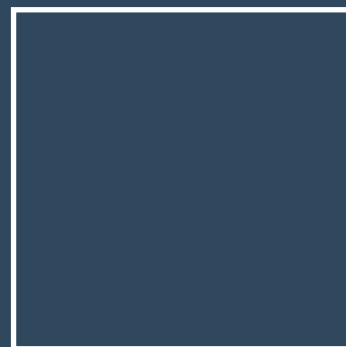
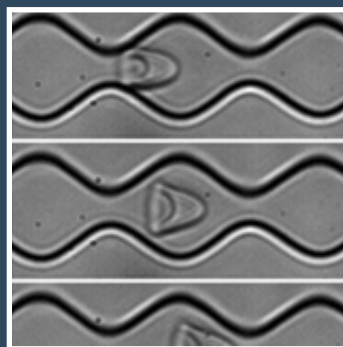
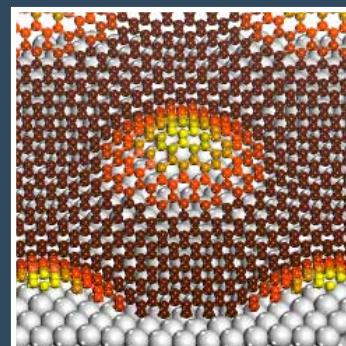
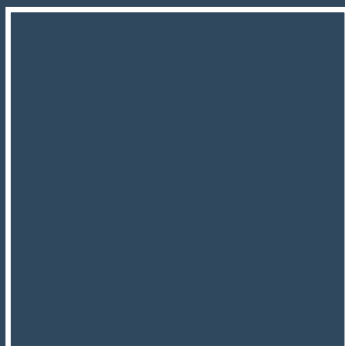
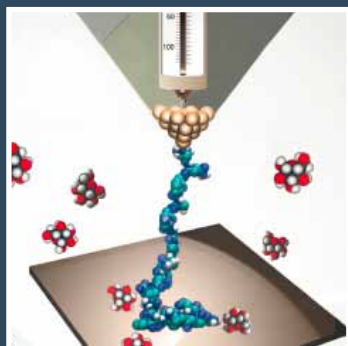


ANNUAL REPORT 2010



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WELCOME

A living network is far more than the sum of its parts – we invite you to see this for yourself when browsing through this account of the activities of the Center of NanoScience in Munich. Nanoscience by its nature is an interdisciplinary endeavor – and one of the key missions of CeNS is to foster collaboration across disciplines.

The researchers in CeNS continue to explore exciting research areas in nanoscience – this is visible each year when the CeNS board has the pleasant task to select the publications for the CeNS publication award. This task is getting more difficult every year due to the excellent scientific output of CeNS. The scientific work of CeNS-members is being recognized by numerous awards. To give just one example, in the past year CeNS researchers were awarded eight of the prestigious ERC Grants in Life Sciences and Physical Sciences. We also thank the CeNS spin-off attocube systems and their partner Wittenstein AG for sponsoring the attocube-Wittenstein award for outstanding scientific theses. As you will see in the report, CeNS members are also very successful in securing positions at other academic institutions – we congratulate them and wish them well in their new adventures. We also welcome the new members of CeNS – and look forward to new opportunities for collaboration!

After more than ten years of flourishing nanoscience in the Munich area, growing attention is directed at the impact of the scientific work on society, such as health care or energy conversion. This was particularly visible in the past year when we joined forces to prepare initiatives and proposals for several Collaborative Research Programs (SFBs) and Research Clusters in the Munich Area.

It can be immensely satisfying when scientific discoveries are transformed into applications. In this spirit, CeNS members continue to explore opportunities to translate their discoveries into successful spin-off companies. For example, see the interview on the spin-off NanoTemper in this report.

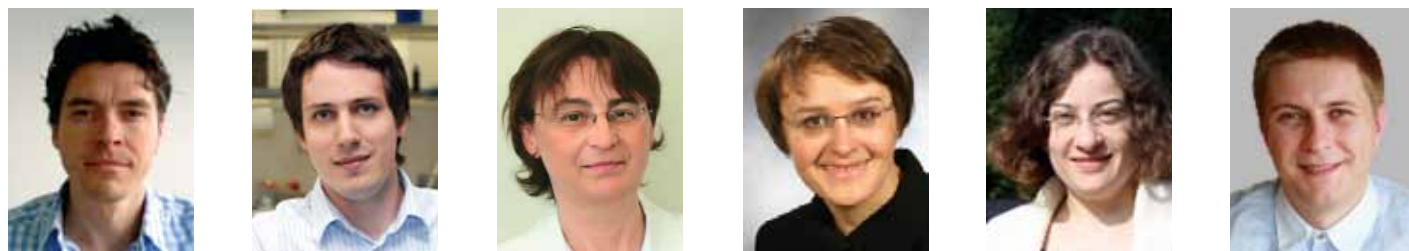
One of the annual highlights for the CeNS community is the international workshop in Venice on the island of San Servolo. Renowned scientists from all over the world join CeNS researchers and graduate students to exchange their newest results and forge collaborations. It is always special to ponder exciting new ideas while taking in the renaissance atmosphere of this wonderful city.

We just heard that Marie-Christine Blüm will leave her position as manager of CeNS for a very attractive position at the University of Zurich. We thank her for doing a truly outstanding job in the management of CeNS during the past years, and we wish her well for her new endeavors. We also thank the whole CeNS management team for their excellent work.

I wish you pleasant reading during your journey through the activities of the Center for NanoScience.

Prof. Thomas Bein
Member of the Scientific Board of CeNS

NEW MEMBERS



New CeNS members (from left to right: Hendrik Dietz, Stefan Duhr, Ulrike Gaul, Dina Fattakhova-Rohlfing, Madeleine Leisner, Andrey Lutich).

PROF. HENDRIK DIETZ

TU Munich

Hendrik Dietz studied physics at the University of Paderborn, Universidad de Zaragoza (Spain), and LMU Munich, from where he graduated with a physics diploma in 2004. In 2007 he then was awarded a doctoral degree from the Physics Department of the Technische Universität Munich for his work on the development and application of novel single-molecule methods for the mechanical and structural analysis of protein molecules. Hendrik Dietz then turned from proteins to DNA and joined a team of nanotechnology enthusiasts at the Dana-Farber Cancer Institute at Harvard Medical School in Boston in order to conduct postdoctoral research on molecular self-assembly with DNA. In June 2009, Dietz returned to the Physics Department at the Technische Universität München as an assistant professor for biological physics.

DR. STEFAN DUHR

NanoTemper Technologies

Stefan Duhr studied biochemistry at the University Witten/Herdecke, Germany with a specialization on Physical Biochemistry and Molecular Biology. After receiving the Diploma Degree in 2004 he began his PhD studies at the Physics Department of the Ludwig-Maximilians-University Munich. In the Systems Biophysics group of Prof. Braun, he worked on the basic principles of thermophoresis. He finished his PhD work in June 2007 with summa cum laude. The results were the basis for patent applications that cover biomolecule analytics using thermophoresis induced by infrared laser heating. After 2007, Stefan Duhr and colleagues further evaluated possible applications of thermophoresis and finally founded the LMU spin-off company NanoTemper Technologies GmbH in

May 2008. The company was awarded prizes in the Munich Business Plan Competition and the nationwide CyberOne Award and was one of three finalists in the European Fast Start Award in 2009. Today, the company develops, produces and sells instruments based on the proprietary Microscale Thermophoresis (MST) technology. Stefan Duhr is CEO of NanoTemper Technologies.

PROF. ULRIKE GAUL

LMU Munich

Ulrike Gaul studied biochemistry and physics at the University of Tübingen and earned a PhD in biology for her research on the genetics of developmental pattern formation in the lab of Herbert Jäckle at Max-Planck-Institute for Developmental Biology. Following postdoctoral work with Garrett Odell at the University of Washington, Seattle, and in the lab of Gerald Rubin at the University of California, Berkeley, she joined the faculty of the Rockefeller University, New York, as assistant professor and head of laboratory in 1993, becoming associate professor in 2000. In 2009, Gaul returned to Germany as the recipient of one of the newly established Alexander von Humboldt Professorships and a CIPSM Professorship. She holds the chair in organismic biochemistry at the Gene Center and the Department of Biochemistry of the LMU, and is a visiting scholar at the HHMI Janelia Farm Research Campus near Washington.

Ulrike Gaul's research is aimed at achieving a systems-level understanding of biological processes, with particular focus on the regulatory networks that control the complex spatio-temporal patterns of gene expression during animal development. Collaborating with physicists and computational biologists, her lab seeks to devel-

op novel methods for tracking regulatory events, such as the binding of transcription factors to DNA, at high molecular resolution, and to devise computational approaches to model regulatory networks in a mechanistically realistic fashion.

DR. FATTAKHOVA-ROHLFING

LMU Munich

Dina Fattakhova-Rohlfing obtained her education in chemistry (diploma and PhD) in Kazan, Russian Federation, and worked afterwards as a research scientist in academic institutes in Kazan, Prague, Bordeaux and Hannover. Since 2006 she works as a lecturer for the international master program Advanced Materials Science (AMS) in the group of Prof. Thomas Bein, where she also works on her habilitation. Starting from her studies, Dina Fattakhova-Rohlfing works in an interdisciplinary field combining electrochemistry and materials chemistry. Her diploma and PhD thesis were devoted to the investigation of mechanisms of electrochemical reactions of organic compounds and further reactions of electrogenerated intermediates. Later she worked on synthesis of electrode materials for the lithium batteries and the investigation of their electrochemical behavior aiming at understanding the relationship between the structure and morphology of the materials and their electrochemical properties. Her present research is devoted to the development of functional nanostructured materials for electrochemical and photoelectrochemical applications. One of the particular systems she works on are transparent conducting oxides with the periodic porous architecture which can act as conducting transparent platforms for immobilization of redox-active guests ranging from biomolecules to inorganic films.



Christian Ochsenfeld, Nadia Ruthardt, Claudia Veigel.

DR. MADELEINE LEISNER

LMU Munich

Madeleine Leisner studied biology at the University of Regensburg and obtained her PhD in physics in 2008 at the LMU. Her doctoral thesis in the group of Prof. Maier at the chair of Prof. Rädler comprised the establishment of single-cell time-lapse fluorescent microscopy for quantitative analysis of basal gene expression. As a postdoc at Harvard in the group of Prof. Benenson she designed a biomolecular computer with up to three transcription factor inputs, in which microRNAs served as mediators between the input and the output (fluorescent reporter) to ensure proper signal transduction. Since July 2010 Madeleine Leisner leads her own group at the chair of Prof. Frey. Her research focuses on the dynamics of complex bacterial interactions, for example leading to pattern formation.

DR. ANDREY LUTICH

LMU Munich

Andrey Lutich was graduated with honors in physics from the Belarusian State University in Minsk in 2004. Pursuing a PhD, he then joined the group of Prof. Gaponenko in the Institute of Physics of National Academy of Sciences of Belarus where he was investigating optical properties of 2D nanostructures based on porous anodic alumina. During his time as a PhD student, Andrey Lutich was a visiting INTAS fellow at TU Dresden working with Prof. A. Eychmüller and visiting STEP scientist at Elletra (Trieste Synchrotron) in the group of Dr. M. Danailov. In 2008, he completed his PhD and joined the group of Prof. Feldmann as a PostDoc. Being awarded an Alexander von Humboldt Fellowship in 2009, Andrey Lutich continued his research in the area of hybrid organic/inorganic composite nanostructures. In

2010, he has become a team leader of the Bioplasmonics group at the chair of Prof. Feldmann developing the techniques of optical and thermal manipulation of metal nanostructures for biological applications.

PROF. CHRISTIAN OCHSENFELD

LMU Munich

Christian Ochsenfeld studied chemistry at the University of Karlsruhe and obtained his PhD in 1994 in the Theoretical Chemistry group of Professor Reinhart Ahlrichs. After three years of postdoctoral research at UC Berkeley in the US, he continued in 1998 his research activities at the University of Mainz supported by a Liebig fellowship and later by an Emmy Noether research grant. In 2001, Christian Ochsenfeld received two offers for professor positions for Theoretical Chemistry at the Universities of Essen and Tuebingen, and was professor for Theoretical Chemistry at the University of Tuebingen from 2002 to 2010. In 2009, he obtained five offers for professorship positions from the Universities of Berlin (FU Berlin), Konstanz, Munich (LMU), Uppsala, and Vienna. Since February 2010, Christian Ochsenfeld holds the chair for Theoretical Chemistry at the LMU Munich. His research focuses on the development and application of quantum-chemical methods for calculating large molecular systems with thousand and more atoms. Such calculations became possible by reducing the scaling of the computational effort with molecular size to linear. Examples for applications of these new methods include the calculation of molecular properties in general (e.g., NMR shieldings), intermolecular interactions and molecular recognition processes, RNA catalysis, or cell-virus interactions.

DR. NADIA RUTHARDT

LMU Munich

Nadia Ruthardt studied biology at the Julius-Maximilians-Universität Würzburg and Yale University, USA. She received her diploma in 2001 with a thesis on neuronal growth cone guidance in *Aplysia californica*. In 2005 she was awarded a doctoral degree from the Institute of Molecular Biotechnology at the RWTH Aachen for her work on endocytosis in plant cells. After her PhD, she returned to mammalian cell systems and joined the group of Prof. Christoph Bräuchle at LMU München as a PostDoc to study the entry of polymeric nanoparticles for gene delivery into cells. Since 2008, Nadia Ruthardt is working on her habilitation in Prof. Bräuchle's group and is investigating the entry of viruses and nanoparticles for gene and drug delivery into cells by highly sensitive fluorescence microscopy on single particle level in living cells.

PROF. CLAUDIA VEIGEL

LMU Munich

Following a MD/PhD in Biochemistry at the Universities of Tübingen and Heidelberg, Claudia Veigel's research has been focused on biophysical studies of cellular motility, phenomena that range from cell division, cell movement and intracellular transport processes, to signal transduction in mammalian hearing.

During a postdoc at the University of York UK, she applied and developed single molecule technologies including optical tweezers to study chemo-mechanical energy transduction in motor proteins at the single molecule level. She was awarded a Royal Society University Research Fellowship in the UK to set up her own group and joined the MRC National Institute of Medical Research in London as a group leader. In 2010, she became Chair at the Department of Cellular Physiology at the LMU Munich. Her group applies a variety of single molecule techniques, including optical tweezers, single molecule fluorescence and atomic force microscopy, to characterise the basic mechanisms of motor proteins and other components of the cytoskeleton in in-vitro systems and in cells. A major part of this work is technological development to adapt these technologies for various specific applications.

NANOTEMPER TECHNOLOGIES: SOME LIKE IT HOT

After the burst of the dot-com bubble and the following crash of the New Economy in 2001-2002, fewer scientists of CeNS took the risk of founding companies based on their research. Fortunately, this period ended in 2007 when young scientists from CeNS started again the adventurous road of taking their results from basic research to application. One of the spin-off companies of this second generation is NanoTemper Technologies which was founded in 2008 by Philipp Baaske and Stefan Duhr who were at that time PhD students at CeNS. In 2009, the NanoTemper team ranked 2nd in the Munich Business Plan Competition and was awarded the CyberOne Award. In 2010, NanoTemper is already selling its products worldwide.

How was the company NanoTemper Technologies founded and what was your personal motivation to become an entrepreneur?

Actually, we combined the results of our PhD projects that we were working on in the group of Dieter Braun, namely the analysis of the properties of nucleic acids and the work on thermophoresis. By doing so we were quite surprised by the sensitivity of the approach and the application range that is achievable with the method we now call "Microscale Thermophoresis". We then applied for several patents to cover the technology, applications and instruments and attended business plan competitions. In the very beginning the driving force was mainly determined by our interest in the entrepreneurial field that is not so well known to students in basic research. The feedback from competitions as well as further successful exploration of possible applications fostered our interest to become entrepreneurs and led to the foundation of the company in May 2008.

Which role did CeNS play in the foundation of NanoTemper?

From early on, the Center for NanoScience has been very helpful, before and after founding the company. Having access to a network of scientists from the life sciences is very important for a

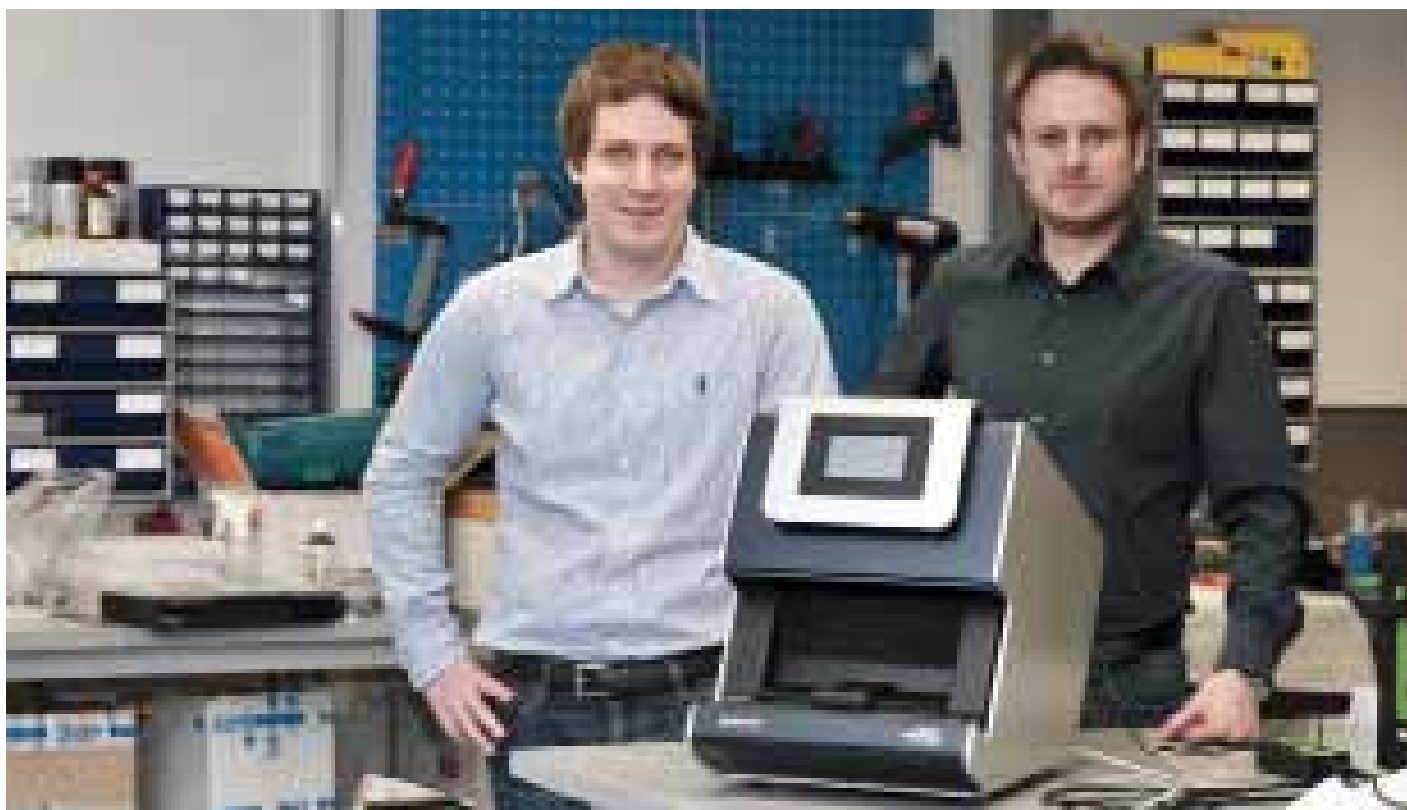
spin-off company founded in the physics department that is aiming at providing solutions for biological research and pharmaceutical industry. The CeNS also supported NanoTemper in the early stages to visit the most important trade fairs in the field. Last but not least the CeNS is a renowned institution worldwide and as a widely unknown company we profited from this.

Did the success of other CeNS spin-off companies such as Advantix, Attocube, Ibidi and Nanion have an impact on your decision to found a company?

Of course they are beacons in the field of successful spin-off companies. It has proved very helpful for us to establish tight relationships to these "CeNS-companies". They are great examples for the creation of successful spin-off firms and are in most cases some years ahead of NanoTemper. To discuss ideas and experiences with the founders of these companies was very helpful in the past.

What products does Nanotemper sell?

NanoTemper sells its first instrument based on Microscale Thermophoresis which we called the Monolith NT.115. This instrument is suited to measure a wide variety of interactions ranging from protein binding to low molecular weight compounds, protein-nu-



NanoTemper founders Dr. Stefan Duhr and Dr. Philipp Baaske with the Monolith NT.115.

cleic acids interactions to interactions of various complexes like ribosomes and receptor-containing liposomes. In addition to the instrument, NanoTemper sells kits for sample preparation and consumables needed for the instrument.

Who are your main customers and which countries do you export your products to?

Two thirds of our customers are basic research facilities. In addition to these customers, we have customers in pharmaceutical industry and biotechnology. Today, NanoTemper has customers in Europe, US and Japan. In the US and Europe NanoTemper distributes the instrument directly, while in Japan a distributor is involved.

How did you acquire the entrepreneurial knowledge necessary to found and run a company?

Learning by doing and discussing topics with experienced entrepreneurs.

How did you find investors?

This was a very important step, since we intended to build a sophisticated scientific instrument. We needed an investor who agreed to finance the development of the instrument and who at the same time had the patience needed for such an undertaking. It took us quite some time to find a person with these characteristics. Or better to say - he found us.

How many employees do you have at present?

The company employs 6 full time employees. People from very different fields work for NanoTemper, ranging from technical assistants, software engineers, physicists, biochemists to biologists.

Do you enjoy being an entrepreneur? Does it meet the expectations you had when you decided to found the company?

Starting a company is a lot of fun and a lot of work. However, you get in touch with very different fields and this makes it an exciting experience.

What are the next steps NanoTemper will have to take? What are your major goals for the future?

The next big step for NanoTemper is to further expand the international distribution of our products. A next major goal is to develop the prototypes of other instruments towards marketability.

Do you have an advice for researchers who think about founding their own company?

In any case, it is worth a try.

Answers by P. Baaske and S. Duhr.

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Website: www.nanotemper.de



MEMBERS' NEWS



Matthias Christandl was appointed assistant professor at the Eidgenössische Technische Hochschule Zürich (ETHZ).

Thorben Cordes declined a call for a tenure-track assistant professorship in Biophysics from Wageningen University.



Kay Gottschalk accepted a call to the University of Ulm as professor for Bionomechanics at the Institute for Experimental Physics.

Thomas Klar accepted a call to the University of Linz as Head of the Institute of Applied Physics and declined a call from the University of Leipzig for a full professorship (W3).



Roland Netz received calls from the University of Potsdam and from the Freie Universität (FU) Berlin.

Robert Stark accepted a call (W3 professorship) from the Technical University of Darmstadt.

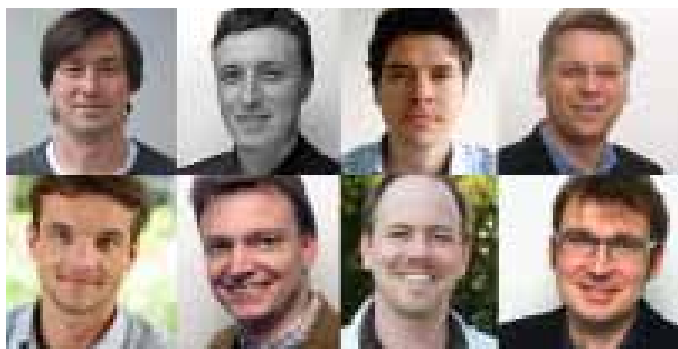


Philip Tinnfeld accepted a call as full professor (W3) of Biophysical Chemistry at the Technical University of Braunschweig.

AWARDS 2010

ERC GRANTS 2010

The year 2010 was an extremely successful year for researchers of CeNS. In the European-wide call for applications, members of CeNS could secure a total of 8 renowned grants in the fields of Life Sciences and Physical Sciences which were awarded by the European Research Council (ERC) in a highly competitive evaluation. Furthermore, two former PhD students of CeNS were awarded a grant by the Council. The ERC is a European funding scheme which supports novel research ideas of individual scientists on different career levels by awarding "Starting Independent Researcher Grants" (Starting Grants) and "Advanced Investigator Grants" (Advanced Grants). The goal is to stimulate scientific excellence by providing funding for innovative research projects that explore the frontiers of knowledge and look for risky, but highly promising ideas. The scientists are especially encouraged to go beyond the boundaries of disciplines in their projects.



CeNS Members who received an ERC grant in 2010.
Upper row (l-r): Dieter Braun, Patrick Cramer, Hendrik Dietz, Jochen Feldmann; Lower row: Rainer Hillenbrand, Thomas Klar, Philip Tinnefeld, and Dirk Trauner.

WINNERS OF ADVANCED GRANT

The following CeNS members received an Advanced Grant in 2010: Prof. Patrick Cramer (LMU Munich) for his project "Mechanism of Regulated Transcription Initiation", Prof. Jochen Feldmann (LMU Munich) for "Hybrid Nanosystems in phospholipid membranes" and Prof. Dirk Trauner (LMU Munich) with his research proposal entitled "Chemical Approaches to Restoring Vision".

WINNERS OF STARTING GRANTS

The following CeNS members received a Starting Grant in 2010: Prof. Dieter Braun (LMU Munich) for his project on "Autonomous DNA Evolution in a Molecule Trap", Prof. Hendrik Dietz (TU Munich) who investigates "Single-molecule studies of protein-protein and protein-DNA interactions, enabled by DNA origami", Prof. Rainer Hillenbrand (now at CIC nanoGUNE, Spain) for his project on "Near-field Spectroscopic Nanotomography at Infrared and Terahertz Frequencies", Prof. Thomas Klar (now at Linz University, Austria) for "Active and low loss nano photonics (ActiveNP)", and Prof. Philip Tinnefeld (now at TU Braunschweig) for his research proposal on "Single-Molecule BioAssays at Elevated Concentrations".

European Research Council



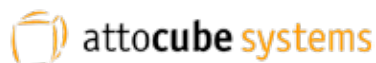
SUCCESSFUL ALUMNI

In addition, two CeNS Alumni who did their PhD at CeNS won a starting grant in 2010: Dr. Richard Neher (now at the MPI for Developmental Biology, Tübingen) for his research proposal on "Intra-patient Evolution of HIV" and Prof. Carsten Sönnichsen (now at the University of Mainz) for "Single metal nanoparticles as molecular sensors".

More information: <http://erc.europa.eu/>

ATTOCUBE-WITTENSTEIN AWARD

In 2010, the CeNS spin-off company attocube systems AG and its partner WITTENSTEIN AG honored outstanding scientists with the attocube-WITTENSTEIN award, which was established in 2009. The happy winners were announced at the CeNS summer party on July 16th subsequent to the annual event "CeNS meets Industry". With this prize, PhD theses and Diploma theses showing outstanding scientific accomplishments and innovative ideas with potential impact on industrial applications were recognized. Dr. Jan Vogelsang and Dr. Franz Weinert were the successful winners in the category "PhD thesis", sharing the prize money of 5'000 EUR. Their supervising laboratories, i.e. the groups of Prof. Philip Tinnefeld and Prof. Dieter Braun, received 5'000 EUR each for their contribution to the successful theses. In the category "Diploma thesis", Thomas Faust from the lab of Dr. Eva Weig was honored and took home a check of 2'500 EUR. The winners were chosen by a jury composed of professors of CeNS and a representative from attocube systems.



Winners of the attocube-WITTENSTEIN Award 2010 (left to right): Jan Vogelsang, Franz Weinert, and Thomas Faust.

PUBLICATION AWARD

Each year, CeNS awards prizes for excellent publications of CeNS members that have been published during the past twelve months. With this award, successful cooperation projects within CeNS as well as outstanding research of individual research groups of CeNS are distinguished. From the numerous submitted articles which appeared in high-impact journals between October 2009 and October 2010, the CeNS board had a hard time to select the 17 winning publications.

Amongst these were successful CeNS-internal collaboration projects such as those between the groups of Joachim Rädler and Achim Wixforth, Erwin Frey and Andreas Bausch, Christina Scheu and Lukas Schmidt-Mende, Thomas Bein and Christoph Bräuchle, Peter Hänggi, Alex Holleitner and Jörg Kotthaus, Hermann Gaub and Philip Tinnefeld, Thomas Carell and Thomas Bein, Robert Stark and Albert Zink. In addition, outstanding articles from individual research groups which were published in renowned journals such as Nature, PNAS, Nature Structural & Molecular Biology and Physical Review Letters were recognized. The announcement of the winners took place at the IDK-NBT/CeNS Come-Together-Event in mid-November.



Two junior researchers who received a publication award for their cooperation project celebrated their success: Martin Hennig and Jürgen Neumann.

>>> **Thomas Carell** was awarded the **Cross of the Order of Merit** of the Federal Republic of Germany (Bundesverdienstkreuz). >>> **Hen-drik Dietz** is the recipient of the **Arnold-Sommerfeld-Award** of the Bavarian Academy of Sciences. >>> **Ralf Metzler** received the **Finland Distinguished Professorship** of the Academy of Finland >>> **Jens Michaelis** won the **Nernst-Haber-Bodenstein-Award** of the German Bunsen Society. >>> **Roland Netz** was rewarded the **Gay-Lussac-Humboldt-Award** of the German-French Science Ministries. >>> The Centre for Theory in Natural Science (CTN) of the Aarhus University, Denmark bestowed the **Lindhard Lecture Prize** to **Peter Hänggi**. >> **Jörg P. Kotthaus** was honoured by being elected a **member of the Acatech**. >>> **Dirk Trauner** was appointed **Givaudan/Karrer Distinguished Visiting Professor** in Organic Chemistry (University of Zurich, Switzerland) and was awarded with the **Andy Derome Lecture** (University of Oxford, United Kingdom). He joined the **Japanese Society for the Promotion of Science** as an elected fellow.

EVENTS & ACTIVITIES

CENS WORKSHOP VENICE 2010

Following the invitation of CeNS, internationally renowned scientists and graduate students of CeNS convened on the sunny island of San Servolo from September 20th to 24th for one week of intensive exchange on nanosciences.

In their stimulating talks, 25 top-notch researchers from all over the world gave an overview on current research topics on nanometer-scale science and presented their latest research highlights to the graduate students, post-doctoral researchers and professors of CeNS. During this workshop, lively discussions between young researchers and experienced scientists from the fields of physics, chemistry and biology took place inside the lecture hall, but also during the breaks on the green yards of San Servolo and while walking along the canals of Venice. In addition to the talks, PhD students and junior researchers presented their scientific results to their colleagues and to the guest speakers at two lively poster sessions which took place in the evenings.

After returning from the conference, the participants heard with surprise and pride the news that one of the speakers, Prof. Kostya Novoselov, had just received the Nobel Prize 2010 in the field of physics! Obviously, the members of the program committee did a good job with their selection of speakers for the conference...

www.cens.de/calendar/past-workshops-events/venice-2010/

FOCUS WORKSHOPS

In addition to organizing workshops and conferences covering all fields of nanosciences, CeNS also supports specific workshops focusing on a subset of nano-related subjects which are initiated and planned by its members.

As such, CeNS supported the international conference organized by the Nanosystems Initiative Munich (NIM) entitled "NaNax4 - NanoScience with Nanocrystals" which took place from April 11th to 15th, 2010 in Tutzing at lake Starnberg. Furthermore, the 22nd German Conference on Zeolites (Prof. Thomas Bein, March 3rd to 5th), the workshop "Chemistry meets Biology" (Prof. Jens Michaelis, August 15th and 16th), and the NIM area workshop "Microfluidics and Enabling Techniques (Priv.-Doz. Dr. Stefan Thalhammer and Dr. Thomas Franke, March 4th) were partly funded by CeNS.

In addition, financial aid was provided for the conference on "Nano-Opto-Electro-Mechanical Systems Approaching the Quantum Regime", held from September 6th to 10th in Trieste (Italy) which was organized by the CeNS members Dr. Eva Weig and Prof. Jan von Delft, as well as for the PhD symposium <interact> which was co-organized by graduate students of CeNS (March 23rd, LMU Munich).

www.cens.de/calendar/past-workshops-events/





PUBLIC EXHIBITION - ART MEETS NANO

At the public exhibition called „Kunst⁹ - nano ...mal anders“, nanoscientists from CeNS and NIM presented an insight into their world of nanoscience with the help of photographs, pictures of simulations and experimental images. The twelve displays were shown to the Munich public from mid-January to mid-February at the entrance of the subway station of LMU Munich. The exhibition was opened on January 14th by CeNS Board Member Prof. Ulrich Schollwöck who welcomed the public and gave a short introduction into the world of nanoscience and the relation between art and natural sciences. At this event, the researchers-artists of the images explained to the interested public what was shown on the displays and answered questions related to nanosciences in general. A further highlight was undoubtedly the music of the band „UnCeNSiert“ who entertained the visitors of the vernissage with their diverse repertoire.

www.cens.de/calendar/past-workshops-events/kunst/

CeNS MEETS INDUSTRY

Once a year, CeNS invites representatives from industry to present their companies and employment opportunities to the CeNS community. At the meeting in 2010, four former PhD students of CeNS presented their career paths in industry and two representatives from international companies introduced their R&D activities and gave an insight into current and potential research cooperation with CeNS groups.

In the first session, the following alumni gave lively talks about their career: Dr. Christine Meyer (Solland Solar Cells, “Improving solar cells”), Dr. Marc Hennemeyer (SÜSS MicroTec Lithography, “Hitchhiker’s guide through the semiconductor industry”), Dr. Johanna Kirstein (Wacker Chemie, “Quality assurance in the polysilicon production”) and Dr. Stefan Beyer (Infineon Technologies, “Technology Development @ Infineon Regensburg - Innovative Top-Down Nanotechnology”). The speakers of the second session were Dr. Gerhard Wagenblast (BASF, “My view to BASF SE”) and Dr. Matthias Linde (BMW Group, “Nothing gets lost - Thermal management as a component of the BMW EfficientDynamics Strategy”).

The event was followed by the traditional summer party where all participants took the opportunity to discuss with the speakers and with other members and alumni of CeNS. This year’s event was supported by the “Kontaktstelle für Forschungs- und Technologietransfer (KFT)” of the LMU and - as usually - animated by the band “UnCeNSiert”.

www.cens.de/calendar/past-workshops-events/cens-meets-industry-2010/

COLLOQUIUM

During the semester, the CeNS team organizes a weekly colloquium where speakers from various research areas are invited to give a talk on a topic related to nanoscience. Preceded by discussions with coffee and cookies, the colloquium takes place every Friday from 3:30 to 4:30 p.m. either on the LMU main campus or at the Chemistry Department in Großhadern.
www.cens.de/calendar/cens-colloquium

MUNICH SCIENCE DAYS

Together with NIM, CeNS organized a booth at this year’s Munich Science Days which were held under the motto “Energy - Basis for life and driving force for the future” and took place at LMU Munich. On October 23rd and 24th, about 20 mostly junior scientists from CeNS and NIM took turns in explaining to the interested public their research activities related to energy subjects. As such, they reported on the different approaches for the development of nanostructured solar cells and informed on fuel cells, novel methods for hydrogen generation and the production of alternative fuels from CO₂ and sun light.

The scientists who work in the groups of Prof. Bein, Dr. Da Como and Dr. Jäckel (both at the Chair of Prof. Feldmann), Prof. Krischer and Prof. Schmidt-Mende shared their time at the booth which was open on both days from 10 am to 6 pm. The public could follow small experiments, watch short movies and have a look at exhibits and the posters which the researchers prepared for this day. As a special motivation for the public to study the posters and ask questions to the presenters, a nano quiz was organized by CeNS program manager Marilena Pinto which attracted many visitors of all ages.

www.muenchner-wissenschaftstage.de/2010/



PHD STUDENTS' CORNER

JUNIOR NANOTECH NETWORK

In 2010, PhD students from CeNS teamed up with their peers at the Center for the Physics of Living Cells (University of Illinois) for a third round of the Junior Nanotech Network (JNN). The JNN project benefits from local expertise and facilities and aims at initiating scientific and personal exchange between junior nanoresearchers at CeNS and partner institutions abroad. The program consisted of two periods of three weeks each (one in Urbana and one in Munich), combining hands-on laboratory and computational work with the participation in conferences. The students were actively involved in the organization of the program and had to conceive and supervise the short research projects. To guarantee social integration of the guests, the visiting researchers were housed at the homes of their local exchange partners.

www.cens.de/international/exchange-programs/jnn/



ENTREPRENEURSHIP WORKSHOPS

To stimulate the entrepreneurial spirit, CeNS offered its PhD students and PostDocs two three-day workshops organized by the Entrepreneurship Center of the LMU (March 3rd to 5th and October 13th to 15th). The seminars covered many relevant topics such as how to recognize business potential, how to write a business plan and how to get early financing for start-ups. One of the workshops, which combined theory and practical exercises, was addressed only to women - which was largely appreciated by the participants. In addition, successful entrepreneurs and specialists shared their knowledge and experience with the participants.

www.entrepreneurship-center.uni-muenchen.de

SCIENCE ROCKS!

Each Thursday at 5:45 p.m. during the semester, PhD students of CeNS gather for an informal seminar where one of them presents his/her research topic. Before and after the talks, the students have the chance to meet other PhD students, make new acquaintances from other groups and discuss about nano-sciences.

www.cens.de/calendar/science-rocks/

PATENTS: HOW TO PROTECT YOUR IDEAS

On March 11th, CeNS invited different speakers to a workshop which aimed at introducing the topics of intellectual property, patents and spin-off creation to its PhD and Diploma students. The program was opened by a stimulating talk of Dr. Khaled Karrai, co-founder of Attocube Systems and Honorary Professor at LMU Munich. Then followed instructive presentations of Sonja Huettich and Dr. Joachim Aigner from the LMU patent office and Guido Angenendt of the Bavarian Patent Alliance. After a lunch break which gave the possibility for more discussions between participants and speakers, CeNS Alumna Dr. Julia Schmitz shared her knowledge about patents with the audience which she acquired in her position at the Patent Attorneys Ter Meer. Continuing the workshop with another Alumnus of CeNS, Dr. Christian Kallinger, now at the European Patent Office, explained in detail the patent application process. The final talk was then given by CeNS Member Dr. Stefan Duhr who presented the story of the creation of his spin-off company NanoTemper Technologies in a very lively manner. The event was then closed by an optional hands-on workshop on how to search in patent data bases, given by Dr. Kallinger.

HOW TO DEAL WITH THE MEDIA

Nowadays, journalists take more and more interest in nanoscience and contact researchers at universities to get information for their articles and TV reports. To prepare PhD students for such contacts with the media, CeNS, in collaboration with NIM, organized a one-day workshop with a PR professional. The trainer, Prof. Perry Reisewitz (Compass Communications GmbH & Macromedia Hochschule für Medien und Kommunikation), gave an introduction into the working methods of journalists and explained how to cooperate with media representatives in a constructive way so that they understand the issue but do not misuse the provided information. He highlighted that the communication with the media has to be well prepared and well trained. Amongst other topics, the participants learned which different types of media formats exist and that scientists have to take great care in simplifying and adapting their research texts for the non-scientist without making misleading or wrong statements.

www.cens.de/calendar/past-workshops-events/



INTERNATIONAL DOCTORATE PROGRAM NANOBIOTECHNOLOGY



SCIENCE MEETS HUMANITIES

In September 2010, the first meeting of the IDK-NanoBioTechnology (NBT) and the IDK "Textualität in der Vormoderne" took place as a joint exploratory workshop of the PhD students (IDK = Internationales Doktorandenkolleg). To get to know each other, the students decided to tell each other about their research in a speed dating format, e.g. having two people discuss with each other during five minutes and then changing to another person, so that at the end of the afternoon each NBT-member had spoken to a member of the other IDK. Afterwards, the two IDKs gathered to learn more about the topics of "NanoBioTechnology" and "Textualität in der Vormoderne". A lively discussion about the risks of nanotechnology and about the relevance of humanities followed. The evening ended with animated conversations between the members, coordinators and spokesmen of the different IDKs and a lot of ideas for interesting topics for further joint projects.

In December 2010, both IDKs met again to organize a lecture evening with renowned speakers from both fields of natural sciences and literature. Fortunately, they could win the popular LMU professor Harald Lesch from Astrophysics (also famous TV presenter) and the well-known LMU professor Peter Strohschneider from German Medieval Studies (also former president of the German Council of Science and Humanities) to give talks on the subject of "Politics and Science". Prof. Lesch's talk was called „Wir irren uns empor“, while Prof. Strohschneider talked about „Politische Entscheidungen und wissenschaftliches Wissen in der Wissenschaftsgesellschaft“. Following the presentations, the audience asked questions and discussions started about the interconnectivity of science and politics. Both professors showed that interdisciplinary talks raise great interest as they attracted over 100 listeners to their speeches at LMU. Both IDKs look proudly back on this lecture event and the reception afterwards. More events will follow.



Left to right: LMU Vice President Prof. Beate Kellner and IDK-NBT Spokesman Prof. Joachim Rädler gave introductory speeches. The speakers: Prof. Peter Strohschneider and Prof. Harald Lesch.



PhD students exchanging ideas at a scientific "speed dating".

IDK-NBT SUMMER SCHOOL

At the IDK-NBT Summer School in July 2010, PhD students of the doctorate program gathered in Aiterbach at lake Chiemsee for three days of intense scientific discussions and personal exchanges. Every participant had to give a 15 minute talk explaining his/her topic in a way that everyone was able to follow the presentation. Not only the miscellaneous research fields led to profoundly diverse talks but also the fact that some of the participants were in their final year, while others have just started on their dissertations. That was a challenge as the IDK-NBT members had to prepare their talks for an interdisciplinary audience as well as for an audience that differed in the stages of their PhDs. The format of the talks enhanced vivid discussions which continued until late into the night. Thanks to their questions, discussions, and active engagement the workshop became a great success not only scientifically but also socially. Apart from the students giving talks about their research, two valuable guest speakers who both hold a PhD in physics were invited to join the students in order to give them an idea about how their professional careers could look like after their dissertation: While Dr. Jörg Bewersdorf decided to stay in academia and is now a professor at Yale University, Dr. Dirk Lumma decided to take another turn and left research for a position at Siemens Management Consulting where he is now Vice President. With their willingness to answer each and every question Prof. Bewersdorf and Dr. Lumma gave the IDK students a hint where their future careers could go and made an important contribution to the school.

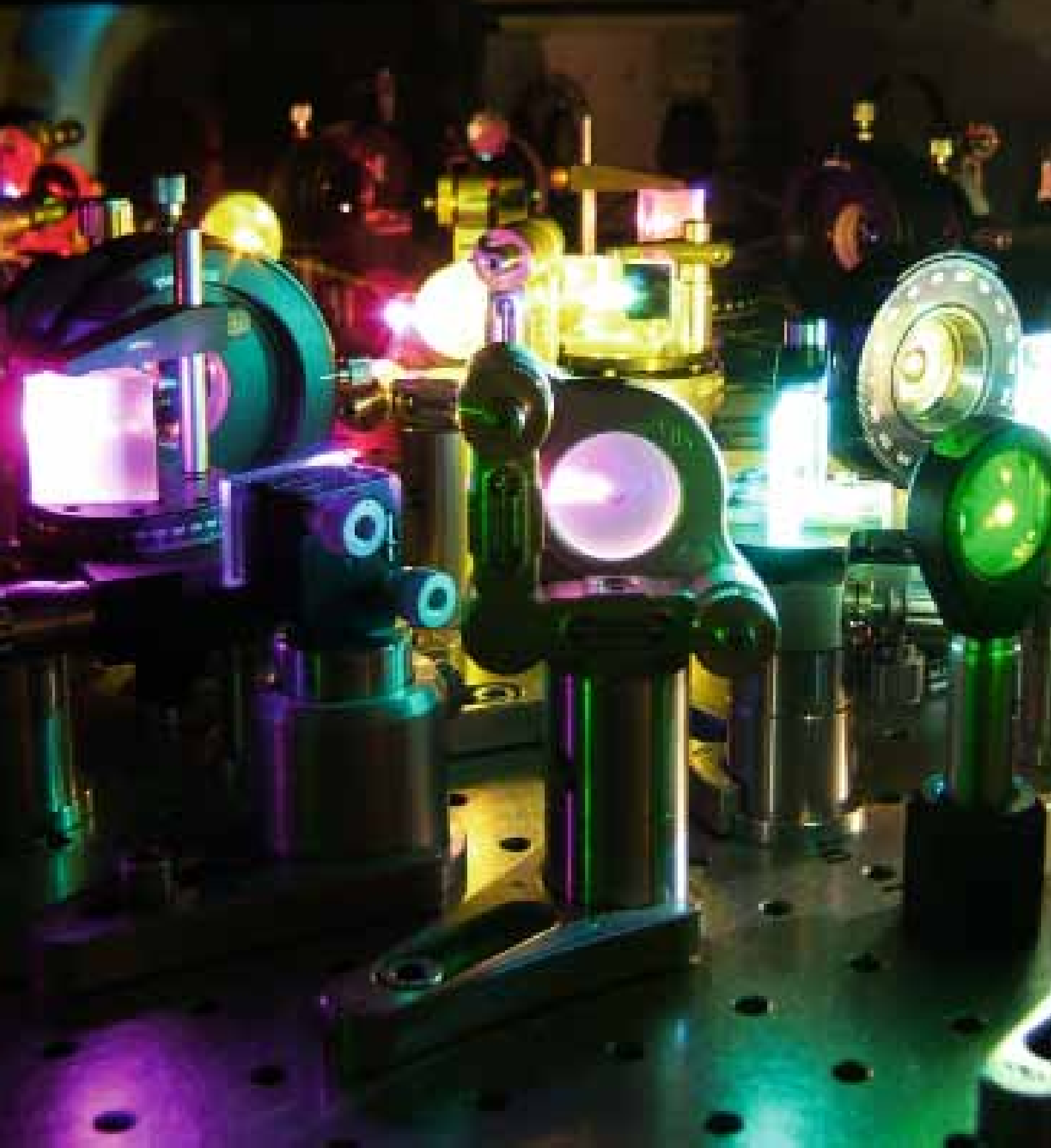
www.cens.de/doctorate-program/

LECTURE SERIES NANOBIOTECH

Once a month, a lecture on nanobioscience topics held by researchers of CeNS and invited guests precedes the CeNS colloquium from 2:00 to 3:00 p.m. This series of lectures is part of the educational program of the International Doctorate Program NanoBioTechnology. The lectures of the series are recorded and are available online for members of CeNS.

www.cens.de/calendar/lecture-series

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VISCOELASTIC DEFORMATION SPECTROSCOPY OF BIOLOGICAL CELLS

Dr. Thomas Franke (University of Augsburg, Institute of Physics)

Prof. Achim Wixforth (University of Augsburg, Institute of Physics)

Soft matter objects are ubiquitous in biological systems. Biological cells are such typical soft entities with the function closely related to their deformability. A prominent example are erythrocytes that get repeatedly deformed many times during their transport through the narrow capillaries of blood vessels. However, the viscoelastic deformability of red blood cells in microcirculation is essential to maintain their shape and function including oxygen uptake among many other functions. The enormous reversible shape deformability is based on the one hand on the non-spherical discoid biconcave resting shape and on the other hand on the mechanical properties of the lipid bilayer and the underlying cytoskeleton.

We have developed a microfluidic system to systematically study the elastic behavior of cells in hydrodynamic flow. Using a microfluidic channel with periodical width we are able to control frequency as well as amplitude of the external deformation excitation. Together with theorists from the FZ Jülich (Prof. Gompper) and Augsburg mathematicians (Prof. Hoppe) we have explored the complex dynamics of the red cell's viscoelastic response.

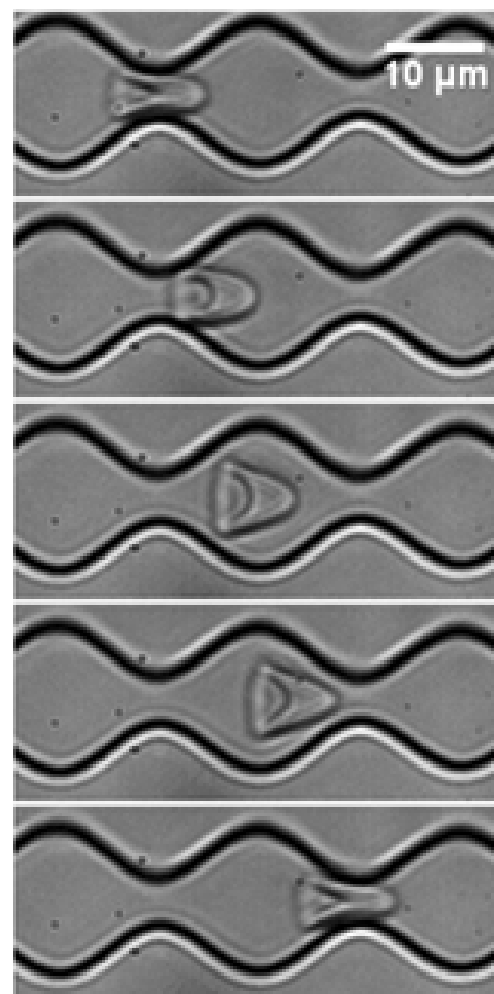
For red blood cells we find a transition from a regime with oscillating tilt angle of red cell main axis and fixed shape to a regime with oscillating shape with increasing flow velocity. We have determined the crossover to occur at a critical ratio $L_y/v_m \approx 2.2 \cdot 10^{-3} \text{ s}$ of channel width L_y and red blood cell velocity v_m . These oscillations are superposed by shape transitions from a discocyte to a slipper shape at low velocities and a slipper to parachute transition at high flow velocities. For lipid vesicles that serve as a simple model system we have observed three types of flow instabilities. At slow migration we found a transition from a state with orientational oscillations of a fixed prolate shape to a state with shape oscillations of symmetrical ellipsoidal or bullet-like shapes with increasing flow velocity as predicted by perturbation theory.

The transitions and their critical values are highly sensitive to the viscoelastic properties of the soft objects and therefore the method offers a simple and efficient approach to measure the cell mechanical properties of single as well as of large numbers of cells with excellent statistics.



Fig. 1: Orientational oscillation of a vesicle in a wide structured channel. The image is a superposition of video frames taken at time intervals of 1 s. The tilt angle oscillates as indicated and is a measure of elastic properties.

Fig. 2: Red blood cell in a tapered sine-modulated microchannel. Other types of shapes occur at different velocities e.g. dicoid and slipper shapes. (Ref: S. Braumüller, L. Schmid, T. Franke, "Dynamics of Red Blood Cells and Vesicles in Microchannels of Oscillating Width", accepted J. Phys. Condens. Matt. (2010)) The shapes depend on the viscoelasticity of the cell's lipid membrane and the underlying spectrin cytoskeleton.



In the future we plan to further exploit the device's potential for diagnostic purposes. For many diseases such as malaria, diabetes mellitus, hypercholesterolemia or spherocytosis the elastic properties significantly vary for erythrocytes. The viscoelastic deformation spectroscopy method as described can be a useful tool to analyze minute amounts of blood samples on a simple fabricated microfluidic "lab-on-a-chip" device. Moreover, it allows for detailed studies of mechanical induced release of ATP and signal molecules when coupled to a sensitive detection system. This in an approach we are currently following in a cooperation with the Stone group in Princeton NJ.

H. Noguchi, G. Gompper, L. Schmid, A. Wixforth, T. Franke, "Dynamics of Fluid Vesicles in Flow through Structured Microchannels", EPL 89, 28002, (2010)

Franke: http://www.physik.uni-augsburg.de/exp1/mitarbeiter/seniors/franke_thomas/

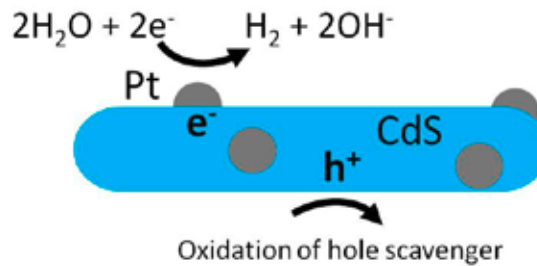
Wixforth: http://www.physik.uni-augsburg.de/exp1/mitarbeiter/profs/wixforth_achim/

HYDROGEN GENERATION WITH Pt-DECORATED COLLOIDAL CdS NANORODS

Dr. Frank Jäckel & Prof. Jochen Feldmann (LMU Munich, Faculty of Physics)

Prof. Andrey Rogach (City University of Hong Kong, Department of Physics and Materials Science)

Hydrogen is presently considered as one of the components of a future green energy mix since its combustion produces only water. Clean hydrogen, in principle, could be generated by electrolysis using a solar cell. In a project with seed-funding from the Nano-systems Initiative Munich (NIM), a more direct approach is used where size- and shape-controlled colloidal CdS nanorods decorated with sub-nm Pt clusters and directly dispersed in water serve as “nanopower plants”. The semiconductor absorbs light generating an electron hole pair. The electron is then transferred to a Pt cluster where it catalyzes the reduction of water to produce hydrogen. The hole is consumed by oxidation of a sacrificial hole scavenger. It was shown that hydrogen can be produced with quantum efficiencies of up to 3.9% with only small amounts of the precious metal catalyst Pt. In particular, deco-



Cartoon representation of hydrogen generation with a Pt-decorated CdS nanorod: Photogenerated electrons catalyze water reduction at the Pt clusters to produce hydrogen. The holes oxidize a sacrificial hole scavenger.

ration with sub-nm clusters was sufficient for significant hydrogen generation. Additional decoration with larger 4.8 nm diameter Pt particles did not increase hydrogen

production. This indicates that efficient CdS nanorod-based hydrogen production with reduced amounts of Pt particles is possible.

M. Berr, A. Vaneski, A. S. Susha, J. Rodríguez-Fernández, M. Döblinger, F. Jäckel, A. L. Rogach, J. Feldmann, Colloidal CdS nanorods decorated with sub-nanometer sized Pt clusters for photocatalytic hydrogen generation, *Appl. Phys. Lett.* 97, 093108 (2010)

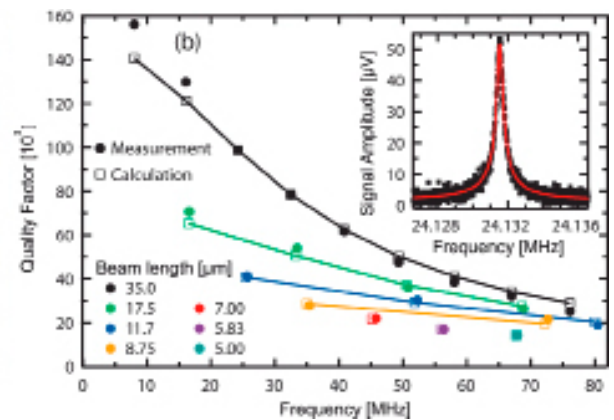
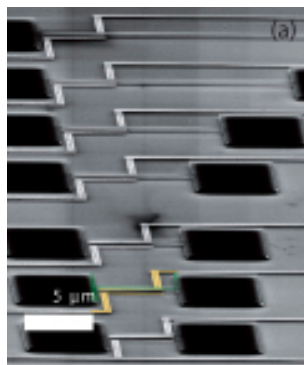
Jäckel, Feldmann: <http://www.phog.physik.uni-muenchen.de/>

Rogach: <http://www6.cityu.edu.hk/cfp/>

NANOELECTRO- AND NANOOPTOMECHANICAL SYSTEMS (NEMS & NOMS)

Prof. Jörg Kotthaus, Dipl.-Ing. Stephan Manus, Dr. Eva Maria Weig (LMU Munich, Faculty of Physics)

The high mechanical quality factors, observed in strained nanomechanical string resonators and reflecting the ratio of stored energy to energy loss per cycle, were explained with a model based on classical continuum mechanics as resulting from a dramatic increase of the energy stored in oscillating strings with increasing prestrain. This more than compensates the moderate increase of the damping with strain. The model corrects previous reports trying to explain increased quality factors with decreased damping. It also paves the way to a microscopic understanding of the relevant damping mechanisms and enables the directed improvement of mechanical quality factors by intelligent design [1]. Furthermore local on-chip detection has been combined with on-chip gradient field actuation and now allows to fabricate many independently actuated and detected mechanical resonators on a single chip. It also enables mechanical oscillator arrays which, biased only by a dc voltage, oscillate via external feedback of the electrical detector signal resulting from thermally activated resonator motion [2] thus acting as micrometer size clocks. The nonlinear behavior of such resonators has been explored in the bistable regime [3] and was found to be switchable on time scales much shorter than mechanical relaxation times if suitably actuated by pulse techniques thus acting as a fast nanoelectromechanical memory [3]. The coupling



of such nanomechanical resonators to high quality optical cavities, studied in collaboration with the group of T. Kippenberg at the Max Planck Institute for Quantum Optics [4] enabled to increase the precision of measuring nanomechanical motion beyond the standard quantum limit. In a collaboration with the group of T. W. Hänsch the resonant coupling of a Bose-Einstein condensate to a micromechanical resonator via surface forces was experimentally explored [5].

Fig.1. (a) Scanning electron micrograph of silicon nitride resonator (green) of different length which are resonantly excited at several harmonic modes by high frequency electric fields provided by two metal electrodes (yellow) underneath. (b) The measured mechanical quality factors of several harmonic resonances of prestrained silicon nitride strings of different length, extracted from measured resonance curves as displayed in the inset, are displayed vs. their resonance frequencies and compared with the corresponding values calculated with a classical continuum model employing only a single frequency-independent damping parameter (after Ref. 1).

Quirin P. Unterreithmeier, et al.: [1] *Phys. Rev. Lett.* 105, 027205 (2010); [2] *Nano Letters* 2010, 10, 887-890 (2010); [3] *Phys. Rev. B* 81, 241405(R) (2010)

[4] G. Anetsberger, et al., *Phys. Rev. A* 82, 061804(R) (2010)

[5] David Hunger et al., *Phys. Rev. Lett.* 104, 143002 (2010)

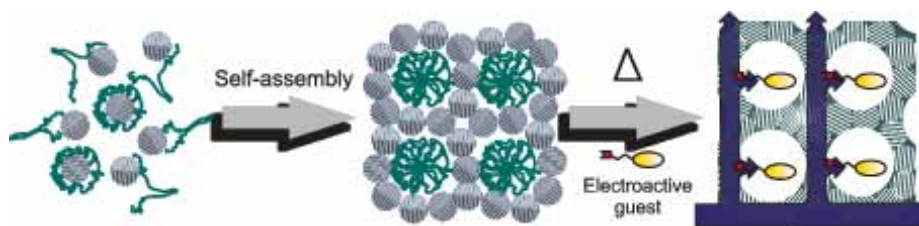
Kotthaus, Manus, Weig: <http://www.nano.physik.uni-muenchen.de/>

TRANSPARENT CONDUCTING ELECTRODES WITH A 3D-POROUS ARCHITECTURE ASSEMBLED FROM PRE-FORMED NANOCRYSTALS

Dr. Dina Fattakhova-Rohlfing (LMU Munich, Department of Chemistry)

3D conducting transparent networks attract great interest as electrodes for advanced optoelectronic devices involving immobilized species or functional layers. However, the manufacturing of such transparent conducting (TCO) electrodes is a non-trivial task. To date just a very few approaches to manufacturing of such layers are reported, all of them being based on self-assembly of sol-gel derived metal oxide precursors assisted by amphiphilic structure-directed agents. Crystallization of the formed amorphous mesostructure without its collapse requires either utilization of special polymers which are not commercially available, or an application of a post-synthetic treatment which is rather elaborate and time-consuming.

This project was devoted to development of a simple and generally applicable procedure for the preparation of transparent conducting 3D-frameworks using an assembly of pre-formed nanocrystals directed by commercially available and cheap polymers. The high crystallinity of the nanoparticles serving as building blocks enables to obtain the fully crystalline inorganic frameworks with sufficient electric conductivity already at temperatures as low as 300°C. Another attractive feature of this approach is the high thermal



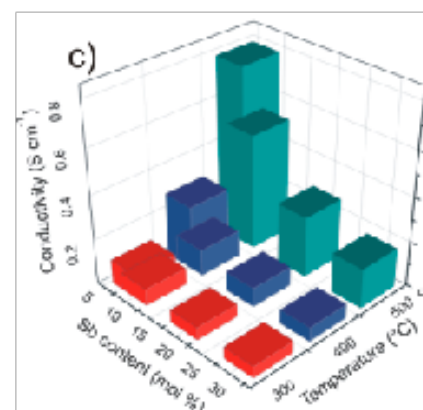
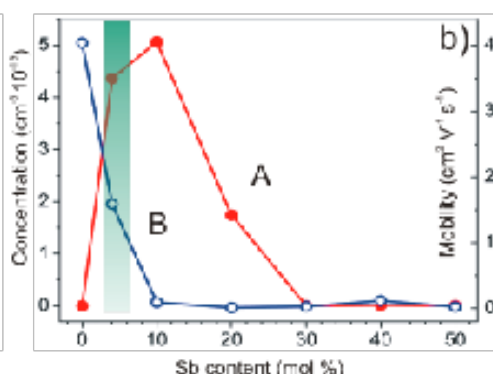
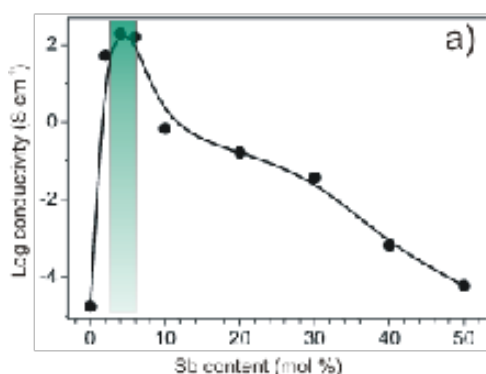
Formation of mesoporous crystalline electrode layers (right) by the self-assembly of crystalline nanoparticles (gray) directed by amphiphilic molecules (green). Violet arrows indicate the direct electron flow to redox species immobilized in the 3D-conducting framework.

stability of the obtained mesostructure exhibiting practically no shrinkage due to the temperature treatment, which is a typical disadvantage of amorphous sol-gel derived precursors. The use of preformed nanocrystals, whose preparation can be controlled with a high precision, ensures a high reproducibility and tuning of conductivity of the assembled films by variation of doping level and sintering temperature.

Owing to the open and accessible character of porosity, the high surface area and the uniform pore size, the obtained mesoporous frameworks are the ideal host materials for the accommodation of functional redox moieties. The high potential of

the obtained mesoporous layers as nanostructured transparent electrodes with the high surface area was demonstrated on an example of ferrocene molecules which were covalently immobilized in the conducting matrix, showing the greatly enhanced electrochemical response proportional to the electrode surface area.

Conductivity of the nanostructured Sb-doped tin oxide (ATO) materials with different Sb concentration: (a) pellets pressed from ATO nanoparticles after calcination in air at 500°C and (b) corresponding charge carrier concentration (A) and charge carrier mobility (B), and (c) conductivity of mesoporous ATO films assembled from nanoparticles.



V. Müller, M. Rasp, J. Rathousky, B. Schuetz, M. Niederberger, D. Fattakhova-Rohlfing: Transparent Conducting Films of Antimony-Doped Tin Oxide with Uniform Mesostructure Assembled from Preformed Nanocrystals; Small 6, 633 (2010)

Fattakhova-Rohlfing: <http://bein.cup.uni-muenchen.de/>

DRUG DELIVERY WITH LIPID BILAYER-COATED 50 NM MESOPOROUS NANOPARTICLES: COLCHICINE RELEASE FROM CMS EFFICIENTLY INDUCES MICROTUBULE DEPOLYMERIZATION UPON CELL UPTAKE

Prof. Christoph Bräuchle (LMU Munich, Department of Chemistry)

Prof. Thomas Bein (LMU Munich, Department of Chemistry)

Prof. Joachim Rädler (LMU Munich, Faculty of Physics)

Colloidal mesoporous silica (CMS) nanoparticles are promising candidates for drug delivery. However, after the drug is loaded into the pores, sealing of the pores against premature drug release and controlled intracellular drug release are challenging tasks. As an approach to seal the mesopores, we encapsulated CMS nanoparticles of 50 nm diameter with a supported lipid bilayer (SLB). We demonstrated the delivery of the microtubule-depolymerising drug colchicine from SLB-coated CMS nanoparticles into liver cancer cells by highly-sensitive fluorescence microscopy. The microtubule network of the cells was destroyed within 2 h of incubation. With this method, colchicine is released directly into the cell showing characteristic effects at concentrations below the amount necessary for application in solution.

THE CAPACITOR MODEL DESCRIBES THE THERMOPHORESIS OF SHORT DNA

Prof. Dieter Braun

(LMU Munich, Faculty of Physics)

In thermophoresis, the thermal analog to electrophoresis, molecules are moved along a microscopic temperature gradient. However its theoretical foundation is still under debate. The Braun lab has previously pioneered a capacitor model to describe thermophoresis [Duhr and Braun, PNAS 2006] which was now tested with the thermophoresis of highly diluted single stranded DNA between 5 and 50 bases in length. The Capacitor model could describe both the salt and size dependence of short DNA without fit parameters, forming the basis for quantitative DNA analytics using thermophoresis.

Philipp Reineck, Christoph J. Wienken and Dieter Braun, Thermophoresis of Single Stranded DNA, *Electrophoresis* 31, 279–286 (2010)

<http://www.biosystems.physik.lmu.de/>

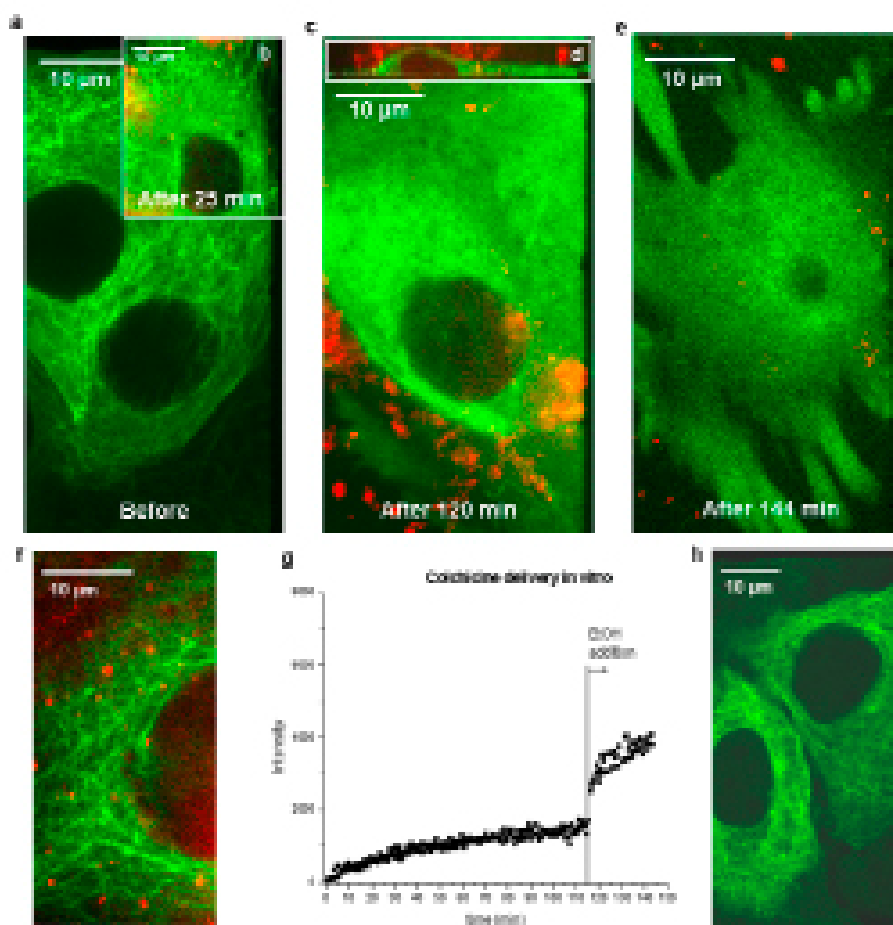


Figure: Drug delivery to HuH7 liver cancer cells. (a) Untreated HuH7 cells show a GFP-labeled microtubule network (green). (b) HuH7 cells (green) were exposed to colchicine-loaded POPC SLB@CMS (shown in red). The microtubule network is still intact. (c) After 120 min, microtubule depolymerization was observed. (d) Side view of the HuH7 cell represented in panel c. Internalized nanoparticles are visible in yellow. (e) After 144 min the cell morphology was disintegrated. (f) HuH7 cells (green) after 2 h of incubation with POPC-SLB@CMS without colchicine. (g) Colchicine release from POPC-SLB@CMS in vitro. After the injection of ethanol, the lipid bilayer was lysed and colchicine was released. (h) Dissolved colchicine from POPC-SLB@CMS was confined into the dialysis-capped tube on the cell culture holder. After 6 h the microtubule network of the HuH7 cells was still intact.

V. Cauda, H. Engelke, A. Sauer, D. Arcizet, C Bräuchle., J. Rädler, T. Bein: Colchicine-loaded lipid bilayer-coated 50 nm mesoporous nanoparticles efficiently induce microtubule depolymerization upon cell uptake, *Nano Lett.* 10(7), 2484 (2010)

J. Michaelis, C. Bräuchle: Reporters in the Nanoworld – Diffusion of single molecules in mesoporous materials; *Chem. Soc. Rev.* 39(12), 4731 (2010)

Bein: <http://bein.cup.uni-muenchen.de/>

Bräuchle: <http://www.cup.uni-muenchen.de/pc/braeuchle/>

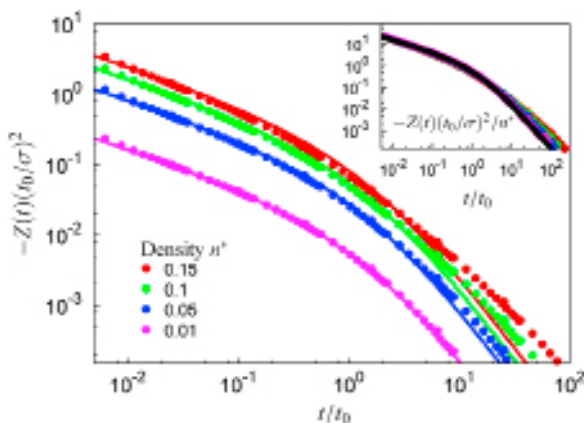
Rädler: <http://softmatter.physik.lmu.de>

PERSISTENT MEMORY FOR A BROWNIAN WALKER IN A RANDOM ARRAY OF OBSTACLES

Prof. Thomas Franosch (LMU Munich, Faculty of Physics - now at the University of Erlangen)

Prof. Erwin Frey (LMU Munich, Faculty of Physics)

Particles performing Brownian motion in a frozen array of scatterers display long-time correlations hidden beneath the mean-square displacement. Defining the velocity autocorrelation function (VACF) via the second time-derivative of the mean-square displacement, power-law tails govern the long-time dynamics similar to the case of ballistic motion. The physical origin of the persistent memory is due to repeated encounters with the same obstacle which occurs naturally in Brownian dynamics without involving other scattering centers. This observation suggests that in this case the VACF exhibits these anomalies already at first order in the scattering density. Here an analytic solution for the dynamics of a tracer for a dilute planar Lorentz gas is provided and the results are compared to computer simulations. These results support the idea that quenched disorder provides a generic mechanism for persistent correlations irrespective of the microdynamics of the tracer particle.



Dimensionless negative VACF $Z(t)$ for the dilute planar Lorentz gas for Brownian dynamics. Symbols correspond to simulation results, full lines to the first order density approximation. Density increases from bottom to top. Inset: Rescaling of $Z(t)$ over n^* .

T. Franosch, F. Höfling, T. Bauer, E. Frey, Persistent memory for a Brownian walker in a random array of obstacles, *Chemical Physics* 375, 540-547 (2010)

T. Bauer, F. Höfling, T. Munk, E. Frey, T. Franosch, Localization transition in the two-dimensional Lorentz model, *EPJ-ST* 189(1), 103-118 (2010)

Franosch: <http://theorie1.physik.uni-erlangen.de/people/thfran/index.html>

Frey: <http://www.theorie.physik.uni-muenchen.de/lfsfrey/index.html>

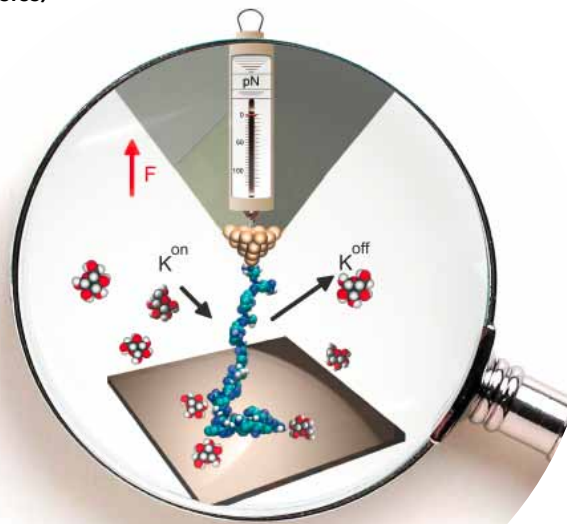
PULLING A SINGLE POLYMER OFF A SUBSTRATE REVEALS BINDING THERMODYNAMICS OF COSOLUTES

Prof. Thorsten Hugel (TU Munich, Department of Physics)

Prof. Roland Netz (TU Munich, Department of Physics)

Cosolutes like ions, ligands or small biomolecules can cause a protein to fold into its biologically functional native form, to associate, to adhere or desorb from an interface or even change its mechanical properties. At the same time, the interaction of cosolutes with macromolecules such as proteins, lipids and DNA themselves are modified by changes in the environment, in particular by binding to surfaces like the cell membrane or the surface of histones and microtubules.

Single molecule atomic force microscopy has been combined with thermodynamic modelling to extract the binding parameters of cosolutes onto a macromolecule in solution as well as in its surface adsorbed state. In specific, values for the adsorption site lengths (inverse maximal line densities) and the association constants are obtained. The considerable effect of substrates on cosolute binding is demonstrated with glucose as cosolute, poly(allylamine) as polymer and surgical stainless steel or oxidized diamond as substrates. Finally, a difference in the binding parameters in solution and at interfaces can be used to manipulate polymer adsorption by the change of cosolute



Schematics of the experiment: A single polymer is covalently attached to the tip of a force sensor (AFM) and pulled off a substrate at various cosolute concentrations to translate binding constants into forces.

concentration, which offers attractive and convenient prospects for the control of macromolecular assembly at surfaces.

M. Geisler, R.R. Netz, T. Hugel, "Pulling a single polymer off a substrate reveals binding thermodynamics of cosolutes", *Angew. Chem. Int. Ed.* 49, 4730 (2010)

Hugel: <http://bio.ph.tum.de/home/e22-prof-dr-hugel/>

Netz: <http://einrichtungen.ph.tum.de/T37/index.html>

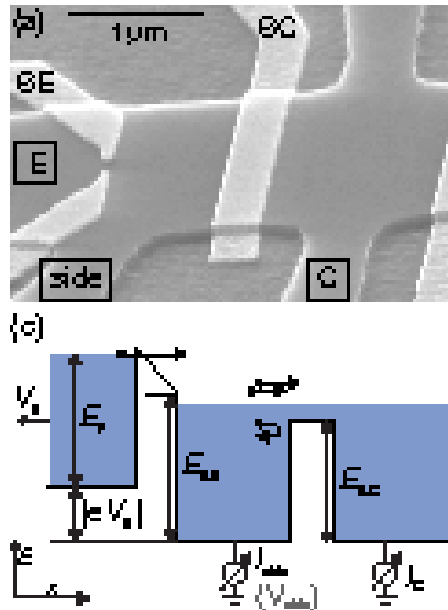
ELECTRON-AVALANCHE AMPLIFIER BASED ON THE ELECTRONIC VENTURI EFFECT

Prof. Stefan Kehrein (LMU Munich, Faculty of Physics)

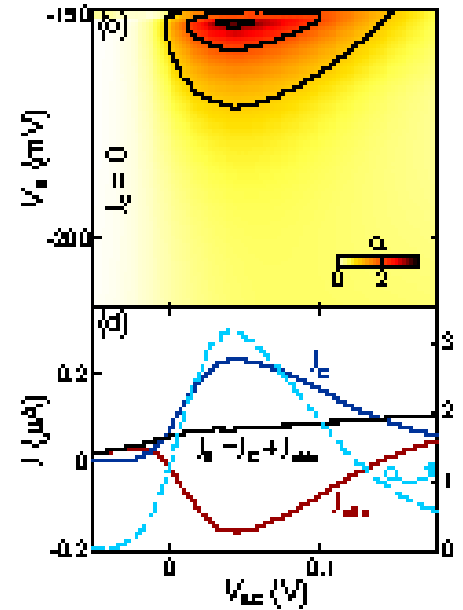
Priv.-Doz. Dr. Stefan Ludwig (LMU Munich, Faculty of Physics)

Bernoulli's principle states that an increase in velocity of an inviscid fluid is accompanied by a pressure decrease. Combined with the continuity equation it leads to the Venturi effect, which describes the pressure decrease in a fluid as it is pushed through a tube with reduced cross section. In a spectacular application, the water jet pump introduced by Bunsen in 1869, the reduced pressure is utilized for evacuating a side port. After passing the side port the fluid is decelerated into a wider collector tube which also seals the pump from its exhaust and improves the vacuum.

Our experiment presents an electronic analog to the water jet pump, "pumping" electrons in a mesoscopic environment instead of a classical fluid. The nanostructure is defined by etching a Hall-bar (elevated area in Figure (a)) which contains a degenerate two-dimensional electron system (at a low temperature). Electrostatic barriers are added by applying negative voltages to gold gates (light gray areas in Figure (a)). Just as a water jet pump, this device has three terminals: A negative voltage is applied to emitter contact "E", while collector "C" and "side" contact are grounded. In a network of Ohmic resistors we would expect electrons to flow from "E" to "C" and the "side" contact; all three currents $I_E = I_{\text{side}} + I_C$ would be positive (per definition). However, if the emitter and collector barriers ("BE" and "BC" in Figure (a)) are tuned to be almost closed, $I_{\text{side}} < 0$ can be observed for an almost closed collector barrier. This is shown in Figure (d) which plots all three currents



as "BC" is opened by increasing the gate voltage V_{BC} . According to Kirchhoff's law ($I_E = I_{\text{side}} + I_C$), $I_{\text{side}} < 0$ is accompanied with $I_C > I_E$ and amplification of the emitter current I_E by $\alpha = I_C / I_E > 1$ (compare Figure (b)). The microscopic explanation of this amplification is sketched in Figure (c): A "hot" injected electron scatters between "BE" and "BC" and transfers part of its excess energy and momentum to "cold" electrons from the degenerate Fermi sea.



A larger number of "warm" electrons passes "BC" while the remaining positive charge is neutralized by electrons being sucked in from the "side" contact.

Our experiments provide new means of studying interaction in mesoscopic systems far from equilibrium. Moreover the observed avalanche amplification could be utilized as a dynamic single electron detector.

D. Taubert, G. J. Schinner, H. P. Tranitz, W. Wegscheider, C. Tomaras, S. Kehrein, and S. Ludwig: Electron-avalanche amplifier based on the electronic Venturi effect; Phys. Rev. B 82, 161416(R) (2010)

Kehrein: <http://www.theorie.physik.uni-muenchen.de/lsvondelft/research/kehrein/index.html>

Ludwig: <http://www.nano.physik.uni-muenchen.de/quantumtransport/index.html>

IMMOBILIZATION OF GOLD NANOPARTICLES ON LIVING CELL MEMBRANES UPON CONTROLLED LIPID BINDING

Prof. Jochen Feldmann (LMU Munich, Faculty of Physics)

Prof. Fernando D. Stefani (University of Buenos Aires, Physics Department)

Gold nanoparticles are appealing optical markers in living cells. In this work we have devised a general, versatile, and controlled strategy to bind individual gold nanoparticles to lipids in living cell membranes. In contrast to most labeling approaches (based on protein-mediated binding), the chemical anchorage of gold nanoparticles to lipids in the cell membrane offers several advantages. First, it cannot be disrupted thermally. Therefore optical heating experiments are feasible without disruption of the entities (lipids) that keep the nanoparticles anchored to the cell surface. Second, the separation

distance between the gold nanoparticles' surface and the cell membrane is small. Therefore the lipid-bound gold nanoparticles can be exploited as active sensing elements on the cell surface. Single-particle tracking reveals that as a result of lipid binding, the gold nanoparticles perform a distinctively slow and spatially limited diffusion at the cell surface, consistent with reported constrained lipid diffusion in cellular membranes. Our method may be exploited as a general, versatile, and controlled way to routinely incorporate gold colloids of varying composition, size, or shape onto cellular membranes, thus pro-

viding a powerful toolbox for the mapping, local sensing and (remote) manipulation of cell membrane processes.

Haojin Ba, Jessica Rodríguez Fernández, Fernando D. Stefani, and Jochen Feldmann: Immobilization of Gold Nanoparticles on Living Cell Membranes upon Controlled Lipid Binding; Nano Letters 10 (8), 3006–3012 (2010)

Feldmann: <http://www.phog.physik.uni-muenchen.de/>

Stefani: <http://nanomaterials-photonics.df.uba.ar/>

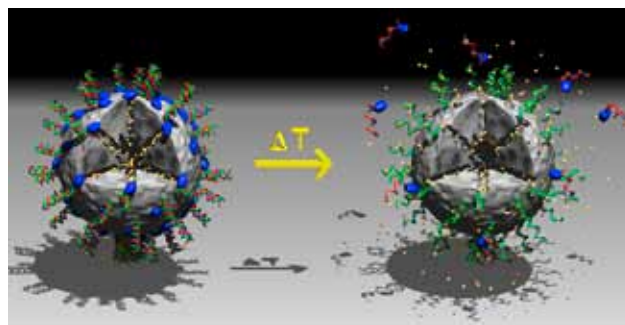
COLCHICINE-LOADED LIPID BILAYER-COATED 50 NM MESOPOROUS NANOPARTICLES EFFICIENTLY INDUCE MICROTUBULE DEPOLYMERIZATION UPON CELL UPTAKE

Prof. Thomas Bein (LMU Munich, Department of Chemistry)

Prof. Thomas Carell (LMU Munich, Department of Chemistry)

Controlled molecular valves for sealed nanocontainers are presently in the focus of interest for important applications such as targeted drug delivery or self-healing polymers. For example, in targeted drug delivery it is essential to release the active agents only at specified locations, conditions and times. The authors present a DNA-based valve system for colloidal mesoporous silica offering a precisely programmable opening temperature. The assembly of this multifunctional nano-device builds on a novel multifunctional core-shell colloidal mesoporous silica host, free available pore volume inside the host, selective functionalization of the pore mouths with a double-stranded DNA linker bearing two dyes for FRET monitoring, and biotin-avidin coupling for valve closure. The possibility to precisely program the opening temperature by varying the length

and sequence of the double-stranded DNA linker makes this system unique and far more flexible and versatile compared to previously reported mechanisms. It is anticipated that the general concept of molecularly programmed release will be of significant importance in the fields of targeted drug delivery, detergents, or encapsulation of polymer hardeners.



Concept of the programmable molecular valve system. The avidin caps are opened by melting the DNA linkers at specifically encoded temperatures.

Axel Schlossbauer, Simon Warncke, M. E. Gramlich Philipp, Johann Kecht, Antonio Manetto, Thomas Carell, and Thomas Bein, "A programmable DNA-based molecular valve for colloidal mesoporous silica," *Angew. Chem. Int. Ed.* 49 (28), 4734-4737 (2010).

Bein: <http://bein.cup.uni-muenchen.de/>

Carell: <http://www.cup.uni-muenchen.de/oc/carell/>

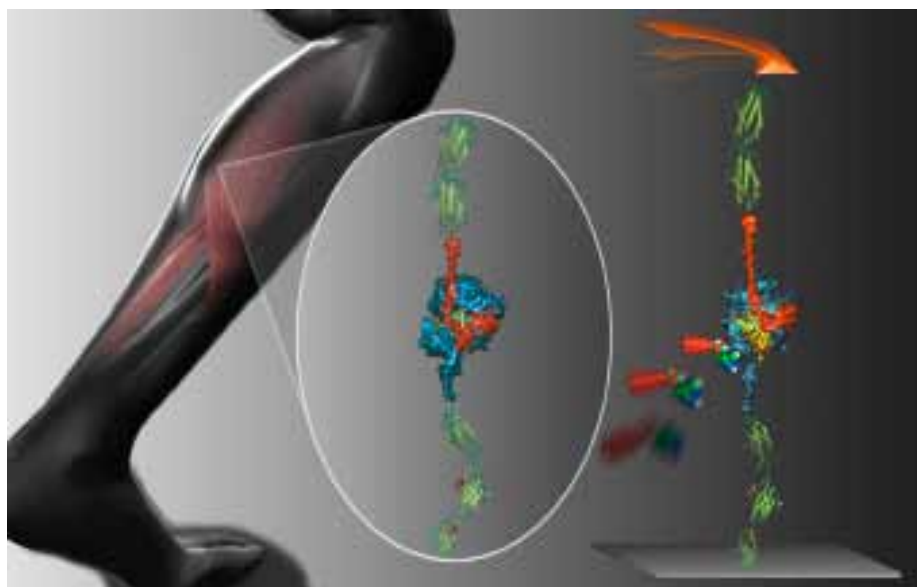
FORCE AND FUNCTION: MECHANOEZYMATICS OF KINASES

Prof. Hermann Gaub (LMU Munich, Faculty of Physics)

Prof. Ulrich Gerland (LMU Munich, Faculty of Physics)

Forces play a pivotal role in life, and the response of live systems to forces requires molecules and molecular interactions with adequate properties to counteract both in a passive and also, if needed, in an active, dynamic manner. However, at the level of individual molecules these forces are so minute, that the development of sophisticated experiments to measure and control them was required. With the maturation of these techniques, particularly the AFM-based single-molecule force spectroscopy more and more studies shine light onto the different aspects of biomolecular mechanics.

Such as the activity of an enzyme manipulated by an AFM with a periodic stretching and relaxation protocol while simultaneously monitoring its catalytic activity: After releasing the stretching force a higher probability for enzymatic activity was resolved. The AFM force spectroscopy related mechanical pump and probe experiment can even explore the conformation-regulated function of individual titin kinase molecules. The direct influence of force on enzymatic activity clearly is pointed out and opens up a new way to study and manipulate (bio)catalytic reactions at the single molecule level. Many surprises turned up and more are waiting for us.



E.M. Puchner, H.E. Gaub: Exploring the conformation-regulated function of titin kinase by mechanical pump and probe experiments with single molecules; *Angew Chem Int Ed Engl.* 49(6):1147-50 (2010)

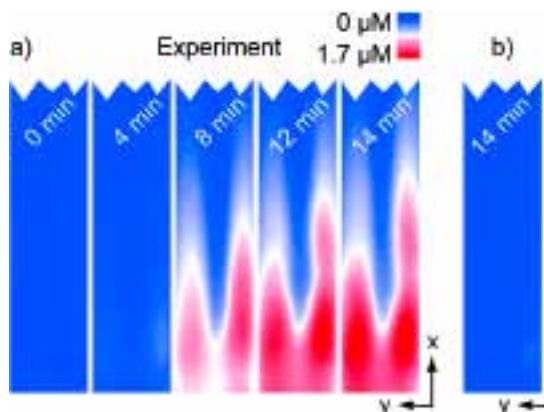
Gaub: <http://www.biophysik.physik.uni-muenchen.de/>

Gerland: http://www.theorie.physik.uni-muenchen.de/lfsrey/group_gerland/

REPLICATION AND TRAPPING BY THERMAL CONVECTION

Prof. Dieter Braun (LMU Munich, Faculty of Physics)

For the first time, the Braun lab experimentally demonstrated a very basic implementation of a Darwin process. Christof Mast managed to replicate and accumulate, i.e. select, DNA in a chamber which was only driven by a thermal gradient. This implements two core functions of life: the replication of genetic molecules and their active storage against diffusion. This experiment, published in *Physical Review Letters*, will stand as milestone as the Braun lab will focus the next 5 years with the help of an ERC Starting grant to experimentally show novel ways of creating molecular evolution from very simple building blocks and using physical rather than chemical principles in the lab.



The hallmark of living matter is the replication of genetic molecules and their active storage against diffusion. Both is implemented by the simple nonequilibrium environment of a temperature gradient. Convective flow both drives the DNA replicating polymerase chain reaction while concurrent thermophoresis accumulates the replicated 143 base pair DNA in bulk solution. The experiments explore conditions in pores of hydrothermal rock which can serve as a model environment for the origin of life. (a) DNA is replicated and trapped. (b) Without initial DNA, no replication is observed.

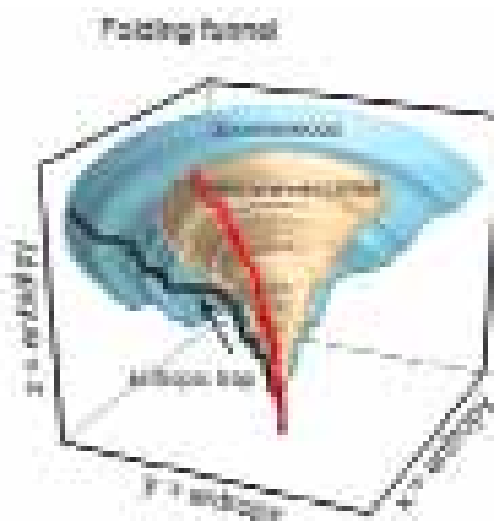
Christof B. Mast and Dieter Braun, *Thermal Trap for DNA Replication*, *Physical Review Letters* 104, 188102 (2010)Braun: <http://www.biosystems.physik.lmu.de/>

RESCUING TRAPPED PROTEINS: THE FUNCTION OF CHAPERONS IN PROTEIN FOLDING

Prof. Don C. Lamb (LMU Munich, Department of Chemistry)

Molecular chaperones are proteins that assist other proteins in reaching their final, functional, three-dimensional form on biologically relevant timescales. The bacterial chaperonin, GroEL, has two cavities where nascent polypeptide chains can fold into their native conformation. A mutant of the maltose binding protein (MBP) was used as a substrate protein as it can fold spontaneously but is accelerated several fold in the presence of GroEL, the cochaperon GroES and ATP. Thus, MBP can be used to investigate the mechanism of chaperone-accelerated protein folding. By combining many biophysical and biochemical methods, the proposed theory that the main function of GroEL/GroES is to isolate the substrate in its cavity and keep it from aggregating could be ruled out. For MBP, no aggregation was observed for protein concentrations in the nM and μM range and hence aggregation cannot be the cause of slower folding kinetics in the absence of GroEL/GroES. In the case of the substrate rubisco, which is known to aggregate, aggregation led to a decrease in yield of folded protein but the rate of folding remained unchanged. To further investigate the mechanism of accelerated protein folding, the affect of conformational entropy was investigated by incorporating disulfide bridges between amino acids that are adjacent in the correctly folded structure but far separated

in the primary sequence. The addition of two disulfide bonds, one in the N-terminal domain and a second in the C-terminal domain, reduced the spontaneous rate of refolding for MBP to that of GroEL/GroES assisted folding. Hence, the steric confinement within the pocket of GroEL/GroES has a similar affect as that of reducing conformational entropy of folding with disulfide bonds. This affect was mediated by negative charges clustered on the wall of the cavity. Ensemble denaturation and refolding experiments showed that MBP was kinetically trapped during refolding. The ability to rescue kinetically trapped proteins by reducing the available conformational space of the unfolded protein may explain the role GroEL with its cochaperon GroES plays within the network of cellular chaperones.



GroEL helps nascent proteins fold into their final native, functional form. One way that GroEL accelerates protein folding is by altering the protein folding landscape.

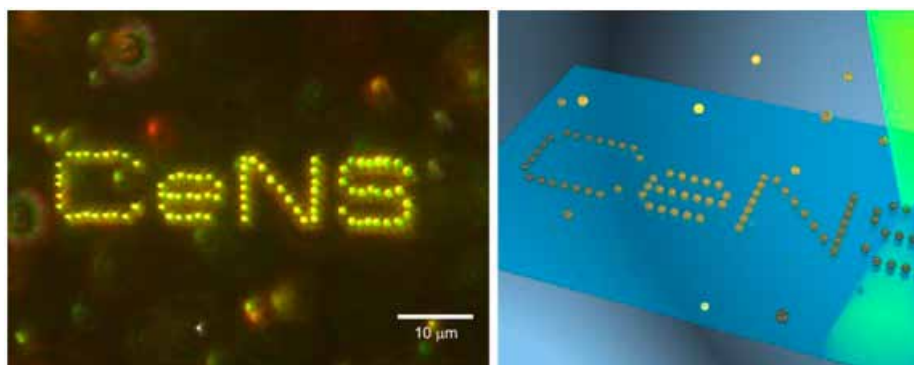
K. Chakraborty, M. Chatila, J. Sinha, Q. Shi, B. C. Poschner, M. Sikor, G. Jiang, D. C. Lamb, F. U. Hartl, and M. Hayer-Hartl, "Chaperonin-Catalyzed Rescue of Kinetically Trapped States in Protein Folding," *Cell* 142, 112-122 (2010).Lamb: <http://www.cup.uni-muenchen.de/pc/lamb/index.html>

LASER PRINTING SINGLE GOLD NANOPARTICLES

Dr. Andrey Lutich, Prof. Jochen Feldmann (LMU Munich, Faculty of Physics)
Prof. Fernando D. Stefani (University of Buenos Aires, Physics Department)

Current colloidal synthesis is able to produce an extensive spectrum of nanoparticles with unique optoelectronic, magnetic, and catalytic properties. In order to exploit them in nanoscale devices, flexible methods are needed for the controlled integration of nanoparticles on surfaces with few-nanometer precision. Current methods for integrating single nanoparticles on substrates for use as devices are generally tedious processes, requiring multiple time-consuming steps and often lacking single nanoparticles precision.

Our new approach uses the optical forces exerted by a laser on single metal nanoparticles to deposit them onto a glass surface. The deposition technique relies fully on optical forces to i) capture the nanoparticles from the colloidal suspension, ii) guide them towards the printing position and iii) fix them on the substrate through van der Waals attraction. The printed



nanoparticles remain immobilized after repeated steps of drying and rinsing. The concept presented here for can easily be extended to other nanoparticles, allowing for the production of various nanoscale devices and circuits.

The 80 nm large particles are bound strongly to the surface via van der Waals forces with a printing accuracy better than 50 nm.

A.S. Urban, A.A. Lutich, F.D. Stefani, J. Feldmann: Laser Printing Single Gold Nanoparticles; *Nano Letters* 10, 4794 (2010).

Lutich, Feldmann: <http://www.phog.physik.uni-muenchen.de/>

Stefani: <http://nanomaterials-photonics.df.uba.ar/>

NANOMAGNETIC DRUG-DELIVERY SYSTEMS AND AN INTEGRATED TECHNOLOGY FOR THERAPEUTICAL APPLICATIONS

Prof. Christian Plank (TU Munich & University Hospital Rechts der Isar, Institute of Experimental Oncology)
Prof. Wolfgang Parak (University of Marburg, Department of Physics)
Priv.-Doz. Stefan Thalhammer (Helmholtz-Zentrum Munich & University of Augsburg)

Christian Plank's group is developing systems for localized nucleic acid delivery. Equipping these systems with magnetic nanoparticles allows localizing delivery and boosting its efficiency by magnetic force. This form of magnetic drug targeting is known in the literature as "Magnetofection".

An extension of magnetic targeting concepts is their combination with modules for triggered drug release. In this context, the Plank group develops thermosensi-

tive magnetic liposomes and magnetic microbubbles. With the latter, localized nucleic acid delivery can be triggered by ultrasound. This has been used advantageously for tissue regeneration in a rat skin-flap model which is relevant in reconstructive surgery. Ultrasound microbubbles are approved contrast agents for ultrasound imaging and can be used as drug carriers. The Plank group collaborators have combined the modules for nanomagnetic and ultrasound guidance by developing magnetic and acoustically active

lipospheres (MAALs), also called magnetobubbles, for combined ultrasound and magnetically-targeted nucleic acid delivery. These objects are formed in a simple manner by self-assembly of lipids, nucleic acids and magnetic nanoparticles in a perfluoropropane atmosphere in a sealed glass vial. An interesting feature of these novel drug carriers is that they can be tracked by magnetic resonance and ultrasound imaging. The work published in 2010 was carried out in collaboration with Wolfgang Parak's group.

D. Vlaskou et al.: *AIP Conference Proceedings* 1311, 485-494 (2010); *Adv Funct Mater* 20, 3881-3894(2010).

P. del Pino, A. Munoz-Javier, D. Vlaskou, P. Rivera Gil, C. Plank, W.J. Parak, Gene silencing mediated by magnetic lipospheres tagged with small interfering RNA, *Nano Lett* 10, 3914-3921 (2010).

T. Holzbach, D. Vlaskou, I. Neshkova, M.A. Konerding, K. Wortler, O. Mykhaylyk, B. Gansbacher, H.G. Machens, C. Plank, R.E. Giunta, Non-viral VEGF(165) gene therapy-magnetofection of acoustically active magnetic lipospheres ('magnetobubbles') increases tissue survival in an oversized skin flap model, *J Cell Mol Med* 14, 587-599 (2010).

N. Tresilwised, P. Pithayanukul, O. Mykhaylyk, P.S. Holm, R. Holzmuller, M. Anton, S. Thalhammer, D. Adiguzel, M. Doblinger, C. Plank, Boosting oncolytic adenovirus potency with magnetic nanoparticles and magnetic force, *Mol Pharm* 7, 1069-1089 (2010).

Plank: <http://www.plank-lab.net/>

Parak: <http://www.physik.uni-marburg.de/de/forschung/biophotonik/home.html>

Thalhammer: <http://www.helmholtz-muenchen.de/iss/strahlenbiophysik/index.html>

In a second project, oncolytic magnetic adenovirus was developed. Oncolytic viruses rank among the most promising anti-cancer agents. During their replication in tumor cells they lyse the host cells. In the study published by the Plank group in collaboration with the Thalhammer and Bein groups, oncolytic adenovirus was associated with magnetic nanoparticles. A gradient magnetic field was used to enhance their uptake into tumor cells in cell culture and in a mouse tumor model. This strategy enhanced significantly the tumor-killing potency of the virus.

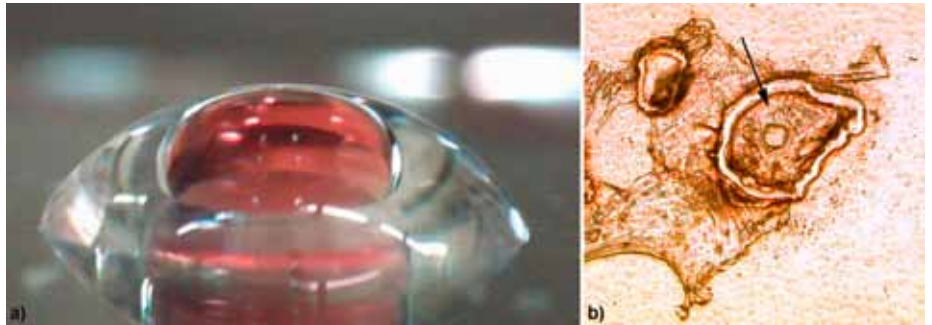
LAB-ON-A-CHIP FOR ANCIENT DNA ANALYSIS

Priv.-Doz. Stefan Thalhammer (Helmholtz-Zentrum Munich & University of Augsburg)

Priv.-Doz. Albert Zink (European Academy of Bozen (EURAC), Institute for Mummies and the Iceman)

In this interdisciplinary project we developed a novel method for contamination-free extraction of minimum amounts of ancient sample material, which results in a greatly improved and more precise forensic and pathological analysis.

Working with ancient DNA extracted from soil buried bones and teeth is generally associated with low DNA quantity, high DNA degradation, DNA contamination from the specimen and technical constraints from the presence of PCR inhibitors. Although there are a variety of DNA extraction techniques but no method exceeds the others since all of these procedures are affected by the problems and limitations mentioned above. We have developed a novel method for contamination-free isolation of micrometer sample material using non-contact laser microdissection. Our studies reveal that this method performs significantly better than traditional methods with respect to extracted ancient DNA quality, decreased DNA degradation and absence of destructive factors. While current DNA extraction operating procedures use whole bone tissue particles for pulverization and subsequent DNA extraction, our method uses non-contact laser microdissection of internal bone areas, comprising the highest probability of preserved vascular cell material and thus present authentic ancient DNA.



a) low volume PCR of the isolated bone segment in 1 μ l total reaction volume while covered with 5 μ l of mineral oil to prevent evaporation and external contamination; b) isolation of an osteon bone particle, diameter 300 μ m, via laser-based microdissection (see black arrow)

Naturally this reduction in target material requires an additional enhancement of analysis sensitivity, which was achieved by using novel tube-less low-volume PCR. Reducing the total reaction volume to just 1 μ l provides amplification of minute amounts of laser-microdissected material in extremely small reaction volumes. Thereby starting amounts of extracted ancient DNA needed for genetic analysis are significantly reduced and external contamination via PCR plastic tubes as potential sources of bioactive environmental

contaminants is circumvented. Altogether, the novel method provides technical benefits from non-contact, contamination-free sample preparation via laser microdissection combined with forensic relevant genetic analyses using more sensitive tube-less low-volume PCR technology. This developed approach could adapt the preparative and extraction procedures to the low amount of preserved ancient DNA, thus bearing a high potential to be used in forensics and pathology for genetic analyses of different kinds of traces.

D. Woide, A. Zink, S. Thalhammer: PCR analysis of minimum target of ancient DNA. *Am J. of Phys. Anthrop.* 142: 321 – 327 (2010)

Thalhammer: <http://www.helmholtz-muenchen.de/iss/strahlenbiophysik/index.html>

Zink: <http://www.eurac.edu/staff/azink/default.html>

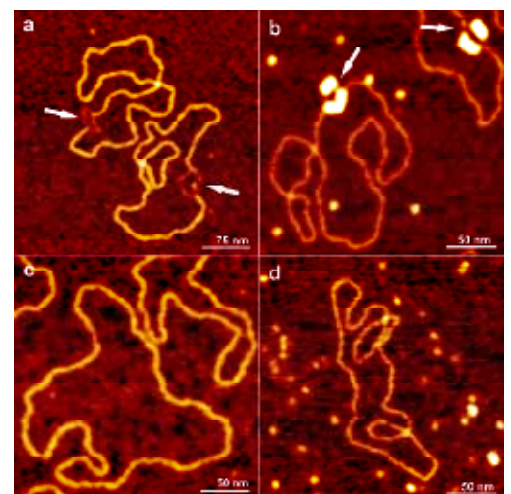
DENATURATION BUBBLES IN TOPOLOGICALLY CONSTRAINED DNA

Prof. Ralf Metzler (TU Munich, Department of Physics)

Chromosomal or plasmid DNA is topologically constrained, i.e., the linking number is conserved. While it has been speculated for a long time that partial release of twist in favour of writhe would lead to local denaturation of the DNA double-strand, in collaboration with the Dietler group at EPFL we could demonstrate the formation of DNA denaturation bubbles in pUC19 plasmids. We developed a theoretical model to calculate all relevant quantities, such as the bubble size as function of the remaining twist, finding excellent quantitative agreement with the AFM measurements. Controls such as incubation with single-stranded DNA binding proteins unequivocally demonstrate that bubble formation occurs in solution. Taking the free binding energies by the single-strand binders into consideration, we obtain excellent agreement of our theoretical results with

the measured probability to find open bubbles at different temperatures and salt conditions.

AFM images of DNA plasmids (pUC19). a: two plasmids with a single denaturation bubble (arrows). b: plasmids treated with SSB in solution and then deposited on mica. One can easily discern the SSB bound to the ssDNA bubble, visible as bright spots. c: plasmids treated with topoisomerase I without any bubble. d: plasmids treated with topoisomerase I and incubated with SSB, no SSBs are observed to be bound to these relaxed plasmids.



J.-H. Jeon, J. Adamczik, G. Dietler, and R. Metzler, Denaturation bubbles in supercoiled circular DNA, *Phys. Rev. Lett.* 105, 208101 (2010)

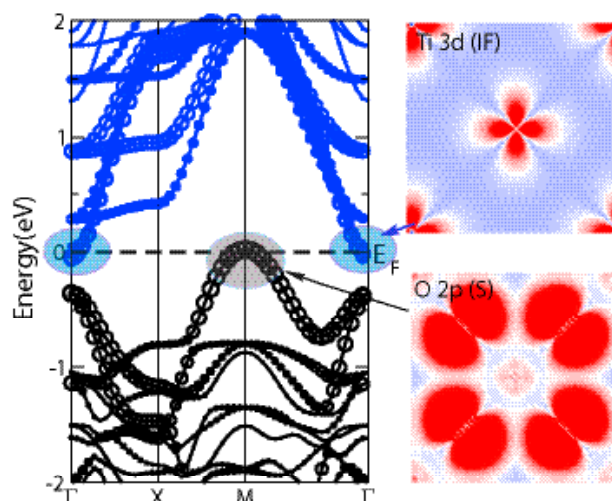
Metzler: <http://users.physik.tu-muenchen.de/metz/index.html>

PARALLEL ELECTRON-HOLE BILAYER IN COUPLED SrTiO₃/LaAlO₃/SrTiO₃ (001) INTERFACES

Priv.-Doz. Dr. Rossitza Pentcheva (LMU Munich, Department of Earth and Environmental Sciences)

The interfaces of complex oxides can show unexpected characteristics distinct from the bulk materials. A targeted manipulation of these properties could yield electronics components with tailored functionalities. Heterostructures of the two perovskites SrTiO₃ and LaAlO₃ have advanced to a model system to investigate the rich electronic phenomena arising at polar oxide interfaces such as conductivity, magnetism and superconductivity. Recently, a critical thickness of four LaAlO₃ monolayers (ML) was reported beyond which the interface loses its insulating characteristics and becomes conductive [Thiel et al., Science 313,1942 (2006)]. An international collaboration between the LMU, UC Davis and the University of Twente has now demonstrated that an additional SrTiO₃ capping layer represents a further parameter to tune the electronic properties of the interface: it not only prevents an atomic reconstruction at the LaAlO₃ surface but also triggers the electronic reconstruction at a much lower

(left panel) Bandstructure of 2ML LaAlO₃/SrTiO₃(001) capped with 2ML SrTiO₃. The closing of the band gap is indirect both in real and reciprocal space as it is due to an overlap between surface O 2p states at the M-point (black circles) and interface Ti 3d states at the Γ -point (blue circles). The electron density, integrated between -0.6 eV and the Fermi level, shows electrons in the Ti 3d_{xy} orbitals at the interface (top, right) and holes in the O 2p _{π} bands at the surface (bottom, right).



LaAlO₃ film thickness (2 ML) than for the uncapped systems. Moreover, first principles calculations and magnetotransport measurements give evidence for the formation of two spatially separated sheets with electron and hole carriers, that are as close as 1 nm. Thus the system becomes interesting to explore excitonic phenomena.

R. Pentcheva, M. Huijben, K. Otte, W.E. Pickett, J.E. Kleibeuker, J. Huijben, H. Boschker, D. Kockmann, W. Siemons, G. Koster, H.J.W. Zandvliet, G. Rijnders, D.H.A. Blank, H. Hilgenkamp, and A. Brinkman, Parallel electron-hole bilayer conductivity from electronic interface reconstruction, Phys. Rev. Lett., 104, 166804 (2010).

R. Pentcheva and W.E. Pickett, Electronic Phenomena at Complex Oxide Interfaces: Insights from First Principles, J. Phys.: Cond. Matter 22, 043001 (2010).

Pentcheva: http://www.kristallographie.geowissenschaften.uni-muenchen.de/personen/wiss_mitarbeiter/pentcheva/index.html

ELUCIDATING THE CONFORMATIONAL CYCLE OF THE MITOCHONDRIAL HSP70 CHAPERONE SSC1

Prof. Don C. Lamb (LMU Munich, Department of Chemistry)

Chaperone proteins aid other proteins in reaching their native, fully functional, three-dimensional structure. Some chaperones aid in folding, other help target the protein to particular compartments or transport it through channels into organelles, such as the mitochondria. The mitochondria heat shock protein 70 (Hsp70), Ssc1, is one of this ubiquitous class of molecular chaperones and is involved in the import of molecules into the mitochondria. As proteins have to be unfolded to pass through the channel into the mitochondria, Ssc1 assists not only in the import process but also keeps the imported proteins from aggregating until they can refold. Little is known about the mo-

lecular function of this class of proteins. To investigate the conformation of Ssc1 during its "folding cycle" where nucleotides, co-chaperons and peptides interact with Ssc1, single-pair Förster Resonance Energy Transfer (spFRET) experiments were performed. Labeling sites were genetically engineered into Ssc1 and labeled with fluorophores such that the distance between the nucleotide binding domain and the substrate-binding domain could be monitored (the domain mutant) or the conformation of the lid on the substrate-binding domain (the lid mutant) determined. The structure of Ssc1 was found to be very heterogeneous in the ADP bound state with an open lid and dynamic fluctuations were

seen between different conformations in the domain mutant. When ATP was bound, the domains moved closer together and the heterogeneity decreased but the lid remained open. It is first when the substrate was present that the lid closed, suggesting that the substrate influences the conformation of the chaperone. Similar conformational behavior was observed for the bacterial Hsp70, DnaK, with the exception that no dynamic fluctuations were detected in domain mutant. This subtle difference in the dynamic behavior of the Hsp70 from different species may give a first clue as to how nature has optimized each Hsp70 for its specific function and why they are not functionally interchangeable.

K. Mapa, M. Sikor, K. Waagemann, V. Kudryavtsev, S. Kalinin, C. A. M. Seidel, W. Neupert, D. C. Lamb, and D. Mokranjac, "The conformational dynamics of the mitochondrial hsp70 chaperone," Mol Cell 38, 89-100 (2010).

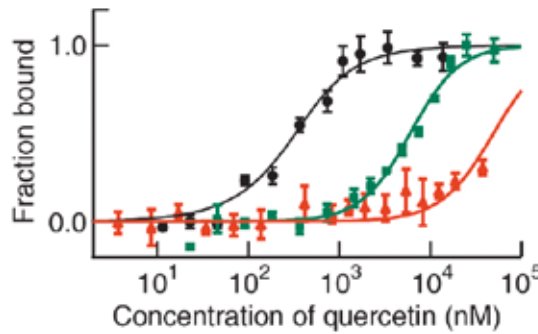
Lamb: <http://www.cup.uni-muenchen.de/pc/lamb/index.html>

PROTEIN-DRUG INTERACTIONS IN BLOOD QUANTIFIED WITH THERMOPHORESIS

Prof. Dieter Braun (LMU Munich, Faculty of Physics)

Dr. Stefan Duhr (NanoTemper Technologies)

Cells control their reactions by specific interactions between molecules. These bindings, mostly between proteins, protein and DNA or protein and smaller reaction substrates, are thus at the core of biological function. Pharmaceutical compounds are typically small molecules which interact with proteins and often inhibit binding. The Braun lab in collaboration with its independent Startup Company NanoTemper showed that the nanoscale environment of proteins can be probed very quantitatively with the drift of proteins along a thermal gradient. In a very important publication in Nature Communications, they have shown that a wide range of biological bindings can be probed. The quantification not only works with a very simple mix-and-read platform with labeling only one binding partner without a very specific binding protocol. The measure-



Microscale thermophoresis can detect the binding of antibodies and small pharmaceutical compounds in 50% serum and cell lysate [1,2]. The apparent dissociation constant K_D of the inhibitor quercetin to the cAMP-dependent kinase PKA changes from $0.13\mu\text{M}$ (black circles) to $6\mu\text{M}$ in 5% human serum (green squares) and $50\mu\text{M}$ in 30% human serum (red triangles).

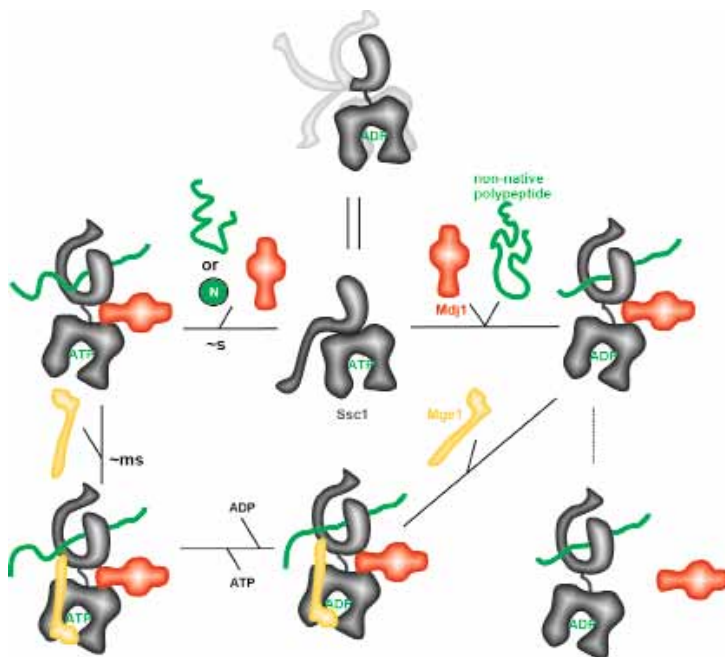
ments can be performed in blood serum and cell lysates, i.e. in very complex biological liquids. The latter is very relevant for drug screening as it stands strategically between rather complex binding assays in pure buffer and functional screening in

cell culture. The first give quantitative dissociation constant, however the latter is only very qualitative. Thermophoresis can bridge this very crucial gap in the drug development process.

Christoph J. Wienken, Philipp Baaske, Ulrich Rothbauer, Dieter Braun and Stefan Duhr, Protein-binding assays in biological liquids using microscale thermophoresis, Nature Communications 1, 100 (2010)

Braun: <http://www.biosystems.physik.lmu.de/>

Duhr: <http://www.nanotemper.de/>



A schematic representation of the "folding cycle" of Ssc1 showing how the structure of the protein changes depending on which nucleotide is bound, whether the peptide is present and which co-chaperons are currently interacting with Ssc1. When known, the timescale for the process is given.

DISULFIDE-BASED DRUG DELIVERY FROM COLLOIDAL MESOPOROUS SILICA EVALUATED BY LIVE-CELL IMAGING ELUCIDATES THE ROLE OF ENDOSOMAL ESCAPE FOR SUCCESSFUL DRUG DELIVERY

Prof. Christoph Bräuchle (LMU Munich, Department of Chemistry)

Prof. Thomas Bein (LMU Munich, Department of Chemistry)

Controlled release of drugs from functionalized mesoporous materials has attracted great interest in recent years. Triggers used to affect the controlled release include e.g. enzymatic digestion of gatekeepers, temperature, competitive binding, light-irradiation, changes in the pH value or changes in the redox potential.

In our approach, we linked a fluorescently labelled model drug (cystein-ATTO633) via a redox-sensitive disulfide bridge inside the pores of CMS. For reduction of the disulfide bonds and release of the drug, the CMS nanoparticles need to reach the cytoplasmic reducing milieu after internalization. We showed that nanoparticles were endocytosed by HuH7 cells, but endosomal escape seems to be a bottleneck for drug release. Using a photosensitizer to induce endosomal escape, successful release of the drug was achieved. Additionally, we found that grafting of ATTO633 at high concentration in the pores of silica nanoparticles results in self-quenching of the ATTO633 fluorescence. Release of dye from the pores promotes a de-quenching effect with an excellent readout signal.

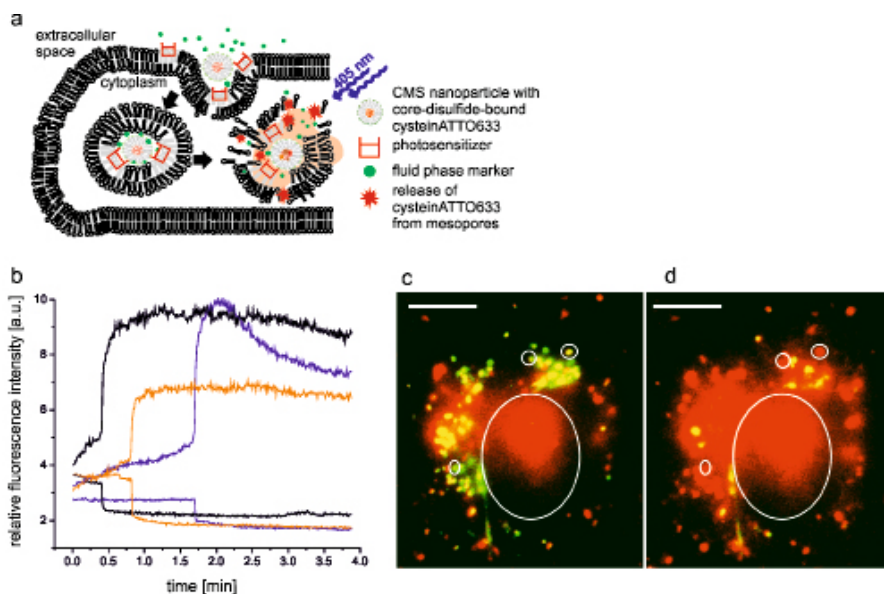


Figure: Photoinduced endosomal release of CMS-CysATTO633_{core}-NH₂^{shell} and fluid phase marker AFD inside living HuH7 cells. A schematic representation of the experiment is shown in (a). The cells were exposed to CMS CysATTO633_{core}-NH₂^{shell} overnight. (b) Intensity plot of three exemplary tracked endosomes (highlighted by small circles in c and d) over time. The fluorescence intensity of CysATTO633 (upper three curves) showed a sudden increase concomitant to the decrease in AFD fluorescence intensity (corresponding lower three curves) due to endosomal rupture and AFD-dye release. (c) Fluorescence microscopy image overlays of the CysATTO633 (red) and fluid phase marker AFD (green) signal at activation of the photosensitizer and (d) 4 min later. The cell nucleus is indicated with the large white circle. Scale bar: 10 μm.

A. Sauer, A. Schloßbauer, N. Ruthardt, V. Cauda, T. Bein, C. Bräuchle: The Role of Endosomal Escape for Disulfide-Based Drug Delivery from Colloidal Mesoporous Silica Evaluated by Live-Cell Imaging; *Nano Lett.* 10, 3684 (2010)

J. Michaelis, C. Bräuchle: Reporters in the Nanoworld – Diffusion of single molecules in mesoporous materials; *Chem. Soc. Rev.* 39(12), 4731 (2010)

Bein: <http://bein.cup.uni-muenchen.de/>

Bräuchle: <http://www.cup.uni-muenchen.de/pc/braeuchle/>

DYNAMICS OF DIPOLAR EXCITONS

Prof. Jörg Kotthaus (LMU Munich, Faculty of Physics)

Prof. Alexander Holleitner (TU Munich, Walter Schottky Institute)

The spin memory of spatially indirect dipolar excitons in a coupled GaAs double quantum well has been investigated via time- and polarization-resolved photoluminescence studies after resonant and non-resonant excitation of the direct and indirect exciton states [1]. Under resonant excitation highly efficient

spin initiation is achieved and the resulting spin polarization is found to decay with a lifetime significantly longer than the radiative lifetime of the indirect excitons, which reaches several tens of nanoseconds. The studies aim at realizing spin memories in electrically tunable microtraps for dipolar excitons.

K. Kowalik-Seidl, X. P. Vögele, B. N. Rimpfl, S. Manus, D. Schuh, W. Wegscheider, A. W. Holleitner, and J. P. Kotthaus, Long exciton spin memory in coupled quantum wells, *Appl. Phys. Lett.* 97, 011104 (2010)

Holleitner: <http://www.wsi.tum.de/Research/HolleitnergrouPE24/tabid/166/Default.aspx>

Kotthaus: <http://www.nano.physik.uni-muenchen.de/>

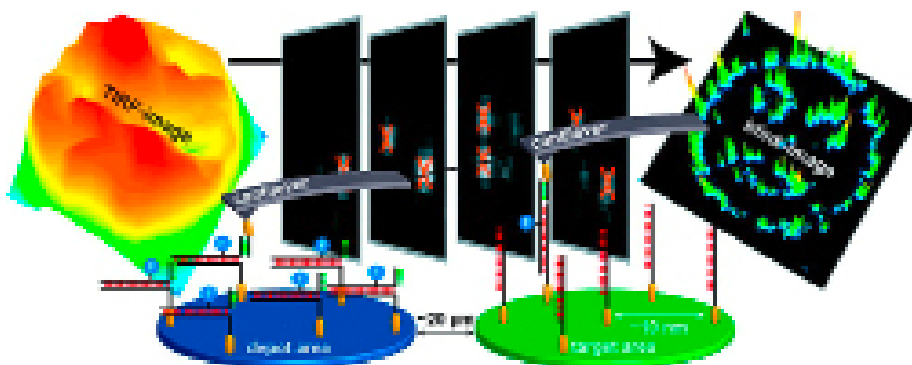
CHARACTERIZING LOCALIZATION-BASED SUPER-RESOLUTION MICROSCOPY USING SINGLE-MOLECULE CUT AND PASTE

Dr. Thorben Cordes (LMU Munich, Faculty of Physics - now at the University of Oxford)

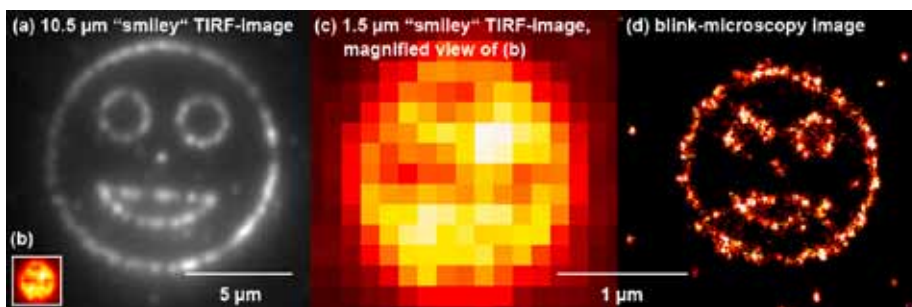
Prof. Hermann Gaub (LMU Munich, Faculty of Physics)

Prof. Philip Tinnefeld (LMU Munich, Faculty of Physics - now at TU Braunschweig)

Short double-stranded DNA is used in a variety of nanotechnological applications, and for many of them, it is important to know for which forces and which force loading rates the DNA duplex remains stable. Actual single-molecule force spectroscopy and recently developed theories even allow for the prediction of the rupture-force distribution for a given DNA duplex sequence and separation velocity. With this knowledge the AFM-based molecule-by-molecule assembly (single-molecule cut-and-paste, SMCP) approach was developed: Individual DNA strands are picked up and deposited on a target surface. This, requires a well elaborated molecular force hierarchy and pre-functionalized surfaces with DNA strands complementary to those that were to be picked up and then deposited.



Recent developments in single-molecule imaging also enabled scientists to overcome the fundamental resolution limit imposed by optical diffraction (≈ 200 nm). Scientists from the groups of Hermann Gaub and Philip Tinnefeld used the super-resolution technique "Blink-Microscopy" to resolve nanoscale patterns. These patterns are difficult to resolve by other techniques because they are soft (hard to resolve by scanning probe techniques) and small (difficult to resolve with diffraction limited optical techniques). The patterns were assembled with single-molecule cut-and-paste. Artificial line patterns then served as calibration structures to characterize parameters, such as the labelling density, that can influence resolution of Blink-Microscopy besides the localization precision of a single molecule. Finally, the adjustability of blink parameters was used to demonstrate the general connection of photophysical parameters with spatial resolution and acquisition time in super-resolution microscopy. The development of highly parallel molecular force essays is expected by the combination of these results and techniques.



Images of patterns assembled by single-molecule cut-and-paste: (a) TIRF-image of a $10.5 \mu\text{m}$ diameter smiley (~ 650 transport-DNA labeled with the fluorophore Cy3) and (b) TIRF image of a $1.5 \mu\text{m}$ diameter smiley from another experiment as inset (~ 125 transported DNA labeled with the fluorophore ATTO655). Scale bar for both panels (a/b) is $5 \mu\text{m}$. (c/d) Magnified TIRF image and corresponding reconstructed super-resolution image of the smiley from inset panel (b) with $1.5 \mu\text{m}$ diameter; please note the smaller size of the scale bar of $1 \mu\text{m}$ corresponding to panels (c/d).

Thorben Cordes, Matthias Strackharn, Stefan W. Stahl, Wolfram Summerer, Christian Steinhauer, Carsten Forthmann, Elias M. Puchner, Jan Vogelsang, Hermann E. Gaub, Philip Tinnefeld: "Resolving Single-Molecule Assembled Patterns with Super-Resolution Blink-Microscopy", *Nano Letters* 10, 645-651 (2010)

Cordes: <http://www.physics.ox.ac.uk/users/cordes/>

Gaub: <http://www.biophysik.physik.uni-muenchen.de/>

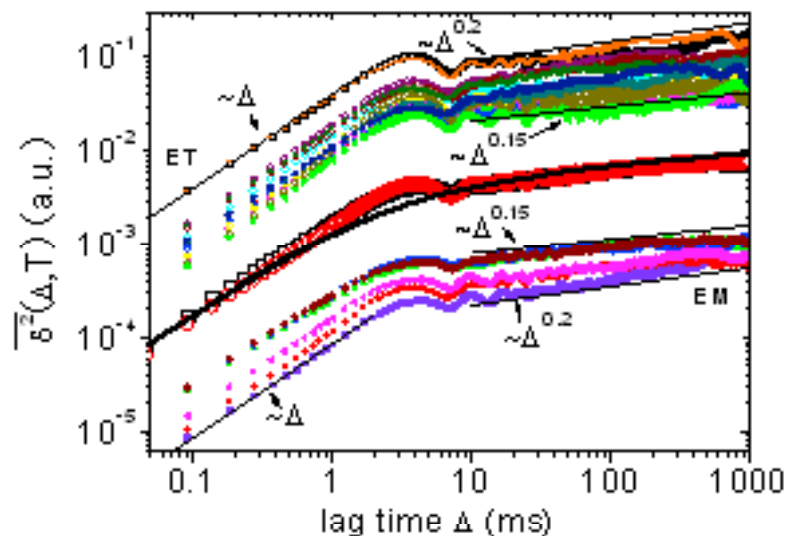
Tinnefeld: <http://www.tu-braunschweig.de/pci/forschung/tinnefeld/people/tinnefeld>

SINGLE PARTICLE TRAJECTORIES IN COMPLEX SYSTEMS

Prof. Ralf Metzler (TU Munich, Department of Physics)

Prof. Fritz Simmel (TU Munich, Department of Physics)

Single particle tracking methods in living cells reveal an increasing number of examples of anomalous diffusion of passively moving molecules and tracers such as RNA, telomeres, DNA loci, lipid granules, or viruses. We study theoretically the behaviour of time averaged quantities such as the mean squared displacement (MSD) for anomalous diffusion. Comparison with experimental data show non-ergodic, non-stationary behaviour at shorter times, as well as ergodic forms of anomalous diffusion at longer times. For anomalous diffusion processes with diverging characteristic time scales free anomalous diffusion leads to a linear growth of the time averaged MSD in contrast to the sublinear growth of the ensemble averaged MSD. Moreover, under confinement the time averaged MSD does not saturate but turns over to a shallower power-law. MSD curves of individual trajectories exhibit pronounced scatter. Such strange behaviour could be identified for the motion of lipid granules in living yeast cells. We also study different forms of anomalous diffusion mechanisms in conjunction with experimental single particle trajectories.



Time averaged mean squared displacement of lipid granules in living fission yeast cells, measured at Early Telophase (ET) and Early Metaphase (EM). The red and black lines in the middle represent the averages over the different single trajectories. The thick black line represents a numerical solution of our anomalous diffusion model. Interestingly, the time averaged mean squared displacement shows a turnover from a linear growth to a power-law with exponent around 0.15 to 0.20. See Jeon et al, PRL 106, 048103 (2011).

S. Burov, R. Metzler, and E. Barkai, Aging and non-ergodicity beyond the Khinchin theorem, Proc. Natl. Acad. Sci. USA 107, 13228 (2010).

V. Tejedor, O. Benichou, R. Voituriez, R. Jungmann, F. Simmel, C. Selhuber-Unkel, L. Oddershede, and R. Metzler, Quantitative analysis of single particle trajectories: Mean maximal excursion method, Biophys. J. 98, 1364 (2010)

Metzler: <http://users.physik.tu-muenchen.de/metz/index.html>

Simmel: <http://www.e14.ph.tum.de/>

SINGLE MOLECULE MECHANICAL STUDIES OF MYOSIN MOTOR PROTEINS

Prof. Claudia Veigel (LMU Munich, Department of Cellular Physiology)

ENERGY TRANSFER IN LAYERED HYBRID ORGANIC/INORGANIC NANOCOMPOSITES

Dr. Andrey Lutich, Prof. Jochen Feldmann (LMU Munich, Faculty of Physics)

Prof. Andrey Rogach (City University of Hong Kong, Department of Physics)

Prof. Fernando D. Stefani (University of Buenos Aires, Physics Department)

The efficiency of energy transfer in hybrid organic/inorganic nanocomposites based on conjugated polymers and semiconductor nanocrystals is strongly dependent on both the energy transfer rate and the rate of the nonradiative recombination of the polymer. The polymer nonradiative recombination can be reduced by the suppression of exciton

diffusion via proper morphology engineering of a hybrid structure. In the layer-by-layer assembled nanocomposite of a conjugated polymer and CdTe nanocrystals the layers of CdTe nanocrystals have a dual role: first, they are efficient exciton acceptors and, second, they reduce nonradiative recombination in the polymer by suppressing exciton diffusion across the layers.

A. A. Lutich, A. Pöschl, G. Jiang, F. D. Stefani, A. S. Susha, A. L. Rogach, J. Feldmann; Efficient energy transfer in layered hybrid organic/inorganic nanocomposites: A dual function of semiconductor nanocrystals, Appl. Phys. Lett. 96, 083109 (2010).

Lutich, Feldmann: <http://www.phog.physik.uni-muenchen.de/>

Rogach: <http://www6.cityu.edu.hk/cfp/>

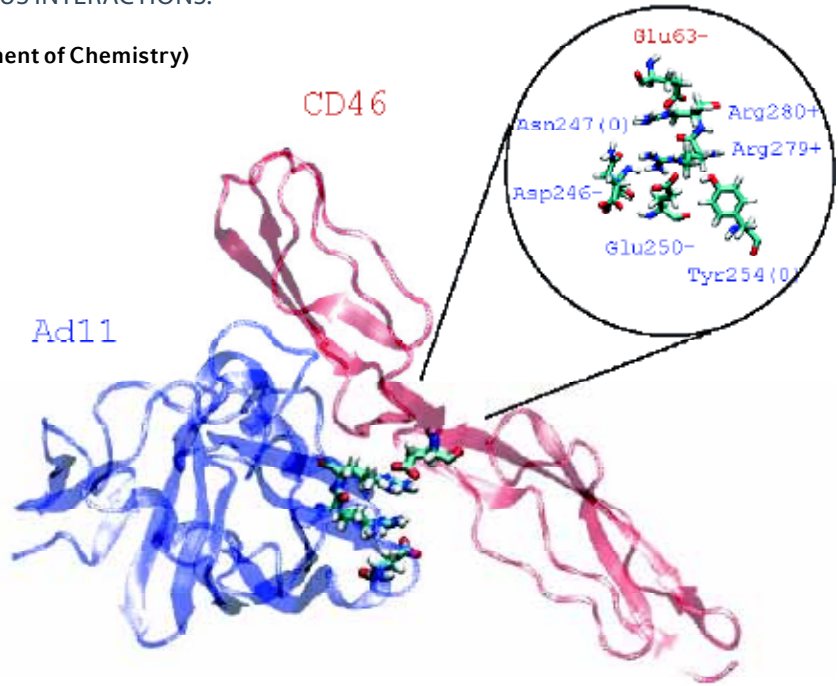
Stefani: <http://nanomaterials-photonics.df.uba.ar/>

Complex forms of cellular motility, including cell division, organelle trafficking or signal amplification in the auditory system, require strong coordination of the myosin motors involved. The most basic mechanism of coordination is via direct mechanical interactions of individual motor heads leading to modification of their mechano-chemical cycles. Here we used an optical trap-based assay to investigate the reversibility of the force-generating conformational change (power stroke) of single myosin-V motor heads. By applying load to the head shortly after binding to actin, we found that at a certain load the power stroke could be reversed and the head fluctuated between an actin-bound pre- and a post-power stroke conformation. This load-dependent mechanical instability might be critical to coordinate the heads of processive, dimeric myosin-V. Non-linear response to load leading to coordination or oscillations amongst motors might be relevant for many cellular functions.

QUANTUM-CHEMICAL INSIGHTS INTO CELL-VIRUS INTERACTIONS:
A DOUBLY-CHARGED ARGININE KEY

Prof. Christian Ochsenfeld (LMU Munich, Department of Chemistry)

Can a stable protein complex comprise a stacked pair of two positively charged arginines in direct proximity? Or is a neutralised arrangement favored? What is the influence of various amino acids or mutations upon binding properties? Modern quantum chemistry can provide valuable answers to such questions which are often difficult to be resolved on purely experimental grounds. The study of such large molecular systems with more than 1000 atoms by quantum-chemical ab-initio methods became only recently possible by the development of new methods that allow to reduce the strong polynomial increase of the computational effort for standard quantum-chemical methods to linear, which is a special focus of the Ochsenfeld group. Examples for applying these new methods include the study of RNA catalyzed reactions, of various DNA systems, but also the study of cell-virus interactions which is the focus of the present work. Here, we consider the attachment complex of an adenovirus (Ad11) to its cellular receptor (CD46). As earlier studies point out [B. D. Persson et al, J. Virol. 83, 673 (2009)], a stacked arginine pair arrangement at the inter-protein surface plays a key role in the formation of a stable complex. Here, it appears surprising that two positively charged residues at a distance of about 4 Å take part in a stable protein complex. In order to gain closer

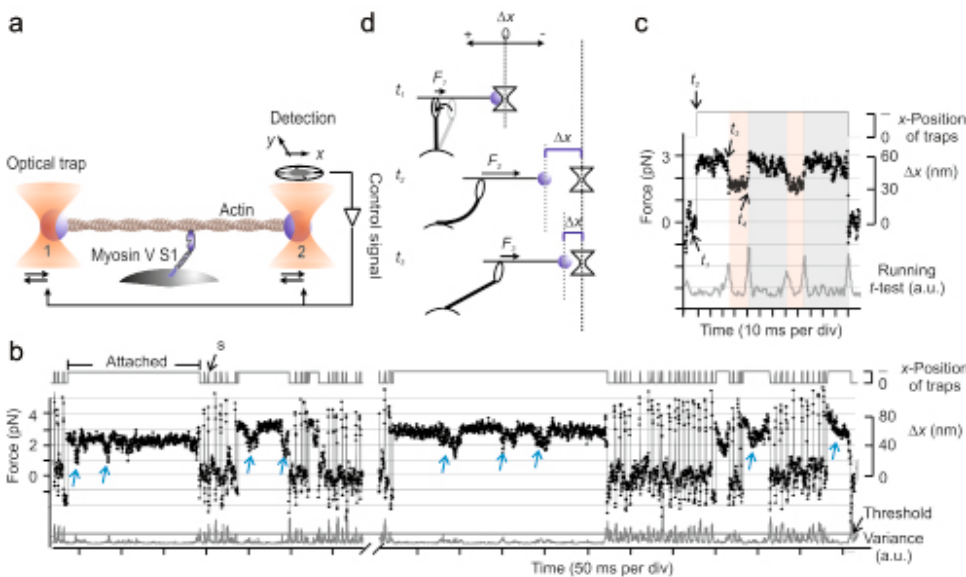


sights we studied various tautomeric forms by means of quantum-chemical calculations, which indicate that the zwitterionic tautomer seems the most stable one, being stabilised by an intricate network of electrostatic effects and hydrogen bonds. Furthermore, the quantum-chemical calculations allow for deeper insights into the binding mode of the virus and how it is influenced by mutations.

The Ad11/CD46 complex with its pivotal arginine pair and its stabilizing microenvironment.

C. V. Sumowski, B. B. T. Schmitt, S. Schweizer, and C. Ochsenfeld: Quantum-Chemical and Combined Quantum-Chemical/Molecular-Mechanical Studies on the Stabilization of a Twin Arginine Pair in Adenovirus Ad11; Angew. Chemie 122, 10147 (2010).

<http://www.cup.uni-muenchen.de/pc/ochsenfeld/>



(a) Single motor heads of the molecular motor myosin-V (myosin-V S1) are attached to the surface of the experimental chamber. They are interacting with an actin filament suspended between two polystyrene beads held in optical traps. The mechanical interactions of the motor with the actin filament are monitored 'on-line' using 4-quadrant photodiodes at millisecond temporal and nanometre spatial resolution. The detection of myosin binding to actin at this high time resolution can be used to control the position of the optical traps. This way, load can be applied to the motor very rapidly after binding has been detected and the mechanics of a single motor head can be studied under a range of loads. (b) Displacements produced by a myosin motor at different resisting forces. (c) In a typical binding event initial binding and conformational change in $+\Delta x$ direction occurred around time point t_1 . Load was applied at time t_2 and at t_3 a negative displacement (see also blue arrows in Fig 1b) occurred, consistent with a reversal of the force generating conformational change (power stroke) of the motor. This is followed by a positive displacement at t_4 . (d) The cartoon shows the sequence of trap displacement and bead movement when force is applied. The experiment shows for the first time that a single cytoskeletal motor head can be forced to move in backward direction under load.

J.R. Sellers and C. Veigel, Direct observation of the myosin-Va power stroke and its reversal, Nature Structural and Molecular Biology 17, 590-595 (2010)

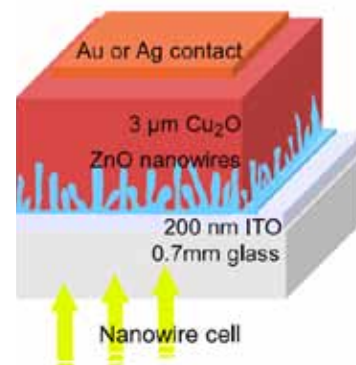
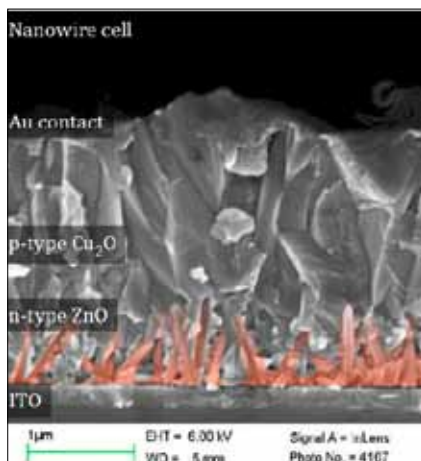
Veigle: http://www.cell.physiol.med.uni-muenchen.de/research_gr/veigell/index.html

STRONG EFFICIENCY IMPROVEMENTS IN ULTRA-LOW-COST INORGANIC NANOWIRE SOLAR CELLS

Prof. Lukas Schmidt-Mende (LMU Munich, Faculty of Physics)

Prof. Christina Scheu (LMU Munich, Department of Chemistry)

The need for sustainable power generation has encouraged research into a variety of photovoltaic materials and structures, with a greater emphasis being placed on a balance between performance and cost. The stability of many semiconducting oxides relative to other inexpensive solar cell technologies, such as organic and dye-sensitized cells, makes them an attractive alternative. Yet low-cost, non-toxic, inorganic solar cell technologies have received comparatively little attention. The potential to synthesize inexpensive Cu₂O photovoltaics on a variety of supporting substrates with minimal energy input is very attractive, not only for traditional solar panels, but also for the integration of solar cells into consumer products and building materials for energy harvesting applications. The CeNS groups of Professors Lukas Schmidt-Mende and Christina Scheu, together with their collaborator Prof. MacManus-Driscoll from the University of Cambridge, identified poor minority carrier transport as the factor currently limiting the performance of electrodeposited Cu₂O-ZnO solar cells. They successfully employed a nanowire architecture to improve minority carrier collection in these devices, resulting in a significant enhancement of the incident-



photon-to-electron conversion efficiency (IPCE up to 85%). Key to the improvement was the design of a continuous nanowire heterojunction with an abrupt interface for the efficient separation of photogenerated charges. This work represents significant progress in the development of ultra-low-

cost, stable, inorganic solar cells. Scalable, low-temperature, solution-based methods have been developed, which permit control of the nanoscale properties of inexpensive photovoltaic materials and enable considerable efficiency enhancements in this exciting class of devices.

Kevin P. Musselman, Andreas Wisnet, Diana C. Iza, Holger Hesse, Christina Scheu, Judith L. MacManus-Driscoll, Lukas Schmidt-Mende, „Strong efficiency improvements in ultra-low-cost inorganic nanowire solar cells“, *Adv. Mater.* 22, E254 (2010)

Schmidt-Mende: <http://www.hybrid-nanostructures.physik.lmu.de/index.html>

Scheu: <http://www.cup.uni-muenchen.de/pc/scheu/>

NANOSTRUCTURE AND MECHANICS OF MUMMIFIED TYPE I COLLAGEN FROM THE 5300-YEAR-OLD TYROLEAN ICEMAN

Dr. Alexander Gigler (LMU Munich, Department of Earth and Environmental Sciences)

Prof. Wolfgang Heckl (TU Munich, Department of Physics & TUM School of Education & Deutsches Museum)

Prof. Robert Stark (TU Darmstadt, Center of Smart Interfaces)

Priv.-Doz. Albert Zink (European Academy of Bozen (EURAC), Institute for Mummies and the Iceman)

Skin is the anatomic outer shielding of the human body. Its structure and function are fundamentally owed to the main component of connective tissue, the fibril protein collagen. Even in its mummified state the skin retains its protective function with collagen playing an eminent role. To draw insights into the mummification process and the preservation of the 5300 years old Neolithic glacier mummy the Iceman, the structural and molecular

integrity of its skin collagen was investigated in an CeNS collaboration work between Dr. Albert Zink from the Institute for Mummies and the Iceman of the European Academy Bolzano (EURAC), Dr. Wolfgang Heckl from the Deutsches Museum, and scientists from the LMU research group of Dr. Robert Stark. They examined the nano- and molecular structure of collagen samples with non-invasive analysis techniques such as atomic force microscope

imaging and Raman spectroscopy. Both techniques revealed that the mummy skin collagen was similar in geometry and molecular structure to recent samples. All samples showed banding patterns characteristic for collagen, and their Raman spectra featured no significant modifications. Nanoindentation measurements however indicated an increased Young's modulus of the mummy collagen, suggesting a change in the mechanical behaviour of the fibrils. The researchers explained this finding by dehydration effects. The increase in collagen stiffness was assumed to be caused by a loss of water through freeze-drying. This could have caused the collagen subfibrils to tighten, and to form a more densely packed fibril structure. As a result, a better resistance to decomposition and thus the maintenance of the skins protective function may have been caused.

Janko, M. ; Zink, A. ; Gigler, A. M. ; Heckl, W. M. ; Stark, R. W. Nanostructure and mechanics of mummified type I collagen from the 5300-year-old Tyrolean Iceman. *Proc. Roy. Soc. B*, 277 pp. 2301-2309 (2010).

Gigler: www.kristallographie.geowissenschaften.uni-muenchen.de/personen/wiss_mitarbeiter/gigler

Heckl: www.nano-science.de/

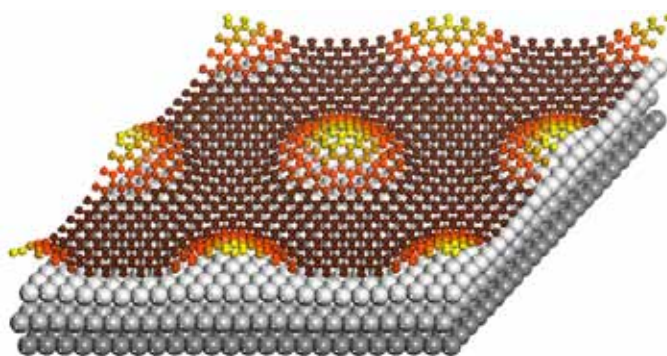
Stark: www.csi.tu-darmstadt.de/staff/mitarbeiterdetails_26752.de.jsp

Zink: www.eurac.edu/staff/azink/default.html

STRUCTURE OF GRAPHENE ON A METAL SURFACE

Prof. Joost Wintterlin (LMU Munich, Department of Chemistry)

Graphene is usually prepared by mechanically “peeling off” single sheets from bulk graphite, a method that leads to well-ordered graphene layers but cannot be scaled up to a mass production process for electronic devices. Alternative ways of synthesizing graphene have the potential for up-scaling, and one of the most promising methods is chemical vapor deposition of hydrocarbon molecules on certain metal surfaces. Recently great progress, as for size and quality of the graphene sheets, has been made by this method. Scientifically, it is surprisingly difficult to understand how graphene interacts with metal surfaces. There have been indications that, depending on the metal, the interactions can be van-der-Waals-like or more covalent, and, by somewhat indirect evidence, that the graphene sheets may remain flat or deform under the influence of these interactions. These ideas could not be confirmed because experimental structure data about these systems had not been available, mainly because the lattice constants of graphene and of the metal supports are usually slightly different, leading to mismatch structures with unusually large unit cells. In the project one of these structures, a graphene overlayer on the hexagonal Ru(0001) surface, was investigated by



Structure model of a graphene layer (C atoms colored) on a Ru(0001) surface (Ru atoms gray). Because of the lattice mismatch and the chemical bonding conditions the graphene deforms, and there is even a small buckling of the top-most metal layers.

a low-energy electron diffraction analysis. The method is standard for surface structures, but, in contrast to x-ray diffraction, one cannot apply ‘direct’ techniques, and it had not been applied before to similarly large unit cells - the graphene sheet and the topmost three Ru layers involve 770 C and Ru atoms. However, the structure could be solved, and the structure parameters are in very good agreement with results of a DFT analysis. The graphene layer

is relatively strongly buckled (by 1.5 angstroms), and the metal-graphene distance varies between typical van-der-Waals distances and shorter distances at which the C atoms interact covalently with metal atoms. Understanding these interactions may help choosing suitable metals and graphene growth conditions, so that the quality of the metal-grown graphene sheets may be further improved.

W. Moritz, B. Wang, M.-L. Bocquet, T. Brugger, T. Greber, J. Wintterlin, and S. Günther, Structure determination of the coincidence phase of graphene on Ru(0001), *Phys. Rev. Lett.* 104, 136102 (2010).

Wintterlin: <http://www.cup.uni-muenchen.de/pc/wintterlin/>

ELECTRICALLY CONTROLLED DNA BONDING TO GOLD SURFACES

Dr. Ralf David, Dr. Ann R. Fornof, Prof. Hermann Gaub (LMU Munich, Faculty of Physics)

DNA is increasingly employed as a programmable building block for nanoscale structures. Self-assembly via specific DNA base-pair recognition allows an unparalleled variety of structures to be formed. The ability to control the interaction of polyelectrolytes, such as DNA or proteins, with surfaces is of pivotal importance for a multitude of biotechnological applications. The development of single-molecule techniques has afforded many new methods for the observation and assembly of supra molecular structures and biomolecular networks. In a first approach single double-stranded DNA molecules, bound to the tip of an Atomic Force Microscope (AFM), are deposited on a bare gold electrode using an electrical trigger

(surface potential cycling). By carefully characterizing the interactions between the DNA and the gold electrode double-stranded DNA was found to chemisorb exclusively at its end through primary amine groups. This finding corroborates experiments in which only a single adenosine nucleotide on a polyethylene glycol spacer was ‘electrosorbed’ to the gold electrode. Furthermore the adhesion of DNA on gold electrodes modified with self-assembled monolayers was biased by the composition of the monolayer and externally controlled by means of the electrode potential: Positive potentials induce DNA adsorption onto OH-terminated electrodes with adhesion forces up to 25 pN (at +0.5 V versus Ag/AgCl), whereas negative potentials sup-

pressed DNA adsorption. The measured contributions of the DNA backbone phosphate charges and the doubly charged terminal phosphate on adsorption agree with a model based on the Gouy-Chapman theory. Experiments on an NH₂-terminated electrode revealed a similar force modulation range of the coulomb component of the desorption force. These findings are important for the development of new DNA-based biochips or supramolecular structures.

M. Erdmann, R. David, A.R. Fornof, H.E. Gaub: Electrically induced bonding of DNA to gold; *Nature Chemistry* 2(9):745-9 (2010).

M. Erdmann, R. David, A.R. Fornof, H.E. Gaub: Electrically controlled DNA adhesion; *Nature Nanotechnology* 5(2):154-9 (2010).

Gaub: <http://www.biophysik.physik.uni-muenchen.de/>

QUANTIZED PHOTOCURRENTS IN NANOSCALE CIRCUITS

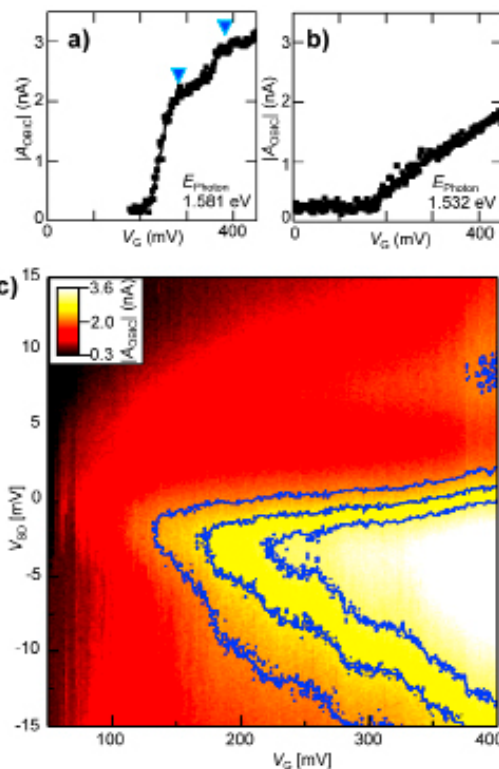
Prof. Peter Hänggi (University of Augsburg, Institute of Physics)

Prof. Jörg Kotthaus (LMU Munich, Faculty of Physics)

Prof. Alexander Holleitner (TU Munich, Walter Schottky Institute)

Quantum wires are one-dimensional constrictions in electronic circuits, and they exhibit a conductance quantized in steps of $2e^2/h$. Here, we verified that also the photocurrent across quantum wires is quantized. We further demonstrated the use of GaAs-based quantum wires to explore the non-equilibrium dynamics of photo-generated charge carriers in nanoscale circuits. In particular, the quantum wires were exploited to spatially resolve and analyze the ballistic flow of photo-generated electrons in a nanoscale circuit. In these experiments, electron-hole pairs are photo-generated in an n-doped quantum well, and the resulting optical beam induced current (OBIC) through an adjacent quantum wire is measured as a function of the laser spot position. The transmission of photo-generated electrons through the quantum wires is governed by the energy dispersion and quantized momentum values of the electron modes in the quantum wire.

(a) Quantized photocurrent across a quantum wire as a function of the gate voltage V_G at a bias voltage $V_{SD} = -5$ meV at 3.4 K and a photon energy E_{Photon} above E_{QW} , the energy of the n-doped quantum well. (b) For $E_{Photon} < E_{QW}$, no steps are detected. (c) Quantized photocurrent as a function of V_{SD} and V_G at 3.4 K and $E_{Photon} = 1.552$ eV. The blue lines correspond to photocurrent steps indicated such as by the blue triangles in Fig. (a).



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THE EFFECT OF INTERNAL AND GLOBAL MODES ON THE RADIAL DISTRIBUTION FUNCTION OF CONFINED SEMIFLEXIBLE POLYMERS

Prof. Erwin Frey (LMU Munich, Faculty of Physics)

Quantifying the statistical properties of biopolymers has been one major goal in polymer physics for decades. Theoretically, many biopolymers may be classified as locally inextensible „semiflexible“ chains, which are characterized through a, compared to the contour length, large persistence length. While, on a single molecule level, the physical properties of such polymers have been well studied in free space, relatively little is known about their statistics in confined environments. Biologically and in the context of technical innovations, however, biopolymers typically live in crowded environments, or they are confined in nar-

row channels within nanofluidic devices, such that confinement, rather than free space, seems to be the natural environment for many scientifically and technically relevant situations.

The present work presents a detailed analytical calculation of the radial distribution function (i.e. the probability distribution associated with the chain's end-to-end distance) of semiflexible polymers in tube-like harmonical confinements and provides an explicit analytical expression for the calculation of the n-th order moment of the end-to-end distance. Special attention is paid to the interplay between

global chain movements and internal degrees of freedom (bending modes) and its effect on the radial distribution function. This work extends a previous calculation of the radial distribution function, which is valid only in the limit of strong confinement (Levi and Mecke, EPL 78, 38001 (2007)), to the case of arbitrary confinement strengths.

The analytical results in this work are tested by comparison to numerical data from Monte Carlo simulations, showing excellent quantitative agreement. In particular, it is shown, that global chain movements may be considered responsible for the formation of a local minimum in the mean end-to-end distance at onsetting confinement - a phenomenon reported previously in studies by means of Monte Carlo simulations.

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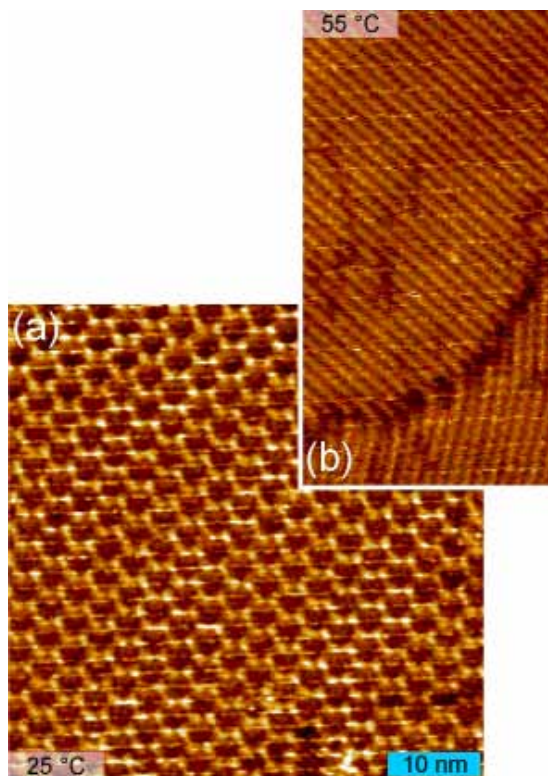
THE INFLUENCE OF TEMPERATURE ON SUPRAMOLECULAR SELF-ASSEMBLY: REVERSIBLE PHASE TRANSITIONS IN MOLECULAR MONOLAYERS

Prof. Wolfgang Heckl (TU Munich, Department of Physics & TUM School of Education & Deutsches Museum)

Priv.-Doz. Dr. Markus Lackinger (LMU Munich, Department of Earth and Environmental Sciences)

This work is the very first report on reversible structural phase transitions of monolayers at the liquid-solid interface. Although many groups worldwide study interfacial supramolecular self-assembly, temperature is a hardly addressed experimental parameter. By means of a home-built heatable sample stage temperature dependent Scanning Tunneling Microscopy experiments became possible and revealed a phase transition from a low temperature nanoporous phase to a high temperature densely packed phase. The transition temperature was found to depend on type of solvent and solute concentration. In order to explain these novel experimental results, a thermodynamical approach was used to identify the driving force of the phase transition. Since the phase transition effectively closes nanopores at higher temperatures, it can be applied for temperature controlled release of guests which were incorporated in the pore.

The aim of this project is to combine instrument development and subsequent usage of the instrumentation for novel experiments. The experimental results were complemented by a theoretical description of the contributions to the free energy to shed light on the thermodynamics of supramolecular self-assembly of monolayers at the liquid-solid interface.



Sequence of STM topographs of a 1,3,5-tris(4-carboxyphenyl)benzene monolayer at the nonanoic acid-graphite interface, obtained at the same position on the sample at different temperatures. For room temperature, an open pore hexagonal structure is observed, while for elevated temperature (~53°C) a phase transition to a more densely packed row structure occurs. In order to demonstrate the reversibility of this phase transition, STM images were alternately acquired at room temperature and above the transition temperature.

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DIPLOMA & MASTER THESES

Matthias Benecke: *Untersuchungen an Quantenpunktkontakten in Hinblick auf die 0.7-Anomalie* (LMU, S. Ludwig); **Martin Ehrensperger:** *Versuche zur Strukturlösung einer Silber-Sauerstoffspezies mit der Methode der LEED-I/V-Analyse* (LMU, J. Wintterlin); **Max Empl:** *Radiofrequenzspektroskopie an tunnelgekoppelten Dreifachquantenpunkten: Pulsexperimente und Charakterisierung* (LMU, S. Ludwig); **Valerie Faessler:** *Manipulation von fluoreszenzresonantem Energietransfer mittels Goldnanopartikel-Nanoresonatoren* (LMU, J. Feldmann); **Simon Geiger:** *Preparation and Diels-Alder reactivity of 3-siloxy-5-methoxy-4-methylpenta-2,4-dienenitrile and its potential use in the total synthesis of naphthomycin K* (LMU, D. Trauner); **Torben Gerke:** *Electrical characterization of vertical silicon electrode devices* (TU Braunschweig, M. Tornow); **Fabian Hanusch:** *Ordered Mesoporous Fullerenol Based Polymers* (LMU, T. Bein); **Daniel Harbusch:** *Untersuchung von Subwellenlängengittern in Vertical Cavity Surface Emitting Lasern* (TUM, A. Holleitner, M.-C. Amann); **Frederik Hetsch:** *Optoelektronische Untersuchungen an kohlenstoffbasierten Nanosystemen* (LMU, A. Holleitner, J. P. Kotthaus); **Florian Mauritius Erasmus Huber:** *I. Synthesis of red-shifted diazene compounds as photochromic, internal blockers of voltage-gated potassium channels II. Progress toward the co-crystallization of the potassium channel Kcs A and photochromic, internal blockers of voltage-gated potassium* (LMU, D. Trauner); **Stephan Hug:** *Towards Chemical Routes for Graphene Production: Synthesis and Characterization of Graphite Oxide* (LMU, B. Lotsch); **Christian Hundschell:** *Strukturelle und optische Charakterisierung von HBC-PDI Doppelschichten für organische Solarzellen* (LMU, B. Nickel); **Markus Jahn:** *Untersuchung der Struktur und Chaperonaktivität des Hitzeschockproteins 90 mit Einzelmolekülmethoden* (TUM, T. Hugel); **Silke Kirchner:** *Mikrofluidische Erzeugung von Phospholipidvesikeln und deren optische Untersuchung* (LMU, J. Feldmann); **Martin Kuehn:** *Implementation of biological models in radiation therapy treatment planning software* (TUM, R. Metzler); **Dominik Lembke:** *Towards Plasmonics in Nanostructured Organic Solar Cells* (LMU, L. Schmidt-Mende); **Svenja Lippok:** *Thermophoretic Immunology* (LMU, D. Braun); **Victor Ruiz Lopez:** *DFT calculations of transition metal oxide interfaces* (U. of Augsburg, PD. Dr. R. Pentcheva); **Florian Lohse:** *Single Molecular Force Spectroscopy on Aminoacids bonded to Gold* (LMU, A. Fornof, Gaub); **Frederik Morgenstern:** *Silver nanowire films as transparent electrodes in hybrid solar cells* (University of Cambridge/LMU, R. Friend, L. Schmidt-Mende); **Simon Noever:** *In Situ Characterization of Ambipolar Organic Field Effect Transistors* (LMU, B. Nickel); **Martin Olbrich:** *Towards Oligomeric and Polymeric Twistane Structures* (LMU, D. Trauner); **Lukas Ost:** *Kontrolliertes Wachstum von Kohlenstoffnanoröhrchen für optomechanische Experimente* (LMU, J. P. Kotthaus); **Tom Pfeiffer:** *Photoporation von Phospholipid-Membranen mit Goldnanopartikeln* (LMU, J. Feldmann); **Jens Prescher:** *Establishment and Optimization of Super-Resolution Fluorescence Microscopy for Multi-Colour Studies of Biological Systems* (LMU Munich, D. C. Lamb, S. Ivanchenko); **Bernhard Rimpfl:** *Die Dynamik von indirekten Exzitonen in elektrostatisch definierten Potentiallandschaften in GaAs/AlGaAs-Doppelquantentöpfen* (LMU, J. P. Kotthaus); **Rebecca Saive:** *Optoelektronische Kopplung von photonischen Kristall-Wellenleitern*



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Beckman Coulter, Inc.

BMW AG

Boston Consulting Group (BCG)

Corimmun GmbH

Crelux GmbH

d-fine GmbH

Deutsch-Israelische Projektkooperation

Dr. Klaus Römer-Stiftung

European Union Framework Programme 7

- **European Research Council (ERC):** *Starting and Advanced Grants*
- **Marie-Curie Intra-European Fellowship**
- **Coordination Action:** *SMALL-4, GAMBA MACAN*
- **Future and Emerging Technologies Open Scheme:** *QNEMS*
- **Initial Training Network:** *ICARUS*

European Science Foundation (ESF)

Excellence Initiative of the German Federal Government and the State Governments (Clusters of Excellence)

- **CIPSM:** *Center for Integrated Protein Science Munich*
- **NIM:** *Nanosystems Initiative Munich*
- **MAP:** *Munich-Centre for Advanced Photonics*

Federal Ministry of Education and Research (BMBF)

Friedrich Baur Stiftung

German Academic Exchange Service (DAAD)

German-Israeli Foundation (GIF)

German Research Foundation (DFG):

- **Collaborative Research Centers (SFB):** *631, 646, 749, 863, 870*
- **SFB/Transregio:** *12, 80*
- **Individual Grants (Einzelförderungen)**
- **Priority Programmes (SPP):** *1121, 1145, 1175, 1236, 1243, 1253, 1313, 1362, 1464, 1495, 1506*
- **Research Units (Forschergruppen):** *801, 917, 1279, 1394, 1406*

Human Frontier Science Program

International Bureau of the BMBF

LMU Center for Advanced Studies (CAS)

- **Research Fellowships**

LMU**excellent**

LMU**innovativ**

- **Bioluminescence Network Munich**
- **Functional Nanosystems**

National Institutes of Health (NIH), USA

National Science Foundation (NSF), USA

Novartis Pharma GmbH

Robert Bosch Foundation

Roche Diagnostics GmbH

Stiftung Industrieforschung

Stiftung der Deutschen Wirtschaft

Studienstiftung des deutschen Volkes

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