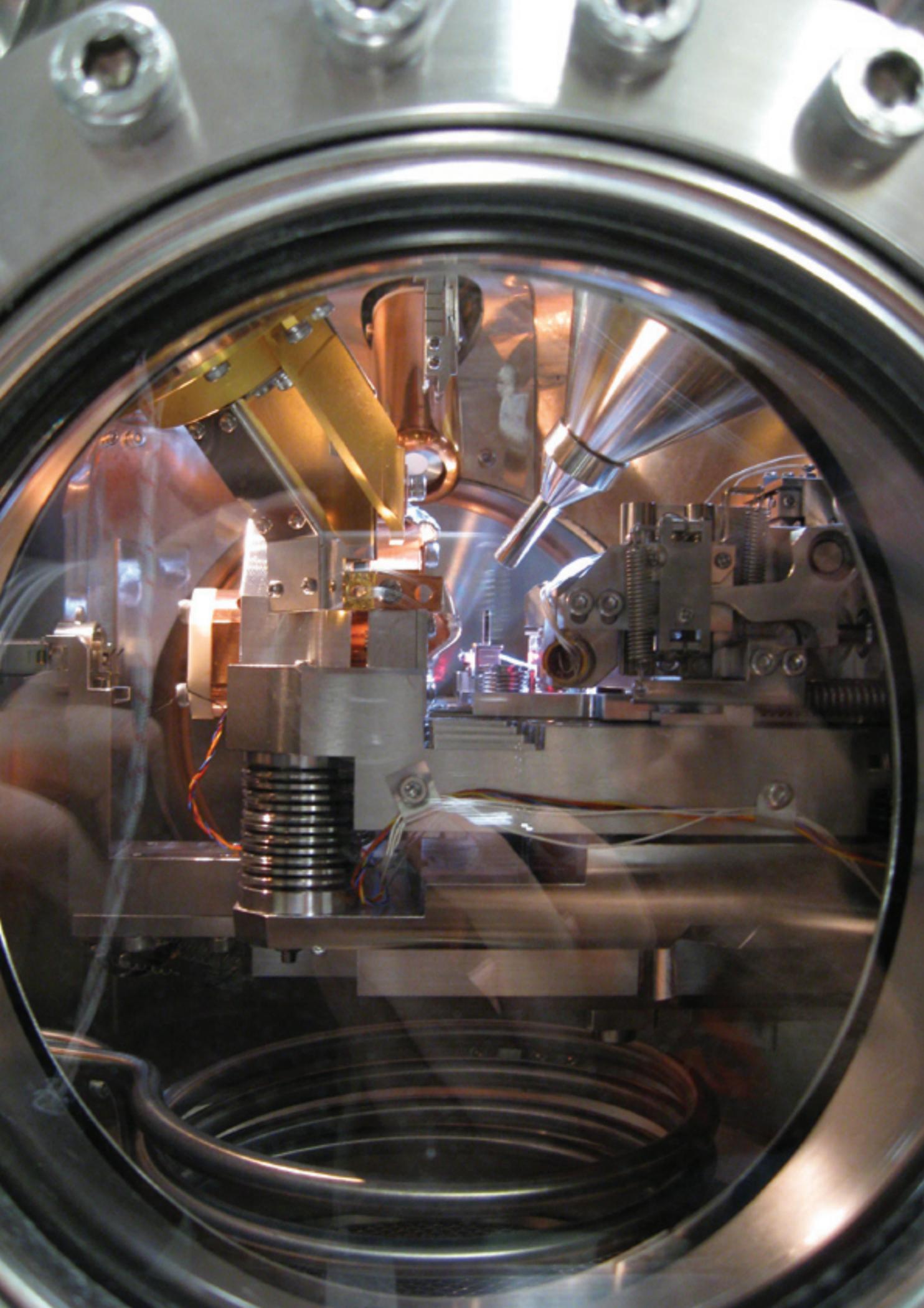


2008

Junior Nanotech Network

A Self-Organized Graduate Student Exchange Program





In a Nut Shell

Advanced research in the fields of nanosciences and nanobiosciences requires joint efforts of enthusiastic scientists trained in different disciplines as well as a strong international network enabling the research to work closely together and exchange knowledge and innovative ideas.

The Junior Nanotech Network (JNN) was initiated in 2006 to meet these new requirements for top-level research. The exchange program was established between graduate students from the Departments of Physics and Chemistry at McGill University in Montréal, Canada, and the Center for NanoScience (CeNS) at the Ludwig-Maximilians-University in Munich, Germany. After a successful first round in 2006, a second group of highly motivated graduate students from Bavaria and Québec came together in 2008 to realize the JNN'08 following the same scheme.

Junior Nanotech Network (JNN): A Self-Organized Graduate Student Exchange Program

Lectures and Lab work

The symmetrical JNN '08 project consisted of a three-week visit of the young scientists from CeNS in Montréal in June 2008, followed by a return visit of the Canadian students in Munich in the autumn of the same year. The scientific program combined lectures from internationally renowned speakers with an extended period of laboratory work.

Learning from Peers

The particularly interesting approach of the JNN is the self-organized character of the project which has been proven to be successful already in the first JNN exchange in 2006. This goal was again realized by giving the students the chance to conceive, teach, and supervise the scientific experiments in an independent manner. The laboratory work was carried out by the guest students under the supervision of the host students. In this way, students coming from different areas of nanosciences and nanobiotechnology were taken to the cutting-edge of a variety of domains via the guidance of the host students. The scientific projects allowed the transfer of broad knowledge and new technical skills and gave the hosts the opportunity to demonstrate their advanced research to a small and enthusiastic audience.

Intercultural Exchange

The scientific program was complemented and enriched by the social, cultural and outdoor activities which were organized by the host students. To guarantee social integration of the guests, the visiting researchers were housed at the homes of their local exchange partners. This close interaction fostered the intercultural exchange and stimulated scientific informal discussions. Combining joint lab work with common leisure activities enabled the creation of strong bonds between the young people from Canada and Germany.



Participants and organizers of the JNN at the CeNS workshop on San Servolo in Venice.



View from the Mont Royal on Montréal, Québec.



View on Munich city with the Alps in the background.

The Workshops: Lectures and Scientific Discussions



Participants of the CeNS Workshop on San Servolo, Venice.

Workshop in Montréal

During the first part of the JNN exchange in Montréal, an interdisciplinary workshop took place in the Rutherford Physics Building at McGill University. This gave the participants from the German and Canadian side the opportunity to present their own research and to familiarize with each other's research projects, which was an integral part of the exchange program.

Invited speakers from McGill University, Université de Montréal (UdeM), Queen's University and Yale University gave detailed insight into their research by presenting their projects, methods and new ideas in the field of nanoscience. The renowned speakers gave lectures on topics ranging from scanning probe microscopy applied to nanoelectronics, the use of DNA as building blocks in supramolecular chemistry, properties and application of novel nanomaterials, methods to study molecular cellular mechanisms on the nanometer scale or time-resolved electron diffraction microscopy to resolve transient atomic motions.

CeNS Workshop in Venice

In the German part of the JNN exchange, the Canadian and German students were invited to join the CeNS Workshop "Complex nanosystems: assembly, control and functionality" at the Venice International University (VIU) on San Servolo in Venice, Italy.

Various selected invited speakers from CeNS and Universities worldwide referred about their projects in the rising fields of nanoscience and nanotechnology, such as molecular biophysics, nanoelectronics, modeling of complex nanosystems, nanomaterials science, etc. (for details see www.cens.de). In addition to the conference talks the young scientists, including the JNN participants, had the chance to present posters and to discuss their own work with the leading researchers of the community. Furthermore, some students were selected to give short presentations of their research. This event was an excellent way for students from McGill and CeNS to network and to create new contacts with internationally renowned researchers as well as with their fellow students.



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Thermal and Mechanical Melting of DNA

With the development of new experimental tools allowing pico-Newton force resolution and Angstrom precision positioning of force sensors, mechanical experiments with single molecules have become possible. Such experiments not only provide new insights into intra- and inter-molecular forces; they also show variations in physical parameters of individual molecules with respect to the mean values derived from ensemble measurements. Furthermore, by investigating single polymers far from their maximum-entropy conformation, these experiments inspire new concepts in polymer physics as for instance conformation transitions of polymers.

Certainly, one of the most important biopolymers is DNA which stores the genetic information of a living organism. The mechanics of a DNA molecule determine significantly its functionality and therefore play a key role in numerous biological processes such as DNA transcription, gene expression and regulation and DNA replication.

The native structure of DNA is called B-DNA, but several other structures like A-DNA and Z-DNA are observed in nature. When DNA is stretched into a single molecule experiment the DNA is converted into an overstretched non-native conformation called S-DNA.

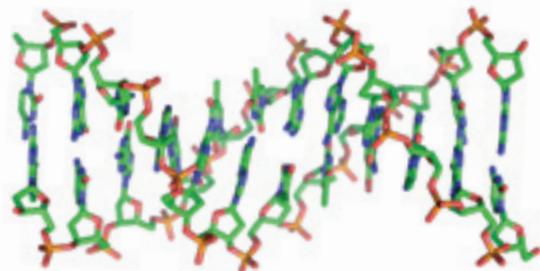


Figure 1: Structure of a short DNA molecule.

During the process of stretching double stranded DNA (dsDNA) goes from B-DNA to the energetically favoured S-DNA which finally melts under high stretching force into two single DNA strands (ssDNA). This can be done at the single molecule level with an atomic force microscope (AFM). By evaluating the force curves it is possible to extract the dissipated energy during the stretching of the DNA and hence the energy of a single base pair or even a hydrogen bond. These energies can be compared to values derived from thermal DNA melting experiments.

When a DNA polymer is heated the hydrogen bonds

stabilizing the helical structure are thermally broken until the double strand divides into two single strands. This causes a gradual increased absorption which can be measured through UV-spectroscopy.

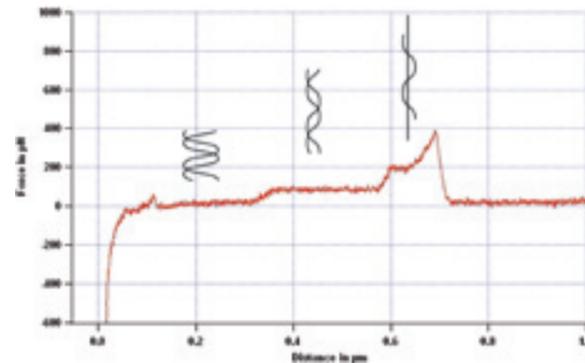


Figure 2: Force-induced melting transition in λ -DNA. Until an applied force of 35 pN the DNA mechanics are dominated by the entropic spring characteristics of the semi flexible DNA helix. Afterwards linear enthalpic effects prevail until the DNA is stretched from the native B-conformation to the 1.7 times longer S-conformation. In the force-distance curves this is represented by the first plateau at 65 pN. At the second plateau the DNA is mechanically melted. The end of the curve is dominated by the entropic spring behavior of the single DNA strand until it detaches from the cantilever.

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Self-Assembled Monolayers: Surface Functionalization on the Molecular Level

Molecular self-assembly on surfaces is a promising approach for the efficient production of functional nanostructures. Monolayer adsorption of organic molecules on different substrates under vacuum conditions is a bottom-up technique capable of producing two-dimensional open-pore networks of varying size on the nanometer scale which can act as a template for incorporating molecular guests or clusters.

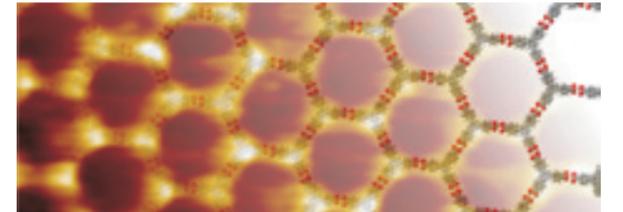


Fig. 1: Hexagonal pattern of a hydrogen-bonded self-assembled monolayer. Left side: STM image, right side: computer model. Cavities can be used to include guest molecules or metal clusters.

Molecular Deposition

Deposition of molecules on previously cleaned surfaces is a crucial step in obtaining self-assembled monolayers (SAMs). The method utilized here is organic molecular beam epitaxy (OMBE). Rate and time of deposition are important factors which influence structure and thickness of the molecular layers.

Sample preparation was the first part of the experiment. In a custom-made vacuum chamber, the molecules were evaporated onto the surface from a Knudsen cell. This is achieved by heating dry powder of the material until sublimation starts. The resulting molecular beam is subsequently guided onto the substrate, resulting in the adsorption of single molecules on the surface. Equipped with appropriate functional groups, the molecules spontaneously start the formation of a SAM. The deposition was stopped before a second layer of molecules could form on the first one.



Fig. 2: Sample manipulation in the UHV chamber

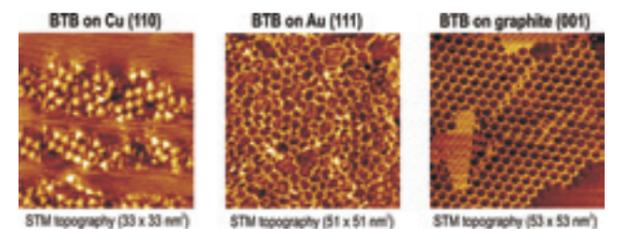


Fig. 3: The same molecule (1,3,5-benzenetribenzoic acid) was evaporated onto different substrates to study the influence of surface on the adsorption behavior. Apparently, the degree of ordering is heavily influenced. (a) copper, (b) gold, (c) graphite.

Characterizing the Monolayer

The second step of the experiment was composed of imaging the SAM. Our tool of choice was a Scanning Tunneling Microscope (STM), which allows mapping the electronic structure with accuracy down to the nanometer scale. Single molecules can thus be resolved and morphology and symmetry of monolayers as well as their crystallographic relation to the substrate can be measured. Imaging is followed by an interpretation of the molecule-molecule and molecule-substrate interactions. Typical images of molecules on different substrates are shown below.

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Antibacterial Effects of Silver Nanoparticles for Water Purification

This project demonstrates the use of nanotechnology for disinfecting drinking water. Our method involves incorporating silver nanoparticles, a known bactericide, into a paper filter. Compared with current technology (such as chlorination), silver nanoparticles have distinct advantages as potent antimicrobial agents for a wide range of bacteria and very low toxicity to humans. For this experiment, we showed silver nanoparticle synthesis in a paper template and a simple antimicrobial activity study.

Paper as a “Nano-Reactor” for Silver Nanoparticles

For the synthesis of nanoparticles, we have used porous materials as templates. The porous surface of cellulose fibers in paper enhances the silver nanoparticle formation by limiting particle aggregation and narrowing the overall size distribution. Researchers have used metallic nanoparticles embedded in solid matrixes for many practical applications, such as fuel cell membranes, catalysis supports, antibacterial films, textiles, and surfaces.

In this project, we have focused on optimizing the concentration of silver nanoparticles in the paper filter. We formed silver nanoparticles in the paper filters by soaking paper in a silver ion solution and converting the ions into nanoparticles with a strong chemical reducer (NaBH₄). The formation of silver nanoparticles is easily monitored by color changes from white to yellow and can be measured using UV/Vis spectrophotometry.



JNN students from Canada and Germany performing the filtration experiment.

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Antibacterial Lab Tests

Several types of metal nanoparticles including silver, copper, and titanium dioxide have been proven to deactivate and kill bacteria. This is most likely due to the high surface area and high reactivity of metal nanoparticles. Additionally, silver has a high affinity for sulfur and thiol groups in proteins, and can lead to protein dysfunction.

To test the effectiveness of the silver nanoparticle paper, we designed a simple filtration experiment. A non-pathogenic strain of E. coli bacteria, a typical coliform bacteria, was suspended in water and passed through the paper filter. The water effluent was analyzed for the presence of live bacteria by a re-growth experiment. Bacteria activity was measured by optical density (turbidity) with a spectrophotometer.

Self Assembly of Silica Nanochannels Revealed by AFM

Modern materials more and more rely on manufacturing techniques not dominated by top-down processing, but bottom-up mechanisms like self assembly to create uniquely shaped structures exhibiting properties superior to those found in conventionally manufactured Systems. In this experiment we studied newly found mechanisms of self assembly on surfaces of mesoporous silica films by tapping mode AFM imaging. These materials can form 3-dimensional nanostructures which are of great interests for a wide range of applications in filters, solar cells, drug delivery and catalysis.

The investigated, Ctab (Cetrimonium bromide) based, mesoporous silicas are prepared in films, with a self organized nanostructure of hexagonally stacked tubes, by spin coating a solution of Ctab, TEOS (Tetraethyl orthosilicate) and ethanol. In the bulk material these structures show ordered tube structures on a length scale of a few hundred nanometer. But under the right conditions bilayers with continuously ordered domains three orders of magnitude larger in area and up to several hundred nanometer thickness can form on the surface of these films (Fig.1 and 2). Understanding the underlying mechanisms of this spontaneous reorganization on the surface of already stabilized films could not only lead to a new class of materials, but also a deeper understanding of phase transitions in metastable solid materials (Fig.3) and a new tool for localized and targeted chemistry .

For the experiment a mesoporous film was spin casted two days prior to the experiment and stored under ambient conditions to stabilize. The growth measurement of the surface domains was conducted by continuous scanning of an 15 μm x15 μm are of the samples with the AFM in tapping mode under ambient conditions. Depending on different parameters like temperature, relative humidity, age and composition of the sample several effects like phase transitions, growth kinetics, growth anisotropy, material transport were observed.

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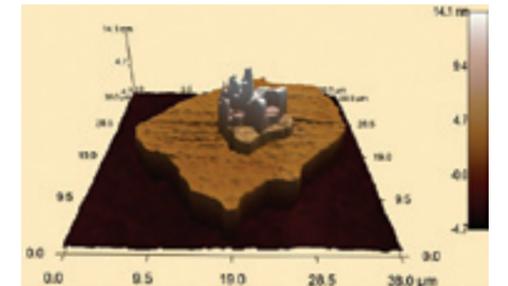


Figure 1: Height Image of a single multilayered domain.

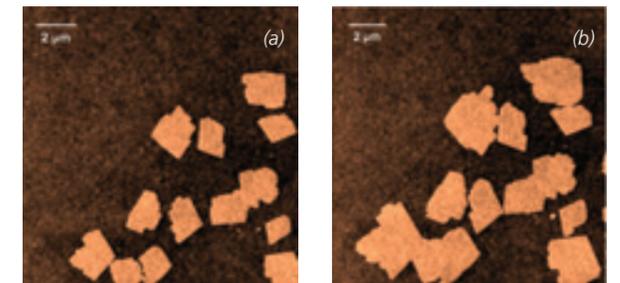


Figure 2: Height Image of a growing sample.

(a) 90 minutes after the beginning of the experiment.
(b) 20 minutes later.

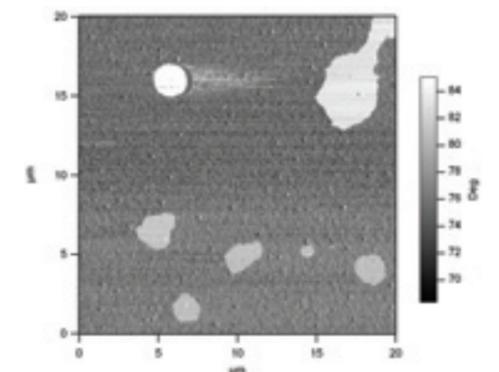


Figure 3: Phase Image of a growing sample, different contrasts expose different material stabilities.

Molecular Dynamics Simulations and 3 Dimensional Visualization of Transient Protein Complexes

Molecular Dynamics simulations are a fundamental tool for the understanding and the studying of processes in biological molecules. The idea is to calculate the time dependent behavior of a chosen molecular system solving Newton's equation of motion modeling Quantum Mechanical effects with intrinsic classical parameters. In this way Molecular Dynamics simulations allow a direct insight into the molecular motion on the atomistic scale. Therefore it can be used to investigate the structure, dynamics and thermodynamic properties of a biological system rendering it particularly suitable for the analysis of inter- and intra-molecular processes. To analyze the computed dynamics of structures, high definition visualization in 3D is a useful utility. Therefore 3D projection methods as well as Holobench systems can significantly improve the insight into structural processes.

Performing Molecular Dynamics Simulations

In this project we provided an insight into computational biophysics. The participants were trained to perform their own simulations of molecular systems. In this context, we examined a transient protein complex model system, consisting of the RNase Barnase as well as the matching inhibitor Barstar. This moderate sized complex allows fast computation of the dynamic behavior. Barnase-Barstar is additionally widely used in genetic engineering processes and Bioengineering.

Our tutorial started with the search of the required structural input data from an online protein structure data base. The obtained structural data was subsequently customized and parametrized for the further computations. Furthermore, the computational environment for the simulation of the molecular complex was designed to reproduce physiological conditions. Additionally the complex was energetically optimized to fit to the new environmental parameters. To relax the surrounding water box a 500ps simulation with restraints on all heavy atoms of the protein was performed. The resulting output structure was then used for a 20ns long simulation of the free complex in solution. During this process the participants monitored the correctness of the process with trajectory and energy visualization tools.

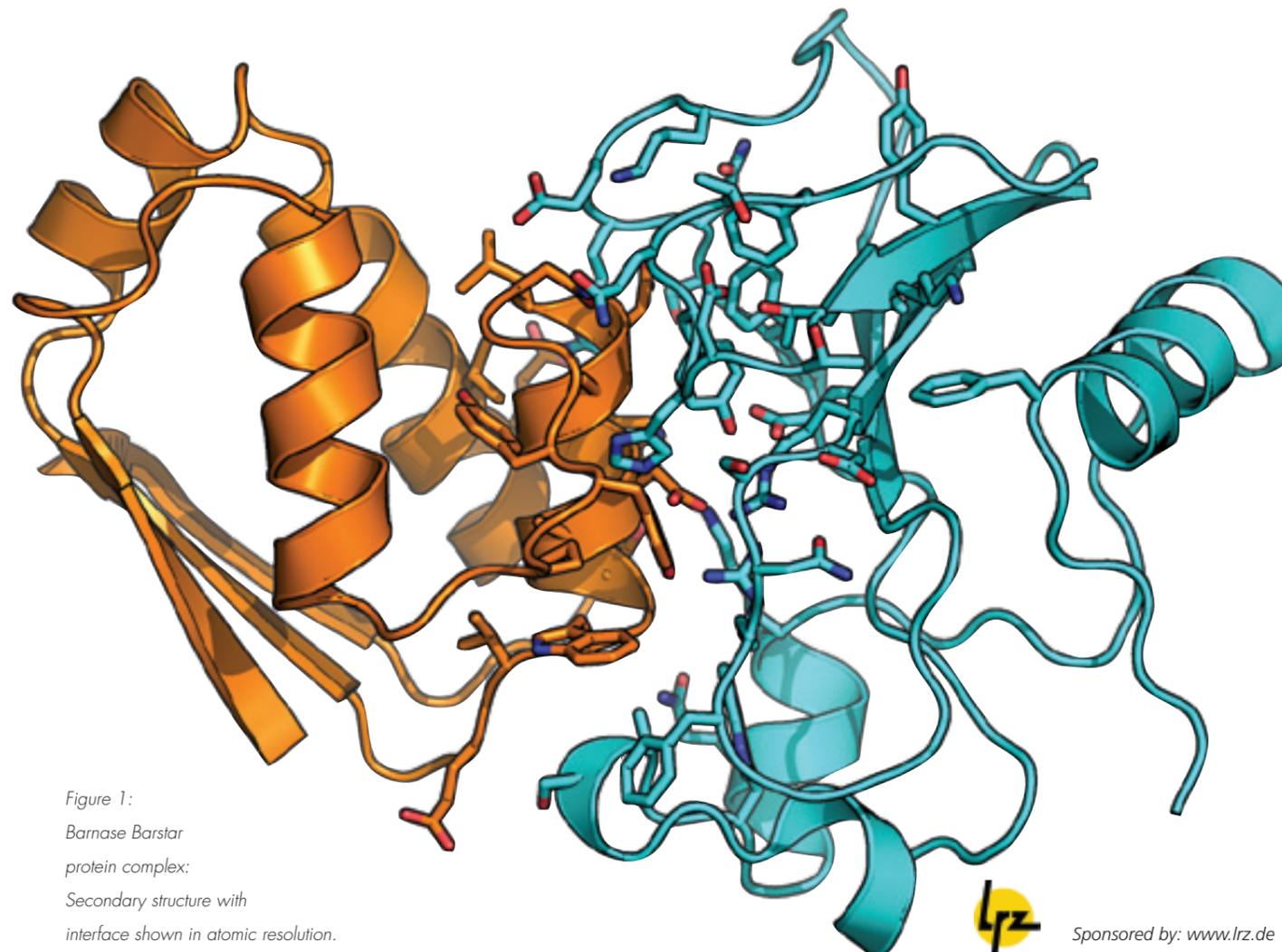


Figure 1:
Barnase Barstar
protein complex:
Secondary structure with
interface shown in atomic resolution.

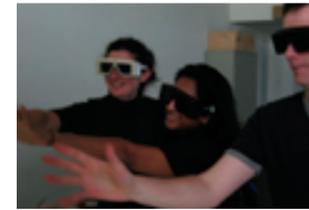


Figure 3: Grabbing a 3D object on the Holobench System.

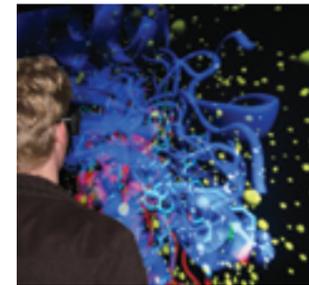


Figure 2: Visualization of complex binding behavior on the 3D Holobench System.

Structural Visualization in 3D of Protein Dynamics

Structural analysis of the output trajectories has been supported by 3D devices. For trajectory analysis, the mobile 3D projection system of the LRZ was used. This system consists of two projectors equipped with polarization filters and a set of polarizing glasses separating the two images for the eyes and generate a single stereoscopic image.

To obtain a deeper insight into the single structures, the 3D Holobench system at the virtualization facilities of the Leibniz-Rechenzentrum (LRZ) was used. The holobench system has two projection planes, driven by synchronized compute nodes.

Shutter goggles with active position detection of the head position and additional movement tracking then provide a levitated, in mid air floating virtual object of the complex structure. A 3D control device with accurate position detection allows haptic interaction with the model such as grabbing, pulling and rotating. In addition an interactive flight through the 3D objects can be steered with this controller.

Furthermore an interactive molecular dynamics simulation (IMD) of a protein-RNA complex was set up on the HLRB2 national supercomputer. This type of simulation allows a direct interaction with the ongoing simulation such as separating the two strands of a DNA double helix by force. As a highlight, we visited "the cube" hosting the HLRB2 supercomputer as well as other computing, archiving and networking infrastructures.

Acknowledgment

We specifically thank Jutta Dreer for the organization and help with the 3D visualization facilities and Ferdinand Jamitzky for the IMD setup as well as the guided tour.

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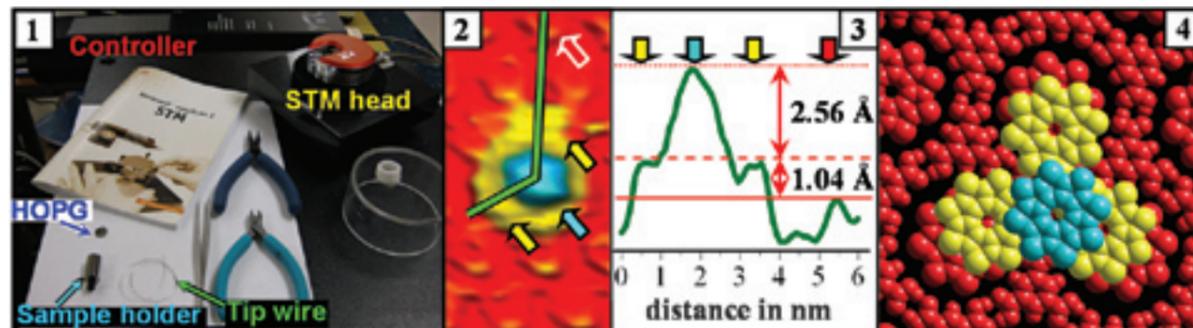
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Self-Assembly in Multi-Component Systems: Ambient STM Study

The self-assembly of molecules can be controlled through non-covalent bonding to form extended two-dimensional (2D) molecular patterns. These types of assemblies, known as self-assembled molecular networks (SAMNs), can be successfully used for surface patterning and building host-guest architectures. SAMNs have been increasingly studied in the last decade due to advances in scanning probe microscopy (SPM) techniques, in particular scanning tunneling microscopy (STM), which allows for topographical and electronic characterization of SAMNs with molecular and even submolecular resolution in situ at the solution/solid interface.



Objectives

To provide basic training in ambient STM. This covers:

- Preparation (tip, substrate, sample)
- Imaging of the surface
- Image processing using software
- To use a multi-component system (trimesic acid (TMA), 1-decanol/1-heptadecanol, solvent) for controlled surface patterning of highly oriented pyrolytic graphite (HOPG) [1]
- To study host properties of TMA SAMN using different molecules as possible guests [2]

References

- [1] K. G. Nath et al., J. Am. Chem. Soc. 128, 4242 (2006)
 [2] S. J. H. Griessl et al., Langmuir 20, 9403 (2004)

Experiment

During two day experiment each group of students went through basic steps involved in a typical STM experiment:

- Microscope and sample preparation
- Image acquisition
- Image processing and analysis
- Molecular modeling

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Single Molecule Study of Protein Binding Kinetics with spFRET-TIRF Microscopy

All cellular organisms depend on DNA molecules as a carrier of genetic information. To turn this information into something 'alive' it is translated into proteins. However, in order to be able to adapt and react to the environment, the cell's capability to regulate the process of protein expression is essential.

Binding of TATA box binding protein (TBP) to the TATA sequence of a eukaryotic gene is the initiating step in DNA transcription – the first step in protein expression. The process of TBP binding can be regulated by various factors. One prominent transcription factor is MOT1, an ATPase able to hinder stable TBP binding and in turn slowing down gene expression. The aim of this experiment was to study the dynamics of TBP binding and the ATP dependence of MOT1 activity on a single molecule level. To resolve the dynamics of the TBP binding process, we used an in vitro single molecule assay based on single pair Fluorescence Resonance Energy Transfer (spFRET) with a Total Internal Reflection Microscope (TIRF).

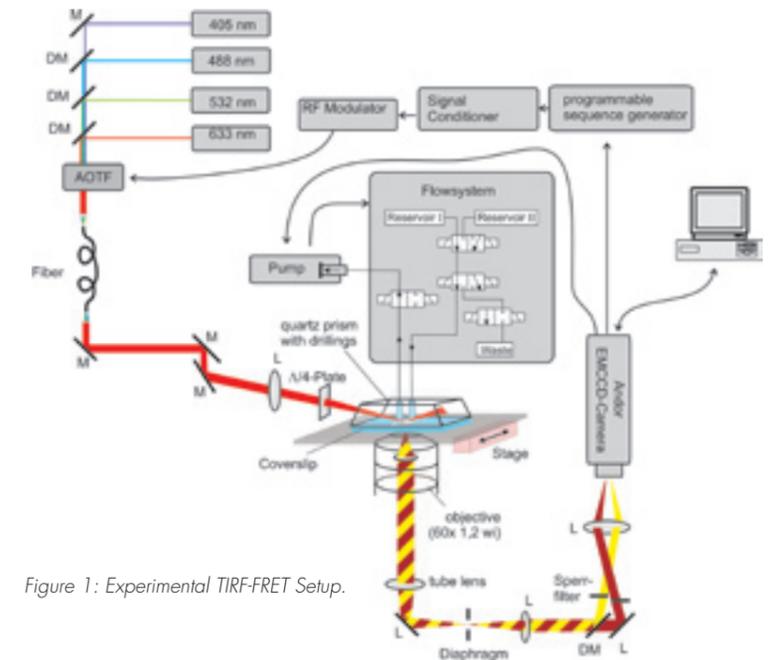


Figure 1: Experimental TIRF-FRET Setup.

Materials and Methods

The biotinylated dsDNA containing the TATA box was immobilized to the biotinylated-PEG-TIRF Prism via streptavidin. The DNA was labeled with Atto647N acting as fluorescent acceptor. A single cysteine-mutant (SER61) of TBP labeled with Cy3 was used as FRET donor. The TBP was incubated together with the dsDNA prior to immobilization to promote TBP/DNA complex formation. After addition of ATP through the flow system, dynamics of TBP binding could be observed by monitoring donor and acceptor fluorescence.

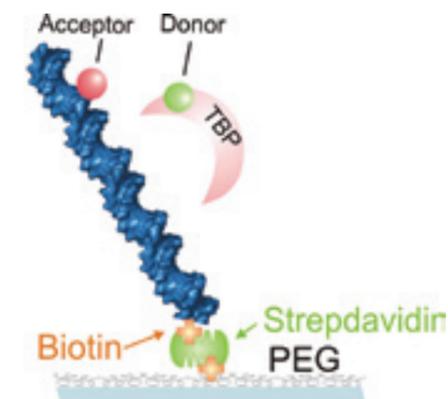


Figure 2: Immobilization of dsDNA to prism surface.

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Material-Dependent Friction Force Contrast by Electrochemical Deposition of Copper on Gold

A friction force microscope with electrochemical control was developed at McGill by the Bennewitz group to study nanotribology in a liquid environment. Many tribological experiments were performed in an ultra high vacuum environment by this group to study the fundamentals of friction on the nanometer scale. However, a liquid environment is more instructive for some systems in the sense that it represents a more realistic model environment – a water layer covers almost every surface on earth, but the same cannot be said for vacuum. The integrated electrochemical cell adds an extra degree of control to the surface being studied. It allows crafting the surface by processes such as electrochemical etching and cleaning, underpotential deposition, bulk deposition, and oxidation, which can all be achieved by varying the potential of the sample and changing the nature of the surrounding solution.

Experiment

This experiment involved measuring the friction between a sharp silicon tip and a single crystal metal surface in an acidic environment. The atomically flat surface was alternated between its original Au(111) composition and a monolayer of copper, via an underpotential deposition process of Cu^{2+} cations and its reversal. The elegance of this technique is that it eliminates systematic errors caused by changing samples (from gold to copper) which inevitably causes a modification of the tip geometry and contact area. By alternatively changing the surface composition in situ, a relative study between the frictional properties of gold and copper versus a silicon tip can be conducted with a much higher degree of accuracy.

More specifically, we started by exploring the entire design of the AFM to understand its pros and cons relative to tribological experiments. Its uniqueness lies in the electrochemical liquid cell which allows full control of the gold sample's environment. A primer in electrochemistry was necessary to understand the electrochemically-induced surface modifications occurring during the cyclic voltammograms. The cleaning of the surface via oxidation-reduction cycles of the gold, and the underpotential deposition of copper were observed electrochemically. We then supported these observations by AFM imaging an atomically flat terrace of Au(111). By switching from gold to copper, a material-dependent friction contrast was observed between the two surfaces.



Figure 1: A zoom-in of the electrochemical liquid cell

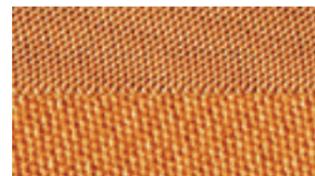


Figure 2: Friction force map of copper (bottom) and gold (top), imaged while switching electrochemical potential of the gold surface.

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Enhancement of Surface Plasmon Resonance in Gold Films Initiated via Selective Gold Nanoparticle Adsorption

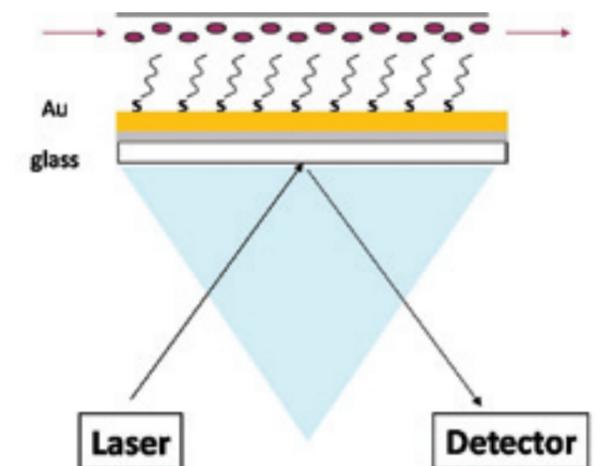
Surface plasmon resonance (SPR) spectroscopy is an analytical technique used for in-situ kinetic studies of adsorption of molecules to surfaces. This technique has various applications in biomolecular systems such as the analysis of antibody-antigen binding events, protein adsorption, and DNA folding. The use of gold nanoparticles to enhance the sensitivity of SPR spectroscopy will be employed using a self-assembled monolayer system on a gold substrate.

Experiment

The spontaneous formation of alkanethiol molecules on a gold surface results in uniform, almost crystalline monolayers on the surface. Time-resolved SPR spectroscopy is used to determine the kinetics of binding of an alkanethiol self-assembled monolayer to a gold surface. The subsequent adsorption of alkanethiol-capped gold nanoparticles to the SAM-modified surface is also monitored via SPR. This experiment will monitor the adsorption of decanethiol-capped gold nanoparticles to a dodecanethiol self-assembled monolayer on a gold surface.

The SPR effect is generated by irradiation of a thin gold film through a high refractive index prism. The light is totally internally reflected through the prism and the resulting evanescent wave couples to the surface plasmons in the metal film at a specific resonance angle. The gold film is also in contact with a constant stream of buffer or analyte (see figure).

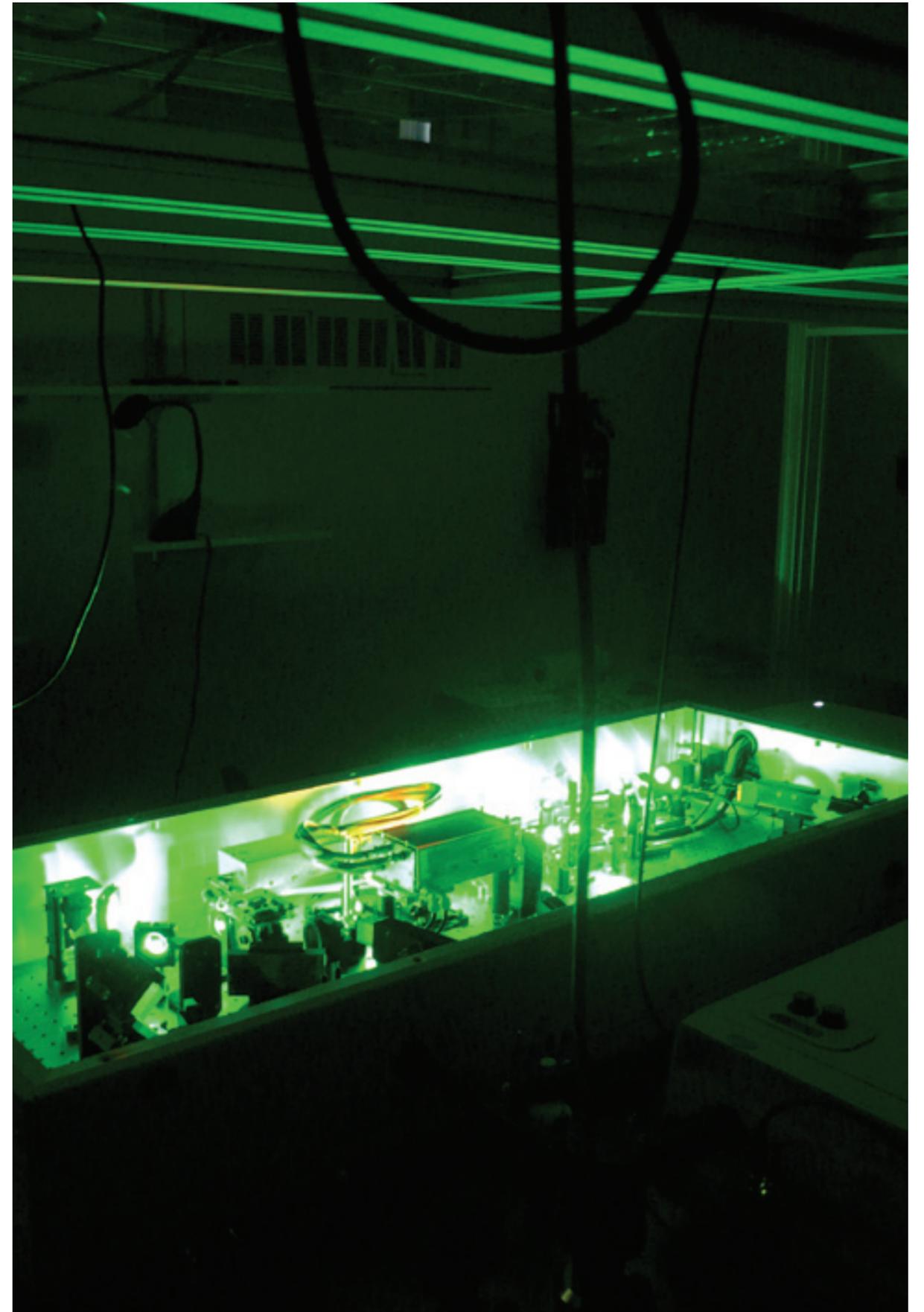
The adsorption of analyte molecules to the gold film results in a change of the refractive index at the interface. The resonance angle depends on the refractive index at the metal/solution interface and thus changes as molecules adsorb to the surface. The difference in resonance angle can be quantified to determine the amount of material adsorbed to the surface. The use of gold nanoparticles is predicted to create a larger change in resonance angle and result in an improvement of the detection limit for SPR spectroscopy.



Schematics of an SPR measurement.

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The Generation of Tunable Femtosecond Laser Pulses and the Observation of Chemical Dynamics Using Ultrafast Spectroscopy

In order to gain a more complete understanding of any chemical process, information about the dynamics involved must be obtained. Ultrafast spectroscopy using UV/visible light provides a means by which to obtain this dynamical information. A sample can be excited by a narrow band pump pulse, which is followed by a broadband probe pulse at a known delay. By monitoring changes in the sample absorption spectrum as a function of probe delay, information about the dynamics of the process can be obtained with sub 100 fs time resolution.

Using various nonlinear optical processes, tunable visible light can be produced from ultrashort laser pulses. In an appropriate nonlinear optical medium (barium borate in our case), the process of difference frequency generation results in 800 nm laser light to be split into two infrared beams. Either of these two infrared beams can be combined with some of the original 800 nm light using sum frequency generation in order to produce tunable visible light throughout the visible spectrum (~460-630 nm). The research group of Dr. Bradley Siwick built an optical parametric amplifier [1] (OPA) which takes advantage of the aforementioned processes to produce tunable femtosecond laser pulses. The OPA produces pump pulses which are tuned to a specific sample resonance and it will be aligned and characterized before the experiment.

After the sample is excited a large band probe pulse, generated by a process known as supercontinuum generation [2], is incident upon it. This nonlinear optical process allows for the production of extremely broadband (~500-2000 nm) pulses which provides the ability to probe the sample throughout the visible with one laser pulse. The probe is split in two with one pulse interacting with the sample and

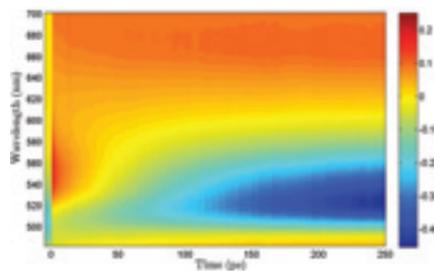


Figure 1: Absorption change in HPTS induced by a 400 nm pump pulse [colour bar represents the change in optical density].

the other being used as a reference. Two spectrometers are used to record the two supercontinuum pulses.

Upon alignment and characterization of the OPA as well as the probe pulse and spectrometers, intramolecular proton transfer from the molecule 8-hydroxy-1,3,6-pyrenetrisulfonic acid (HPTS) was studied. HPTS is a photo acid which, upon photo-excitation, increases its acidity by six orders of magnitude. This allows the proton-transfer reaction to be initiated with a pulse of light and the subsequent chemical dynamics to be monitored with the probe pulse. The rate of this reaction increases with increasing base concentration.

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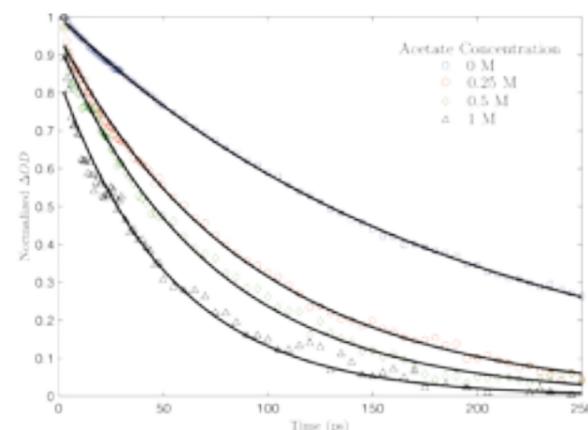


Figure 2: Absorption change in HPTS at 530 nm for various base concentrations (400 nm pump pulse).

Investigation of Switching Field Distribution on Permalloy Nanoscale Structures

There is ongoing interest in understanding the switching field distribution (SFD) of nanoscale patterned magnetic elements, which show great potential for novel applications such as magnetic quantum cellular automata [1] or magnetic random access memory [2] architectures. To make these architectures technologically viable, it is essential for patterned magnetic elements to have a reproducible and controllable magnetic switching mechanism, thus a narrow SFD. Factors that affect the SFD are not known and might be of various natures: thermal effects, shape, imperfections in fabrication, microstructure, edge roughness, seed-layer, anisotropy variations and magnetostatic interactions with neighbors, etc. With the help of the German students we investigated the effects of both shape and edge roughness.

To address these issues, we use a combination of atomic/magnetic force microscopy (AFM/MFM) [3] and transmission electron microscopy (TEM) on indexed arrays of permalloy nanoscale structures, which were previously sputter-deposited via stenciling on ultra thin silicon nitride membranes. The stencil-masks used during the deposition process feature ordered arrays of nano-apertures, previously prepared by focused ion beam milling.

The permalloy structures were firstly characterized by AFM to assess their topography. MFM was then used in constant height mode to obtain the magnetic state (domains) and SFD of the structures. Magnetization reversal was studied by applying an in situ magnetic field parallel to the sample surface with a pair of rotating NdFeB permanent magnets. The structures that switch magnetization direction at lower fields are identified as “early” switchers and structures that switch at larger fields are identified as “late” switchers. TEM was then performed on these “early” and “late” switchers. These images were compared to TEM performed on “normal” switchers to look for structural variations, which may induce differences in behavior and broaden the SFD.

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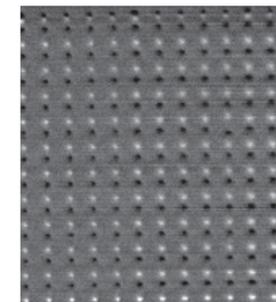


Fig. 1: MFM image ($27\mu \times 25\mu$) taken at constant height mode with an external magnetic field of -60mT . White corresponds to north and black corresponds to south pole of magnetization.

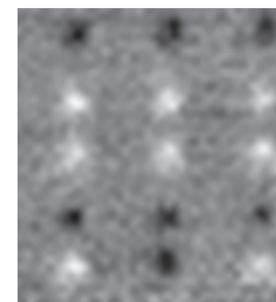


Fig. 2: MFM image ($5\mu \times 7\mu$) taken at constant height mode with an external magnetic field of 5mT . Note some structures have switched magnetization direction.

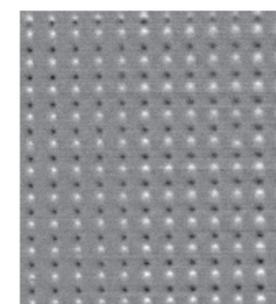


Fig. 3: MFM image ($27\mu \times 25\mu$) taken at constant height mode with an external magnetic field of 40mT . Note all structures have switched magnetization direction.

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Platelet Activation in Microfluidic Systems

Polydimethylsiloxane (PDMS) microfluidic systems were used to perfuse platelets over different substrates. The activation and adherence of platelets, on the material surface was imaged and analyzed.

The photoresist SU-8 has proven to be a favorable material for microfabrication and 3D-lithography since it is easy to process and chemically stable. It can also be used for the fabrication of polymer microfluidic systems. Such systems serve as tools for biological and medical analysis, since they are minimizing the required fluid volumes. This leads to the question whether SU-8 may be used as a material in order to mimic blood vessels. Hence, to clarify the applicability of the material its compatibility to blood has to be examined.

Blood is a suspension of the liquid plasma and the solid corpuscle, platelets as well as red and white blood cells. Platelets make up approximately 5% of the number of blood corpuscle (200–300x10³/μl). They are responsible for the occlusion of vascular lesions by adhering at the damaged sites in order to seal them. However, due to platelet agglomeration a thrombus may be formed which may lead to closure of veins or stenosis causing e.g. myocardial infarction, pulmonary embolisms, or

cerebrovascular accidents. Those are among the leading and most fatal diseases in western societies. Thus, the hemocompatibility of the materials used for artificial blood vessels needs to be investigated.

During the lab course a group of three students perform blood compatibility measurements. Under medical supervision, a small amount of blood was drawn from a volunteer and processed to obtain platelet rich plasma. The number of cells per μl was counted in a Neubauer counting chamber and then diluted to a concentration of 2x10⁸/μl. Microfluidic systems made of PDMS were cast from a mold and used for perfusion. The system was attached to the substrate and the platelet rich plasma was perfused under physiological flow conditions using a stepper motor driven syringe. Optical microscopy was used to monitor the platelet adhesion and to identify the quantity of adhered platelets. Atomic force microscope images were acquired to determine the state of activation of the platelets.

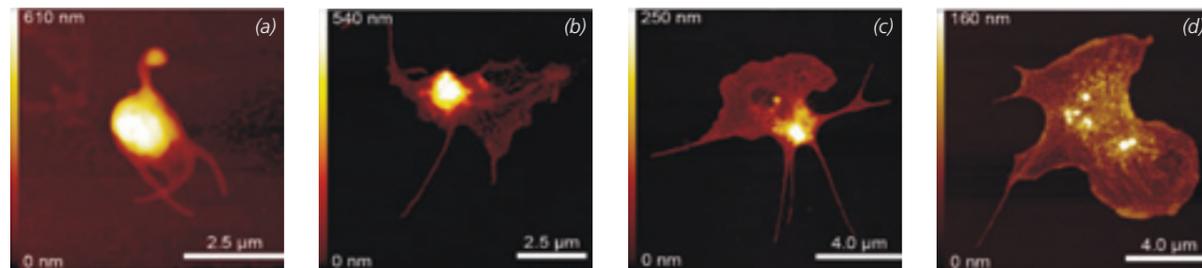


Figure 1: Different stages of platelet activation.

(a) for glass, settling and subsequent spreading are typical. For SU-8, all different stages of activation under shear stress can be observed:

(b) little activation,

(c) formation of pseudopodia, and

(d) full spreading of the platelet.

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Synthesis of Gold Nanoparticles

Gold nanoparticles, which have existed for centuries, have been the subject of intense research in recent years. They are used in a wide variety of applications, ranging from biology, fuel cell technology, and even textile colouring.

Experiment

Each group of participants was shown how to synthesize gold nanoparticles using the well known Brust-Schiffrin method. With each different group a new type of particle synthesis was explored. In order to vary the synthesis, each group varied:

- The temperature at which the particles were synthesized
- The capping ligand used to stabilize the nanoparticles.

The ligands used were all alkythiols of varying chain lengths. Ranging from an 8-carbon alkyl chain, to a 20-carbon alkyl chain. Although the most stable and monodisperse samples were prepared using a room temperature synthesis with octanethiol, syntheses at elevated temperatures were found to afford a surprising amount of size control.



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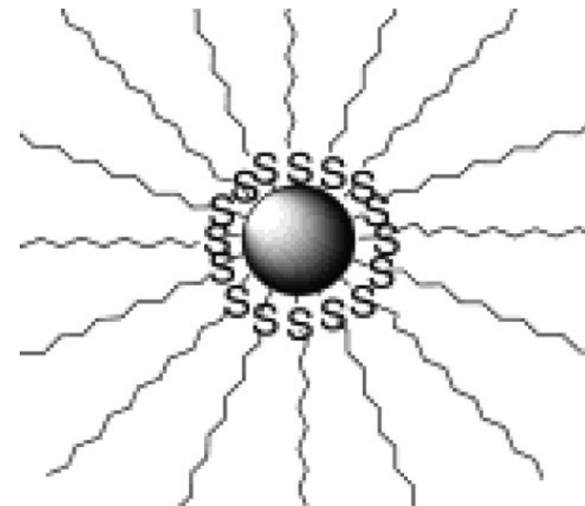


Figure 1: Schematic representation of an alkythiol capped gold nanoparticle.

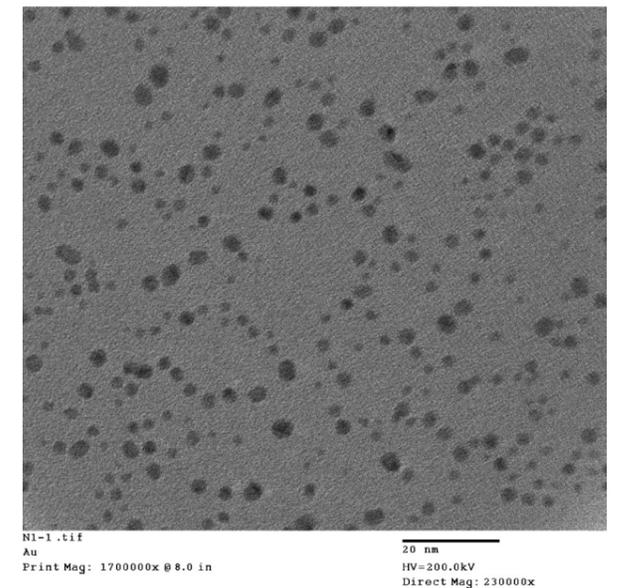
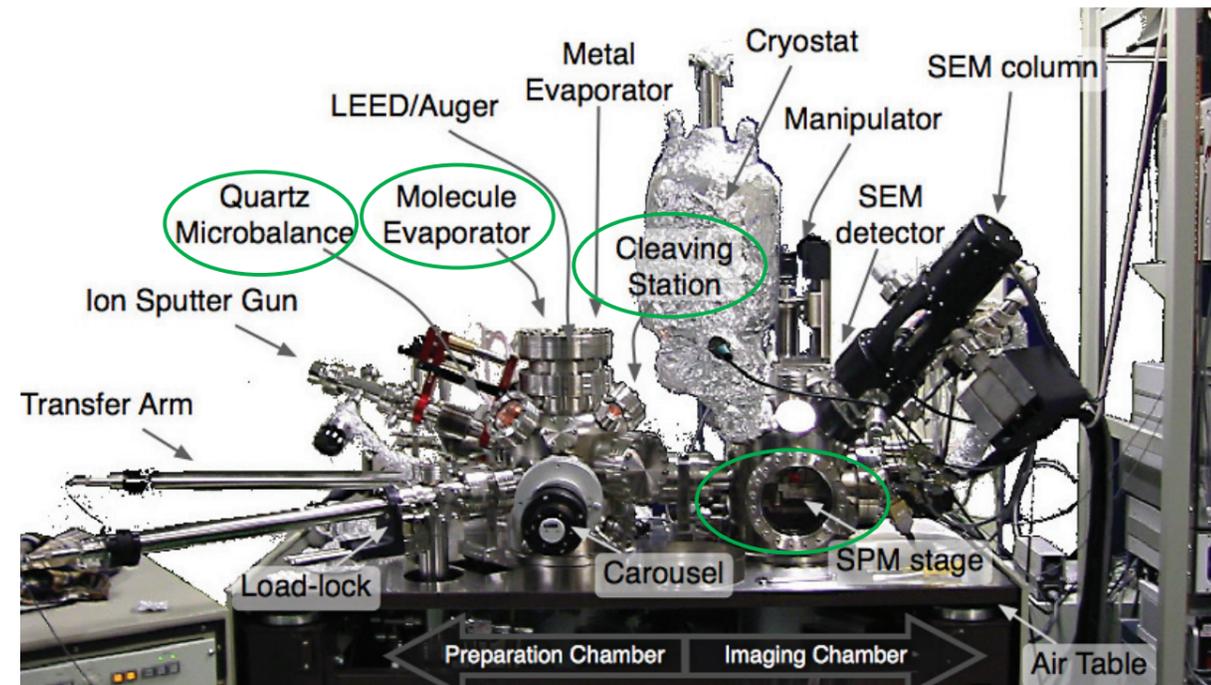


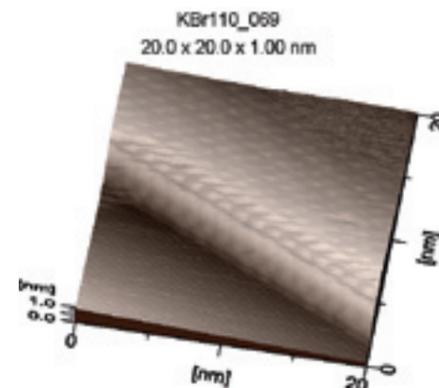
Figure 2: TEM of HS-(CH)15-CH₃ capped gold nanoparticles synthesized at 80°C.

NC-AFM: Deposition and Imaging of PTCDI Molecules on KBr

The interesting optical and electronic properties of certain organic molecules advocate their employment as components of organic optoelectronic circuits. Insulating substrates such as alkali halides are an advantageous choice on which to build molecular electronic devices, providing the ability to electrically isolate the device from the underlying surface. However, the surface science of insulators is not well understood, and therefore we attempt to obtain a more complete understanding of the interaction between organic molecules and the substrate. Non-contact atomic force microscopy (NC-AFM) is a non-destructive, high resolution technique ideal for imaging insulating surfaces, on which scanning tunneling microscopy (STM) is not possible. 3,4,9,10-Perylenetetracarboxylic diimide (PTCDI) is a promising organic molecule with interesting electronic and optical properties, similar to the well studied 3,4,9,10-perylenetetracarboxylic dianhydride (PTCDA). We investigate its behavior on potassium bromide (KBr) using the JEOL JSPM 4500A Ultra-High Vacuum (UHV) Atomic Force Microscope (AFM) system. This information is needed to build a solid basis upon which to design nanoelectronic devices.



The JEOL JSPM 4500A Ultra-High Vacuum (UHV) Atomic Force Microscope (AFM) system.

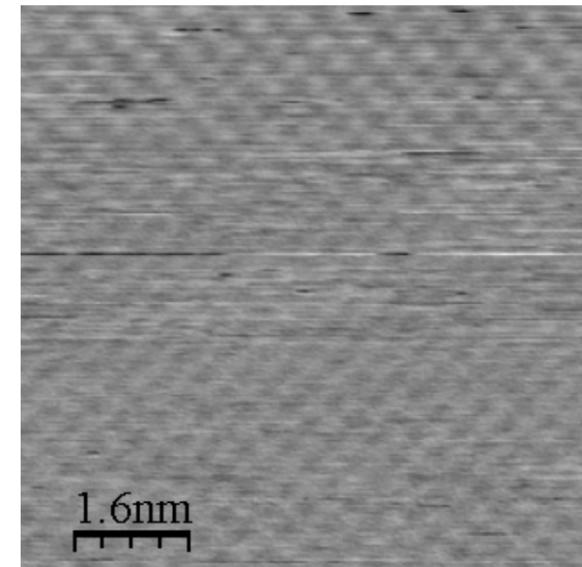


20 × 20 nm 3D rendered molecular and atomic resolution image of the edge of a PTCDI island and underlying KBr substrate, $\Delta f = -12$ Hz.

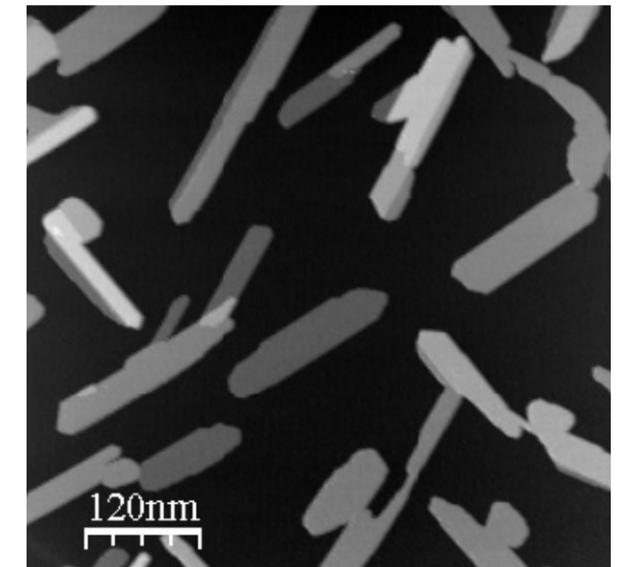
Experiment

The experiment began with the preparation of a clean KBr substrate. A block of KBr was scribed ex situ, placed in a sample holder, put in the UHV system, cleaved under UHV, and heated to $\sim 150^\circ\text{C}$ for 1 hour to dissipate surface charge, providing a clean, atomically flat KBr substrate. The sample was then transferred from the preparation chamber to the imaging chamber of the UHV system, where it was imaged by NC-AFM.

New cantilever tips were prepared and baked overnight in preparation for the second stage of the experiment, and swapped and aligned the next day by students. 0.4 monolayers (ML) of PTCDI were deposited on the KBr using the molecular evaporator (Kentax). The sample was then imaged again by NC-AFM, and the island growth behavior of PTCDI on KBr was observed.



10 × 10 nm atomic resolution image of the bare KBr substrate, $\Delta f = -16$ Hz.



150 × 150 nm image of island growth of PTCDI on KBr, $\Delta f = -3$ Hz

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Design and Fabrication of Multifunctional Organic Field Effect Transistors

Recently, there has been growing interest in lightweight and portable optoelectronic devices. In this regard, multifunctional organic-based devices, which are integrated with more than two functions, are attractive because they provide such opportunity by simplifying the design and fabrication processes. There have been several reports on multifunctional devices using organic materials. Light-emitting solar cells [1], ambipolar organic field effect transistors (OFETs), and integrated organic-based field effect transistors and light emitting diodes [2], are the examples of the multifunctional devices [3]. Combining the emission property of organic light-emitting diodes (OLEDs) with the switching property of OFETs offers a new class of highly integrated optoelectronic devices: organic light-emitting transistors (OLETs) [4].

In the experiment, the basic knowledge of the design, fabrication and testing of the organic light-emitting transistors based on pentylstyryl tetracene (PST) was provided.

Methods and Procedures

- Chemical functionalization of the dielectric surface (wet method and contact angle measurements)
- Deposition of a semiconductor (vacuum evaporation, spin-coating)
- Extraction of the key transistor parameters (carrier mobility, threshold voltage, on/off ratio) from samples of real experimental data
- Evaluation of optical properties of organic semiconductors (UV-Vis and Fluorescence techniques)

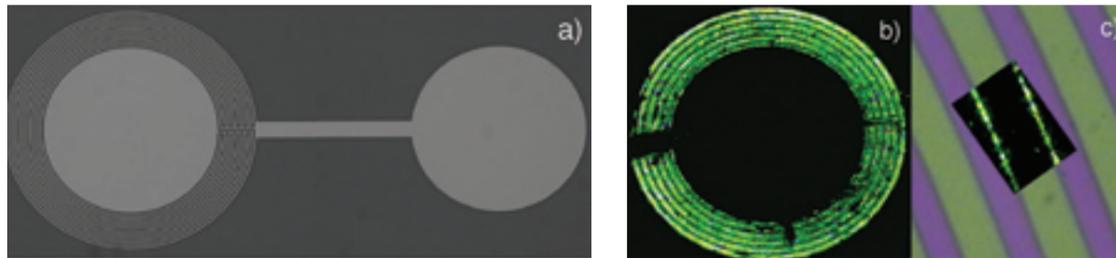


Fig. 1: Optical images of:
a) Interdigitated bottom-contact device
b) Green electroluminescence of PST-LET
c) magnified contacts and localized light emission.

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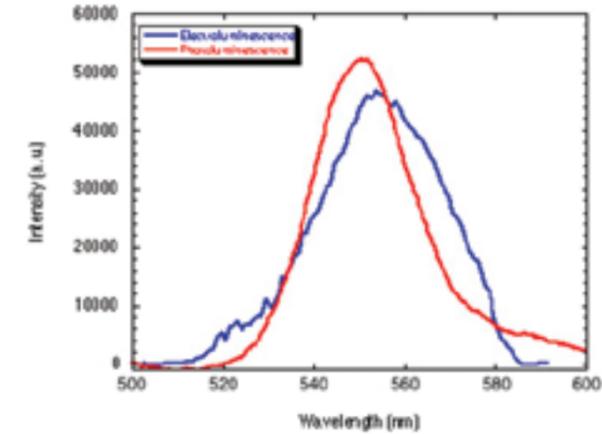


Fig. 2: Electroluminescence spectrum (blue) of a PST-LET biased at $V_{ds} = V_g = -60$ V and photoluminescence spectrum (red) of the same film.

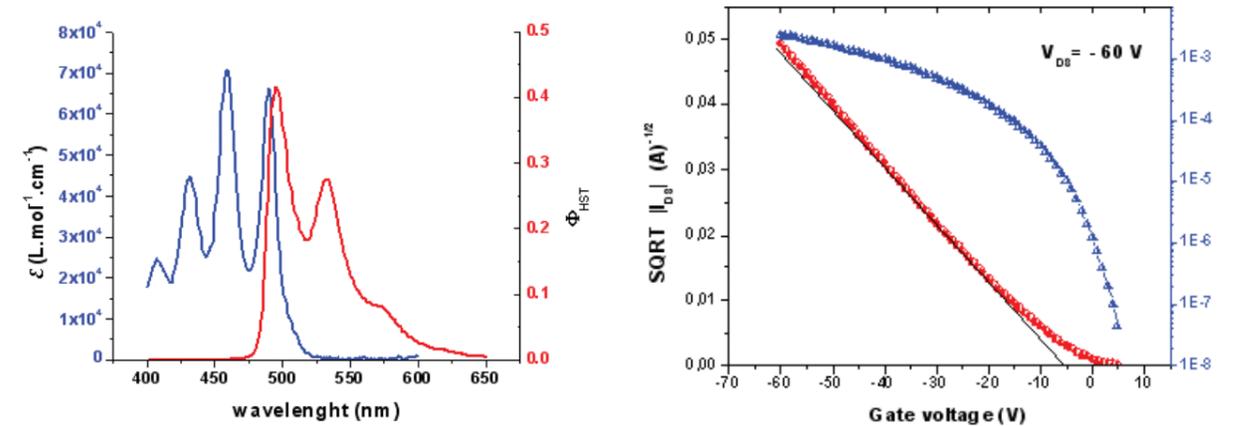


Fig. 3: The extinction coefficient and normalized fluorescence spectrum versus wavelength of PST molecule dissolved in 98% dichlorobenzene.

Fig. 4: Transfer characteristics of a PST-FET (deposition rate = 0.2 Å/s, nominal thickness = 18 nm, $W/L=18800/40$ μm/μm).

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Net- Working Beyond Science

Exploring the German Museum in Munich: Discoveries and Discussions

Visiting the “Deutsches Museum” in Munich was one of the events which linked science with leisure time. Despite the tight scientific schedule of the JNN program in Munich, the participants enjoyed the occasion to spend an afternoon discovering the famous German Museum with its masterpieces of science and technology. As a special honor, Prof. Wolfgang Heckl, General Director of the museum and member of CeNS, invited the participants of the JNN exchange to a guided tour through selected parts of the exposition, giving many interesting information about the shown exhibits.

Open Research Lab and Exposition on Nanotechnology

Especially the part of the museum dealing with nano-sciences and nanotechnology was in the focus of the guided tour. Currently, these topics are treated in the “Gläsernes Labor”, the open research laboratory, and at the special exhibition about nanotechnological applications in commercial products.

Researcher Paul Hix explained in detail how the open research lab informs the visitors of the museum about what is nanoscience and about how nano-research is done by performing real experiments “live” under the eyes of the visitors.

Welcome Reception

The event continued with a welcome reception in the museum which offered the possibility for informal discussions with Prof. Wolfgang Heckl, General Director of the Deutsches Museum, Axel Honsdorf, Director of the Cooperation Center of Bavarian and French Universities (Bayerisch-Französisches Hochschulzentrum, BFHZ), Dr. Florence Gauzy-Krieger from the Bavarian Research Alliance, Dr. Peter Freier from the Representation of Québec in Bavaria and Dr. Jean-Luc Steffan, French Attaché for scientific cooperation in Bavaria.

Prof. Hermann Gaub, the German organizer of the JNN program, thanked Mr. Honsdorf for the financial support from the BFHZ and Dr. Gauzy-Krieger and Dr. Freier for their continuous support and interest in the program.



JNN participants in front of the main entrance of the German Museum in Munich.



The “Gläsernes Labor” of the German Museum: The visitors of the museum are invited to look over the shoulders of nano-researchers who run their experiments within the museum.



Prof. Hermann Gaub (left), JNN Project Leader on the German side, discusses with Dr. Peter Freier (right) from the Representation of Québec in Bavaria.



Prof. Wolfgang Heckl (left), General Director of the German Museum, chats with a JNN participant from Montréal.



Axel Honsdorf (right), Director of the Cooperation Center of Bavarian and French Universities (BFHZ), discusses with JNN participants from Munich and Montréal.

Getting to Know People and Culture



Whitewater rafting near Montréal

The JNN 2008 exchange did not only involve experiments, lab courses and conference talks. The Quebecois and Bavarian junior scientists organized several spare time activities and excursions in both cities of Munich and Montréal and their surroundings – besides the scientific exchange JNN also became a cultural exchange. The fact that every student hosted another one made it a lot easier to get a deeper insight in people and culture far off the common tourist paths.

Activities



Bike ride at Tegernsee

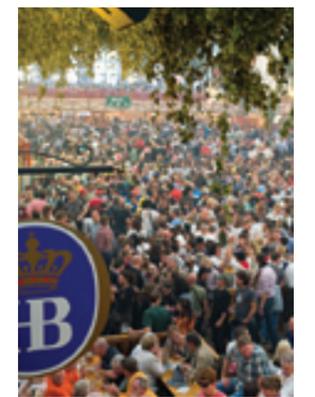
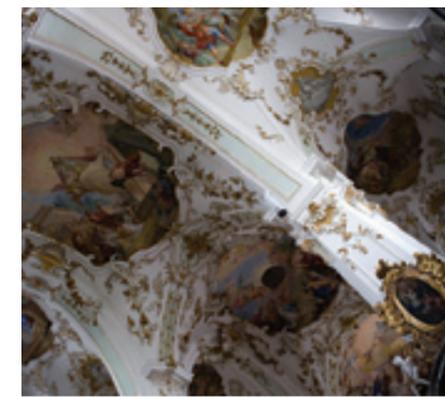
The activities in Montréal included a long bike tour around the old town and the harbour front, an afternoon at the cottage of Prof. Peter Grütter, JNN project leader on the Canadian side, a wild-water rafting experience on the Red River and a visit of the world-famous Montréal Jazz festival. The Bavarian counterpart program featured a bike ride at the foothills of the Alps starting at the Tegernsee and ending at Prof. Hermann Gaub's cottage, a guided tour of the Deutsche Museum by Prof. Wolfgang Heckl and the obligatory visit of the Oktoberfest, just to mention a few.

European Culture



Venice, Piazza San Marco.

Insights into the European culture were not limited to Bavaria but extended to Venice, where the 2008 CeNS workshop was organized. One week of high-class conference talks on San Servolo island south of the Piazza San Marco were accompanied by sight-seeing in one of the most beautiful towns of Europe. Traditional Bavarian customs were thus escorted by the Mediterranean style of living.



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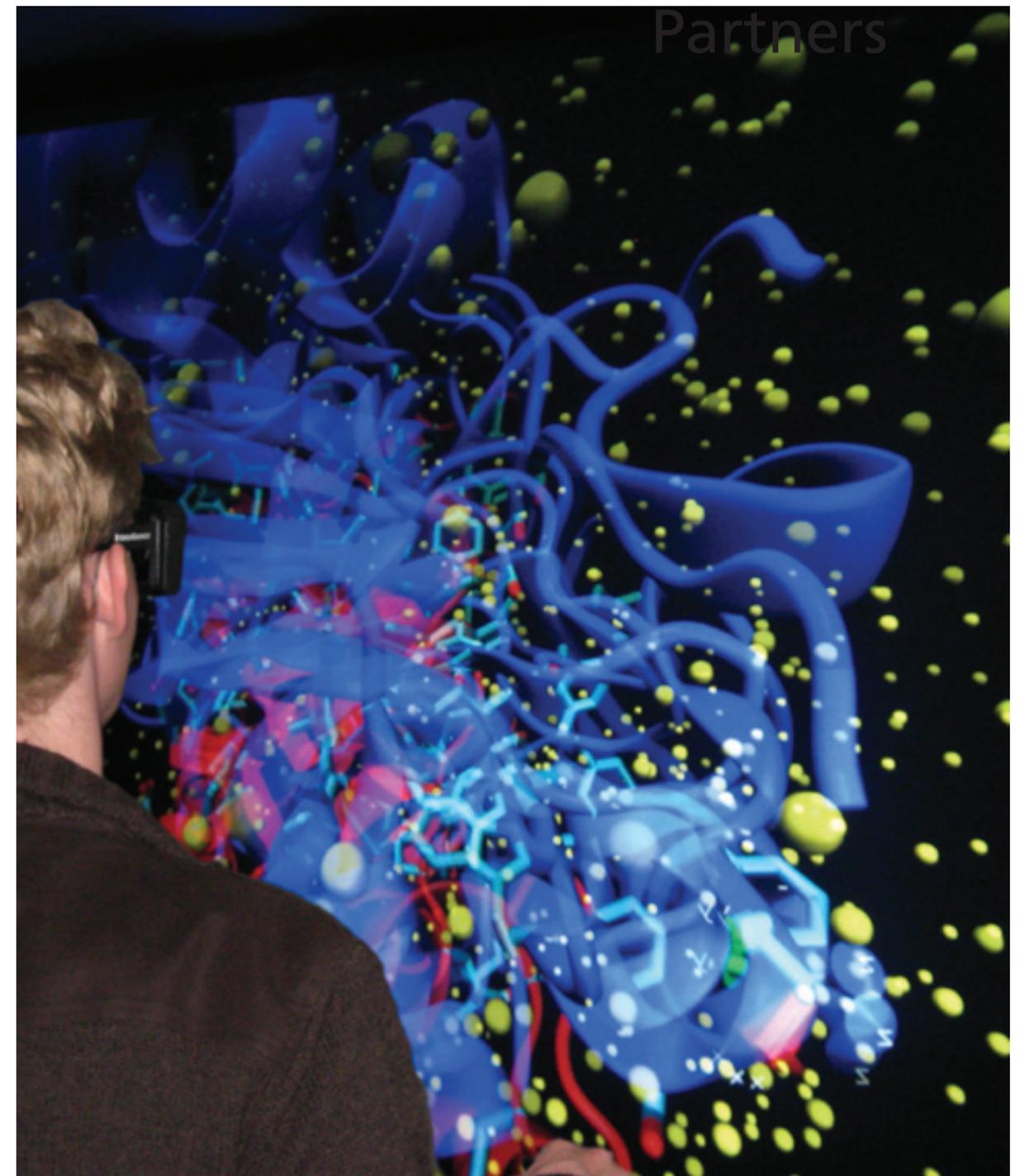
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