

# Recent Highlights in the Nanoworld

**Joint Workshop of  
CeNS, CNSI, SFB 513 and Biozentrum Basel**

**Wildbad Kreuth  
6-9 October 2002**



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**Program Committee:**

David Awschalom, Christoph Bräuchle, Andreas Engel, Hermann Gaub,  
Evelyn Hu, Jörg P. Kotthaus, Paul Leiderer

**Organisation:**

Monika Kaempfe, Evelyn Morgenroth

# Program

## Monday, 7th October 2002

- 7.30 – 8.20      *Breakfast*
- 8.20 – 8.30      **Jörg P. Kotthaus, CeNS**  
Welcome and Introduction
- 8.30 – 9.10      **Hermann Gaub, CeNS**  
Single Molecule Experiments by AFM-Related Techniques
- 9.10 – 9.50      **Kevin Plaxco, UCSB**  
Protein folding: the theory and application of a naturally-occurring, nm-scale self assembly process
- 9.50 – 10.30     **Paul Leiderer, SFB 513**  
Optical near field effects in nanostructuring and nanocleaning
- 10.30 – 11.00    *Coffee/Tea*
- 11.00 – 11.40    **Jochen Feldmann, CeNS**  
Photonics with Functionalized Nanoparticles \*
- 11.40 – 12.20    **David Awschalom, CNSI**  
Spin Gating and Nuclear Imprinting in Semiconductor Nanostructures
- 12.30 – 14.00    *Lunch*
- 14.00 – 14.40    **Teun Klapwijk, DIMES**  
Conduction in Organic Molecular Crystals: a Progress report \*
- 14.40 -15.20    **Martin Bastmeyer, Jena**  
Cell behaviour on micropatterned substrates
- 15.20 – 16.00    **Joachim Rädler, CeNS**  
Self-assembly of lipid/DNA nanostructures
- 16.00 – 16.30    *Coffee/Tea*
- 16.30 – 17.10    **Martin Stolz, BioZentrum Basel**  
Nanotechnology in Medicine: Moving from the Bench to the Patient
- 17.10 – 17.50    **Hsian-Rong Tseng, CNSI**  
From Molecular Recognition and Self-Assembly via Molecular Electronics to NanoElectroMechanical Systems
- 18.30 – 22.00    *Conference Dinner*

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\* no abstract available at time of print

## Tuesday, 8<sup>th</sup> October 2002

- 7.30 – 8.30      *Breakfast*
- 8.30 – 9.10      **Branden Brough, UCLA**  
Motion control of bio-molecules in fluidics
- 9.10 – 9.50      **Jan von Delft, CeNS**  
Kondo effects in strongly correlated quantum dots
- 9.50 – 10.30     **Dimitrios Fotiadis, BioZentrum Basel**  
Atomic Force Microscopy of Native Membranes
- 10.30 – 11.00    *Coffee/Tea*
- 11.00 – 11.40    **Evelyn Hu, CNSI**  
Quantum Dots and microcavities: a harmonious match
- 11.40 – 12.20    **Christoph Bräuchle, CeNS**  
Single Virus Tracing: Observation of a single dye-labelled virus on its infection pathway into a living cell
- 12.30 – 14.00    *Lunch*
- 14.00 – 18.00    **Hiking tour**
- 18.30 – 20.00    *Dinner*
- 20.00 – 22.00    **Poster Session**

## Wednesday, 9<sup>th</sup> October 2002

- 7.30 – 8.30      *Breakfast*
- 8.30 – 9.10      **Arthur Gossard, UCSB**  
Metal-semiconductor nanostructures\*
- 9.10 – 9.50      **Fritz Keilmann, CeNS**  
Optics on a nanometer scale
- 9.50 – 10.30     **Gerd Ganteför, SFB 513**  
Properties of mass-selected clusters: every atom counts
- 10.30 – 11.00    *Coffee/Tea*
- 11.00 – 11.40    **Andrew Cleland, CNSI**  
Nanomechanical Systems Probed by Electron Tunneling
- 11.40 – 12.20    **Thomas Bein, CeNS**  
Functional Nanostructures in Designed Spaces
- 12.30 – 14.00    *Lunch*
- 14.00 – 14.40    **Departure**

**Lectures**

**Abstracts**

# **Single Molecule Experiments by AFM-Related Techniques**

**Hermann E. Gaub**  
**Applied Physics and Center for Nanoscience**  
**University Munich, Amalienstr. 54, 80799 Munich**

The rapid development of novel experimental tools allowing the precise application and measurement of minute forces has opened exciting new perspectives in material- and life sciences. Particularly scanned probe techniques, which combine unparalleled spatial resolution with superb sensitivity, have allowed the development of a fundamental understanding of bio-molecular interactions and their nano-mechanical properties. Mechanical experiments with single molecules have become possible, and intramolecular as well as intermolecular forces could be studied directly at the molecular level. Molecular recognition processes between many different ligand-receptor systems were meanwhile investigated and these studies have provided detailed insight in the underlying fundamental mechanisms. Even adhesion between live cells was resolved at the single molecule level. The option to investigate mechanical properties of bio-molecules, such as polysaccharides, proteins and nucleic acids, attracted the interest of researchers, and in turn stimulated new developments in instrumentation. Proteins were unfolded at the resolution of individual helices with the precision of single amino acids. With the accessible force window, the whole range from entropic forces at several piconewtons (pN) to the rupture of covalent bonds at several nanonewtons (nN) can now be investigated. As single-molecule force spectroscopy continues to be a rapidly evolving field and now emerges as a widely used tool for the structural and functional investigation of bio-molecules in their native environment, this lecture will highlight the advances of the recent years.

# **Protein folding: the theory and application of a naturally-occurring, nm-scale self assembly process**

**Kevin W. Plaxco**

**Department of Chemistry and Biochemistry and Program in BioMolecular Science and Engineering, University of California, Santa Barbara CA 93106**

Small molecules quickly achieve their most favourable configurations via a random conformational search. Proteins, in contrast, fold some  $10^{30}$  times more rapidly than the predicted rate of a random search mechanism. My talk will describe our parallel, basic and applied studies of this spontaneous and extraordinarily precise self-assembly process. Our basic research emphasizes a simple, quantitatively predictive model of folding. Our applied studies focus on the task of controlling and harnessing folding's speed and specificity in order to create rapid, specific sensors and responsive materials.

# **Optical near field effects in nanostructuring and nanocleaning**

**Paul Leiderer, Fachbereich Physik, Universität Konstanz, 78457 Konstanz, Germany**

The interaction of light with small particles, first studied in detail by Mie already a century ago, is of utmost importance in many fields of science and has interesting applications well beyond optics. A well-known example are optical tweezers, which allow to manipulate a particle by trapping it in the focus of a laser beam and thus exert forces and carry out mechanical experiments on a micro- or even nanoscale. We report here on the interaction of small particles with pulsed laser light and investigations of the optical near field of such particles. As will be shown, nanomechanical phenomena and nanopatterning can be induced by the laser pulse: i) a combination of optical and mechanical effects can lead to the ablation of the nanoparticle from the surface, an effect which is used in the so-called “laser cleaning” technique to remove dust particles e.g. from silicon wafers; ii) if the intensity of the optical near field is high enough, it will give rise to local ablation of the substrate, an effect which on one hand can be applied for imaging the near field with a resolution much better than the wavelength of light, and on the other hand can be utilized for nanostructuring the surface on a relatively large scale (up to  $\text{cm}^2$ ) with a single laser shot. Since the typical resonance frequencies of nanoparticles are of the order of Gigahertz or higher, “nano-opto-mechanics” with laser pulses in the nanosecond to femtosecond range appears as a powerful tool for nanoscience.



# **Spin Gating and Nuclear Imprinting in Semiconductor Nanostructures**

**David Awschalom, Center for Spintronics and Quantum Computation,  
University of California, Santa Barbara**

There is a growing interest in the use of electronic and nuclear spin in semiconductor nanostructures as a medium for the manipulation and storage of classical and quantum information. Femtosecond-resolved optical experiments reveal a remarkable resilience of electronic spin states to environmental decoherence in a variety of bulk semiconductors, heterostructures, and quantum dots. Spin lifetimes are seen to exceed hundreds of nanoseconds, enabling the transport of coherent spin packets over hundreds of microns. Furthermore, coherent spin information can flow across interfaces of dissimilar materials in engineered structures over a broad range of temperatures, and the transport of spin information can be controlled with both electric and magnetic fields [1]. Recent experiments show that the electron  $g$ -factor can be continuously tuned by displacing the wave function within spin-engineered nanostructures [2]. Gate-voltage mediated control of coherent spin precession is obtained, including complete suppression of precession, reversal of the sign of  $g$ , and operation up to room temperature. In addition, hybrid ferromagnet/semiconductor systems have the potential for controlling coherent states by combining photonic, electronic, and magnetic manipulation of spin, thereby introducing new possibilities for engineering multifunctional spin-based electronics. Dynamical measurements in a series of hybrid structures unexpectedly reveal that the magnetization of a ferromagnet can be "imprinted" into the nuclear spin system [3]. Surprisingly, photoexcited electrons in the semiconductor spontaneously spin-polarize due to the proximity of an epitaxial ferromagnetic metal [4], exhibiting coherent dynamics that persist over time scales comparable in magnitude to traditional optical injection.

[1] I. Malajovich et al., *Nature* 411, 770 (2001).

[2] G. Salis et al., *Nature* 414, 619 (2001).

[3] R.K. Kawakami et al., *Science* 294, 131 (2001).

[4] R.J. Epstein et al., *Phys. Rev. B Rapid Commun.* 56, 121202 (R), (2002).

# **Cell behaviour on micropatterned substrates: limits of extracellular matrix geometry for adhesion, spreading and migration**

**Martin Bastmeyer, Universität Jena, Institut für Allgemeine Zoologie und  
Tierphysiologie, Erbertstr. 1, 07743 Jena, Germany**

Cell adhesion, spreading and migration requires the dynamic formation and dispersal of contacts with the extracellular matrix (ECM). In vivo, the number, availability and distribution of ECM binding sites dictate the shape of a cell and determine its mobility. To analyze the geometrical limits of ECM binding sites required for cell attachment and spreading, we used microcontact printing to produce regular patterns of ECM protein dots of defined size separated by nonadhesive regions. Cells cultured on these substrates adhere to and spread on ECM regions as small as  $0.25 \mu\text{m}^2$ . Dot separation of smaller than  $2 \mu\text{m}$  is interpreted as homogeneous substrate by a cell and spacing of  $5\text{-}25 \mu\text{m}$  induces a cell to adapt its shape to the ECM pattern. The ability to spread and migrate ceases when the dot separation is larger than  $30 \mu\text{m}$ . The extent of cell spreading is directly correlated to the total substrate coverage with ECM-proteins, but irrespective of the geometrical pattern. An optimal spreading extent is reached at a surface coating above 15%. Knowledge of these geometrical limits is essential for an understanding of cell adhesion and migration, and for the design of artificial surfaces that optimally interact with cells in a living tissue.

# **Self-Assembly of Lipid/DNA Nanostructures**

**Joachim Rädler, Sektion Physik der LMU München**

We present various strategies to assemble cationic lipid-DNA and polypeptide DNA nanocomplexes. For application in gene therapy well-controlled single-plasmid particles are formed in dilute mixtures of DNA and oppositely charged polypeptides. The internal structure, size and transport properties of the complexes are characterized using fluorescence correlation and small angle X-ray scattering. With respect to the FCS analysis we demonstrate in particular that fluorescence correlation can be applied to study the internal dynamics of macromolecules, if the size exceeds the focal diameter. Finally we present a novel assembly strategy based on synthetic bio-organic dendrimers as core units of functional supramolecular particles. Future developments of ionic networks in reverse oil phases are envisaged.

## **Nanotechnology in Medicine: Moving from the Bench to the Patient**

**Martin Stolz, Maurice E. Mueller Institute for Structural Biology,  
Biozentrum/University of Basel Klingelbergstr.70 4056 Basel**

The atomic force microscope (AFM) has opened completely new vistas for nanotechnology in clinical applications. Not only provides the AFM the "eyes" for imaging biological matter all the way from the mm via the  $\mu\text{m}$  to the nm scale, but it may also be used as the "fingers" to measure and manipulate biological matter at these different length scales.

As a first example, we have employed indentation-type (IT) AFM for *ex vivo* characterization of the mechanical properties of normal, diseased and engineered articular cartilage at the nanometer and the micrometer scale. Articular cartilage exhibits biomechanical properties so that it will stay intact for 70 or more years, unless pathological situations such as acute trauma or chronic inflammation may cause its gradual degradation. One of the most critical biomechanical parameters to assure this longevity of articular cartilage, is its elasticity which only tolerates small variations to stay intact.

For performing elasticity measurements at the micrometer scale we glued micrometer-sized spheres onto tipless cantilevers. As expected, the elasticity of articular cartilage determined at this length scale was in accordance with published values determined by clinical indentation devices at the millimeter to centimeter scale. For comparison, elasticity measurements obtained by indentation-type (IT) AFM at the nanometer scale (i.e. by employing sharp pyramidal tips) yielded elasticity moduli that were typically 100- to 500-fold lower.

In recent years, it has become clear that myocardial infarction is not a random event, but has a clear pathophysiologic target: inflammatory processes in atherosclerotic plaques lead to rupture of the so-called "cap" of the vulnerable plaques, thereby leading to the development of thromboses, followed by vessel obstruction, myocardial necrosis, and possibly death. Hence as a second example, we are using IT-AFM for *ex vivo* characterization of the atherosclerotic plaques. More specifically, we are developing methods for detecting the vulnerable plaques before a myocardial infarction develops, thereby having potential to ultimately yield completely new strategies for prevention of cardiovascular events.

For future clinical applications, our *ex vivo* measurements of articular cartilage elasticity by IT-AFM call for moving this diagnostic tool from the lab to the patient, i.e. by bringing the AFM directly into, for example, the knee joint using minimally invasive surgical procedures such as arthroscopy. Similarly, we are also implementing *in situ* detection of atherosclerotic plaques by taking advantage of their distinct physical and chemical properties by using multifunctional/ functionalized AFM tips that will be directly inserted into heart catheters.

# From Molecular Recognition and Self-Assembly via Molecular Electronics to NanoElectroMechanical Systems

Hsian-Rong Tseng

*Department of Chemistry and Biochemistry and  
California NanoSystems Institute,  
University of California, Los Angeles,  
405 Hilgard Avenue, Los Angeles, CA 90095  
[tseng@chem.ucla.edu](mailto:tseng@chem.ucla.edu)*

Mechanically interlocked molecules, such as catenanes and rotaxanes, can now be synthesized efficiently using template-directed protocols that rely upon molecular recognition, self-assembly and supramolecular assistance to covalent synthesis. By incorporating different non-degenerate recognition units into certain components, such compounds can be induced to switch between different ground-state geometries to create substantial relative movement in either rotary or linear manners. Thus, rotaxanes can be likened to linear motors and catenanes to rotary motors. They can be activated by switching the recognition units on and off chemically, electrically, and optically to mimic the moving parts in macroscopic and biological machines. This presentation will highlight the design and synthesis of various types of motor-molecules. Keeping the bottom-up approach very much in mind – with the assistance of top-down fabrication techniques – numerous applications of these molecular motors will be discussed. I will begin my talk by describing the development of some molecular electronic devices that utilize motor-molecules as the fundamental switching elements, and move toward the investigation of devices that exploit the mechanical properties of these molecules to create NanoElectroMechanical Systems.

## Selected Relevant Literature in Chronological Order

• “A [2]Catenane Made to Order,” *Angew. Chem. Int. Ed. Engl.* **1989**, *28*, 1396. • “A Molecular Shuttle,” *J. Am. Chem. Soc.* **1991**, *113*, 5131. • “Self-Assembly in Organic Synthesis,” *Synlett* **1991**, 459. • “Making Molecules to Order,” *Chem. Br.* **1991**, *27*, 714. • “[2]Rotaxanes and a [2]Catenane Made to Order,” *J. Am. Chem. Soc.* **1992**, *114*, 193. • “Whither and Thither Molecular Machines,” *Chem. Aust.* **1992**, *59*, 576. • “A Photochemically-Driven Molecular Machine,” *Angew. Chem. Int. Ed. Engl.* **1993**, *32*, 1301. • “A Chemically and Electrochemically Switchable Molecular Device,” *Nature* **1994**, *369*, 133. • “Concept Transfer from Biology into Materials,” *Nanobiology* **1994**, *3*, 149. • “Interlocked and Intertwined Structures and Superstructures,” *Chem. Rev.* **1995**, *95*, 2725. • “Self-Assembly in Natural and Unnatural Systems,” *Angew. Chem. Int. Ed. Engl.* **1996**, *35*, 1154. • “The Art and Science of Self-Assembling Molecular Machines,” *Nanotechnology* **1996**, *7*, 183. • “Synthetic Supramolecular Chemistry,” *Acc. Chem. Res.* **1997**, *30*, 1643. • “Artificial Molecular Machines,” *Angew. Chem. Int. Ed.* **2000**, *39*, 3349. • “A Photochemically Driven Molecular-Level Abacus,” *Chem. Eur. J.* **2000**, *6*, 3558. • “Working Supramolecular Machines Trapped in Glass and Mounted on a Film Surface,” *Angew. Chem. Int. Ed.* **2001**, *40*, 2447. • “Dynamic Covalent Chemistry,” *Angew. Chem. Int. Ed.* **2002**, *41*, 898. • “Chemical Synthesis Gets a Fillip from Molecular Recognition and Self-Assembly Processes,” *Proc. Natl. Acad. Sci.* **2002**, *99*, 4797.

## **Motion Control of Bio-molecules in Fluidics**

Branden Brough, Jeff Tza-Huei Wang, Pak Kin Wong, Joanne Deval, Chih-Ming Ho  
Mechanical and Aerospace Engineering Department  
University of California, Los Angeles  
420 Westwood Plaza, Engineering IV  
bqbrough@ucla.edu

Nanotechnology is the technology of characterizing and manipulating macro functional molecules for facilitating engineering processes. Controlling the position and motion of functional molecules, DNA/RNA, proteins, and supermolecules is essential for most biological and chemical processes including molecular recognition, biochemical reactions, and self assembly. Since these processes always take place in fluid flows, nanofluidics becomes the backbone for a wide spectrum of bio/nano applications such as genosensing, drug discovery, and health maintenance. A fundamental understanding of the interactions between intermolecular force fields and global forces provides the pathway for the development of efficient nano-fluidic technologies. Fluid flow is classically considered as a continuum in macroscale but it cannot be applied in nanospace where molecular effects dominate. In addition, the force fields used for motion control need to be expanded from primarily pressure forces to include electrokinetic forces, which are more powerful in the micro/nano world. This presentation will detail the many different force fields that influence molecular positioning motion and control in fluid flows as well as the natural phenomena that govern nano fluidic technology design and performance.

Examples include:

- Strategically positioned electrodes along a microchannel that can create electrophoretic forces, thus enabling molecular focusing for single target detection and potentially, molecular patterning.
- The use of hydrodynamic forces to stretch DNA in order to perform research at specific genomic sites.
- Dielectrophoretic forces which can be exploited to create chaotic mixing within self contained biomedical systems.

The work is supported by DARPA contracts monitored by SPAWAR. The travel fund is supported by CNSI.

Conference Abstract: "Recent Highlights in the Nanoworld" Wildbad Kreuth, Germany, October 6-9, 2002

# **Kondo effects in strongly correlated quantum dots**

**Jan von Delft, LMU München**

When a quantum dot is coupled sufficiently strongly to leads and the temperature is sufficiently low, the quantum dot can be viewed as a tunable Kondo impurity that gives rise to strong correlations between the dots and the leads. In particular, a strong resonance, the so-called Kondo resonance, develops in the density of states of the dot, which strongly affects the transport properties through the dot at low temperatures and voltages. After reviewing some of first generation of experiments that demonstrated the elementary features of tunable Kondo impurities, I shall highlight some recent developments in experiment and theory, that focus on more sophisticated incarnations of Kondo physics in quantum dots. These include a  $SU(4)$ -symmetric Kondo effect in a double quantum dot, and the non-equilibrium Kondo effect.

# **Atomic Force Microscopy of Native Membranes**

**Dimitrios Fotiadis and Andreas Engel**

M. E. Müller Institute for Microscopy, Biozentrum of the University of Basel  
Klingelbergstrasse 70, CH-4056 Basel, Switzerland

In the last few years, the atomic force microscope (AFM) has been used with great success to study the structure and function of numerous membrane proteins under physiological conditions. Most of the investigated membrane proteins were purified and reconstituted into two-dimensional crystals or densely packed vesicles prior AFM analysis. Although this situation is very close to the native state, i.e. the protein is integrated in a lipid bilayer, it does not provide the real image of the protein in its native environment. Here, we have studied the organisation of rhodopsin in native disk membranes by AFM. These membranes were isolated without application of detergents. The AFM topographs acquired unveil the organisation of rhodopsin in the eye retina and demonstrate that rhodopsin is packed into dimers.



# **Quantum Dots and Microcavities: A harmonious Match**

**Evelyn L. Hu**

CNSI

University of California, Santa Barbara

The interaction between quantum dot emitters and carefully constructed optical resonators can result in profound changes in the optical behavior of the system, influencing factors as fundamental as the spontaneous lifetimes of the emitters. The very narrow width of the quantum dot emission peaks, together with the very high optical selectivity that can be exercised by high quality resonators make it possible not only to tune the fundamental optical properties of the quantum dots, but also suggest various information processing approaches. This talk will describe recent results achieved for quantum dots within microdisk cavities and nanostructured photonic bandgap cavities. Exceptionally high Q values have been observed for both the microdisk structures ( $> 17,000$ ), and for the photonic bandgap materials ( $>4000$ ). Possible materials choices, fabrication approaches and systems realizations will be discussed.

**SINGLE VIRUS TRACING:  
OBSERVATION OF A SINGLE DYE-LABELED VIRUS ON ITS INFECTION  
PATHWAY INTO A LIVING CELL**

**C. Bräuchle, A. Zumbusch, T. Endreß, R. Bausinger, S. Maier**

Ludwig-Maximilians-Universität München, Department of Chemistry and Center of NanoScience,  
Butenandtstr. 5-13, Haus E, D-81377 München, Germany, E-Mail: [Christoph.Braeuchle@cup.uni-muenchen.de](mailto:Christoph.Braeuchle@cup.uni-muenchen.de)

A single fluorescent dye-molecule was attached to the protein capsid of an Adeno-associated virus in order to follow its migration into a living HeLa cell by single molecule techniques. Only one dye-molecule was used not to influence the specific virus-cell compartment interactions and to keep true physiological conditions. The infection entry pathway of such an individually labeled virus could be monitored in real time with high spatial (40 nm) and time (10 ms) resolution. A movie is obtained following the infection pathway from the first touch of the virus with the cell surface to the final deposition of the virus DNA in the nucleus of the cell. Thus all stages of the infection pathway can be monitored in great detail revealing the 'movie script' of a virus infection. A detailed picture of the processes involved was modeled. Adeno-associated viruses show promising prospects for the use in human gene therapy. For this purpose a detailed understanding of the interactions of the virus and the target cell is important.

The actual investigations of our single virus tracing method are experiments with synthetic viruses (used in gene therapy) and various important virus systems like Baculo Virus and HIV.

G. Seisenberger, M.U. Ried, T. Endreß, H. Büning, M. Hallek, C. Bräuchle, *Science* **294** (2001) 1929.

C. Bräuchle, G. Seisenberger, T. Endreß, M.U. Ried, H. Büning, M. Hallek, *ChemPhysChem* **3** (2002) 299.

# **Metal-semiconductor nanostructures**

**Arthur Gossard, UCSB**

I describe the growth and properties of multiple layers of epitaxial metal nanoparticles in semiconductors by the molecular beam epitaxy of ErAs particles in GaAs and InGaAs. The nanoparticle size and distributions are determined by the growth conditions and govern the electrical conduction and electron-hole recombination processes in the materials. The resultant composite materials are promising for high speed photoconduction and photomixing use.

## **Optics on a nanometric scale**

**Fritz Keilmann, Max-Planck-Institut für Biochemie, 82152 Martinsried  
phone 0049 89 8578 2617, email keilmann@biochem.mpg.de**

Optical near-fields exist close to any illuminated or radiating object. Near fields contain detailed information on the local optical property of the object surface, in principle on a 1 nm scale and even below. Measuring their amplitude and phase distribution is of great interest as this can be directly linked to local optical properties, at a resolution which is very much smaller than the wavelength.

We show that the probing tip of an AFM can be used to scatter the optical near-field so that a detector at large distance can register its amplitude and phase distribution over a sample surface, simultaneously with mapping the topography. We are interested in combining this new "scattering-type near-field microscopy" (s-SNOM) with spectroscopy to gain specific material contrasts, e.g., of free electrons or polar crystals by their plasmonic or phononic responses, respectively.

Knoll & Keilmann, APL 77, 3980 (2000);  
Hillenbrand & Keilmann, PRL 85, 3029 (2000);  
Hillenbrand, Taubner & Keilmann, Nature 418, 159 (2002).

# Properties of mass-selected clusters: every atom counts

**Gerd Ganteför**

Department of Physics, University of Konstanz,

D-78464 Konstanz, Germany

The structures and properties of very small particles depend strongly on the number of atoms. The most famous species are the “magic” clusters  $C_{60}$  and  $C_{70}$ , which are much more stable than all other carbon cluster in the size regime up to 100 atoms corresponding to a size of roughly 1nm. From such “magic” clusters new materials can be synthesized using the clusters as building blocks. However, in many other cases like, e.g., silicon even the structures of the free clusters are unknown. With laser spectroscopy we obtained structural information for bare silicon and gold clusters in the gas phase. In a second step, mass-selected clusters are deposited on a substrate and the modification of their chemical and physical properties by the substrate is studied using standard surface analysis tools. In addition, first results on the passivation of these - in most cases - highly reactive particles using hydrogen are presented.

# **Nanomechanical Systems Probed by Electron Tunneling**

**Andrew Cleland, CNSI**

My group has been integrating active electronic devices with nanomechanical systems, in order to probe both the mechanical and thermodynamical behavior of the integrated system. I will discuss experiments in which we use superconductor-normal metal tunnel junctions to develop an ultrasensitive bolometer and calorimeter, with which we have been able to confirm the observation of the quantum of thermal conductance, the integration of single-electron transistors with mechanical resonators, displacement sensing using an integrated quantum point contact, and the development of a double quantum dot integrated with an L-band mechanical resonator. I will briefly discuss the potential application of these types of integrated probes for quantum-limited measurements.

# Functional Nanostructures in Designed Spaces

Thomas Bein

*Department of Chemistry, University of Munich, Butenandtstr. 5-13 (E),*

*81377 Munich, Germany*

Design of structure and function at the nanometer scale often requires the use of novel strategies such as self-assembly, non-covalent interactions, host-guest chemistry, and structural templates. We will provide an overview on key aspects of this approach, including the synthesis of nanoscale zeolite crystals, growth of oriented channel structures on substrates, and inclusion chemistry using the nanoporous hosts as templates. Nanoscale zeolites are being used as building blocks for the seeded growth of thin microporous films with controlled crystal orientation. Another approach is the controlled growth of zeolites on molecularly functionalized surfaces. We have recently discovered a method for the production of nanoporous micelle-templated silica films with accessible, vertically-aligned one-dimensional pore structures, using an electric field. Microporous and mesoporous hosts in the form of bulk and thin films are being employed as structural templates for the synthesis and stabilization of molecular guests such as dyes, or of nanometer scale conducting structures such as conducting polymers, carbon filaments, and charge-transfer salts. These systems serve as models for the construction of more complex conducting networks at the nanometer scale.

**Posters**

**Abstracts**



## Poster Session

**P. R. Andres, U. S. Schubert**

Self-Assembly of Non-Helical and Helical Metallo-Supramolecular Polymers

**C. Bacca, H.-F. Pernau, E. Scheer**

Transport Measurements on Ferromagnetic and Semimetal Quantum Point Contacts

**Ch. Bartels**

Local Field Enhancement at Particles on Surfaces in Nanostructuring and Laser Cleaning

**J. P. A. Bayer, A. Gansen, R. Galeneder, V. Kahl, J. O. Rädler**

Charge Transport in Lyotropic Lipid/DNA Nano-Networks

**F. W. Beil, R. H. Blick, A. Wixforth, D. Schuh, M. Bichler**

Broadband Acoustical Tuning of Nano-Electromechanical Systems

**J. Crewett, S. Riechel, U. Lemmer, J. Feldmann, U. Scherf, K. Forberich, A. Gombert, V. Wittwer**

Microreplicated Organic Photonic Crystal Lasers

**J. DeRouchey**

Controlling Self-Assembly on Multiple Length Scales in DNA Polyplexes \*

**M. Dreher, M. Schwarz van Doorn, D. Fischer, G. Günther, H. Knoth, D. Löding, U. Mack,**

**P. Nielaba**

Structures, Phases and Phase Transitions in Nanostructures

**E. Dulkeith, A. C. Morteani, T. Niedereichholz, T. A. Klar, J. Feldmann**

Drastic Changes of Radiative and Non-Radiative Decay Rates from Fluorescent Molecules attached on Gold Nanoparticles

**N. Fertig, R. H. Blick, J. C. Behrends**

A Nanostructured Probe in Glass Substrates for Single Ion Channels in Cell Membranes

**L. T. C. França, S. Thalhammer, M. Hennemeyer, W. M. Heckl**

The Combination of Atomic Force Microscopy and Laser-Based Microdissection as a Tool for Molecular Biology

**K. Franzrahe, G. Schafranek, R. Stadelhofer, P. Nielaba**

Structures, Phases and Phase Transitions in Nano-Systems

**H. G. Frey, R. Guckenberger**

A New Kind of Aperture Probe with High Topographical and Optical Resolution for Fluorescence Near-Field Imaging by SNOM

**C. Friedsam**

Desorption of Single Poly(Acrylic) Acid Chains from various Substrates studied by AFM

**J. Grebing, T. Böhler, G. Ganteför, E. Scheer (1st Part)**

Transport Measurements on Nano-Particles

**C. Debuschewitz, E. Scheer (2nd Part)**

Spatial Dependence of the Superconducting Proximity Effect in Metallic Nanostructures

**S. Griessl, M. Edelwirth, W. Heckl**

*Multi-stable Switching of a Single Molecule in a Self-assembled Grid*

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\* no abstract available at time of print

***U. Hartmann***

Decoherence of Charge States in Double Quantum Dots due to Cotunneling

***S. Heinrichs, P. Maass***

Influence of Adatom Interactions on Second Layer Nucleation in Thin Film Epitaxy

***C. Hellriegel, C. Seebacher, C. Bräuchle, S. Altmaier, P. Behrens, M. Ganschow, D. Wöhrle***

Dynamical Behaviour of Single Molecules in Molecular Sieves

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Metallo-Supramolecular Polymers: Grafting and Cross-linking

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***C. Höhberger, M. Vogel, C. Meyer, H. Lorenz, K. Karrai***

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***E. M. Höhberger, J. Kirschbaum, R. H. Blick, J. P. Kotthaus, T. Brandes, W. Wegscheider, M. Bichler, D. Schuh***

Electron-Phonon Interaction in Freely Suspended Quantum Dots

***T. Hugel, W. Jöstl, H. E. Gaub, M. Seitz***

Desorption of Single Polyelectrolyte Chains from Solid Supports Studied by SMFS

***A. K. Hüttel et al.***

Coupling Electronic and Nuclear Spins

***S. Keller, D. Lumma, J. Rädler***

Probing Relaxations of Dilute  $\lambda$ -Phage DNA with Fluorescence Correlation Spectroscopy

***C. Kirchner, B. Stein, W. J. Parak, U. Klemradt, M. Seitz***

Surface Structural and Electrical Characterization of Organosilicate Layers on GaAs

***F. Kühner, A. Wehle, G. Mayer, M. Blind, H.E. Gaub***

Affinity Measurements between Aptamers and Proteins with an AFM

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On-Chain Defect Emission and Exciton Migration in conjugated Polymers

***M. Manghi***

Polymers and Polyelectrolytes at Interfaces

***C. Meyer, K. Karrai, H. Lorenz***

Optical Detection of Nanotweezers' Movement

**J. Müller, C. Sönnichsen, H. von Poschinger, G. von Plessen, T. A. Klar, J. Feldmann**  
Electrically Controlled Light Scattering of Nanoparticles embedded in a Liquid Crystal

**J. G. Müller, G. Raschke, J.M. Lupton, U. Lemmer, U. Scherf, J. Feldmann**  
Spectroscopy on Single conjugated Polymer Chains W. Sub-Fs Time-Resolution

**R. Netz**  
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**G. Neuert**  
Single Molecule Motor

**D. Scheible**  
The Nanomechanical Single Electron Transistor

**J. Schiener, S. Witt, R. Guckenberger**  
Atomic Force Microscopy of Chaperonin GroEL

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**M. Sindel, L. Borda, J. von Delft**  
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**B. Stein, M. George, J. C. Behrends, W. J. Parak, H. E. Gaub**  
Extracellular recordings with the Light Addressable Potentiometric Sensor (LAPS)

**M. Storz**  
Decoherence of coupled solid state qubits

**T. Taubner**  
Phonon-enhanced light-matter interaction in nanosystems

**F. Treubel, T. Ulbrich, A. Maier, B. Riedlinger, M. Albrecht, M. Maret, E. Beaupaire, R. Poinso, G. Schatz**  
Self-organized magnetic nanostructures of  $MPt_3(111)$  (M= Co, Cr, V) on  $WSe_2(0001)$

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A new form of bulk silicon consisting of „magic“ clusters?

**A. K. Wehle, M. Benoit, A. Kardinal, U. Weiland, R. Eibl, H. E. Gaub**  
Integrin Interactions Measured on Living Cells

**F. Wilhelm**  
Superconducting Quantum bits: Control, Coherence, and Read-Out

**D. Wouters, U. S. Schubert**  
Nanolithography and Nanochemistry in the sequential Build-Up of nanometer-sized Structures

**L. Xu, J. Feldmann**  
Photonic Crystal Properties of large Area Silica-Based Opal Film

**G. Weissmueller\***  
Protein-membrane recognition by AFM-force spectroscopy

# Self-Assembly of Non-Helical and Helical Metallo-Supramolecular Polymers

(P. R. Andres, U. S. Schubert)

*Poster abstract for the CeNS-Workshop at Wildbad Kreuth (October 6-9, 2002)*

Polymers bearing metal-complexes in the polymer backbone are of increasing interest for gaining access to a new class of inorganic/organic hybrid systems with i.e. new material, optical and conductive properties [1,2]. Also in nano-technology such self-assembled metallo-polymeric systems have the potential i.e. for the utilization as conductive and/or photoactive wires on a molecular level. Concerning the utilized ligand there is an increasing number of examples based on 4'-functionalized 2,2':6',2''-terpyridines which upon complexation with different transition metal ions lead to stable, linear metallo-polymeric structures [3]. In the work presented here, low molar mass *bis*-terpyridine building blocks are used as the ligands for metal-complexation with iron(II) ions. The ligand system is synthesized utilizing a facile synthesis starting from readily available (cyclo)-alkane-diols and 4'-chloro-2,2':6',2''-terpyridine [4]. Complexation with iron(II) ions then leads to metallo-polymers with alternating terpyridine-iron complex and alkane moieties. An additional challenge is the attempt to induce helicity into the polymer chain [5]. Therefore, a small, rigid, chiral *bis*-terpyridine has also been prepared and complexed with iron(II) ions. The characterization of the metallo-polymeric systems was carried out by <sup>1</sup>H-NMR-, UV/Vis- and CD-spectroscopic measurements. First results indicate the formation of metallo-polymeric chains as well as a chiral superstructure in the case where the chiral *bis*-terpyridine has been used as the ligand.

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# Transport Measurements on Ferromagnetic and Semimetal Quantum Point Contacts

*C. Bacca, H.-F. Pernau and E. Scheer*  
Department of Physics, University of Konstanz

The nature of transport channels of single-atom contacts of Au, Al, Pb and Nb have successfully been explained by a quantum-chemical model which correlates electronic transport to the chemical valence. Experimentally the information about a channel can be explored by analysing current-voltage characteristics in the superconducting state in which multiple Andreev-reflection occurs. Our next goal is to measure the conductance of atomic contacts made of the semimetals bismuth and antimony, which have complex electronic structures. The second goal is respectively analysis on magnetic quantum-point-contacts (e.g. Ni or Co with superconducting leads) in the signatures of spinpolarised transport channels.

Both experiments require very stable and clean atomic-size contacts. We produce these by nanofabrication and a break-junction-technique: Using electron beam lithography and a reactive ion etching step, a metallic nanobridge on an elastic substrate is suspended over a few micrometers between two anchors. The substrate is first bent till the bridge breaks at the center and the two parts are then slowly brought back into contact. The high mechanical reduction ratio of the bending mechanism allows controlling the formation of a very stable contact at atomic scale.

# **LOCAL FIELD ENHANCEMENT AT PARTICLES ON SURFACES IN NANOSTRUCTURING AND LASER CLEANING**

**Christof Bartels, Universität Konstanz**

We investigated the local enhancement of laser intensity near particles whose sizes are comparable to the wavelength of the laser radiation.

Experimentally, submicrometer particles of different shapes and materials have been deposited on smooth surfaces. Irradiation with femtosecond laser pulses caused an ablation pattern reflecting the intensity distribution under the particle. These ablation patterns have then been imaged by atomic force microscopy.

The intensity distributions found for spherical particles have been compared to the results of Mie's analytical theory which assumes a spherical particle in a homogenous medium. A numerical technique (MMP) has been applied to take the influence of the substrate into account. The influence of the particles' shapes was investigated by deforming polystyrene spheres through heating.

The near fields of triangular gold structures have been imaged. We found a strong intensity enhancement at the tips of the structures, and a dependence on the orientation of the tips relative to the polarization of the laser light. These results are in good qualitative agreement with numerical calculations.

While substrate damages caused by local field enhancement at dust particles generally have to be avoided in laser cleaning of high purity surfaces, the field enhancement at small particles can successfully be used in nanostructuring using 2-dimensional colloidal masks.

## **Charge transport in lyotropic Lipid/DNA nano-networks**

*J. P. A. Bayer, A. Gansen, R. Galeneder, V.Kahl, J. O. Rädler*

*Ludwig-Maximilians-Universität, Geschwister-Scholl-Platz 1, 80539 München, Germany*

The electro kinetic effects of charged macromolecules like DNA and charged membranes are poorly understood. In order to detect adsorbing DNA on cationic lipid bilayers, we developed a combined laser trap electrophoresis technique. This technique enables us to measure small changes of around 100 elementary charges, whereas the time resolution is on the order of seconds. Analysing the adsorption of DNA on positive membranes, we detected a stepwise decrease of the zeta-potential. These jumps in the zeta-potential correspond to the adsorption of one DNA molecule. Four DNA molecules neutralize the positive membrane. Adding more DNA to the membrane, we observe relaxation processes of the surface charge. This could be connected to DNA desorbing.

Inspired by the idea of molecular wires, we try to develop an organic molecular wire based on DNA. In contrast to many experiments, we want to investigate DNA tube-structures based on water/lipid/oil microemulsions. In this case, DNA is the track for positive charged counterions and cationic lipids, which will act as the effective charge carriers. This DNA based organic molecular wire system will be the base for a lot of experiments covering the area of molecular electronics.

# Broadband acoustical tuning of nano-electromechanical systems

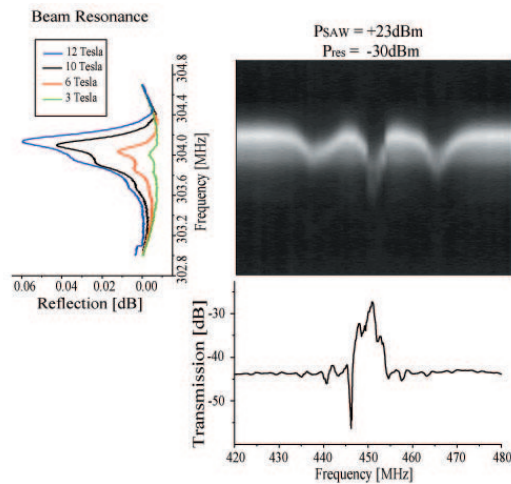
F.W. Beil, R.H. Blick, A. Wixforth,  
D. Schuh\* and M. Bichler\*

Center for NanoScience and Sektion Physik, Ludwig-Maximilians-Universität,  
Geschwister-Scholl-Platz 1, 80539 München, Germany.

\*Walter-Schottky-Institut der Technischen Universität München, Am Coulombwall,  
85747 Garching, Germany.

For a variety of applications in integrated communication and sensor devices nano-electromechanical systems (NEMS) will enable a new generation of tools [1]. So far conventional ways of driving NEMS are based either on high magnetic (magnetomotive) or electric fields (electromotive) which limits the use of NEMS devices.

Here we will present experiments utilizing an acoustic mode on a piezoelectric material (GaAs) to interact with a nanomechanical resonator operating at frequencies up to 300 MHz. The resonators are realized as free standing beams [2] with dimensions in the nanometer range placed in the acoustic path of a Rayleigh type surface wave (SAW), generated by conventional interdigital transducers (IDT). After characterizing the mechanical properties of the resonators via standard impedance spectroscopy [3] the influence of the SAW on the magnetomotively excited mode is observed. Fig. 1 shows the acoustic tuning of the resonator mode together with the corresponding SAW spectra. The off-resonant SAW enables broadband tuning of the inherent characteristics of the resonator, such as quality factor and eigenfrequency. This broadband mechanical interaction allows resonant driving of the resonator sensors when matching the frequency of the SAW to the resonators eigenfrequency such decreasing losses resulting from standard driving mechanisms.



**Figure 1:** Resonator-SAW interaction: To the left the dependence of the reflected spectra at the resonator on magnetic field is presented, showing the mechanical character of the resonance peak. In the lower graph the SAW spectrum corresponds well with the shifts of the mechanical resonance (greyscale plot) when the acoustic mode interacts with the beam.

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Corresponding author: F. W. Beil, Center for NanoScience and Sektion Physik,  
Ludwig-Maximilians-Universität, Geschwister-Scholl-Platz 1, 80539 München, Germany.  
phone: +49 (0)89 2180 3586, Fax: +41 (0)89 2180 3182,  
email: florian.beil@physik.uni-muenchen.de



# Microreplicated organic photonic crystal lasers

**J. Crewett<sup>1</sup>, S. Riechel<sup>1</sup>, U. Lemmer<sup>2</sup>, J. Feldmann<sup>1</sup>, U. Scherf<sup>3</sup>, K. Forberich<sup>4</sup>,  
A. Gombert<sup>4</sup> und V. Wittwer<sup>4</sup>**

<sup>1</sup>Lehrstuhl für Photonik und Optoelektronik, Ludwig-Maximilians-Universität München

<sup>2</sup>Lichttechnisches Institut, Universität Karlsruhe

<sup>3</sup>Lehrstuhl für Polymerchemie, Universität Potsdam

<sup>4</sup>Fraunhofer Institut für Solare Energiesysteme ISE, Freiburg

Surface relief gratings prepared by holographic exposure and subsequent microreplication offer a large area/low cost approach for producing 2D photonic crystals. It has already been demonstrated that a combination of UV-embossed nanostructures with optically amplifying organic semiconductors opens a novel route to large area photonic crystal lasers. Methods to engineer the bandgap by oblique evaporation of high refractive index materials are explored. These structures are decorated with organic semiconductors and the resulting laser properties are measured. The effects of the enhanced refractive index contrast on coupling length and photonic band structure are investigated. Additionally, different 2D grating geometries (square/hexagonal) are compared in terms of their photonic band structures and laser feedback mechanisms.

# Structures, phases and phase transitions in nanostructures

**M. Dreher, M. Schwarz van Doorn, D. Fischer, G. Günther,  
H. Knoth, D. Löding, U. Mack, P. Nielaba  
Universität Konstanz**

We have investigated structures, phases and phase transitions in solid nanosystems by classical Monte Carlo simulations, Path Integral Monte Carlo (*PIMC*) simulations and Car-Parrinello-methods (*CP*).

We studied the height growth stop of *Au* on *WSe<sub>2</sub>*, the reduction of the melting temperature with decreasing size of selforganized nanostructures of Indium on *WSe<sub>2</sub>* and the phase diagrams of adsorbed layers of *Ar<sub>x</sub>(N<sub>2</sub>)<sub>1-x</sub>* on graphite as function of *T*, mixing ratio and disorder average.

Elastic interactions of the constituents of alloys were studied with the help of Monte Carlo simulations, while the deposition of *Si<sub>4</sub>*-Clusters on *Au* were simulated using Car-Parrinell methods (*CP*) and analysed using the density functional theory.

A quantum mechanical three-dimensional hard sphere fluid was investigated in *PIMC* simulations and using Molecular Dynamic simulations we looked at the formation of a single atom contact in an *Au* wire.

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## **Drastic changes of radiative and non-radiative decay rates from fluorescent molecules attached on gold nanoparticles**

E. Dulkeith, A. C. Morteani, T. Niedereichholz, T. A. Klar and J. Feldmann  
Photonics and Optoelectronics Group, Physics Department and CeNS,  
University of Munich, Amalienstrasse 54, 80799 Munich, Germany

S. Levi, F. C. J. M. van Veggel, D. N. Reinhoudt,  
Laboratories for Supramolecular Chemistry and Technology, University of  
Twente, 7500 AE Enschede, The Netherlands

D. I. Gittins  
Max-Planck-Institute of Colloids and Interfaces, 14424 Potsdam, Germany

M. Moeller  
Abteilung Organische Chemie III/Macromolekulare Chemie-OC III, Albert-  
Einstein-Allee 11, Universität Ulm, D-89069 Ulm, Germany

Resonant energy transfer (RET) systems consisting of organic dye molecules bound to gold nanoparticles play an important role in materials science as well as in biophotonics. After excitation of the molecule the energy can be transferred resonantly to the metal nanoparticle. Supplementary to this non-radiative decay process one has to consider the effect the nanoparticle exerts on the radiative rate of the dye molecule.

We find that both processes play a crucial role in fluorescence quenching. Even for very small particles of 1 nm radius the fluorescence yield is reduced by 99.8 % [1]. Time-resolved fluorescence experiments have been performed on donor-acceptor systems composed of lissamine dye molecules attached to gold nanoparticles. The distance between the chromophoric part of the molecules and the particle surface is 1 nm. The time constants for RET vary on a picosecond time scale and decrease when the particle radius is increased from 1 nm to 30 nm. In addition the dye's radiative rate turns out to decrease by more than an order of magnitude in the presence of the gold nanoparticles. Qualitative agreement of these drastic changes of the decay rates with the model proposed by Gersten and Nitzan is found. Quantitative discrepancies can be explained by non-local effects.

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## **A nanostructured probe in glass substrates for single ion channels in cell membranes**

Niels Fertig, Robert H. Blick, and Jan C. Behrends

*Departments of Physiology, Semiconductor Physics and Center for NanoScience (CeNS), University of Munich, and Nanion Technologies GmbH, D-80336 Munich, Germany.*

The state of the art technique for analysing the function of single ion channel proteins is patch clamping with glass micropipettes. Inherent limitations of this approach include low (<100 kHz) bandwidth, inaccessibility of the channel-containing membrane for scanning probe (AFM, SNOM) and high-resolution optical techniques, low throughput (one measurement at a time) and the requirement for a highly specialised and skilled operator. We have, therefore, developed a planar equivalent of the patch pipette based on a  $\mu\text{m}$ -sized aperture in a glass chip that replicates the geometry of the aperture of a micropipette. These apertures are produced by a combination of lithography, wet-etching (HF) and single ion trace etching (SITE). We present both recordings from planar lipid membranes as well as whole cell (ensemble) and single channel currents recorded with this device from cell membranes. The probes show low capacitance and access resistance, easily admit a variety of optical and scanning probe techniques which will allow us to study dynamic structure-function relationships in single ion channels. They can, furthermore, be produced in arrays of 16 to provide simultaneous recordings to increase throughput. Because of the planar arrangement, there is no need for micromanipulation so that the process of contacting the cell membrane can be readily automated. A fully functional device containing 16 apertures is currently being developed that will dramatically speed the discovery process for ion channel active drugs in the pharmaceutical industry.

Supported by CeNS and the DFG (SFB 486, TPA6)

# THE COMBINATION OF ATOMIC FORCE MICROSCOPY AND LASER-BASED MICRODISSECTION AS A TOOL FOR MOLECULAR BIOLOGY

França, L.T.C., Thalhammer, S., Hennemeyer, M., Heckl, W.M.  
Institute for Crystallography – LMU, Munich, Germany  
[www.nano-geo.uni-muenchen.de](http://www.nano-geo.uni-muenchen.de)

The combination of atomic force microscopy (AFM) and laser-based microdissection provides a direct approach for the isolation of cell clusters, single cells and even cell components down to single chromosomes and chromosomal parts. Besides used as a high resolution microscope, the atomic force microscope can be used as a manipulation and isolation tool in the nanometer scale. The noncontact laser methods, *laser micromanipulation* and *laser pressure catapulting* (LMM&LPC), are used for the isolation of single cells and cell clusters from tissue sections and the isolation of genetic material. The laser precisely cuts around the selected area leaving a micron sized gap. The isolated specimen are subsequently ejected from the slide by single laser shots onto a collection device. The isolated material can be used for further genetics analysis.

In this work we present an overview of the combination of AFM and LMM&LPC for imaging, micromanipulation and microdissection of double stranded DNA and metaphase chromosomes for structural analysis of the genome organisation and molecular diagnosis. LMM and LPC were used for the isolation of: (i) single chromosomes and chromosomal fragments, (ii) detection of TT virus in single cells and tissue areas, (iii) isolation of single chloroplasts, and (iv) isolation of single tumor cells and areals from membrane mounted tissue sections.

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# Structures, Phases and Phase Transitions in Nano-Systems

K. Franzrahe, G. Schafranek, R. Stadelhofer, P. Nielaba  
Universität Konstanz

Classical Monte Carlo simulations of a two-dimensional, antiferromagnetic hard disk fluid showed the existence of a square lattice solid in the medium density region ( $\rho^* \in [0.70, 0.875]$ ) of the temperature-density phase-diagram, while in the high density region a triangular solid phase was observed.

Quantum mechanical Path Integral Monte Carlo Simulations were used to investigate, if this new quadratic phase is stable. It could be shown, that for  $T^* < 0.4$  there exists no stable quadratic phase in the quantum mechanical, antiferromagnetic fluid.

Investigations with classical Monte Carlo simulations on the phase transitions in binary mixtures of twodimensional hard disk fluids were also carried out. Various different phases could be identified for such fluids depending on the diameter ratio of the constituents.

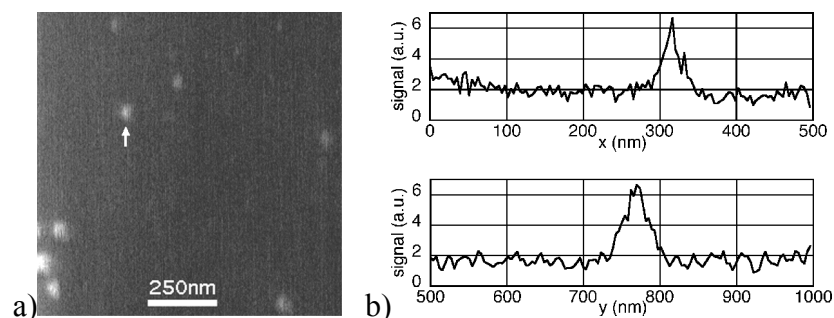
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# A new kind of aperture probe with high topographical and optical resolution for fluorescence near-field imaging by SNOM

Heinrich G. Frey, Reinhard Guckenberger

Max-Planck-Institut für Biochemie, Abt. Molekulare Strukturbiologie, 82152 Martinsried, Germany

We improve the optical and topographical resolution of scanning near-field optical microscopy (SNOM) by using a new kind of aperture probe. The central part of this probe is a metallic tip formed on the aperture of a conventional fiber probe. The tip concentrates the light, which passes through the aperture. Thus the advantages of aperture and apertureless SNOM are combined: high optical and topographical resolution with only a small background. When imaging fluorescent beads we observe a lateral resolution better than 40nm (full width half maximum).



a) Fluorescence image of dye loaded beads (diameter 7nm - 19nm)

b) Orthogonal cross-sections through the fluorescent spot marked by a white arrow in a).

The near-field shows a strong distance dependence. It decays to the half of its maximum value within 5nm distance of the probe to the bead in z-direction, thus promising even higher resolution with sharper tips.

# DESORPTION OF SINGLE POLY(ACRYLIC) ACID CHAINS FROM VARIOUS SUBSTRATES STUDIED BY AFM

Claudia Friedsam  
Ludwig Maximilians Universität München  
Center for NanoScience CeNS

AFM based force spectroscopy allows the measurement of intra- and intermolecular forces of single molecules [1,2]. It has recently been used to investigate the desorption of single polyvinylamine chains from silica, mica, gold and calcite surfaces [3].

In this work a new chemistry for the tip-attachment of the polymers was developed which improves the stability of the investigated system by far. Long term measurements for longer than one week with the same molecule which produce at least 20,000 force spectra became possible. This opens up the vista to perform very substantial and precise measurements with one and the same molecule. At the same time a variety of system parameters can be changed in situ one after the other.

The technique was applied to investigate a negatively charged polyelectrolyte, namely poly(acrylic) acid, in contrast to the positively charged polyvinylamine. The desorption of single poly(acrylic) acid chains from various unfunctionalized (silica, mica, gold, calcite) and functionalized surfaces (COOH-, OH- and CH<sub>3</sub>-terminated self assembled monolayers) under variation of the ions in solution, the ion concentration and the pH was measured. In some aspects this polyelectrolyte shows a completely different behaviour compared to polyvinylamine. In general the desorption forces belonging to the different substrates are slightly higher than those for polyvinylamine and no dependence on salt concentration was found which indicates a non-electrostatic desorption force. In some cases no desorption-plateaus were found but numerous ruptures at high forces appeared.

As a whole we have extended our possibilities to investigate the adsorption behaviour of polyelectrolytes in general and to create promising applications.

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# **Transport Measurements on Nano-Particles**

**J. Grebing, T. Böhler, G. Ganteför and E. Scheer**  
**Department of Physics, University of Konstanz**

Since their introduction in 1985 [1] mechanically controllable break-junctions (MCB) have become a widely used tool for the creation of single-atom contacts. While a lot of information can be obtained from measurements on these contacts their exact geometry on the atomic scale cannot be revealed. Thus no experimental data concerning the relation between the exact geometry of a contact and its conductance can be gained. A way to get these experimental data is to investigate the conductance of structures with well known atomic geometries. Our work which we hereby present is currently concentrated on Si<sub>4</sub> clusters and the famous C<sub>60</sub> Fullerene. Both of them have quite well known structures[2,3]. We want to deposit the particles in the gap of an opened MCB using electrostatic trapping [4]. After the deposition the measurements can be performed in situ under (U)HV conditions.

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The second part of the poster is devoted to the

## **Spatial Dependence of the Superconducting Proximity Effect in Metallic Nanostructures**

**C. Debuschewitz and E. Scheer**  
**Department of Physics, University of Konstanz**

The leaking of superconducting properties into a normal metal at an interface between a superconductor and a normal metal is called the 'proximity effect'. Its underlying process are the so called Andreev reflections. We investigate the spatial dependence of the proximity effect on a mesoscopic length scale by means of scanning tunneling spectroscopy. With a low temperature STM (below 1 K) we want to measure the density of states as a function of the distance to the interface between a normal metal (or a ferro magnet) and the superconductor.

# **Multi-stable Switching of a Single Molecule in a Self-assembled Grid**

**Stefan Griessl, Michael Edelwirth and Prof. Wolfgang Heckl**

The adsorption of Trimesic Acid (TMA) to a single crystal graphite surface has been studied under Ultra High Vacuum conditions. This work focuses on initiating a particular self-assembly structure by OMBE (Organic Molecular Beam Epitaxy). The structure is characterized by periodic non-dense-packing of the molecules. Two coexisting phases could be imaged by STM with sub-molecular resolution. Induced by directed hydrogen bonding, the organic molecules built in both cases a two-dimensional grid architecture with molecular caves. This two-dimensional host structure can accept single trimesic acid guest molecules at different positions. Furthermore the switching process of a single guest molecule within the molecular grid structure is demonstrated. STM induced movement of a single molecule to six stable positions was observed. These states of the molecular switch have a distance of 0.15 nm. The calculated energy barriers indicating that the switch is stable at room temperature are consistent with the experiment.

# **Decoherence of charge states in double quantum dots due to cotunneling**

**Udo Hartmann, Sektion Physik, LMU München**

Quantum computation needs a coherent time evolution. Therefore it is of central importance to minimize decoherence through external baths in particular in solid state systems. In this case, the basis states of a (charge) qubit are defined by the position of an additional, spin-polarized electron in the system of two laterally coupled quantum dots, i.e. one can find this electron either on the left or the right dot. The coupling of these two states can electrostatically be controlled by a quantum point contact between the two dots. The readout should work by using another quantum dot or by applying a transport voltage. We provide a theoretical analysis of this system. We observe several non-equilibrium transport regimes through the double-dot system and we propose optimum operating points for quantum calculation and measurement (control of decoherence through a non-equilibrium between the two leads).

# **Influence of Adatom Interactions on Second Layer Nucleation in Thin Film Epitaxy**

**Stefan Heinrichs and Philipp Maass**

Fachbereich für Physik, Universität Konstanz, Universitätsstr.10, 78457 Konstanz, Germany

We present a theory for the inclusion of adatom interactions in the nucleation process on top of islands in epitaxial growth. The interactions considered are due to ring barriers between pairs of adatoms and binding energies of unstable clusters. The theory is based on a master equation, which describes the time development of microscopic states that are specified by cluster configurations on top of an island. The transition rates are derived by scaling arguments and tested against kinetic Monte-Carlo simulations. As an application we reanalyze experiments to determine the step edge barrier for Ag/Pt(111).

## **Dynamical behaviour of single molecules in molecular sieves**

C. Hellriegel\*, C. Seebacher, C. Bräuchle,  
Department Chemie, LMU-München, Butenandtstr. 11, 81377 München, Germany

S. Altmaier, P. Behrens,  
Inst. f. Anorganische Chemie, Universität Hannover, Callinstr. 9, 30167 Hannover, Germany

M. Ganschow, D. Wöhrle,  
Inst. f. Organische und Makromolekulare Chemie, Universität Bremen, Postfach 330440,  
28334 Bremen, Germany.

The synthesis and the characterisation of functional materials which can be controlled on the length-scale of nanometres have found an increasing amount of scientific effort in recent years. Such materials are e.g. molecular sieves. The ordered structure in the nanometre range can act as a host-environment for the incorporation of fluorescent guest molecules. With these materials we intend to construct molecular devices such as optical switches, shutters or valves and rotors. To pursue these ideas it is feasible to characterise the dynamics e.g. the diffusion and the orientation of the included single molecules. The translational motion of individual TDI dye molecules incorporated into the organic part of a monolithic M41S-host was observed with confocal microscopy and characterised in great detail [1]. In addition, the orientations of individual Oxazine molecules with different sizes incorporated into an AlPO<sub>4</sub>-5 crystal were determined. It is shown that the orientational distribution function can only be evaluated with single molecule data. Additionally some of the molecules show distinct orientational jumps. The observation of orientational changes of single molecules is a promising step to the design of e.g. molecular switches.

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# Phase transitions of classical and quantum hard disks in external periodic potentials: a Path Integral MC Study

Peter Henseler, Wolfram Strepp and Peter Nielaba  
Department of Physics, University of Konstanz, D-78457 Konstanz, Germany

Hard and soft disks in external periodic potentials show rich phase diagrams including freezing and melting transitions when the density of the system is varied. We report on extensive Monte Carlo simulations for detailed finite size scaling analyses of various thermodynamic quantities like the order parameter, its cumulants etc. in order to map the phase diagram of the system for various values of the density and the amplitude of the external potential. For hard disks we find clear indication of a reentrant liquid phase over a significant region of the parameter space. Our simulations therefore show that the system of hard disks behaves in a fashion similar to charge-stabilized colloids which are known to undergo an initial freezing, followed by a re-melting transition as the amplitude of the imposed, modulating field produced by crossed laser beams is steadily increased. Detailed analysis of our data shows several features consistent with a recent dislocation unbinding theory of laser-induced melting. The differences and similarities of systems with soft potentials (DLVO,  $1/r^{12}$ ) are discussed.

In order to quantify the quantum effect of the finite particle masses on the phase diagram, we investigated the system by PIMC. We find a increased reentrance region which can be even larger than the freezing region. A possible explanation of this effect, based on quantum delocalisation in conjunction with the external potential, is presented.

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# Material specific mapping of nanosystems using visible and infrared s-SNOM

Rainer Hillenbrand, Max-Planck-Institut für Biochemie, Martinsried

Scattering-type scanning near-field optical microscopy (s-SNOM) uses the optical near-field interaction between an illuminated metal or dielectric probe tip and the sample surface[1-5]. Its spatial resolution is not limited by diffraction but rather by the actual size of the scattering probe tip (< 20 nm).

We describe the principles of contrast formation and compare the material specific measurements with two s-SNOMs, one operating at 633 nm wavelength, the other at 10  $\mu\text{m}$ .

In both microscopes we show examples of material-specific imaging of the same nanostructured, three-component sample. The achieved resolution is similar at both widely different wavelengths, reaching down to 10 nm. Common to both the mid-infrared and the visible wavelengths, the Au islands are the brightest objects, while the PS particles appear darker than the Si substrate. The observed brightness agrees with an electrostatic model which predicts a simple analytical relation to the local refractive index of the sample material[3].

Our results are evidence that the imaging process of s-SNOM is wavelength-independent, namely that the resolution is mainly determined by the tip's properties, and that the contrast is given by the refractive index of the sample. This categorizes s-SNOM contrast into the material classes of metals, semiconductors, and polymers enabling a simple, high resolution material-specific mapping of nanosystems [4,5].

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# **Manipulation of DNA Molecules on Nanostructured Surfaces**

**Marion Hochrein, Sektion Physik, LMU München**

Fluorescently labelled DNA molecules adsorb onto a fluid cationic lipid bilayer on a glass substrate restricting the DNA movements to the two dimensional lipid plane. This allows the use of fluorescence microscopy to study DNA dynamic behavior by analyzing the moments of fluorescence intensity. DNA molecules have been found to behave as 2D model polymers. Therefore, this system provides a molecular workbench for single molecule manipulation. Adsorbed macromolecules could be relocated, positioned, stretched or separated and analysed. To realize relocation, DNA molecules on a cationic lipid bilayer have been studied under the influence of electric fields. Theory predicts that DNA molecules stretch on certain nanostructured lipid layers which, in the future, could be used to study DNA interaction with individual molecules by single molecule fluorescence microscopy.



# Metallo-supramolecular Polymers: Grafting and Cross-linking

H. Hofmeier, U. S. Schubert

*Poster presentation at the CeNS workshop Wildbad Kreuth 2002*

A series of poly(methyl methacrylate) copolymers with terpyridine units in the side chains was obtained by free radical polymerization (see also ref.<sup>[1]</sup>). The free terpyridine units were complexed with several different terpyridine ruthenium-*monocomplexes*, yielding metallo-supramolecular graft copolymers<sup>[2]</sup>. The obtained materials were characterized by NMR, UV-vis, GPC as well as DSC. Micelles were obtained from the amphiphilic graft copolymers and investigated by light scattering as well as AFM. By titration of iron(II) and zinc(II) ions to the uncomplexed copolymer, the complexation behavior was studied by UV-vis spectroscopy and viscosity measurements. A complexation of the polymer chains could be observed which resulted in inter- and intramolecular cross-linking<sup>[3]</sup>. Addition of hydroxethyl ethylenediaminrtriacetic acid (HEEDTA) resulted in an efficient decomplexation.

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# Magneto-optical properties of charged excitons in quantum dots

A. Högele<sup>1</sup>, C. Schulhauser<sup>1</sup>, A. O. Govorov<sup>2</sup>, R. J. Warburton<sup>3</sup> and K. Karrai<sup>1</sup>

<sup>1</sup>*Center for NanoScience and Sektion Physik, Ludwig-Maximilians-Universität,  
Geschwister-Scholl-Platz 1, 80539 München, Germany*

<sup>2</sup>*Ohio University, Department of Physics and Astronomy, Athens OH 45701;*

<sup>3</sup>*Department of Physics, Heriot-Watt University, Edinburgh EH14 4AS, UK*

W. Schoenfeld<sup>4</sup>, J. M. Garcia<sup>5</sup> and P. M. Petroff<sup>4</sup>

<sup>4</sup>*Materials Department and QUEST, University of California, Santa Barbara,  
California 93106, USA*

<sup>5</sup>*Instituto de Microelectrónica de Madrid, Isaac Newton 8, 28760 Tres Cantos, Madrid, Spain*

A semiconductor quantum dot (QD) represents an ideal model system for the investigation of quantum mechanical electron-electron interactions. This is because Coulomb blockade allows electrons to be added or removed one by one simply with a gate electrode [1,2]. As a result, the electrical [2], optical [3]- [6] and magnetic properties [7] are tunable. An exciton complex consists of a hole bound to the electrons in a QD. The spatial extent of the excitonic wave function reflects the joint effects of the QD's confinement potential and the Coulomb interactions and can be probed by applying a magnetic field,  $B$ . For neutral excitons, the energy increases quadratically with  $B$ , the so-called diamagnetic shift, with a curvature proportional to the area of the wave function. The linear dependence on the magnetic field leads to the characteristic Zeeman splitting of the spin degenerated branches, from which the excitonic Landé factor can be derived. However, the behaviour of charged excitons is less well known and potentially much more interesting because of the more elaborate Coulomb interactions.

Here we present the experimental results of low temperature (4.2K) magneto-luminescence measurements performed on charge-tunable GaInAs self-assembled QD. The photoluminescence generated by recombining single, twofold and threefold charged excitons in a single QD with the magnetic field ramped up to 9Tesla is investigated. While the diamagnetic shift is found to depend on the charging state of the dots, the Zeeman splitting is measured to be independent of the charge. For excitons involving more than one excess charge, the singlet and triplet state lead to a fine structure splitting. We report here on their energy dispersion in magnetic field. In particular, we highlight the suppression of the diamagnetic shift in the dispersion of the singlet line of doubly charged excitons within the full range of 0-9Tesla as well as the collapse of the Hund's rule for the threefold charged excitons at higher magnetic fields. Above a critical magnetic field the fine structure splitting, a consequence of the Hund's rule, can no longer be observed and a new broad line appears in the spectrum. The intensity of the line oscillates as the magnetic field is ramped up with a period in  $1/B$ , revealing well defined anticrossings with Landau levels.

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# **Light back-action on opto-mechanical oscillators**

**C.Höhberger, M. Vogel, C. Meyer, H. Lorenz, K. Karrai**

CeNS, LMU Munich, Geschwister-Scholl-Platz 1, 80539 Munich

Since the introduction of AFM this technique was refined such that it is possible to detect down to single electronic charges or pull on single molecules. Nonetheless it would be desirable to make force detection more sensitive for a broad range of applications. This can for example be achieved by constructing very compliant AFM cantilevers. However, they get delicate to such extent, that they become difficult to handle.

We were able to optically change the mechanical rigidity of bilayer cantilevers with spring constants of about 0.1 N/m. Using the thin gold film on the back of the cantilever as one mirror of a Fabry-Pérot microcavity it is possible to change its mechanical spring constant in a controlled way under the effects of light-induced force gradients. We were able to observe negative effective spring constants and hence bistable behaviour of the cantilever. AC-frequency behaviour of the system was investigated.

# Electron-Phonon Interaction in Freely Suspended Quantum Dots

E. M. Höhberger\*, J. Kirschbaum, R. H. Blick, J. P. Kotthaus  
*Center for Nanoscience und Sektion Physik der LMU München, Germany*

T. Brandes  
*Department of Physics, University of Manchester (UMIST), United Kingdom*

W. Wegscheider  
*Institut für Angewandte und Experimentelle Physik, Universität Regensburg, Germany*

M. Bichler, D. Schuh  
*Walter-Schottky-Institut der TU München, Germany*

An electron-phonon cavity is realized by a lateral quantum dot embedded in a free-standing nanostructure. Starting from a GaAs/AlGaAs heterostructure containing an additional sacrificial layer samples are processed by electron-beam lithography. Freely suspended structures are obtained in a combination of anisotropic and isotropic etch steps [1,2] and characterized in low-temperature Coulomb blockade measurements [3]. Due to the combination of the discrete electronic spectrum of a single electron transistor with a quantized set of phonon modes permitted by the cavity dimensions electron transport in the suspended quantum dot is strongly modified by the coherent coupling of individual electrons and phonon modes. We find a complete suppression of single electron tunneling around zero bias leading to the formation of a distinct energy gap in the transport spectrum [4]. Strikingly similar features have been obtained for single electrons tunneling onto a C<sub>60</sub> molecule [5]. The observed blocking effect is induced by the recoil transferred to the cavity by the tunneling electron resulting in the excitation of a localized cavity phonon. This *phonon blockade* can be overcome at bias voltages large enough to bridge the energy gap, or at a sufficiently high bath temperature. Furthermore, phonon blockade of transport is lifted at magnetic fields where higher electronic states with nonzero angular momentum are brought into resonance with the phonon energy such that these states are enabled to replace the ground state after reabsorption of the cavity phonon.

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\* Email: Eva.Hoehberger@physik.uni-muenchen.de

# **Desorption of Single Polyelectrolyte Chains from Solid Supports Studied by SMFS**

**Thorsten Hugel, Willi Jöstl, Hermann Gaub, Markus Seitz**

*Lehrstuhl für Angewandte Physik & Center for NanoScience, LMU München, Amalienstr. 54, 80799 München*

AFM-based force spectroscopy measures intra- and intermolecular forces of single molecules. It recently was used to investigate the desorption of single polymer chains from silica, mica and calcite surfaces. In first experiments the desorption of polyelectrolytes from an equilibrated physisorbed polymer film on silica was investigated. These experiments show that the coulomb interaction between polymer and substrate depends linearly on the Debye screening length and the polymer's line charge density. Besides, a 'zero charge' contribution was found, which did not depend on any charges in the system [1]. Further experiments were performed with tip-attached polymers on bare mica and calcite surfaces. They confirmed the conjecture that this 'zero charge' contribution reflects the Van-der-Waals properties of the surface quantified by the Hamaker constant. Finally, with the tip-attached polymers a study of the desorption dynamics of single polymer chains seems possible.

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# Coupling electronic and nuclear spins

A.K. Hüttel et al., Sektion Physik, LMU München

Spin states in semiconductor quantum dots are known to have many properties desired for qubit base states. As long as more than one electron is present, however, the quantum dot level spectra can be quite complex. An example of such a situation is given by spin blockade - where internal spin coupling changes between subsequent electron numbers, leading to a large spin difference and a suppression of SET tunneling. As can be seen, perturbation terms of the Hamiltonian such as spin-orbit coupling and hyperfine coupling play an important part in explaining the data.

The spin blockade scenario enables control of the electronic spin and its transitions by the externally applied gate voltage. In addition, the perturbation terms couple the electronic spin system selectively to the nuclear lattice spins, as predicted and observed in similar situations. We present data on the detection of a nuclear spin polarization via the single electron tunneling through a quantum dot. Since we are working at extremely low external magnetic fields orthogonal to the 2DES ( $B_{\perp} < 0.25\text{T}$ ) and since the phenomenon does not depend on a magnetic field parallel to the 2DES (tested for  $0\text{T} < B_{\parallel} < 1\text{T}$ ), orbital momentum states seem to play an important role.

# **Probing Relaxations of Dilute $\lambda$ -Phage DNA with Fluorescence Correlation Spectroscopy**

**Simon Keller, Dirk Lumma, and Joachim Rädler**

Ludwig-Maximilians-Universität, Geschwister-Scholl-Platz 1, 80539 München, Germany

Fluorescence correlation spectroscopy (FCS) counts chromophores in a microscopic effective volume created by a laser focus of sub-micron waist size. The size and shape of intensity fluctuations due to fluorescent molecules entering and leaving the open volume yield information about their density and diffusion properties.

We extend the application of FCS to flexible macromolecules that i) carry more than one randomly distributed label and ii) are larger than the focal waist. Therefore the dynamic structure factor of the  $\lambda$ -phage DNA under study has to be taken into account. The resulting relaxation times and scaling exponents from a series of measurements with varying label densities agree with theoretical models for semiflexible polymers [1].

Furthermore the chromophores exhibit an on-/off-process on shorter timescales consistent with modes diffusing along the chain.

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## Surface structural and electrical characterization of organosilicate layers on GaAs

Christian Kirchner, Bernhard Stein, Wolfgang J. Parak, Uwe Klemradt\*, Markus Seitz  
Lehrstuhl für Angewandte Physik, Prof. H.Gaub, LMU München

\* RWTH Aachen, II. Physikalisches Institut B

GaAs is a semiconductor with interesting electrical and optical attributes. The chemical modification of its surface provides many opportunities for tuning the electronic properties of the underlying bulk semiconductor material and for creating surfaces with tailored physicochemical properties, e.g., for the design of chemical or biophysical sensors. (Seker, Meeker et al. 2000)

The present work presents our strategy to use ultra-thin solution sol-gel layers of polysilicates for the long term functionalization of the GaAs surface in aggressive environments. (Kirchner, George et al. 2002) AFM, ellipsometry and voltammetry are used to investigate the efficiency of protective layers with a thickness of 5-15 nm under physiological conditions. The variability of the sol-gel process allows to introduce vertical and lateral structuring of the organosilicates. Structural characterization is done by measurements of the X-ray reflectivity under grazing incidence, ellipsometry, contact angle measurements and the cultivation of living cells.

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## AFFINITY MEASUREMENTS BETWEEN APTAMERS AND PROTEINS WITH AN AFM

Ferdinand Kühner<sup>1</sup>, Angelika Wehle<sup>1</sup>, Günter Mayer<sup>2</sup>, Michael Blind<sup>2</sup> and Hermann Gaub<sup>1</sup>

<sup>1</sup>*Lehrstuhl für Angewandte Physik & Center for Nanoscience, Ludwig-maximilians Universität, Amalienstr. 54, 80799 München, Germany*

<sup>2</sup>*NascaCell GmbH, Bahnhofstraße 9-15, 82327 Tutzing*

Aptamers are small, in vitro selectable single stranded nucleic acids that are capable of binding proteins and other molecules with specificity and dissociation constants similar or better to those of antibodies. Aptamers can be used for protein biosensors or for drug development. The aptamer D17.4ext (ext is the abbreviation for an extended D17.4) has a length of 45 nucleic acids and forms a stem-loop structure, which has a dissociation constant (Kd) of about 1nM for human-IgE(1). We are using an AFM to specify the unbinding force. The force sensor (cantilever) is functionalised with the aptamer via a polymerspacer, to avoid unspecific bindings. The human-IgE is immobilised in the same way to the substrate. Primary measurements show an unbinding force distribution around 85pN. Due to this high force and to the many reruns, we assume, that the 3-dimensional structure of the Aptamer seems to stay preserved.

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High-Affinity Oligonucleotide Ligands to Human IgE Inhibit Binding to Fce Receptor I  
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# **On-chain defect emission and exciton migration in conjugated polymers**

**John M. Lupton, Sektion Physik, LMU München**

Conjugated polymers are a fascinating new class of materials with considerable technological potential. Much of the focus of research to date has been on aspects relating to the bulk material properties such as supramolecular ordering and film morphology. Recently, however, it has become apparent that nanoscopic chemical defects can exist on the backbone of conjugated polymers, which dramatically influence both charge transport and emission characteristics. An example of these emissive defects are keto groups on the backbone of the conjugated polymer polyfluorene, which lead to a broad, red-shifted and time delayed emission. Using gated fluorescence and electroluminescence spectroscopy, the influence of these defects, which have previously been confused with excimers and aggregates in the literature, on the emission dynamics and the charge transport characteristics may be studied. A further class of exciting chemical defects are covalently bound metal atom. We were recently able to demonstrate that a trace amount of metallic contamination in the organic structure, corresponding to less than one metal atom for 1000 polymer repeat units, is sufficient to generate efficient and fast phosphorescence at room temperature. The effect provides a decay channel for triplet excitons, which are the dominant excited state species in polymer light-emitting diodes. In the absence of metallic impurities, triplet excitons generally decay non-radiatively, generating heat in the organic material. To date there have been no direct means of characterising these heating processes. We present a novel technique based on a phosphorescent molecular thermometer, which allows thermal imaging to be carried out on a variety of structures and materials. Finally, we address the issue of intermolecular interactions and the origin of spectral broadening in organic semiconductors. By using a model material for conjugated polymers based on star-shaped dendrimers we are able to distinguish between dispersive spectral diffusion within the inhomogeneously broadened density of emitting states and intermolecular interactions resulting in the formation of intermolecular excited state species. This is achieved by varying the intermolecular distance as well as the relative conformation of adjacent molecules.

# **Polymers and polyelectrolytes at interfaces**

**Manoel Manghi, Sektion Physik, LMU München**  
**manghi@theorie.physik.uni-muenchen.de**

We present a theoretical description of the organization of polymers at interfaces in terms of loops and tails formed by the adsorbed chains. We use a new variational approach which combines the statistical physics of a loop population of different sizes and scaling laws. This theory is applied to the issue of the dependence of the surface tension of polymer liquids on molecular weight, temperature and volume fraction in the bulk. The role of the tensio-activity of chain ends and of the entropy associated to the loop distribution are enlightened. This theory is then generalized to describe the adsorption of flexible polyelectrolytes onto an oppositely charged surface in the semi-dilute regime. The layer structure is described analytically and the presence of an external layer made of large loops induces the inversion charge process.

# **Optical Detection of Nanotweezers' Movement**

**C. Meyer, K. Karraï, H. Lorenz**

**CeNS and Sektion Physik, LMU Munich, Geschwister-Scholl-Platz 1, 80539 Munich**

Nowadays the interest in nanoelectromechanical systems and their applications is growing. The nanocantilevers presented here form a tweezers structure and are designated to rearrange nanocomponents which are difficult to position directly, like nanotubes or other macromolecular systems. Our structures are based on SOI-material. Electron beam deposited tips are grown on top of lithographically defined silicon cantilevers.

Whereas most nanomechanics groups concentrate on suspended wires and thus can identify movements by changes of the charge transport properties, we have to detect them directly. For this purpose it seems evident to study the expected bendings with an electron microscope. However, the movement as a reaction to an applied DC voltage of the nanotweezers presented here, could not be visualized by electron microscopy. Firstly the cantilevers get contaminated by carbon and moreover, they melt if voltages are applied while scanning the electron beam. Optical microscopes in contrast are not even able to resolve the nanotweezers appropriately.

Here we introduce a new optical technique allowing to detect 200 nm wide tweezers as well as their movement according to an applied low frequency AC voltage using a laser of 633 nm wavelength (HeNe) and lock-in technique. The measurement takes advantage of interference phenomena and should work for most nanomechanic applications.

# **Electrically Controlled Light Scattering of Nanoparticles embedded in a Liquid Crystal**

J. Müller, C. Sönnichsen, H. von Poschinger, G. von Plessen<sup>\*</sup>, T. A. Klar, and J. Feldmann

*Photonics and Optoelectronics Group, Department of Physics and CeNS,  
University of Munich, Amalienstr. 54, D-80799 Munich, Germany*

*\*present address: I. Physikalisches Institut A, RWTH Aachen, 52056 Aachen, Germany*

A new concept to electrically control the scattering of light is introduced. The idea is to embed noble metal nanoparticles in an electro-optical material such as a liquid crystal in order to induce a spectral shift of the particle plasmon resonance by applying an electric field. Light scattering experiments on single gold nanoparticles show that spherically shaped nanoparticles become optically spheroidal when covered by an anisotropic liquid crystal. The two particle plasmon resonances of the optically spheroidal gold nanoparticles can be spectrally shifted up to 50 meV when electric fields of more than 10 kV/cm are applied.

# **SPECTROSCOPY ON SINGLE CONJUGATED POLYMER CHAINS W. SUB-NS TIME-RESOLUTION**

J.G. Müller<sup>1</sup>, G. Raschke<sup>1</sup>, J.M. Lupton<sup>1</sup>, U. Lemmer<sup>2</sup>, U. Scherf<sup>3</sup>, J. Feldmann<sup>1</sup>

<sup>1</sup> Lehrstuhl für Photonik und Optoelektronik, Sektion Physik, Ludwig-Maximilians-Universität München

<sup>2</sup> Lichttechnisches Institut, Universität Karlsruhe

<sup>3</sup> Institut für Physikalische und Theoretische Chemie, Universität Potsdam

We study the intrachain energy transfer on single chains of a conjugated polymer. Using a confocal microscope, photo-luminescence spectra of single polymer molecules were taken with a time-resolution of 200 ps. At cryogenic temperatures, several narrow emission lines are observed for each molecule, representing the individual chromophores on the polymer chain. The time-evolution of the single-molecule spectrum allows for a direct observation of the energy transfer between the chromophores. Exciton migration to low energy regions of the chain is identified as well as not interacting chromophores.

# Polymers under Tension

**Prof. Roland Netz, Sektion Physik, LMU, Theresienstr. 37, 80333 München**

Polymers under mechanical and electrical tension are considered.

- i) For strongly stretched polymers, quantum-chemistry calculations allow to determine the stretching modulus in an ab-initio manner without adjustable parameters. For fully saturated carbon backbones we obtain a modulus of 28nN which agrees with experiments and allows to eliminate one (otherwise free) fit parameter in the data analysis.
- ii) We theoretically analyze the stretching response of a freely-rotating chain model (which is closest to the chemical structure of a synthetic carbon polymer chain) and find a regime at large stretching forces within which a continuous description such as the worm-like chain model breaks down and where the discrete structure of the chain becomes important.
- iii) Charged polymers form highly polarizable structures due to the loose binding of oppositely charged counterions. In electrical fields, those polymers orient along the field and are stretched. These effects might be important for electrophoretic separation studies.

# **Single Molecule Motor**

**Gregor Neuert, Sektion Physik, LMU München**

The reversible, optical switching of individual polymer molecules was observed using molecular force spectroscopy in combination with optical excitation in total internal reflection. We synthesized a polypeptide with multiple photoactive azobenzene groups incorporated in the backbone. The cis to trans configurational transition induced by ultraviolet light resulted in a measurable change in polymer contour length. The ability to shorten the polymer against an external load is the first demonstration of photomechanical energy conversion in an individual molecule. This is a significant milestone in the road towards molecular level machines.



# **The Nanomechanical Single Electron Transistor**

**Dominik Scheible, LMU München**

We manufactured electromechanical single electron transistors (emSET) featuring a mechanically oscillating single electron island. The emSET consists of a nano-machined cantilever with a metallic island on the tip. The island vibrates between source and drain contact, shuttling electrons at radio-frequency. The enhanced precision of an emSET, due to the absence of co-tunneling effects, promises many applications of this device, ranging from metrology to quantum limited displacement detection. We present an overview of the concept, an introduction to theoretical considerations, and actual samples and their recent experimental results.

# **Atomic Force Microscopy of Chaperonin GroEL**

**Jens Schiener, Susanne Witt, Reinhard Guckenberger**

Max-Planck-Institut für Biochemie, Martinsried

Scanning force microscopy is an established method for imaging biological samples in solution. Here it is used for investigating the chaperonin GroEL, a member of the family of chaperones. ‘Single ring’ mutants of the native chaperonin (GroEL-SR1) are suitable objects for scanning force measurements. Their flat and defined ring shape is advantageous for topographical mapping. The aim was imaging the GroEL-SR1 and visualisation of substrate (citrate synthase) and cochaperonin (GroES) binding at the level of a single molecule.

This was realized by collecting series of images showing the single molecule reactions. The reaction was induced by changing the buffer during scanning and was accompanied by a change in height and shape of the chaperonin which could be visualized. Additional biochemical methods were used to identify all reaction members.

# DNA-based assembly and nanodevices

Friedrich C. Simmel

[friedrich.simmel@physik.uni-muenchen.de](mailto:friedrich.simmel@physik.uni-muenchen.de)

Sektion Physik and CeNS, LMU München,  
Geschwister-Scholl-Platz 1, D-80539 München, Germany

DNA has proven to be a versatile molecular building material which can be utilized for the rational assembly of complex supramolecular structures and the organization of nanometer-sized particles. Moreover, recent experiments have shown that DNA can even be used to build molecular-scale actuators which can perform simple motions on a scale of several nanometers. Similar dynamical nanostructures might form the basis of a more complex molecular machinery aiding in self-assembly processes. Here several examples of DNA-based nanomechanical devices are presented which can be arbitrarily switched between two or three distinct mechanical states [1,2,3]. These DNA devices exploit the different mechanical properties of single-stranded and double-stranded DNA molecules and the biochemical process of branch migration. The concept of hybridization inhibition and hybridization catalysis which might be used to build free-running machines out of DNA is also discussed [4].

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# **Transmission Phase Shift of a Quantum Dot with Kondo Correlations**

Michael Sindel, Laszlo Borda and Jan von Delft  
Sektion Physik und CeNS, Ludwig-Maximilians-Universität,  
Theresienstr. 37, 80333 Muenchen,  
email:sindel@theorie.physik.uni-muenchen.de

Recently Ji et al. [1] measured the amplitude and the phase of the complex transmission amplitude of a Quantum Dot in the unitary limit. They observed that the phase of the transmission amplitude evolves linearly over a range of about  $1.5 \pi$  when the Fermi energy is scanned through a pair of Coulomb blockade peaks in between which the dot exhibits Kondo correlations. Moreover, the phase in the Coulomb blockade peak, adjacent to the Kondo pair retained a memory of the Kondo correlation. Both, the large phase span of the transmission phase in the Kondo regime and the memory of the Kondo effect in the adjacent peaks is not in accord with the theoretical analyses by Gerland et al. [2] which was based on a single-level Anderson model. We extend the latter analyses to the case of a multilevel Anderson model and also analyse the phase modulating effects of a nearby gate electrode. Finally we compare our results with experiment.

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# Extracellular recordings with the Light Addressable Potentiometric Sensor (LAPS)

B. Stein, M. George, J.C. Behrends, W. J. Parak, H.E. Gaub  
Sektion Physik and Center for Nano Science at the Ludwig-Maximilians Universität  
Amalienstr. 54 D-80799 München

To detect extracellular potentials of living cells a potentiometric sensor with high spatial resolution is desirable. The light addressable potentiometric sensor (LAPS) has the advantage of having a laterally unstructured surface. First extracellular recordings could be implemented in combination with patch-clamp technology.

Most basic approaches, like microelectrode- or field-effect transistor arrays, are based on individually contacted sensor elements that are separated by insensitive areas. This implies the problem, that cells, which grow on the interspace between the measurement sites, cannot be monitored. A promising example for a potential sensor that overcomes this problem is the light-addressable potentiometric sensor (LAPS). In contrast to the former examples it consists of a laterally completely unstructured EIS-structure (Electrolyte-Insulator (Si<sub>3</sub>N<sub>4</sub>, SiO<sub>2</sub>) - Semiconductor(Si)), where any point of the surface can be addressed by illumination with a pulsed light-pointer.

In this study a mouse neuroblastoma cell line (N1E-115) was used as a test system. Sensor chips were coated with PDL (polydelysine) and neuroblastoma cells N1E-115 were then seeded on the chip, in a concentration of about 40 000 cells/ml, and incubated for 48h. By applying stimulation pulses (in the VC- and the CC-mode) with the patch-clamp setup, extracellular potentials were measured with the LAPS. Because of the low signal to noise ratio we could not obtain extracellular signals with a single stimulation. The patch-clamp technique offers the possibility to trigger cells, and therefore to average over many cycles. With this technology it was possible to measure active action potentials (active ionic currents) in a non-invasive way with the light addressable potentiometric sensor.

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Tanaka H, Yoshinobu T, Iwasaki H. (1999) Application of the chemical imaging sensor to electrophysiological measurement of a neural cell. *Sensors and Actuators B* **59**, 21-25

# **Decoherence of coupled solid state qubits**

**Markus Storcz, Sektion Physik, LMU München**

Quantum computation needs a coherent time evolution. Therefore it is of central importance to minimize decoherence through external baths in particular in solid state systems. We already know much about decoherence of single qubits. Not so much is known about systems of two coupled qubits. However at least two qubits are needed to investigate the key properties of entanglement. We develop a realistic model of two coupled solid state qubits which are coupled via Ising type coupling and apply Bloch-Redfield theory to determine decoherence times and the dynamics of the system. Furthermore we evaluate characteristic gate quantifiers which allow us to judge the quality of a quantum gate operation. The advantages of proper use of symmetries in the inter-qubit coupling Hamiltonian are discussed. We investigate the properties of a flux transformer as a device to couple two qubits.

# Phonon-enhanced light-matter interaction in nanosystems

Thomas Taubner, Max-Planck-Institut für Biochemie, Martinsried

We demonstrate in theory and in experiment that the spectral behaviour of a polar sample can change dramatically when observed with a scattering-type near-field infrared microscope (s-SNIM). The infrared light-matter interaction between the probing tip and a polar sample (SiC) also strongly enhances the measured scattered light due to lattice vibrations (phonons).

Our experiment consists of imaging a partly gold-covered SiC surface in our scanning-near-field optical microscope[1,2] at various wavelengths in the mid-infrared. We observe a strongly increased signal on SiC at  $920\text{ cm}^{-1}$ , exceeding the signal on gold more than 20 times[3]. By changing frequency of the illuminating light and comparing the signals obtained on SiC with the signals on gold we obtain a sharply resonant spectrum.

Theoretically, we calculate the contrast of SiC relative to gold, by employing our model of dipole/mirror dipole interaction outlined earlier[1,2]. Comparing theory with the experiment, we find a good agreement of the strong resonant behaviour in both, resulting in an amplitude contrast that ranges over almost 3 orders of magnitude.

This new, phonon-enhanced near-field interaction allows to study phonon-resonant nanosystems (analogous to plasmon-resonant particles) and can also be used to image local chemical and crystal structure of nanoscale polar materials, e.g. to investigate the process of biomineralization in bone or teeth.

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# **Self-organized magnetic nanostructures of MPt<sub>3</sub>(111) (M= Co, Cr, V) on WSe<sub>2</sub>(0001)**

**F. Treubel (1), T. Ulbrich (1), A. Maier (1), B. Riedlinger (1), M. Albrecht (1), M. Maret (1), E. Beaurepaire (2), R. Poinsoot (2), G. Schatz (1)**

(1) University of Konstanz, Faculty of Science, Department of Physics, D-78457 Konstanz, Germany

(2) Institute de Physique et Chemie des Matériaux de Strasbourg, F-67067 Strasbourg, France

CoPt<sub>3</sub>(111) nanostructures and films were formed at various temperatures ( $T_s$ ) by co-deposition of Co and Pt atoms on the van der Waals surface (0001) of the layered semiconductor WSe<sub>2</sub> under UHV conditions. The high mobility of adatoms on this type of surface leads to the formation of self-organized monocrystalline islands with a 111-oriented fcc structure and a narrow size distribution. For deposits of  $\sim 1$  ML at  $T_s = 300^\circ\text{C}$ , the islands have a hexagonal prism shape with average lateral size and height equal to 4.4 nm and 1.2 nm and are superparamagnetic above 40 K. For thicker deposits of  $\sim 15$  ML (3 nm), dense ensembles of such islands are obtained with lateral sizes remaining in the range of a few nanometers. In comparison with continuous films, such nanostructured films exhibit very surprising properties. For growth temperatures between 20 and  $100^\circ\text{C}$  perpendicular magnetic anisotropy (PMA) with coercivities of 200 Oe is observed. For higher temperatures, PMA vanishes due to the appearance of L1<sub>2</sub>-type chemical long-range ordering (LRO), which already occurs at  $150^\circ\text{C}$ , a much lower temperature than that observed in continuous films [1,2]. This low onset temperature of ordering is attributed to the nanostructured shape of these films, which enhances the atomic arrangements of both top and side-wall facets during the growth process. For deposits larger than 5 nm, a gradual approach to the behavior of the continuous films (concerning LRO and PMA) is observed [3].

First experiments on CrPt<sub>3</sub> and VPt<sub>3</sub> are shown.

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Project is financially supported by the DFG (SFB 513).



## A new form of bulk silicon consisting of „magic“ clusters ?

M. Grass<sup>1</sup>, D. Fischer<sup>1,2</sup>, M. Mathes<sup>1</sup>, G. Ganteför<sup>1</sup>, P. Nielaba<sup>1</sup>

<sup>1</sup> Department of Physics, University of Konstanz, D-78457 Konstanz, Germany

<sup>2</sup> IBM Research, Zurich Research Laboratory, CH-8803, Rüschlikon Switzerland

The question, whether stable “magic” silicon clusters are suitable as building blocks for new cluster materials is examined. Si<sub>4</sub> clusters are soft-landed on an inert Van-der-Waals surface and the island formation is studied using x-ray photoelectron spectroscopy (XPS) and UV photoelectron spectroscopy (UPS). The XPS data indicate that the clusters do not fuse to Si islands but survive as individuals (Fig. 1). The potential energy surface of two Si<sub>4</sub> clusters is calculated and a barrier against fusion is found in agreement with the experiments (Fig. 2). Both results support the existence of a new form of silicon consisting of Si<sub>4</sub> clusters.

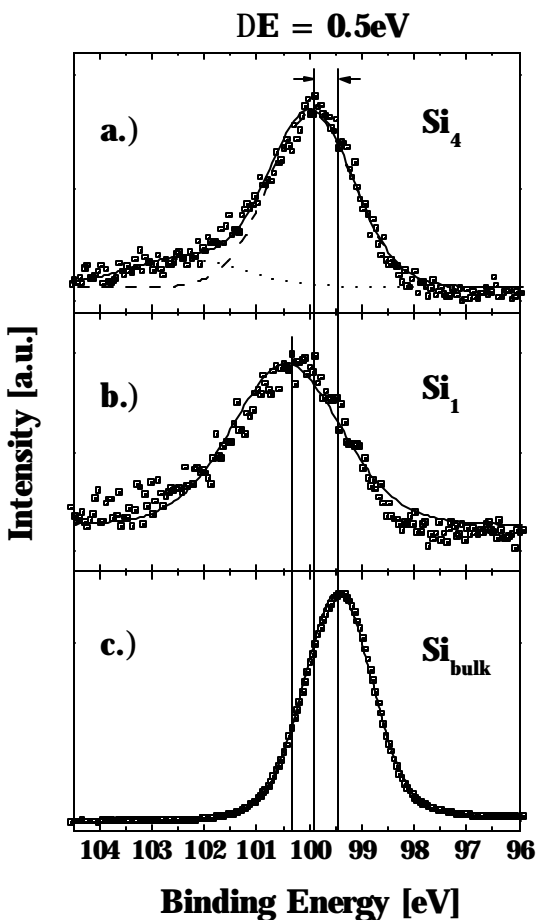


Fig. 1: XPS of the Si 2p lines of (a) 0.1 ML Si<sub>4</sub> soft-landed on amorphous carbon, (b) 0.1 ML Si<sub>1</sub> on amorphous carbon, and (c) for reference a silicon bulk sample. The deposition energy in (a) and (b) was 5 eV. There is a considerable line shift between the three cases that hints towards the existence of individual Si<sub>4</sub> clusters on the surface in spectrum (a).

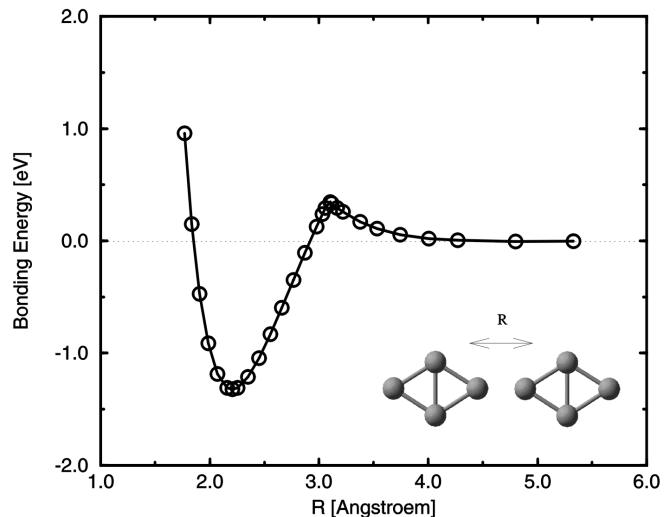


Fig. 2: A strong binding potential is found between two Si<sub>4</sub> clusters that approach each other as indicated. But at a distance of about 3 Å there is a small barrier that blocks fusion.

# Integrin Interactions Measured on Living Cells

*Angelika K. Wehle<sup>1</sup>, Martin Benoit<sup>1</sup>, Angelika Kardinal<sup>1</sup>, Ulrich Weiland<sup>2</sup>, Robert Eibl<sup>3</sup>,  
Hermann E. Gaub<sup>1</sup>*

<sup>1</sup> Lehrstuhl für angewandte Physik, Center for Nanoscience, LMU, Amalienstr. 54, 80799 München, Germany,

<sup>2</sup> Fakultät für Biologie, Universität Konstanz, 78434 Konstanz, Germany

<sup>3</sup> Material Sciences, Max Planck Institut, Ackermannweg 10, 55128 Mainz, Germany

Interactions between single cells are crucial for many mechanisms in biology and medicine. Many are mediated by integrin interactions. These differences in cell adhesion for various integrins and their specificity are investigated by atomic force microscopy.

One set of experiments probed a B16 cell adhered via polylysine to the AFM cantilever against a micro structured surface with dots of fibronectin. The cell is carrying the integrins binding specifically to fibronectin. We detected differences in the adhesion to the surfaces coated with fibronectin and to uncoated surfaces. The strength of adhesion is sensitive to the contact area and the contact time. The contact area was varied with different dot sizes and dot gaps. Increasing the contact area or the contact times increased the maximum adhesion force mediated by many adhesion molecules in parallel. The single molecule interaction force is to be expected in the range of 80 to 100 pN (Litvinov 2002).

A different set up allowed measuring single molecule events of the cell cell contact. These measurements reveal that the measured forces are at the limit of the resolution of the force spectroscopy and therefore much smaller than other single molecule forces measured earlier (Ros 1998; Benoit 2000; Dettmann 2000). Therefore we had to reduce the noise by decreasing the force constant of the cantilever and evaluating the data in consideration of the thermal noise. The results obtained are varying from 12 to 28 pN for different cell types and different adhesion molecules. The activation state of the cells should influence the frequency of binding and the maximum adhesion force.

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# **Superconducting quantum bits: Control, coherence, and read-out**

**Frank Wilhelm, Sektion Physik, LMU München**

Superconducting circuits can be miniaturized and isolated from their environment such that their collective degree of freedom behaves quantum-mechanically. Studying these systems permits to explore the boundary between classical and quantum physics and, once this boundary has been overcome, can potentially be used as a scalable architecture for quantum computers. Experimentally, it has been shown that the current states in a superconducting loop can be brought in a superposition of states which correspond to clockwise and counterclockwise currents involving up to  $10^{10}$  Cooper pairs. In a number of setups, quantum coherent Rabi oscillations have been observed.

I will describe the physics of these devices and outline the experimental status in this field. I will discuss the impact of decoherence during the time-dependent driving and control of the qubit as well as the properties of the quantum read-out process as viewed from the perspective of this system. I will show, how decoherence describes the measurement process and will pay special attention to the selection of the preferred final states of a quantum measurement through the properties of the detector. These results can be used as engineering rules for quantum-mechanical circuits. In a setup of coupled qubits, decoherence is not uniquely quantified through decay rates, but through local and nonlocal quality factors. I will discuss these quality factors in a setup of coupled superconducting qubits and will comment on the importance of the correlation length of the fluctuations leading to decoherence. If time permits, I will comment on the classification the experimentally observed states in terms of the size of a Schrodinger cat.

# Nanolithography and nanochemistry in the sequential build-up of nanometer-sized structures

Daan Wouters and Ulrich S. Schubert

Nanolithography and the controlled build-up of small but controlled structures are important techniques in nanotechnology. There is at present an enormous drive in science towards the development of routes for the minituralization of devices with novel applications, e.g. high-density data storage and biological detector arrays.

In this poster results on the application of Scanning Probe Techniques in the fabrication of nanometer-sized structures on octadecyltrichlorosilane (OTS) passivated silicon wafers are presented. By applying a bias voltage on a conductive AFM-tip the OTS layer on the surface can be oxidized very locally. The oxidation changes the local properties of the surface, thus opening routes to controlled surface modification via both absorption as well as chemical modification routes. Presented here are first results of the (sequential) functionalization of surfaces with (cationic)gold nanoparticles, quaternary ammonium salts and the attachment of terpyridine functionalized polymers by metal-ligand complexations.

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# Photonic crystal properties of large area silica-based opal film

XU Ling<sup>a,b</sup> and Jochen Feldmann

<sup>a</sup> *Photonics and Optoelectronics Group Physics Department and CeNS,  
University of Munich, Amalienstr. 54, 80799 Munich, Germany*

<sup>b</sup> *National Laboratory of Solid State Microstructures and Department of Physics,  
Nanjing University, Nanjing 210093, P. R. China*

Colloidal particles with narrow size distribution are ideal building blocks for the formation of two or three-dimensional periodic dielectric structures. If these structures have feature size of the order of the optical wavelength, they can possess photonic band gap (PBG) which results in the suppression and enhancement of spontaneous emission.

Highly monodispersed colloidal silica spheres in submicrometer size with distribution standard deviation less than 5% were synthesized by chemical method. Using self-assembly of silica spheres, we successfully obtained clear, transparency and highly uniform silica-based opal films. The uniform area of a typical sample could reached as large as 3x1 cm<sup>2</sup>. Diffractive colors from green to red could be readily seen when the top surface of samples was put under a lamp and the observation angle was changed. AFM characterization show an ordered close packed arrangement over a sample area of 20 μm. Sharp peaks in 2D Fourier transform pattern confirm the presence of a long-range crystalline order of our sample. Deep dips in transmission spectra can also been seen which can be referred to as a (111)-oriented photonic gap of artificial opals.

# **General Information**

## **Conference Center at Wildbad Kreuth**

The conference center is run by the Hanns-Seidel-Stiftung (HSS). They provide the rooms and all meals. If you encounter any problems with the rooms, please refer directly to a representative of the HSS. CeNS will cover all your costs for rooms and food, if you have paid your registration fee. Please note though: We will hold you financially responsible for any rooms booked but not occupied.

The contact data of the conference center are:

Bildungszentrum Wildbad Kreuth

83708 Kreuth

Tel: 08029 / 170

Fax: 08029 / 17 34

E-mail: kreuth@hss.de

## **Meals**

Kindly note: The meals have been booked in advance and there is no choice available. If you need a special diet (e.g. as a vegetarian), please state so clearly during check-in.

Please pay for your drinks before leaving the dining area. This does not apply to the conference dinner, where all drinks are included (with the exception of spirits).

## **Hiking tour**

We plan to organize two hiking tours with different difficulty. Details will mainly depend on the weather and will be announced on short notice.

To gain time for the longer tour, we will provide packed lunches after the last presentation on Tuesday. If you plan to take part in the longer tour, please sign the appropriate list before the conference dinner on Monday.

For all other participants, normal lunch will be available. The shorter hiking tour will start after lunch.

## **Enquiries**

Scientific program and general organization: Monika Kaempfe

Rooms and Meals: Hanns-Seidel-Stiftung

## Participants

Alén	Benito	LMU München	jbalen@uv.es
Andres	Philip	Universität Eindhoven	p.r.andres@tue.nl
Awschalom	David	CNSI	awsch@physics.ucsb.edu
Bacca	Cecile	Universität Konstanz	cecile.bacca@uni-konstanz.de
Bartels	Christof	Universität Konstanz	christof.bartels@uni-konstanz.de
Bastmeyer	Martin	Universität Jena	martin.bastmeyer@uni-konstanz.de
Bayer	Johannes	LMU München	Johannes.Bayer@physik.uni-muenchen.de
Beierlein	Udo	LMU München	udo.beierlein@physik.uni-muenchen.de
Beil	Florian	LMU München	florian.beil@physik.uni-muenchen.de
Bein	Thomas	LMU München	tbein@cup.uni-muenchen.de
Benoit	Martin	LMU München	martin.benoit@physik.uni-muenchen.de
Beyer	Stefan	LMU München	stefan.beyer@physik.uni-muenchen.de
Biemmi	Enrica	LMU München	enrica.biemmi@cup.uni-muenchen.de
Binnig	Gerd	IBM Zurich Research Lab.	gbi@zurich.ibm.com
Boneberg	Johannes	Universität Konstanz	johannes.boneberg@uni-konstanz.de
Bräuchle	Christoph	LMU München	Christoph.Braeuchle@cup.uni-muenchen.de
Brough	Branden	UCLA	bqbrough@ucla.edu
Bujok	Oliver	VDI Technologiezentrum	bujok@vdi.de
Cleland	Andrew	CNSI	cleland@iquest.ucsb.edu
Crewett	Jana	LMU München	jana.crewett@physik.uni-muenchen.de
Darga	Alex	LMU München	alex.darga@cup.uni-muenchen.de
Debuschewitz	Christian	Universität Konstanz	christian.debuschewitz@uni-konstanz.de
DeRouchey	Jason	LMU München	jason.derouchey@physik.uni-muenchen.de
Dreher	Markus	Universität Konstanz	markus.dreher@uni-konstanz.de
Dulkeith	Eric	LMU München	Eric.Dulkeith@Physik.Uni-Muenchen.de
Feldmann	Jochen	LMU München	jochen.feldmann@physik.uni-muenchen.de
Fertig	Niels	LMU München	niels.fertig@web.de
Fotiadis	Dimitrios	Biozentrum Basel	dimitrios.fotiadis@unibas.ch
Franca	Lilian	LMU München	lila@lrz.uni-muenchen.de
Franzl	Thomas	LMU München	thomas.franzl@physik.uni-muenchen.de
Franzrahe	Kerstin	Universität Konstanz	Kerstin.Franzrahe@uni-konstanz.de
Frey	Heinrich	MPI für Biochemie	frey@biochem.mpg.de
Friedsam	Claudia	LMU München	Claudia.Friedsam@physik.uni-muenchen.de
Ganteför	Gerd	Universität Konstanz	gerd.gantefoer@uni-konstanz.de
Gärtner	Andreas	LMU München	andreas.gaertner@physik.uni-muenchen.de
Gaub	Hermann E.	LMU München	hermann.gaub@physik.uni-muenchen.de
Gossard	Arthur	UCSB	gossard@engineering.ucsb.edu
Grebing	Jochen	Universität Konstanz	jochen.grebing@uni-konstanz.de
Griessl	Stefan	LMU München	stefan.griessl@uni-muenchen.de
Guckenberger	Reinhard	MPI für Biochemie	guckenbe@biochem.mpg.de
Guttenberg	Zeno	Advantix AG	guttenberg@advantix.de
Hartmann	Udo	LMU München	hartmann@theorie.physik.uni-muenchen.de
Heckl	Wolfgang	LMU München	W.Heckl@lrz.uni-muenchen.de
Heinrichs	Stefan	Universität Konstanz	Stefan.Heinrichs@uni-konstanz.de
Hellriegel	Christian	LMU München	christian.hellriegel@cup.uni-muenchen.de
Henseler	Peter	Universität Konstanz	peter.henseler@uni-konstanz.de
Hillenbrand	Rainer	MPI für Biochemie	hillenbr@biochem.mpg.de
Hochrein	Marion	LMU München	Marion.Hochrein@physik.uni-muenchen.de
Hofmeier	Harald	Universität Eindhoven	h.hofmeier@tue.nl
Högele	Alexander	LMU München	alexander.hoegel@physik.uni-muenchen.de
Höhberger	Constanze	LMU München	constanze.hoehberger@physik.uni-muenchen.de
Höhberger	Eva	LMU München	eva.hoehberger@physik.uni-muenchen.de
Hu	Evelyn	CNSI	hu@ece.ucsb.edu
Hugel	Thorsten	LMU München	Thorsten.Hugel@physik.uni-muenchen.de
Hüttel	Andreas	LMU München	huettel@lmu.de
Kaempfe	Monika	LMU München	kaempfe@cens.de
Kallinger	Christian	Deutsches Patentamt	Christian.Kallinger@dpma.de
Kampschulte	Lorenz	LMU München	lorenz.kampschulte@gmx.de
Kardinal	Angelika	LMU München	angelika.kardinal@physik.uni-muenchen.de
Keilmann	Fritz	MPI für Biochemie	keilmann@biochem.mpg.de
Keller	Simon	LMU München	Simon.Keller@physik.uni-muenchen.de

Kinnaird	Alison	LMU München	alison.kinnaird@cup.uni-muenchen.de
Kirchner	Christian	LMU München	kirchner@lmu.de
Klapwijk	Teun	DIMES, Delft	t.m.klapwijk@tnw.tudelft.nl
Klar	Thomas	LMU München	thomas.klar@physik.uni-muenchen.de
Kotthaus	Jörg P.	LMU München	kotthaus@cens.de
Kraus	Robert	LMU München	robert.kraus@web.de
Kriele	Armin	LMU München	armin.kriele@physik.uni-muenchen.de
Kühner	Ferdinand	LMU München	Ferdinand.Kuehner@physik.uni-muenchen.de
Leiderer	Paul	Universität Konstanz	paul.leiderer@uni-konstanz.de
Lingk	Christoph	LMU München	Christoph.Lingk@Physik.Uni-Muenchen.De
Lorenz	Heribert	LMU München	bert.lorenz@physik.uni-muenchen.de
Lorke	Axel	Universität Duisburg	lorke@uni-duisburg.de
Lupton	John	LMU München	john.lupton@physik.uni-muenchen.de
Manghi	Manoel	LMU München	manoel.manghi@physik.uni-muenchen.de
Meyer	Christine	LMU München	Christine.Meyer@physik.uni-muenchen.de
Morgenroth	Evelyn	LMU München	morgenroth@cens.de
Müllen	Klaus	MPI für Polymerforschung	muellen@mpip-mainz.mpg.de
Müller	Alexander	LMU München	alexander.mueller@physik.uni-muenchen.de
Müller	Jürgen	LMU München	juergen.mueller@physik.uni-muenchen.de
Netz	Roland	LMU München	netz@theorie.physik.uni-muenchen.de
Neuert	Gregor	LMU München	Gregor.Neuert@physik.uni-muenchen.de
Pescini	Laura	LMU München	laura.pescini@physik.uni-muenchen.de
Plaxco	Kevin	UCSB	kwp@chem.ucsb.edu
Rädler	Joachim	LMU München	Joachim.Raedler@physik.uni-muenchen.de
Rajakovic	Vladana	LMU München	vladana.rajakovic@cup.uni-muenchen.de
Raschke	Gunnar	LMU München	gunnar.raschke@physik.uni-muenchen.de
Reufer	Martin	LMU München	martin.reufer@physik.uni-muenchen.de
Rogach	Andrey	LMU München	rogach@chemie.uni-hamburg.de
Sattel	Marco	Universität Konstanz	marco.sattel@uni-konstanz.de
Scheible	Dominik	LMU München	dominik.scheible@lmu.de
Schiener	Jens	MPI für Biochemie	schienen@biochem.mpg.de
Schröer	Daniel	LMU München	daniel.schroer@physik.uni-muenchen.de
Schubert	Ulrich	Universität Eindhoven	u.s.schubert@tue.nl
Simmel	Friedrich	LMU München	friedrich.simmel@physik.uni-muenchen.de
Sindel	Michael	LMU München	sindel@theorie.physik.uni-muenchen.de
Stein	Bernhard	LMU München	stein@lmu.de
Stolz	Martin	Biozentrum Basel	martin.stolz@unibas.ch
Storz	Markus	LMU München	storz@theorie.physik.uni-muenchen.de
Strobl	Christoph	LMU München	christoph.strobl@physik.uni-muenchen.de
Taubner	Thomas	MPI für Biochemie	taubner@biochem.mpg.de
Thalhammer	Stefan	LMU München	s.thalhammer@lrz.uni-muenchen.de
Treubel	Frank	Universität Konstanz	frank.treubel@uni-konstanz.de
Tseng	Hsian-Rong	CNSI	tseng@chem.ucla.edu
Ulbrich	Till	Universität Konstanz	till.ulbrich@uni-konstanz.de
Veiga	Manoel	LMU München	manoel.veiga@cup.uni-muenchen.de
Vilaseca	Montse	LMU München	montse.vilaseca@cup.uni-muenchen.de
von Delft	Jan	LMU München	vondelft@theorie.physik.uni-muenchen.de
v.Gynz-Rekowski	Felix	Universität Konstanz	Felix.von-Gynz-Rekowski@uni-konstanz.de
Wehle	Angelika	LMU München	wehle@lmu.de
Weissmueller	Gilberto	LMU München	gilberto@ufrj.br
Wilhelm	Frank	LMU München	wilhelm@theorie.physik.uni-muenchen.de
Wouters	Daan	Universität Eindhoven	d.wouters@tue.nl
Xu	Ling	LMU München	Xu.Ling@physik.uni-muenchen.de
Olapinski	Michael	Universität Konstanz	michael.olapinski@uni-konstanz.de
Rief	Matthias	LMU München	Matthias.Rief@physik.uni-muenchen.de
Vilfan	Mojca	LMU München	mojca.vilfan@ijs.si



## Program

	<b>Monday 7.10.</b>	<b>Tuesday 8.10.</b>	<b>Wednesday 9.10.</b>
7.30 – 8.20	<b>Breakfast</b>	<b>Breakfast</b>	<b>Breakfast</b>
8.20 – 8.30	<b>Jörg P. Kotthaus, CeNS</b> Welcome and Introduction		
8.30 – 9.10	<b>Hermann Gaub, CeNS</b> Single Molecule Experiments by AFM-Related Techniques	<b>Branden Brough, UCLA</b> Motion control of bio-molecules in fluidics	<b>Arthur Gossard, UCSB</b> Metal-semiconductor nanostructures
9.10 – 9.50	<b>Kevin Plaxco, UCSB</b> Protein folding: the theory and application of a naturally-occurring, nm-scale self assembly process	<b>Jan von Delft, CeNS</b> Kondo effects in strongly correlated quantum dots	<b>Fritz Keilmann, CeNS</b> Optics on a nanometer scale
9.50 – 10.30	<b>Paul Leiderer, SFB 513</b> Optical near field effects in nanostructuring and nanocleaning	<b>Dimitrios Fotiadis, BZ Basel</b> Atomic Force Microscopy of Native Membranes	<b>Gerd Ganteför, SFB 513</b> Properties of mass-selected clusters: every atom counts
10.30 – 11.00	<b>Coffee/Tea</b>	<b>Coffee/Tea</b>	<b>Coffee/Tea</b>
11.00 – 11.40	<b>Jochen Feldmann, CeNS</b> Photonics with Functionalized Nanoparticles	<b>Evelyn Hu, CNSI</b> Quantum Dots and microcavities: a harmonious match	<b>Andrew Cleland, CNSI</b> Nanomechanical Systems Probed by Electron Tunneling
11.40 – 12.20	<b>David Awschalom, CNSI</b> Spin Gating and Nuclear Imprinting in Semiconductor Nanostructures	<b>Christoph Bräuchle, CeNS</b> Single Virus Tracing: Observation of a single dye-labelled virus on its infection pathway into a living cell	<b>Thomas Bein, CeNS</b> Functional Nanostructures in Designed Spaces
12.30 – 14.00	<b>Lunch</b>	<b>Lunch</b>	<b>Lunch</b>
14.00 – 14.40	<b>Teun Klapwijk, DIMES</b> Conduction in Organic Molecular Crystals: a Progress report	Hiking tour	Departure
14.40 -15.20	<b>Martin Bastmeyer, Jena</b> Cell behaviour on micropatterned substrates		
15.20 – 16.00	<b>Joachim Rädler, CeNS</b> Self-assembly of lipid/DNA nanostructures		
16.00 – 16.30	<b>Coffee/Tea</b>		
16.30 – 17.10	<b>Martin Stolz, BZ Basel</b> Nanotechnology in Medicine: Moving from the Bench to the Patient		
17.10 – 17.50	<b>Hsian-Rong Tseng, CNSI</b> From Molecular Recognition and Self-Assembly via Molecular Electronics to NanoElectroMechanical Systems	(17.00: meeting of the Advisory Board)	
18.30 – 20.00	<b>Conference Dinner</b>	<b>Dinner</b>	
20.00 – 22.00		Poster Session	