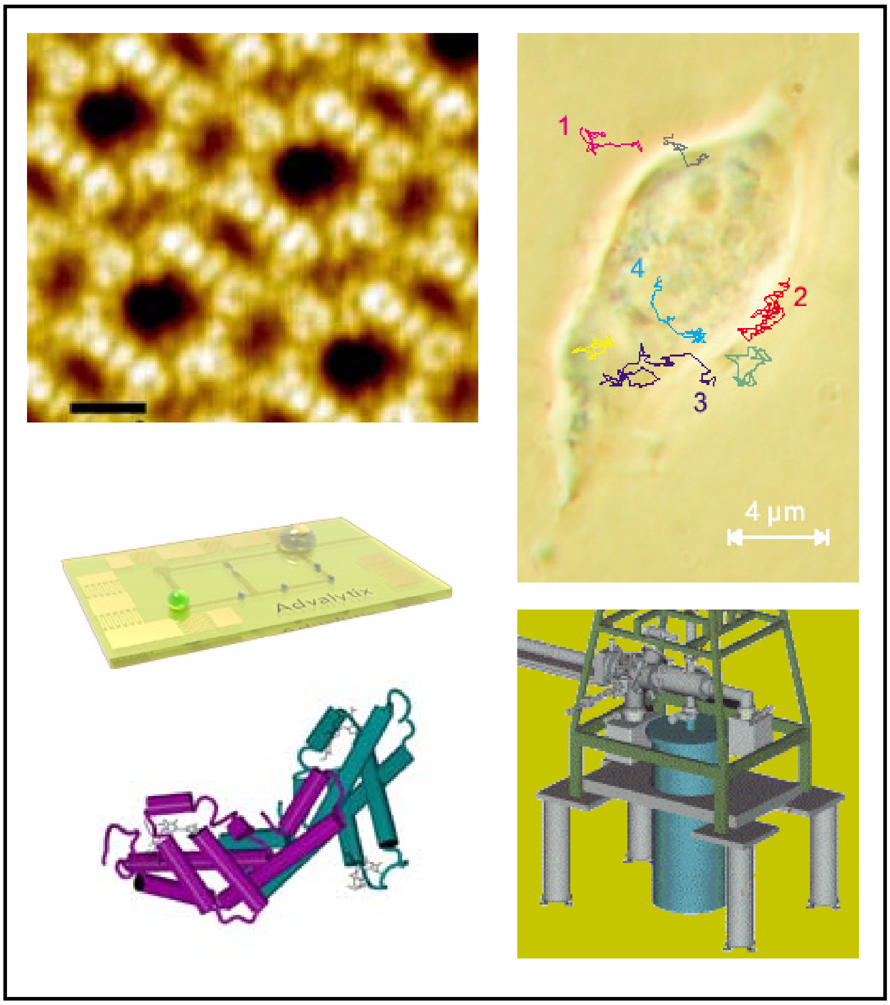
Center for NanoScience
Ludwig-Maximilians-Universität

Annual Report 2001



Index

Introduction **3**

Research Projects **5**

- Electronic, mechanical and optical properties of nanostructures **5**
- Biophysical research on a nanometer scale **12**
- Chemical processes for nanostructural assembly **18**
- Technological applications of nanoscience **20**
- Theoretical analyses of nanostructures **24**
- Scanning Probe Techniques **25**
- News from CeNS Spin-Offs **27**

Joint CeNS Projects **30**

Cooperations and Guests **34**

Publications **38**

Patents **47**

Invited Talks **48**

Theses **53**

Awards **55**

CeNS in the Media **56**

New Companies **57**

Funding **58**

Introduction

In the year 2001, CeNS continued the success story and expanded with new members, new science and educational activities and thriving industrial spin-offs.

With hirings at the faculty of the LMU physics department dedicated to areas related to NanosSciences the number of full members has significantly increased. We are happy to welcome Prof. Jan von Delft, Prof. Matthias Rief and Prof. Joachim Rädler as full CeNS members.
New extraordinary members who have joined CeNS are the LMU junior scientists Dr. Udo Beierlein, Dr. Martin Benoit, Dr. Monika Kaempfe, Dr. Thomas Klar, and Dr. Thomas Müller, Dr. Fritz Keilmann from the Martinsried Max Planck Institute for Biochemistry and Dr. Christoph Gauer and Dr. Zeno Guttenberg, both with the CeNS spin-off Advalytix.

Other junior members of CeNS have been offered attractive faculty positions elsewhere and have left or are in the process of leaving LMU to join other institutions:

- Dr. Uli Lemmer as full professor (C4) at Technical University Karlsruhe
- Dr. Achim Wixforth as full professor (C4) at Universität Augsburg
- Dr. Gero von Plessen as professor (C3) at Technische Hochschule Aachen
- Dr. Boris Steipe as professor at Toronto, Canada

In February 2001, Dr. Monika Kaempfe began her work as Scientific Manager of CeNS immediately challenged with the successful organization of the first CeNS winterschool and in May Evelyn Morgenroth joined the team as our new competent secretary.

Increased interdisciplinary research activities have been stimulated by the various CeNS workshops and seminars listed below, which hosted prominent guest speakers from all areas of NanoScience and introduced new students, postdocs and faculty members to the network of CeNS.

- "Sensing and Manipulating in the Nanoworld", Mauterndorf, 18 – 23 February 2001
- "CeNS meets Industry", 6 July 2001
- "Nanoscience: Tools and Devices", Venice, 24 – 28 September 2001
- The weekly seminar by CeNS

Major events were the winter school at Mauterndorf and the workshop at Venice, both bringing together experienced researchers in key subjects of NanoScience from all over the world with members and associates of CeNS. Set in beautiful surroundings, intense scientific exchange was supplemented with ample time for informal discussions. As previous workshops the recent ones also triggered new collaborations within CeNS and with other national and international partners.

In addition to the above mentioned workshops and the weekly "CeNS Oberseminar" (jointly offered with the "Sektion Physik") with many highlight topics, a number of seminars with many international speakers were part of the weekly CeNS calendar (link) and reflect the international interaction of CeNS. In addition CeNS hosted a large number of prominent guests from all over the world as listed below who interacted fruitfully with CeNS members and students.

The successful interdisciplinary activities at CeNS are best demonstrated by the large number of publications in international journals of high visibility, many of which are coauthored by CeNS members belonging to different groups and disciplines as well as external partners. Consequently a large number of invited talks at conferences and workshops have been extended to CeNS members. A significant number of joint publications can be traced to informal encounters between CeNS members at previous workshops.

CeNS also supported and organized a funding application for a Bavarian research network called “ForNano” to the Bavarian Research Foundation, which – granted in 2002 – supports research aiming at miniaturized analytical tools ("lab on chip") via nanotechnology in biochemistry, chemistry and physics. ForNano joins 9 research groups at CeNS, the Technical University of Munich and of Würzburg University with 8 industrial partners, most of which are part of the Bavarian start-up scene.

The amazingly successful start-up activities developed by CeNS members were a special highlight of 2001: Four new company ventures were triggered with the help of the Munich Business Plan Competition. Here Attocube Systems won the first prize in the final round of 2001, Nanoscape and the Virus Tracing Group shared the third prize and Nanion ran in sixth position in a field of 114 competing teams. With Nanotools, Nanotype and Advalytix formed in previous years CeNS is proud to have already generated seven thriving spin-offs in the Munich area.

In their yearly meeting, the CeNS members decided on additions to the CeNS statute and established two additional forms of association with CeNS. Former CeNS members who want to keep close links to CeNS, but feel unable to contribute as actively as expected from full members, can now apply to be CeNS Alumni. The status of Alumnus does not expire unless requested. The new status of CeNS Graduate recognizes the important and active roles that are played by doctoral and diploma students working under the guidance of a CeNS member. To keep the CeNS membership alive and active all members (except for the alumni) need to reapply for their member status after 3 years. With CeNS completing its first 3 year period at the end of 2001 we are happy that all founding members that are still researching in the Munich area have reapplied to keep their membership.

As a result of the many CeNS activities, especially the huge success of its spin-off companies, the CeNS management has been approached by a number of Venture Capital companies and by the press for further information on the “Success factors” of CeNS. In addition, several CeNS members were represented in the media, as listed below. One highlight should be mentioned here though: Christoph Bräuchle’s Single Virus Tracing article in “nature” resulted in follow-up articles in all major media in Germany and all over the world.

CeNS also hosted a number of visiting delegations or single company representatives who were interested in learning about the wide science spectrum of CeNS as well as its unorthodox structures based solely on the voluntary engagement of CeNS members that make CeNS even for its founding members surprisingly successful.

Hoping that our friends and colleagues all over the world will enjoy the more detailed report below it is my pleasure to thank all CeNS members and associates for contributing to good science, promising technologies and fun education.

Jörg P. Kotthaus
Spokesman of the board

Research projects

Electronic, mechanical and optical properties of nanostructures

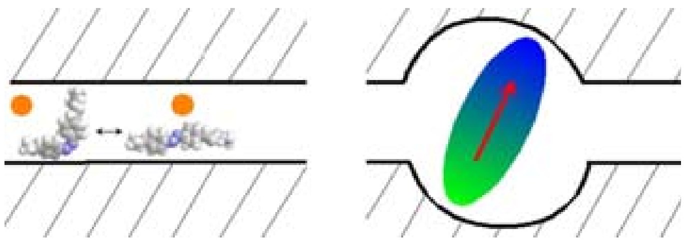
Conducting nanostructures in accessible host systems (Prof. Thomas Bein)

In the context of the newly established SFB 486 at the University of Munich, we explore different means of structuring very thin films with accessible channel systems that can serve as hosts for the oriented growth of ordered patterns of conducting and semiconducting materials. This work builds on our previous efforts directed towards the encapsulation of conducting polymers, carbon, and charge-transfer salts in the nanometer channels of mesoporous hosts. We have recently achieved a breakthrough in the generation of oriented channels in thin mesoporous films that can serve as hosts for a variety of conducting and semiconducting guest filaments at the nanoscale. Carbon nanotubes are the first examples to be synthesized in association with these and related films. The resulting conducting nanostructures in host systems will be investigated in collaboration with our colleagues in Physics, by using, for example, scanning probe microscopies.

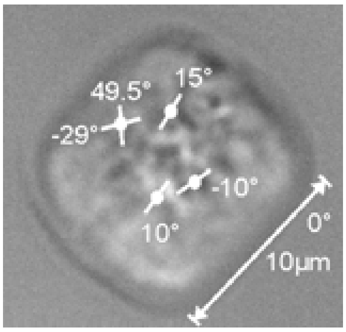
A nanomechanical single electron shuttle (Dr. Robert Blick, Prof. Wilhelm Zwerger)

In this work a most notable experiment is pursued which combines nano-electromechanical systems (NEMS) and single electron circuitry. The basic idea of this approach is to not only control single electrons with a high accuracy, but also the mechanical degree of freedom on the nanoscale. In previous work the focus was set on measurements on mechanical structures only. Several mechanical resonators were characterized and the basic physics and possible applications in sensor technology were determined. In this work the focus is on integration of a tunneling transducer into the nanomechanical resonators for extremely sensitive, high speed displacement detection.

Single Molecule Functional Devices and Molecular Machines
(Prof. Christoph Bräuchle, Dr. Andreas Zumbusch)



Nanostructured materials on the basis of organic guest molecules incorporated in a suited inorganic channel structure (molecular sieve) have intrinsic mechanical degrees of freedom. By the modification of size, shape and chemistry of the guest and the host these degrees of freedom can be adjusted in many ways. Our goal is the realization of molecular rotors, valves and switches in these nanostructured systems. The first figure shows a schematic representation of a nanosized molecular valve (left) in a nanometer sized channel and a molecular rotor (right).



With a confocal mircoscope we inestigate the spatial, spectral and orientational properties of single molecules. The image(left) shows the individual orientations of four single Oxazine-1 molecules within an $AlPO_4$-5 crystal. Three of the molecules align in the unidimensional pores along the crystal main axis indicated with an arrow. In one case a jump in the orientation from +49.5° to -29° with respect to the pore direction could be observed.
This project is a cooperation with the groups of P. Behrens, Hannover, D. Wöhrle, Bremen, and T. Bein, LMU Munich.

Ultrafast electronic processes of quantum dot lasers (Prof. Jochen Feldmann)

Nonlinear optical experiments with femtosecond time-resolution have been performed on III-V quantum dot laser structures. Our temperature-dependent results show that multiple optical phonon emission is the dominant carrier capture mechanism into quantum dots at low carrier densities. In addition, the formation and propagation of so-called dark pulses have been investigated by disturbing an electrically pumped quantum dot laser by short optical IR-pulses.

Unusual nonlinear optical light scattering from semicontinuous metal films (Prof. Jochen Feldmann)

For rough metal films at the percolation threshold giant field enhancement effects are expected to occur locally in so-called hot spots. We have performed angle-resolved second harmonic generation (SHG) experiments to verify the existence of such hot spots. We have found that the hot spots increase the SHG signals by orders of magnitude compared to a smooth metal film. The assumption of hot spots also explains the unusual observation that the semicontinous metal films behave like mirrors in first order experiments but as diffusive and strongly scattering surfaces for the SHG light.

Quantumchemical investigation of dye molecules under tensile strain (Dr. Irmgard Frank)

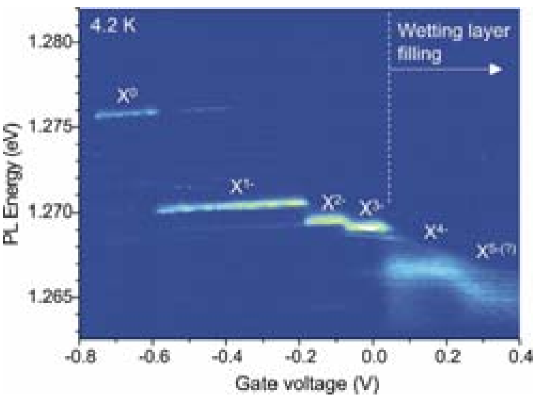
In collaboration with Dr. Markus Seitz and Dr. Andreas Zumbusch, we have investigated the change of the optical properties of Hemicyanine dyes exposed to tensile strain in an AFM experiment. We have employed different quantumchemical methods (semiempirical and ab-initio) in order to estimate the effect of mechanical stress on (a) the absorption wavelengths, (b) the oscillator strengths, and (c) the frontier orbitals. It was found that a significant change of the absorption wavelength emerges if a binding interaction of the HOMO is distorted by application of stress. A change of the oscillator strength was observed for dye molecules that are non-planar due to steric hindrance. These concepts help to design dyes that are optimally suited for single-molecule experiments.

Optical and infrared near-field microscopy (Dr. Fritz Keilmann)

We are developing "apertureless" or scattering-type near-field microscopy which has a demonstrated optical resolution capability in the 1-10 nm range. It is fortunate for applications in the nanosciences that this approach has also full spectral capability including long-wavelength infrared operation. Here vibrational absorption resonances offer compound-specific assignment and thus enable a chemical contrast for the mapping of multicomponent nanostructures. Recent achievements include the introduction of phase contrast into near-field microscopy, the detection and quantification of sub-surface-implanted free carriers, the discovery of a categorial contrast among metals, semiconductors and low-index dielectrics, and the mapping of eigenfields that surround plasmon-resonant gold nanoparticles.

Optics with Nanostructures
(D. Haft, A. Högele, C. Schulhauser, Dr. Richard Warburton, and Prof. Khaled Karraï)

Quantum dots or rings are artificial nanometer-sized clusters that confine electrons in all three directions. They can be fabricated in a semiconductor system by embedding an island of low-band-gap material in a sea of material with a higher band-gap. Quantum dots are often referred to as artificial atoms because, when filled sequentially with electrons, the charging energies are pronounced for particular electron numbers; this is analogous to Hund's rules in atomic physics. But semiconductors also have a valence band with strong optical transitions to the conduction band. These transitions are the basis for the application of quantum dots as laser emitters, storage devices and fluorescence markers. One main field of interest is, how the optical emission (photoluminescence) of a single quantum ring changes as electrons are added one-by-one. We find that the emission energy changes abruptly whenever an electron is added to the artificial atom, and that the sizes of the jumps reveal a shell structure.



Reflected Image of a Strongly Focused Spot
(Prof. Khaled Karraï)

We describe the reflection of a strongly focused beam from an interface between two dielectric media. If the beam is incident from the optically denser medium, the image generated by the reflected light is strongly aberrated. This situation is encountered in high-resolution confocal microscopy and data sampling based on solid immersion lenses and oil immersion objectives. The origin of the observed aberrations lies in the nature of total internal reflection, for which there is a phase shift between incident and reflected waves. This phase shift displaces the apparent reflection point beyond the interface, similarly to the Goos–Hänchen shift.
This project is in cooperation with Lukas Novotny, University of Rochester and Robert D. Grober, Yale University.

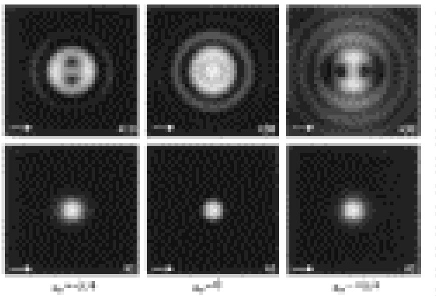
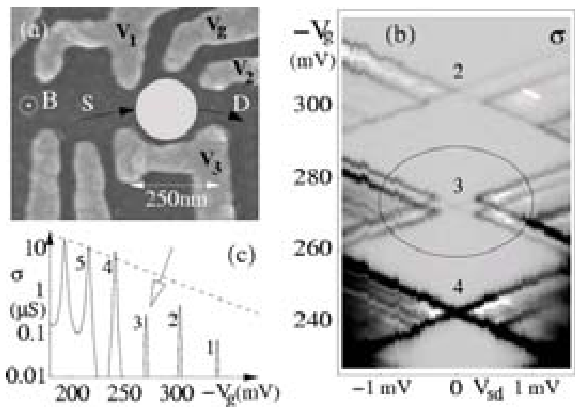


Figure: Reflected images of a diffraction-limited focused spot. The spot is moved in steps of a quarter wave length across the interface. z_o is positive (negative) when the focus is below (above) the interface. Upper row, glass–air interface, lower row, glass–metal interface. The arrow indicates the direction of polarization of the incoming beam. Image size, 4.75 x wavelength.

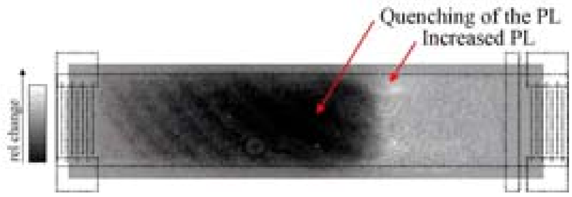
Electronic Properties of Nanostructures
(S. Böhm, C. Decker, S. de Haan, A. Holleitner, A. Hüttel, F. Liou, H. Qin, C. Schäflein, A. Tilke, J. Weber, A. Würtz, Dr. Udo Beierlein, Dr. Robert Blick, Dr. Heribert Lorenz, Prof. Axel Lorke and Prof. Jörg P. Kotthaus)

With electron beam lithography we prepare laterally patterned landscapes into two-dimensional electron systems confined either to a GaAs-, AlGaAs or a $Si\text{-}SiO_2$ interface. Ballistic electron motion in lateral nanostructures with broken symmetry is utilized for rectification and charge pumping. Coulomb blockade, Kondo resonances, spin-blockade, phase coherent transport and photon-assisted transport are studied in detail in single and coupled quantum dots electrostatically defined on GaAs-AlGaAs heterojunctions. Coulomb blockade and ballistic transport through ultra-small quantum wires and dots prepared on Si on insulator wafers are investigated up to room temperature. Epitaxial Lift-off of GaAs quantum wells is used to prepare and study the Quantum Hall effect in two-dimensional electrons systems wrapped on a cylinder. Most recently, we aim our research at molecular systems, such as carbon nanotubes. Our goal is the detailed understanding of the new physical phenomena associated with a dramatic reduction of size, to explore new grounds for future device applications, and to be prepared for the day when nano-electronics will take over the role of micro-electronics! Further information can be found here.



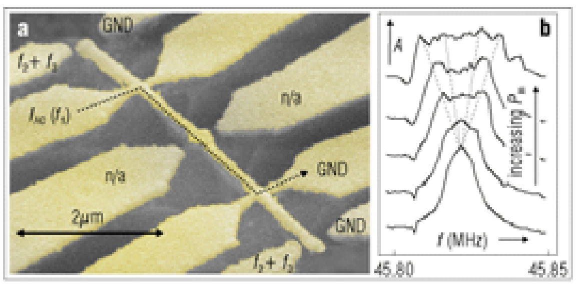
Static and Dynamic Lateral Superlattices (F. Beil, C. Bödefeld, P. Halke, A. Haubrich, J. Krauß, H.-J. Kutschera, A. Müller, C. Strobl, Apl. Prof. Achim Wixforth, and Prof. Jörg P. Kotthaus)

Surface acoustic waves are modes of elastic energy which can propagate on the surface of different materials. If the substrate is piezoelectric, those waves are accompanied by electric fields which then propagate at the speed of sound. The electric fields of the wave can couple to the mobile carriers within a semiconductor structure and modify its electronic and elastic properties. By measuring the attenuation of the wave and the renormalization of the sound velocity we can, for instance, extract information on the dynamic conductivity of the electron system. We also investigate the possibility to use a SAW for a dynamical lateral potential modulation and we study the influence of a SAW onto the optical properties of an electron system. Also, quantum dots are employed to modify the emission properties of the sample. A stripe-like potential modulation in a semiconductor structure similar to that of a surface-acoustic wave can also be achieved by using interdigitated metal electrodes on top of the structure. When a bias is applied to these electrodes, there is a strong, tunable in-plane potential modulation. In contrast to the traveling wave, this modulation is static. Our experiments presently cover the frequency range between 100 MHz and 6 GHz, corresponding to surface acoustic wavelengths between 30 microns and 500 nm, respectively. Further information can be found here.



Nano-Electro-Mechanical Systems (NEMS)
(F. Beil, E. Höhberger, A. Hörner, J. Kirschbaum, A. Kraus, L. Pescini, D. Scheible, Dr. Artur Erbe, Dr. Heribert Lorenz, Dr. Robert Blick, and Prof. Jörg P. Kotthaus)

The approach pursued in this work is mainly based on three-dimensional nanostructuring of semiconducting materials. This allows for building nano-electromechanical systems (NEMS) for studying dissipation on the nanometer scale via the electron-phonon interaction and applications in sensor and communication technology. Especially, heterostructures grown by molecular beam epitaxy are perfect candidates for 3D nano-fabrication, since electronically and optically active layers can be embedded. One of the projects we are focussing on is the integration of two-dimensional electronic systems in suspended cavities. The cavities will eventually reveal phonon size quantization, which directly interacts with discrete electronic modes in the cavities. This should finally enable probing electronic dephasing mechanism limit by electron-phonon scattering.



Another impetus of our work is on applying NEMS for ultra-sensitive charge and displacement detection. This is achieved by a combination of suspended nano-crystals and single electron transistors. Transport measurements are the perfect tool for sensing minute displacements of the resonating cantilevers, induced by environmental changes of the whole galaxy. Part of these studies concerns the purely mechanical response of NEMS in the nonlinear regime, i.e. nanometer sized mechanical systems as chaotic oscillators. In summary NEMS are valuable tools not only for applications but also for the nano-sciences. Further information can be found here.

Tetraarylmethanes with Chromo- and Electrophore Sidechains - Syntheses and Intramolecular Electronic Communication of Tetrahedral Arranged π-Systems (Prof. Thomas J. J. Müller)

In this project we focus on the synthetic access to threedimensional nanometersized conjugated molecules with tetrahedral symmetry. The electronic properties in the ensemble reveal a significant electronic coupling between the four electrophor branches. A perspective of these novel molecules is the use in OLED or OFET as tetrafunctional emitter, electron or hole transport layers. We now plan a detailed characterization of the self assembly and possible nanostructuration.

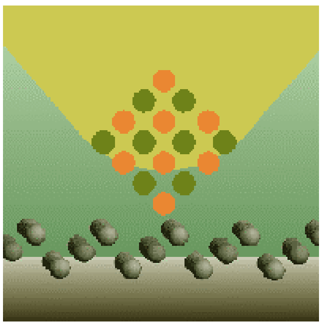
Phenothiazinyldiades and -triades as Models for Coupled Redox-Addressable Molecular Wires (Prof. Thomas J. J. Müller)

In this project we focus on the synthetic access to oligophenothiazines with nanometersized dimension. Electronically, these redox active oligomers display a strong electronic coupling as shown by cyclic voltammetry in the ensemble. First measurements of the current-voltage behavior in a hole-only OLED reveals that this class of materials is an excellent hole conductor. Alkynylbridged systems were self assembled on HOPG and display for the pattern a significant dependence on the N-alkyl substitution. Future plans for using oligophenothiazines as hole transport layers in OLED and OFET are currently under investigation. The detailed characterization of self assembly and nanostructuration is also pursued.

Polymeric Phenothiazines as Coupled Redox-Addressable Molecular Wires (Prof. Thomas J. J. Müller)

In this project the experience from project 2 is applied to the synthesis phenothiazine polymers and their structural, electronic and self-assembly characterization. The ultimate goal is the incoroporation of these organic wires into break junctions or between nanotweezers.

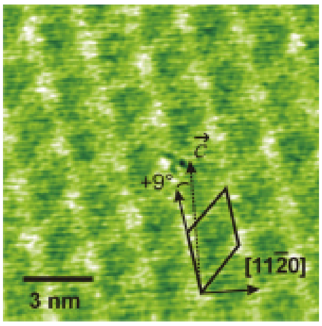
Quantitative atomic resolution force microscopy on fluorite (Prof. Michael Reichling)



Tip-surface interaction

Atomic resolution imaging on ionic surfaces with dynamic mode force microscopy is investigated in close cooperation between experiment and theory. Theoretical partners are A. L. Shluger (University College London) and A.S. Foster (Helsinki University). A quantitative understanding of contrast formation was obtained for $CaF_2(111)$ where it could be demonstrated for the first time that force microscopy is capable of identifying different sub-lattices of an insulating crystal. A comparison of experiments to simulations also allows an absolute calibration of tip-surface distance. $CaF_2(111)$ is now a standard for atomic and nano-scale tip characterization.

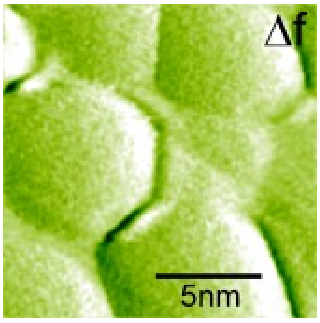
Atomic details and nanoscopic domains on reconstructed sapphire surfaces (Prof. Michael Reichling)



$Al_2O_3(0001)$ √31x√31 9°

We solved the long standing problem of direct, atomic resolution imaging on insulating oxide surfaces. As a first target, we chose sapphire that is interesting in its complicated bulk and surface structure and technologically important as a substrate and insulating layer material in nanotechnology. The high temperature reconstructed surface of $Al_2O_3(0001)$ could be shown to be composed of domains with hexagonal atomic order in the centre and disorder at the periphery and we could positively exclude a cubic surface structure. Regions of disorder appear as protrusions in highly resolved force microscopy images and, therefore, the nanometer-sized surface unit cell is immediately apparent.

Growth and morphology of metal clusters on insulators (Prof. Michael Reichling)



Ni on $Al_2O_3(0001)$

Nanometer-sized clusters of Nickel were grown on the (0001) surface of sapphire. Their size, shape and distribution is studied as a function of deposition and annealing conditions with high resolution force microscopy where the emphasis is on the initial stages of nucleation of a few atoms on the surface. Nickel precipitates appear in the form of well ordered clusters with a height of several atomic layers and a shape determined by the crystallographic structure of low index surfaces of Nickel. In close cooperation with Th. Risse (Fritz-Haber-Institut Berlin), nanoparticle growth is now studied for different surfaces and surface preparations.

Metallo-Supramolecular Assemblies (Prof. Ulrich S. Schubert)

The outstanding complexing ability of bipyridine and terpyridine ligands for transition metal complexes was utilized for several research projects: Functionalized fullerene units (cooperation with K. Müllen/MPI Mainz) were reacted with functionalized bipyridines and terpyridines in order to obtain metal complexing fullerene building blocks. After addition of suitable metal ions, dimers or dendritic assemblies could be prepared and investigated. Furthermore, this methology allows the access to metallo-supramolecular assemblies of fullerenes and dyes (such as perylene) or conducting polymers (such as PPV). The same ligands were combined with biological units, such as, e.g., biotin, and used for the combination of "synthetic" metallo-supramolecular binding with "natural" biological binding. Finally, the *N*-heterocyclic ligands were used for the stabilization of metallic nanoparticles as well as for their further functionalization and arrangement into ordered arrays. First results have been obtained with gold, palladium and CdS nanoparticles (cooperation with J. Feldmann).

Physical Characterization of Supramolecular Architectures (Prof. Ulrich S. Schubert)

With respect to the physical characterization of supramolecular architectures, powerful methods are available for systems existing as single crystals or as ordered surface layers. For supramolecular complexes in solution, however, the situation is much less favorable, in particular for metallo-supramolecular systems. This even holds for studies on rather basic problems, like that of the molar mass or the related problem of the state of association of a supramolecular structure in a special solvent. For this purpose we applied analytical ultracentrifugation for synthetic supramolecular sytems (cooperation with D. Schubert/Universität Frankfurt). We could demonstrate, in extensive investigations, that analytical ultracentrifugation is ideally suited to answer the questions concerning the state of association of metallo-supramolecular species in solution utilizing sedimentation equilibrium or sedimentation velocity analysis. At present, no other methods are available which could deal with the described problems with comparable rigor and versatility.

Biophysical research on a nanometer scale

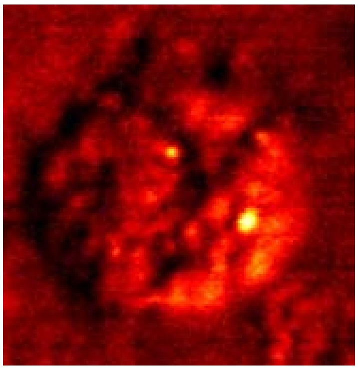
Single-Virus-Tracing (Prof. Christoph Bräuchle, Dr. Andreas Zumbusch)

Single virus tracing (SVT) is a novel method: For the first time it is possible to visualize the motion of a single virus on its infection pathway into a living cell under natural and physiological conditions. This means that the virus is labeled with only one dye molecule, thus minimizing any distortion of the virus-cell interactions. It is imaged with single molecule techniques. SVT is a real time technique with high spatial (40 nm) and time (10 ms) resolution. The movement of the virus in- and outside the cell is monitored by a running camera. The obtained movies provide detailed image sequences revealing the "movie script" of the entry pathway and thus give detailed insights into the mechanisms of virus uptake and virus trafficking. Never before viruses could be visualized in such details on their way into a living cell from the first touch at the cell membran to the final deposition of the viral DNA in the cell nucleus. From the observed mechanisms of the virus uptake and trafficking new strategies for antiviral drug design and for the use of viruses as gene shuttles e.g. in gene therapy can be developed. The figure (right) shows traces of single virus particles diffusing in solutin (1,2), touching at the cell membrane (2), penetrating the cell membrane (3), diffusing in the cytoplasm (3,4), penetrating the nuclear envelope (4), and diffusing in the nucleoplasm. This project is a cooperation with the groups of Profs. M. Hallek, K. Koszinowski, and E. Wagner, all LMU Munich.

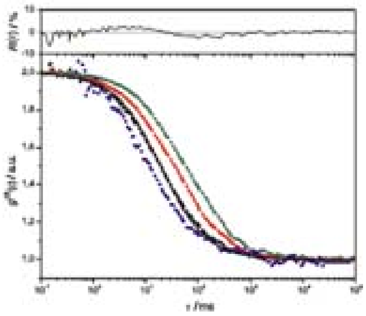
Single Molecule Imaging Of The Life-Cycle Of Prions In Living Cells (Prof. Christoph Bräuchle, Dr. Andreas Zumbusch)

Direct observation of single molecules and single molecular events inside living cells can dramatically improve our understanding of basic cellular processes and intracellular transport. The advantages of this method will be used to follow the different endocytic pathways of single prion molecules and their receptor, the 37kDa/67kDa lamin receptor, in living cells. A detailed study of the precise location of the prion protein and its receptor within the life cycle of prions will open new ways for a powerful therapeutic intervention in prion diseases. This project is a cooperation with the group of Stefan Weiss, Gene Center, LMU Munich.

Coherent Anti-Stokes Raman (CARS) Microscopy (Dr. Andreas Zumbusch)

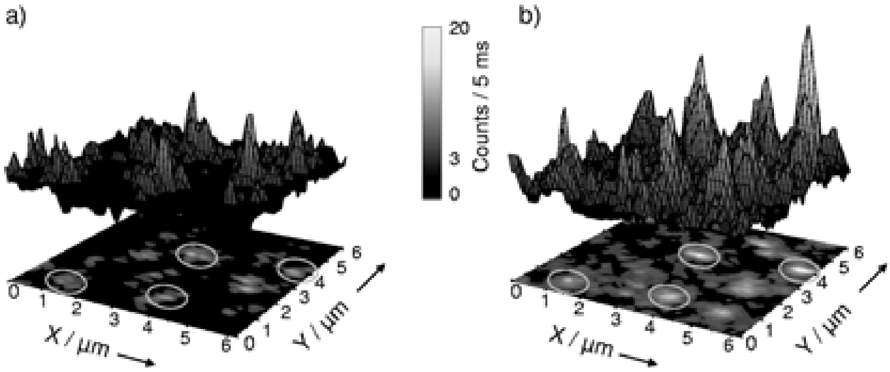


Fluorescence microscopic methods based on confocal microscopy or two photon excitation have become important tools in molecular biology. Despite their undeniable value, some problems inherent to fluorescence excitation like phototoxicity of the employed dyes or their bleaching persist. To overcome the need for staining we developed a novel microscopic technique with contrast generation based on Coherent Anti-Stokes Raman Scattering (CARS). In this case the resonant excitation of molecular vibrations of the sample is exploited for selective imaging. Simple tuning of the frequency of one of the exciting lasers now allows for the visualization of structures with different vibrational spectra. Other than IR microscopy and conventional Raman microscopy, CARS microscopy offers high sensitivity at low excitation intensities with a three dimensional spatial resolution similar to confocal microsopy. With this method live cell imaging with a molecular vibrational contrast and visible optical resolution for the first time becomes possible (Fig. 1 shows a HeLa cell with mitochondrias as bright spots). The method has recently been extended to CARS correlation spectroscopy, which allows the labelfree detection of the diffusion of sub-100 nm particles. An example of autocorrelations for differently sized polystyrene beads is shown in Fig. 2. CARS microscopy and correlation spectroscopy thus opens exciting possibilities for live cell investigations and observations of aggregation phenomena which are of central importance in many biological processes.



Fluorescence correlation spectroscopy and single molecule spectroscopy of the green fluorescent protein (Prof. Christoph Bräuchle, Dr. Andreas Zumbusch)

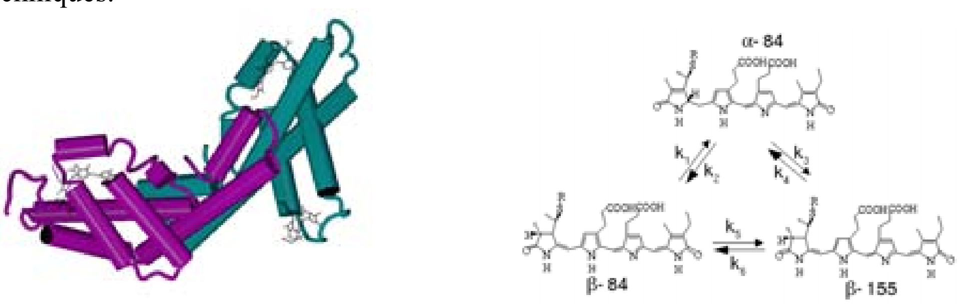
The green fluorescent protein (GFP) and its mutants nowadays are the most widely used labels in molecular biology. Their observation on the single molecule level would open a new horizon for the kinetics of protein-protein interactions in-vivo. Therefore, GFP's photophysics are in the focus of our scientific interest. We introduced a new two-color excitation technique to fluorescence correlation spectroscopy (FCS). This approach allows us to analyze the fluorescence fluctuations which are responsible for the weak fluorescence of GFP on the single molecule level. This knowledge makes it possible to enhance the fluorescence yield of single molecules of GFP with simultaneous two-color irradiation. This advance leads to better visualization of single GFPs in living organisms.



The figure shows one-color (a) and two-color (b) fluorescence image of single GFP molecules from the same sample area. Some molecules are marked by circles. This project is a cooperation with the group of Boris Steipe, Gene Center, LMU Munich.

Single Molecule Spectroscopy of the Phycoerythrocyanin (PEC)
(Prof. Christoph Bräuchle, Dr. Andreas Zumbusch)

Phycoerythrocyanin (PEC) is the short wavelength absorbing pigment in cyanobacteria. In this work we perform single molecule investigations of PEC at room temperature as well as at cryogenic temperatures in order to gain a better understanding of the energy transfer in PEC. In a collaboration with the group of Prof. H. Scheer (Botanisches Institut, LMU Munich) we are able to investigate the different subunits separately and study the influence of aggregation of the different subunits constituting the native trimeric and hexameric form of the protein. Results from experiments employing polarization sensitive and spectrally selective excitation and emission detection show a wealth of different behaviours unobservable with common bulk techniques.



Left: Structure of the monomeric subunit (Duerring et al., J. Mol. Biol. 211 (1990) 633-644); Right: Sketch of the energy transfer pathways within the monomeric subunit. This project is a cooperation with the group of H. Scheer, Bot. Inst., LMU Munich.

Simulation of the photoisomerization of rhodopsin (Dr. Irmgard Frank)

In collaboration with Prof. Dr. Ursula Röthlisberger (ETH Zürich) we are developing a method for the treatment of photoreactions in proteins. To this aim we have combined the QM-MM method developed at the ETH Zürich with our density-functional scheme for the treatment of excited states (Restricted open-shell Kohn-Sham, ROKS). As a first application we are investigating the photoisomerization of rhodopsin. We have developed a model of the protein in a membrane-mimetic environment (about 24000 Atoms) on the basis of a recently resolved X-ray structure of the membrane protein. This model was found to be stable in a classical molecular dynamics simulation without applying any constraints, and shall represent the starting point for a QM-MM excited-state simulation.

Single molecule biophysics (Prof. Hermann Gaub)

Our research is focused on biophysics and material sciences and ranges from structure and dynamics of lipid films to molecular processes at cell surfaces. There is a two-fold interplay between physics and life science which spurs our research activities.

i) Modern biology provides stunningly clean and well controlled samples making precise Physics experiments possible and allowing the design of new materials with novel properties. Concepts that were developed in Physics allow a better understanding of the basic mechanisms of the organization of life systems. Key problems may now be address quantitatively and backed up with theory.

ii) The complexity of biological systems requires as many different techniques as possible. Many novel experimental approaches were developed in Physics. Biophysicists may integrate both sides and are adept best to further develop the techniques according to the specific needs of live systems.

a) Unbinding of single ligand receptor pairs in living cells (A. Wehle, Dr. Martin Benoit)

Living cells can communicate through receptor molecules on their extracellular membrane.

With the recently developed technique of immobilizing cells on a force sensor of an AFM these communication molecules directly can be probed with respect to their unbinding forces.

Such forced unbinding of receptor ligand pairs has provided novel information on the specific molecular recognition mechanisms. Now various cell adhesion molecules and adhesion mechanisms on living cells are scrutinized with this technique.

b) Single Molecule Mechanics of DNA Drug Interaction (R. Krautbauer)

Force spectroscopy was used to investigate the interaction of small molecules with individual DNA molecules. It could be shown that the stretching profiles allow the discrimination between different binding modes, such as intercalation, groove bindiung and crosslinking. The binding processes could be followed directly on single DNA molecules, allowing the purely mechanical detection of chemical reactions on single molecules.

c) Unfolding the membrane protein Bacteriorodopsin (M. Kessler)

Atomic force microscopy and single-molecule force spectroscopy were combined to image and manipulate purple membrane patches. Individual bacteriorhodopsin proteins were first localized, then addressed and finally extracted from the membrane; the remaining vacancies were imaged again. Upon extraction, the unfolding of the helices was measured. The force spectra revealed the individuality of the unfolding pathways. The most pronounced peaks could be assigned to the pairwise extraction and unfolding of the alpha-helices. However, details in the force spectra showed that intermittent steps (e.g. unfolding of single alpha-helices or extracellular loops) also occur. Data obtained over a wide pH range, revealed that these events are not significantly depending on the pH.

d) Activity and motion of single molecules and molecular motors (Prof. Matthias Rief)

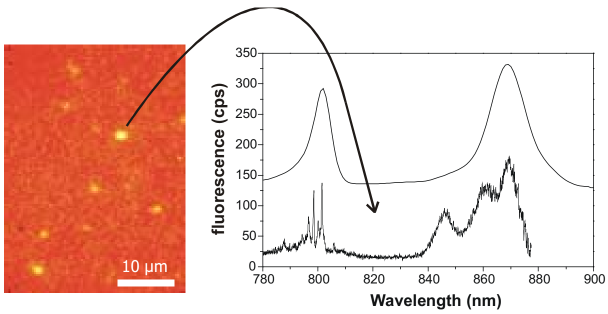
Motor proteins are involved in a variety of transport processes in living organisms. They are responsible for muscle contraction, intracellular transport processes, flagella movement of bacteria and even transcription of DNA. We are investigating the molecular motors myosin V and kinesin We employ optical traps which use the momentum of light to trap dielectric particles in the focussed laser beam. The movement of these particles can be detected with nanometer precision and the forces acting on these particles can be measured with subpiconewton resolution. We are using an optical trap to observe the steps of single motor molecules directly. Using this technique, details of the chemomechanical coupling of motors, like step size and coupling ratio (number of ATPs per step) can be measured. We are trying to understand these nanomachines and explore their potential for future applications in the nano-sciences. We are currently integrating single molecule fluorescence detection into our optical trap. We will soon be able to see single ATP molecules bind to the motor and then measure its mechanical response.

Scanning force microscopy (SFM) of proteasomes (Dr. Reinhard Guckenberger)

The ability of SFM to work very well in fluids. e.g. in buffer, makes the SFM an excellent tool for investigations of biological specimens. Our applications mainly concentrated on the proteasome of archaea. Proteasomes are an essential part in the degredation machinery for proteins. We want to elucidate functional aspects, with emphasis on the interaction forces between proteasome and the proteins to be degraded. In a first step we succeeded in oriented deposition of proteasomes on mica supported NTA-lipid films via His-tags and established methods for force measurements to be performed on the system proteasome – substrate protein.

Pigment-protein complexes (Prof. Jürgen Köhler)

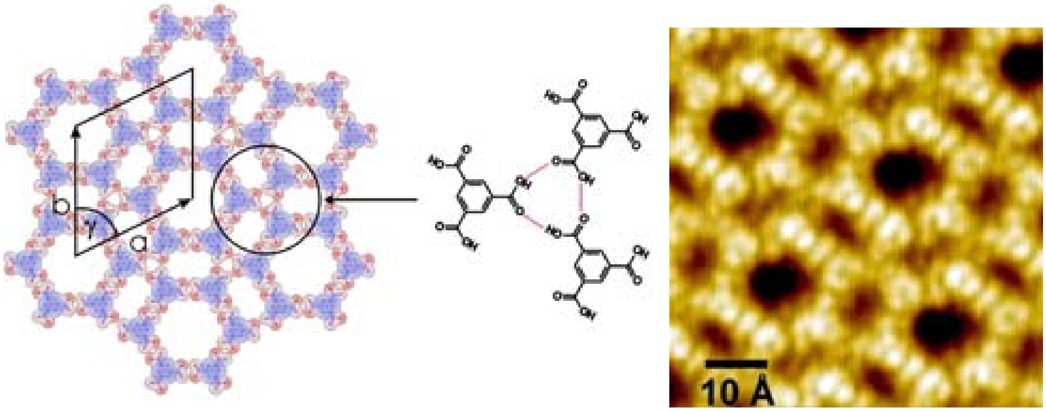
Pigment-protein complexes play an important role in light harvesting of bacterial photosynthesis. They are organised in so-called light harvesting complexes (LH1 and LH2) which are responsible for the absorption of sunlight and the rapid transfer of energy towards the reaction.



In order to elucidate structure-function relationships of these systems detailed knowledge of the electronic structure of the complexes is inevitable. We obtain the fluorescence-detected absorption spectra of individual complexes (either LH1 or LH2) at 1.4 K which are rich in details usually masked in ensemble experiments by inhomogeneous line broadening effects. Important new insights in the electronic and structural properties of light harvesting complexes of various bacterial species have been obtained.

Self-Assembled Two-Dimensional Molecular Host-Guest Architectures (Prof. Wolfgang Heckl)

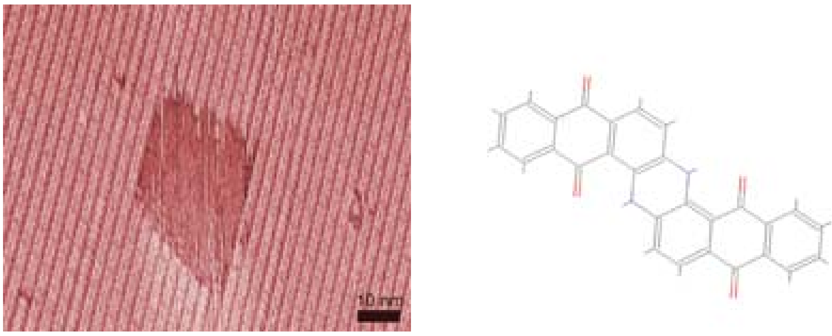
For some years the concept of inclusion compounds or host-guest systems has been part of the supramolecular chemistry. In this context, the adsorption of 1,3,5-Benzenetricarboxylic (Trimesic) Acid (TMA) to a single crystal graphite surface has been studied under Ultra High Vacuum conditions. This work focuses on inducing a particular self-assembly structure by OMBE (Organic Molecular Beam Epitaxy), characterized by periodic non-dense-packing of the molecules. Two coexisting phases could be imaged with sub-molecular resolution by STM. 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 in different positions. The guest molecules can actively be positioned and manipulated by the STM tip.
Work has been performed within CeNS and the SFB 486 „Nanomanipulation"



STM image of flower structure of trimesic acid host guest nanoarchitecture
(from Griessl et al. Single Molecules, in press 2002)

Molecular manipulation of self assembled organic molecules (Prof. Wolfgang Heckl)

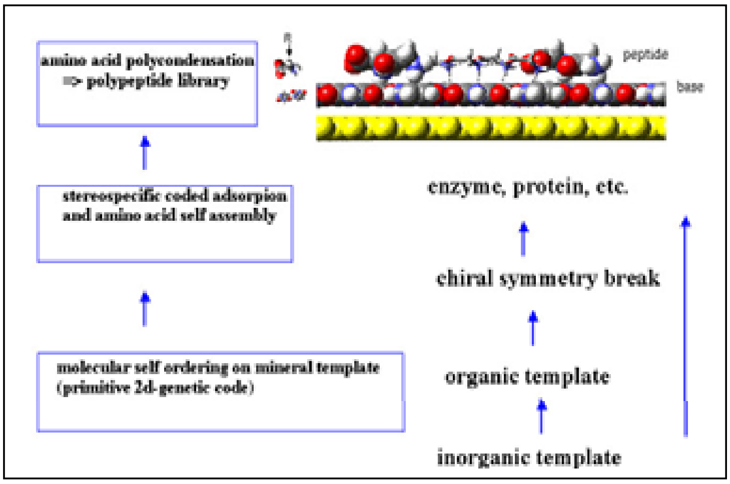
Self assembled pigment dye molecular films have been used for basic investigations of elementary processes of structuring on the nanoscale. The tip of a STM can be used for nanoablation on the molecular scale, thus writing patterns with 2 nm line width. These molecular imprints can be written at room temperature in ambient conditions and have demonstrated their stability for weeks up to 50 degrees centigrade. They can be erased mechanically. Thus the primary steps write, read and erase for a molecular storage with theoretically 10 to 100 Terabyte/cm2 could be demonstrated.



STM image of indanthrone dye molecules / chemical structure of indanthrone

Nanotechnology at the Origin of Life (Prof. Wolfgang Heckl)

We have presented an organic template model for the first molecular steps which may lead to the origin of life (Sowerby and Heckl, Origins of Life and Evolution of the Biosphere, 28, 283-310, 1998). Genetically based supramolecular architectures from self-assembled DNA-bases build a primitive code for amino acid polymerization. The experimental basis is measuring and STM imaging of the adsorption of molecules on a mineral template surface in a primordial soup scenario, together with force field molecular modeling calculations. (The base coding theory was developed in collaboration with Dr. Stephen Sowerby and Prof. George Petersen from University of Otago, New Zealand)



Model for the assembly of polypeptides based on a 2d-DNA-base library at the solid-liquid mineral interface in primitive earth conditions (from *Molecular Self-Assembly and the Emergence of Life*, W.M.Heckl, in: Astrobiology, The Quest for the Conditions of Life, 361-371, eds. G. Horneck, C. Baumstark-Khan, Springer Berlin, Heidelberg 2002)

Soft Condensed Matter and Biophysics (Prof. Joachim O. Rädler)

At the end of 2001 Joachim Rädler joined the Center of NanoSciences. He leads a soft condensed matter and biophysics group with research focus on structure and dynamics of biopolymers, lipid membranes and microemulsions. The assembly of macromolecules into non-covalently linked supramolecular units is a key principle in living systems. In many cases the self-assembly can be studied *in vitro* using reconstituted or synthetic molecules. In particular mixtures of DNA and polycations are studied that form composite bulk materials with ordered phases of typically mesoscopic length scales. Their structure can be probed by X-ray and neutron diffraction. Complementary optical light microscopy and fluorescence correlation spectroscopy is employed to assess the dynamics of labeled molecules in complex macromolecular environments. Understanding molecular assemblies will allow to engineer artifical nanostructures that can be used as smart delivery systems, nanomachines or nanonetworks. The key molecule that is suited for biological engineering is nucleic acid due to its universal coding and linking capabilities. One mayor research goal is the development of synthetic gene delivery complexes. Polycation-DNA complexes build the core of virus-like particles that are furnished with functional peptides for cell targeting and nuclear localization. The assembly of oppositely charged macromolecules can be controlled in microfluidic devices and single colloid microelectrophoresis is used to measure the zeta-potential associated with single molecule events.

Chemical processes for nanostructural assembly

Zeolite synthesis and combinatorial methodology for the synthesis of porous materials (Prof. Thomas Bein)

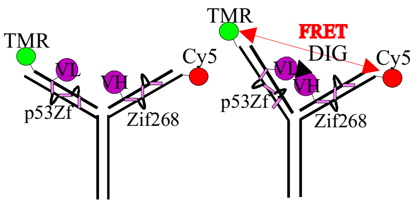
The resaerch program is focused on chemistry and function in designed nanoscopic spaces. Much of the work deals with porous materials such as zeolites and periodic mesoporous hosts. In order to enhance our understanding of these hosts, we study zeolite crystallization in colloidal (nanoscale) systems as well as the role of molecular templates for the growth of novel zeolite structures. The nucleation and growth of colloidal zeolite crystals having diameters smaller than 100 nm and different structure types such as LTA, FAU, BEA and MFI is being studied with high-resolution electron microscopy, dynamic light scattering (DLS), powder X-ray diffraction (XRD) and vibrational spectroscopy. In the field of zeolite synthesis, we develop automated, parallel methodologies that allow us to access a range of synthetic parameters vastly greater than the range possible with manual techniques. With this approach we can access the multi-parameter, multi-component space for the exploration and optimization of synthesis conditions for known and new materials, including aluminosilicates, aluminophosphates, and titanosilicates.

Chemically selective nanostructures (Prof. Thomas Bein)

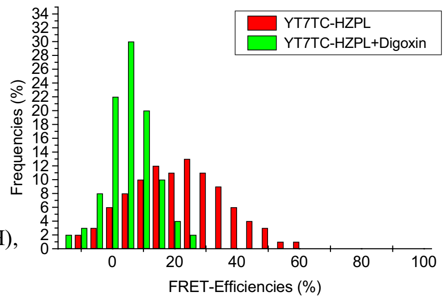
In this project we develop assembly strategies for porous materials on planar surfaces for applications in selective chemical sensors; this is relevant for several transduction mechanisms such as acoustic waves on piezoelectric crystals, microcalorimetric detection (on special silicon chips or with infrared imaging), and optical changes in zeolite-encapsulated solvatochromic molecules. We are developing a family of assembly methods for this purpose; these range from oriented zeolite crystallization on self-assembled monolayers to the electrostatic assembly of pre-formed nanoscale zeolite crystals. We have demonstrated molecular sieve selectivity combined with the intrinsic response of the transduction principles such that selective chemical sensor arrays can be constructed. A collaboration with the group of Professor Jörg Kotthaus and Dr. Achim Wixforth has been started in this area. Structural studies of these films using synchrotron radiation are being pursued with Dr. H. Metzger at ILL at Grenoble.

Functional Nanoassemblies (Nanomachines) with DNA Architecture Characterized by Single Molecule FRET Measurements
(Prof. Christoph Bräuchle, Dr. Andreas Zumbusch)

It has been shown by N. C. Seeman et al. that DNA can be used for building up nanostructures with specific intermolecular associations. In this project a DNA Y-Junction will be prepared (group of B. Steipe) with special antigen-antibody recognition sites. An additional pair of donor/acceptor molecules will detect the receptor ligand bonding of the antigen and the antibody by fluorescence resonance energy transfer (FRET).



The DNA-junction YT7TC with Variable Heavy chain (VH), Variable Light chain (VL) and the zinc-finger domains p53Zf and Zif268.

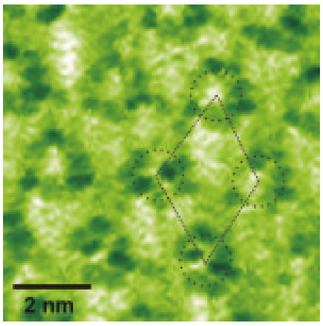


The function of this nanomachine will be studied in detail. So far first single molecule FRET measurements on donor/acceptor molecules attached to DNA and an Y-Junction have been carried out. The figure shows an example of a biological nano-assembly constructed for antigen-detection. This project is in cooperation with the group of B. Steipe, Genzentrum, LMU Munich.

Electric-field directed layer-by-layer assembly of semiconductor nanoparticles
(Prof. Jochen Feldmann)

Electric fields have been used to direct semiconductor nanoparticles and polyelectrolyte molecules to specific positions on a substrate to locally create a layer-by-layer self-assembled heterostructure. By using this method heterostructures exhibiting different functions can be laterally ordered on a substrate or on a chip. As one first example we have created a multi-color electroluminescent pixel array.

Self-organized cluster arrangements on sapphire as templates for organic nanostructures (Prof. Michael Reichling)



Structures on Al_2O_3

The structure of $Al_2O_3(0001)$ √31x√31 9° exhibits high chemical activity in regions of surface atomic disorder. Upon interaction of water molecules with this surface, defects are preferentially located in regions of disorder and upon heavy dosage form regular, self-organized arrangements of hydroxide clusters in form of circles centred at the edges of reconstruction rhombi. These nanometer sized structures are found to be very stable as a result of the effective passivation by hydroxide formation. We now explore their chemical properties and possibilities to use them as templates for the assembly of organic and eventually biological nanostructures.

Metallo-Supramolecular Architectures on Surfaces (Prof. Ulrich S. Schubert)

One of the most challenging targets in supramolecular chemistry concerns molecular building blocks containing subunits. During the last few years we have focused on the further development of $[2 \times 2]$ metal grids. Several approaches were used for the preparation of extended metallo-supramolecular architectures on surfaces. Thin films could be prepared utilizing self-assembly of the grids into thin monomolecular films by adsorption onto polyelectrolyte-covered substrates (cooperation with T. Salditt/Universität München). Scanning tunneling microscopy (STM) techniques were used to image and write in grid monolayers on solid surfaces with molecular resolution (cooperation with M. Möller/Univ. Ulm). In first molecular manipulation experiments the extraction of single grids from the monolayer was performed, by applying a short negative voltage pulse.

Technological applications of nanoscience

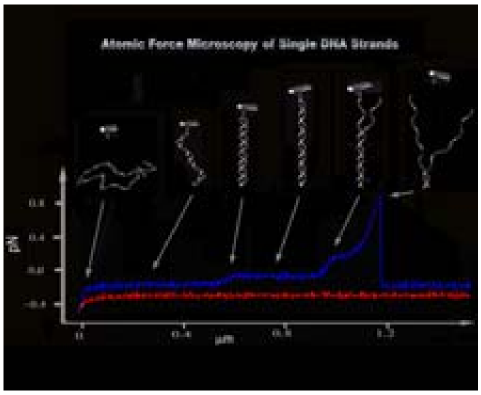
Hybrid catalyst systems (Prof. Thomas Bein)

Porous hosts can be modified by immobilizing or grafting selective molecular catalysts (such as transition metal complexes) into the interior of their channel systems, thereby creating highly selective heterogeneous catalysts. Presently we are developing synthetic strategies to achieve control over the site density, orientation, and molecular environment of the catalyst in the cages and channels, including periodic mesoporous systems. Recent work has focused on the assembly of molecularly attached porphyrin catalysts in the channels of mesoporous thin films. A related focus of attention, with the associated instrumental challenges, is the development of combinatorial strategies for a more detailed exploration of the structure-reactivity relationships in such systems.

Whole Cell Patch Clamp Recordings on a Planar Glass Chip (N. Fertig, C. Sobotta, Robert H. Blick, and Jan C. Behrends)

The state of the art technology for the study of ion channels is the patch clamp technique. Ion channels mediate electrical current flow, have crucial roles in cellular physiology and are important drug targets. The most popular (whole cell) variant of the technique detects the ensemble current over the entire cell membrane. Patch clamping is still a laborious process, requiring a skilled experimenter to micromanipulate a glass pipette under a microscope to record from one cell at a time. We have developed a planar, microstructured quartz chip for whole cell patch clamp measurements without micromanipulation or visual control. A quartz substrate of 200 µm thickness is perforated by wet etching techniques resulting in apertures with diameters of about 1 µm. The apertures replace the tip of glass pipettes commonly used for patch clamp recording. Whole cell recordings from different cell types (CHO, N1E-115 neuroblastoma) are performed with microstructured chips studying BK channels and voltage gated Ca^{2+}-channels.

Simultaneous Force and optical spectroscopy of single molecules (Prof. Christoph Bräuchle, Dr. Andreas Zumbusch)



Both force spectroscopy and optical spectroscopy of single molecules deliver valuable information about molecular behavior on a microscopic scale. The simultaneous application of the two techniques to an individual molecule promises to yield an even deeper insight. On the one hand, exertion of an external force can be used to study its influence onto the optical properties of a chromophore, while on the other hand, optical excitation can be used to induced mechanically detectable changes. Both approaches are currently used in investigations of polymers and biologically relevant molecules such as DNA.

The figure (right) shows a Phage DNA force spectrum with a schematic description of the prominent stretching regions. This project is a cooperation with the group of M. Seitz, physics section, LMU Munich

A compact tunable solid state laser utilizing a thin film organic semiconductor (Prof. Jochen Feldmann)

Optically pumped organic semiconductor lasers have been fabricated by evaporation of a thin organic film on top of a polyester substrate with an embossed grating structure. We have achieved low-threshold, longitudinally monomode distributed-feedback laser operation. By varying the film thickness of the organic semiconductor film, the wavelength of the surface-emitting laser can be tuned over 44 nm. The low laser threshold allows the use of a very compact all-solid-state pump laser (only 10 cm long). This concept opens up a way to obtain low-cost lasers that are tunable over the whole visible range.

Cell-Semiconductor Hybrids (Dr. Markus Seitz, Prof. Hermann Gaub)

Cell-semiconductor hybrids promise to be the future building blocks of artificial neuronal networks. One major issue is the compatibilty of semiconductor surfaces with biological systems. This interface between live cells and solid state physics has been an important topic of our research during the last several years.

This is especially critical for Gallium Arsenide, a material providing several electronic advantages over silicon, as the chemical instability of its surface poses a serious limitation to its use under ambient conditions. We have developed corrosion protection layers for long-term stability and biocompatibility of the GaAs surface prepared from polymerized organic mercaptosilanes a few tens of nanometers thick, and with the ability to introduce chemical groups that allow easy, further surface functionalization. The interfacial polymer layers provide an adhesion-promoting interface, which allowed the cultivation of electrically excitable cells, normal rat kidney (NRK) fibroblasts, on GaAs. As a next step towards the implementation of GaAs technology in future cell—semiconductor hybrids, the electrical performance of GaAs and GaAs/InGaAs heterostructures in water was now improved, even under moderate electrochemical loads. For this, the surface attachment of interfacial layers was studied carefully in a cooperation with Dr. Uwe Klemradt (CeNS) employing synchrotron radiation from Hasylab was used, to determine the structural properties of the interfacial layers with sub-nanometer resolution.

Response of thin ferroelectric films to temperature and electric fields (Dr. Uwe Klemradt)

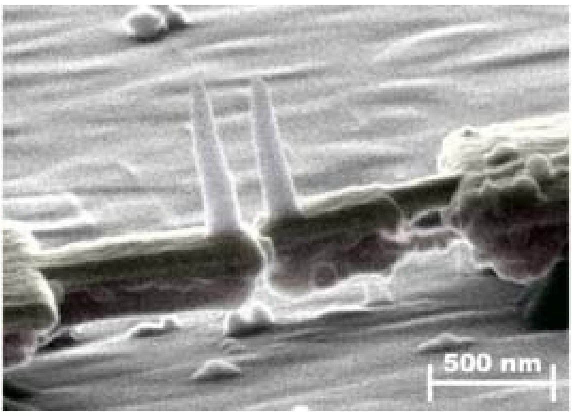
Thin ferroelectric films are of central importance to a number of modern technologies like electromechanical actuators, tunable high-k dielectrics or non-volatile (NV) memories. $Ba_{0.5}Sr_{0.5}TiO_3$ and $SrBi_2Ta_2O_9$ belong to the most promising materials for such applications. Since properties like polarizability, piezoelectric coefficients and fatigue are largely determined by surface effects and the atomic and electronic structure of electrode interfaces, x-ray scattering techniques under grazing angles are well suited to study these systems. We investigated ferroelectric films in-situ at various temperatures and under the influence of electric fields up to $2 \cdot 10^7$ Vm^{-1}. Structural properties of the films (thickness, density, lattice parameter) and interfacial morphologies have been determined with sub-nanometer resolution using x-ray reflectivity and grazing incidence diffraction.

Passivation of GaAs surfaces by polymeric layers (Dr. Uwe Klemradt)

GaAs has a reactive surface that spontaneously forms an oxide layer. Defects that are created as a result of this process pin the Fermi level, which prevents the efficient use of GaAs in MOS devices and sensor applications, particularly under ambient or aqueous conditions. Therefore a passivation layer is required to protect the surface from the environment. We studied GaAs samples passivated by a thin film of the bio-compatible polymer (3-mercaptopropyl) trimethoxysilane. Synchrotron radiation from Hasylab was used to determine the structural properties of ultrathin, buried layers with sub-nanometer resolution. A first study of the efficiency of current preparation techniques indicated strong differences in the resulting passivation, although no technique proved to be able to prevent entirely the build-up of an interfacial oxide layer.
This project is a cooperation with LS Gaub (Seitz group) and originated from a discussion at the CeNS workshop in Wildbad Kreuth, October 2000.

Nanodevices
(H.-J. Kutschera, C. Meyer, A. Müller, L. Pescini, C. Strobl, A. Tilke, Dr. Heribert Lorenz, Apl. Prof. Achim Wixforth and Prof. Jörg P. Kotthaus)

Science and technology on the scale of a nanometer -one billionth of a meter- is revolutionary. Nanotechnology refers to the ability to manipulate individual atoms and molecules, making it possible to build machines on the scale of human cells or create materials and structures from the bottom up or the top down, building in desired properties. Nanotechnology could change the way almost everything is designed and made, from medicines to computers to automobile tires to objects not yet imagined.
The goals of our nanoscale research and engineering are:
- Biosystems at the nanoscale - the relationship among chemical composition, shape and function.
- Nanoscale structures, novel phenomena and quantum control - how to overcome existing limits to miniaturization.
- Device and system architecture - integrating nanoscale devices into measurement and control assemblies.



We investigate different realizations of devices fabricated in silicon-on-insulator (SOI)-films. We built a nanoscale field-emitter device working at atmospheric pressure. The underlying idea for this kind of device is a combination of well-established silicon nanotechnology and the principle of a triode amplifier. Another goal is to develop electrically driven nanotweezers, which allow a specific manipulation of particles with sizes in the range of some 10 nm. We demonstrate the fabrication of a tweezers-structure out of SOI material and electron beam deposited material.
Other topics of our nanodevice research combine surface acoustic wave technology with biological applications. This can be used for sensing or for the manipulation of small droplets down to the range of femtoliters.
Also, we have developed a planar, microstructured quartz chip for patch clamp measurements to replace the commonly used glass pipettes. Whole cell recordings from different cell types were performed with the microstructured chips. Further information can be found here.

Nanomanipulation of Biomaterials – The Nanoendoscope (Prof. Wolfgang Heckl)

The mechanical extraction of small amounts of biological material for modern analytical methods requires very precise tools. On the micrometer-scale UV-microlaser beam techniques proved its versatility for cutting biological specimen like tissues or cells. Non-contact material extraction is done by the so-called laser-pressure catapulting method, where a short laser pulse is used to separate a dissected part of the specimen from the tissue. In order to allow for a material extraction on a single molecule level, additional nanoscopic methods are needed. Today, the atomic-force microscope is a well-established tool for the manipulation and investigation of single biological molecules.
The combination of conventional microscopic techniques (e.g. brightfield and fluorescence) with the modern techniques of scanning probe microscopy and laser microbalation in one instrument offers a broad range of specimen analysis and sample extraction methods from the micrometer to the nanometer scale.

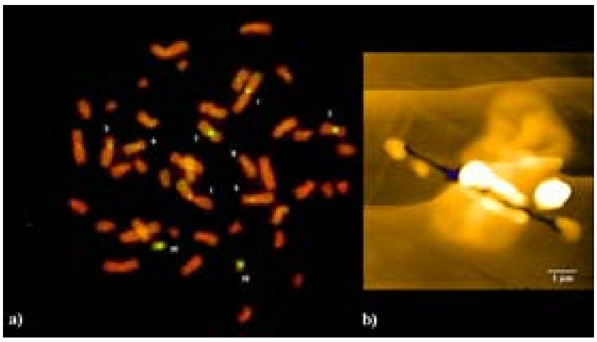
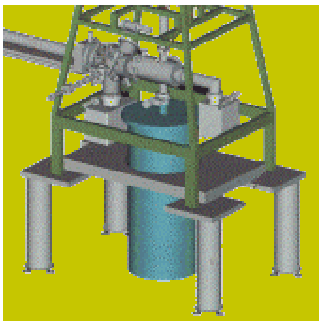


Figure: Human metaphase chromosomes: a) Optical Fluorescence image after in situ hybridization of AFM nanoextracted DNA from centromer of a C-group chromosome shown in AFM image

Low-temperature scanning force microscopy (Prof. Michael Reichling)



Low temperature SFM

Although atomic resolution scanning force microscopy is now routine and yields excellent imaging results, room temperature measurements are limited by instrumental thermal drift and a loss in details by fast thermally activated surface processes. Drift also limits capabilities of force spectroscopy above specific atomic sites. To overcome these limitations, we started the development of a low temperature force microscope operated in a liquid Helium cryostat. This project is conducted in close cooperation with the CENS group of K. Karrai as we share interest in highest resolution imaging of charge distributions at low temperatures and ultra-sensitive force detection.

Modification of AFM Tips with Terpyridines (Prof. Ulrich S. Schubert)

In a “Sonderforschungsprojekt” of the DFG the modification of AFM tips with terpyridines and the molecular self-assembly process in the presence of metal ions have been investigated in detail (cooperation with H.E. Gaub). To avoid unspecific adhesion processes, the metal binding unit was separated from the tip and surface by a polymer spacer. For this purpose, poly(ethylene oxide) was used. After addition of metal ions, formation of the complexes could be observed. However, the set-up suffered in part from cross-linking that occurs between the terpyridines bound to the substrate and the terpyridines at the tip. Utilizing Ru(III)-Ru(II) chemistry this problem could be overcome. In this case, the complex dissociates at approximately 100 pN. Multiple binding interactions were revealed by values two, three or multiple times higher.

Theoretical analyses of nanostructures

Theory of realistic solid-state quantum bits (F. K. Wilhelm, H. Gutmann, M. Storcz, U. Hartmann, Prof. Jan von Delft)

We explore the possibility to control and manipulate quantum states in mesoscopic devices, such as superconducting junctions or quantum dots, in real time. This requires studying the fundamental concepts of quantum mechanics on a macroscopic, instead of atomic, level. Achieving a high degree of quantum control is an essential first step toward a quantum computer, which would accelerate the solution of certain hard computational tasks.

Transport through ferromagnetic nanograins with discrete electronic states (S. Kleff, Prof. Jan von Delft)

We have been working on a model for electron transport through ferromagnetic nanograins that are so small that the conduction electron spectrum becomes discrete. This work was inspired by experimental studies on such grains in the group of Dan Ralph (Cornell University), in which such discrete spectra could be resolved experimentally for the first time. They observed a tunnelling spectrum with discrete resonances, whose spacing was much smaller than what one would expect from naive independent-electron estimates. We have suggested that this is a consequence of nonequilibrium excitations. Assuming (i) that such nonequilibrium spin accumulation occurs and that (ii) the anisotropy energy varies among different eigenstates of one grain our model can qualitatively account for the features observed in experiments.

Transport properties of coupled quantum dots with Kondo Correlations
(M. Sindel, L. Borda, Prof. Jan von Delft)

Especially in Quantum dots Kondo correlations can be studied very well. Experiments allow changing couplings between the dot and the reservoirs, to sweep the energy levels inside the dot and even to couple several of these dots (e.g. in series).
We use the numerical renormalization group method to compute physical quantities in the Kondo regime.
In recent Aharonov-Bohm experiments some poorly-understood features of the transmission phase were observed.
We are currently exploring whether these features can be understood within the framework of a multi-level Anderson model since more than one energy level seems to be involved.
We used the NRG to calculate the local level occupation, the spectral function, the spin-spectral function and finally the phase change. Moreover, we also investigate in serial-coupled double dot systems to calculate transport properties.

Properties of two Josephson-coupled superconducting nanograins
(D. Gobert, Prof. Jan von Delft)

We study the Josephson effect between two superconducting grains in the limit that the grains become so small that the mean level spacing is comparable to the bulk-superconducting gap.
We calculate the condensation energy as a function of the phase of the tunnelling matrix element and then extract the Josephson energy. This is done within a canonical framework using the Density Matrix Renormalization Group, which has been recently applied to mesoscopic systems by Dukelsky and Sierra.

This allows us to study the remnants of the Josephson effect in a regime where the notion of a superconducting order parameter with a well-defined phase is no longer applicable.

Chemical reactions induced by mechanical stress (Dr. Irmgard Frank)

In collaboration with the groups of Prof. Christoph Bräuchle and Prof. Hermann Gaub we are investigating polymers under mechanical stress using ab-initio molecular dynamics (Car-Parrinello molecular dynamics, CPMD). For polyethyleneglycol in water, we found that a complex heterolytic reaction takes place in the moment of bond breaking. For the simpler case of homolytic bond-breaking that occurs in less polar systems, we have developed a theoretical model for the estimation of rupture forces. From our simulations it is evident that the rupture forces depend on several external parameters like pulling velocity and temperature. However, it was possible to show that the experimentally measured rupture forces of about 2 nN clearly correspond to the breaking of a covalent bond.

Scanning Probe Techniques

Basics of tapping mode SFM (Dr. Reinhard Guckenberger)

Part of our SFM work was devoted to a better understanding of the tapping mode. High resolution phase imaging in fluids turned out to be dominated by topography, but this influence can be largely corrected by image processing. For tapping in air, we found that measurement of higher eigenmode oscillation of the cantilever allows to analyze the tip sample interaction in time. Generalizing this approach we even succeeded in measuring for the first time the forces acting on the SFM tip during tapping quantitatively and time-resolved. This work was supported by a collaboration with the group of Wolfgang Heckl.

Scanning near-field optical microscopy (SNOM) in fluorescence
(Dr. Reinhard Guckenberger)

Fluorescence allows easy identification of labelled parts of biological specimens. Besides increased resolution, the main advantage of the SNOM in comparison to the confocal laser scanning microscope consists in the simultaneous acquisition of a topographical signal in addition to the optical one. For minimization of fluorophore bleaching a SNOM of the aperture type is best choice. We are currently developing such a SNOM with enhanced topographical resolution for investigations of the function of biomolecules in fluids. To achieve this enhancement we test electron beam deposited tips in collaboration with the group of Heribert Lorenz.

Low-Temperature Scanning Probe Microscopy of Surface and Subsurface Charges
(Markus Vogel, Bernhard Stein, Hakan Pettersson, and Khaled Karraï)

The operation of a cryogenic scanning force microscope is demonstrated with a sensitivity of about 50 fN / $Hz^{1/2}$ at 5 kHz modulation. This microscope is used as an electrometer in noncontact mode in order to map the local electrostatic forces and capacitance of several nanostructures at 4.2 K. Capacitance imaging of nanostructured surfaces with subatto-Farad resolution is demonstrated.

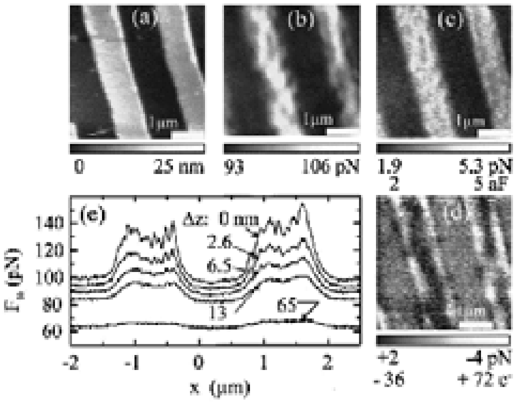
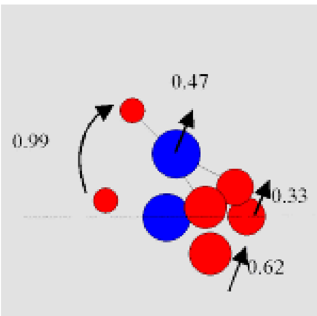


Figure: Scanning force microscopy at cryogenic temperatures. a) Topography of the Al_0 O_3 stripes (bright) on a gold back contact (dark). (b) and (c) Corresponding harmonic and second harmonic forces. The resulting local charge distribution is shown in (d). The line scans of first harmonic forces are shown in (e) for decreasing tip-to-gold-contact. The noise-like features in (e) over the Al 2 O 3 stripes are fully reproducible and represent single electronic charges.

Dynamic phenomena in atomic scale dynamic scanning force microscopy
(Prof. Michael Reichling)



Rotation of CO_3^{2-} group

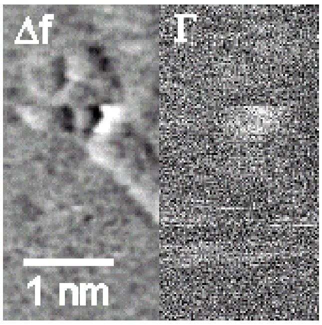
The strong interaction of the tip-terminating nanocluster with surface species may result in a strong relaxation of tip and surface atoms and considerable deformation of surface clusters. Such phenomena were studied in dynamic scanning force imaging on the $CaCO_3(10\bar{1}4)$ surface where we found a strong dependence of the details in atomic contrast of the CO_3^{2-} group on scanning direction. Theoretical modelling performed by A.S. Foster (Helsinki University) and A. L. Shluger (University College London) shows that the CO_3^{2-} group is rotated in two axes and upon close approach of the tip, the outermost oxygen atom may be pulled out of the surface plane by up to 100 pm.

Tip instability and atomic manipulation of single atoms with the dynamic force microscope (Prof. Michael Reichling)

Al_2O_3(0001) $\sqrt{31}$x$\sqrt{31}$ 9°

Force imaging at the atomic scale is most often accompanied by instabilities of the contrast forming cluster at the tip end. Such instability occurs in form of a pick up or drop off of atoms from or to the surface and motions of atoms on the tip apex. The activation energy for this motion is provided by the strong chemical interactions between tip and surface atoms. We found that the dissipation signal in dynamic force microscopy is a most sensitive detector for any kind of tip instability and allows a classification of instability events. We now develop strategies for a controlled positioning of single atoms by the tip in a way similar to vertical manipulation in low temperature STM.

Atomic manipulation of metallic clusters on insulating surfaces (Prof. Michael Reichling)



Ca cluster on CaF_2(111)

On atomically flat insulating surfaces, nanometer sized metallic clusters are weakly bound and can be manipulated with the tip of the dynamic force microscope during scanning. Such manipulation occurs as a sliding motion of single atoms or small clusters into a stable configuration minimizing dissipation in tip-cluster interaction. Cluster stability is gained by higher coordination of its atoms. The success of such manipulation can be checked by monitoring the dissipation signal during scanning. From this signal, it can also be unambiguously be deduced whether an image contrast change is due to the motion of the cluster on the surface or due to a change in tip configuration.

News from CeNS Spin-Offs

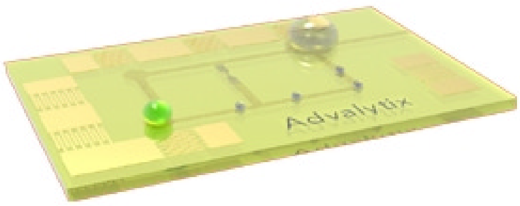
Advalytix

Advalytix AG was founded on Nov. 3rd, 2000 by Dr. Christoph Gauer (formerly Infineon), Eckart Neuhaus (formerly Biofrontera AG), Dr. Jürgen Scriba (formerly Der Spiegel), and Dr. Achim Wixforth (still CeNS). Investors are Infineon AG (lead) and Nano Venture, a Hamburg based VC company.

To start with, we rented some 100 square meters at the Center for Nano Science, right below the famous "Dachterrasse".

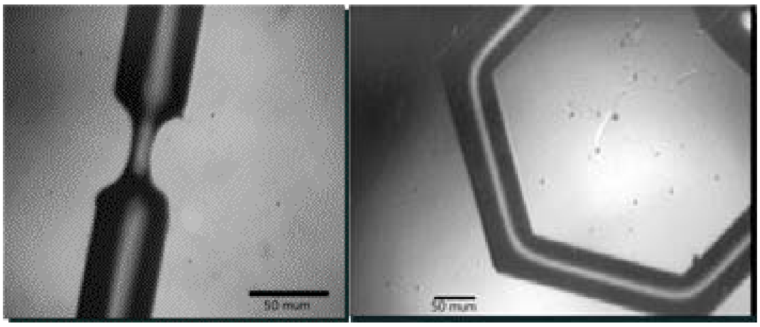
After some weeks of renovation and installations, we were up and running, and the first employees were hired.

Our vision is the creation of a programmable processor for microfluidic applications, based on a unique combination of technologies for fluid handling on the nano-litre scale. Based on a surface acoustic wave technology, small volumes of liquid can be agitated, actuated, merged and split on a chip. Together with integrated sensors, we envision a new generation of programmable biology.



To make this vision come true, a small lab was installed and first proofs of concept were fabricated. This was possible by the generous support of Prof. Kotthaus' group and CeNS in general: the first devices were fabricated in the cleanrooms at the CeNS. Later, we started a very fruitful cooperation with Profs. Herberg and Sotier at the Fachhochschule München for processing 4" wafers.

In parallel, a strong surface chemistry group emerged in the company, specializing in the fabrication of "fluidic tracks" and surface treatment for biological applications.



Shortly after, some very talented biologists showed up and the first oligonucleotides, DNA fragments and proteinsfound their home on the Advalytix chips.

Clearly, the existing labs became way too small after a while and Advalytix started to look for a new home. On August 07, 2001 the company moved to Brunnthal, where Ludwig Bölkow's former rocket testing bunkers were rebuild to meet the needs for a high tech chip company.

A cleanroom for 4" wafer processing, a biology application lab, and a chemistry lab were quickly installed. The mechanical workshop was soon ready to produce prototypes for the chip housings, and the electronics workshop produced the first hardware components to get the chips humming. Our physics group started testing the systems while also evaluating novel concepts.

In cooperation with Grohmann Biotech Engineering in Prüm, the company developed their first product: the **ArrayBooster** for the dramatically improved hybridization of micro array slides. Key component of this device is the **AdvaCard**, holding a smart mixer chip to agitate the sample volume during the hybridization process. Computer controlled agitation protocol and temperature control comes along with an extremely small sample volume and easiest handling of the process! Works great with DNA chips, protein chips and tissue microtome samples!

Meanwhile (as of March 1st, 2002), the company has filed 17 patent applications, runs on 25 employees in 1300 square meters of lab space. Many promising cooperations and research proposals have been setup, partly already running smoothly.

Weblinks

At the following websites, further information on the stated research projects can be found:

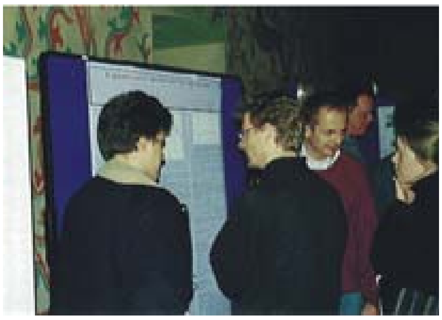
Dr. Reinhard Guckenberger:	www.biochem.mpg.de/spm
Group of Prof. Jörg Kotthaus:	http://www.nano.physik.uni-muenchen.de/report/rep01/
Prof. Michael Reichling:	http://www.phys.chemie.uni-muenchen.de/Reichling/
Prof. Jürgen Köhler	http://www.ep4.phy.uni-bayreuth.de/ag_jkoehler/

Joint CeNS Projects

In 2001, CeNS organised two workshops in Mauterndorf, Austria and in Venice, Italy respectively.
At Munich, CeNS was host to a weekly seminar, with many internationally renowned speakers.

CeNS Winterschool 2001 at Mauterndorf, 18 – 23 February 2001

Titled „Sensing and Manipulating in the Nanoworld", the CeNS winter school at Mauterndorf, Austria, attracted some 100 CeNS members, affiliates and friends who spent a fruitful week at Mauterndorf, learning more about subjects like:



- Nanomechanics
- Single molecule spectroscopy
- Colloids
- Molecular motors
- Carbon nanotubes

CeNS was honoured by interesting presentations of these fundamental concepts of nanoscience by lecturers from both sides of the Atlantic:

- Thomas Basché, Universität Mainz
- Clemens Bechinger, Universität Konstanz
- Vicky Colvin, Rice University
- Andrew Cleland, UCSB
- J.K.G. Dhont, FZ Jülich
- Erwin Frey, Harvard University
- Jason Hafner, Harvard University
- Michel Orrit, Université Bordeaux I
- B.N.J. Persson, FZ Jülich
- Matthias Rief, LMU
- Michael Roukes, Caltech
- Ullrich Steiner, University of Groningen
- Christian Schönenberger, Nanocenter Basel
- Fraser Stoddart, UCLA
- Terence Strick, Cold Spring Harbor Labs
- John Walz, Yale University

The winter school took place at the medieval castle of Mauterndorf, beautifully set above the village. Balancing the scientific work, most participants also enjoyed the skiing opportunities offered by the Mauterndorf region.

CeNS Workshop at Venice International University
24 – 28 September 2001

Similar to the CeNS winter school at Mauterndorf, about 100 CeNS members and associated attended this workshop. This time though, the talks represented an interesting mixture of experts in their respective fields, and presentations of current research topics by younger members.

Venice International University is located on an island 10 minutes away from St. Marcus place in Venice. Apart from the conference rooms this island provides a cafeteria, some student rooms and especially a big garden. It is therefore ideally suited for discussions between talks and for an informal get-together.

The following speakers gave presentations at our workshop:

- Bertram Batlogg
- Flemming Besenbacher
- Gerd Binnig
- Jan von Delft
- Artur Erbe
- Robert Grober
- Dirk Haft
- James Heath
- Rainer Hillenbrand
- Thorsten Hugel
- Gregor Jung
- Thomas Klar
- Jan Krauss
- Rupert Krautbauer
- Albert Libchaber
- Daniel Müller
- John Pethica
- Nikolay Petkov
- Joachim Rädler
- Jake Reder
- Michael Reichling
- Dan Rugar
- Friedrich Simmel
- Carsten Sönnichsen
- Frank Wilhelm
- Daan Wouters

CeNS meets Industry

On July 6th, CeNS organized an afternoon seminar „CeNS meets Industry“, where scientists gave a short summary of what they have been doing since they left university. Despite a very hot day, some 60 students – undergraduate and graduate – took part in this event, where the following speakers gave an account of their experience:

- **Dr. Gunnar Brink, Nanotype:** Als Physiker im Start-Up-Unternehmen

- **Dr. Matthias Bolz, The Boston Consulting Group:**
  Vom Teilchenphysiker zum Strategieberater

- **Dr. Lothar Risch, Infineon:** Infineon Corporate Research and Nanotechnology

- **Dr. Abdul Aleem, DigitalFocus:** Working in Technology in America

- **Dr. Nancy Hecker, Siemens:**
  Research and Development of Optical Communication Systems at Siemens AG

- **Dr. Christian Kallinger, Deutsches Patent- und Markenamt:**
  Patentprüfer - Als Naturwissenschaftler im gewerblichen Rechtsschutz

- **Dr. Christoph Gauer, Advalytix:** Vom Laborexperiment zur AG-Gründung

CeNS Oberseminar 2001

The guests at the weekly seminar organised by CeNS were (in alphabetical order):

- Prof. Peter Bäuerle, Universität Ulm
- Dr. Dietrich Bertram, Philips Research Laboratories, Aachen
- Prof. Flemming Besenbacher, Aarhus University
- Prof. Norman O. Birge, Michigan State University
- Dr. Frank Caruso, MPI Golm
- Prof. Roberto Cingolani, University Lecce, Italy
- Prof. Jan von Delft, Universität Bonn
- Dr. Gregor Dernick, Cornell University
- Prof. Theodor Doll, TU Ilmenau
- Dr. Ricardo Garcia, Instituto de Microelectrónica de Madrid
- Prof. Rudolf Gross, Walther Meissner Institut, München
- Prof. Dietrich Haarer, Universität Bayreuth
- Dr. Thomas Heimburg, MPI Göttingen
- Prof. Franz Himpsel, University of Wisconsin in Madison
- Prof. Eli Kapon, University Lausanne
- Prof. Klaus Kern, MPI für Festkörperfoschung, Stuttgart
- Prof. Arthur Konnerth, Institut für Physiologie, LMU
- Dr. Alfred Leitensdorfer, TU München
- Dr. Harald Reichert, Max-Planck-Institut für Metallforschung, Stuttgart

- Dr. Isabelle Robert, Laboratoire de Photonique et Nanostructures (LPN), Bagneux
- Prof. Josef Salbeck, Universität Kassel
- Dr. Claus Seidel, MPI für Biophysikalische Chemie, Göttingen
- Prof. Mansour Shayegan, Princeton University
- Dr. Jürgen Smet, MPI Stuttgart
- Dr. Wolfgang Wernsdorfer, Grenoble, France
- Prof. Dieter Weiss, Universität Regensburg

Cooperations and Guests

The CeNS members maintain a large number of contacts amongst each other and with partners from all over the world, which are in many cases so complex that it is difficult to list them in a linear form. These range from regular scientific exchanges to involved experimental cooperations. An attempt at listing the network in a linear form can be found below. It is strongly suggested to refer also to the list of publications by the CeNS members, which gives an equally good idea of the number of all cooperations.
Cooperations without personal contact will not be strong for a longer period of time. Accordingly, the CeNS members invited numerous guests to stay with their groups for scientific exchange and for performing experiments. Listed below are only guests who stayed for a longer period. Additional short-time guests may also be found in the list of speakers of the weekly CeNS seminar.

Internal CeNS cooperations

- Dr. Jan Behrends, Dr. Robert Blick
- Dr. Jan Behrends, Prof. Hermann Gaub
- Prof. Thomas Bein, Prof. Christoph Bräuchle
- Prof. Thomas Bein, Prof. Jörg P. Kotthaus and Dr. Achim Wixforth
- Prof. Thomas Bein, Dr. Hartmut Metzger
- Dr. Robert Blick, Prof. Willi Zwerger
- Prof. Christoph Bräuchle, Dr. Boris Steipe
- Prof. Christoph Bräuchle, Prof. Hermann Gaub
- Prof. Hermann Gaub, Prof. Jörg Kotthaus
- Prof. Hermann Gaub, Prof. Axel Lorke
- Prof. Hermann Gaub, Prof. Ulrich S. Schubert
- Prof. Jochen Feldmann, Prof. Jörg Kotthaus
- Prof. Jochen Feldmann, Dr. U. Lemmer, Prof. Thomas J. J. Müller: Characterization of the charge mobility of oligophenothiazine layers; Screening for an application in OFET
- Prof. Jochen Feldmann, Prof. Ulrich S. Schubert
- Dr. R. Guckenberger, MPI for Biochemistry, Martinsried , Prof. Wolfgang M. Heckl
- Prof. Wolfgang M. Heckl, Dr. Heribert Lorenz, CeNS, LMU München
- Prof. Khaled Karraï, Prof. Michael Reichling: Low temperature scanning force microscopy and spectroscopy
- Prof. Jörg Kotthaus, Prof. Johann Peisl
- Prof. K. Meerholz, Prof. Thomas J. J. Müller: Investigation of hole conductors on the basis of oligophenothiazines
- Dr. Hartmut Metzger, Prof. Axel Lorke, Prof. Johann Peisl
- Prof. Thomas Bein, Dr. Hartmut Metzger
- Prof. Jörg Kotthaus, Prof. Axel Lorke
- Prof. Tim Salditt, Prof. Ulrich S. Schubert

External cooperations

<u>Prof. Thomas Bein</u>
- Dr. Valentin Valtchev, University of Mulhouse, France

Prof. Christoph Bräuchle

- Prof. Michel Orrit, University Leiden, Netherlands
- Prof. Peter Behrens, University Hannover
- Prof. Dieter Wöhrle, University Bremen
- Prof. Michael Hallek, Gene Center, LMU
- Prof. Ulrich Koszinowski, Medical Department, LMU
- Prof. Hugo Scheer, Botanisches Institut, LMU
- Prof. Ernst Wagner, Zentrum für Pharmaforschung, LMU
- Dr. Stephan Weiss, Gene Center, LMU

Prof. Jochen Feldmann

- G. Abstreiter and M.C. Amann, Walter-Schottky-Institute, TU München
- S. Cundiff, JILA, University of Colorado, USA
- R. Cingolani, National Nanotechnology Center, INFM, University of Lecce, Italy
- V. Shalaev, University of New Mexico, Las Cruces, USA
- J.C. Rivoal, Paris, France
- A. Gombert and V. Wittwer, Fraunhofer-Institute for Solar Energy Systems, Freiburg
- W. Brütting, University of Bayreuth
- P. Mulvaney, University of Melbourne, Australia

Dr. Irmgard Frank

- Prof. Ursula Röthlisberger, ETH Zürich

Prof. Hermann E. Gaub

- Stephanie Allen, The University of Nottingham, United Kingdom
- Bioelastics Research Ltd., Birmingham, AL, USA
- nanotype, Gräfelfing

Prof. Wolfgang M. Heckl

- Prof. George Petersen, Dr. Stephen Sowerby, University of Otago, New Zealand
- Prof. Bill Schopf, University of California at Los Angeles
- Prof. Morfil, MPI for Extraterrestrial Physics, Garching
- Prof. Gerd Frösner, Max von Pettenkofer Institut
- Prof. Rolf Gebhardt, Institut für Biochemie, Universität Leipzig
- Prof. Giovanni Mazzotti, Department of Human Anatomy, University Bologna
- Prof. Pietro Gobbi, University of Urbiono, Italy
- Prof. Günther Heubl, Botanisches Institut, LMU
- Prof. Andreas Nerlich, Krankenhaus Bogenhausen, Pathologie
- Dr. M. Ott, Uniklinikum Hannover
- PD. Dr. M. Speicher, Humangenetik, TU München

Prof. Khaled Karrai

- Robert D. Grober, Department of Applied Physics, Yale University, New Haven, Connecticut, USA
- Serge Huant, Laboratoire de Spectrométrie Physique, Université Joseph Fourier Grenoble and CNRS, Saint Martin d'Hères, France
- Lukas Novotny, The Institute of Optics, University of Rochester, Rochester, New York, USA
- Pierre M. Petroff, University of California - Santa Barbara, California, USA.

- Dieter Schuh, Max Bichler, Gerhard Abstreiter, Walter Schottky Institut, TU München, Garching

Dr. Uwe Klemradt

- Hasylab, DESY, Hamburg
- ESRF, Grenoble/France
- Infineon Technologies, München
- Group of Prof. X. Xi, Pennsylvania State University, USA
- Group of Prof. T.R. Finlayson, Monash University, Melbourne, Australia

Prof. Jürgen Köhler

- Thijs J. Aartsma, Department of Biophysics, Huygens Laboratory, Leiden University
- Jan Schmidt, Centre for the Study of Excited States of Molecules, Huygens Laboratory,
- Leiden University
- Hugo Scheer, Botanisches Institut, University of Munich
- Leszek Fiedor, Institute of molecular biology, Jagiellonian University, Krakow/Poland
- Hartmut Michel, Dept. of Molecular Membrane Biology, MPI of Biophysics, Frankfurt, Germany
- Richard J. Cogdell, Biochemistry and molecular biology, University of Glasgow
- D. Oesterhelt, MPI für Biochemie, Abt. Membranbiochemie, Martinsried/Germany
- Francesco Francia, Department of Biology, Laboratory of Biochemistry and Biophysics, University of Bologna/Italy

Group of Prof. Jörg P. Kotthaus (apl. Prof. Achim Wixforth, Dr. Robert Blick, Dr. Heribert Lorenz, Dr. Udo Beierlein)

- Alik Chaplik, Institute of Semiconductor Physics, Novosibirsk, Russia
- Valeri Dolgopolov, Russian Academy of Sciences, Chernogolovka, Russia
- Karl Eberl, Max-Planck-Institut für Festkörperforschung, Stuttgart
- Art C. Gossard, Materials Department, University of California - Santa Barbara, USA
- Alexander O. Govorov, Institute of Semiconductor Physics, Novosibirsk, Russia
- Patrik Hoffmann, University Lausanne
- Paul Leiderer, University of Konstanz
- Harri Lipsanen, Optoelectronics Laboratory, Helsinki University of Technology, Finland
- Karl Neumaier, Walther-Meissner-Institut für Tieftemperaturforschung, Garching
- Pierre M. Petroff, University of California - Santa Barbara, California, USA.
- Klaus H. Schmidt, and U. Kunze, Werkstoffe der Elektrotechnik, Ruhr-Universität Bochum
- Dieter Schuh, Max Bichler, Gerhard Abstreiter, Walter Schottky Institut, TU München, Garching
- Werner Wegscheider, Institut für Angewandte und Experimentelle Physik, Universität Regensburg
- Daniel van der Weide, University of Wisconsin-Madison, USA
- Dietmar Weinmann, Institut de Physique et Chimie des Matériaux de Strasbourg, France
- Advalytix
- Nanotools
- Nanion

Prof. Michael Reichling

- A. Foster, Helsinki University of Technology: Theoretical modelling of SFM
- Th. Risse, Fritz-Haber-Institut Berlin: Metallic clusters on dielectric surfaces
- A.L. Shluger, University College London: Theoretical modelling of SFM

Prof. Ulrich S. Schubert

- Prof. Harald Fuchs, Westfälische Wilhelms-Universität Münster
- Dr. Walter Mächtle, Kunststofflabor, BASF AG
- Prof. George R. Newkome, University of Akron (Ohio), USA)
- Prof. Dieter Schubert, Institut für Biophysik, Johann Wolfgang Goethe-Universität

Guests

- Jim Allen, University of California, Santa Barbara/USA
- Stephanie Allen, Laboratory of Biophysics and Surface Analysis, School of Pharmaceutical Sciences, University of Nottingham/UK
- C. Anceau, Ecole Normale Supérieure de Cachan/France
- Marco Anni, University of Lecce/Italy
- Robert Blith, University of Lecce/Italy
- S. Gresillon, Ecole Normale Supérieure de Cachan/France
- Milena De Giorgi, University of Lecce/Italy
- Valeri Dolgopolov, Russian Academy of Sciences, Insitute of Solid State Physics, Chernogolovka/Russia
- Trevor R. Finlayson, 2.-17. September 2001
- Alexander O. Govorov, Russian Academy of Sciences, Insitute of Semiconductor Physics, Novosibirsk/Russia
- Matthew Grayson, Maryland/USA
- Nicola Green, Laboratory of Biophysics and Surface Analysis, School of Pharmaceutical Sciences, University of Nottingham/UK
- Alexander Kalameitsev, Institut of Semiconductor Physics, Novosibirsk/Russia.
- Martijn Ketelaars, Department of Biophysics, Huygens Laboratory, Leiden University
- Vadim Khrapei, Insitute of Solid State Physics, Chernogolovka/Russia
- Prof. Dr. Oldenburg, Marine Biology Lab Woods Hole
- Prof. Michel Orrit as a Humboldt fellow, January, 15th to March, 15th 2001
- Pierre Petroff, University of California, Santa Barbara/USA
- Hua Qin
- Sean Shaheen, University of Arizona/USA
- Mansour Shayegan, Princeton University/USA
- Alexei Platonov, Ioffe-Institute St. Petersburg/Russia
- Martin Richter, University of Bayreuth/Germany
- Julie Thompson, University of Lecce/Italy
- Dan Urry, University of Minnesota at St. Paul/USA and Bioelastics Research Ltd.
- Valentin Valtchev Laboratory for Mineral Materials, Université de Haute Alsace, Mulhouse/France
- Wenke Zhang, Jilin University, China

Publications

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Patents

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R.H. Blick, A. Erbe, J.P. Kotthaus, *Electromechanical Single Electron Switch*, DE 19961811.9, patent (published in 2001) is pending

H.E. Gaub & Nanotype GmbH, *Verfahren und Vorrichtung zur Charakterisierung und/oder zum Nachweis eines Bindungskomplexes*, DE 10051143.0

W. Heckl, *Nahfeldoptische Spitze,* DE 195 04 662.5-42

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Invited talks

Prof. Thomas Bein

- "Hydrothermic Synthesis Using Porous Solids", NOVABIOCHEM Basel/Schweiz, Scientific Conference and Workshop (18.01.2001)
- „Growth of Micro- and Mesoporous Materials on Substrates", 13. Deutsche Zeolith-Tagung, Erlangen/Germany (07.-09.03.2001)
- "Chemistry in Nanoporous Materials", Keynote Lecture im Symposium "Materials chemistry for the future", WORLD CHEMISTRY CONGRESS, Brisbane/Australia (01.-06.07.2001)

Dr. Robert H. Blick

- „Nanoelectromechanical Systems: Physics & Applications", Workshop on Quantum Non-Planar Nanostructures & Nanoelectronics (QNN'01), AIST-Tsukuba,/Japan, Tsukuba (July 2001)
- „Nanofabricated Electro-Mechanical Devices: Physics & Applications", 48th International Symposium of the American Vacuum Society, San Francisco/USA (November 2001)

Prof. C. Bräuchle

17.-21.02.2001	Annual Meeting Biophysical Society, Boston/USA
18.-22.02.2001	CeNS Winterschool, Mauterndorf
05.-07.03.2001	2nd International Symposium on Physics, Chemistry and Biology with Single Molecules, Kloster Banz
19.-21.03.2001	Einzelmolekülspektroskopie/Nanotechnologie, ETH Zürich, Andermatt/Schweiz
30.03.-07.04.2001	ACS 221st National Meeting, San Diego/USA
21.-23.06.2001	Leopoldina Symposium "Single Molecule Chemistry", Wittenberg
09.07.2001	Société Francaise de Physique, Straßburg/Frankreich
04.-08.09.2001	10th International Conference on Unconventional Photoactive Systems, Les Diablerets/Schweiz
24.09.2001	GDCh Jahrestagung, Würzburg
24.-28.09.2001	CeNS Workshop, Venedig/Italien
03.-06.10.2001	Joint Meeting of the European Societies of Physical Chemsitry: Interaction of Laser Radiation with Matter at Nanoscopic Scales: from Single Molecule Spectroscopy to Materials Processing 2001, Venedig/Italien
13.-16.10.2001	Minerva-Meeting, Rehovot/Israel
16.-24.11.2001	7th Meeting on Hole Burning, Single Molecule and Related Spectroscopies, Taipei/Taiwan

Prof. Jochen Feldmann

- "Optoelectronics with soft materials", 10th International Laser Physics Workshop (LPHYS'01), Moscow/Russia (2001)
- "Organic solid-state lasers", Workshop on Micromechanical Technologies, Kassel/Germany (2001)
- "Faszination Licht", Workshop of the Studienstiftung des Deutschen Volkes, Olang/Italy (2001)

- “Optoelectronic devices based on metal nanoparticles”, VDI Workshop, Bad Orb/Germany (2001)

Dr. Irmgard Frank

- “Ab-initio simulation of ionic reactions”, Car-Parrinello Molecular Dynamics 01, Schloss Ringberg, Rottach-Egern (30.1.2001)
- „Ab-initio simulation of photoreactions”, Ab-Initio Modelling in the Biological Sciences, CECAM workshop Lyon/France (12.6.2001)
- „First-principles investigation of photoreactions in complex systems”, CECAM workshop New Methods for Combining Born-Oppenheimer Ab-Initio Calculations and Empirical Force-Fields in Large-Scale Simulation Studies, Lyon/France (14.6.2001)

Prof. Wolfgang M. Heckl

- „Scanning Probe Microscopy: A versatile Tool for Nanoscience“, Colloquium Center for Interdisciplinary Plasma Science, Institute for PlasmaPhysics, MPG, München (08.02.2001)
- „Nanotechnologie“, Burda Akademie zum 3. Jahrtausend, München (12.02.2001)
- „Nanotechnologie“, IHK Siegen (15.02.2001)
- “Molecular Self-Assembly”, 3. Brazilian-German Workshop on Heterogenic Catalysis, Florianopolis/Brazil (05.-09.03.2001)
- „Nanoendoscopy“, 1. Latin American Symposium on Scanning Microscpy, Sao Pedro/Brazil (02.-04.04.2001)
- „Nanotechnologie“, Compaq Symposium, Frankfurt (13.09.2001)
- „Self-Assembly von organischen Molekülen auf Grenzflächen“, Haereus Physik-Sommerschule, Chemnitz (18.09.2001)
- „NanoScience auf Kristalloberflächen – Beiträge zur Evolution“, Vortrag im Rahmen von Physik und Leben, Deutsches Museum München (12.10.2001)
- „Ursprung des Lebens auf Mineraloberflächen“, Verein für Naturkunde (22.10.2001)
- „Molecular Self-Assembly“, Symposium über Molekulare Orientierung als Funktions-kriterium in chemischen Systemen, SFB 424, Universität Münster (9.11.2001)

Prof. Khaled Karraï

- „Interband Spectroscopy of Ring-Shaped quantum dots“, DPG Frühjahrstagung – Hamburg/Germany (29.03.2001)
- „Spectroscopy of charge tuneable quantum rings“, International Conference on Dynamical Processes in Excited States of Solids 2001, Lyon/France, (03.07.2001)
- „Emission spectroscopy on single charge tuneable quantum dots“, Interaction of Laser Radiation with Matter at Nanoscopic Scales LANMAT 2001, Venice/Italy, (03.10.2001)
- „Optical emission of charge tuneable single quantum dots and low-temperature scanning probe microscopy of surface and subsurface charges“, Meeting of the SFP: Daniel Dautreppe 2001, Nanomonde exploration & Future (October 2001)

Dr. Fritz Keilmann

- „Vibrational infrared near-field microscopy“, 1st Int. Conf. Advanced Vibrational Spectroscopy, Turku (19.-24.08.2001)
- „Infrared near-field microscopy“, 26th Int. Conf. on Infrared and Millimeter Waves, Toulouse/France (10.-14.09.2001)

Dr. Thomas Klar

- „Diffraction resolution barrier in fluorescence microscopy broken by Stimulated Emission Depletion“, CeNS-Workshop, Venice/Italy (2001)

Prof. Jürgen Köhler

- “Optical Spectroscopy of Individual Pigment-Protein Complexes”, Symposium: Light-Induced Dynamics in Proteins, Freising, Germany (02.-06.04.2001)
- “Spectroscopy of single light-harvesting complexes”, Spring School: Optical Spectroscopy and Microscopy of Single Objects, Les Houches/France (06.–11.05.2001)
- “Optical Spectroscopy of Individual Light-Harvesting Complexes”, Sondersymposion Fachgruppe Photochemie der Gesellschaft deutscher Chemiker: Photochemie in den Life Sciences, GdCh Jahrestagung, Würzburg/Germany (23.-29.09.2001)

Prof. Jörg P. Kotthaus

- “Nanostructured Silicon for Electronic and Electromechanic Devices”, March Meeting of the American Physical Society, Seattle/USA (March 2001)
- “Electronic Interactions in Quantum Dots”, Int. Workshop "Frontiers in the Physics of Complex Systems", Israel (March 2001)
- “Electronic Structure and Single Electron Charging in Self-Assembled Quantum Dots”, “Piezoelectric Surface Acoustic Waves as Sensors and Conveyor Belts for Charge Carriers in Quantum Wells” and “Manipulating Electrons in Nanostructured Semiconductors”, 10^{th} Brazilian Workshop on Semiconductor Physics, Guaruja/Brazil (April 2001)
- “Nanostructured Semiconductors as Sensors and Manipulators”, LASERION Workshop "Microfabrication, Nanostructured Materials and Biotechnology", Schloss Ringberg (June 2001)
- “Electronic Interactions in Quantum Dots” and “Mechanically Manipulating Electrons in Nanostructured Semiconductors”, Winterschool: “Low Dimensional Physics” of the South African Institute of Physics, Durban/South Africa (July 2001)
- “Electronic and Electromechanical Interactions in Quantum Dot Systems”, Institute of Theoretical Physics Program on Nanoscience, UC Santa Barbara/USA (August 2001)
- “Nanostructures as Sensors and Manipulators”, Chemical Nanotechnology Talks II, DECHEMA, Frankfurt/Germany (October 2001)
- “Manipulating Electrons in Nanostructures”, Inauguration of the DFG-Center for Functional Nanostructures, Karlsruhe/Germany (December 2001)

Dr. Rupert Krautbauer

- "Molecular Mechanics of DNA", The Second RIES-Hokudai Symposium, Sapporo/Japan (08.-09.03.2001)

Dr. Ulrich Lemmer

- „Organic photonic crystal lasers“, Workshop on "Photonic Crystals", Karlsruhe/Germany (2001)
- „Organic solid state lasers“, Workshop on "Dyes and Dye Assemblies for New Technologies", Ulm/Germany (2001)
- „Organic solid state lasers“, European Conference on Organic Electronics and Related Phenomena, (ECOER 2001), Potsdam/Germany (2001)

Christoph Lingk

- "Ultrafast dynamics of InAs/GaAs quantum dot lasers", 17th International Conference on Coherent and Nonlinear Optics (ICONO 2001), Minsk/Belarus (2001)

Dr. Heribert Lorenz

- „Nanotechnologie - der Schlüssel zum 21. Jahrhundert", Hans-Seidel-Stiftung, Workshop on Nanotechnology, Wildbad Kreuth/Germany (02.-04.03.2001)
- „Nanolithographie - Herstellung von Nanostrukturen mit dem Rasterkraftmikroskop", Otti-Technik-Kolleg, 2nd Workshop on Nanotechnology, Würzburg, Germany (23.-24.10.2001)

PD Dr. Klaus Meerholz

- "Combinatorial Methods in Physics", Photonics West, San Jose/USA (20.-26.01.2001)
- Makromoleculares Symposium, Freiburg/Germany (21.-23.02.2001)
- Chemiedozententagung, Leipzig/Germany (19.-21.03.2001)
- Workshop "Electrode Reaction Mechanisms and Interfacial Structure", Bad Koesen/ Germany (05.-08.04.2001)
- SPIE annual meeting (2 invited), San Diego/USA (29.07.-03.08.2001)
- ICPOP, Cheju Island/Korea (19.-25.08.2001)
- UPS'01, Les Diablerets/Switzerland (04.-09.09.2001)
- VW-Photonik-Symposium, Vienna/Austria (23.-25.09.2001)

Prof. Thomas J.J. Müller

- "Synthesis and electronic properties of redox active tetraarylmethanes", Oral Presentation at the 221st ACS meeting at San Diego/USA, Organic Division (01.-05.04.2001)
- „Coupled Phenothiazinyl Dyads and Triads - Models for Redox Active Nanowires?", 5th International Symposium of the Volkswagen-Stiftung on Intra- and Intermolecular Electron Transfer, Chemnitz/Germany (16.-19.05.2001)
- **„**Phenothiazinyldiaden und -triaden als Modelle für gekoppelte Redoxdrähte", GDCh-Jahrestagung Chemie 2001, Würzburg/Germany (23.-29.09.2001)

Group of Prof. Reichling

A.S. Foster, C. Barth, M. Reichling, A.L. Shluger
- "Unambiguous interpretation of atomically resolved force microscopy images on an insulator", E-MRS spring meeting 2001, Strasbourg/France (June 2001)

Prof. Michael Reichling
- "Towards quantitative atomic resolution scanning force imaging on insulators", UK Scanning Probe Microscopy Meeting, Leeds/UK (April 2001)

Prof. Matthias Rief

- „Single Molecule Mechanics of Proteins", European Meeting of the Protein Society, Paris/France (4/2001)
- „Spectrin Elasticity", Symposium on „Elastic Proteins" of the Royal Society, London (5/2001)

Group of Prof. Schubert

- S. Schmatloch, B.G.G. Lohmeijer, A.A. Precup, D. Wouters, C. Eschbaumer, U.S. Schubert. "Supramolecular Polymers: Materials with new Properties?" EPF Congress (European Polymer Federation), Eindhoven (18.07.2001)

U.S. Schubert

- "Metallo-supramolecular Assemblies and Polymers: Towards new Materials", PTN Workshop Macromolecules, Lunteren/Netherlands (12.02.2001)
- „Von der Supramolekularen Chemie zur Nanowissenschaft", Fonds der Chemischen Industrie, FCI Steinheimer Gespräche, Hanau/Germany (13.05.2001)
- "Engineering with Metallo-Supramolecular Macromolecules", SMARTON 5, Kasteel Vaeshartelt Maastricht/Netherlands (16.11.2001)
- "Engineering with Macromolecules", Workshop Molecular Organisation & Dynamics at Interface, Ulm/Germany (17.11.2001)
- U.S. Schubert, G. Bilancia, D. Wouters, A.A. Precup, S. Schmatloch. "Towards Functional Nanoparticles", ACS National Meeting, Chicago/USA (29.08.2001)
- U.S. Schubert, G. Hochwimmer, S. Schmatloch, M. Heller. "New Macromolecules Utilizing Supramolecular Initiators", EPF Congress (European Polymer Federation), Eindhoven/Netherlands (18.07.2001)
- U.S. Schubert, B.G.G. Lohmeijer, C. Eschbaumer, A.A. Precup, S. Schmatloch. „Supramolecular polymers: materials with new properties?", APME Conference (Advanced Polymers via Macromolecular Engineering), Gatlinburg/USA (19.08.2001)
- U.S. Schubert, B.G.G. Lohmeijer, J. Pahnke, C. Eschbaumer, S. Schmatloch. „Nicht-kovalente Polymere: Materialien mit neuen Eigenschaften?", GDCh Jahrestagung, Würzburg/Germany (25.09.2001)
- U.S. Schubert, B.G.G. Lohmeijer, S. Schmatloch. "Synthesis of Metallo-Supramolecular Block-Copolymers", ACS National Meeting, Chicago/USA (29.08.2001)
- U.S. Schubert, A.A. Precup, H. Hofmeier, S. Schmatloch. "Towards Metallo-Supramolecular Architectures based on Terpyridine Metal Complexes", ACS National Meeting, Chicago/USA (30.08.2001)
- C.H. Weidl, A.A. Precup, C. Eschbaumer, U.S. Schubert. "Towards Block Copolymers utilizing Non-Covalent Polymerization on the Basis of Metal-Ligand Interactions", ACS National Meeting, San Diego/USA (05.04.2001)
- D. Wouters, B.G.G. Lohmeijer, S. Schmatloch, A.A. Precup, H. Hofmeier, P.R. Andres, U.S. Schubert. "Metallo-Supramolecular Systems based on Terpyridines", CeNS workshop, Venice/Italy (25.09.2001)

Dr. Markus Seitz

- XIV. Aachen Colloquium on Biomaterials, Aachen (March 2001)
- Workshop on Nano-Chemistry and Physics, Université catholique de Louvain, Louvain-la-Neuve/Belgium (May 2001)
- CIF'2, Chitose/Japan (September 2001)
- Dr. Hermann-Schnell-Stiftungssymposium, GDCh-Tagung, Würzburg/Germany (September 2001)
- Xiangshan Science Conference on Functional Supramolecular Systems (XSCSS 2001), Beijing/China (October 2001)

Dr. Carsten Sönnichsen

- „Optics with single metal nanoparticles“, Workshop on Plasmon Photonics, Obernai/France (2001)
- „Colorful metallic nano-rods and –dots“, CeNS-Workshop, Venice/Italy (2001)

Prof. Gero von Plessen

- „Carrier Dynamics in Semiconducting and Metallic Nanoparticles“, Winter School of the Ioffe Physico-Technical Institute, St. Petersburg/Russia (2001)
- „Dynamics of surface plasmons and lattice in noble-metal nanoparticles“, 17th Interdisciplinary Laser Science Conference, Long Beach/USA (2001)

apl. Prof. Achim Wixforth

- „Nonlinear acoustics in semiconductor nanostructures“, 14th International Conference on Electronic Properties of Two-Dimensional Systems (EP2DS-14), Prague/Czech Republic (30.07.-03.08.2001)

Dr. Andreas Zumbusch

- “Optical Spectroscopy of Single Proteins”, Seminar week Prof. Wild, ETH Zürich, Andermatt, Schweiz
- "CARS-Microscopy", Focus on Microscopy, Amsterdam, Netherlands
- "Two Color Single Molecule Imaging and Fluorescence Correlation Spectroscopy of the Green Fluorescent Protein", Physical chemistry seminar, Chemistry Department, Ohio State University, Columbus (OH), USA
- "Single molecule spectroscopy of the Green Fluorescent Protein", Spring School on Optical Spectroscopy and Microscopy of Single Objects, Les Houches
- "Ultrasensitive detection with vibrational contrast: coherent anti-Stokes Raman scattering (CARS) microscopy " LANMAT 2001, Joint Meeting of the European Societies of Physical Chemistry, Venice, Italy
- "Microscopie à Coherent Anti-Stokes Raman Scattering (CARS)", Journée GDR MATFON, École Normale Superieure de Cachan

Habilitation, Doctoral and Diploma theses, “Zulassungsarbeiten”

Habilitation theses:

- Dr. Ulrich Lemmer, *Organische Optoelektronik: Herstellung und Photophysik neuartiger Laser, Photodetektoren und Leuchtdioden*
- Dr. Gero von Plessen, *Ultraschnelle Prozesse in Edelmetallnanopartikeln*

Doctoral theses:

- Markus Aspelmeyer, *Einfluss externer Felder auf Struktur und Grenzflächenmorphologie dünner ferroelektrischer Filme*
- Clemens Barth, *Atomar aufgelöste Kraftmikroskopie auf ionischen Oberflächen: Fluoride, Calcit und Saphir*
- Kylie Crompton, *Microstructural studies of a passivation layer on GaAs* (B.Sc. (Hons.) dissertation, Monash University, Melbourne, Australia)

- Tanja Drobek, *Die Torsionsobertonmikroskopie als Methode zur Messung mechanischer Materialeigenschaften*
- Artur Erbe, *Nanomechanischer Elektronentransport*
- C. Eschbaumer, *Metallo-supramolecular polymers*
- Alexander Haubrich, *Akustoelektrischer Strom durch lateral definierte Quantenpunktkontakte*
- M. Heller, *Aufbau Funktionaler Polymerarchitekturen mit supramolekularen Einheiten*
- Rainer Hillenbrand, *Nahfeldoptische Amplituden- und Phasenkontrastmikroskopie zur nanoskopischen optischen Abbildung von Materialkontrast und optisch resonanten Partikeln*
- Gregor Jung, *Zweifarben-Fluoreszenzspektroskopie am Grün fluoreszierenden Protein und seinen Mutanten*
- Hua Qin, *On the Dynamics of Single-Electron Tunneling in Semiconductor Quantum Dots under Microwave Radiation*
- Georg Seisenberger, *Mikroskopische Untersuchungen zum Infektionsweg von Adeno-assoziierten Viren in lebenden HeLa-Zellen auf der Ebene einzelner Moleküle und Modelluntersuchungen zu FRET*
- Carsten Sönnichsen, *Plasmons in metal nanostructures*
- Martin Stark, *Signal- und Kontrastentstehung durch die Spitze-Probe-Interaktion in der dynamischen Kraftmikroskopie*
- Stefan Thalhammer, *Rasterkraftmikroskopie und Laser-gestützte Mikromanipulation – Einsatzmöglichkeiten in der molekularen Zytogenetik*

Diploma theses:

- Christian Bauer, *Charakterisierung eines InGaAs/GaAs-Quantenfilms zur Realisierung eines THz-Filters*
- M. Bierenstiel, *Synthese und physikalische Charakterisierung von vernetzbaren Emittern für OLEDs*
- Carsten R. Decker, *Spineffekte in kleinen Quantenpunkten*
- Stefan Fischerländer, *Einzelmolekül-Kraftspektroskopie an DNA*
- Sebastian Gritschneder, *Atomare Kontraste in der dynamischen Kraftmikroskopie auf Fluoriden und Calcit*
- Peter Halke, *Ortsaufgelöste Untersuchung des quantisierten Hall-Effekts mit akustischen Oberflächenwellen*
- Marc Hennemeyer, *Einfluß dynamischer und oberflächenphysikalischer Parameter auf die rasterkraftmikroskopische Mikrodissektion*
- Andreas Hörner, *Mechanische Hochfrequenzanregungen von nanomechanischen Resonatoren*
- Andreas K. Hüttel, *Tunnelgekoppelte Quantenpunktsysteme und ihre kapazitive Wechsel-wirkung*
- Arpad Jakap, *Elektrisch kontrollierte Lichtstreuung mit Partikelplasmonen*
- Christina Mooser, *Elektrostatische Rasterkraftmikroskopie mit dem Ziel, einzelne Ladungen zu detektieren*
- Arne C. Morteani, *Fluorescence quenching of dyes in the close vicinity of gold nanoparticles*
- Christel Nonnenberg, *Photochemie von Butadien: Ein Test für ROKS*
- Margerita Öhm, *Fluoreszenzmikroskopische Untersuchungen auf Einzelmolekülbasis zur infektion lebender CHO-Zellen durch adeno-assoziierte Viren unter besonderer Berücksichtigung der Wechselwirkung mit der Zellmembran*

- Nina Reckefuß, *Fluoreszenzmikroskopie von Zellbestandteilen: Ausarbeitung konvokal-mikroskopischer Methoden, die mit einzelmolekülsensitiven Experimenten an farbstoff-gelabelten Viren kompatibel sind*
- Javier Rubio, *Nanomanipulator*
- Dominik V. Scheible, *Gekoppelte nanomechanische Systeme für den Transport einzelner Elektronen*
- Johann Schermer, *Femtosekunden-Aufkonversionsexperimente an einem oberflächenemit-tierenden Halbleiterlaser auf GaInP-Basis*
- Christian Schulhauser, *Optische Magneto-Spektroskopie an einzelnen Halbleiter-Quantenringen*
- Christoph Strobl, *Flüssigkeitstransport durch Oberflächenwellen*
- Alida Würtz, *Spektroskopie von Randzuständen im Quanten-Hall-Effekt*

„Zulassungsarbeit“:

- Marcus Bauer, *Elektrische Charakterisierung ferroelektrischer Materialien*

Awards

Attocube Systems AG, Münchner Business Plan Wettbewerb: 1. Platz

C. Bräuchle, G. Seisenberger, T. Endress, „Single virus tracing project“, honored at the Münchener Business-Plan Wettbewerb 2000/2001 (business plan for a startup company)

J. Feldmann:
Gottfried-Wilhelm Leibniz Award of the Deutsche Forschungsgemeinschaft
Verdienstkreuz am Bande of the President of the Federal Republic of Germany

T. Franzl:
Best Poster Award on *Sweet Plasmons* of the Faculty of Physics, University of Munich

J. Müller et al.:
Best Poster Award on Directed lateral patterning of layer-by-layer self-assembled films for optoelectronic applications, Spring-Meeting of the German Physical Society

Thomas J. J. Müller:
2001 SYNTHESIS-SYNLETT-Journals Award, 1/2001

Nan]i[on Technologies GmbH:
Genius Biotech Award: Sonderpreis für beste technologische Innovation
www.science4life.de: 6. Platz
Münchner Business Plan Wettbewerb: 6. Platz
Mikrosystemtechnikwettbewerb (Dortmund-Projekt): 3. Platz und Sonderpreis für Prototypenentwicklung

NanoScape AG:
Third Prize in the final round of Münchner Business Plan Wettbewerb

M. Seitz:
Dr. Hermann Schnell-Preis der Gesellschaft Deutscher Chemiker

C. Sönnichsen:
Röntgen Award of the University of Würzburg

CeNS in the Media

Group of Prof. Christoph Bräuchle

"Science" organized a press conference on November 29th, 2001 according to the appearence of our paper in "science" (294 (2001) 1929, 1803) with the following result:
Virus Tracing as a topic in broadcasting and television magazines:
26.09.01 BR-Fernsehen Hauptnachrichten
19.10.01 3SAT: ForNano Wissenschaftssendung
29.11.01 ARD Hauptnachrichten
29./30.11.01 ZDF div. Hauptnachrichtensendungen
30.11.01 SAT1 Abendnachrichten
30.11.01 RTL Mittagsnachrichten
30.11.01 BR-Rundfunk / Deutschlandfunk
Virus Tracing as a topic in print-media
26.09.01 "Sueddeutsche Zeitung"
11.11.01 "Die Welt", "Die Welt am Sonntag"
29.11.01 dpa and Reuters N.Y.
30.11.01 "FAZ" incl. Sonderteil Viren "FAZ am Sonntag"
30.11.01 "Handelsblatt", "Münchner Merkur", "Abendzeitung"
10.12.01 "Focus"
Virus Tracing as a topic of Essays in sci. press
Nature Medicine 8, (2002), 23
Nature Biotechnology 20, (2002), 35
Journal of Cell Biology 155, 7, (2001), 1094
Molecular Therapy 5, 3, (2002), 215-216

CeNS in the Press

Prof. Jochen Feldmann

Laser Focus World, September 2001, p. 15: *Thin-film organic laser tunes very compact DFB*

Prof. Feldmann's Leibniz-Award was covered by: Süddeutsche Zeitung, Münchner Merkur, Hamburger Abendblatt, Westfalenpost, Bonner Stadtanzeiger

Prof. Wolfgang Heckl

Fliegende Mikroskope, Süddeutsche Zeitung, 6. 12. 2001

Dr. Fritz Keilmann

G. Chin, Editors' Choice - Highlights of the recent literature, Science 291, 15 (2001).

Prof. Jörg P. Kotthaus

„Zehn hoch minus neun – vom Aufbruch in den Nanokosmos", Interview des DeutschlandRadios vom 10.6.2001

Prof. Michael Reichling

The Nature paper (414, 54 (2001)) was covered by articles in Süddeutsche Zeitung and Telepolis.

Prof. Ulrich Schubert

Nachrichten aus der Chemie, 49, 6 (2001). "Selbstorganiserende Bioabbaubare Polymere"
Nachrichten aus der Chemie, 29, 955 (2001). "Steinheim 2001 - Vielfalt der Themen"
*Nachrichten aus der Chemie,*29, 360 (2001). "Trendbericht - Makromolekulare Chemie"

CeNS in Television

Prof. Jochen Feldmann

His Leibniz-Award was cover by Heute-Journal, ZDF

Group of Prof. Gaub

Filipp Oesterhelt: Membranextraktion von Bakteriorhodopsin; 9.5. in: "Nano" (3-Sat)

Prof. Wolfgang Heckl

1.8. 2001 Nanobiotechnology (BR-alpha)

Fairs and Presentations

Prof. Jochen Feldmann

Fair 'Laser 2001': Presentation of a 'Flexible Organic Laser'
(U. Lemmer and J. Feldmann)

Studienstiftung des Deutschen Volkes: Seminar on 'Nanotechnology' for two weeks in Olang, Italy (C. Sönnichsen and J. Feldmann)

Prof. Hermann Gaub

„Physik und Leben“, special exhibition in Deutschen Museum 8.-12.10. 2001: experiment and lectures by M.Rief and H.E.Gaub

Prof. Wolfgang Heckl

Organisation of Physics and Life in Deutschen Museum München, 8.-12.-10.2001 (together with Prof. P. Fromherz)

Dr. Klaus Meerholz

Laser 2001 (Bayern Innovativ/CeNS)

New Companies founded from CeNS groups

Attocube Systems AG
NanoScape
Nanion Technologies
Virus Tracing Group
SupraMAT Technologies AG

Funding

- Advalytix AG, München
- Alexander-von-Humboldt Foundation
- Bavarian California Technology Center (BaCaTec)
- Bavarian-French University-Center
- Bayern Innovativ
- Bayfor Neue Materialien
- BMBF (Federal Ministry of Education and Research)
- CMI company
- DAAD (German Academic Exchange Service)
- DFG (German Research Foundation) via: SFB 338, SFB 348, SFB 455, SFB 486, SFB 533, SFB 563 and numerous single grants
- European Space Agency (ESA)
- European Union
- Fonds der Chemischen Industrie
- FORMAT (Forschungsverbund "Neue Materialien")
- FORPRION
- Land Bayern
- Leibniz-Rechenzentrum
- NSF
- Studienstiftung des deutschen Volkes
- U.S. Department of Energy
- U.S. National Science Foundation
- VDI
- Volkswagen Stiftung