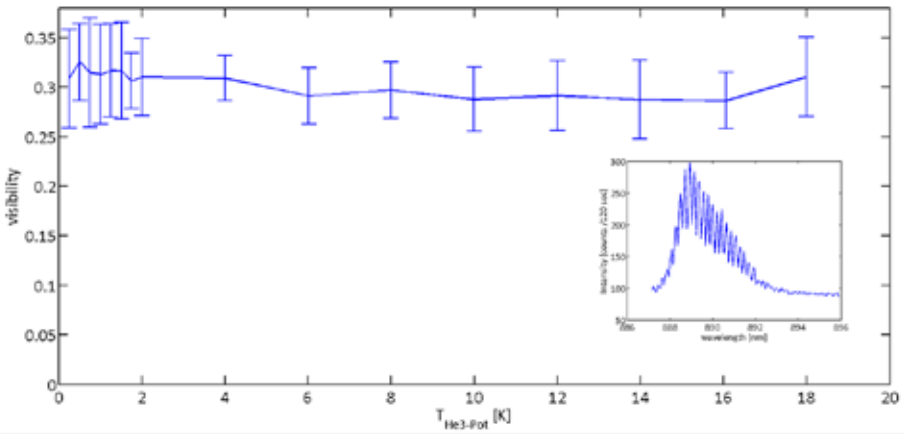

Temperature dependence of the visibility of interference oscillations in the photoluminescence spectra of indirect excitons. Insert: spectrum of indirect excitons at a base temperature of 500 mK measured at an optical path difference of 3.7 mm between the different arms of the Mach-Zehnder-Interferometer.

Studies of nanotoxicity and cellular self-organization on micropatterned single cell lattices with high throughout time-lapse microscopy

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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. The arrangement of cells on defined lattice sites is preferred. However, the problem of filling lattice sites with individual cells has not been systematically addressed. Microstructured surfaces with plasma-induced patterning in combination with a PEG backfill were created, whose surface chemistry and geometry has been optimized to allow self-organization of cells after seeding. Moreover, the automated single cell image analysis of apoptosis (induced by nanoparticles and staurosporine) has been demonstrated. A time dependence of the phase of early and late apoptosis is observed.

Dynamic Pattern Formation in Driven Systems

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Even active systems that appear simple at first sight, show a plethora of intriguing phenomena and often we find complexity were we would have expected simplicity. In many such systems it is neither possible to predict the dynamic properties nor to draw a comprehensive picture of the underlying mechanisms and the emerging properties. This becomes even worse if active processes are coupled to other generic processes like aggregation and growth, as it is the case for cytoskeletal systems. Here the mechanical properties of the emergent structures nontrivially interfere with the active processes like motor-mediated transport. To shed light on the dynamic properties and the aggregation mechanisms in active systems, we investigate reconstituted systems consisting of highly concentrated actin filaments and associated motor proteins in quasi 2D and 3D geometries (1,2). The bulk material properties of these systems like the connectivity and the elasticity are adjusted by actin binding and crosslinking proteins. We show that the interplay of active force generation and passive crosslinking leads to a heterogenization of the active material, with structures crucially depending on the morphology of the specific crosslinker. The reconstituted approach consisting of a minimal set of purified components allows us to address the microscopic processes underlying the pattern formation in these materials.

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Programmable patterns based on DNA nanostructures

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Here we report on the utilization of nucleic acid based logical functions for the programmable generation of patterns on DNA nanostructures. DNA origami structures are used as a platform on which predefined positions can react to specific inputs with a change in structure. As an example we modified various positions on the origami structures with molecular AND-functions that specifically respond to either one or two DNA input strands. The AND-functions are realized by DNA hairpin structures, which reveal hidden sequence domains upon binding of the input strands. Complementary marker strands from solution can bind to these activated sequence domains and are used for visualization. Marker strands either carry a fluorescent dye for imaging with optical microscopy or they are labeled with streptavidin proteins bound to biotinylated DNA and visualized in the AFM height contrast image. The formation of patterns takes place on the nanoscale suggesting AFM as the first choice imaging method. In contrast optical microscopy enables a less invasive characterization of the patterns but is limited by diffraction. To overcome this limit we use DNA-PAINT, a super-resolution microscopy technique based on stochastic read-out of the fluorescent signal1. Depending on how the base structure is programmed in advance, different inputs will subsequently cause a distinct non-trivial pattern on the origami structure. Further studies will aim at the implementation of additional functions like OR- or NAND- functions and the combination of these. Apart from DNA as molecular input we also plan to utilize RNA molecules such as microRNA or RNA signals transcribed in situ. Apart from programmable patterns on DNA nanostructures we show the arrangement of DNA origami on lithographically designed glass slides. The combination of lithographically manufactured arrays, a biological platform with nanoscale addressability and the applicability of optical microscopy leads to a promising micro-chip device for both micron-scale and single-molecule studies.

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Stiffness and Supertwist of DNA Nanotubes

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We measure the persistence length of DNA nanotubes of defined circumference (Yin, et al. 2008) using fluorescence microscopy. The tubes are confined in a thin (~2um) PVP coated chamber in which they diffuse laterally. Imaging individual tubes over time and tracing their contours allows us to extract their persistence length. DNA nanotubes are commonly described by a simple mechanical model (Rothemund, et al. 2004), which assumes a close packed tube, where every DNA duplex has a radius of r=1nm, a persistence length of 50nm and is oriented parallel to the tube axis. This model fails to describe the kind of DNA nanotube we investigate since it systematically underestimates their persistence length. Our measurements also show that within a sample of tubes with given circumference there is a large heterogeneity in their stiffness. We propose a model in which tubes can close with different amounts of "supertwist" meaning that the DNA helices are twisted about the tube axis. The free energy associated to these supertwisted conformations, can be calculated as the sum of the energy required to bend the helices and the energy to twist them. We show that tube closure with a certain amount of supertwist is energetically favorable for the tubes.

Entropic Particle Separation

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Diffusive transport of particles or, more generally, small objects, is a ubiquitous feature of physical and chemical reaction systems. In configurations containing confining walls or constrictions, transport is controlled both by the fluctuation statistics of the jittering objects and the phase space available to their dynamics. In the talk I will report on recent advances in the theoretical and numerical investigation of stochastic transport occurring in geometries of varying cross sections. For particles undergoing biased diffusion in confined static suspension media, transport exhibits intriguing features such as 1) a decrease in nonlinear mobility with increasing temperature or also 2) a broad excess peak of the effective diffusion above the free diffusion limit [1]. The presence of uneven boundaries, giving rise to an entropic contribution to the potential, may upon application of a periodic driving force result in an increase of the spectral amplification at an optimum value of the ambient noise level yielding the effect of Entropic Stochastic Resonance [2].

In nanopores lacking mirror symmetry about a vertical axis rectification favoring transport in one pore direction occurs. The combined action of a time-dependent driving force and this Entropic Rectification can be utilized for particle separation with respect to the particle size [3]. The mechanisms turned out to be very efficient and can be controlled by tuning the geometrical parameters of the pore leading to different velocities and directions of the particles.

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Protein Dynamics & Aggregate Size Distributions at Molecular Resolution by smTIRF

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Single molecule techniques provide unprecedented in-sight into intrinsically heterogeneous systems. We apply single-molecule total internal reflection fluorescence (smTIRF) spectroscopy to gain knowledge about both, static and dynamic heterogeneity: The molecular chaperone Heat-Shock-Protein 90 (Hsp90, s. Fig. 1a)) is an important and abundant protein in eukaryotic cells, essential for the activation of a large set of signal transduction and key regulatory proteins, such as the steroid hormone receptor, the tumor suppressor protein p53, etc. We measured single protein dynamics of this ho-mo-dimer by Förster resonance energy transfer (FRET) and found that the N-termini of Hsp90 undergo large conformational changes. In contrast to the well-known power-stroke behavior of motor proteins, these thermal fluctuations are not strictly coupled to ATP hydrolysis, but occur even in the ab-sence of nucleotides [2]. Furthermore, we are interested in the size distributions of amyloidogenic alpha-synuclein oligomers. Although the function of this natively unfolded protein is unknown, it is commonly accepted that small alpha-synuclein oligomers - not fibrils - are the toxic species causing Parkinson's disease [3]. The exact alpha-synuclein oligomer size distribution, however, has remained ambiguous, so far - in part because of the polydispersity of the system and the lack of single molecule methods. We utilize single-molecule photo-bleaching to determine the size distribution of alpha-synuclein oligomers at dif-ferent stages of oligomerization (s. Fig. 1b).

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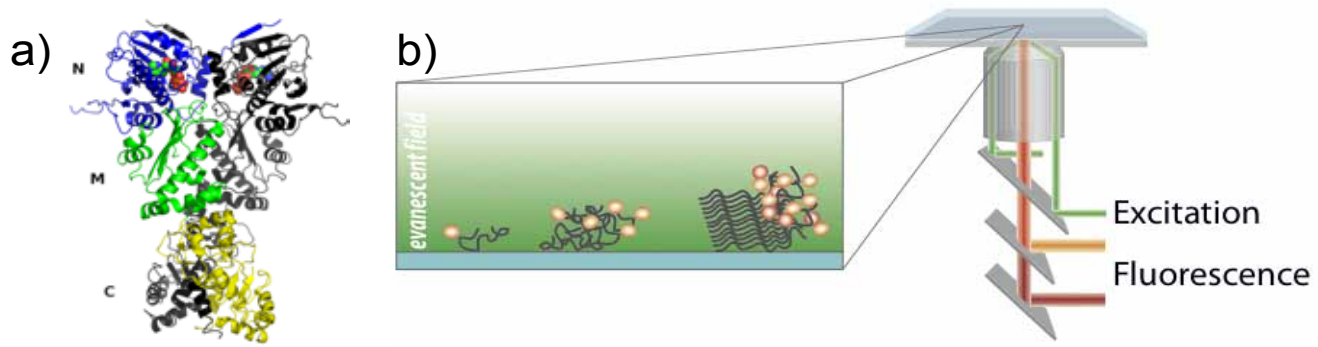

a) Hsp90 crystal structure [1], b) schematics of a photo-bleach experiment with differently sized oligomers.

Towards a New Generation of 2D Photocatalysts: Visible-Light Driven Hydrogen Evolution from Triazine-Based Carbon Nitrides

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Photochemical water splitting for the generation of H_2 as a high-energy and environmentally clean energy carrier is a key challenge of modern materials chemistry. Carbon nitrides (CNs) have gathered attention recently as chemically and thermally stable, easily accessible photocatalysts, that at the same time feature tunable electronic properties. The thermal condensation of CNs such as dicyandiamide or melamine, results in a wide variety of compounds which differ in terms of their photocatalytic activity depending on their degree of condensation, defects, crystallinity and morphology. In contrast to all known CN photocatalysts which are largely ill-defined and based on heptazine building blocks (e.g. melon), poly(triazine imide), PTI, is the only structurally characterized, highly crystalline 2D CN featuring imide-linked triazine units, which can be synthesized in a two-step ionothermal synthesis.[1,2] We demonstrate that while PTI shows moderate H_2 evolution in the presence of a cocatalyst, its activity can be amplified by chemically modifying the material with

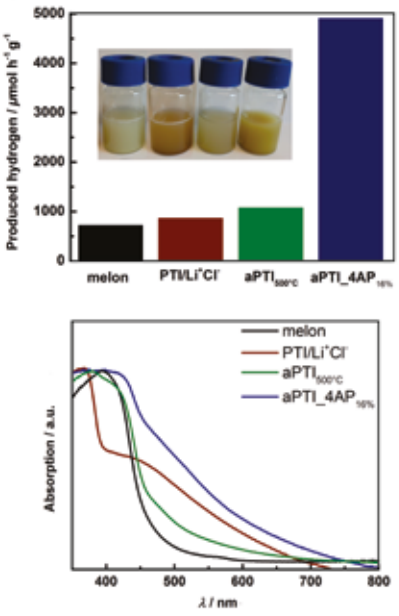

Figure 1: Photocatalytic activity towards hydrogen production (top). UV/Vis spectra (bottom) and color of the water suspensions (inset) of 16% 4AP doped amorphous PTI synthesized at 550°C compared to crystalline PTI/Li⁺Cl⁻, amorphous PTI synthesized at 500°C, and melon.

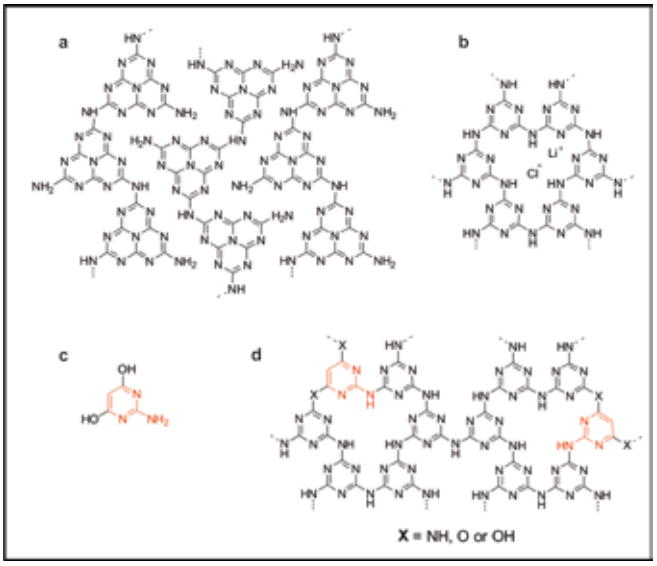

Figure 2: Chemical structures of a) melon, b) idealized PTI/Li⁺Cl⁻, b) the dopant 4AP and c) idealized 16% 4AP doped PTI.

4-amino-2,6-dihydroxypyrimidine (4AP) as dopant and lowering its crystalline order through changing the synthesis conditions. 16% 4AP doped amorphous PTI shows a 6 to 7 times enhanced photocatalytic activity compared to raw melon, which corresponds to a H_2 evolution rate of 4.9 mmol g-1 within the first three hours of illumination with visible light ($\lambda > 420$ nm, 3.4% quantum efficiency). We believe that it is possible to design a plethora of light-harvesting triazine-based semiconductors with controlled functions by simply doping with a variety of organic and inorganic molecules.

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Human mitochondrial RNA polymerase "at work"

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Mitochondria are responsible for the metabolic energy production of organisms in form of ATP. These cellular "powerstations" are also involved in a variety of other catabolic and anabolic reactions or in apoptotic regulation. In mammals, many diseases are suggested to be linked to mutations in the mitochondrial genome which is transcribed by the mitochondrial RNA polymerase (mtRNAP). Based on the recently published structure of human mtRNAP (Ringel et al., Nature 2011) we now investigate the functional states of mtRNAP during the mitochondrial transcription cycle by X-ray crystallography. The structural elucidation of mtRNAP trapped in its functional states will reveal the regulatory mechanisms of the individual stages during transcription of the mitochondrial genome (e.g. pre-initiation, initiation, elongation or termination). Due to the huge similarity between human mtRNAP and T7 RNAP, experimental strategies can be adapted from the intensively investigated T7 system. Structural analysis of the mtRNAP in combination with RNA/DNA oligonucleotides or in complex with transcription factors can stabilize flexible loop regions involved in DNA binding and thereby complete the picture of the existing structure. In a more long term view the deeper understanding of the unique features of transcription by mtRNAP assists the future design of more effective mitochondrial-targeting and antiviral drugs.

Coordinated and Disordered Cell Migration on Microstructured Surfaces

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Collective migration of cell assemblies plays an important role in a great variety of processes like wound healing, different phases of the embryogenesis or tumor growth. Nevertheless, the mechanisms by which the cells align and coordinate their movements are only partially understood. Here, we study the migratory behavior of small numbers of epithelial cells under defined boundary conditions. On circle shaped microstructures we observe a symmetry breaking event: the onset of a cohort circular migration with a common constant angular velocity dependent on the number of confined cells. The angular velocity decreases with increasing number of cells per assembly. Furthermore, the directional persistence as well as the time it takes for the symmetry breaking event to appear strongly depends on the number of cells within the system. Analyzing these quantities, we observe the stepwise transition from single cell random walk like behavior to multi cellular directional persistent motion. Based on that, we postulate a model of collective migration in which the cells interact as polarizable bodies what results in an intercellular positive feedback for directional persistence.

Flexible Biomolecular Interaction Analysis via Microscale Thermophoresis

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Thermophoresis, the motion of molecules in temperature fields, is highly sensitive to changes in size, charge and solvation shell. Since at least one of these parameters is affected by any biomolecular binding event, Microscale Thermophoresis (MST) is successfully used for biomolecular interaction analysis (BIA). In an all-optical approach thermophoresis is induced via infrared laser absorption and recorded via fluorescence. MST has several advantages compared to other well established BIA methods. As measurements are performed in free solution, time consuming immobilization procedures and the danger of surface artifacts, as e.g. present in surface plasmon resonance, are avoided. Compared to the "gold standard" of BIA, isothermal titration calorimetry, MST is characterized by a much lower sample consumption – a major advantage when working with precious biological material. MST experiments can be performed label free utilizing the intrinsic UV-fluorescence of tryptophan residues in proteins. This exempts from tedious labeling procedures and clean-up steps. Thus, time and sample consumption is further reduced and the danger of altering the binding behavior by attaching fluorescence labels is averted. Label free MST was employed to study the binding of numerous types of ligands to different protein classes, e.g. ligands to iGluR membrane receptors and small molecules to kinase p38. Using a fluorescently labeled binding partner for MST, on the other hand, allows for measurements in complex biological liquids, the natural environment of biomolecule interaction. By measuring in untreated human blood serum with a newly developed autocompetitive strategy, we were able to directly quantify both, affinity and absolute concentration of antibodies as disease-related biomarkers. Label Free MST and serological MST demonstrate the techniques high flexibility. It can, thus, be adapted to the binding system of interest to guarantee biological relevance of the results.

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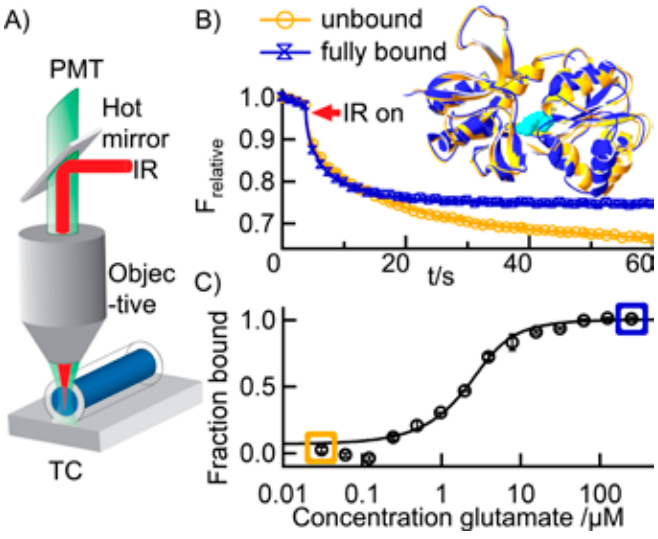

Label Free Microscale Thermophoresis. (A) Experimental setup. A glass capillary containing a protein sample with intrinsic tryptophan fluorescence is placed on a thermoelectric cooler (TC) providing a constant basis temperature. Fluorescence is excited via LED and recorded via photomultiplier tube (PMT). An IR laser is coupled into the fluorescence microscope with a heat reflecting hot mirror to locally heat the sample. B) The heat spot's normalized fluorescence plotted against time. IR laser heating induces thermophoresis: the molecules move away from the heat spot. Unbound iGluR2 (yellow; PDB code 1FTO) shows stronger thermophoretic depletion than the complex (blue; PDB code 1FTJ) with glutamate (light blue) reflecting the proteins conformational change upon binding. (C) Binding curve. A K_D of 835±43 nM is derived from the change in thermophoresis upon glutamate titration to iGluR2.

Ultrafast photocurrents and THz-generation in single InAs-nanowires

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To clarify the ultrafast temporal interplay of the different photocurrent mechanisms occurring in single InAs-nanowire-based circuits, we utilize an on-chip photocurrent pump-probe spectroscopy based on coplanar striplines. We identify a photothermoelectric current and a drift transport of photo-generated holes to the electrodes as the dominating ultrafast photocurrent contributions. Moreover, we show that THz-radiation is generated in the optically excited InAs nanowires, which we explain by a photo-Dember effect. Our results are relevant for nanowire-based optoelectronic and photovoltaic applications as well as for the design of nanowire-based THz-sources.

Single-Cell Studies of Stem Cells in Micro-Trenches

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Single cell studies give insight on the time course of the differentiation in individual stem cell and their role in population dynamics. This is specially important in studying the fate of stem cells [1]. However, statistically significant data requires high throughput single cell devices. We developed microfluidic devices with arrays of micro-wells for single cell investigation. This semi-3D structures are made of PEGDA (polyethylene glycol diacrylate), an inert hydrogel. Length and width of micro-trenches are optimized to hold four cells in one line but apply no mechanical stress on them. We use spherical, non-adherent MEL (murine erythroleukemia) cell-line as a model system for stem cells. We successfully tracked single cell over two generations in one trench. Afterwards, these trenches would be used to observe the differentiation of bone-marrow derived progenitor cells into either Macrophage (M) or Granulocyte (G) lineage. It is known that this differentiation happens within two generations. Stem cell differentiation is characterized by the expression of specific surface markers. Here, we developed a label-free technique based on analysis of Brownian motion to detect differentiated cells. The bottom surface of micro-well is functionalized with the antibody of the surface marker. Differentiated cells will bind to this surface while non-differentiated cells move freely. The Brownian motion analysis distinguishes the cells that are attached to the surface, and therefore has been differentiated. The developed micro-structures and label-free detection technique are promising approaches toward high throughput single cell tracking of stem cell fate. This provides an efficient method to study the fate of individual stem cell on the one hand, and get statistically significant data from parallel observation on the other hand.

[1] Schroeder, T. "Long-term single-cell imaging of mammalian stem cells", Nat Meth., 2011, 8, S30-S35

Interaction of latex beads with surface acoustic waves in microfluidic devices

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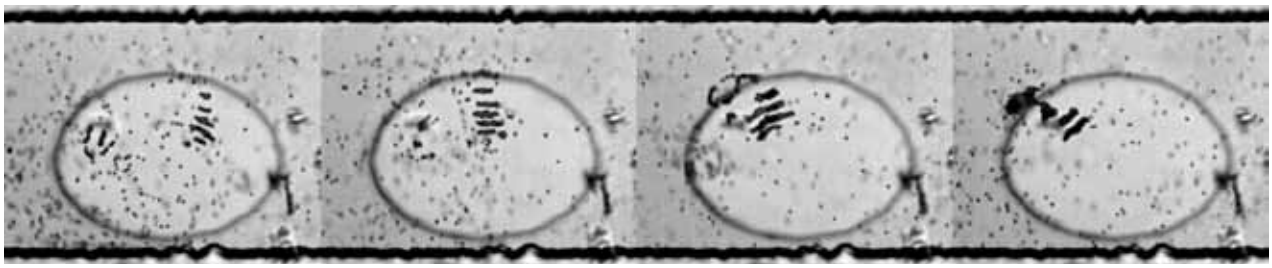
One fast-growing field of research in nano-biotechnology is the development of µ-TAS (micro total analysis systems) and accordingly the development of lab-on-a-chip-systems. Those mini-labs utilize the principles of microfluidics and are offering a huge amount of applications. Important building blocks of such systems are the transportation, manipulation, mixing or even sorting of particles in fluids. For experiments, acoustic methods are most important. Hereby we mostly use waves which are propagating along a surface, so called SAW's (surface acoustic waves). Those high frequency waves (MHz-order) are generated from IDTs on a LiNbO3-substrate. The microchannels are cheap, disposable PDMS devices which are made by lithographical processes. One goal to achieve is to arrange particles according to size. Therefore we use mixtures of latex beads with different sizes were we can sort out one specific beadsize depending on the adjusted frequency of the IDT. Mixtures of beads from 1µm - 10µm can be sorted in a frequency range from 75MHz - 300MHz. 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.



The image shows the movement of beads from right to left simply by varying the IDT's frequency in steps of 1 MHz

A Born-Haber cycle for monolayer self-assembly at the liquid-solid interface – quantifying the enthalpic driving force

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Department of Physics, TUM School of Education, Tech. Univ. Munich, Schellingstr. 33, 80799 Munich and Deutsches Museum, Museumsinsel 1, 80538 Munich

We used terephthalic acid (TPA) monolayers at the nonanoic acid (9A) / graphite interface as model system to study the enthalpic driving force for monolayer self-assembly at the liquid-solid interface. The system was independently and consistently studied by both experimental techniques and theoretical methods. Unfortunately, the decisive enthalpy difference between TPA molecules in solution and TPA molecules incorporated into the monolayer is difficult if not impossible to assess. However, by using an effusion cell, UV/VIS absorption spectroscopy, and temperature programmed desorption, we experimentally quantified the sublimation enthalpy, the enthalpy of dissolution, and the binding energy of TPA in the monolayer with respect to vacuum. By using the principle of the Born–Haber cycle, the adsorption enthalpy from solution into a monolayer on graphite was quantified for the first time. The agreement of the experimental enthalpies with molecular mechanics and molecular dynamics simulations is remarkable and provided further confidence in the quantitative assessment. Determination of the concentration threshold below which monolayer self-assembly becomes thermodynamically unstable facilitates an indirect quantification of the entropic cost of self-assembly. Comparison with values of translational and rotational entropy that were calculated according to established methods suggests that solvation of the TPA molecules plays an important role.

Influence of scattering and screening processes on the propagation of photogenerated charge carriers in a 2DEG

Markus Stallhofer,[1] C. Kastl,[1] C. Karnetzky,[1] M. Brändlein,[1] D. Schuh,[2] W. Wegscheider,[3] G. Abstreiter,[1] J. P. Kotthaus,[4] and A. W. Holleitner[1]

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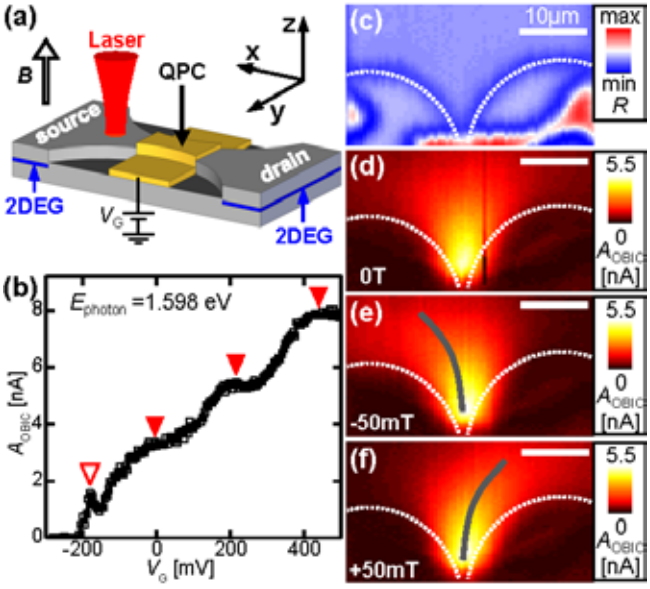
Utilizing the so called optical-beam–induced-current (OBIC) technique, we spatially resolve and analyze the non-equilibrium flow-patterns of photogenerated electrons in a GaAs based two-dimensional electron gas (2DEG) at a perpendicular magnetic field, as shown in Fig. 1 [1, 2]. We observe laterally curved trajectories with a radius being inversely proportional to |B|, as expected for cyclotron motion. However, the radii of the measured trajectories are 10 to 30 times larger than anticipated. Both the experimental findings and Monte Carlo simulations suggest that due to an enhanced influence of electron-electron scattering, the radius of the trajectories of hot electrons is generally enlarged. Furthermore, the extracted propagation length of the photogenerated electrons in the 2DEG depends non-monotonically on the laser intensity [3]. For the lowest excitation intensities, we determine a quasi-ballistic transport regime in which the measured propagation length of the photogenerated electrons approaches the mean free path lmfp of the 2DEG without laser excitation. With increasing excitation intensity, this propagation length decreases because of an increased scattering phase space and, finally, it increases again due to screening of momentum scatterers at higher densities of the photogenerated electrons. Our observations underline the predominant influence of scattering and screening processes in mesoscopic and nanoscale photodetectors.

We acknowledge financial support by the German Science Foundation DFG (Ho 3324/4), the Nanosystems Initiative Munich (NIM), and the Center for NanoScience (CeNS).



(a) Experimental method. (b) AOBIC as function of VG. Quantization steps reveal one-dimensional subbands (filled triangles).

(c) Spatially resolved reflection map. (d)-(f) Spatial map of AOBIC for (d) |B|= 0 T, (e) -50 mT, and (f) 50 mT

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[2] M. Stallhofer, C. Kastl, M. Brändlein, D. Schuh, W. Wegscheider, J. P. Kotthaus, G. Abstreiter, A. W. Holleitner, Phys. Rev. B (2012), accepted.

[3] M. Stallhofer, C. Kastl, M. Brändlein, C. Karnetzky, D. Schuh, W. Wegscheider, A. W. Holleitner, Phys. Rev. B (2012), accepted.

Impact of nanoparticles on the phase state of phospholipid membranes

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The understanding of the uptake of nanoparticles (NPs) to living cells starts with gaining insight in their interaction with the cell membrane and with the lipid bilayer as its basic structure respectively. Calorimetric investigations on lipid vesicles reveal changes of the the thermodynamic state of lipid membranes upon particle contact. In the case of silica nanoparticles size dependent effects are observed and explained by a Landau type model including the elastic energy of different membranes. It was shown in earlier work that changes of the thermodynamic state can trigger transport relevant processes like pore formation and morphological transitions. Indeed we show that particle induced pore formation by means of voltage clamped black lipid membranes (BLMs). Microscopic studies on giant unilamellar vesicles (GUVs) reveal that attractive forces between particles and membrane can lead to a phase transition triggered uptake of particles into the vesicle volume. These findings give a deeper insight in possible interactions between particles and pure lipid membranes and emphasize their relevance for uptake mechanisms in biological systems.

Detailed quantification of nanoparticle uptake by cells reveals that silica particles are more harmful to endothelial than to cancer cells

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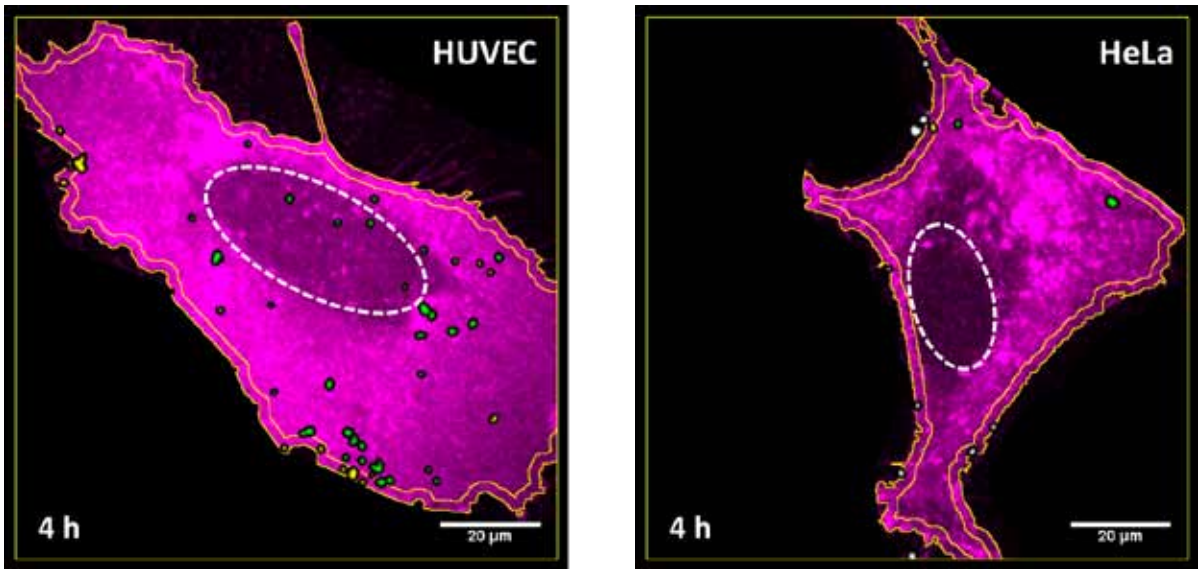
Nanoscaled silica particles have found a number of applications as additives to pharmaceutical drugs, cosmetics, food and in biomedical and biotechnological fields such as biosensors, biomarkers and cancer therapy. For this reason it is of paramount importance to assess the potential risk of silica nanoparticles to human health. In this study we investigate the impact of 310 nm silica nanoparticles on human vascular endothelial cells (HUVEC) in comparison to a cancer cell line derived from the cervix carcinoma (HeLa). We show that the amount of internalized nanoparticles is cell-type dependent and that it can be correlated with cytotoxic effects. We use live-cell imaging followed by digital image analysis [1] to visualize and quantify the uptake of silica nanoparticles into either HUVEC or into HeLa cells (Figure 1). More than 120 cells of each cell type were analyzed for incubation times of 1 to 4 hours applying the same controlled conditions. Our results show that over time the amount of intracellular particles for HUVEC always exceeds the amount measured for HeLa cells. The difference reaches up to 20 times more particles taken up into the endothelial cells after 4 hours. Interestingly, this disparity in the number of taken up nanoparticles is reflected by the metabolic activity and membrane integrity of the individual cell types [2], what indicates that HUVEC are more sensitive than HeLa cells upon silica nanoparticle exposure.

[1] A. A. Torrano, J. Blechinger, C. Osseforth, C. Argyo, A. Reller, T. Bein, J. Michaelis, C. Bräuchle. A fast analysis method to quantify nanoparticle uptake on a single cell level (Nanomedicine, 2012, under review).

[2] J. Blechinger, A. T. Bauer, A. A. Torrano, C. Gorzelanny, C. Bräuchle, S. W. Schneider. Silica Nanoparticles: Nanotoxicity is Dependent on the Uptake Behavior of the Cell and Therefore Cell Type Dependent (Small, 2012, submitted).



Confocal live-cell imaging of 310 nm silica nanoparticles internalized by HUVEC and HeLa cells after 4 hours of incubation time. Cells were fluorescently labeled with CellMask™ and appear in magenta. Nanoparticles were labeled with perylene. Our evaluation method [1] creates a 3D representation of the cell with three different regions. Nanoparticles are then pseudo colored according to their location. Intracellular particles are displayed in green, membrane-associated in yellow and extracellular ones in gray. The detailed quantification achieved by this method allowed us to determine that HUVEC are up to 20 times more efficient than HeLa cells to internalize 310 nm silica nanoparticles.

Experimental demonstration of genetic-information emergence in a catalytic polymer soup

Shoichi Toyabe and Dieter Braun

Systems Biophysics, Faculty of Physics, LMU Munich

We demonstrate the emergence of genetic information in a catalytic polymer soup by numerical simulations and preliminary experiments. One of the most distinguished properties of living systems is that they sustain genetic information and reproduce it. A proto-life form is considered to emerge in a molecular soup comprising a variety of catalytic polymers in the prebiotic earth. Although the emergence of genetic information is thought to be the crucial step for the emergence of the proto-life form, the mechanism remains elusive. We performed ligase chain reactions of DNA strands of semi-random sequences under a nonequilibrium flux by serial dilutions that simulates a likely prebiotic environment. DNA sequences form a reaction network, where each sequence is related to others by template-directed ligations. The ligations elongate the strands and increase their sequence diversity basically. However, our numerical simulation indicated that the symmetry breaks spontaneously. The network self-organized into an ordered state where a stochastically chosen small set of sequence motifs is dominant. The mechanism is as follows. The serial chain reactions in the network amplify strands not exponentially like ordinary chain reactions but hyperbolically. This hyperbolic property with the nonequilibrium driving amplifies spontaneous fluctuations and sustains it beyond a Darwinian selection. Such a spontaneous symmetry breaking is nothing but the emergence of genetic information; the ordered states are physically equivalent, chosen stochastically, and have sufficient stability. We can also code information by external stimulus such as biased compositions of initial strands.

Chemical warfare and survival strategies in range expansions

Gabriele Poxleitner, Markus F. Weber, Elke Hebisch, Erwin Frey, and Madeleine Leisner

Department of Physics and Center for NanoScience (CeNS), Ludwig-Maximilians-University (LMU) Munich, Munich, Germany

Bacterial communities represent complex and dynamic ecological systems. Different environmental conditions as well as bacterial interactions determine the establishment and sustainability of bacterial diversity and can lead to the formation of segregation patterns during range expansions. Stable coexistence of bacterial strains is often only possible under well-defined conditions. Here, we study different ecological scenarios for combinations of *Escherichia coli* strains representing the Colicin E2 system. In this system, a colicin producing strain C competes with a colicin resistant strain R, and a colicin sensitive strain for new territory. We observe that the different ecological scenarios lead to either single-strain dominance, pairwise coexistence or coexistence of all strains. In order to elucidate the mechanisms used for surviving a range expansion, we developed a stochastic agent-based model to capture the scenarios in silico. In a combined theoretical and experimental approach we were able to show that the level of biodiversity depends crucially on the strains' growth rate ratios and relative initial amounts in the droplet of inoculation, as well as on the range of the toxic colicin interaction.

Nanostructured Interfaces in Hybrid Solar Cells

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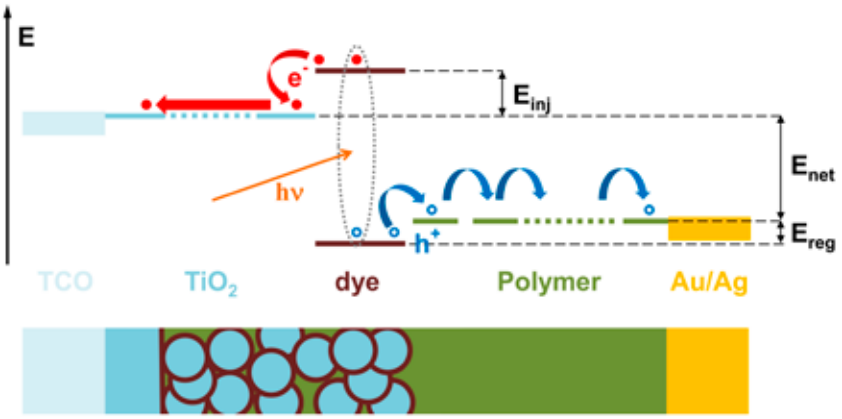
Organic solar cells are a promising technology due to easy processibility and potential low cost production. Power conversion efficiencies beyond 8 % have been reported recently for polymer-fullerene bulk heterojunction solar cells. However, the morphology of the active layer cannot be directly controlled. There are only limited studies on morphological effects on device physics and the "ideal" morphology is still unknown. The introduction of nanostructured TiO_2 is an interesting approach to influence the morphology of the bulk heterojunction. Organic material can be easily infiltrated into the TiO_2 which also exhibits favorable electronic properties as electron collecting electrode. The organic acceptor can also be completely replaced with the inorganic TiO_2 in so called hybrid solar cells. The TiO_2 can be modified by decoration with monolayers of dye molecules or other interfacial materials thus adjusting the energetic landscape of the TiO_2 surface. Thus, control over the properties of the hybrid interface is possible. Additionally, the heterojunction morphology can be directly controlled via shape and structure of the TiO_2. The main aim of this project is to understand the influence of heterojunction morphology on device physics and identify requirements for an optimized organic-inorganic junction. Loss mechanisms like recombination and insufficient exciton separation should be monitored to reveal principle design rules for hybrid solar cells.



Geometry and working mechanism of a hybrid solar cell. A film of sintered TiO_2 nanoparticels on a transparent conductive oxide substrate is decorated with a monolayer of dye molecules and infiltrated with a hole conducting polymer. Upon photon absorption in the dye or the polymer charges are separated at the inorganic-organic interface and collected at the external electrodes.

Thermal Stress of Supported Lipid Bilayer Induces Uniform Radius Tubules

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Biomolecular Science and Engineering Program and Physics Department, University of California, Santa Barbara, California 93106, USA

Biological membranes spatially transform in response to environmental stresses. Adhesion (e.g., to a culture plate or a cytoskeletal network) likely influences this remodeling, but little is quantitatively known about the process. Supported lipid bilayer (SLB) is a model membrane system in which a planar bilayer is adsorbed to surface. We study zwitterionic SLB on a glass surface to quantitatively investigate fluid bilayer transformation from a planar to a tubular morphology. A large mismatch in thermal expansivity forces the bilayer to expand relative to its support upon heating. Under a fixed temperature ramp (~0.8°C/min), small increases in temperature (~1°C) cause the bilayer edge to creep along the surface. Larger increases (>5°C) also cause semi-flexible lipid worms to extend from the SLB, since edge creep is too slow to accommodate the expansion. Through osmotic swelling, we demonstrate that these worms are bilayer tubules. Individual tubules are typically < 0.2 μm in diameter, but can reach hundreds of microns in length. At high ionic strength, these sub-resolution tubules adhere to the SLB, allowing us to measure their radii to within ±5 nm based on fluorescence intensity. Radii appear uniform to within ~6% along any given tubule but vary from tubule to tubule by more than 50%. Such large variation in radius occurs even in tubules separated by only tens of microns. The distribution of radii is insensitive to the details of the temperature change (e.g., the initial or final temperature or the magnitude of increase), suggesting that microscopic variations in the texture or chemistry of the surface play a dominant role in determining tubule radius.

High-resolution live-cell imaging of photoinduced drug delivery from multifunctional mesoporous silica nanoparticles

Veronika Weiß, Stefan Niedermayer, Alexandra Schmidt, Christian Argyo, Stephan Mackowiak, Thomas Bein , Christoph Bräuchle

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Colloidal mesoporous silica core-shell nanoparticles (CMS) have attracted great attention in recent years as versatile vehicles for drug delivery. CMS nanoparticles offer high surface areas and pore volumes, defined and tunable pore sizes, and various functionalization possibilities of the inner and outer surface.[1] After uptake of the CMS nanoparticles by cancer cells, a major bottle-neck in drug delivery is the endosomal entrapment. To overcome this obstacle, various strategies in the field of drug delivery through nanoparticles have been investigated. For example, it was shown that photosensitizers can open up the endosome upon light irradiation as has been employed in photodynamic therapy.[2] Previous work in our groups has taken advantage of this by combining CMS nanoparticles, surrounded by a supported lipid bilayer (SLB), with photosensitizers.[3,4] Now we are working on further improvements on the nanoparticles. On the one hand we changed the photosensitizer from blue to red light activation. On the other hand we replaced the nanoparticle cover from supported lipid bilayers to a pH-dependent polymer. The polymer is water insoluble at neutral pH, and gets water soluble in acidic compartments. Therefore it is able to release drugs, out of the CMS, already in the endosome and only the endosomal membrane itself must be opened by the photosensitizer. A major improvement to previously published work is the better biocompatibility and a potentially deeper penetration of the excitation beam into the tissue thanks to the excitation near the optical transparent window. To gain insights into the mechanisms of nanoparticle uptake, trafficking and endosomal escape of drugs, highly sensitive fluorescence microscopy is used.

Acknowledgement: The Authors are grateful for funding from DFG through the SFB 749 and the Center for NanoScience CeNS.

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Dynamical Diversity of a Compartmentalized Programmable Biochemical Oscillator

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Compartmentalization and small molecule numbers have a strong influence on the dynamics of chemical processes in living cells. Statistical variations in molecule numbers may lead to considerable variability within populations of superficially identical cells [1]. Furthermore, the stochastic nature of chemical reactions noticeable at low molecule numbers results in 'biochemical noise', leading to additional cell-to-cell variations in gene expression levels [2]. Here we describe and analyze the emergence of variability in an in vitro transcriptional system – a programmable biochemical oscillator [3] – compartmentalized into femto- to picoliter volume microemulsion droplets [4]. Depending on the size of the droplets, strong variations in amplitude, frequency, and phase are observed. Numerical simulations suggest that this dynamical diversity is caused mainly by statistical variations in the concentrations of the oscillator species, and hence is similar to 'partitioning' effects arising in cell division.

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Tuning the Activity of the Hammerhead Ribozyme

Paul Zakrevsky, Yen-Ping Lin, and Luc Jaeger

University of California - Santa Barbara, USA

In nature, RNA molecules adopt complex three-dimensional folds making use of both Watson-Crick and non-canonical base pairing interactions. The *Schistosoma mansoni* hammerhead ribozyme is a self-cleaving RNA motif, which contains a loop-receptor tertiary interaction composed non-canonical base pairs. This loop-receptor interaction occurs away from the catalytic core of the ribozyme, but is required for ribozyme activity at low magnesium concentrations. The primary nucleotide sequence of the receptor has the ability to adopt two distinct local secondary structures. This potential for the receptor to adopt two conformations is not unique to the *S. mansoni* hammerhead, but is also seen in hammerhead ribozymes from multiple other organisms. We have designed a tectoRNA self-dimerization system based on the loop-receptor interaction from the *S. mansoni* hammerhead, and assayed multiple receptor variants for their ability to bind. The results from several mutant receptors indicate that the wild-type receptor exists in equilibrium between two conformations, one that facilitates loop-receptor binding, and one that disrupts the interaction. A further investigation in to the activity of the full-length ribozyme indicates that the ribozyme's activity can be tuned by influencing the conformational equilibrium of the receptor to favor one state or the other. These *in vitro* results suggest the wild-type loop-receptor interaction is sub-optimal, and we theorize it may be used to regulated activity *in vivo*.

Presenting Authors

Hotels

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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 € 8.00 (pasta course, main course, side order of vegetables or salad, yoghurt, bread and water). There are also reduced menus for € 4.50 (pasta course, side order of vegetables or salad, water and bread) and € 5.50 (main course, side order of vegetables or salad, water and bread). A bar is also available on campus and is located on the ground floor of Area 6 in the main building.

Timetables

TRAIN TO VENICE AND BACK TO MUNICH

To Venice (18.09.)		Back to Munich (23.09.)	
Munich Main station	**Venezia Santa Lucia**	**Venezia Santa Lucia**	**Munich Main station**
11:31	18:10	13:34	20:25

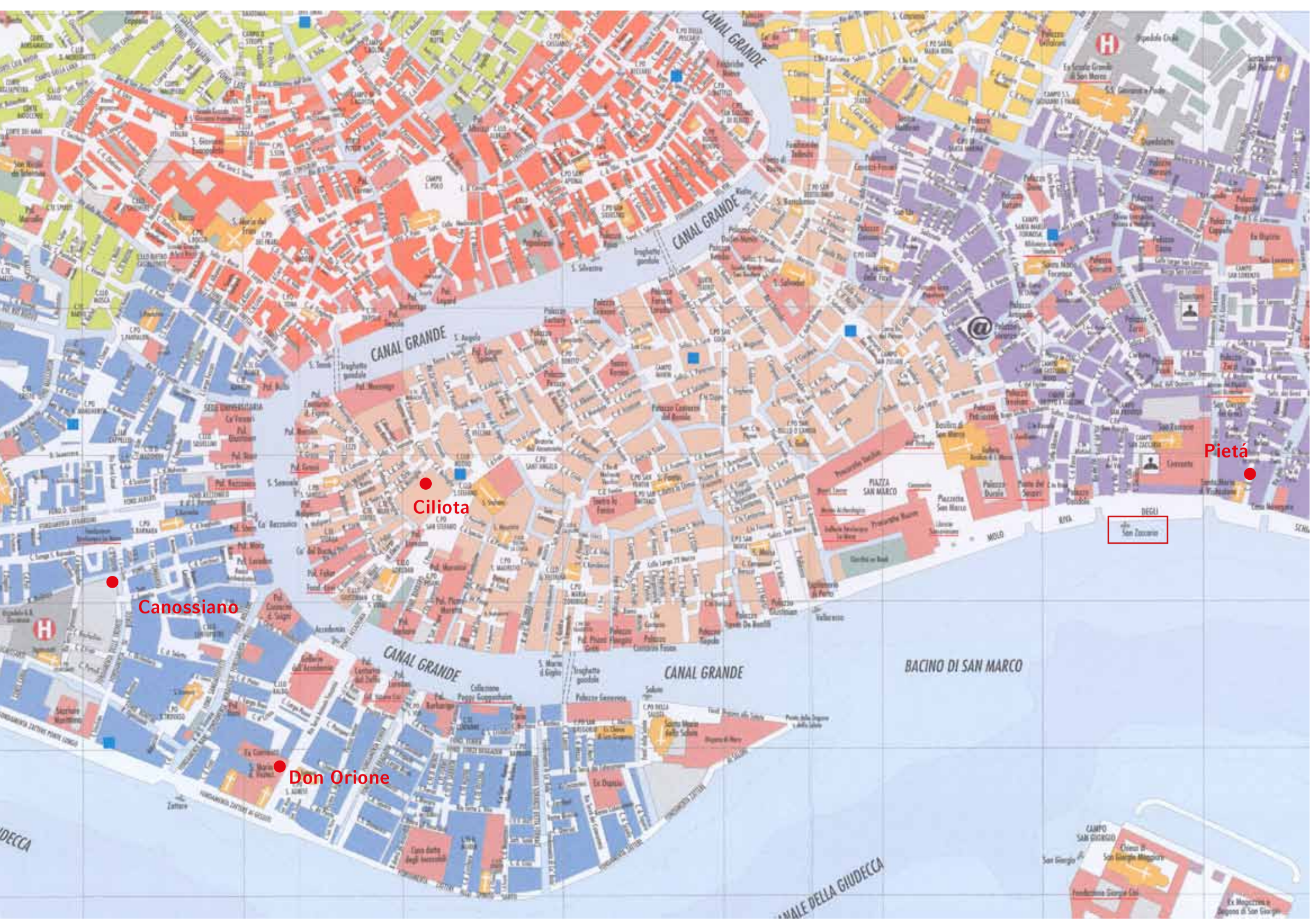
BOAT LINE 20 TO WORKSHOP LOCATION (SAN SERVOLO)

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*
8:15	*8:25*	*9:10*	*9:20*
8:35	*8:45*	*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*
1:30	*1:40*	*23.40*	*23.50*

Internet

Access to the WLAN internet on San Servolo:
Network: UNIVIU
Username: censworkshop2012
Password: censworkshop2012
Internet activity will be monitored and recorded as required by italian law.

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.


Ciliota
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BACINO DI SAN MARCO
PIAZZA SAN MARCO
DEGLI SCHIAVONI
San Zaccaria
CAMPO SAN GIORGIO
San Giorgio
CANALE DELLA GIUDECCA

Schedule

Time	Monday, September 17
	Boat departing at 9:00
09:20	**Welcome**
09:30	**Justin Molloy** NIMR London
10:15	**Erwin Frey** LMU München
11:00	**Coffee break**
11:30	**Todd Squires** UC Santa Barbara
	Lunch (12:15-14:30)
14:30	**Vincent Croquette** Ecole Normale Supérieure Paris
15:15	**Frank Koppens** ICFO Barcelona
16:00	**Coffee break**
16:30	**Immanuel Bloch** LMU München
17:15	**Alexander Govorov** Ohio University
18:00	**Welcome Reception**

Time	Tuesday, September 18
	Boat departing at 9:00
09:20	**Daniel Robert** University of Bristol
10:05	**Deborah Fygenson** UC Santa Barbara
10:50	**Coffee break**
11:15	**Sigmund Kohler** ICMM-CSIC Madrid
12:00	**Alexander Kuhn** Université de Bordeaux
	Lunch (12:45-14:30)
14:30	**Enrico Da Como** University of Bath
	Posters Session I & Coffee (15:15-17:00)
17:00	**Hubert Krenner** Universität Augsburg
17:45	**Alexander Högele** LMU München

Time	Wednesday, September 19
	Boat departing at 9:00
09:20	**Omar Saleh** UC Santa Barbara
10:05	**Klaus Kroy** Universität Leipzig
10:50	**Coffee break**
11:15	**Ullrich Steiner** University of Cambridge
12:00	**Thomas Mallouk** Penn State University
	Lunch (from 12:45)
	Informal Discussions

Time	Thursday, September 20
	Boat departing at 9:00
09:20	**Sarah Tolbert** UC Los Angeles
10:05	**Eli Barkai** Bar Ilan University
	Posters Session II & Coffee (10:50-12:35)
12:35	**Viola Baumgärtel** LMU München
	Lunch (13:20-14:30)
14:30	**Mansour Shayegan** Princeton University
15:15	**Valeri Dolgopolov** RAS Chernogolovka
16:00	**Coffee break**
16:30	**Günther Bauer** JKU Linz
17:15	**Gerhard Abstreiter** TU München
18:00	**Reception**

Time	Friday, September 21
	Boat departing at 9:00
09:20	**Donald Ingber** Wyss Institute Boston
10:05	**Joost Wintterlin** LMU München
10:50	**Closing Remarks**
	Boat leaves at 11:20 / 12:10 **Train to Munich leaves at 13:34 h from train station**