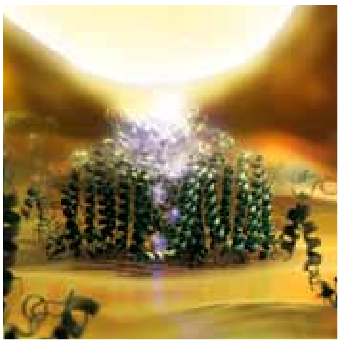
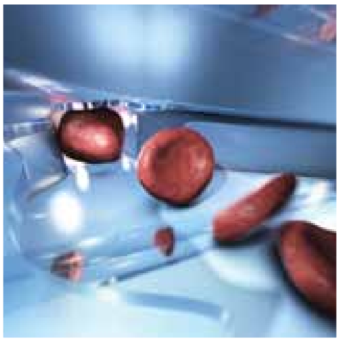
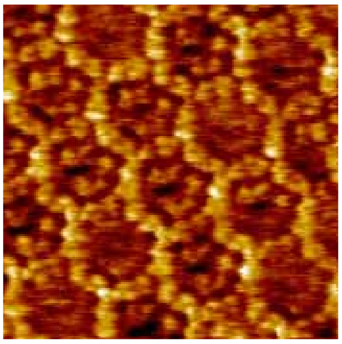
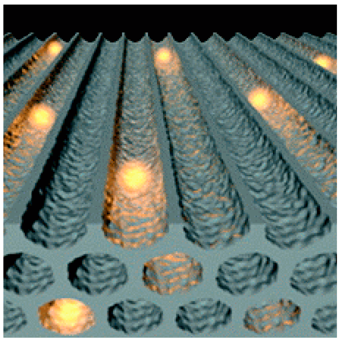
Center for NanoScience

ANNUAL REPORT 2012









CeNS
Center for NanoScience | LMU

ANNUAL REPORT 2012

CONTENTS

WELCOME

2012 was an exceptionally successful year for the nanosciences in Munich. First of all, the reader will find fine examples of the vivid and fruitful scientific collaborations within CeNS in this annual report. As always, we can present only a selection of the over 250 publications that came out of CeNS in 2012. Since mid-2012, a new Collaborative Research Centre (SFB1032) "Nanoagents for Spatiotemporal Control of Molecular and Cellular Reactions", initiated by CeNS members from LMU, TUM and the Max Planck Institute of Biochemistry, is funded by the DFG. Moreover, the Nanosystems Initiative Munich (NIM) was granted funding for five more years within the second round of the German Excellence Initiative. A great success! The CIPSM excellence cluster and the newly founded graduate school "Quantitative Biosciences" (QBM) were also successful. CeNS members are involved in each of these initiatives. In addition, the Bavarian Initiative "Soltech: Solartechnologies go hybrid" was launched with a total of 50 million euro funding. The Soltech initiative was tied to an agreement to finance a new research building for the NIM cluster and energy research on the former campus of the veterinary clinics at the English Garden. This is the first time that a building dedicated to nanoscience is to be built at the LMU – a milestone for the Center for NanoScience too!

This issue will also report from our annual conference in Venice, which this time was held under the slogan "Nanosciences: Soft, Solid, Alive and Kicking". At the conference, a special session was dedicated to Jörg Kotthaus, who retired at the end of the year. As the guiding spirit and long-time spokesman of CeNS, Jörg Kotthaus made a tremendous contribution to the success of CeNS. He has inspired many of us to work and do research in the field of nanoscience and shaped the culture of CeNS. The idea of a center entirely based on deliberate participation and bridging between disciplines is as ingenious as it is fruitful and created a place where we enjoy science. Sincere thanks to Jörg for 14 years of shaping CeNS!

We owe just as much gratitude to Hermann Gaub for his continuous work as spokesman of the CeNS board over the past six years. He did a great job in fostering the special spirit of CeNS. Thanks to his efforts, CeNS successfully expanded its network character with innovative formats like the Junior Nanotech Network on a global scale. Thank you Hermann!

Among numerous activities, CeNS organized a new "Junior Nanotech Network" (JNN), an exchange program for graduate students with the CNSI Santa Barbara under the guidance of Tim Liedl and Deborah Fygenson. The positive feedback from the PhD students demonstrates how much stimulation is derived from such programs. For this reason CeNS decided to continue many of the achievements of the International Doctorate Program "NanoBioTechnology", which ended at the end of last year. In particular, a board of CeNS student representatives was formed that will contribute actively to the management of CeNS graduate activities.

CeNS appreciates and supports the emergence of entrepreneurial opportunities in the field of nanoscience, and we have witnessed the founding of more than 12 spin-off companies over the last 15 years. Last year we had the pleasure of congratulating Nanion, one of CeNS' very first spin-offs, on their 10th anniversary. Furthermore, several prestigious business awards for CeNS spin-offs impressively demonstrate the success of these companies in 2012.

Last but not least we would like to thank the CeNS management team Susanne Hennig (managing director), Marilena Pinto (program manager) and Claudia Kleylein (team assistant) for their commitment and continuous support.

Prof. Joachim O. Rädler
Spokesman of the Scientific Board of CeNS

NEWS & EVENTS

NEW MEMBERS

DR. BORIS JOVANOVIC

LMU Munich

Dr. Boris Jovanovic received his PhD in Toxicology with a co-major in Fisheries Biology from Iowa State University (ISU) in 2011 in Ames, USA. After the PhD, Dr Jovanovic worked as a Postdoctoral Research Fellow at the University of British Columbia Fisheries Centre as part of the Sea Around Us Project. In June 2012, Boris was appointed as Research Group Leader at LMU's Faculty of Veterinary Medicine. His main research interests are in the areas of aquatic ecotoxicology, aquatic ecosystems & environmental health, as well as nanotoxicology. His current research includes investigations on how environmentally relevant concentrations of nanoparticles modulate immune responses in fish models and how such immunocompromised fish respond to the pathogen infections.

DR. JESSICA RODRÍGUEZ-FERNÁNDEZ

LMU Munich

Dr. Jessica Rodríguez-Fernández studied Chemistry at the University of Vigo (Spain), where she graduated with Honors in 2004. In the same year she joined the Colloidal Chemistry Group of Prof. Luis M. Liz-Marzán (University of Vigo) for her PhD as a fellow of the Spanish Ministry of Science (FPU fellow). Her PhD focused on the synthesis, reactivity and optical studies of gold nanoparticles of various shapes. During her PhD Jessica was also a visiting researcher for several months at the Nanoscience Group of Prof. Paul Mulvaney (University of Melbourne, Australia) and the Soft Condensed Matter Group of Prof. Jan K. Dhont (Institute of Solid State Research, Jülich Forschungszentrum, Germany). In September 2008 Jessica was awarded her PhD and in November 2008 she joined the Photonics and Optoelectronics Group (PhOG) of Prof. Jochen Feldmann (Physics Department & CeNS, LMU Munich) as a postdoctoral researcher. Since July 2009 Jessica heads the chemistry laboratory and since April 2011 she has been group leader of "Functional Nanoparticles & Nanostructures" research at PhOG. Her research interests span functional nanoparticles, hybrid nanocomposites, nanostructures and functional assemblies with appealing optical properties for applications ranging from optics, to photocatalysis, photovoltaics or biology.

PROF. OLIVER LIELEG

TU Munich

Professor Oliver Lieleg carries out research on biopolymer-based hydrogels such as the extracellular matrix, mucus or bacterial biofilms. The main focus of this research is the dual properties of these biomaterials including their mechanical properties and the regulation of the passive transport of particles and molecules through these hydrogels. After completing undergraduate studies in biophysics at TUM, Professor Lieleg worked with Professor A. Bausch and completed his PhD in cellular biophysics in 2008. A scholarship awarded by the German Academic Exchange Service, DAAD, enabled him to work with Professor K. Ribbeck as a postdoctoral researcher at the FAS Center for Systems Biology at Harvard University (2009). Between 2010 and 2011 he worked as an instructor in the Department of Biological Engineering at Massachusetts Institute of Technology, USA. Since fall 2011 he has directed the biomechanics research group at the Institute of Medical Engineering (IMETUM) as an associate professor.

PROF. PETER MÜLLER-BUSCHBAUM

TU Munich

Professor Peter Müller-Buschbaum carries out research on semi-conducting and photoactive polymers as well as inorganic-organic hybrid materials for applications in photovoltaics. His further research interests are Nanostructured Polymer Films and Functional Polymer Materials. After completing his undergraduate studies and his PhD in physics at the University of Kiel, he was a postdoctoral fellow at the Max Planck Institute of Polymer Research, Mainz. In 1997, Peter Müller-Buschbaum was a visiting scientist at Institut Laue-Langevin (ILL) and the European Synchrotron Radiation Facility (ESRF), Grenoble (France). In 1999, he became group leader of the "Polymer Interface Group" at the chair of Prof. Petry, Physics Department, TU Munich. Professor Müller-Buschbaum received his habilitation in experimental physics at TU Munich in 2003. Since 2006, he has been a full professor (Chair of Functional Materials) at the Physics Department of TU Munich.

CALLS

Dina Fattakhova-Rohlfing was appointed as an interim professor (W2) for Advanced Materials Science at the Chemistry Department of LMU Munich.

Thomas Franke accepted an interim professorship at the Institute for Physics, Augsburg University.

Manfred Ogris received a call from Vienna University (Austria) for a professorship in Pharmaceutical Sciences at the Faculty of Pharmacy.

Eva Weig accepted a call as a full professor (W3) in experimental physics at the University of Konstanz and declined a call for a full professorship in experimental solid state physics at the Georg-August-Universität Göttingen.

AWARDS 2012

ERC GRANTS

Prof. Thomas Bein (LMU) received an ERC Advanced Grant for his project "Electroactive Donor-Acceptor Covalent Organic Frameworks".

Prof. Alexander Holleitner (TUM) won an ERC Consolidator Grant for his research project "Real-time Nanoscale Optoelectronics".

Prof. John Lupton (Uni Regenburg) was awarded an ERC Starting Grant for his research proposal "Molecular Mesoscopics for Organic Nano-Opto-electronics".

MISCELLANEOUS

Prof. Patrick Cramer was awarded the Federal Cross of Merit (Bundesverdienstkreuz), the Paula und Richard von Hertwig-Preis, and the Vallee Foundation Visiting Professorship.

Prof. Hendrik Dietz received the Hoechst-Dozentenstipendium.

Prof. Jochen Feldmann was elected as a member of the Leopoldina.

Prof. Peter Hänggi became an elected member of the ERC-panel PE13 (statistical physics and condensed matter).

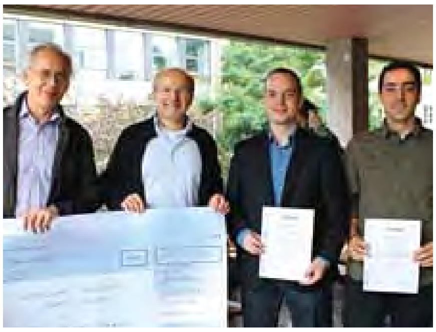
PD Dr. Markus Lackinger won the publication award of the Deutsches Museum in the research category.

Prof. Christian Ochsenfeld was honored by the Mulliken Lecture 2012 at the University of Georgia, USA .

Prof. Ernst Wagner was elected as a member of the Scientific Advisory Board of the Controlled Release Society (CRS). In addition, he received a 2012-13 senior visiting scholarship from Fudan University (Shanghai).

ATTOCUBE-WITTENSTEIN AWARD

In 2012, outstanding junior scientists from CeNS were honored with the atto**cube**-WITTENSTEIN award for the third time. The award is donated by the CeNS spin-off company atto**cube** systems AG and its partner WITTENSTEIN AG and recognizes PhD theses and Master's theses that demonstrate outstanding scientific accomplishments and innovative ideas with potential impact on industrial applications. The happy winners were announced at the CeNS summer party following the annual event "CeNS meets Industry" on July 20. **Dr. Christian Dohmen** was the successful winner in the category "PhD thesis" with 5,000 EUR prize money. In his thesis entitled "Precise and multifunctional conjugates for targeted siRNA delivery" he developed a target-specific, oligomer-based system for the transport of innovative drugs. The supervising laboratory, i.e. **Prof. Ernst Wagner**'s group, received 10,000 EUR for their contribution to the successful thesis.



Prof. Khaled Karrai (left) from attocube presented the attocube research awards to M.Sc. Adriano de Andrade Torrano (1st from right), Dr. Christian Dohmen (2nd from right) and Prof. Ernst Wagner.

In the category "Master's thesis", **Adriano de Andrade Torrano** from the lab of Prof. Christoph Bräuchle was honored and took home a check for 2,500 EUR. In his thesis within the ERASMUS-Mundus Master's program "Functionalized Advanced Materials and Engineering", Adriano developed the quantitative image analysis software "Nano_In_Cell_3D", which can be used for rapid and precise quantification of nanoparticle uptake in live cells. The winners were chosen by a jury composed of professors from CeNS and a representative from atto**cube** systems.

www.cens.de/research/attocube-research-award/

CENS PUBLICATION AWARD

Each year, CeNS awards prizes for excellent publications by CeNS members that have been published during the past twelve months. This award recognizes successful cooperation projects within CeNS as well as outstanding research by individual research groups from CeNS. The CeNS board had a hard time selecting the 21 winning publications from the numerous submitted articles which appeared in high-impact journals between October 2011 and October 2012.

Katrin Schneider, Prof. Christoph Bräuchle and Prof. Heinrich Leonhardt won one of the CeNS publication awards 2012 for their joint publication in Advanced Functional Materials.

Successful CeNS internal collaboration projects, such as those between the groups of Prof. Tim Liedl, Prof. Friedrich Simmel and Prof. Alexander Högele or between Prof. Heinrich Leonhardt, Prof. Thomas Bein and Prof. Christoph Bräuchle, were amongst those who received an award. In addition, outstanding articles from individual research groups which were published in renowned journals such as Nature, Nature Physics, PNAS or ASC Nano were recognized. The announcement of the winners took place at the CeNS Come-Together-Event in November.

www.cens.de/research/cens-publication-award

The CeNS band "UnCeNSiert" playing at the CeNS Come-Together Event 2012.

NEASPEC

"Trusted to deliver cutting-edge solutions for nanoscale optical imaging & spectroscopy for research laboratories in industry and academic institutions" - this is Neaspec's credo. The company has developed the NeaSNOM microscope that was launched in 2009. NeaSNOM combines the nanoscale resolution of atomic force microscopy (AFM) with the analytical power of visible, infrared and even THz imaging & spectroscopy and thus opens a new era for modern nano-analytical applications. During the past four years, Neaspec has been rapidly expanding globally and now serves numerous scientists in highly regarded research laboratories on four continents.

How and when was Neaspec founded?

Neaspec GmbH was founded in 2007 as a spin-off from the Max Planck Institute of Biochemistry. Three of the four founders had been working together in the same laboratory. For more than a decade, they had successfully developed the basic physics of near-field microscopy and established a unique international standing in infrared nanoplasmonics.

What role did the Max Planck Institute play in the foundation of Neaspec?

The director of the Max Planck Institute gave the founders ample freedom and constructive support to help them obtain and exploit a BMBF grant explicitly for research toward a spin-off. Personal connections to CeNS members helped the founders to acquire business skills, in particular, how to deal with IP and licensing, obtain a Bavarian startup grant, and write a business plan. The formation of an LMU-led excellence cluster came at just the right time, as it provided the funds for Neaspec's first customer.

What products does Neaspec sell?

Neaspec develops and distributes the NeaSNOM microscope, a near-field optical microscope which has a spatial resolution far better than the diffraction limit, 20 nm independently of the wavelength, which makes it the first commercial nanoscope that can work in infrared. It combines the best of two worlds – the nanoscale resolution of atomic force microscopy (AFM) with the analytical power of infrared imaging & spectroscopy, requiring standard AFM sample preparation only. This opens a new era for modern nano-analytical chemistry. As the method also works in the visible and THz spectral ranges, other cutting-edge applications such as nano-plasmonic field mapping (VIS & IR) or free charge carrier nano-mapping (THz) are also possible.

Who are your main customers and how large is your market?

Neaspec's main customers are nano-material research scientists in academic institutions and industry labs. The scientists employ the NeaSNOM microscope in diverse disciplines such as chemistry, polymer science, semiconductor technology and even life science. The total available market for the NeaSNOM microscope is estimated to be about 250-500 million euro.

How many employees work for Neaspec at present?

Neaspec currently employs 15 highly skilled employees. But this is just a snapshot, as Neaspec is a fast growing start-up.

How important are the contacts to academic institutions like CeNS for you?

As our main customers are mainly nano-material research scientists, the contacts to CeNS are extremely valuable for Neaspec. On the one side as direct customers, but more importantly to discover new application potential for our technology. Moreover, CeNS also serves as the primary source for Neaspec's future employees. Therefore we welcome the association with CeNS.

Extraordinary CeNS member Dr. Fritz Keilmann, member of the board of directors at Neaspec (left), and CeNS alumnus Dr. Stefan Schiefer, CEO of Neaspec (right)

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

Learning by doing! The founders had records of writing and selling patents, of working with postdocs who started businesses of their own, and of running small business activities besides their research. Chats at trade shows were most valuable first experiences in understanding what a market is at all, and its central role in business. In general, you have to build up a good business network quickly in order to be successful, so that you can quickly learn from topic experts and other entrepreneurs, e.g. other CeNS start-ups. So you shouldn't be shy and you should always consult experts when setting up and running a business. The first step is of course always to write a business plan that you should send to experts for feedback. This can mean either approaching experts who you know personally or taking part in a business plan contest like the Munich Business Plan Competition. And if you are lucky to have what's called "good business sense", then the rest is just learning by doing.

In your opinion, which were/are the most challenging tasks when setting up and running a company?

For high-tech start-ups, the most challenging task is to gather a highly motivated and skilled start-up team. A perfect product can be of no value if you don't have the right team. Also a realistic business plan and a careful liquidity management are key success factors. So always watch your cash!

What are your major goals for the future?

Our vision is a very simple "A NeaSNOM in every nano-analytical lab". That said, we will continue to rapidly expand globally to serve researchers and scientists in highly-regarded research labs around the world.

What would be your most important advice for researchers on their way to becoming an entrepreneur?

In life you usually regret the things you did not do. So if you have a good idea, just do it. And if you decide to do so, always consult experts and go find a good team. - From the scientist's point of view, you do not know the definition of what is a good idea. This is your basic barrier which keeps you from starting a business. The best thing you can do is to make friends with someone who runs a business but whom you respect as a scientist. Try your idea out on him.

Answers by Dr. Fritz Keilmann and Dr. Stefan Schiefer.

Contact:
Neaspec GmbH
Bunsenstr. 5
D-82152 Martinsried (Munich), Germany

Tel.:+49 89 787 939 78
E-mail: info@neaspec.com
Website: *www.neaspec.com*

SPIN-OFF NEWS

ATTOCUBE

Attocube won the 2012 **R&D magazine 100 award** for their attoFPS. Called the "Oscars of Innovation", the R&D 100 Awards recognize and celebrate the top 100 technology products of the year. Attocube's FPS3010 - Real Time Interferometric Sensor is a high-bandwidth optical displacement sensor with sub-meter range and the ability to read target position variations at the picometer level.

www.attocube.com

NANOTEMPER

NanoTemper was awarded the **German Innovation Award 2012** for being Germany's most innovative start-up company. The prize was awarded for the MST technology that NanoTemper introduced in 2010. NanoTemper's Monolith instruments rapidly convinced users around the world in basic research as well as pharma and biotech companies. To date, hundreds of scientist use the technology which allows them to carry out experiments that were not possible before. The second big success for NanoTemper was winning the **STEP Award 2012**. In addition, NanoTemper's Monolith was awarded the world wide renowned **red dot award**. In combination with this award, the instrument was also awarded the predicate "Best of the best 2012" which is only given to a few products each year. "This prize recognizes the unusual design and high quality of our Monolith series instruments" said extraordinary CeNS member Dr. Philipp Baaske, CEO of NanoTemper Technologies.

www.nanotemper.de

ETHRIS

After having closed a series A financing round with the QureInvest II funds which is managed by HS LifeSciences in December 2011, ethris moved to fully equipped lab and office space in Martinsried at the beginning of 2012. Since then, ethris has made major progress in the development of messenger RNA therapies, so-called transcript therapies, for bone regeneration and hereditary diseases. At the end of 2012 ethris closed a first research and development deal with the international pharma company Shire.

www.ethris.com

IBIDI

For the fourth year in a row, ibidi, a supplier of products used for analyzing living cells, has received an award from the **"Deloitte Technology Fast 50"** competition. The Fast 50 is an award program that honours companies that demonstrate exceptional business growth, technological innovation, and entrepreneurial spirit. The program ranks the 50 fastest-growing technology companies in Germany, based on their percentage of revenue growth over a five-year period. ibidi is the only Life Science company to be listed. ibidi also received a **"BEST OF" Industry Award 2012** for their µ-Slide Chemotaxis with a top 10 ranking in this category, out of more than 500 total applicants. The µ-Slide Chemotaxis allows optical analysis of the movement of chemotactically active cells and aids research to discover effective agents, e.g. for cancer therapies.

www.ibidi.de

NANION

In 2012, Nanion celebrated its **10th anniversary**. In 2002, Nanion Technologies started out as a CeNS spin-off in a small loft at the Institute of Physiology of LMU Munich. Since then, Nanion has grown from 2 to 40 employees and has successfully launched and established four different product families for ion channel drug discovery and research. Nanion is a strongly innovation-driven company and had several new product launches in 2012.

www.nanion.de

STS NANOTECHNOLOGY

Gold nanohelices are now commercially distributed as chiral markers for electron microscopy tomography applications. The products can be obtained through STS Nanotechnology, a CeNS spin-off, and a large German provider of electron microscopy supplies, Science Services, which is led by the extraordinary CeNS member Stefan Schöffberger.

www.sts-nano.com
www.scienceservices.eu

EVENTS & ACTIVITIES

CENS WORKSHOP VENICE 2012

"Nanosciences: Soft, Solid, Alive and Kicking" - this was the motto of the annual CeNS workshop in 2012 on the island of San Servolo, Venice. The program committee, i.e. Dina Fatthakova-Rohlfing, Peter Hänggi, Alexander Holleitner, Tim Liedl and Claudia Veigel, drew up an impressive schedule with renowned speakers from all over the world (Eli Barkai, Vincent Croquette, Deborah Fygenson, Alexander Govorov, Donald Ingber, Sigmund Kohler, Frank Koppens, Klaus Kroy, Alexander Kuhn, Tom Mallouk, Justin Molloy, Daniel Robert, Omar Saleh, Todd Squires, Ulrich Steiner, and Sarah Tolbert), covering a wide range of topics from bionanoscience, nanomaterials, optoeletronics and hybrid technologies to quantum phenomena. In addition, senior and junior researchers from CeNS and NIM (Viola Baumgärtel, Immanuel Bloch, Enrico Da Como, Erwin Frey, Alexander Högele, Hubert Krenner and Joost Wintterlin) provided fascinating insights into their work. PhD students and master's students, including Junior Nanotech Network participants from Munich and Santa Barbara, presented and held a lively discussion of their latest results during the two poster sessions.

A special session, including talks by Gerhard Abstreiter, Günther Bauer, Valeri Dolgopolov and Mansour Shayegan, was dedicated to Jörg Kotthaus, who retired in 2012. The subsequent reception with a cheerful speech by Achim Wixforth and music from the CeNS band "UnCeNSiert", together with the enchanting atmosphere of the island of San Servolo made this a memorable evening for all participants.

www.cens.de/calendar/past-workshops-events/venice-2012/

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 4:30 to 5:30 p.m. either on the LMU main campus or at the Chemistry Department in Großhadern.

www.cens.de/calendar/cens-colloquium

FOCUS WORKSHOPS

Several focus workshops organized by CeNS members were supported by CeNS in 2012. In May, Prof. Hermann Gaub organized the one-day workshop "Probing and Manipulating Biomolecules: From Single Molecules to an Ensemble" with colleagues from CeNS, Bayreuth, Tel Aviv University and Ben Gurion University.

In October, CeNS member Prof. Don Lamb hosted a "Workshop on Advanced Fluorescence Methodologies" at LMU for five days. The workshop was a collaboration with the Laboratory of Fluorescence Dynamics (University of California, Irvine) and was comprised of advanced theoretical lectures, computer based training on data analysis and simulations and hands-on laboratory training.

CeNS also supported the PhD symposium <interact2012> which took place in March 2012. <interact>, organized entirely by PhD students from LMU, TUM and the Max Planck Institutes, has firmly established itself as a great event for PhD students in the field of life sciences. Each year, CeNS associates participate actively in the program.

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

Participants of the workshop "Probing and Manipulating Biomolecules: From Single Molecules to an Ensemble"

SCIENCE ROCKS!

Each Thursday at 5:45 p.m. during the semester, PhD students from 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 nanosciences.

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

KEY QUALIFICATION WORKSHOPS

CeNS supported its associates with several key qualifications workshops. A workshop on International Publishing was organized together with the IDK NanoBioTechnology in March 2012. To acquire the necessary skills to start their own business and to broaden their entrepreneurial skills, CeNS PhD students and postdocs had the opportunity to attend a two-day workshop, which introduced them to the basic principles of business management and economics. In addition, CeNS associates took the chance to join the three-day Entrepreneurship Seminars organized by the LMU Entrepreneurship Center in March and October 2012.

www.cens.de/calendar/past-workshops-events/
www.entrepreneurship-center.uni-muenchen.de

MUNICH SCIENCE DAYS

The 12th Munich Science Days (October 20-23, 2012) dealt with the subject “Sustainability - Basis of our Future”. Together with the Nanosystems Initiative Munich, CeNS presented the topic “Sustainable with Nano” to the public over the four days. Continuing the theme, PhD students and postdocs from the CeNS and NIM groups of Prof. Jochen Feldmann, Prof. Hermann Gaub and Prof. Katharina Krischer presented research projects about e.g. nanosystems for energy conversion or designer cellulosomes for future biofuel production from wood and waste. Nanoexperiments for kids, interesting exhibits like an AFM model, a sometimes tricky nano quiz and most of all the enthusiasm of the junior researchers when explaining their projects made the CeNS/NIM booth a center of attraction for visitors.

www.muenchner-wissenschaftstage.de/2012/

CENS MEETS INDUSTRY

As every year, CeNS invited representatives and alumni from industry and various business sectors to present their company and employment opportunities to the junior reserachers of CeNS. In 2012, CeNS organised a very diverse program with representatives from the publishing sector, the European Space Agency, a CeNS spin-off, and CeNS alumni working in large and medium-sized companies.

In his talk “A career with the ESA materials investigators - the role of failure analysis in space system“, Dr. Tommaso Ghidini from the European Space Research & Technology Centre gave exciting insights into the work of ESA and opportunities for nanoscientists. Dr. Rosamund Daw from Nature presented the job of an editor with its pros and cons. Her talk was followed by CeNS member Dr. Valentin Kahl, who explained the twists and turns on the way from research to market for CeNS spin-off ibidi. Perspectives in an international, technology-driven company were given by CeNS alumnus Dr. Alexander Gigler, who described his career path from Physics via Geosciences to Sensor Applications at Siemens Corporate Technology. The program ended with a talk by another CeNS and IDK alumnus: Dr. Manfred Walter spoke about polymer electronics at PolyIC GmbH, a company that develops smart and flexible printed solutions.

The event was followed by the traditional CeNS summer party. Despite not very summerlike temperatures, the CeNS band “UnCeNSiert” infected the guests with good vibrations. A highlight was the presentation of the attocube awards 2012 (see page 9). As always, the summer party was a great opportunity for discussions between CeNS members, speakers, guests and alumni.

www.cens.de/calendar/past-workshops-events/cens-meets-industry-2012/

PARENTS IN SCIENCE

Initiated by IDK program manager Marilena Pinto in 2012, CeNS and NIM have started to establish get-togethers for reseachers with children. The get-togethers are intended to serve as a place for discussions between young parents in a relaxed and child-friendly atmosphere, to provide parents-to-be with role models and to help young parents to stay in contact with other scientists in order to facilitate their return to work after maternity leave. The event attracts not only young mothers but also young fathers and fathers-to-be.

JUNIOR NANOTECH NETWORK (JNN) 2012

For the fourth time, CeNS organized a Junior Nanotech Network (JNN), a bilateral exchange program for PhD students. The aim of this program is to exchange knowledge of world class nanoscience and nanobioscience between graduate students from different institutions worldwide. This time, the JNN was initiated by Prof. Tim Liedl and Prof. Alexander Holleitner (CeNS) and by Prof. Deborah Fygenson (CNSI), financially supported by the Bavaria California Technology Center (BaCaTeC).

The first part of the JNN 2012 was coordinated by members of the California Nanosystems Institute (CNSI). It was held from March 19 to April 6 at the University of California, Santa Barbara (UCSB). Ten PhD students from LMU Munich, TU Munich and the University of Augsburg were able to enjoy the vivid scientific atmosphere and high-quality research environment at UCSB as well as spectacular views of the Santa Ynez Mountains and the Pacific Ocean surrounding the university campus. The program included an experimental part, in which the German PhD students chose scientific modules of interest and gained hands-on experience of the projects carried out by the UCSB students. Each module was designed to have a theoretical introduction to the ongoing project and a set of experiments to test the proposed scientific hypothesis and see the state-of-the-art equipment. The students could get a perspective on the variety of possible projects in different fields of nanotechnology: learn techniques such as micro- and nanofluidics and optical tweezers, DNA nanotubes and DNA origami, design RNA-based nanorings and test DNA-based biosensors *in vivo*, synthesize the polymers for the artificial membranes and much more.

All students presented their own research projects during a one-week symposium at CNSI and got feedback on their obtained results from professors of UCSB and LMU. In addition, they also heard invited talks from different speakers. Apart from the vivid scientific interaction during the symposium, the students and the professors discussed topics such as career planning and women in science in a relaxed and friendly atmosphere. Of course, during the weekends the students also had a chance to enjoy the pleasant climate of California: they tasted Californian wine at famous wineries, hiked in the spectacularly beautiful Channel Islands National Park, enjoyed the stunning views along the coastline of Big Sur, and visited Monterey and Los Angeles.

During the second part of the JNN (September 10-28, 2012), the participants from UCSB visited CeNS. After a Bavarian welcome breakfast on their first day, the students visited most of the involved labs at TUM and LMU and decided on their lab projects for the upcoming weeks. The first week in Munich was then dedicated to lab rotations: small groups of two or three Californian students visited their German hosts and performed hands-on experiments in the labs on topics such as thermophoretic quantification of biomolecule concentration and affinity, live recording of the conformational dynamics of single proteins by FRET, single molecule cut&paste and much more. The second week brought another highlight of the program: All students took part in the CeNS workshop “Nanosciences – Soft, Solid, Alive and Kicking” on the beautiful island of San Servolo. The students presented their projects in two poster sessions. In addition, there was ample opportunity for discussions with speakers and other participants in a charming Mediterranean atmosphere.

After their return to Munich, the students continued with their second week of lab rotations and used the opportunity to learn about very different topics at the LMU Physics and Chemistry Departments, TUM Physics Department and Medical Faculty, Deutsches Museum or the University of Augsburg. Beside the scientific program, the Californian students also enjoyed a barbecue with students and supervisors, a tour of the New Technologies Center at the German Museum, a trip to Neuschwanstein and the vivid atmosphere of the Oktoberfest. Strong ties between German and Californian students were established not only by these educational and social activities but also by the unusual housing concepts, since private accommodation for all guests was provided by the host students. The JNN 2012 was a true scientific as well as social success for all participants and will certainly help to deepen existing collaborations and to establish new co-operations between CeNS and CNSI Santa Barbara.

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

INTERNATIONAL DOCTORATE PROGRAM NANOBIOTECHNOLOGY

NanoBio Technology
INTERNATIONAL DOCTORATE PROGRAM

The International Doctorate Program "NanoBioTechnology" (IDK-NBT) ended in October 2012 after eight years of funding by the Elite Network of Bavaria, but its impact on graduate education at CeNS was exceptional. The program was intended to educate young students in Nano(bio)technology, to broaden their minds and to create a place of communication between the disciplines of biology, chemistry and physics. In this sense, the IDK-NBT was a great success. The structures and practices built up within the IDK, such as the co-supervisor system, a lecture series and soft skills training, but also international recruitment using an online application tool were trendsetting. Moreover, the commitment of the students in actively shaping the program was outstanding, thanks also to the great efforts of IDK program manager Marilena Pinto. The IDK also established the annual election of student representatives who - jointly with the IDK board - organized most of the IDK events. Many features of the IDK will now be continued by CeNS, e.g. student-initiated workshops, an international call for applications or the election of CeNS student representatives.

BIONANOSCIENCE - FROM BASICS TO INTERDISCIPLINARITY

At the IDK Summer School 2011, the idea for a workshop to get a general understanding of topics covered within the IDK was born. Due to the high number of active and committed IDK members an organizing committee was quickly formed, and volunteers for the presentation of selected topics were easily found. The four talks gave either a sound practical insight based on the speakers' experience (e.g., microfluidics) or a broad, general overview of the topic, like "Principles of cell and molecular biology", "The Phenomenon of fluorescence and its most common applications" and "Mechanisms underlying solar cells" along with cutting edge solutions in that field. For the seven speakers, the workshop was a great opportunity to present their area of expertise in a form that could be easily understood by a general audience. The workshop was also open to all CeNS associates and generated a lot of interest and lively discussions.

Due to its great success, as second workshop following the same principle was organized in December 2012, covering new topics such as "Labelling techniques", "Surface Functionalization" and "Bio-lab Experiments".

IDK-NBT FINAL SYMPOSIUM

In July 2012, IDK members, supervisors, IDK alumni and guests from CeNS gathered for a final IDK event in Herrsching at Lake Ammersee. The symposium started with opening remarks about the Doctorate Program from IDK Spokesman Prof. Joachim Rädler, who was followed by Dr. Beate Lindner (Elite Network of Bavaria), and Dr. Isolde von Bülow (GraduateCenter^{LMU}). Prof. Helmut Grubmüller (MPI for Biophysical Chemistry Göttingen), a member of the Advisory Board of the IDK, then gave a fascinating opening lecture about "Energy barriers and driving forces of tRNA translocation through the ribosome" and made more general comments on setting-up, managing and continuing PhD programs. The following three sessions covered three different research fields represented within the IDK: DNA nanotechnology, protein nanotechnology and photovoltaic/solar cells. Despite their different scientific backgrounds, all speakers had something in common: They were all connected to the IDK, be it as IDK supervisors (Prof. Thomas Bein, Prof. Lukas Schmidt-Mende, Prof. Philip Tinnefeld), as IDK alumni (Prof. Tim Liedl, Dr. Hanna Engelke) or as a member of the selection committee (Prof. Dietmar Martin). In addition, IDK members Stephan Heucke, Kamila Klamecka and Ida Pavlichenko gave interesting insights into their work. The poster session in the afternoon provided further opportunities for scientific discussions.

On the second day, the participants divided into three groups for soft-skills workshops on "How to deal with difficult situations" and "Working in teams". The day finished with a remarkable and often very amusing intercultural workshop in which international IDK members presented special topics about their home countries. The last day of the symposium was dedicated to a workshop: "Ethics: dilemmas faced in science and technology". This part of the symposium was organized in collaboration with members of the Bioethics Research Training Group from the University of Tübingen. The introductory talks provided a solid basis for the intense discussions during the three breakout sessions.

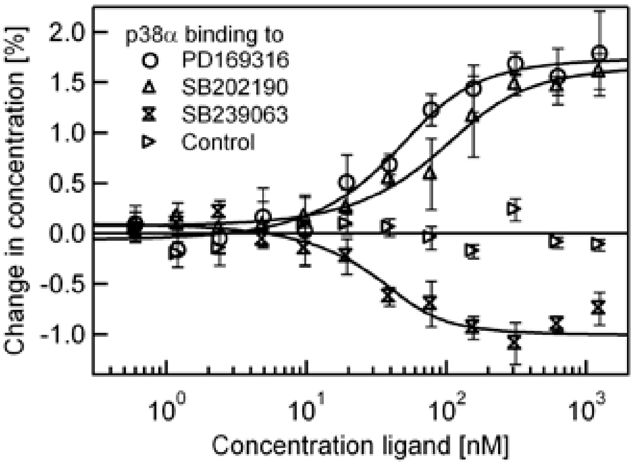
The symposium finished with a session on "The Future of the IDK - what should be preserved?" with IDK members, IDK management and the IDK spokesman. All participants agreed that, in addition to the interdisciplinary scientific exchange within the IDK, numerous structural achievements of the program should be continued.

SELECTED RESEARCH PROJECTS

LABEL-FREE DETECTION OF BINDING USING THERMOPHORESIS

Dr. Philipp Baaske, Dr. Stefan Duhr (NanoTemper Technologies GmbH) *www.nanotemper-technologies.com*
Prof. Dieter Braun (LMU Munich, Faculty of Physics) *www.biosystems.physik.uni-muenchen.de*
Prof. Dirk Trauner (LMU Munich, Department of Chemistry) *www.cup.uni-muenchen.de/oc/trauner*

The movement of molecules in a thermal gradient can be used to measure the strength of binding. This is the basis of the recent startup company NanoTemper at the Center for NanoScience. In the Braun lab we continued to develop the method towards new applications. This method of Microscale Thermophoresis (MST) allows for quantitative analysis of protein interactions in free solutions and with low sample consumption. In a recent addition to the method, protein intrinsic UV-fluorescence can be utilized thus allowing for label-free MST analysis. Its flexibility in assay design qualifies MST for biomolecular interaction analysis in complex experimental settings, which we herein demonstrate by addressing typically challenging types of binding events from various fields of life science.



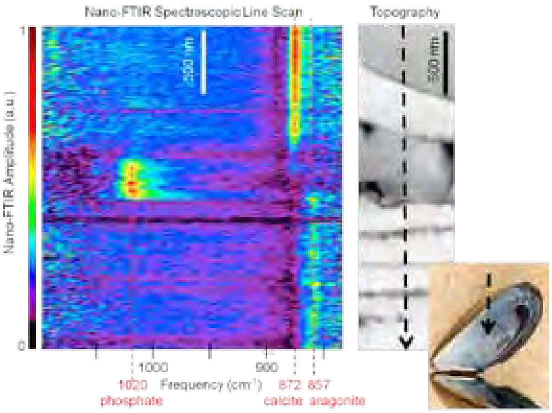
Label-free Thermophoresis. By using the intrinsic tryptophane label, the binding of proteins to pharmaceutical compounds can be quantified by thermophoresis. The differential movement of the proteins in a thermal gradient is a function of the binding mode of the small molecules. This allows the competitive probing of binding sites.

S.A.I. Seidel, C.J. Wienken, S. Geissler, M. Jerabek-Willemsen, S. Duhr, A. Reiter, D. Trauner, D. Braun and P. Baaske: *Label-Free Microscale Thermophoresis discriminates sites and affinity of protein binding;* Angewandte Chemie International Edition 51(42), 10656-10659 (2012)

INFRARED NANOSCOPY OF BIOMINERALS

Dr. Fritz Keilmann (LMU Munich, Faculty of Physics) *www.attoworld.de/SharedPages/People/KeilmannFritz/KeilmannFritz.html*
Prof. Wolgang Schmahl (LMU Munich, Department of Geosciences) *www.kristallographie.geowissenschaften.lmu.de*

Methods for imaging of nanocomposites based on X-ray, electron, tunneling or force microscopy provide information about the shapes of nanoparticles; however, all of these methods fail on chemical recognition. Neither do they allow local identification of mineral type. In contrast, infrared near-field microscopy - a method developed within CeNS - solves these requirements at 20 nm spatial resolution, highlighting, in its first application to natural nanostructures, the mineral particles in shell and bone. "Nano-FTIR" spectral images result from Fourier-transform infrared (FTIR) spectroscopy combined with scattering scanning near-field optical microscopy (s-SNOM). On polished sections of Mytilus edulis shells we observe a reproducible vibrational (phonon) resonance within all biocalcite microcrystals, and distinctly different spectra on bioaragonite. Quite remarkably, previously unknown 20 nm thin nanoparticles are discovered featuring distinctly different spectra that are characteristic of crystalline phosphate (see figure). Multicomponent infrared phosphate bands are investigated in a nanoscopic study of human tooth sections. These spectra vary characteristically near tubuli in dentin, proving a chemical or structural variation of the apatite nanocrystals. The infrared band strength correlates with the mineral density determined by electron microscopy. Since nano-FTIR sensitively responds to structural disorder it is well suited for the study of biomineral formation. Thus nano-FTIR is generally suitable for the analysis and identification of composite materials in any discipline indeed, from nanoelectronics to even the clinical investigation of osteopathies.



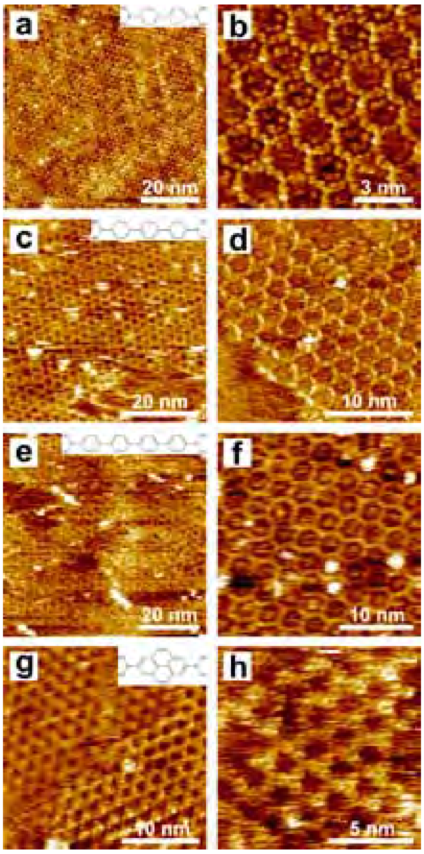
Nanoscopy of a polished cross section of a mussel shell. The AFM topography (right) displays individual crystals whose general shape appears changed in the lower half. To reveal their chemical nature 300 infrared spectra were recorded along the dashed line, in 50 min, and displayed (left). Prominent infrared resonances positively identify them as calcite crystals in the outer (upper region), and aragonite crystals in the inner "nacre" part of the shell. Quite surprisingly, a 10-nm thin, ca. 300 nm wide crystal flake with distinctly different infrared resonance is discovered about midway, identified as phosphate.

S. Amarie, Paul Zaslansky, Y. Kajihira, E. Griesshaber, W.W. Schmahl, and F. Keilmann: *Nano-FTIR chemical mapping of minerals in biological materials;* Beilstein J. Nanotechol. 3, 312 (2012)

ON-SURFACE SYNTHESIS OF STRUCTURALLY VERSATILE TWO-DIMENSIONAL COVALENT ORGANIC FRAMEWORKS BY REVERSIBLE POLY-CONDENSATION OF BORONIC ACIDS

PD Dr. Markus Lackinger and Prof. Wolfgang Heckl (TU Munich, Department of Physics, TUM School of Education and Deutsches Museum) www.2d-materials.com/
Prof. Thomas Bein (LMU Munich, Department of Chemistry) http://bein.cup.uni-muenchen.de

In a previous study the groups of Lackinger and Bein reported on the synthesis of two-dimensional covalent organic sheet materials through the on-surface self-condensation of diboronic acids. In this proof of principle study, a straightforward synthesis protocol was developed based on the monomer 1,4-benzenediboronic acid serving as a model compound. In further studies, a more general applicability of the synthesis protocol was demonstrated by extending the range of suitable monomers to a series of para-diboronic acids ranging from benzenediboronic acid to quaterphenyldiboronic acid. All compounds yield two-dimensional covalent organic frameworks (COF), with lattice parameters (pore sizes) ranging from 1.5 nm (1.0 nm) to 3.8 nm (3.2 nm). The demonstrated tunability of pore sizes is an important requirement for applications. A detailed study of temperature thresholds for the thermally activated polymerization on the molecular level revealed distinct differences for the monomers studied, where the polymerization temperature increases with monomer size. Additional studies of non-covalent self-assembly indicated stable self-assembled monolayers only for sufficiently large diboronic acid monomers with enhanced molecule-surface interaction. This provides evidence that interactions with the surface can play an important role for polycondensation reactions on surface. In addition, it was demonstrated that also diboronic acids with an aromatic pyrene core are suitable monomers for 2D COF synthesis. Corresponding bulk COFs were already shown to have interesting optic and electronic properties that renders them suitable for applications. The research cooperation could show that pyrene-2,7-diboronic acid is an equally suited monomer for the synthesis of 2D COFs with aromatic backbone.

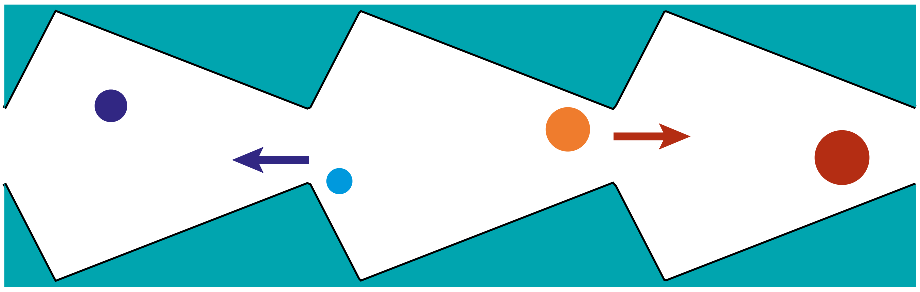


STM images of 2D COFs derived from polycondensation of the following monomers: biphenyldiboronic acid; terphenyldiboronic acid; quaterphenyldiboronic acid; 5, pyrene-2,7-diboronic acid. The chemical structures of the respective monomers are depicted in the insets.

J.F. Dienstmaier, D. Medina, M. Dogru, P. Knochel, T. Bein, W.M. Heckl, and M. Lackinger: *Isoreticular Two-Dimensional Covalent Organic Frameworks Synthesized by On-Surface Condensation of Diboronic Acids;* ACS Nano 6, 7234 (2012)

ENTROPIC SPLITTER FOR PARTICLE SEPARATION

Prof. Peter Hänggi (University of Augsburg, Institute of Physics) www.physik.uni-augsburg.de/theo1/hanggi



Nanoparticles in two-way-traffic

Speed, convenience, and accuracy: these are the most important features of a good analytic device. Currently, a variety of instruments already exist which are able to detect even very faint traces of a given substance. But in all existing methods there remains the potential for improvement. Recently, a team around Professor Peter Hänggi from the University of Augsburg and Professor Jose Miguel Rubi from the University of Barcelona developed a very accurate process to separate DNA fragments of different sizes. To do this, they took advantage of several entropy potentials of the particle dynamics. Computer simulations demonstrate that this is the reason why the particles divide go in two directions. Furthermore the calculations demonstrate that the new technique can reach a degree of purity of 99,9 percent - a significant improvement on other common methods.

D. Reguera, A. Luque, P. S. Burada, G. Schmid, J. M. Rubi, and P. Hänggi: *Entropic splitter for particle separation;* Phys. Rev. Lett. 108, 020604 (2012)

ANOMALOUS DIFFUSION IN LIPID BILAYERS

Prof. Ralf Metzler (University of Potsdam, Institute of Physics and Astronomy and Physics Department, Tampere University of Technology, Finland) www.agnld.uni-potsdam.de/~metz/rmetzler.html

Double layers of lipid molecules form the backbone of biological membranes, hosting a variety of other molecules such as protein channels or cholesterol molecules, among many others. In such bilayers the lipids are arranged quite densely. Thus, while lipid bilayers above their critical temperature are liquids, the motion of a single lipid becomes significantly affected by the crowded environment. We performed an extensive molecular dynamics simulations study of lipid bilayers of different chemical composition. Using single trajectory analysis of individual lipid molecules, we observe pronounced anomalous diffusion of lipids. While in pure lipid systems above the transition temperature this anomalous diffusion turns over to normal diffusion at very short times of a few nanoseconds, the presence of cholesterol significantly enhances the regime of anomalous diffusion, clearly stretching beyond the time scale of 100 nanoseconds limited by the simulations. Moreover, for pure lipid bilayers below the critical temperature, the subdiffusion is even more pronounced, and also persists beyond 100 nanoseconds. Our detailed stochastic analysis demonstrates that in all investigated cases: pure lipids above the critical temperature, lipids with cholesterols, and pure lipids below the critical temperature, the motion of the lipids is governed by the same stochastic mechanism. Thus the lipid motion follows the generalised Langevin equation with power-law correlated noise. This mechanism is known to emerge as effective one-particle description in viscoelastic media. The extended occurrence of subdiffusion in lipid bilayer systems and the observation of a unique stochastic behaviour will be instrumental for future studies of the dynamics of lipid membranes. In particular, we expect that, consistent with recent single molecule tracking experiments, anomalous diffusion in natural bilayers will be even more relevant, due to the pronounced disorder in the presence of various molecule types of significantly different sizes.

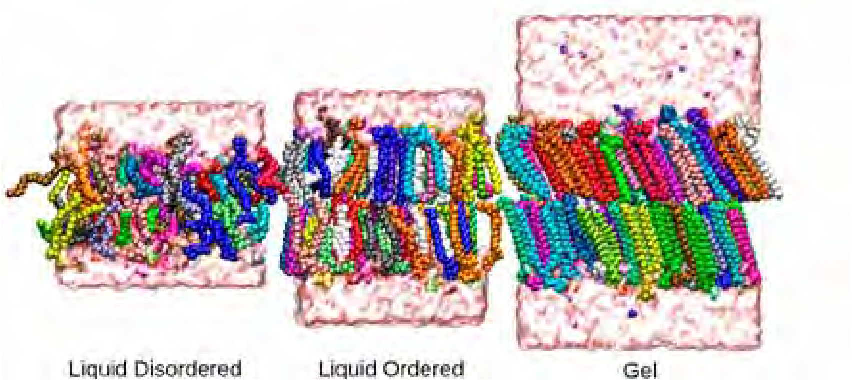


Fig. 1: Final configurations of simulations of DOPC bilayer at 338 K (Left), DOPC and cholesterols at 338 K (Middle), and DSPC at 310 K (Right) in the liquid disordered, liquid ordered, and gel phases, respectively (note the difference in packing states). Each color represents a different phospholipid. Explicit water molecules correspond to the upper and lower transparent coatings. Cholesterols appear in white (Middle), Na$^+$ and Cl$^-$ ions as blue spheres (Right).

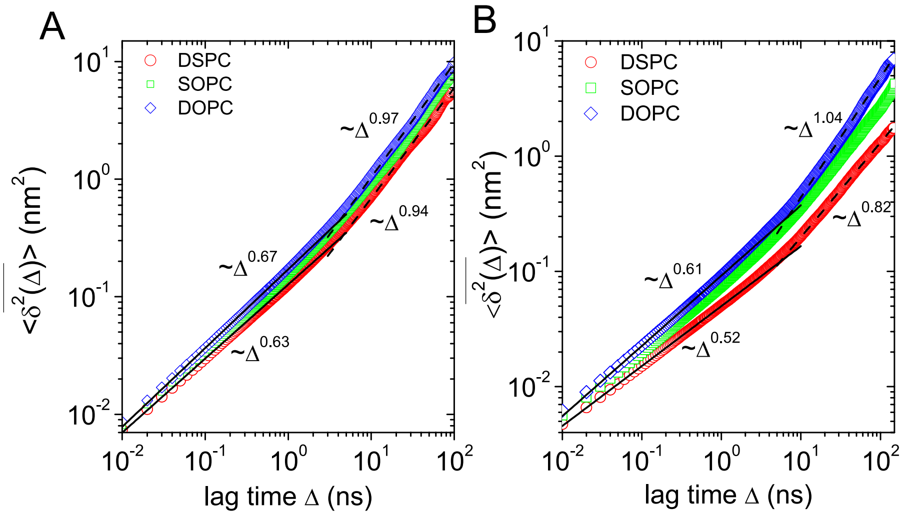


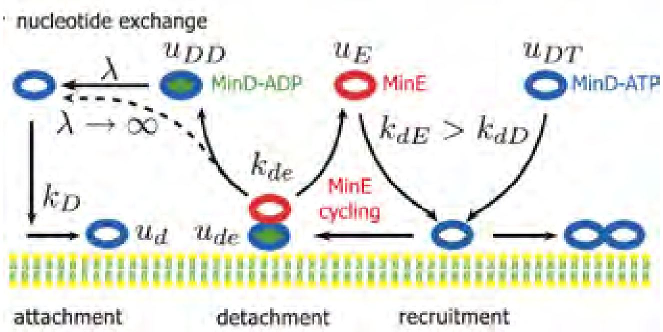
Fig. 2: Time averaged mean squared displacement of DSPC, SOPC, and DOPC molecules in liquid phase bilayers. A. Cholesterol-free case. B. With cholesterol. The numbers indicated in the plots are the fitted power-law exponents, alpha<1 indicating subdiffusion, while alpha=1 corresponds to normal diffusion.

J.-H. Jeon, H. Martinez-Seara Monne, M. Javanainen, and R. Metzler: *Lateral motion of phospholipids and cholesterols in a lipid bilayer: anomalous diffusion and its origins;* Phys. Rev. Lett. 109, 188103 (2012)
E. Barkai, Y. Garini, and R. Metzler: *Strange kinetics of single molecules in living cells;* Physics Today 65(8), 29 (2012)

THEORY OF MIN OSCILLATIONS IN *E. COLI*

Prof. Erwin Frey (LMU Munich, Faculty of Physics) www.theorie.physik.uni-muenchen.de/lsfrey

Min-protein oscillations in *Escherichia coli* are characterized by the remarkable robustness with which spatial patterns dynamically adapt to variations of cell geometry. Moreover, adaption, and therefore proper cell division, is independent of temperature. These observations raise fundamental questions about the mechanisms establishing robust Min oscillations, and about the role of spatial cues, as they are at odds with present models. Here, we introduce a robust model based on experimental data, consistently explaining the mechanisms underlying pole-to-pole, striped, and circular patterns, as well as the observed temperature dependence of the oscillation period. Contrary to prior conjectures, the model predicts that MinD and cardiolipin domains are not colocalized. The transient sequestration of MinE and highly canalized transfer of MinD between polar zones are the key mechanisms underlying oscillations. MinD channeling enhances midcell localization and facilitates stripe formation, revealing the potential optimization process from which robust Min-oscillations originally arose.



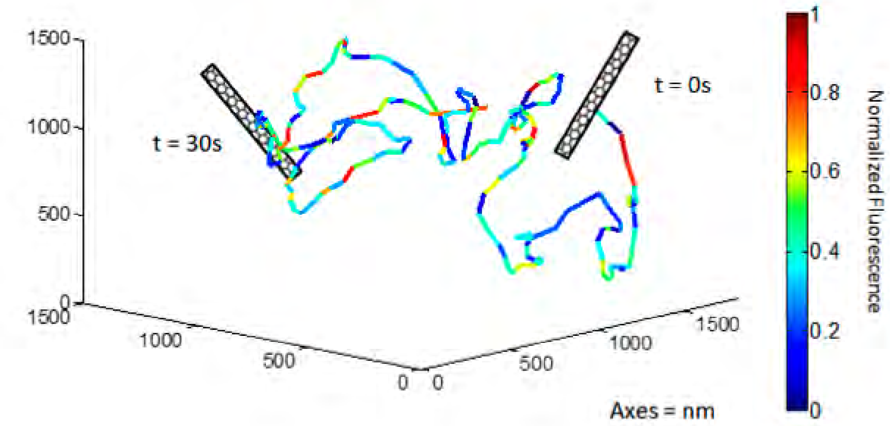
Minimal Model Dynamics and Dynamical Instabilities. Cytosolic MinD-ATP attaches to the membrane where it recruits further MinD-ATP and MinE from the cytosol. Recruitment of MinE leads to the formation of MinDE complexes, which disintegrate to cytosolic MinD-ADP and MinE. Finally, MinD-ADP exchanges nucleotides. The scheme highlights the possibility of local MinE cycling, given a sufficiently high density of membrane bound MinD.

J. Halatek and E. Frey: *Highly Canalized MinD Transfer and MinE Sequestration Explain the Origin of Robust MinCDE-Protein Dynamics;* Cell Reports 1 (6), 741-752 (2012)

SINGLE PARTICLE TRACKING OF SINGLE-WALLED CARBON NANOTUBES

Prof. Don C. Lamb (LMU Munich, Chemistry Department) www.cup.uni-muenchen.de/pc/lamb

Semiconducting single-walled carbon nanotubes (SWNTs) are promising fluorescent probes due to their remarkable photostability, showing no bleaching or blinking, their large Stokes shift and the ability to modulate the fluorescence of SWNTs with analytes. Due to the large Stokes shift, the SWNTs luminesce in the near infrared, which is very beneficial for measurements in live cells and tissue where there is minimal absorption and scattering of the light. The fluorescence intensity is strongly dependent on the nanotubes's surface chemistry and can be modulated through the binding of analytes. Hence, SWNTs can be engineered into biosensor constructs by non-covalent wrappings that are selective to target analytes. In this paper, the authors utilized a 3D orbital tracking microscope to track single SWNTs in real time in vitro and in living cells. As orbital tracking functions with real-time feedback, the tracked SWNT remain in focus during the measurement. Hence, fluorescence intensity variations due to translational motion are avoided and any residual variations could be attributed to the orientation of the anisotropic particle, provided the viscosity is high enough. They used the translational and rotational diffusion coefficients to characterize the length distribution of SWNTs. After characterizing the diffusive behavior of SWNTs in vitro, SWNT were tracked in live HeLa cells. Using the SWNTs as probes, the authors could map corral volumes, determine active transport velocities and measure local viscosities within the cell. With respect to the future use of SWNTs as sensors in living cells, the sensing fluorescence change necessary for separation of the sensor signal from fluctuations due to rotation of the SWNT was quantified. This work has broad implications for the use of nanoparticles in live-cell experiment.



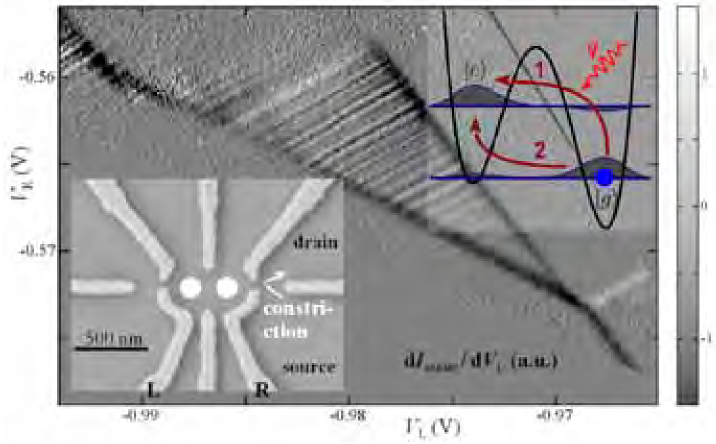
The three-dimensional trajectory of a SWNT in a glycerol/buffer solution is shown. The fluorescence intensity of the SWNT during the trajectory is color coded into the trajectory. From the trajectory and intensity fluctuations, both the translational and rotational diffusion coefficients could be determined, which provides an estimation for both the length of the SWNT and the viscosity of the surrounding media.

N.F. Reuel, A. Dupont, O. Thouvenin, D.C. Lamb, and M.S. Strano: *Three-dimensional tracking of carbon nanotubes within living cells;* ACS Nano 6, 5420 (2012)

QUANTUM INTERFERENCE AND PHONON-MEDIATED BACK-ACTION IN LATERAL QUANTUM-DOT CIRCUITS

PD Dr. Stefan Ludwig (LMU Munich, Faculty of Physics) www.nano.physik.uni-muenchen.de/quantumtransport

Lateral few-electron quantum-dot circuits are promising candidates for metrology and quantum information applications. Qubit readout typically involves a charge measurement made probing the current through a nearby biased quantum point contact (QPC). For quantum applications it is critical to understand the back-action disturbances resulting from such a measurement approach. It is well-established that QPC detectors emit phonons up to an energy corresponding to the voltage drop across the QPC. These phonons can be reabsorbed by nearby qubits which, therefore, can be seen as very sensitive phonon detectors. In this project we have observed a pronounced back-action effect in multiple dot circuits, where the absorption of detector-generated phonons is strongly modified by a quantum interference effect. It comes about, because each phonon can be absorbed by one and the same electron at two alternative positions. The reported phenomenon is well described by a theory incorporating both the QPC and coherent phonon absorption in coupled dots. It also promises applications: destructive interference allows strategies to suppress back-action during the qubit readout procedure. Furthermore, our experiments reveal the usability of coupled dots as a single phonon detector and spectrometer.



The figure illustrates an example of a single phonon interference effect as observed in the charge stability diagram of a double quantum dot. The lower inset shows a scanning electron microscope image of the AlGaAs/GaAs heterostructure containing a two-dimensional electron system 80 nm beneath the surface. The light gray regions are metal gates used to electrostatically define a double quantum dot (white circles) and two narrow constrictions. For charge sensing we apply a source drain voltage across the right narrow constriction, which is tuned to act as a tunnel barrier, and we detect the linear response of the tunneling current Iconstr (white arrow) while the voltage V_L applied to the left plunger gate is slightly modulated. The main figure plots the resulting transconductance dI_{constr}/dV_L as a function of plunger gate voltages V_L and V_R of the double quantum dot at a temperature of 30 mK. Local extrema (dark and bright lines) indicate changes in the average charge occupation of the double quantum dot (from zero to one electron). The striped triangle indicates a non-equilibrium configuration. Its origin results from the absorption of single phonons. In our experiment the phonons originate from charge fluctuations in the narrow constriction. The upper inset in the figure sketches the absorption process. In the presence of a finite energy detuning a phonon can be absorbed in either one of the two dots via inelastic tunneling. The resulting two absorption paths indicated by red arrows in the inset acquire a phase-difference which depends on the double quantum dot detuning. In our example the stripe pattern of the non-equilibrium triangle is interpreted as interference fringes caused by the absorption/detection of one phonon at a time.

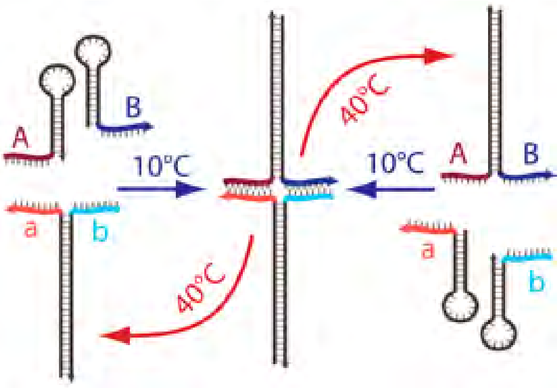
G. Granger, D. Taubert, C. E. Young, L. Gaudreau, A. Kam, S. A. Studenikin, P. Zawadzki, D. Harbusch, D. Schuh, W. Wegscheider, Z. R. Wasilewski, A. A. Clerk, S. Ludwig, A. S. Sachrajda: *Quantum interference and phonon-mediated back-action in lateral quantum-dot circuits;* Nature Phys. 8, 522–527 (2012)

AUTONOMOUS REPLICATOR FROM TRNA

Prof. Dieter Braun (LMU Munich, Faculty of Physics) www.biosystems.physik.uni-muenchen.de

Evolving systems rely on the storage and replication of genetic information. The Braun lab was able to demonstrate an autonomous, purely thermally driven replication mechanism using tRNA molecules. A pool of hairpin molecules, derived from transfer RNA (tRNA) replicates the succession of a two letter-code. Energy is first stored thermally in metastable hairpins. The experiments propose a physical rather than a chemical scenario for autonomous replication of protein encoding information in a disequilibrium setting.

tRNA as replicator. Strategies common in DNA Nanomachines allow to replicate sequence information solely by base hybridization. Interestingly, tRNA, which nowadays used to translate from RNA sequences to protein formation, could have played the role as replicator of codon sequences. The replicator shows exponential replication and is much faster than purely chemical ligation.

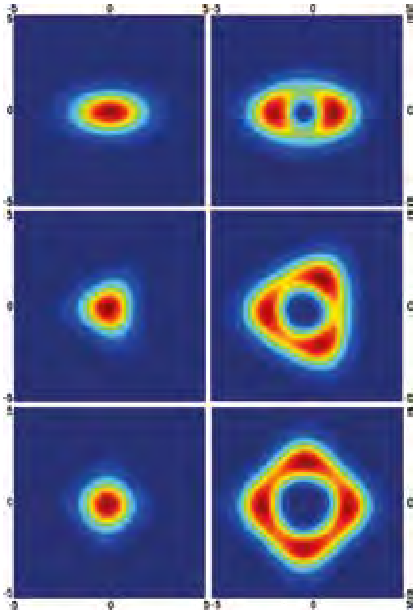


H. Krammer, F.M. Möller, and D. Braun: *Thermal, Autonomous Replicator Made from Transfer RNA;* Physical Review Letters 108, 238104 (2012)

THE JOSEPHSON PHOTOMULTIPLIER

Prof. Frank Wilhelm-Mauch (Saarland University, Faculty of Natural Sciences and Technology II) http://qsolid.uni-saarland.de

We have investigated the backaction of a novel microwave single photon counter on the measured state and showed that due to its strong coupling to the measured object it is in general nonlinear – a photon subtraction rather than a lowering operator. This allows to turn the tables and use detection as a means to create nonclassical states of microwaves – contrary to the usual expectation that quantum measurement renders the measured object more classical.

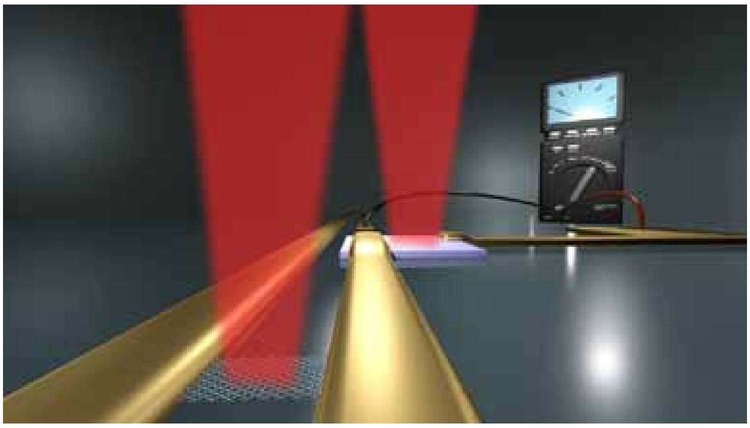


This figure shows the Husimi Q functions for the states created by a generalized protocol involving classical pulses and detections, figures (a), (c) and (e), and those created by one additonal photon detection after displacement to the origin, figures (b), (d) and (f).

L.C.G Govia, E.J. Pritchett, S.T. Merkel, D. Pineau and F.K. Wilhelm: *Theory of Josephson photomultipliers: optimal working conditions and back action;* Phys. Rev. A 86, 032311 (2012)

ULTRAFAST PHOTOCURRENTS AND THZ GENERATION IN GRAPHENE

Prof. Alexander Holleitner (TU Munich, Walter Schottky Institute and Department of Physics) www.nanoptronics.de



Sketch of the optoelectronic pump-probe scheme. Graphene is incorporated in metal striplines and optically excited by a pump laser pulse. A probe laser triggers the on-chip read-out of the photocurrent dynamics.

The Holleitner group explored the ultrafast photocurrent dynamics in graphene. The high charge-carrier mobility of graphene has spurred a tremendous interest in graphene-based high-speed electronic devices such as field-effect transistors and pn-junctions. In combination with its excellent optical properties, graphene further qualifies for optoelectronic applications. Various graphene-based THz-sources and detectors have been proposed, since the frequency of plasma waves, the gap of graphene nanoribbons, and the tunable bandgap in bilayer graphene lies in the THz-range. While the RC-limited bandwidth of graphene-based photodetectors can be estimated to be as large as 640 GHz, common electronic apparatuses cannot resolve the underlying ultrafast charge-carrier dynamics because available equipment cannot produce electronic trigger signals and detect transients faster than tens of picoseconds. In the experiments of the Holleitner group, THz-radiation is demonstrated to be generated in optically pumped, freely suspended graphene [1]. The electro-magnetic radiation is detected by a coplanar metal stripline, which acts as a highly sensitive near-field antenna and waveguide with a bandwidth of up to 1 THz. The ultrafast experiments further clarify the optoelectronic mechanisms contributing to the photocurrent generation at graphene-metal interfaces. So far, this photocurrent has been extensively investigated by spatially resolved, but time-integrated photocurrent imaging techniques. The results verify that both built-in electric fields, similar to those in semiconductor-metal interfaces, and a photothermo-electric effect give rise to the photocurrent at graphene-metal interfaces at different time scales. Furthermore, the ultrafast optoelectronic spectroscopy allows investigating a large variety of nanoscale circuits, e.g. based on semiconductor nanowires [2].

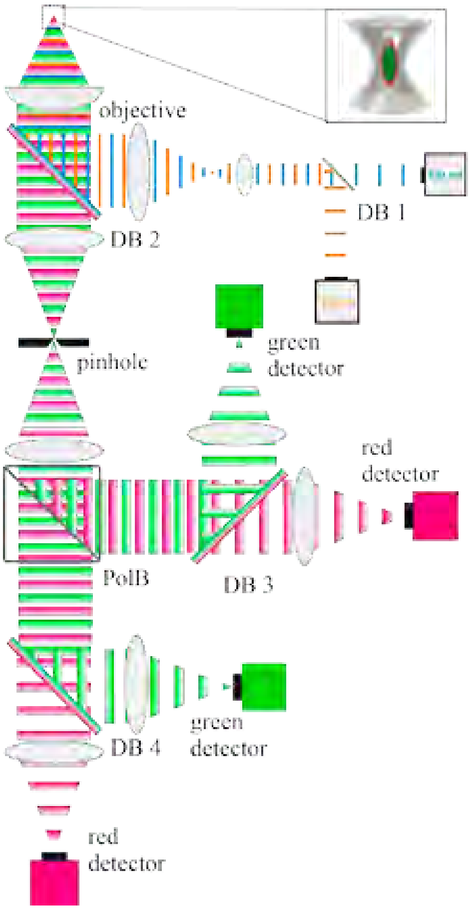
[1] L. Prechtel, L. Song, D. Schuh, P. Ajayan, W. Wegscheider, A.W. Holleitner: *Time-resolved ultrafast photocurrents and terahertz generation in freely suspended graphene;* Nature Communications 3, 646 (2012)

[2] L. Prechtel, M. Padilla, N. Erhard, H. Karl, G. Abstreiter, A. Fontcuberta i Morral, A.W. Holleitner: *Time-resolved photoinduced thermoelectric and transport currents in GaAs nanowires;* Nano Letters 12, 2337 (2012)

DEVELOPMENT OF ULTRASENSITIVE SINGLE MOLECULE METHODOLOGIES

Prof. Don C. Lamb (LMU Munich, Chemistry Department) *www.cup.uni-muenchen.de/pc/lamb*

Single molecule experiments are changing the way the physical world is investigated. By looking at individual molecules, a wealth of information beyond the ensemble average becomes available. One means of extracting this information is by using multiparameter fluorescence detection (MFD) on fluorescence bursts coming from molecules in solution as they diffusion through the focus of a confocal microscope. The method of MFD collects the maximum amount of information currently available from each detected photon including the time the emitting molecule spent in the excited state (lifetime information), its color (spectral information) and its polarization (anisotropy information). All the photons detected from a single molecule within a burst are binned together and, from the various characteristics of the individual molecules, different subpopulations can be distinguished. MFD can be further expanded by incorporating pulsed interleaved excitation (PIE), which provides information regarding the excitation source of the detected fluorescence photon (and thereby the stoichiometry). Förster Resonance Energy Transfer (FRET) is a method that is sensitive to distances on the molecular scale and is a powerful method for investigating how individual proteins, complexes and other nanomachines function. However, accurate FRET measurements are challenging and require the determination of several calibration and correction factors. Using the additional information available with PIE and the capability of MFD to extract subpopulations, it is possible extract all calibration and correction factors necessary for an accurate single-pair FRET experiment from a single measurement. In addition, one can use the PIE-MFD data to check for and correct experimental artifacts such as photobleaching and the influence of labeling on the photoproperties of the fluorophores. In an MFD-PIE experiment, the spFRET data can be analyzed in detail, for example, to look for multiple subpopulations and dynamics in biological samples, as the calibration and control experiments have been performed and can be extracted from the same data.



A schematic of a multiparameter fluorescence detection confocal microscope with pulsed interleaved excitation is shown. The excitation lasers are pulsed and synchronized with a delay such that the colors interleaved. The emitted fluorescence is focused through a confocal pinhole and separated into different detection channels with a polarizing beamsplitter followed by a dichroic filter. The photons are then detected using time-correlated single-photon counting. In this way, information regarding parameters such as anisotropy, fluorescence lifetime, FRET efficiency and stoichiometry can be determined for individual molecules.

This work is dedicated to Professor Christoph Bräuchle on the occasion of his 65th birthday in honor of his pioneering research in single molecule fluorescence spectroscopy and microscopy.

V. Kudryavtsev, M. Sikor, S. Kalinin, D. Mokranjac, C.A. Seidel, and D.C. Lamb: *Combining MFD and PIE for Accurate Single-Pair Forster Resonance Energy Transfer Measurements;* ChemPhysChem 13, 1060 (2012)

CONTROLLING EXCITON DECAY DYNAMICS IN SEMICONDUCTING SINGLE-WALLED CARBON NANOTUBES BY SURFACE ACOUSTIC WAVES

Prof. Achim Hartschuh (LMU Munich, Chemistry Department) *www.cup.uni-muenchen.de/pc/hartschuh*
Dr. Hubert Krenner and Prof. Achim Wixforth (University of Augsburg, Institute of Physics) *www.physik.uni-augsburg.de/exp1*

Semiconducting single-walled carbon nanotubes (SWCNTs) are quasi-one-dimensional materials with unique properties making them potential candidates for device applications in electronics and optoelectronics. A key requirement to fully exploit their application potential is the ability to control their optical properties by easily accessible external parameters. The optical response of SWCNTs is determined by excitons; strongly bound electron-hole pairs which recombine by emission of light. Compared to conventional semiconductor nanowires, exciton binding energies are increased in SWCNT by more than one order of magnitude. This study reports on the control of the exciton decay dynamics of SWCNTs films by propagating radio frequency surface acoustic waves (SAWs). SAWs are acousto-mechanical waves on the surface of solids that propagate nearly without dissipation over distances of several millimeters. SAWs are all-electrically launched directly on a commercial piezoelectric $LiNbO_3$ substrate. When the SAW interacts with the SWCNTs, the emitted light intensity is strongly suppressed due to an inhibition of the radiative exciton recombination. Time-resolved measurements reveal that photoluminescence quenching is caused by a decrease of the radiative recombination rate by up to 25% on picosecond timescales for the accessible SAW amplitudes. The polarization of the luminescent exciton by the SAW-induced piezoelectric field is identified as the underlying mechanism. The strong fields act as a quasi-static perturbation and reduce the oscillator strength of the radiative transition following a quadratic dependence characteristic for the Stark effect. The demonstrated hybrid SAW-based approach represents the first step towards remote and contact-free acousto-electrical high-speed optoelectronic nanotube-based devices.

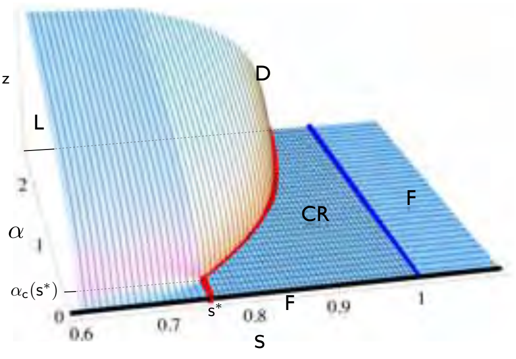
Exciton decay in carbon nanotubes is remotely controlled by surface acoustic waves. The electric fields associated with surface acoustic waves slow down exciton decay. The slowdown is caused by a decreased radiative rate due to the quadratic Stark effect. Remote-control could be of interest for device applications of carbon nanotubes.

M. E. Regler, H. J. Krenner, A. A. Green, M. C. Hersam, A. Wixforth, A. Hartschuh: *Controlling exciton decay dynamics in semiconducting single-walled carbon nanotubes by surface acoustic waves;* Chem. Phys. published online 06.11.2012, http://dx.doi.org/10.1016/j.chemphys.2012.10.014 (2012)

CRITICAL AND STRONG-COUPLING PHASES IN ONE- AND TWO-BATH SPIN-BOSON MODELS

Prof. Jan von Delft (LMU Munich, Faculty of Physics) *http://homepages.physik.uni-muenchen.de/~vondelft*

When a local quantum degree of freedom, such as a spin ½, is coupled to a bath involving a continuum of excitations, its behavior can change dramatically – a phase transition can occur between a delocalized phase, where the spin is free to rotate in response to an applied field, and a localized phase, where the interactions with the bath cause the spin to prefer certain directions. An interesting question is to which extent such a quantum phase transition can be described using a quantum-to-classical correspondence, that relates the problem to a classical phase transition via a mapping to a classical model. For the subohmic spin-boson model, this question had been controversially discussed in the past. In this project, this controversy was conclusively resolved by introducing a variational matrix product state approach involving an optimized boson basis, rendering possible high-accuracy numerical studies across the entire phase diagram. For the subohmic spin-boson model with a power-law bath spectrum, ωs, classical mean-field behavior was confirmed for $s < 1/2$, correcting earlier numerical renormalization-group results. Moreover, the first results were provided for an XY-symmetric model of a spin coupled to two competing bosonic baths, where a rich phase diagram as found, including both critical and strong-coupling phases for $s < 1$, different from that of classical spin chains. This illustrates that symmetries are decisive for whether or not a quantum-to-classical correspondence exists.



Schematic sketch of the phase diagram for the XY-symmetric of a spin coupled to two competing bosonic baths, as function of the spectral exponent, an applied magnetic field in the z-direction, and the spin-bath coupling constant, showing localized (L), delocalized (D), free (F) and critical (CR) phases.

C. Guo, A. Weichselbaum, J. von Delft, M. Vojta: *Critical and strong-coupling phases in one- and two-bath spin-boson models;* Phys. Rev. Lett. 108, 160401 (2012)

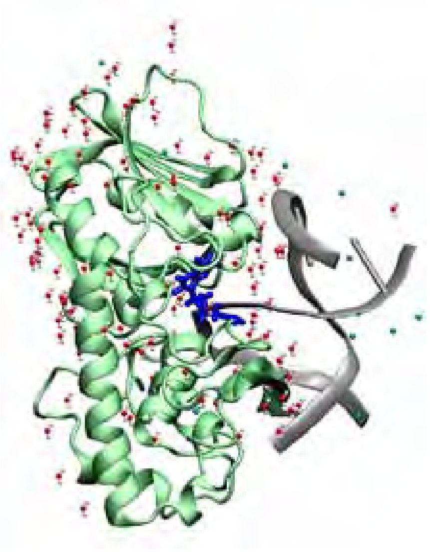
PROBES FOR THE LOCALITY OF ELECTRONIC STRUCTURE

Prof. Christian Ochsenfeld (LMU Munich, Chemistry Department) www.cup.uni-muenchen.de/pc/ochsenfeld

Over the last decades large molecular systems with thousands of atoms have become accessible to quantum-chemical methods by reducing the polynomial time complexity to linear. Nevertheless, the prefactors of quantum-chemical calculations are still significant, although any speed-up in computer performance will directly translate into the treatable molecular size. While molecular systems with a few thousands atoms are accessible on simple workstation computers, the description of complex biosystems including the solvent environment with several ten or hundred thousand atoms is extremely demanding.

An alternative pathway is provided by combining quantum-chemical with simple molecular-mechanical methods within so-called QM/MM frameworks. While many research groups have been working on the tricky interface between quantum and classical methods, the Ochsenfeld group recently combined such schemes with their linear- and sublinear-scaling quantum-chemical methods. In this way, it was for the first time possible to systematically converge molecular properties with the chosen QM sphere. As a probe for the locality of electronic structure the nuclear spin was employed as detected in NMR spectroscopy and by computing the NMR shielding tensor.

The study by Flaig et al. shows typically an accelerated convergence with the QM sphere by using QM/MM methods, since as compared to 'pure QM' calculations all the atomic charges of the molecular system are included for any QM sphere (at least at the MM level). Nevertheless, for a reliable description of the electronic structure in an active center region, large QM spheres with 200-1000 atoms are necessary. This does also hold if explicit solvent molecules are involved. If specific electronic effects are not included in the simple MM model, such as, e.g., aromatic ring current influences on NMR shieldings, then the convergence remains unchanged. For reliable results the QM sphere needs to be systematically converged using linear-scaling methods.



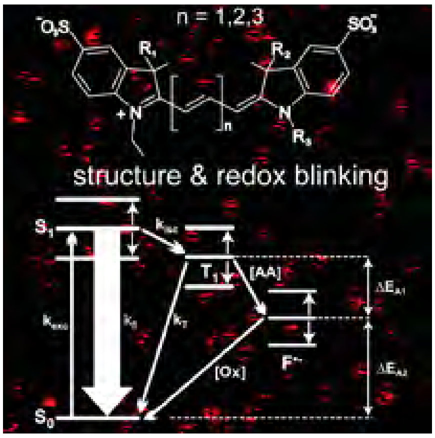
Computed DNA repair complex for oxidative damages comprising a total of 30647 atoms (QM/MM) with up to 1752 atoms in the QM sphere (water molecules only partially shown).

D. Flaig, M. Beer, C. Ochsenfeld: *Convergence of Electronic Structure with the Size of the QM region: Example of QM/MM NMR Shieldings;* J. Chem. Theory Comput. 8, 2260 (2012)

LINKING SINGLE-MOLECULE BLINKING TO CHROMOPHORE STRUCTURE AND REDOX POTENTIALS

Prof. Philip Tinnefeld (TU Braunschweig, Institute of Physical andTheoretical Chemistry) www.tu-braunschweig.de/pci
Prof. Thorben Cordes (University of Groningen, Faculty of Mathematics and Natural Sciences) www.molecular-microscopy.nl

Intensity fluctuations between an ON-state and an OFF-state, also called blinking, are common to all luminescent objects when studied at the level of individuals. We studied blinking of three dyes from a homologous series (Cy3, Cy5, Cy7). The underlying radical anion states were induced by removing oxidants (i.e. oxygen) and by adding the reductant ascorbic acid. We find that for different conditions with distinct levels of oxidants in solution the OFF-state lifetime always increases in the order Cy3<Cy5<Cy7. Longer OFF-times are related to higher reduction potentials of the fluorophores, which increase with the size of the chromophore. Interestingly, we find reaction rates of the radical anion that are unexpectedly low at the assumed oxygen concentration. On the other hand, reaction rates meet the expectations of similar Rehm-Weller plots when methylviologen is used as oxidant, confirming the model of photoinduced reduction and oxidation reactions. The relation of OFF-state lifetimes to redox potentials might enable predictions about the nature of dark states, depending on the fluorophores' nano-environment in super-resolution microscopy.

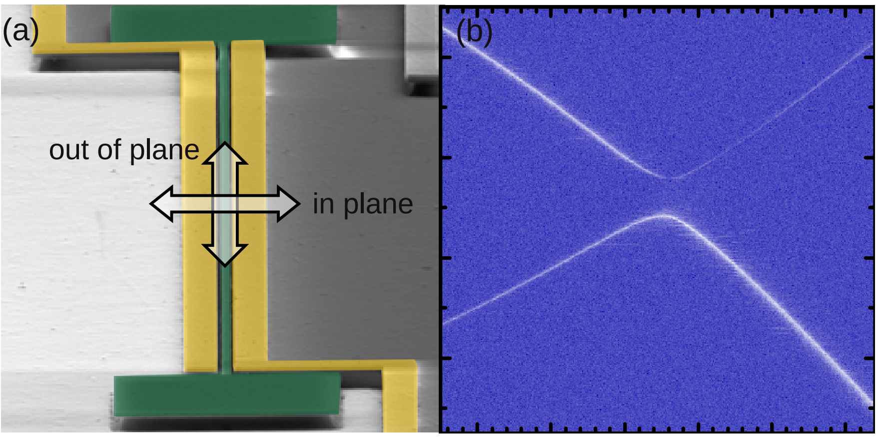


Blinking of three dyes from a homologous series (Cy3, Cy5, Cy7) is studied (see picture). The underlying radical anion states are induced by controlling the oxygen concentration and by adding the reductant ascorbic acid. For different conditions the OFF-state lifetime always increases in the order Cy3<Cy5<Cy7. Off-state lifetimes are related to higher reduction potentials as well as chromophore size.

I. H. Stein, S. Capone, J. H. Smit, F. Baumann, T. Cordes, P. Tinnefeld: *Linking Single-Molecule Blinking to Chromophore Structure and Redox Potentials;* ChemPhysChem 13, 931-937 (2012)[Front cover]

DIELECTRIC TRANSDUCTION AND NON-ADIABATIC DYNAMICS OF STRONGLY COUPLED NANOMECHANICAL RESONATOR MODES

Prof. Eva M. Weig (University of Konstanz, Faculty of Physics) www.nano.uni-konstanz.de
Prof. Jörg P. Kotthaus (LMU Munich, Faculty of Physics) www.nano.physik.uni-muenchen.de



(a) Scanning electron micrograph of the high stress silicon nitride string (green) and the adjacent electrodes (yellow) employed for dielectric transduction and tuning. Arrows denote the two orthogonal fundamental flexural modes vibrating in and out of the sample plane. (b) Color-coded vibration spectrum as a function of actuation frequency and applied dc tuning voltage. A pronounced avoided crossing between the two modes is observed.

Nanomechanical resonators subject to strong tensile stress are known to exhibit extremely large mechanical quality factors. For example, high stress silicon nitride nanostrings processed on a fused silica substrate feature room temperature quality factors exceeding 300,000 for eigenfrequencies in the range of 10 MHz [1]. A favourable actuation and tuning scheme for these high Q nanoresonators is based on dielectrically induced gradient forces. Sensitive dielectric displacement detection can be accomplished with an additional microwave cavity which is employed for heterodyne sensing [1]. Full dielectric transduction is obtained by combining all required dc, rf, as well as microwave signals in the device circuitry [2]. The electrode geometry strongly affects the dielectric frequency tuning [2]. For the geometry displayed in the figure, dielectric tuning softens the in-plane fundamental flexural mode, whereas the corresponding out-of-plane mode gets stiffer. This allows tuning both modes into resonance, where a pronounced avoided crossing is observed. The extracted coupling strength is much larger than the linewidth of the mechanical resonances, indicating that the system is clearly in the strong-coupling regime [3]. To demonstrate the potential impact of mode control in strongly coupled nanomechanical systems, a pulsed measurement scheme is implemented to analyze the time-dependent evolution of a previously initialized mode as it is swept across the coupling region. This allows to investigate a classical nanomechanical model system for the well-known Landau-Zener transition, a fundamental concept for dynamical quantum systems that has been studied in numerous fields of physics. The measured transition probabilities show excellent quantitative agreement with the Landau-Zener model [3]: At low sweep rates, the system adiabatically follows the energy eigenstates, whereas the energy is transferred from one branch to the other during fast sweeps. Furthermore, the energy relaxation time of the system is shown to exceed the length of the manipulation pulses, enabling coherent control of the nanomechanical system.

[1] T. Faust, P. Krenn, S. Manus, J. P. Kotthaus, and E. M. Weig: *Microwave cavity-enhanced transduction for plug and play nanomechanics at room temperature;* Nature Communications 3, 728 (2012)

[2] J. Rieger, T. Faust, M. J. Seitner, J. P. Kotthaus, and E. M. Weig: *Frequency and Q-factor control of nanomechanical resonators;* Appl. Phys. Lett. 101, 103110 (2012)

[3] T. Faust, J. Rieger, M. J. Seitner, P. Krenn, J. P. Kotthaus, and E. M. Weig: *Non-adiabatic dynamics of two strongly coupled nanomechanical resonator modes;* Phys. Rev. Lett. 109, 037205 (2012)

PRESERVATION OF 5300-YEAR-OLD RED BLOOD CELLS IN THE ICEMAN

Prof. Albert Zink (European Academy of Bozen) www.eurac.edu
Prof. Robert Stark (Technische Universität Darmstadt, Center of Smart Interfaces) www.csi.tu-darmstadt.de/institute/pos/index.de

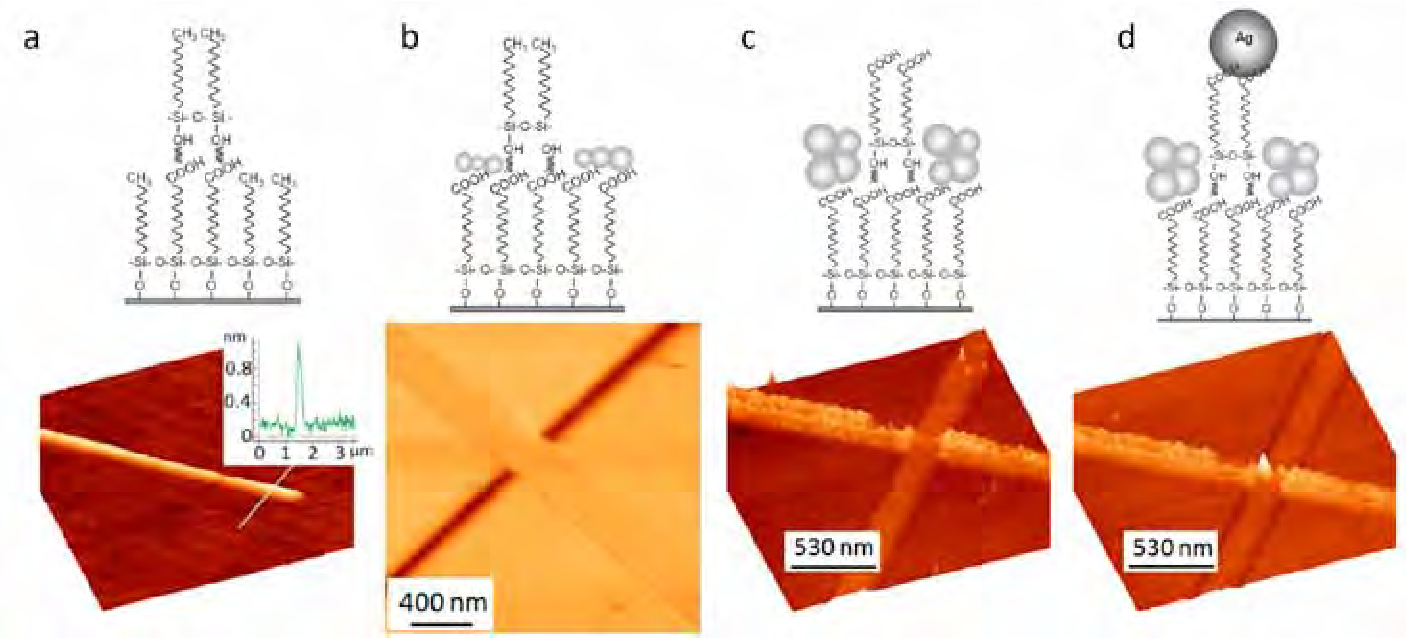
Changes in elasticity and structures of red blood cells are important indicators of disease, and this makes them an interesting object for medical studies. In forensics, blood analyses represent a crucial part of crime scene investigations. For these reasons, the recovery and analysis of blood cells from ancient tissues is of major interest. In this study we show that red blood cells were preserved in Iceman tissue samples for more than 5000 years. The morphological and molecular composition of the blood corpuscle is verified by atomic force microscope and Raman spectroscopy measurements. The cell size and shape approximated those of healthy, dried, recent red blood cells. Raman spectra of the ancient corpuscle revealed bands, which are characteristic of haemoglobin. Additional vibrational modes typical for other proteinaceous fragments, possibly fibrin, suggested the formation of a blood clot. The band intensities, however, were approximately an order of magnitude weaker than those of recent red blood cells. This fact points to a decrease in the red blood cell specific metalloprotein haemoglobin and thus, to a degradation of the cells. Together, the results show the preservation of red blood cells in the 5000-year-old mummy tissue and give first insights on their degradation.

M. Janko, R. W. Stark, and A. Zink: *Preservation of 5300 year old red blood cells in the Iceman;* J Roy. Soc. Interface 9, 2581-2590 (2012)

NEW SFM ELECTRO-OXIDATION DESIGN CONCEPTS FOR THE FABRICATION OF NANOMETRIC GAP STRUCTURES

Prof. Ulrich S. Schubert (Friedrich-Schiller-Universität Jena, Faculty of Chemical and Earth Sciences) www.schubert-group.com

Electro-chemical structuring of a n-octadecyltrichlorosilane (OTS) self-assembled monolayer (SAM) was used to fabricate nanometric gap structures. For this purpose, a hierarchical structuring was implemented to achieve excellent control over the device and in particular the gap dimensions of the fabricated structures. Essential feature of the oxidation of the self-assembled monolayer are the different oxidation conditions which are required to induce the oxidation process. Thus, the concept of a combined monolayer/bilayer OTS structure was introduced. Oxidation at conditions which are suitable to induce the local conversion of the surface terminal $-CH_3$ groups into polar, chemically active $-COOH$ groups across a OTS-OTS bilayer line results in line features, which are automatically interrupted on top of the bilayer feature. Subsequent metallization of the inscribed lines results in well-defined gap features. Additionally, further chemical activation of the OTS-OTS bilayer feature within the gap structure can be induced by the local application of a longer oxidation pulse during the point contact of the SFM tip and the bilayer. It could be demonstrated that this additional activation induces addressable surface sites, which can be utilized to selectively bind nanomaterials, such as individual nanoparticles. This fabrication concept was introduced as a highly controllable construction principle for nanoelectronic circuits, which integrate nanometric building blocks and provides a means to efficiently contact individual nanoparticles, carbon nanotubes, etc. This extension of the classical 2 dimensional structuring allows expanding the assessable chemical structures significantly and opens new design approaches, which ultimately will extend the variety of nanodevice layouts.



Fabrication sequence of hierarchically fabricated nanometric gap structures. a) An OTS-OTS bilayer line was fabricated. b) Electro-oxidation of a perpendicular line was inscribed across the bilayer line. Oxidation is restricted to the monolayer level (dark line) and the line is interrupted on top of the OTS-OTS bilayer feaure. c) Metallization of the newly inscribed line was performed. d) By an additional oxidation with long oxidation time a new addressable area can be inscribed on top of the bilayer and within the gap structure. This chemically activated site was used to self-assemble an individual nanoparticle in this position.

D. Meroni, S. Höppener, S. Ardizzone, U.S. Schubert: *Probe-based Electrooxidative Lithography of OTS SAMs deposited onto Transparent ITO Substrates: A Scanning Kelvin Probe Microscopy Study;* Adv. Funct. Mater. 22, 4376 – 4382 (2012)

T.S. Druzhinina, S. Hoeppener, U.S. Schubert: *New Design Concepts for the Fabrication of Nanometric Gap Structures - Electrochemical Oxidation of OTS Mono- and Bilayer Structures;* Small 8, 852-857 (2012)

NONEQUILIBRIUM DYNAMICS OF THE QUANTUM TRANSVERSE-FIELD ISING CHAIN IN CIRCUIT QED

Prof. Florian Marquardt (Friedrich-Alexander-Universität Erlangen-Nürnberg, Department of Physics) www.thp2.nat.uni-erlangen.de
Prof. Jan von Delft (LMU Munich, Faculty of Physics) http://homepages.physik.uni-muenchen.de/~vondelft/

Circuit Cavity QED systems are macroscopic, man-made quantum systems in which superconducting artificial atoms interact with the electromagnetic field in a microwave resonator. These systems have been invented to mimic the physics of quantum optical cavity QED systems with real atoms in a scalable and more flexible framework. This opens up a variety of possible applications of circuit QED systems. For instance, they provide a promising platform for processing quantum information. Today, circuit QED systems containing a small number of artificial atoms can be fabricated and well-controlled, and the experimental technology is rapidly moving toward multi-atom, multi-resonator architectures with drastically enhanced coherence times. This makes circuit QED increasingly attractive also for quantum simulations of interacting quantum many-body systems from solid state physics, even more so because of the current widespread interest in the nonequilibrium dynamics of these systems. Here, a circuit QED design is proposed and analysed that simulates the quantum Ising spin chain in a time-dependent transverse magnetic field with current technology (Fig. 1). This setup, which could easily be extended to break the integrability of the simulated spin system, provides a new platform for observing the nonequilibrium dynamics of interacting quantum many-body models. To offer a guideline for its initial experimental characterization, the excitation spectrum of the proposed setup is calculated. It is demonstrated that quench dynamics and the propagation of localized excitations can be observed with the setup (Fig. 2 shows an example), and further possible applications and modifications of this circuit QED quantum simulator are discussed.

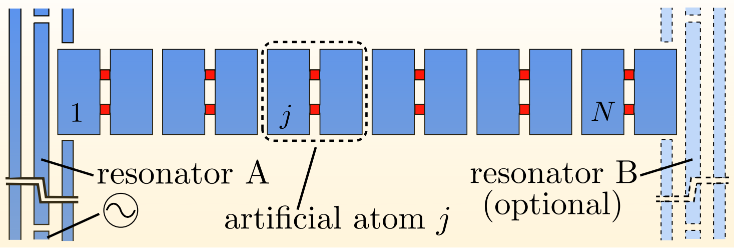


Fig. 1: Circuit QED implementation of the quantum Ising spin chain with a transverse magnetic field. Resonator A (B) facilitates initialization and readout of the first (Nth) artificial atom by standard circuit QED techniques.

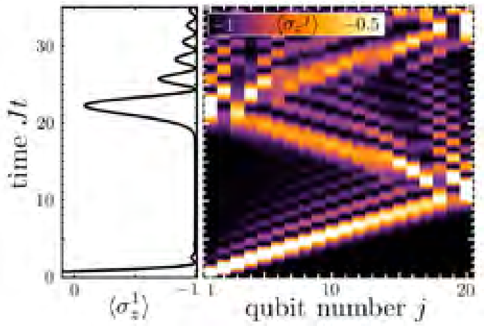


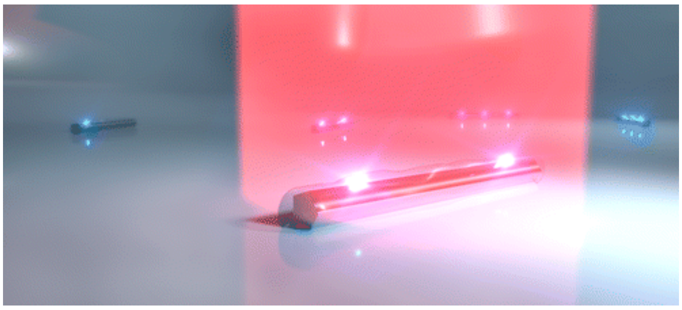
Fig. 2: Propagation of a localized excitation. Right: nonequilibrium time evolution of the local magnetization of a transverse-field Ising chain with 20 spins after the first spin has been flipped. Values >0.5 are plotted in white. Left: separate plot on the same time scale. This quantity can be measured in the setup of Fig. 1.

O. Viehmann, J. von Delft, and F. Marquardt: *Observing the nonequilibrium dynamics of the quantum transverse-field Ising chain in circuit QED;* Phys. Rev. Lett. 110, 030601 (2013)

SILVER NANOWIRE/PLASMON COUPLING

Prof. Jens Michaelis (Universität Ulm, Physics Department) www.uni-ulm.de/nawi/nawi-biophys.html
Prof. Christoph Bräuchle (LMU Munich, Chemistry Department) www.cup.uni-muenchen.de/pc/braeuchle
Prof. Christina Scheu (LMU Munich, Department of Chemistry) www.cup.uni-muenchen.de/pc/scheu

Davies et al. investigated optical and structural properties of silver nanowires by wide-field optical microscopy in combination with transmission electron microscopy based techniques, such as high-resolution, bright-field imaging, electron diffraction, high-angle annular dark-field imaging, and energy-dispersive X-ray spectroscopy. Single-molecule tracking experiments revealed coupled luminescence emission from different distinct positions along the silver nanowires. The chemical compositions of the emissive areas were analyzed using energy-dispersive X-ray spectroscopy, which led to the model that the active emissive centers were small silver clusters generated photochemically. Since the emitters were located within a few micrometers on the nanowire, the authors attributed the coupled emission to plasmonic coupling through the wire.



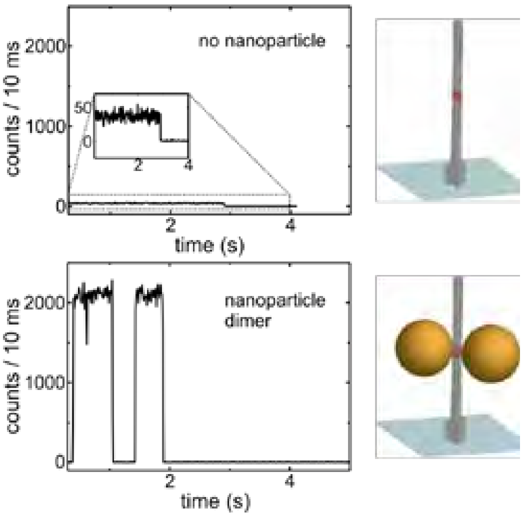
Investigation of synchronous emission from different distinct positions along silver nanowires with correlative wide-field fluorescence and transmission electron microscopy.

M. Davies, A. Wochnik, F. Feil, C. Jung, C. Bräuchle, C. Scheu, and J. Michaelis: *Synchronous Emission from Nanometric Silver Particles through Plasmonic Coupling on Silver Nanowires;* ACS Nano, 6(7), 6049 (2012)

SINGLE MOLECULE FLUORESCENCE ENHANCEMENT ON DNA ORIGAMI

Prof. Philip Tinnefeld (TU Braunschweig, Institute of Physical andTheoretical Chemistry) www.tu-braunschweig.de/pci
Prof. Friedrich C. Simmel (TU Munich, Physics Department) www.e14.ph.tum.de
Prof. Tim Liedl (LMU Munich, Faculty of Physics) http://softmatter.physik.lmu.de/tiki-index.php?page=CVLiedl

The DNA origami technique allows positioning arbitrary objects precisely with respect to each other on the nanometer scale. Therefore, a ~8 kbases long DNA strand is folded into predefined shapes by the aid of ~200 short synthetic oligonucleotides, termed 'staple strands'. The individual staple strands can be easily modified to incorporate bio-molecules as well as metallic nanoparticles at specific sites within the nanostructure. We used the DNA origami as a breadboard to place fluorescent dyes next to gold nanoparticles. In collaboration with the groups of Fritz Simmel and Tim Liedl, we attached gold nanoparticles and fluorescent dyes to a rectangular DNA origami and studied the distance dependent fluorescence properties on the single-molecule level [1]. For 10 nm gold particles, we observe strong fluorescence quenching for short distances, in quantitative agreement with electromagnetic simulations. Based on these findings, we designed a DNA origami nanopillar that allowed attaching a dimer of different size particles and to place a single fluorescent molecule in the equatorial plane between the particles (see Figure). In this configuration, the nanoparticle dimer acts as a plasmonic nanoantenna that can strongly enhance the fluorescence of the fluorescent dye. These nanoantennas enable ~100fold more sensitive detection of even single molecules than previous approaches. Besides the higher sensitivity achieved the concentration barrier of single molecule optical spectroscopy is broken allowing experiments at higher and physiologically relevant concentrations of fluorescently labeled molecules. The DNA origami additionally enables to place biomolecular assays directly in the hot-spot of the nanoantenna by introducing docking sites. This is demonstrated by a single-molecule DNA detection experiment and a FRET experiment of the dynamics of a DNA 4way (Holliday) junction.



The pillar shaped DNA origami is used as breadboard where a nano-antenna consisting of two metallic gold nanoparticles is positioned. In the gap between the particles, a fluorescence dyes is incorporated to sample the antenna properties. The structure is further aligned to the exciting light so that upon illumination, both particles get polarized yielding a fluorescence enhancement. The fluorescence transient taken on single molecules indicate the huge fluorescence enhancement of ~80fold for these specific molecules.

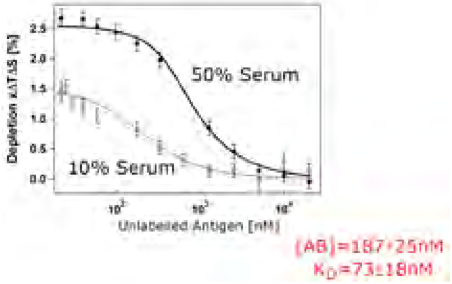
[1] G.P. Acuna, M. Bucher, I.H. Stein, C. Steinhauer, A. Kuzyk, P. Holzmeister, R. Schreiber, A. Moroz, F.D. Stefani, T. Liedl, F.C. Simmel, and P. Tinnefeld: *Distance dependence of Single-Fluorophore Quenching by Gold Nanoparticles studied on DNA Origami;* ACS Nano 6, 3189-3195 (2012)

[2] G.P. Acuna, F.M. Möller, P. Holzmeister, S. Beater, B. Lalkens and P. Tinnefeld: *Fluorescence Enhancement at Docking Sites of DNA-Directed Self-Assembled Nanoantennas;* Science 338, 506-510 (2012)

THERMOPHORETIC DIAGNOSTICS: DETECTION OF CONCENTRATION AND AFFINITY OF ANTIBODIES

Prof. Dieter Braun (LMU Munich, Faculty of Physics) www.biosystems.physik.uni-muenchen.de
Dr. Stefan Duhr (NanoTemper Technologies GmbH) www.nanotemper-technologies.com

The direct quantification of both binding affinity and absolute concentration of disease-related biomarkers in biological fluids is particularly beneficial for differential diagnosis and therapy monitoring. The Braun lab extended the existing microscale thermophoresis (MST) to target immunological questions. Optically generated thermal gradients were used to deplete fluorescently marked antigens in two and ten-fold diluted human serum. With an autocompetitive strategy, it was possible to independently fit concentration and dissociation constant of autoimmune antibodies against the cardiac α1-adrenergic receptor related to dilated cardiomyopathy (DCM). The simplicity of the mix and probe protocol minimizes systematic errors, making thermophoresis a promising detection method for personalized medicine.



Diagnostic Thermophoresis. For the first time we could demonstrate that thermophoresis is capable to measure both the concentration and the affinity of antibodies in unmodified blood serum using an autocompetition protocol. This new development paves the way to use thermophoresis in diagnostic applications.

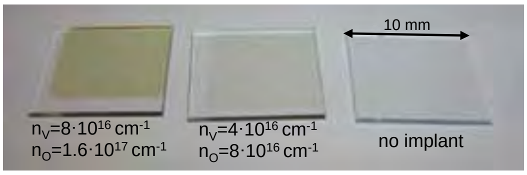
S. Lippok, S. A. I. Seidel, S. Duhr, K. Uhland, H.-P. Holthoff, D. Jenne, and D. Braun: *Direct Detection of Antibody Concentration and Affinity in Human Serum Using Microscale Thermophoresis;* Analytical Chemistry 84, 3523–3530 (2012)

ION BEAM SYNTHESIS OF NANOTHERMOCHROMIC DIFFRACTIVE OPTICAL ELEMENTS

Dr. Hubert J. Krenner and Prof. Achim Wixforth (University of Augsburg, Institute of Physics) www.physik.uni-augsburg.de/exp1

Vanadium dioxide (VO_2) undergoes a metal-insulator transition (MIT) at a moderate critical temperature of TC = 68°C. At this MIT, the electronic state of this material changes from a low temperature insulting to a high temperature metallic phase. This gives rise to a strong decrease of the electric resistivity and a strong modulation of the refractive index. Embedded VO_2 nanocrystals (NCs) are synthesized by sequential ion beam implantation of vanadium and oxygen into a silica matrix followed by a rapid thermal anneal step. NCs layers can be identified by bare eye as seen in Fig. 1 (a) and their high structural quality is confirmed by transmission electron microscopy [Fig. 1 (b)]. Diffraction gratings are realized either (i) directly by site-selective synthesis or (ii) by spatially selective deactivation of the MIT. The latter is achieved by ion irradiation which generates defects within the NCs. Both types of gratings are clearly visible in the optical microscope images shown as insets in Fig. 2. These defects in turn block the MIT. Representative diffraction scans recorded from a directly synthesized and a selectively deactivated grating at room temperature (blue) and 100°C (red) are depicted in Fig 2 (a) and (b), respectively. For both types of gratings a dramatic enhancement of the diffraction efficiency by a factor of >3 for the directly synthesized grating and more than one order of magnitude for the selectively deactivated grating are resolved. This pronounced thermochromic switching arises from a strong variation of the refractive index when the active VO_2 NCs undergo the MIT. Moreover, all optical characterization was performed at wavelengths technologically most relevant for fiber optical communications with a maximum switching contrast at λ = 1550 nm. The ion beam synthesized VO_2 NCs offer a number of additional advantages over thin films or bulk material including long time stability and absence of multiple metallic and insulating domains. This single-domain nature gives rise to a broad thermal hysteresis which extends down close to room temperature. This unique property is a direct consequence of the nanoscopic dimensions and makes our system ideally suited for bistable optical memory device applications.

(a) – VO_2 nanocrystals in fused silica



(b) Transmission electron micrograph

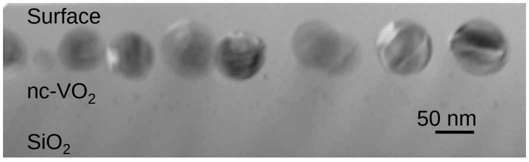


Fig. 1: (a) Fused silica substrates with (left to right) high density, mdeium density and no VO_2 NCs. (b) Transmission electron micrograph of ~90 nm diameter VO_2 NCs.

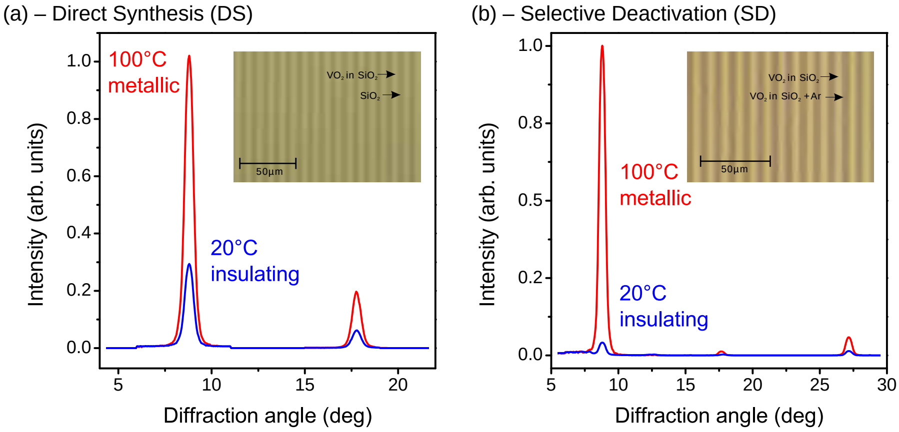


Fig. 2: Angular resolved light diffraction (λ = 1550 nm) and optical microscope images (insets) for a directly synthesized (a) and selectively deactivated nanothermochromic diffraction grating. For both types of grating giant switching of the diffracted light intensity is observed when the active NCs undergo the MIT from the insulating (a) to the metallic (b) state.

J. Zimmer, A. Wixforth, H. Karl, and H. J. Krenner: *Ion beam synthesis of nanothermochromic diffraction gratings with giant switching contrast at telecom wavelengths;* Applied Physics Letters 100, 231911 (2012)

LIVE-CELL IMAGING/EGF RECEPTOR

Prof. Christoph Bräuchle (LMU Munich, Department of Chemistry) www.cup.uni-muenchen.de/pc/braeuchle
Prof. Ernst Wagner (LMU Munich, Department of Pharmacy) www.cup.uni-muenchen.de/pb/aks/ewagner

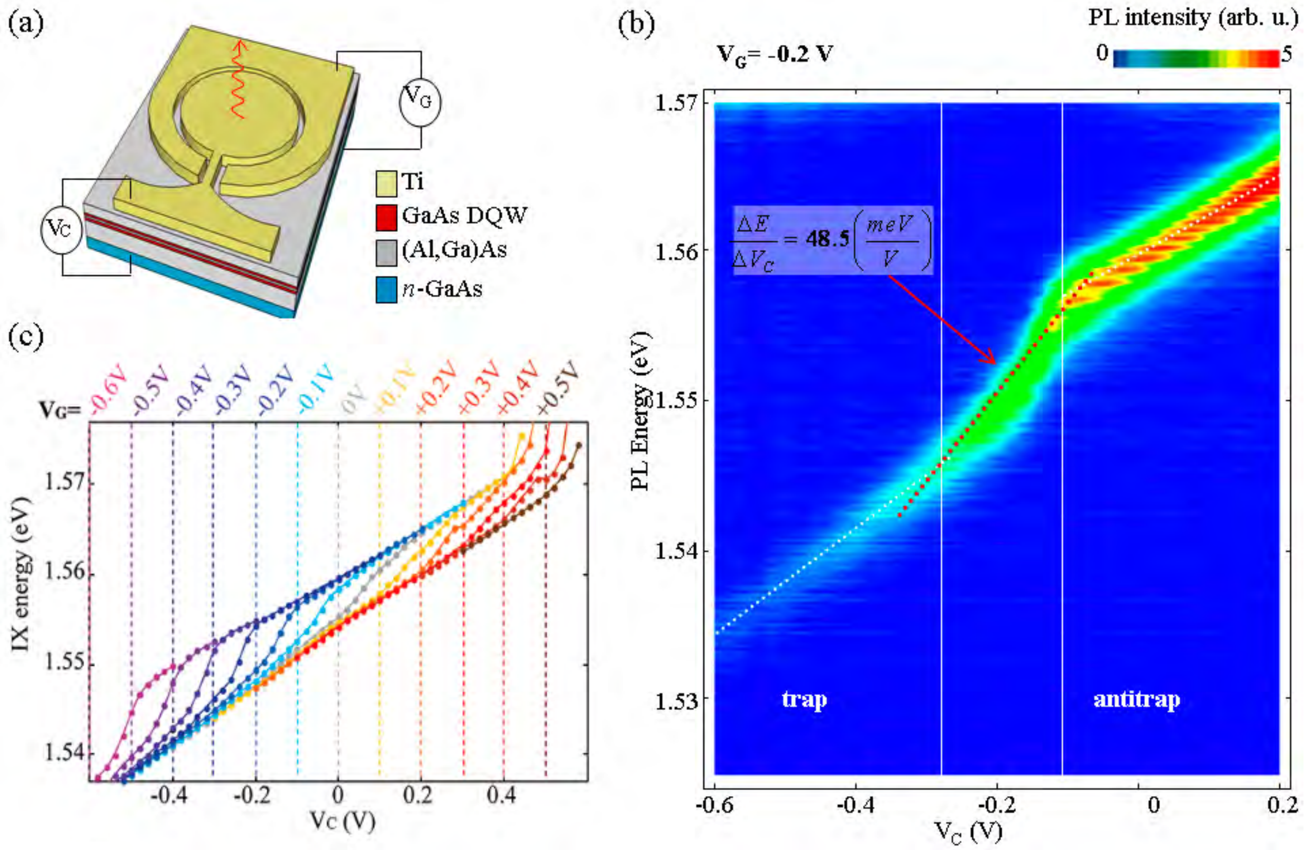
Therapeutic nanoparticles can be directed to cancer cells by incorporating selective targeting ligands. Here, the epidermal growth factor receptor (EGFR)-mediated endocytosis of gene carriers (polyplexes) are investigated, either targeted with natural EGF or GE11, a short synthetic EGFR-binding peptide. Highly sensitive live-cell fluorescence microcopy with single particle resolution unraveled the existence of two different uptake mechanisms; EGF triggers accelerated nanoparticle endocytosis due to its dual active role in receptor binding and signaling activation. For GE11, an alternative EGFR signaling independent, actin-driven pathway is presented.

F.M. Mickler, L. Möckl, N. Ruthardt, M. Ogris, E. Wagner, and C. Bräuchle: *Tuning nanoparticle uptake: Live-cell imaging reveals two distinct endocytosis mechanisms mediated by natural and artificial EGFR targeting ligand;* Nano Lett. 12 (7), 3417 (2012)

TUNABLE PHOTOEMISSION FROM AN EXCITONIC ANTITRAP

Prof. Jörg P. Kotthaus (LMU Munich, Faculty of Physics) *www.nano.physik.uni-muenchen.de*
Prof. Alexander W. Holleitner (TU Munich, Walter Schottky Institute and Department of Physics) *www.nanoptronics.de*

Dipolar excitons formed in double quantum wells by spatially separated electrons and holes can be electrostatically trapped in devices with microscopic gates as sketched in Fig.a employing the voltage-dependence of their emission energy via the quantum-confined Stark effect. They are of high current interest for both, fundamental studies of excitonic many body interactions and their potential application as easily tunable light emitters and modulators. Surprisingly, it is found that such dipolar excitons which are photogenerated in the center of the trap emit more efficiently in an antitrap configuration ($V_C > V_G$) which repels dipolar excitons from under the trap gate than in the attractive trap configuration ($V_C < V_G$) [1]. This is explained by the varying escape dynamics of photogenerated charge carriers from the trap during the formation of dipolar excitons. In the transition regime between both trapping configurations one finds a typically threefold enhanced Stark effect as discernible in Figs. b and c. The understanding and control of such trapping devices has potential applications in electrooptic devices and paves the way for excitonic logic circuits.



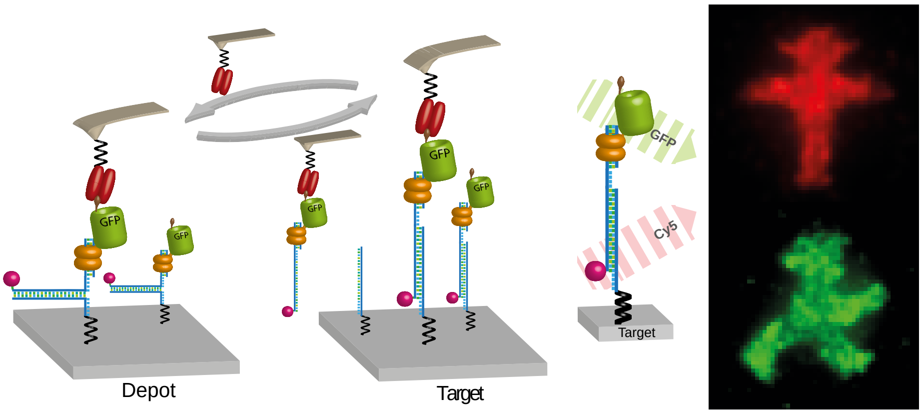
(a) Sketch of the trapping devices. The central trap gate (yellow), biased with voltage V_C with respect to a back contact (blue), is surrounded by a guard gate biased with voltage V_G with respect to a back contact. (b) PL energy of indirect excitons as function of V_C at V_G = -0.2 V for a device with trap gate diameter of 24 µm. Colours encode the emission intensity. Vertical lines mark the transition of the trap-antitrap configuration. Dotted white lines highlight the linear Stark shift in the trap (left) and antitrap (right) configuration. The dotted red line represents a linear fit for the transition region. (c) The tunability of the emission energy with the center gate voltage V_C for various guard gate voltages V_G is represented by the coloured traces.

[1] K. Kowalik-Seidl, X. P. Vögele, B. N. Rimpfl, G. J. Schinner, D. Schuh, W. Wegscheider, A. W. Holleitner, and J. P. Kotthaus: *Tunable Photoemission from an Excitonic Antitrap;* Nano Lett. 12, 326 (2012)

ARRANGING INDIVIDUAL FUNCTIONAL BIOMOLECULES BY UTILIZING PICO NEWTON FORCES

Prof. Hermann E. Gaub (LMU Munich, Faculty of Physics) *www.biophysik.physik.uni-muenchen.de*

Protein-based nanostructures are key to the organization of life and it is their precise arrangement that determines their specific function. A single-molecule approach for the directed assembly of protein arrangements allows for a controlled composition of systems based on protein components. Using Single-Molecule Cut- and-Paste (SMC&P), protein-DNA complexes could be assembled into complex patterns with the functionality remaining unimpaired. [1] Adhesion of environmentally responsive polymers to biocompatible surfaces can support such assemblies and act in nanobiotechnology applications. [2] Particulary cellulose-degrading enzyme systems are of significant interest from both a scientific and technological perspective due to the diversity of cellulase families, their unique assembly and substrate binding mechanisms, and their potential applications in several key industrial sectors, notably cellulose hydrolysis for second-generation biofuel production. Cellulosomes are multimodular extracellular complexes produced by numerous anaerobic bacteria. By single-molecule force spectroscopy, the mechanical stability of their intermolecular interfaces between the cohesin and the dockerin modules were investigated. These modules are responsible for self-assembly of the cellulosomal components into multi-enzyme complexes. The observed cohesin–dockerin rupture forces (>120 pN) are among the highest reported for a receptor–ligand system to date. [3]



Schematics of the transfer process. The GCN4–GFP–zinc finger construct with the anchor DNA pulled open in the weak zipper geometry can then be transferred to the target site, where the shear geometry bond to the target DNA is stronger than the bond between antibody and GCN4 peptide. The protein construct is deposited in the target area, whereas the antibody on the cantilever is free again and can be reused in the next transfer cycle. After 900 transport cycles of the protein–DNA construct a pattern displaying the red man of a pedestrian traffic light was assembled. The red emission of the Cy5 label at the DNA part was then measured. Next, the pattern of a green man was assembled, and this time the green fluorescence of the transferred GFP molecules was recorded. It proves that not only the cantilever-bound antibody fragment but also the transfer construct stays intact during the transfer cycles. The forces occurring during the transfer process are low enough so that the functionality of the transported GFP is not destroyed.

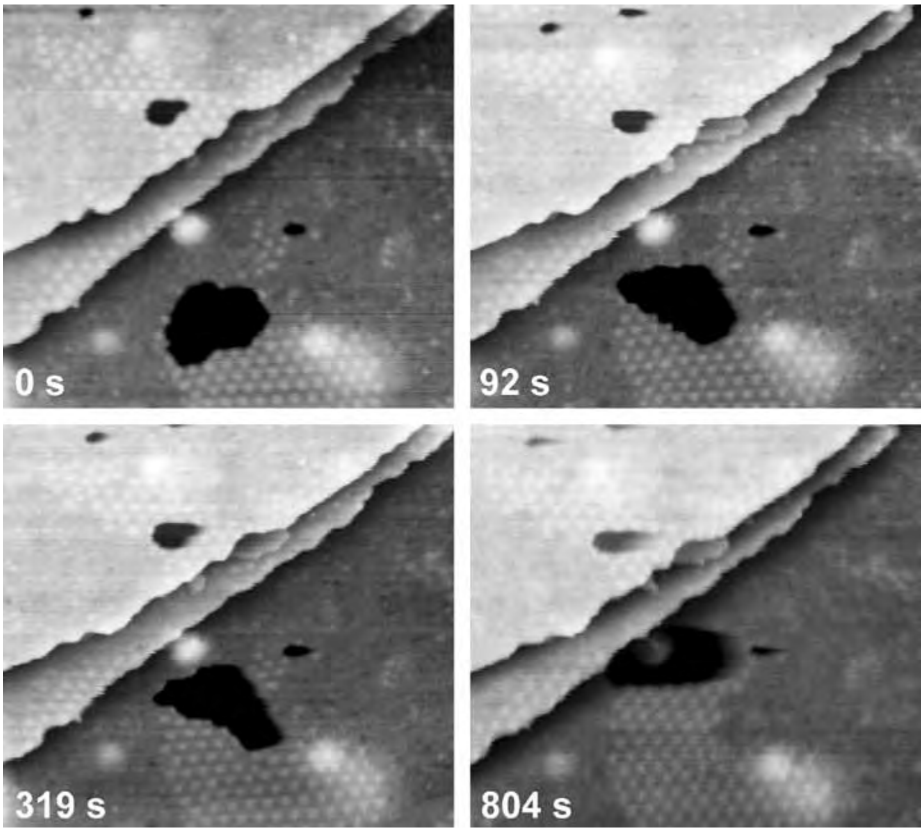
[1] M. Strackharn, D.A. Pippig, P. Meyer, S.W. Stahl, and H.E. Gaub: *Nanoscale arrangement of proteins by Single-Molecule Cut & Paste;* JACS 134(37), 15193-6 (2012)
[2] M.A. Nash and H.E. Gaub: *Single-Molecule Adhesion of a Stimuli-Responsive Oligo(ethylene glycol)Copolymer to Gold;* ACS Nano 6 (12), 10735–10742 (2012)
[3] S.W. Stahl, M.A. Nash, D.B. Fried, M. Slutzki, Y. Barak, E.A. Bayer and H.E. Gaub: *Single-molecule dissection of the high-affinity cohesin–dockerin complex;* PNAS 109 (50), 20431–20436 (2012)

Cover image: Christoph Hohmann (NIM) / ACS Nano [2].

ORDERING OF AMORPHOUS CARBON INTO GRAPHENE

Prof. Joost Wintterlin (LMU Munich, Department of Chemistry) www.cup.uni-muenchen.de/pc/wintterlin

How does an amorphous carbon layer order into graphene? This question is relevant for several currently tested synthesis methods in which at least partially disordered carbon layers are annealed to high temperatures to give graphene. By which mechanisms such ordering processes occur, and which factors have so far limited the success of such methods, is largely unknown. The difficulty is to obtain atomic-scale insight into the rearrangement processes in the disordered carbon network. In this project scanning tunneling microscopy (STM) was used, a method that only recently has been improved so far that it can be applied at the extreme temperatures required for the ordering. In the experiments an amorphous carbon layer with almost the same carbon density as graphene was prepared on an (0001)-oriented ruthenium single crystal. This was achieved by decomposing ethylene molecules on the metal surface and then carefully annealing the sample to desorb hydrogen, without simultaneously ordering the carbon layer. Then the temperature was raised, and the changes in the layer were monitored by STM. The figure shows a time series recorded at 920 K. At the beginning, most of the surface is covered by a flat, structureless layer that represents amorphous carbon. At some locations one can already recognize a hexagonal structure that is caused by ordered graphene; the hexagonal structure results from the moiré effect originating from the superposition of the graphene lattice and the hexagonal metal surface. The important observation is a large hole (black spot in the image center) that travels through the carbon layer. The area on the path along which the hole has moved shows the hexagonal moiré pattern, i.e. the area has transformed into graphene. These observations suggest an atomic mechanism by which the ordering takes place: Carbon atoms detach from the disordered side of the hole and reattach at the graphene side, so that the hole moves and the graphene area increases. In this way structure rearrangements in the dense parts of the layer, which are connected with high energies, are avoided. This mechanism could be made use of to improve graphene synthesis methods by intentionally using incomplete layers.



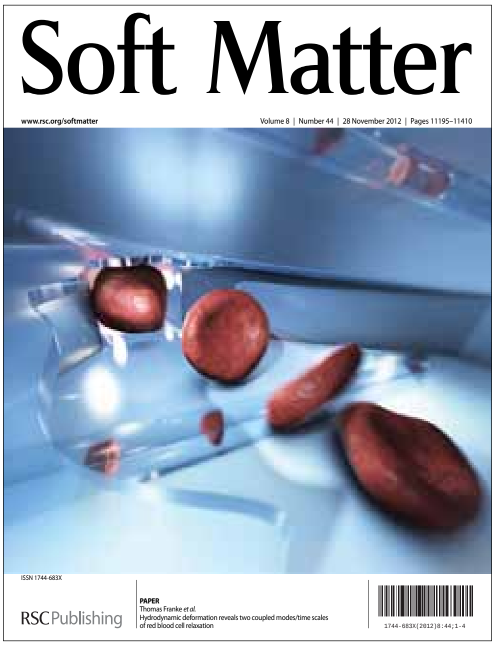
Series of STM images of a Ru(0001) surface recorded during ordering of an amorphous carbon layer into graphene. The 1100 Å x 1100 Å images were taken at 920 K. The flat parts of the surface are amorphous carbon, the hexagonal areas are graphene, the black central spot is a hole in the carbon layer. The motion of the hole transforms the amorphous carbon into graphene.

S. Günther, S. Dänhardt, M. Ehrensperger, P. Zeller, S. Schmitt, J. Wintterlin: *High-temperature scanning tunneling microscopy study of the ordering transition of an amorphous carbon layer into graphene on ruthenium(0001);* ACS Nano 7, 154 (2013)

HYDRODYNAMIC DEFORMATION OF RED BLOOD CELLS - THE EFFECT OF ATP

Prof. Thomas Franke and Prof. Achim Wixforth (University of Augsburg, Institute of Physics) www.physik.uni-augsburg.de/exp1

During their transport through the capillaries of blood vessels, erythrocytes (red blood cells) are repeatedly strongly deformed undergoing morphological transitions from parachute to discoid shapes. A high degree of elastic deformability of the cells is essential to enable them to move during their whole lifetime of 120 days through the narrow capillaries exhibiting diameters some of which are smaller than those of the cells themself. The astonishing softness of red blood cells in microcirculation and the enormous reversible shape deformability are based on the large surface to volume ratio and on the mechanical properties of the lipid bilayer and the underlying cytoskeleton. In a recent publication the mechanical relaxation behavior of human red blood cells was studied by observing the time evolution of shape change of cells flowing through microchannels with abrupt constrictions. Two relaxation processes were identified. In the first fast process ($T_{1\sim}$ 200 ms) the initially parachute shaped cells relax into cup-shaped cells (stomatocytes). These cells then relax and reorient in a second relaxation process with a response time of $T_{1/2\sim}$ 10 s eventually into the equilibrium discoid shapes. However, when plotting $T_{1/2}$ against T_1, we find a linear relationship between the two timescales and are able to relate both to the elastic properties of the spectrin cytoskeleton underlying the red cell's plasma membrane. Adenosine Triphosphate (ATP) enhances dissociation of spectrin filaments resulting in a reduced shear modulus. We modify the cytoskeleton connectivity by depletion and repletion of ATP and study the effect on relaxation. Both the linear relationship of timescales as well as the ATP dependence can be understood by theoretical models. We conclude that ATP plays an important role for blood flow because it allows to control the viscoelastic properties of the cells. Furthermore, it is known that red blood cells release at ATP when subjected to strong deformation. The combination of both results in a self-regulating effect that reduces the pulmonary vascular resistance of blood. Therefore, this mechanism is of great importance in many diseases and also for the effect of drugs to treat these diseases. For example in hypercholesterolemia were high cholesterol concentrations stiffen the red blood cells, ATP release is enhanced to compensate for this effect. Also Simvastatin that is used in statin therapy to treat chronic stable angina has been demonstrated to have a significant effect on red blood cell deformation (see publication of the group in "microvascular research").


Soft Matter

www.rsc.org/softmatter
Volume 8 | Number 44 | 28 November 2012 | Pages 11195–11410

ISSN 1744-683X

RSCPublishing

PAPER
Thomas Franke *et al.*
Hydrodynamic deformation reveals two coupled modes/time scales of red blood cell relaxation

1744-683X(2012)8:44;1-4

Red blood cell flowing out of a narrow constriction. Cover image: Christoph Hohmann (NIM) / Soft Matter.

S. Braunmüller, L. Schmid, E. Sackmann, and T. Franke: *Hydrodynamic deformation reveals two coupled modes/time scales of red blood cell relaxation;* Soft Matter 8, 11240 (2012)[cover article]

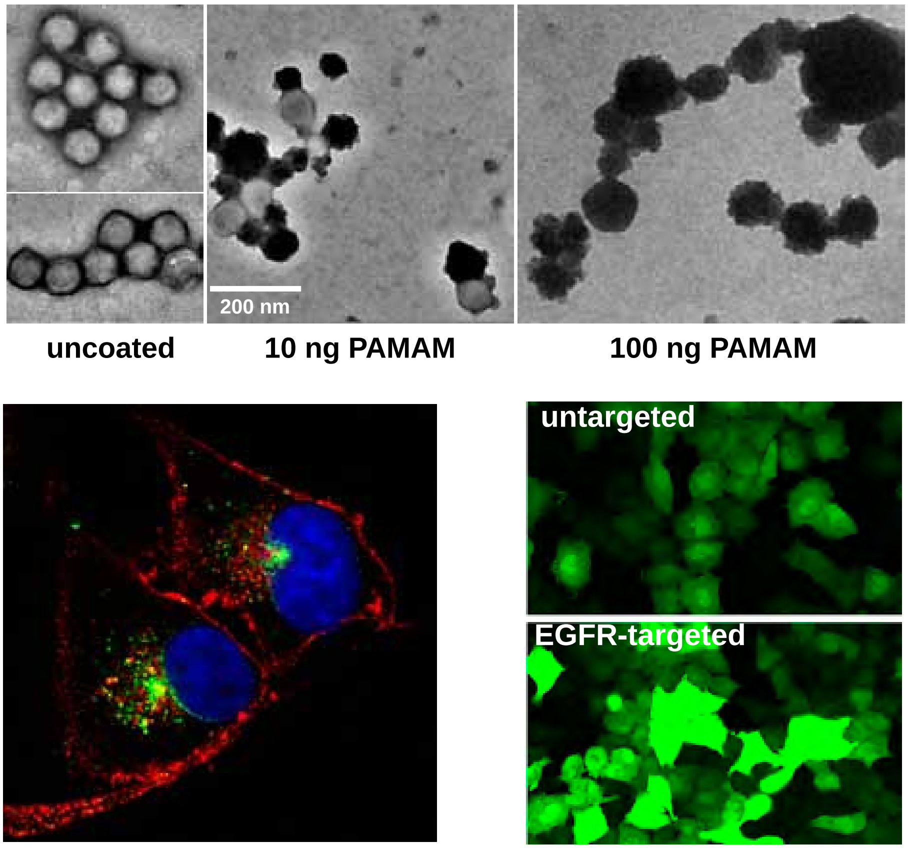
A.M. Forsyth, S. Braunmüller, J. Wan, T. Franke, and Howard A. Stone: *The effects of membrane cholesterol and simvastatin on red blood cell deformability and ATP release;* Microvascular Research 83, 347 (2012)

T. M. Geislinger, B. Eggart, S. Braunmüller, L. Schmid, and T. Franke: *Separation of blood cells using hydrodynamic lift;* Appl. Phys. Lett. 100, 183701 (2012)

DENDRIMER COATED ADENOVIRUS FOR CANCER GENE THERAPY – CORRELATING ULTRASTRUCTURE WITH BIOLOGICAL ACTIVITY

PD Dr. Manfred Ogris (LMU Munich, Department of Pharmacy) *www.cup.uni-muenchen.de/dept/ph/pharmabio/ogris.php*
Prof. Christina Scheu (LMU Munich, Department of Chemistry) *www.cup.uni-muenchen.de/pc/scheu*

Targeted delivery of therapeutic genes into cancer cells is a prerequisite for successful tumor gene therapies. Recombinant adenovirus is one of the most powerful and efficient gene vectors applied in gene therapy. Binding and internalization into cells depends on the Coxsackie-and-Adenovirus receptor (CAR), which is expressed in several body tissues. Unfortunately, especially aggressive and metastatic cancers do not express CAR making them 'invisible' for the virus. In this study the virus surface was coated with PAMAM dendrimer conjugates, where a polycationic domain binds to the virus capsid by electrostatic interaction. The physical properties of the coated virus have been thoroughly analyzed by transmissions electron microscopy (TEM) and laser light scattering and were correlated with its biological activity in terms of cellular uptake and reporter gene studies. TEM studies revealed that dendrimer concentrations used correlated with the degree of virus coating, and the surface charge of the particles changed from net negative to net positive. The dendrimer efficiently masked virus proteins, which are otherwise visible as hexagonal structure. Coated Ad allowed efficient cellular binding, -internalization and transport towards the nuclear membrane also on CAR negative cell lines, were unmodified virus was not able to bind. The Epidermal growth factor receptor (EGFR) is overexpressed on many solid tumors, and its level correlates with tumor aggressiveness. Hence, molecular conjugates of PAMAM dendrimer were designed and synthesized, where the EGFR specific peptide ligand GE11 was chemically coupled to PAMAM via a polyethyleneglycol (PEG) linker molecule. Both, cellular uptake and reporter gene expression (enhanced green fluorescent protein) was clearly enhanced on tumor cells with high EGFR expression. Taken together, this study clearly proves non-covalent, charge-based coating of Ad vectors with ligand-equipped dendrimers as a viable strategy for efficient transduction of cells otherwise refractory to Ad infection.

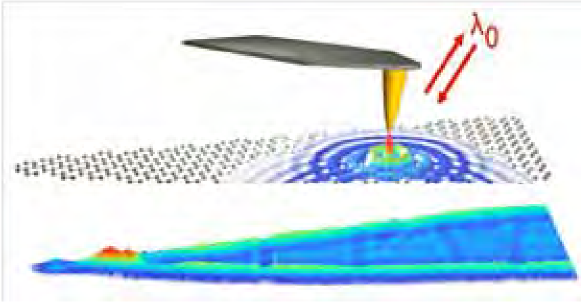


Top panel: transmission electron microscopy of uncoated and PAMAM coated adenovirus; lower left panel: laser scanning microscopy of epidermal growth factor receptor (EGFR) positive U87MG human glioblastoma cells transduced with PAMAM-PEG-GE11 coated adenovirus (red: EGFR, green: adenovirus, blue: cell nucleus); lower right panel: reporter gene expression (enhanced green fluorescent protein) of EGFR positive A549 human lung carcinoma cells transduced with PAMAM coated adenovirus (top) or EGFR targeted PAMAM-PEG-GE11 coated adenovirus (bottom).

A. Vetter, K.S. Virdi, S. Espenlaub, W. Rödl, E. Wagner, P.S. Holm, C. Scheu, F. Kreppel, C. Spitzweg, and M. Ogris : *Adenoviral vectors coated with PAMAM dendrimer conjugates allow CAR independent virus uptake and targeting to the EGF Receptor;* Mol Pharm. 10, 606-618 (2013)

GRAPHENE SURFACE PLASMONS

Dr. Fritz Keilmann (LMU Munich, Faculty of Physics) *www.attoworld.de/SharedPages/People/KeilmannFritz/KeilmannFritz.html*
Prof. Rainer Hillenbrand (CIC nanoGUNE San Sebastian) *www.nanogune.eu/en/research/nanooptics/people/rainer*



Optical nanoimaging of graphene surface plasmons. Upper panel: A laser-illuminated scanning tip launches plasmons on graphene; detection is by recording the light backscattered from the tip. Lower panel: Infrared (λ= 10 µm) near-field image of a graphene flake, where the fringes at period $\lambda/2 \approx 100$ nm visualize the interference of the graphene plasmons

Graphene is a fascinating material with extraordinary mechanical, electrical and optical properties. Surface plasmons—wave-like excitations that were predicted to exist in the “sea” of conduction electrons of graphene—were long not experimentally confirmed because their wavelength is 10 to 100 times smaller than what can be seen with conventional light microscopes. A novel technique developed within CeNS named “scanning plasmon interferometry” has enabled the first experimental images of graphene plasmons, and furthermore demonstrated that the plasmon wavelength can be tuned by biasing common graphene/SiO2/Si back-gated structures with d.c voltage. The results support the notion of prominent many-body effects in graphene beyond the picture of non-interacting Dirac fermions. They were obtained with infrared near-field microscopes made by CeNS spin-off Neaspec GmbH, and published back-to-back in Nature by both the Keilmann and Hillenbrand groups. In scanning plasmon interferometry the near-field microscope’s sharp metallic tip converts incident light into a nanoscale hot spot that provides photons with high momentum. This constitutes the extra push needed for the plasmons to be created. At the same time the tip probes the presence of plasmons. Near the edge of a graphene flake, the plasmon field is the coherent sum of outgoing and edge-reflected waves. Therefore, a scanned plasmon image constitutes a plasmon standing wave which directly reveals wavelength, damping, edge reflectivity and phase of plasmons. As demonstrated by the researchers, graphene plasmons can be used to electrically control light in a similar fashion as is traditionally achieved with electrons in a transistor. These capabilities, which until now were impossible with other existing plasmonic materials, enable new highly efficient nano-scale optical switches which can perform calculations using light instead of electricity. Graphene is a novel and unique material for plasmonics, truly bridging the fields of nano-electronics and nano-optics.

Z. Fei, G.O. Andreev, W. Bao, A.S. McLeod, M. Wagner, L.M. Zhang, Z. Zhao, M. Thiemens, G. Dominguez, M.M. Fogler, A.H. Castro Neto, C.N. Lau, F. Keilmann, and D.N. Basov: *Gate-tuning of graphene plasmons revealed by infrared nano-imaging;* Nature 487, 83 (2012)
J. Chen, M. Badioli, P. Alonso-Gonzalez, S. Thongrattanasiri, F. Huth, J. Osmond, M. Spasenovic, A. Centeno, A. Pesquera, P. Godignon, A. Z. Elorza, N. Camara, F. Javier Garcia de Abajo, R. Hillenbrand and F.H.L. Koppens: *Optical nano-imaging of gate-tunable graphene plasmons;* Nature 487, 80 (2012)

SOUND WAVES AT SOFT INTERFACES AND THEIR ROLE IN BIOLOGY

Prof. Matthias Schneider (Boston University, Department of Mechanical Engineering) *https://sites.google.com/site/schneiderslab/*
Prof. Achim Wixforth (University of Augsburg, Institute for Physics) *www.physik.uni-augsburg.de/lehrstuehle/exp1/*

An acoustic pulse propagating along a 2D-interface is predicted to be the physical basis of protein communication and a crucial mechanism for enabling the cell or an organ to orchestrate its activities as an individual entity.

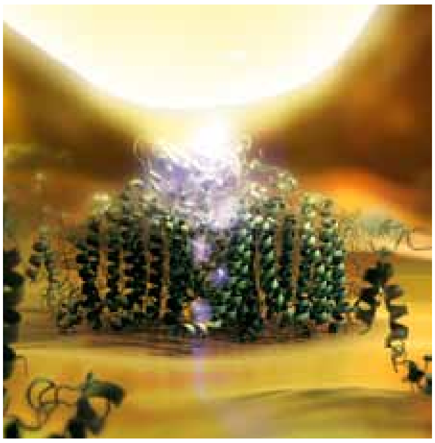
What is the physical basis of biological communication and synchronization? What makes the cell an individual unit and not just an accumulation of many single molecules? In order to test their hypothesis that single molecules (e.g. enzymes) embedded at interfaces can indeed communicate via sound pulses, physicists from Boston University and the University of Augsburg created a set up in which such pulse propagation could be in fact observed. In their work, published in Phys Rev Lett they found, that a local perturbation of a lipid monolayer can indeed propagate over macroscopic distances and is controlled by the thermodynamic state of the interface. Furthermore, based on thermodynamic arguments they have predicted that the discoverd density pulse should be accompanied by a pulse of electrical potential. In a second paper, published in Phys Rev E, they were able to experimentally demonstrate the existence and electro-mechanical coupling of this propagating voltage pulse. The role of this work for biology has an enormous potential. It not only supports the idea that nerve pulse propagation may occur as a propagating density pulse, but since biological systems are full of hydrated interfaces of simple or complex topology, this work suggests a physical explanation of signalling and cellular communication based on propagating pulses, which change the kinetics of membrane embedded molecules (e.g. turn-over rates of enzymes).

J. Griesbauer, S. Bössinger, A. Wixforth, M. F. Schneider: *Propagation of 2D Pressure Pulses in Lipid Monolayers and Its Possible Implications for Biology;* Phys Rev Lett 108, 198103 Editors Suggestion (2012)
J. Griesbauer, S. Bössinger, A. Wixforth, and M.F. Schneider: *Simultaneously propagating voltage and pressure pulses in lipid monolayers of pork brain and synthetic lipids;* PRE (86) 061909 (2012)

SOLAR CELL MADE OUT OF ONE PROTEIN

Prof. Alexander Holleitner (TU Munich, Walter Schottky Institute and Department of Physics) www.nanoptronics.de

The Holleitner group verified the photocurrent of a single photosynthetic protein for potential photovoltaic applications [1]. Photosynthesis is used by plants, algae and bacteria to convert solar energy into stable chemical energy. It has been previously shown that single small molecules can be used as functional components in electric and optoelectronic circuits ([2] and [3]), but it has proved difficult to control and probe individual molecules for photovoltaic and photoelectrochemical applications. In cooperation with the Barth group of the TUM and the Carmeli group in Tel Aviv, the Holleitner group demonstrated that the photocurrent generated by a single photosynthetic protein can be measured using a scanning near-field optical microscope set-up. One side of the protein is anchored to a gold surface that acts as an electrode, and the other is contacted by a gold-covered glass tip. The tip functions as both counter electrode and plasmonic near-field light source. A photocurrent of 10 pA is recorded from the covalently bound single-protein junctions, which is in agreement with the internal electron transfer times of the PS I. The results demonstrate that individual photosynthetic proteins can be integrated and selectively ad-dressed in nanoscale photovoltaic devices while retaining their biomolecular functional properties. They act as light-driven, highly efficient single-molecule electron pumps that can function as current generators in nanoscale electric circuits.



Sketch of a photosynthetic protein on a gold surface contacted by a gold-coated glass tip. Image: Christoph Hohmann (NIM).

[1] D. Gerster, J. Reichert, H. Bi, J. V. Barth, S. M. Kaniber, A.W. Holleitner, I. Visoly-Fisher, S. Sergani, and I. Carmeli: *Photocurrent of a single photosynthetic protein;* Nature Nanotechnology 7, 673 (2012)

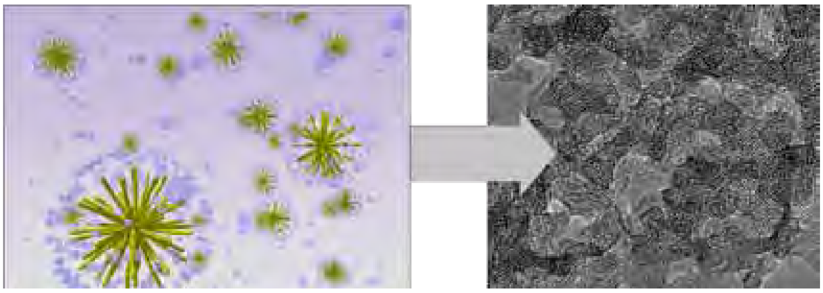
[2] M. Mangold, M. Calame; M. Mayor, and A.W. Holleitner: *Resonant Photoconductance of Molecular Junctions Formed in Gold Nanoparticle Arrays;* Journal of the American Chemical Society 133, 12185 (2011)

[3] M. Mangold, M. Calame, M. Mayor, and A.W. Holleitner: *Negative Differential Photoconductance in Gold Nanoparticle Arrays in the Coulomb Blockade Regime;* ACS Nano 6, 4181 (2012)

NANOSCALE POROUS FRAMEWORK OF LITHIUM TITANATE FOR ULTRAFAST LITHIUM INSERTION

Prof. Thomas Bein and Prof. Dina Fattakhova-Rohlfing (LMU Munich, Chemistry Department) http://bein.cup.uni-muenchen.de

The rapidly growing market for electric vehicles and mobile electronics demands the development of electrochemical energy storage systems with both high energy density and high power. While supercapacitors can deliver very high powers, their attainable energy densities are far lower than those of batteries. On the other hand, batteries need a significant time for charging. In our study it was demonstrated that a judiciously designed porous nano-morphology leads to a dramatic reduction of charging times of lithium titanate which is currently used as an anode material in commercial lithium batteries and hybrid supercapacitors. In our project a new synthesis strategy was introduced that enables the formation of fully crystalline interconnected porous frameworks composed of ultrasmall lithium titanate spinel (LTO) nanocrystals of a few nm in size (see figure). These frameworks feature a gravimetric capacity of about 175 mAh g^{-1} at rates of 1–50 C and can deliver up to 73% of their maximum capacity at unprecedented high rates of up to 800 C without deterioration up to a thousand cycles. This rate corresponds to only 4.5 sec for charge/discharge and represents the fastest ever-reported lithium insertion process in titania morphologies. The ultrafast LTO anodes set a new standard in the performance of insertion materials and have great potential for the development of Li-ion batteries that can operate both at high energy density and high power. A novel non-aqueous synthesis approach developed in our group is also applicable to other classes of nanomaterials, extending the scope of the available metal oxide nanoparticles. The particles prepared in this way are crystalline, dispersible und very small, with the size which can be varied from 2.5 to 5 nm. Such nanoparticles demonstrate excellent properties in the application involving interfacial charge transfer and bulk charge transport processes such as dye-sensitized solar cells, catalysts for electrochemical water splitting and energy storage.



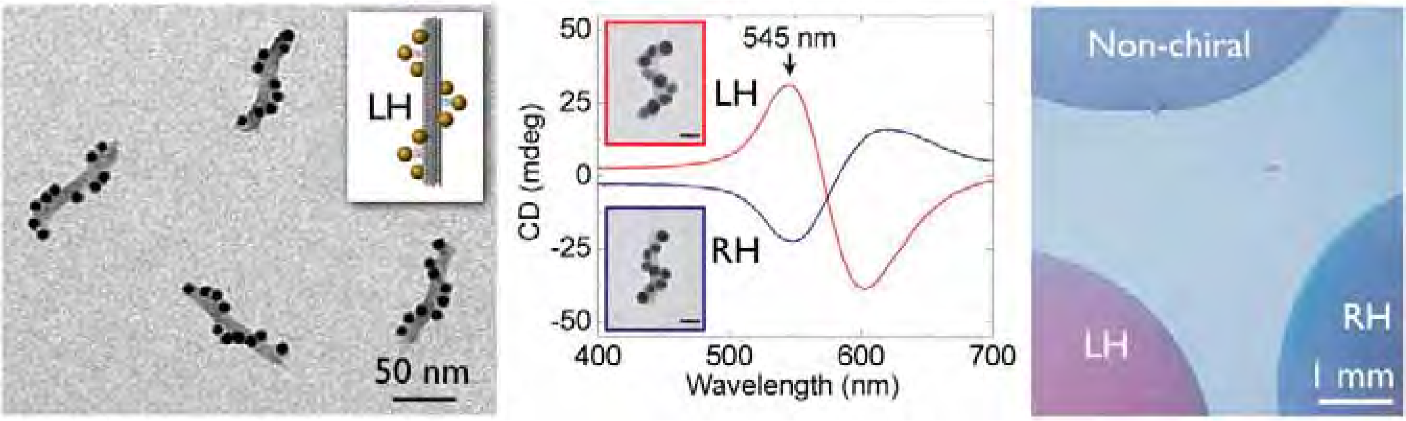
Formation of the crystalline porous framework composed of ultrasmall lithium titanate spinel nanocrystals via solvothermal reaction.

J. M. Feckl, K. Fominykh, M. Döblinger, D. Fattakhova-Rohlfing, T. Bein: *Nanoscale porous framework of lithium titanate for ultrafast lithium insertion;* Angew. Chem. Int. Ed. 51, 7459 (2012)

DNA ORIGAMI METAFLUIDS: TAILORING LIGHT WITH CHIRAL GOLD PARTICLE ASSEMBLIES

Prof. Tim Liedl (LMU Munich, Faculty of Physics) http://softmatter.physik.lmu.de/tiki-index.php?page=CVLiedl
Prof. Alexander Högele (LMU Munich, Faculty of Physics) http://www.nano.physik.uni-muenchen.de/nanophotonics/
Prof. Friedrich C. Simmel (TU Munich, Physics Department) www.e14.ph.tum.de

Different isomers of natural compounds like lactic acid, L(+) and D(-), exhibit different optical activities, mostly in the ultraviolet range. The production of artificial chiral nanoparticle assemblies, however, has been challenging so far. Here, DNA origami was used for the fabrication of self-assembled nanoscopic materials that have strong optical activity in the visible range. In DNA origami, a virus-based eight kilobase-long DNA single-strand is folded into shape with the help of ~ 200 synthetic oligonucleotides. The resulting DNA nanostructures can be designed to adopt any three-dimensional shape and can be addressed through DNA-hybridization and chemical conjugation of a wide variety of linkers with nanometer-precision. With this technique, plasmonic particles were assembled in solution to form helices of controlled handedness that have a diameter of ~35 nm and a length of ~ 90 nm. We achieved spatial control over particle placement better than 2 nm and attachment yields of 97% and above. As a collective optical response emerging from the dispersed nanostructures, pronounced circular dichroism (CD) originating from the plasmon-plasmon interactions in the particle helices was detected. The results can be explained quantitatively with theoretical models based on plasmonic dipole interaction and demonstrate the potential of DNA origami for the assembly of plasmonic metafluids with optical properties defined by design.



Left: DNA-origami structures (cylinders) with attached goldparticles (spheres) forming helices of defined chirality, here left-handed (LH) helices are shown. Middle: Fluids containing gold nanohelices display strong circular dichroism (CD). Right: If droplets of such fluids are placed between two crossed polarizers, frequency-dependent optical rotatory disprersion (ORD) can be observed.

A. Kuzyk, R. Schreiber, Z. Fan, G. Pardatscher, E. Roller, A. Högele, F. C. Simmel, A. O. Govorov, and T. Liedl: *DNA-based self-assembly of chiral plasmonic nanostructures with tailored optical response;* Nature 483, 311-314 (2012)

MESOPOROUS SILICA CHANNELS

Prof. Thomas Bein (LMU Munich, Chemistry Department) http://bein.cup.uni-muenchen.de
Prof. Christoph Bräuchle (LMU Munich, Chemistry Department) www.cup.uni-muenchen.de/pc/braeuchle
Prof. Heinrich Leonhardt (LMU Munich, Biology Department II) www.humangenetik.bio.lmu.de/forschung/epigenetik

Schloßbauer *et al.* reported how multifunctional core–shell colloidal mesoporous silica nanoparticles are combined with covalently surface-linked protoporphyrin IX (PpIX) as an on-board photosensitizer showing localized photoactivity in vitro and in living cells. To demonstrate the activity of these nanodevices, different agents were adsorbed into the mesopores. The loaded particles were encapsulated by a supported lipid- bilayer, incubated with HuH7 human cancer cells and, after cellular uptake of the particles, irradiated with violet light. Subsequent release of the loaded agents into the cytosol, by first photochemical rupture of the supported lipid bilayer, and secondly photochemical endosomal escape was investigated by wide-field and spinning disk confocal fluorescence microscopy at a single cell level. Depending on the guest molecule loaded in the mesopores, the multifunctionality of this smart and programmable nano-carrier as "surgical" photoactive drug delivery or for selective cell structure imaging was exploited. This work represents the first report combining rupture of supported lipid-bilayer coats and endosome escape of CMS by singlet oxygen generation. It demonstrates for the first time that, using the above approach, different membrane-impermeable cargos in a broad size-range can be efficiently delivered into cells via illumination in a cascaded process while achieving local confinement of the photoactivity and still preserving the cell viability.

Rühle *et al.* reported about a strategy for synthesizing 2D-hexagonal mesoporous silica thin films with highly oriented and parallel aligned mesopores over large domains. For an immediate feedback about the structure of the pores Single Molecule Microscopy was applied. Therefore fluo-

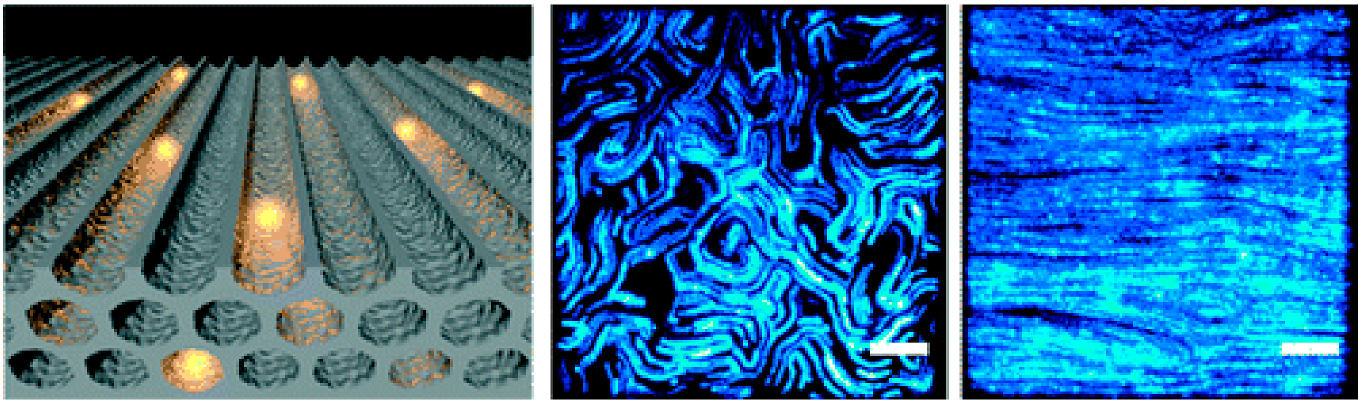


Fig. 1: Single molecules analyzing the pore alignment of 2D-hexagonally arranged mesopores (left: structure model). Maximum projections of the individual frames of a wide-field movie taken from the mesoporous silica material with non-aligned pores (middle) and with aligned pores (right). Scale bars are 5 µm.

rescent TDI dye molecules were added to the EISA precursor solution (containing tetraethylorthosilicate (TEOS), Pluronic F127, ethanol, HCl and water) and incorporated into the channels at very low concentrations (10^{-10}-10^{-11}M). The dye molecules could explore and map out the possible pathways within the mesoporous channel network in a non-invasive way. A "maximum projection" immediately gave a global overview ("map") of the pore structure, thus providing direct feedback for tuning synthesis conditions. The maximum projections are created by recording a movie with a fluorescence microscope and subsequently reconstructing an image in which each pixel assumes the maximum value it reaches in the individual frames. From the maximum projections one can immediately see whether the structure of the synthesized silica mesopores is random or well-aligned. Moreover single molecule tracking was used to gain more detailed information about the domain size and correlation length of the cylindrical mesopores, the defects in the silica walls, and the dead ends of the channel. In addition the diffusion was described as a 1D random walk where the molecules diffuse along the highly oriented, parallel channels and sometimes switch from channel to channel through small defects in the pore walls.

Feil *et al.* studied the diffusion dynamics of terrylene diimide (TDI) dye molecules and dye-labeled double-strand DNA (ds-DNA labeled with Cy3 and Cy5) in micrometer long silica filaments containing collinear, oriented mesopores. They functionalized the pores (pore diameter of 4 nm) with one or two types of trialkoxysilane groups to enhance the affinity between the silica channels and the guest molecules. The diffusion of the molecules could be controlled by exposure to vapors of water or chloroform. Single Molecule Microscopy was also used to investigate the translational and orientational dynamics of the guest molecules within the silica pores. Single TDI trajectories reveal the mesoporous structure. Additionally, the stability of DNA oligomers (15 base pairs, bp, about 5.3 nm long) within the mesopores was examined, showing no degradation of the oligonucleotide upon incorporation into the mesopores.

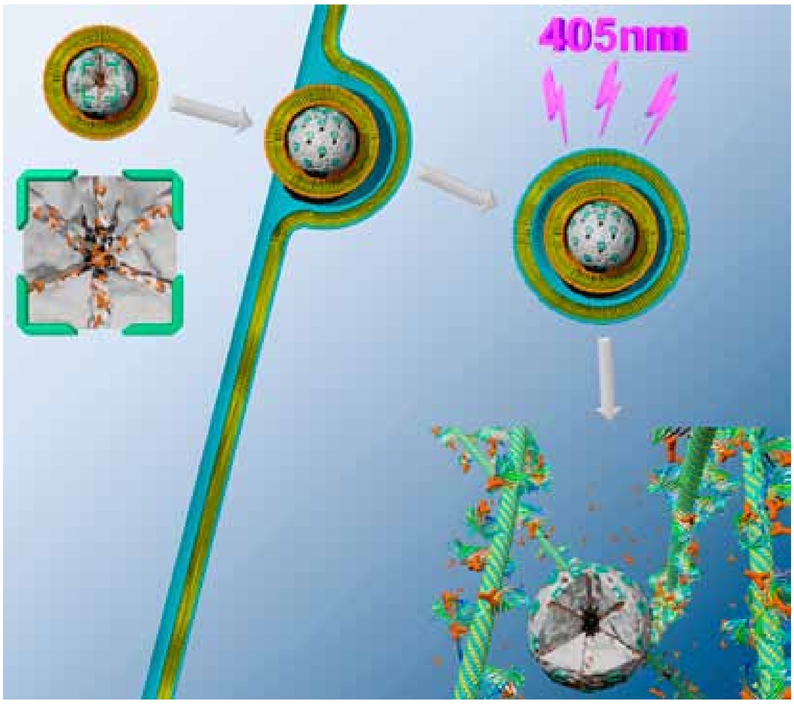


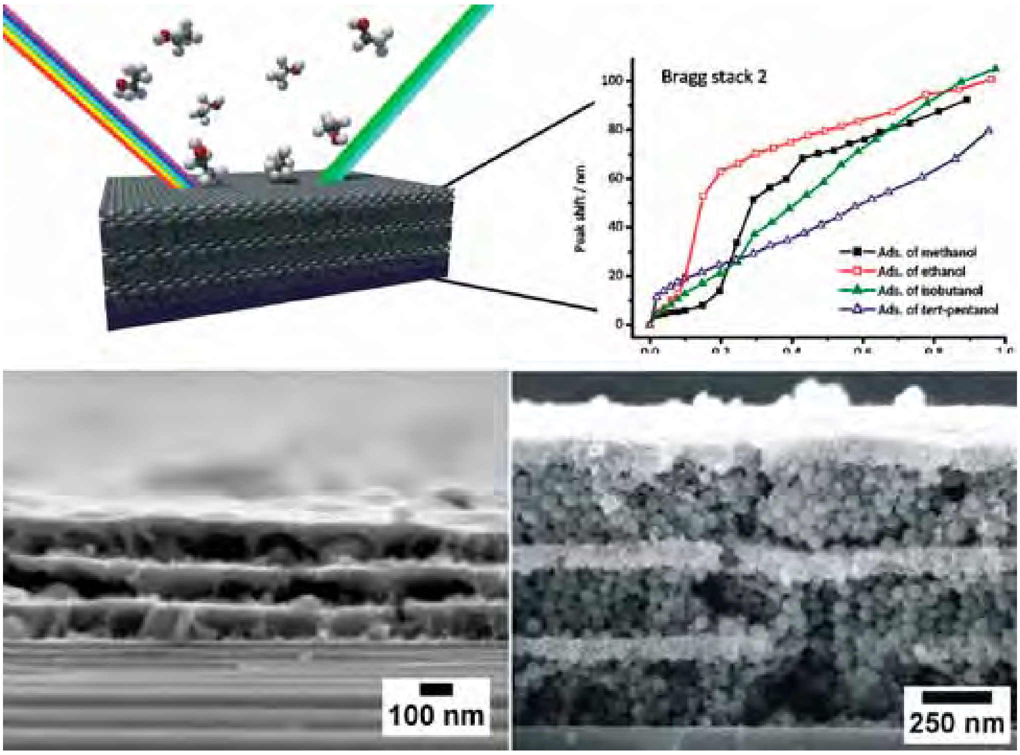
Fig. 2: Different bioactive molecules are released into living cells from lipid-covered mesoporous silica nanoparticles. The release is triggered by light, as the particles feature covalently attached photosensitizers as membrane-opening agents. It is demonstrated that the particles achieve endosomal escape and that they release their cargo into the cytosol.

A. Schloßbauer, A.M. Sauer, V. Cauda, A. Schmidt, H. Engelke, U. Rothbauer, K. Zolghadr, H. Leonhardt, C. Bräuchle, T. Bein: *Cascaded Photoinduced Drug Delivery to Cells from Multifunctional Core-Shell Mesoporous Silica;* Advanced Healthcare Materials 1(3), 316 (2012)
B. Rühle, M. Davies, T. Lebold, C. Bräuchle, T. Bein: *Highly Oriented Mesoporous Silica Channels Synthesized in Microgrooves and Visualized with Single Molecule Diffusion;* ACS Nano 6(3), 1948 (2012)
F. Feil, V. Cauda, T. Bein, C. Bräuchle: *Direct Visualization of Dye and Oligonucleotide Diffusion in Silica Filaments with Collinear Mesopores;* Nano Lett. 12(3), 1354 (2012)

ONE-DIMENSIONAL METAL-ORGANIC FRAMEWORK PHOTONIC CRYSTALS USED AS PLATFORMS FOR VAPOR SORPTION

Prof. Bettina V. Lotsch (LMU Munich, Chemistry Department, and MPI for Solid State Research) *www.cup.uni-muenchen.de/ac/lotsch/*
Prof. Thomas Bein (LMU Munich, Chemistry Department) *http://bein.cup.uni-muenchen.de/*

Metal-organic frameworks (MOFs) represent a class of crystalline porous materials exhibiting tunable sorption properties, therefore rendering MOFs suitable for monitoring selective host-guest interactions at the molecular level. In order to understand and control these interactions, the project aims at utilizing different types of chemo- and size-selective MOFs, as well as studying the impact of different framework topologies and linker modifications on the sorption behavior. This aim is accomplished by the fabrication of MOF-based photonic multilayer structures acting as optical transducers, thus providing the basis for novel MOF-based sensing concepts. The incorporation of a prototypic MOF - the zeolitic imidazolate framework ZIF-8 - into multilayers (1D photonic crystals, dubbed Bragg stacks, BSs), was realized via two complementary synthesis approaches. The heterostructures are composed of ZIF-8 layers serving as functional components, which are either dense or nanoparticulate. The ZIF-8 layers alternate periodically with mesoporous TiO_2, used as high refractive index material to enhance the dielectric contrast. While the presence of textural porosity is desired to guarantee molecular diffusion within the BS, inherently microporous ZIF-8 adds molecular selectivity to the system. Upon the adsorption of a molecular guest species, a change in the effective refractive index and, hence, the BS´s interference color is induced. Accordingly, host-guest interactions at the molecular level are translated into an optical readout, which allows for a label-free sensing scheme. As a proof-of-concept, optical sorption isotherms recording the optical shift as a function of the partial pressure of certain analytes demonstrate high sensitivity, size- and chemoselectivity of the ZIF-8/TiO_2 BS with respect to different alcohol vapors. These results contribute to the design of a new generation of chemically versatile and label-free optical sensing platforms based on MOF-derived photonic crystals, which will be extended to various MOF species and photonic architectures to target a large range of molecular host-guest interactions.



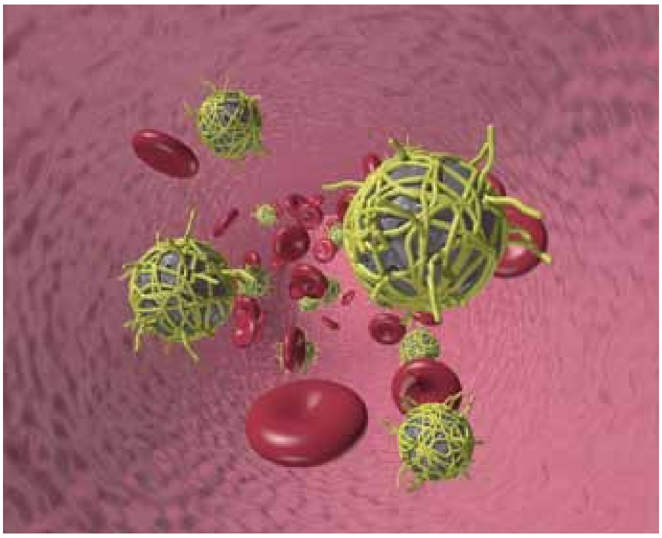
F. Hinterholzinger, A. Ranft, J. Feckl, B. Rühle, T. Bein, and B.V. Lotsch: *One-dimensional metal-organic framework photonic crystals used as platforms for vapor sorption;* J. Mater. Chem. 22, 10356 (2012)
E. Flügel, A. Ranft, F. Haase, and B.V. Lotsch: *Synthetic routes toward MOF nanomorphologies;* J. Mater. Chem. 22, 10119 (2012)

GUEST MOLECULES IN STRUCTURED MESOPOROUS MATERIALS

Prof. Thomas Bein (LMU Munich, Chemistry Department) *http://bein.cup.uni-muenchen.de*
Prof. Joachim Rädler (LMU Munich, Faculty of Physics) *www.softmatter.physik.uni-muenchen.de/*

Argyo *et al.* developed heparin-coated core-shell mesoporous nanoparticles with spatial control of functionality where heparin, a highly sulfated, anionic polysaccharide known for its anticoagulant properties, is covalently bound to outer-surface amino-functionalized particles. Blood-clotting tests and binding-experiments with antithrombin (AT) proved the multifunctionality of these mesoporous particles as efficient anticoagulant nano-carrier with great potential as blood stream-injectable drug delivery system, offering new options for smart drug delivery systems, for example in cancer therapy.

C. Argyo, V. Cauda, H. Engelke, J. Raedler, G. Bein, and T. Bein: *Heparin-Coated Colloidal Mesoporous Silica Nanoparticles Efficiently Bind to Antithrombin as an Anticoagulant Drug-Delivery System;* Chem. Eur. J. 18, 428 (2012)



Visualization of heparin-coated mesoporous silica nanoparticles in a blood vessel (schematic)

SELECTED PUBLICATIONS

SELECTED PUBLICATIONS

A. Abdellah, K.S. Virdi, R. Meier, M. Döblinger, P. Müller-Buschbaum, C. Scheu, P. Lugli, and G. Scarpa: *Successive Spray Deposition of P3HT/PCBM Organic Photoactive Layers: Material Composition and Device Characteristics;* Advanced Functional Materials 22 (19), 4078 (2012).

G. Abourbeh, A. Shir, E. Mishani, M. Ogris, W. Rödl, E. Wagner, and A. Levitzki: *PolyIC GE11 polyplex inhibits EGFR-overexpressing tumors;* IUBMB Life 64, 324-330 (2012).

***G.P. Acuna, M. Bucher, I.H. Stein, C. Steinhauer, A. Kuzyk, P. Holzmeister, R. Schreiber, A. Moroz, F.D. Stefani, T. Liedl, F.C. Simmel, and P. Tinnefeld:** *Distance dependence of Single-Fluorophore Quenching by Gold Nanoparticles studied on DNA Origami;* ACS Nano 6, 3189-3195 (2012).

G.P. Acuna, F.M. Möller, P. Holzmeister, S. Beater, B. Lalkens, and P. Tinnefeld: *Fluorescence Enhancement at Docking Sites of DNA-Directed Self-Assembled Nanoantennas;* Science 338, 506-510 (2012).

J. Adamcik, J.-H. Jeon, K. Karczewski, R. Metzler, and G. Dietler: *Quantifying supercoiling-induced denaturation bubbles in DNA;* Soft Matter 8, 8651 (2012).

L.L.A. Adams, T.E. Kodger, S.-H. Kim, H.C. Shum, T. Franke, and D.A. Weitz: *Single step emulsification for the generation of multi-component double emulsions;* Soft Matter 8 (41), 10719-10724 (2012).

L. Albertazzi, F. Mickler, G.M. Pavan, F. Salomone, G. Bardi, M. Panniello, E. Amir, T. Kang, K. Killops, C. Bräuchle, R. Amir, and C. Hawker: *Enhanced bioactivity of internally functionalized cationic dendrimers with PEG cores;* Biomacromolecules 13, 4089 (2012).

S. Amarie, P. Zaslansky, Y. Kajihira, E. Griesshaber, W. Schmahl, and F. Keilmann: *Nano-FTIR chemical mapping of minerals in biological materials;* Beilstein J. Nanotechol. 3, 312 (2012).

C. Argyo, V. Cauda, H. Engelke, J. Raedler, G. Bein, and T. Bein: *Heparin-Coated Colloidal Mesoporous Silica Nanoparticles Efficiently Bind to Antithrombin as an Anticoagulant Drug-Delivery System;* Chem. Eur. J. 18, 428 (2012).

* CeNS Publication Award

S. Azimifar, R. Böttcher, S. Zanivan, C. Grashoff, M. Krüger, K. Legate, M. Mann, and R. Fässler: *Induction of membrane circular dorsal ruffles requires co-signalling of integrin-ILK-complex and EGF receptor;* Journal of Cell Science 125, 435-48 (2012).

C. Baker, S. Stapfner, D. Parrain, S. Ducci, G. Leo, E.M. Weig, and I. Favero: *Optical instability and self-pulsing in silicon nitride whispering gallery resonators;* Opt. Express 17, 29076 (2012).

C. Batters, K. Woodall, C. Toseland, C. Hundschell and C. Veigel: *Cloning, expression and characterisation of a novel molecular motor Leishmania myosin-XXI;* J Biol Chem 287, 27557-66 (2012).

M. Bauer and R. Metzler: *Generalized facilitated diffusion model for DNA-binding proteins with search and recognition states;* Biophys. J. 102 (10), 2321-30(2012).

V. Baumgartel, B. Muller, and D.C. Lamb: *Quantitative live-cell imaging of human immunodeficiency virus (HIV-1) assembly;* Viruses 4, 777 (2012).

N.A.W. Bell, C.R. Engst, M. Ablay, G. Divitini, C. Ducati, T. Liedl, and U.F. Keyser: *DNA Origami Nanopores;* Nano Letters 12, 512-517 (2012).

***M.J. Berr, F.F. Schweinberger, M. Döblinger, K.E. Sanwald, C. Wolff, J. Breimeier, A.S. Crampton, C.J. Ridge, M. Tschurl, U. Heiz, F. Jäckel, and J. Feldmann:** *Size-Selected Subnanometer Cluster Catalysts on Semiconductor Nanocrystal Films for Atomic Scale Insight into Photocatalysis;* Nano Letters 12(11), 5903–5906 (2012).

S. Böcklein, S. Günther, R. Reichelt, R. Wyrwich, M. Joas, C. Hettstedt, M. Ehrensperger, J. Sicklinger, and J. Wintterlin: *Detection and quantification of steady-state ethylene oxide formation over an Ag(111) single crystal;* J. Catal. 299, 129 (2012).

S. Braunmüller, L. Schmid, E. Sackmann, and T. Franke: *Hydrodynamic deformation reveals two coupled modes/time scales of red blood cell relaxation;* Soft Matter 8, 11240 (cover article) (2012).

D. Brown, N. Sanguantrakun, B. Schulze, U.S. Schubert, and C. Berlinguette: *Microsecond excited-state lifetimes in bistridentate ruthenium-terpyridine;* J. Am. Chem. Soc. 134, 12354 – 12357 (2012).

***A. Cattani-Scholz, K.-C. Liao, A. Bora, A. Pathak, C. Hundschell, B. Nickel, J. Schwartz, G. Abstreiter, and M. Tornow:** *Molecular Architecture: Construction of Self-Assembled Organophosphonate Duplexes and Their Electrochemical Characterization;* Langmuir 28(20), 7889-7896 (2012).

J. Cremer, A. Melbinger, and E. Frey: *Growth dynamics and the evolution of cooperation in microbial populations;* Scientific Reports 2, 281 (2012).

***M. Davies, A. Wochnik, F. Feil, C. Jung, C. Bräuchle, C. Scheu, and J. Michaelis:** *Synchronous Emission from Nanometric Silver Particles through Plasmonic Coupling on Silver Nanowires;* ASC Nano 6 (7), 6049 (2012).

S. Depenbrock, I.P. McCulloch and U. Schollwöck: *Nature of the spin liquid ground state of the S=1/2 Heisenberg model on the kagome lattice;* Phys. Rev. Lett. 109, 067201 (2012).

***J.F. Dienstmaier, D. Medina, M. Dogru, P. Knochel, T. Bein, W.M. Heckl, and M. Lackinger:** *Isoreticular two dimensional covalent organic frameworks synthesized by on-surface condensation of diboronic acids;* ACS Nano 6, 7234 (2012).

***J. Do, R. Schreiber, A.A. Lutich, T. Liedl, J. Rodríguez-Fernández, J. Feldmann:** *Design and Optical Trapping of a Biocompatible Propeller-like Nanoscale Hybrid;* Nano Letters 12, 5008-5013 (2012).

M. P. Dobay, A. Piera Alberola, E. Mendoza, J. O. Rädler: *Modeling nanoparticle uptake and intracellular distribution using stochastic process algebras;* J. Nano Research 14 (4), 821 - 833 (2012).

A. Dobrinevski and E. Frey: *Extinction in neutrally stable stochastic Lotka-Volterra models;* Phys. Rev. E85, 051903 (2012).

C. Dohmen, D. Edinger, T. Fröhlich, L. Schreiner, U. Lächelt, C. Troiber, J.O. Rädler, P. Hadwiger, H.P. Vornlocher, and E. Wagner: *Nano sized carrier system with beneficial biophysical properties for folic acid receptor specific siRNA delivery;* ACS Nano 6, 5198–5208 (2012).

S. K. Dondapati, M. Ludemann, R. Müller, S. Schwieger, A. Schwemer, B. Händel, D. Kwiatkowski, M. Djiango, E. Runge, and T.A. Klar: *Voltage-Induced Adsorbate Damping of Single Gold Nanorod Plasmons in Aqueous Solution;* Nano Lett. 12 (3), 1247-1252 (2012).

***T. Faust, P. Krenn, S. Manus, J.P. Kotthaus, and E. Weig:** *Microwave cavity-enhanced transduction for plug and play nanomechanics at room temperature;* Nature Communications 3, 728 (2012).

T. Faust, J. Rieger, M. J. Seitner, P. Krenn, J.P. Kotthaus, and E.M. Weig: *Non-adiabatic dynamics of two strongly coupled nanomechanical resonator modes;* Phys. Rev. Lett. 109, 037205 (2012).

***J. M. Feckl, K. Fominykh, M. Doeblinger, D. Fattakhova-Rohlfing, and T. Bein:** *Nanoscale Porous Framework of Lithium Titanate for Ultrafast Lithium Insertion;* Angew. Chem. 51, 745 (2012).

***Z. Fei, A.S. Rodin, G.O. Andreev, W. Bao, A.S. McLeod, M. Wagner, L.M. Zhang, Z. Zhao, M. Thiemens, G. Dominguez, M.M. Fogler, A.H. Castro Neto, C.N. Lau, F. Keilmann and D.N. Basov:** *Gate-tuning of graphene plasmons revealed by infrared nano-imaging;* Nature 487, 83-85 (2012).

F. Feil, V. Cauda, T. Bein, and C. Bräuchle: *Direct Visualization of Dye and Oligonucleotide Diffusion in Silica Filaments with Collinear Mesopores;* Nano Lett. 12(3), 1354 (2012).

***F. Feil, S. Naumov, J. Michaelis, R. Valiullin, D. Enke, J. Kärger, and C. Bräuchle:** *Single-Particle and Ensemble Diffusivities—Test of Ergodicity;* Angew. Chem. Int. Ed. 124(5), 1178–1181 (2012).

A.M. Forsyth, S. Braunmüller, J. Wan, T. Franke, and H.A. Stone: *The effects of membrane cholesterol and simvastatin on red blood cell deformability and ATP release;* Microvascular Research 83, 347 (2012).

T. Franke, R.H.W. Hoppe, C. Linsenmann, L. Schmid, C. Willbold, and A. Wixforth: *Coupled Fluid Flow in Energy, Biology and Environmental Research Numerical simulation of the motion of red blood cells and vesicles in microfluidic flows;* Computing and Visualization in Science 14 (4), 167-180 (2012).

T. Fröhlich, D. Edinger, R. Kläger, D. Schaffert, C. Troiber, N. Badgujar, I. Martin, E. Salcher, P. Hadwiger, H.P. Vornlocher, and E. Wagner: *Structure-activity relationships of precise oligo(ethane amino) amides for siRNA delivery;* J. Control Rel. 160, 532-541 (2012).

T.M. Geislinger, B. Eggart, S. Braunmüller, L. Schmid, and T. Franke: *Separation of blood cells using hydrodynamic lift;* Appl. Phys. Lett. 100, 183701 (2012).

***D. Gerster, J. Reichert, H. Bi, J.V. Barth, S. M. Kaniber, A.W. Holleitner, I. Visoly-Fisher, S. Sergani, and I. Carmeli:** *Photocurrent of a single photosynthetic protein;* Nature Nanotechnology 7, 673 (2012).

A.M. Gigler, C. Dietz, M. Baumann, N. F. Martinez, R. Garcia, and R.W. Stark: *Repulsive bimodal atomic force microscopy on polymers;* Beilstein J. Nanotechnol. 3, 456-463 (2012).

L.C.G Govia, E.J. Pritchett, S.T. Merkel, D. Pineau and F.K. Wilhelm: *Theory of Josephson photomultipliers: optimal working conditions and back action;* Phys. Rev. A86, 032311 (2012).

***G. Granger, D. Taubert, C.E. Young, L. Gaudreau, A. Kam, S.A. Studenikin, P. Zawadzki, D. Harbusch, D. Schuh, W. Wegscheider, Z.R. Wasilewski, A.A. Clerk, S. Ludwig, and A.S. Sachrajda:** *Quantum interference and phonon-mediated back-action in lateral quantum-dot circuits;* Nature Phys. 8, 522–527 (2012).

C. Guo, A. Weichselbaum, J. von Delft, and M. Vojta: *Critical and strong-coupling phases in one- and two-bath spin-boson models;* Phys. Rev. lett. 108, 160401 (2012).

T. Ha and P. Tinnefeld: *Photophysics of Fluorescence Probes for Single-Molecule Biophysics and Super-resolution Imaging;* Ann. Rev. Phys. Chem. 63, 595-617 (2012).

J. Halatek and E. Frey: *Highly Canalized MinD Transfer and MinE Sequestration Explain the Origin of Robust MinCDE-Protein Dynamics;* Cell Reports 1 (6), 741-752 (2012).

M. Handloser, R. Dunbar, A. Wisnet, P. Altpeter, C. Scheu, L. Schmidt-Mende, and A. Hartschuh: *Influence of metallic and dielectric nanowire arrays on the photoluminescence properties of P3HT thin films;* Nanotechnology 23, 305402 (2012).

F. Hinterholzinger, A. Ranft, J. Feckl, B. Rühle, T. Bein, and B. Lotsch: *One-dimensional Metal-Organic Framework Photonic Crystals Used as Platforms for Vapor Sorption;* J. Mater. Chem. 22, 10356 (2012).

J. Honer, J.C. Halimeh, I.P. McCulloch, U. Schollwöck, and H.-P. Büchler: *Fractional excitations in cold atomic gases;* Phys. Rev. A 86, 051606 (2012).

A. Högele, M. Kroner, C. Latta, M. Claassen, I. Carusotto, C. Bulutay, and A. Imamoglu: *Dynamic nuclear spin polarization in the resonant laser excitation of an InGaAs quantum dot;* Phys. Rev. Lett. 108, 197403 (2012).

S. Hug, M. Tauchert, S. Li, U. Pachmayr and B. Lotsch: *A functional triazine framework based on N-heterocyclic building blocks;* J. Mater. Chem. 22, 13956 (2012).

***F. Huth, A. Govyadinov, S. Amarie, W. Nuansing, F. Keilmann and R. Hillenbrand:** *Nano-FTIR absorption spectroscopy of molecular fingerprints at 20 nm spatial resolution;* NanoLetters 12, 3973 (2012).

S. Junggeburth, K. Schwinghammer, K. Virdi, C. Scheu, and B. Lotsch: *Towards Mesostructured Zinc Imidazolate Frameworks;* Chem. Eur. J. 18, 2143 (2012).

B. Khani, S.T. Merkel, F. Motzoi, J.M. Gambetta, and F.K. Wilhelm: *High-fidelity quantum gates in the presence of dispersion;* Phys. Rev. A 85, 022306 (2012).

S. Kienle, S. Liese, N. Schwierz, R.R. Netz, and T.Hugel: *The effect of temperature on single polypeptide adsorption;* ChemPhysChem 13, 982 (2012).

K. Klein, A. M. Gigler, T. Aschenbrenner, R. Monetti, W. Bunk, F. Jamitzky, G. Morfill, R. W. Stark, and J. Schlegel: *Label-Free Live-Cell Imaging with Confocal Raman Microscopy;* Biophys. J. 102, 360-368 (2012).

D.R. Koenig and E.M. Weig: *Voltage-sustained self-oscillation of a nano-mechanical electron shuttle;* Appl. Phys. Lett. 101, 213111 (2012).

***K. Kowalik-Seidl, X. Vögele, B. Rimpfl, G. Schinner, D. Schuh, W. Wegscheider, A. W. Holleitner, and J.P. Kotthaus:** *Tunable photo-emission from an excitonic antitrap;* Nano Letters 12, 326 (2012).

***I. Kriegel, C. Jiang, J. Rodríguez-Fernández, R.D. Schaller, D.V. Talapin, E. Da Como, and J. Feldmann:** *Tuning the Excitonic and Plasmonic Properties of Copper Chalcogenide Nanocrystals;* JACS 134(3), 1583–1590 (2012) .

V. Kudryavtsev, M. Sikor, S. Kalinin, D. Mokranjac, C.A. Seidel, and D.C. Lamb: *Combining MFD and PIE for Accurate Single-Pair Forster Resonance Energy Transfer Measurements;* ChemPhysChem 13, 1060 (2012).

***A. Kuzyk, R. Schreiber, Z. Fan, G. Pardatscher, E.-M. Roller, A. Högele, F.C. Simmel, A.O. Govorov, and T. Liedl:** *DNA-based self-assembly of chiral plasmonic nanostructures with tailored optical response;* Nature 483, 311-314 (2012).

H. Krammer, F.M. Möller, and D. Braun: *Thermal, Autonomous Replicator Made from Transfer RNA;* Physical Review Letters 108, 238104 (2012).

M. Lackinger, M.S. Janson, and W. Ho: *Localized interaction of single porphyrin molecules with oxygen vacancies on TiO_2(110);* J. Chem. Phys. 137, 234707 (2012).

L. Larivière, C. Plaschka, M. Seizl, L. Wenzeck, F. Kurth, and P. Cramer: *Structure of the Mediator head module;* Nature 492, 448-451 (2012).

***T. Lebold, A. Schlossbauer, K. Schneider, L. Schermelleh, H. Leonhardt, T. Bein, and C. Braeuchle:** *Controlling The Mobility Of Oligonucleotides In The Nanochannels Of Mesoporous Silica;* Adv. Funct. Mater 22, 106 (2012).

N. Li, J. Ren, L. Wang, G. Zhang, P. Hänggi, and B.W. Li: *Phononics: Manipulating heat flow with electronic analogs and beyond;* Rev. Mod. Phys. 84, 1045-1066 (2012).

L. Li, O. Lieleg, S. Jang, K. Ribbeck, and J. Han: *Microfluidic in Vitro System for Quantitative Study of Stomach Mucus Barrier Function;* Lab on Chip 12(20), 4071-4079 (2012).

** CeNS Publication Award*

O. Lieleg, C. Lieleg, J. Bloom, C. Buck, and K. Ribbeck: *Mucin biopolymers as broad-spectrum antiviral agents;* Biomacromolecules 13(6), 1724-1732 (2012).

C. Li and B. Lotsch: *Stimuli-responsive 2D polyelectrolyte photonic crystals for optically encoded pH sensing;* Chem. Commun. 48, 6169 (2012).

S. Lippok, S.A.I. Seidel, S. Duhr, K. Uhland, H.-P. Holthoff, D. Jenne, and D. Braun: *Direct Detection of Antibody Concentration and Affinity in Human Serum Using Microscale Thermophoresis;* Analytical Chemistry 84, 3523–3530 (2012).

Y. Liu, G. Stefanic, J. Rathousky, O. Hayden, T. Bein, and D. Fattakhova-Rohlfing: *Assembly of mesoporous indium tin oxide electrodes from nano-hydroxide building blocks;* Chem. Sci. 3, 2367 (2012).

***A. Mader, K. Gruber, R. Castelli, B.A. Hermann, P.H. Seeberger, J.O. Rädler, and M. Leisner:** *Discrimination of E. coli strains using Glycan Cantilever array sensors;* Nano Letters 12(1), 420–423 (2012).

K. Maier and E. Wagner: *Acid-labile traceless click linker for protein transduction;* J. Am. Chem. Soc. 134, 10169-73 (2012).

K. Maier, I. Martin, and E. Wagner: *Sequence Defined Disulfide-linked Shuttle for Strongly Enhanced Intracellular Protein Delivery;* Mol. Pharmaceutics 9, 3560–3568 (2012).

M. Mangold, M. Calame, M. Mayor, and A.W. Holleitner: *Negative Differential Photoconductance in Gold Nanoparticle Arrays in the Coulomb Blockade Regime;* ACS Nano 6, 4181 (2012).

H. Mannell, J. Pircher, F. Fochler, Y. Stampnik, T. Rathel, B. Gleich, C. Plank, O. Mykhaylyk, C. Dahmani, M. Wornle, A. Ribeiro, U. Pohl, and F. Krotz: *Site directed vascular gene delivery in vivo by ultrasonic destruction of magnetic nanoparticle coated microbubbles;* Nanomedicine 8(8), 1309-1318 (2012).

A.-K. Marel, A. Piera Alberola, and J. O. Rädler: *Proliferation and collective migration of small cell groups released from circular patches;* Biophysical Reviews and Letters Vol. 7, 15-28 (2012).

S.A. Maurer, D.S. Lambrecht, D. Flaig, and C. Ochsenfeld: *Distance-Dependent Schwarz Based Integral Estimates for Two-Electron Integrals - Reliable Tightness vs. Rigorous Upper Bounds;* J. Chem. Phys. 136, 144107 (2012).

A. Mayer, M. Heidemann, M. Lidschreiber, A. Schreieck, M. Sun, C. Hintermair, E. Kremmer, D. Eick, and P. Cramer: *CTD tyrosine phosphorylation impairs termination factor recruitment to RNA polymerase II;* Science 336, 1723-1725 (2012).

***A. Melbinger, L. Reese, and E. Frey:** *Microtubule Length Regulation by Molecular Motors;* Phys. Rev. Lett.108, 258104 (2012).

M.Y. Melnikov, J.P. Kotthaus, V. Pellegrini, L. Sorba, G. Biasiol, and V.S. Khrapai: *Influence of e-e scattering on the temperature dependence of the resistance of a classical ballistic point contact in a two-dimensional electron system;* Phys. Rev. B 83, 075425 (2012).

***F.M. Mickler, L. Möckl, N. Ruthardt, M. Ogris, E. Wagner, and C. Bräuchle:** *Tuning nanoparticle uptake: Live-cell imaging reveals two distinct endocytosis mechanisms mediated by natural and artificial EGFR targeting ligand;* Nano Lett. 12(7), 3417 (2012).

S. Milani, F. Baldelli Bombelli, A. Pitek, K. A. Dawson, J. O. Rädler: *Reversible versus Irreversible Binding of Transferrin to Polystyrene Nanoparticles: Soft and Hard Corona;* ACS Nano 6 (3), 2532 - 2541 (2012).

V. Müller, F. Haase, J. Rathousky, and D. Fattakhova-Rohlfing: *Surface functionalization of mesoporous antimony doped tin oxide by metalorganic reaction;* Mater. Chem. Phys. 137, 207 (2012).

E.-P. Ng, D. Chateigner, T. Bein, V. Valtchev, and S. Mintova: *Capturing Ultrasmall EMT Zeolite from Template-Free Systems;* Science 335, 70 (2012).

J. Perelaer, R. Jani, M. Grouchko, A. Kamyshny, S. Magdassi, and U.S. Schubert: *Plasma and microwave flash sintering of a tailored silver nanoparticle ink yielding 60 % bulk conductivity on cost-effective polymer foils;* Adv. Mater. 24, 3993-3998 (2012).

L. Prechtel, L. Song, D. Schuh, P. Ajayan, W. Wegscheider, and A.W. Holleitner: *Time-resolved ultrafast photocurrents and terahertz generation in freely suspended graphene;* Nature Commun. 3, 646 (2012).

E.M. Puchner and H.E. Gaub: *Single-Molecule Mechanoenzymatics;* Annual Review Biophysics 41, 497-518 (2012).

N. Rauhut, M. Engel, M. Steiner, R. Krupke, P. Avouris, and A. Hartschuh: *Antenna-Enhanced Photocurrent Microscopy on Single-Walled Carbon Nanotubes at 30 nm Resolution;* ACS Nano 6, 6416 (2012).

C. Ratzke, F. Berkemeier, and T. Hugel: *Hsp90's mechano-chemical cycle is dominated by thermal fluctuations;* PNAS 109 (1), 161 (2012).

C. Ratzke, M. Nguyen, M. Mayer, and T. Hugel: *From a ratchet mechanism to random fluctuations – evolution of Hsp90's mechano-chemical cycle;* JMB 423, 462 (2012).

A.K. Reckhenrich, C. Koch, J.T. Egana, and C. Plank: *The use of non-viral gene vectors for bioactive poly-(D,L-lactide) implant surfaces in bone tissue engineering;* Eur Cell Mater 23, 441-448 (2012).

M.E. Regler, H.J. Krenner, A.A. Green, M.C. Hersam, A. Wixforth, and A. Hartschuh: *Controlling exciton decay dynamics in semiconducting single-walled carbon nanotubes by surface acoustic waves;* Chem. Phys. 413, 39-44 (2013).

N.F. Reuel, A. Dupont, O. Thouvenin, D.C. Lamb, and M.S. Strano: *Three-dimensional tracking of carbon nanotubes within living cells;* ACS nano 6, 5420 (2012).

J. Rieger, T. Faust, M.J. Seitner, J.P. Kotthaus, and E.M. Weig: *Frequency and Q factor control of nanomechanical resonators;* Appl. Phys. Lett. 101, 103110 (2012).

S. Rudorf and J. O. Rädler: *Self-Assembly of Stable Monomolecular Nucleic Acid Lipid Particles with a Size of 30 nm;* Journal of the American Chemical Society 134, 11652 - 11658 (2012).

B. Rühle, M. Davies, T. Lebold, C. Bräuchle, and T. Bein: *Highly Oriented Mesoporous Silica Channels Synthesized in Microgrooves and Visualized with Single Molecule Diffusion;* ACS Nano 6(3), 1948 (2012).

S. Sainsbury, J. Niesser, and P. Cramer: *Structure and function of the initially transcribing RNA polymerase II-TFIIB complex;* Nature Epub Nov 14. doi: 10.1038/nature, 11715 (2012).

E. Salcher, P. Kos, T. Fröhlich, N. Badgujar, M. Scheible, and E. Wagner: *Sequence-defined four-arm oligo(ethanamino) amides for pDNA and siRNA delivery: Impact of building blocks on efficacy;* J. Control. Rel. 164, 380–386 (2012).

G. Sax, F. Feil, S. Schulze, C. Jung, C. Bräuchle, and G. Winter: *Release pathways of interferon α2a molecules from lipid twin screw extrudates revealed by single molecule fluorescence microscopy;* Journal of Controlled Release 162, 295 (2012).

I. Schaap, F. Egiaian, A. des Georges and C. Veigel: *Effect of envelope proteins on the mechanical properties of infuenz virus;* J Biol Chem 287, 41078-88 (2012).

A. Schloßbauer, A.M. Sauer, V. Cauda, A. Schmidt, H. Engelke, U. Rothbauer, K. Zolghadr, H. Leonhardt, C. Bräuchle, and T. Bein: *Cascaded Photoinduced Drug Delivery to Cells from Multifunctional Core-Shell Mesoporous Silica;* Advanced Healthcare Materials 1(3), 316 (2012).

S. Schlögl, W.M. Heckl, and M. Lackinger: *On-surface radical addition of triply iodinated monomers on Au(111) - the influence of monomer size and thermal post-processing;* Surf. Sci. 606, 999 (2012).

L. Schmid, A. Wixforth, D.A. Weitz, and T. Franke: *Novel surface acoustic wave (SAW)-driven closed PDMS flow chamber;* Microfluidics and nanofluidics 12 (1-4), 229-235 (2012).

J.J. Schmied, A. Gietl, P. Holzmeister, C. Forthmann, C. Steinhauer, T. Dammeyer and P. Tinnefeld: *Fluorescence and super-resolution standards based on DNA origami;* Nature Methods 9, 1133–1134 (2012).

J. Schuster, G. He, B. Mandlmeier, T. Yim, K. T. Lee, T. Bein, and L. F. Nazar: *Spherical Ordered Mesoporous Carbon Nanoparticles with High Porosity for Lithium-Sulfur Batteries;* Angew. Chem. 51, 3591 (2012).

F.J.R. Schülein, J. Pustiowski, K. Müller, M. Bichler, G. Koblmüller, J.J. Finley, A. Wixforth, and H. J. Krenner: *Surface acoustic wave controlled charge dynamics in a thin InGaAs quantum well;* JETP Letters 95, 575-580 (2012).

N. Schwierz, D. Horinek, S. Liese, T. Pirzer, B. Balzer, T. Hugel, and R. Netz: *On the relationship between peptide adsorption resistance and surface contact angle: A combined experimental and simulation single-molecule study;* JACS 134, 19628 (2012).

S.J. Sedlmaier, T. Dennenwaldt, C. Scheu, and W. Schnick: *Template-free inorganic synthesis of silica-based nanotubes and their self-assembly to mesocrystals;* Journal of Materials Chemistry 22, 15511 (2012).

***S.A.I. Seidel, J.C. Wienken, S. Geissler, M. Jerabek-Willemsen, S. Duhr, A. Reiter, D. Trauner, D. Braun, and P. Baaske:** *Label-Free Microscale Thermophoresis discriminates sites and affinity of protein binding;* Angewandte Chemie 51 (42), 10656-10659 (2012).

T. Shalev, A. Gopin, M. Bauer, R. W. Stark, and S. Rahimipour: *Non-leaching antimicrobial surfaces through polydopamine bio-inspired coating of quaternary ammonium salts or an ultrashort antimicrobial lipopeptide;* J. of Mater. Chem. 22, 2026-2032 (2012).

M. Stallhofer, C. Kastl, M. Brändlein, D. Schuh, W. Wegscheider, J.P. Kotthaus, G. Abstreiter, and A.W. Holleitner: *Enlarged magnetic focusing radius of photoinduced currents in mesoscopic circuits;* Phys. Rev. B 86, 115315 (2012).

H. Stein, S. Capone, J.H. Smit, F. Baumann, T. Cordes, and P. Tinnefeld: *Linking Single-Molecule Blinking to Chromophore Structure and Redox Potentials;* ChemPhysChem 13, 931-937 (2012).

T. Stögbauer, L. Windhager, R. Zimmer, and J. O. Rädler: *Experiment and Mathematical Modeling of Gene Expression Dynamics in a Cell-Free System;* Integrative Biology 4 (5), 494 - 501 (2012).

***M. Strackharn, D.A. Pippig, P. Meyer, S.W. Stahl, and H.E. Gaub:** *Nanoscale Arrangement of Proteins by Single-Molecule Cut-and-Paste;* JACS 134(37), 15193–15196 (2012).

B. Su, A. Cengizeroglu, K. Farkasova, J.R. Viola, M. Anton, J.W. Ellwart, R. Haase, E. Wagner, and M. Ogris: *Systemic TNFα Gene Therapy Synergizes With Liposomal Doxorubicine in the Treatment of Metastatic Cancer;* Mol. Ther. 21, 300-308 (2013).

J.M. Szeifert, D. Fattakhova-Rohlfing, J. Rathousky, and T. Bein: *Multilayered high surface area "Brick and Mortar" mesoporous titania films as efficient anodes in dye-sensitized solar cells;* Chem. Mater. 24, 659 (2012).

***R. Tautz, E. Da Como, T. Limmer, J. Feldmann, H.-J. Egelhaaf, E. von Hauff, V. Lemaur, D. Beljonne, S. Yilmaz, I. Dumsch, S. Allard, and U. Scherf:** *Structural Correlations in the generation of polaron pairs in low-bandgap polymers for photovoltaics;* Nature Communications 3, 970 (2012).

P. Tinnefeld and T. Cordes: *Self-Healing Dyes – Intramolecular Stabilization of Organic Fluorophores;* Nature Methods 9, 426–427 (2012).

N. Tresilwised, P. Pithayanukul, P.S. Holm, U. Schillinger, C. Plank, and O. Mykhaylyk: *Effects of nanoparticle coatings on the activity of oncolytic adenovirus-magnetic nanoparticle complexes;* Biomaterials 33(1), 256-269 (2012).

B. Treutlein, A. Muschielok, J. Andrecka, A. Jawhari, C. Buchen, D. Kostrewa, F. Hög, P. Cramer, and J. Michaelis: *Dynamic architecture of a minimal RNA polymerase II open promoter complex;* Mol Cell 46, 136-146 (2012).

C. Troiber, J.C. Kasper, S. Milani, M. Scheible, F. Schaubhut, S. Küchler, J. Rädler, F.C. Simmel, W. Friess, and E. Wagner: *Physico-chemical characterization of siRNA polyplexes: size and stability;* Eur J. Pharm. Biopharm., doi: 10.1016/j.ejpb.2012.08.014. (2012).

S. Trotzky, Y.-A. Chen, A. Flesch, I. P. McCulloch, U. Schollwöck, J. Eisert and I. Bloch: *Probing the relaxation towards equilibrium in an isolated strongly correlated 1D Bose gas;* Nature Physics 8, 325 (2012).

O. Viehmann, J. von Delft, and F. Marquardt: *Observing the nonequilibrium dynamics of the quantum transverse-field Ising chain in circuit QED;* Phys. Rev. Lett. 110, 030601 (2013).

I. Vladescu, O. Lieleg, S. Jang, and K. Ribbeck: *A bead translocation assay to probe bulk transport through hydrogels;* Journal of Pharmaceutical Sciences 101(1), 436-442 (2012).

A. Vollrath, A. Schallon, C. Pietsch, S. Schubert, T. Nomoto, Y. Matsumoto, K. Kataoka, and U.S. Schubert: *A toolbox of differently sized and labeled PMMA nanoparticles for cellular uptake investigations;* Soft Matter 9, 99-108 (2012).

S. Völk, F. Knall, F.J.R. Schülein, T.A. Truong, H. Kim, P.M. Petroff, A. Wixforth, and H.J. Krenner: *Surface acoustic wave mediated carrier injection into individual quantum post nano emitters;* Nanotechnology 23, 285201 (2012).

C. Walmacq, A. Cheung, M. Kireeva, L. Lubkowska, C. Ye, D. Gotte, J. Strathern, T. Carell, P. Cramer, and M. Kashlev: *Mechanism of translesion transcription by RNA polymerase II and its role in cellular resistance to DNA damage;* Mol Cell 46, 18-29 (2012).

C. Weber, V. Schaller, A.R. Bausch, and E. Frey: *Nucleation-induced transition to collective motion in active systems;* Phys. Rev. E 86, 030901(R) (2012).

A. Weichselbaum: *General framework for non-abelian symmetries in tensor networks;* Annals of Physics 327, 2972-3047 (2012).

C. Westerhausen, F.G. Strobl, R. Herrmann, A.T. Bauer, S.W. Schneider, A. Reller, A. Wixforth, and M.F. Schneider: *Chemical and Mechanical Impact of Silica Nanoparticles on the Phase Transition Behavior of Phospholipid Membranes in Theory and Experiment;* Biophysical Journal 102 (5), 1032-1038 (2012).

A. Wild, J. Kierig, J. Sailer, J. W. Ager, E.E. Haller, G. Abstreiter, S. Ludwig, and D. Bougeard: *Few electron double quantum dot in an isotopically purified 28Si quantum well;* Appl. Phys. Lett. 100, 143110 (2012).

A. Winkler and E. Frey: *Validity of the law of mass action in three-dimensional coagulation processes;* Phys. Rev. Lett.108, 108301 (2012).

A. Wisnet, M. Thomann, J. Weickert, L. Schmidt-Mende, and C. Scheu: *Nanoscale investigation on large crystallites in TiO_2 nanotube arrays and implications for high-quality hybrid photodiodes;* Journal of Material Science 47 (17), 6459 (2012).

A. S. Wochnik, C. Heinzl, F. Auras, T. Bein and C. Scheu: *Synthesis and Characterization of $CuInS_2$ Thin Film Structures;* Journal of Materials Science 47 (4), 1669 (2012).

P. Zeller, S. Dänhardt, S. Gsell, M. Schreck, and J. Wintterlin: *Scalable synthesis of graphene on single crystal Ir(111) films;* Surf. Sci. 606, 1475 (2012).

J. Zimmer, A. Wixforth, H. Karl, H. J. Krenner: *Ion beam synthesis of nanothermochromic diffraction gratings with giant switching contrast at telecom wavelengths;* Applied Physics Letters 100, 231911 (2012).

** CeNS Publication Award*

THESES

MASTER'S THESES

Francesco Alaimo: *On the Effects of Spin Orbit Interaction on the Conductance through a Quantum Dot in the presence of Kondo Correlations* (LMU, J. von Delft); **Thomas Becker:** *Raman Spektroskopie an Graphen* (LMU, E. Da Como); **Matthias Berger:** *Temperaturabhängigkeit der Aktivität von Hsp90* (TUM, T. Hugel); **Sophia Betzler:** *Synthesis and Characterization of TiO_2 and NbxOy nanostructures* (LMU, C. Scheu); **Iris Blank:** *Quantum-Chemical Calculations on the DNA-Repair Mechanism of Formamidopyrimidine-DNA Glycosylase* (Uni Tübingen, C. Ochsenfeld); **Benjamin Böhm:** *Thermophoresis of Conjugated Polymers* (LMU, H. Gaub); **Evelyn Calta:** *Light-Responsive Capping Systems for Colloidal Mesoporous Silica Nanoparticles* (LMU, T. Bein); **Andrea Ebert:** *Cell-to-cell variability of gene expression in inducible regulatory networks* (LMU, J. Rädler); **Anna Eder:** *Low temperature measurements on mesoscopic systems in non-equilibrium* (LMU, S. Ludwig); **Christian Engst:** *Single-molecule detection with DNA origami* (LMU, T. Liedl); **Thomas Felix Fehm:** *Symmetry Breaking in the early C. Elegans Zygote* (LMU, E. Frey); **Ksenia Fominykh:** *Synthesis of Ultra-Small NiO Nanocrystals* (LMU, T. Bein); **Benjamin Gmeiner:** *Nanomechanical resonators in the strong coupling regime* (LMU, J. Kotthaus); **Oliver Gretz:** *Development of High-Bandwidth High-Voltage Amplifiers and an Embedded System Transient Generator for Scanning Tunneling Microscopy Applications* (LMU, M. Lackinger); **Tobias Gubbey:** *The essential Core Factor complex is recruited to RNA Polymerase I by the specific transcription initiator RRN3* (LMU, P. Cramer); **Timo Hanke:** *Soft Colloids & Vibrated Disks - Model Systems for the Emergence of Collective Motion* (LMU, E. Frey); **Julian Hartmann:** *Single molecule force measurements of integrin αVß3 and α5ß1 interactions with fibronectin* (LMU, H. Gaub); **Simon Haug:** *Akustomechanische Kontrolle des Metall-Isolator-Übergangs in Vanadiumdioxid Nanokristallen* (Uni Augsburg, H. Krenner); **Elke Hebisch:** *Bacterial Interactions: Visualization-Characterization-Manipulation* (LMU, M. Leisner); **Matthias Hiermaier:** *Investigation of focal adhesion kinase binding to phosphatidylinositol (4,5)-bisphosphate in lipid membranes with force spectroscopy* (LMU, H. Gaub); **Tanja Holzmann:** *Systematic Investigation on the Exfoliation Behaviour of Layered Cuprates and Analysis of Photocatalytically Active Nanocomposites* (LMU, B. Lotsch); **Ingo Homrighausen:** *Fluctuation Effects in Chemical Reactions with Anomalous Diffusion* (LMU, E. Frey); **Benedikt Andreas Hook:** *Modelling of a vibrated polar disk* (LMU, E. Frey); **Miriam Huber:** *Growth of Bacterial Colonies - Biomechanical Interaction in Dense Cell Populations* (LMU, E. Frey); **David Jahn:** *Evolution of Heterogeneity in Stochastic Population Models* (LMU, E. Frey); **Julia Janik:** *Zeitaufgelöste konfokale und nahfeldoptische Mikroskopie zur Charakterisierung einzelner Nanodrähte* (LMU, A. Hartschuh); **Christoph Karnetzky:** *Polarization controlled photocurrents in topological insulators* (TUM, A. Holleitner); **Sara Kesel:** *Heterogeneity in bacterial peptide antibiotic resistance systems* (LMU, M. Leisner); **Jochen Kursawe:** *Ageing effects in fractional Langevin equations and fractional Brownian motion* (TUM, R. Metzler); **Simon Lanzmich:** *Accumulation and Replication in Prebiotic Environments* (LMU, D. Braun); **Ulrich Lichnovsky:** *Comparison of Differential Scanning Calorimetry with Thermophoresis of Proteins* (LMU, D. Braun); **Patrik Loch:** *Beugungsdetektion zweidimensionaler GaAs-Säulengitter in verschiedenen Umgebungsmedien* (LMU, J. Kotthaus); **Arne Lünser:** *The Calculation of Nuclear Magnetic J-Coupling Constants with Reduced Time Complexity* (LMU, C. Ochsenfeld); **Alexander Maier:** *DNA-based Nano-Swimmers* (LMU, T. Liedl); **Benjamin Martini:** *Studien zur Realisierung einer nanoskopischen organischen Leuchtdiode auf der Spitze einer Rasterkraftsonde* (TUM, A. Holleitner); **Stephan Mauell:** *Measuring Mechanical Properties of Human Basement Membranes by Force Spectroscopy* (LMU, H. Gaub); **Philipp Meyer:** *Nanoassembly & Investigation of Individual Biomolecules and Multicolor TIRF-Microscopy* (LMU, H. Gaub); **Sybille Meyer:** *Magneto-thermogalvanic experiments on (Ga,Mn)As thin-films* (LMU, S. Ludwig and R. Groß); **Tobias Mittereder:** *Diffraction measurements on a lattice of actuated nanomechanical GaAs pillars* (LMU, J. Kotthaus); **Friederike Möller:** *Fluorescence Enhancement at Docking Sites of DNA-Directed Self-Assembled Nanoantennas* (LMU, P. Tinnefeld); **Erika Mühlbauer:** *Macroporous Materials constructed with Metal-Organic Frameworks* (LMU, T. Bein); **Alexander Müller:** *Transmissionselektronenmikroskopische Untersuchungen von dünnen $TbMnO_3$ und $BiFeO_3$ Filmen* (LMU, C. Scheu); **Matthias Rank:** *History-Dependent Random Walks. From Molecular Spiders to Territorial Dynamics* (LMU, E. Frey); **Daniel Riedel:** *Effizienzsteigerung organischer Solarzellen mit Mehrschicht-Strukturen* (LMU, E. Da Como); **Sven Roßbach:** *Theoretical studies on the dNTP vs. NTP discrimination in the active centre of RNA Polymerase II* (Uni Tübingen, C. Ochsenfeld); **Gergely Rozsa:** *Cäsium als Promotor. Untersuchungen an polykristallinen Silberfolien als Katalysatoren in der Epoxidierung von Ethylen* (LMU, J. Wintterlin); **Johannes Schmelzl:** *Optomechanik nanostrukturierter SiN-Membranen in einer faserbasierten Fabry-Pérot Kavität* (LMU, J. Kotthaus); **Johannes Schopka:** *Photoconductance of gold nanoparticle arrays* (TUM, A. Holleitner); **Christian Schwall:** *Mimmicking Protein Channels on a Chip* (LMU, T. Liedl und U. Keyser); **Mathias Schwarz:** *Regulation of Colicin E2 release in Escherichia coli - How post-transcriptional regulation may efficiently regulate SOS pathways despite noisy genes* (LMU, E. Frey, M. Leisner); **Katharina Schwinghammer:** *Photocatalytic Properties of Chemically Modified Poly(triazine imide) and its Exfoliation for Thin Film Fabrication* (LMU, B. Lotsch); **Maximilian Seitner:** *Mechanische und dielektrische Manipulation nanomechanischer Resonatoren* (LMU, J. Kotthaus); **Valentin Stierle:** *Multimer analysis of von Willebrand Factor using single-molecule fluorescence intensity spectroscopy* (LMU, J. Rädler); **Matthias Strauch:** *Terahertz study on nanoscale charge transport* (LMU, R. Kersting); **Georg Urtel:** *Game Theory in PCR* (LMU, D. Braun); **Simon Weber:** *Hot & Cold Phase separation of two Species with different Activities* (LMU, E. Frey); **Fabian Wehnekamp:** *3D Real Time Orbital Tracking* (LMU, D. Lamb); **Johannes Wendler:** *Untersuchungen zur Stabilität und Aktivität von Katalysatoren für Hochtemperatur-Protonenaustauschmembran-Brennstoffzellen* (LMU, C. Scheu); **Tino Wendler:** *Einfluss aktiver Motilität auf die Entwicklung bakterieller Kolonien* (LMU, M. Leisner); **Karl Wienand:** *Cooporation in Changing Enviroments* (LMU, E. Frey); **Sabine Wollmann:** *Ultraschall unterstützte Deposition von kolloidale Kristallen* (Uni Augsburg, H. Krenner); **Regina Wyrwich:** *Untersuchungen zur Ethylen-Epoxidierung* (LMU, J. Wintterlin); **Alejandro Zielinski:** *Stochastic Many Particle Systems With Cyclic Interaction* (LMU, E. Frey).

PHD THESES

Haojin Ba: *Plasmonic Heating of Gold Nanoparticles in an Optical Trap and on the Cell Membrane* (LMU, J. Rodriguez-Fernandez); **Maximilian Berr:** *Photokatalytische Aktive Kolloidale Platindekorierte Cadmiumsulfidnanostäbchen zur Wasserproduktion* (LMU, F. Jäckel); **Julia Blechinger:** *Nanoparticles and human health - Development and application of an experimental strategy designed to characterize uptake kinetics, uptake pathways and cytotoxicity of SiO_2 nanoparticles interacting with human cells using fluorescence microscopy methods* (LMU, C. Bräuchle); **Miriam Böhmler:** *Tip-enhanced near-field optical microscopy on the quasi 1D semiconductors carbon nanotubes and CdSe nanowires* (LMU, A. Hartschuh); **Stefan Bössinger:** *Coupling the thermodynamic state with the dynamics of lipid interface layers – and its possible role for biology* (Uni Augsburg, A. Wixforth); **Arzu Cengizeroglu:** *Targeted RNAi and pDNA based therapy for gastrointestinal tumors* (LMU, E. Wagner); **Lucien Cyril Clin:** *Cholesky Decomposed Density Matrices in Laplace Transform Møller-Plesset Perturbation Theory* (LMU, C. Ochsenfeld); **Sebastian Dänhardt:** *Graphenwachstum auf Ru(0001) - in-situ STM-Untersuchungen zur Temperaturabhängigkeit* (LMU, J. Wintterlin); **Pamela Dobay:** *Dynamics of stochastic membrane rupture events: effects on drug delivery and gene expression* (LMU, J. Rädler); **Mirjam Dogru:** *Functionalization of Covalent Organic Frameworks* (LMU, T. Bein); **Christian Dohmen:** *Precise and multifunctional conjugates for targeted siRNA delivery* (LMU, E. Wagner); **Leila Esmaeili Sereshki:** *Modelling diffusion controlled reactions in living cells* (TUM, R. Metzler); **Florian Feil:** *Single molecule diffusion studies in nanoporous systems. From fundamental concepts to material science and nano-medicine* (LMU, C. Bräuchle); **Denis Benjamin Flaig:** *Beschreibung dynamischer molekularer Systeme mit effizienten linear-skalierenden QM- und QM/MM-Methoden* (LMU, C. Ochsenfeld); **Thomas Fröhlich:** *Novel sequence-defined oligo (ethane amino) amides for siRNA delivery* (LMU, E. Wagner); **Cheng Guo:** *DMRG treatment of time-dependent impurity models* (LMU, J. von Delft); **Mario Herzog:** *Thermophoresis and Cooperative Binding of Nucleotides* (LMU, D. Braun); **Andreas Holzner:** *DMRG studies of Chebychev-expanded spectral functions and quantum impurity models* (LMU, J. von Delft); **Hubert Krammer:** *A tRNA world* (LMU, D. Braun); **Jan-Timm Kuhr:** *Statistical Properties of Microbial Phenotypes and Colony Growth* (LMU, E. Frey and J. Rädler); **Stephan Langer:** *Transport and real-time dynamics in one-dimensional quantum magnets and ultra-cold atomic gases* (LMU, U. Schollwöck); **Yan Li:** *Periodic Mesoporous Organosilicas with Functional Chromophores* (LMU, T. Bein); **Thomas Limmer:** *Influence of carrier density on the ultrafast optical response of graphene and few-layer grapheme* (LMU, E. Da Como); **Yujing Liu:** *Nanostructured Transparent Conducting Oxide Electrodes through Nanoparticle Assembly* (LMU, T. Bein); **Christina Lumme:** *Einzelmolekül-Fluoreszenzmessungen an der Proteintranslokase Toc 34* (TUM, T. Hugel); **Kevin Maier:** *Design of an Acid Labile Traceless-cleavable Click Linker for Use in a Novel Protein Transduction Shuttle* (LMU, E. Wagner); **Börn Meier:** *Chemotactic Gradient Generator* (LMU, J. Rädler); **Anna Melbinger:** *The Role of Dynamics and Fluctuations in Biologicals Systems* (LMU, E. Frey); **Leonhard Möckl:** *Players on the Cell Surface Studies on the Glycocalyx and Integrin Dynamics* (LMU, C. Bräuchle); **Prajakta Oak:** *Development of novel combinatorial treatment strategies to overcome resistance in breast cancer* (LMU, E. Wagner); **Cristina-Maria Pop:** *Non-equilibrium relaxation: From language change to semiflexible polymer networks* (LMU, E. Frey); **Georg Schinner:** *Correlated behavior of electrostatically trapped dipolar excitons at low temperatures* (LMU/TUM, J. Kotthaus and A. Holleitner); **Björn Schwalb:** *Dynamic transcriptome analysis (DTA). Kenetic modeling of synthesis and decay of mRNA transcripts upon perturbation in S. cerevisiae, S. pombe and D. melanogaster* (LMU, P. Cramer); **Dorothee Schupp:** *Elucidating virus uptake and fusion by single virus tracing* (LMU, D. Lamb); **Philip Severin:** *Modulation der DNA-Mechanik durch Methylierung und Transkriptionsfaktoren* (LMU, H. Gaub); **Stefan Stahl:** *Konnektivität molekularer Domänen bei der kraftinduzierten Entfaltung einzelner Biomoleküle* (LMU, H. Gaub); **Tobias Stögbauer:** *Experiment and quantitative modeling of cell-free gene expression dynamics* (LMU, J. Rädler); **Mathias Strackharn:** *Arrangements einzelner Biomoleküle auf der Grundlage von Single-Molecule Cut&Paste* (LMU, H. Gaub); **Daniela Taubert:** *Electronic transport experiments on low-dimensional nanostructures at non-equilibrium conditions* (LMU, S. Ludwig); **Christoph Westerhausen:** *On the role of soft interfaces for the understanding of blood clotting* (Uni Augsburg, A. Wixforth); **Anton Winkler:** *Analytic Approaches to Stochastic Many-Particle Systems* (LMU, E. Frey).

HABILITATIONS

Matthias Schneider: *Thermodynamische Zustände und Übergänge als Grundlage biologischer Funktionen* (Uni Augsburg, A. Wixforth); **Andreas Weichselbaum:** *Matrix product state treatment of quantum impurity models* (LMU, J. von Delft).

FUNDING

Alexander von Humboldt Foundation

attocube systems AG

BASF

Bavaria California Technology Center (BaCaTeC)

Bavarian State Ministry of Sciences, Research and the Arts

- **Elite Network of Bavaria:** *International Doctorate Programs (NanoBioTechnology, CompInt), Research Scholarships (Bayerisches Eliteförderungsgesetz)*
- **Solar Technologies Go Hybrid (Soltech)**

Bayerische Forschungsstiftung

Bayerisch-Französisches Hochschulzentrum (BHFZ)

BMW AG

Boehringer Ingelheim Fonds

Boston Consulting Group (BCG)

Carl-Zeiss-Stiftung

Chinese Scholarship Council (CSC)

d-fine GmbH

Deutsch-Israelische Projektkooperation

Dr. Klaus Römer-Stiftung

European Union Framework Programme 7

- **European Research Council (ERC):** *Starting, Consolidator and Advanced Grants*
- **Coordination Action:** *SMALL-4, GAMBA*
- **Future and Emerging Technologies Open Scheme:** *QNEMS, QUAINT*
- **Initial Training Network:** *EscoDNA, POCAONTAS*

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*

Graduate School:

- **QBM:** *Quantitative Biosciences Munich*

Federal Ministry of Education and Research (BMBF)

Federal Ministry of Economics and Technology (BMWi)

German Academic Exchange Service (DAAD)

German-Israeli Foundation (GIF)

German Research Foundation (DFG):

- **Collaborative Research Centers (SFB):** *631, 646, 749, 863, 870, 960, 1032, 1035*
- **SFB/Transregio:** *12, 80*
- **Graduate Training Group:** *1721*
- **Individual Grants (Einzelförderungen)**
- **Priority Programmes (SPP):** *1175, 1236, 1243, 1253, 1285, 1313, 1362, 1459, 1464, 1479, 1506, 1543, 1617*
- **Research Units (Forschergruppen):** *801, 1406, 1543*

International Human Frontier Science Program Organization (HFSP)

LMU Center for Advanced Studies (CAS)

- **Research Fellowships**

LMU*excellent*

LMU*innovativ*

- **BioImaging Network Munich**
- **Functional Nanosystems**
- **Chemical Dynamics – From Femtochemistry to Biological Machines**

Max-Planck-Gesellschaft

NanoTemper Technologies GmbH

National Institutes of Health (NIH), USA

Roche Diagnostics GmbH

Verband der Chemischen Industrie

Volkswagen Foundation

Wyatt Techology Europe

IMPRINT

PUBLISHER

Center for NanoScience (CeNS)
Ludwig-Maximilians-Universität
Geschwister-Scholl-Platz 1
D-80539 Munich, Germany

Phone: +49-89-2180-3547
Fax: +49-89-2180-5649

Website: www.cens.de

Board
Prof. Thomas Bein
Prof. Joachim O. Rädler (Spokesman)
Prof. Ulrich Schollwöck

Prof. Tim Liedl (Advisory Member)
Prof. Christina Scheu (Advisory Member)

Managing Director
Dr. Susanne Hennig

Program Manager
Marilena Pinto, M.A.

Team Assistant
Claudia Kleylein, M.A.

CONCEPT & LAYOUT

Dr. Susanne Hennig

IMAGES

p. 5: private photograph
p. 7: Christof Mast/CeNS
p. 9: Christoph Hohmann (NIM)
p. 8: private photographs
p. 9: private photographs & CeNS
p. 10: private photographs
p. 12: CeNS
p. 13: CeNS
p. 14: CeNS/CNSI
p. 15: Christof Mast/CeNS
p. 17: Christoph Hohmann (NIM),
Anton Kuzyk & Robert Schreiber
p. 34: Christoph Hohmann (NIM)/
ASC Nano
p. 36: Christoph Hohmann (NIM)/
RSC Publishing
p. 45: Claudia Kleylein/CeNS
p. 51: iStock
p. 45: Claudia Kleylein/CeNS

LUDWIG-
MAXIMILIANS-
UNIVERSITÄT
MÜNCHEN