SAARLAND

Großes entsteht immer
im Kleinen.

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Geschäftsführer: Prof. Dr. Eduard Arzt (Vorsitz),
Prof. Dr. Aránzazu del Campo, Günter Weber

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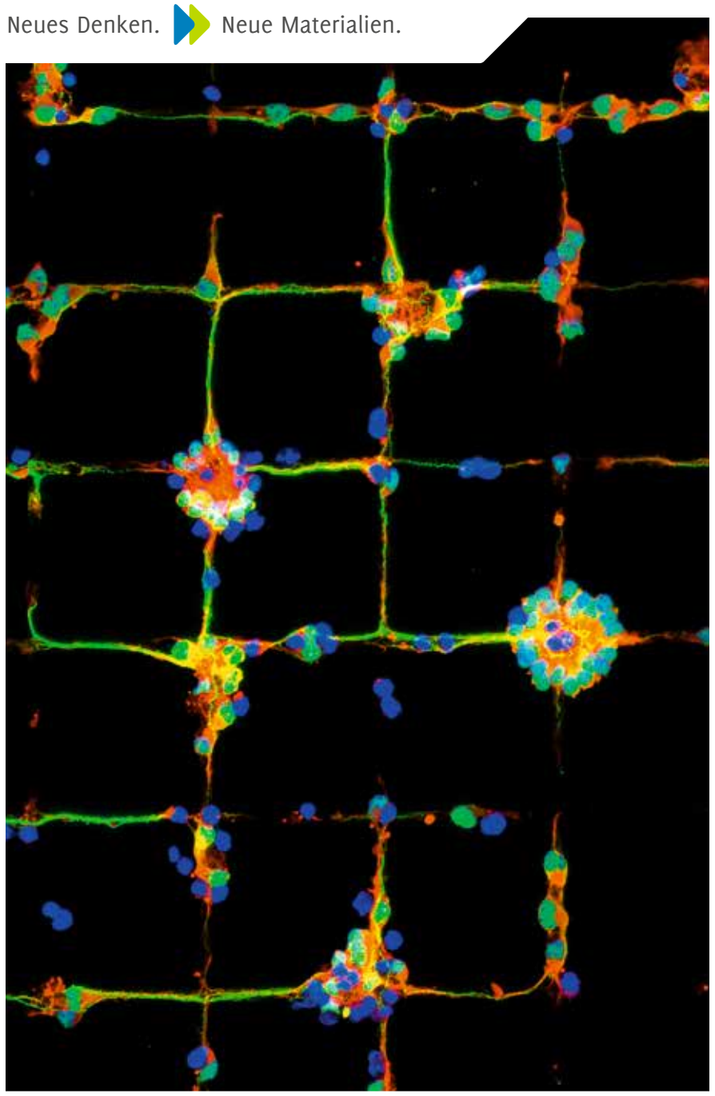
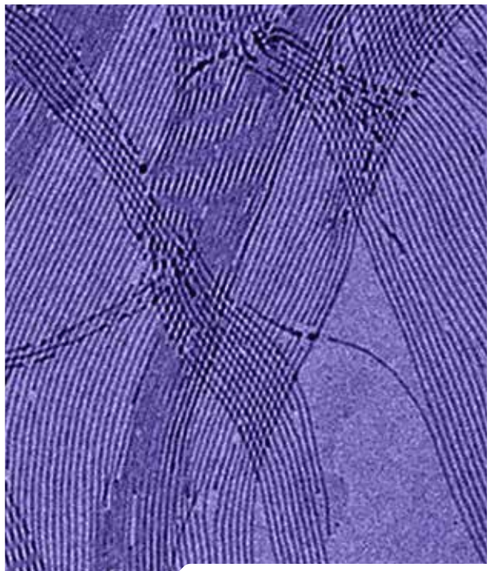
Neues Denken. Neue Materialien.





JAHRESBERICHT 2015
ANNUAL REPORT 2015

Leibniz-Gemeinschaft

INM
Leibniz-Institut für Neue Materialien

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LIEBE FREUNDINNEN UND FREUNDE DES INM,

zum ersten Mal dürfen wir Sie an dieser zu Stelle zu dritt begrüßen: Seit September 2015 verstärkt die Chemikerin Aránzazu del Campo die wissenschaftliche Geschäftsführung des INM. Mit ihrem neu aufgebauten Programmbereich *Dynamische Biomaterialien* wird sie insbesondere im INM-Forschungsfeld *Biogrenzflächen* neue wissenschaftliche Impulse setzen.

Neue Inhalte bringen auch Jiaxi Cui und Daniel Strauss. Ersterer ergänzt mit seiner Juniorforschungsgruppe *Schaltbare Mikrofluidik* die Arbeiten im Forschungsfeld *Grenzflächenmaterialien*. Letzterer, tätig an der Hochschule für Technik und Wirtschaft und der Universität des Saarlandes, erforscht als neuer INM Fellow *Haptische Mensch-Maschine-Grenzflächen*.

Insgesamt können wir auf ein äußerst erfolgreiches Jahr am INM zurückblicken. Nicht nur alle „Indikatoren“ zeigen weiter nach oben, auch unsere Projekte und Kooperationen nehmen zu: So fördert die Leibniz-Gemeinschaft in ihrem Wettbewerbsverfahren erstmals ein Projekt für den Transfer unserer Gecomer®-Technologie in die Anwendung. Das 2014 eingerichtete *InnovationsZentrum INM* hat mit internationalen Industriekooperationen sehr gut Fahrt aufgenommen. Und mit Volker Presser hat das INM seit Herbst 2015 einen neuen W3-Professor an der Universität des Saarlandes.

Unsere Erfolge können nur gemeinsam entstehen. Wir danken daher besonders unseren Mitarbeiterinnen und Mitarbeitern für ihre hervorragende Arbeit sowie unseren Partnern, Förderern und Freunden für die Unterstützung. Und Ihnen wünschen wir nun eine interessante Lektüre.

DEAR FRIENDS OF INM,

It is our first-time pleasure to welcome you in this place as a trio. In September 2015, the chemist Aránzazu del Campo joined the scientific management of INM. Her newly formed Program Division *Dynamic Biomaterials* will give new scientific impetus, in particular to the INM research area of *Biointerfaces*.

New output is also being generated by Jiaxi Cui and Daniel Strauss. Cui's Junior Research Group *Switchable Microfluidics* complements the work in the area of *Interface Materials*. Strauss, working at the University of Applied Sciences in Saarbrücken and Saarland University, investigates *Haptic Human-Machine Interfaces* as a new INM fellow.

Overall, we look back on an extremely successful year at INM. Not only do all the "indicators" keep pointing up, our projects and collaborations continue to rise as well. For the first time, the Leibniz Association is funding a project, within its competition procedure, aiming to transfer our Gecomer® technology to application. Our *InnovationCenter INM*, established in 2014, has gathered great momentum in international industrial cooperation. And since Volker Presser accepted the offer of Saarland University in autumn 2015, INM has been proud to count one more W3 professor.

Our achievements can only be made working together. We therefore give special thanks to our colleagues for doing an excellent job, and to our partners, funders and friends for their support. We wish you an interesting read.

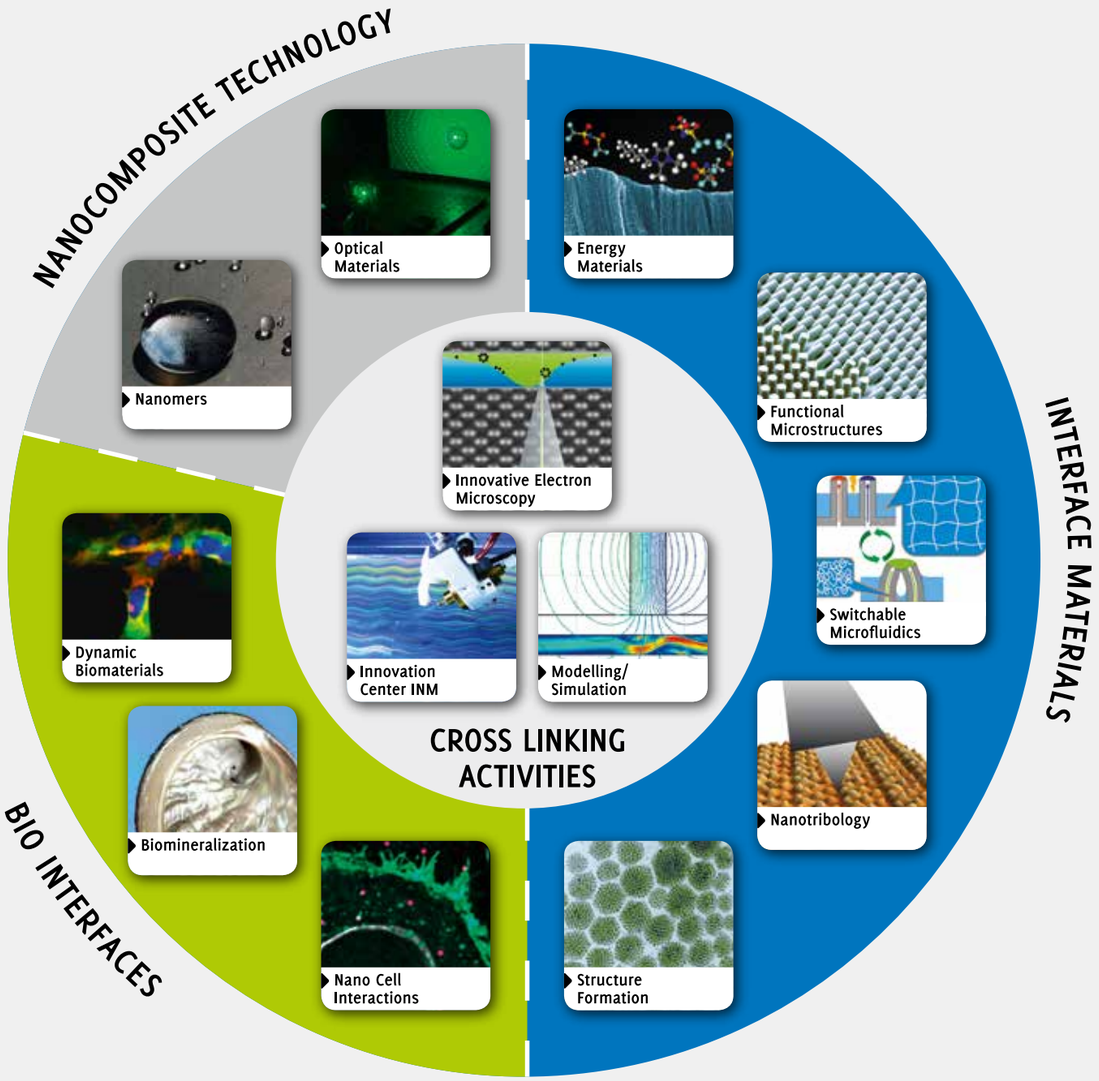
Günter Weber
Kaufmännischer Geschäftsführer / Business Director

Prof. Dr. Aránzazu del Campo
Wissenschaftliche Geschäftsführerin / Scientific Director

Prof. Dr. Eduard Arzt
Wissenschaftlicher Geschäftsführer und Vorsitzender der Geschäftsführung / Scientific Director and CEO

GRUPPENBERICHTE / GROUP REPORTS

FORSCHUNGSFELDER / RESEARCH FIELDS



DIE FORSCHUNGSFELDER DES INM

Die Arbeitsgruppen des Instituts werden in drei Forschungsfelder und ein *Querschnittsfeld* gegliedert, die thematisch nahestehende Programmbereiche und Juniorforschungsgruppen zusammenfassen:

Grenzflächenmaterialien: Das Forschungsfeld beschäftigt sich mit neuen Methoden der Oberflächen- und Grenzflächenstrukturierung und erforscht insbesondere physikalische Mechanismen an Oberflächen. Im Vordergrund stehen u. a. neue Materialien zur Energiespeicherung, steuerbare tribologische und adhäsive Phänomene, flexible Schichten für die Photovoltaik, sowie Wechselwirkungen zwischen strukturierten Oberflächen und Haut.

Biogrenzflächen: Die Arbeiten in diesem Feld konzentrieren sich auf die Schnittstelle zwischen Materialwissenschaft und Biologie bzw. Medizin. Schwerpunkte sind die Steuerung von Zellen durch zellinstruktive Materialien, Perspektiven der ressourcen- und umweltschonenden Herstellung von Materialien mittels adaptierter Biomineralisation sowie die Interaktionen zwischen Nanopartikeln und Zellen, Geweben und Organen.

Nanokomposit-Technologie: Das Feld widmet sich nichtmetallisch-anorganischen Hybridmaterialien und ihren funktionellen, insbesondere optischen, tribologischen und protektiven Eigenschaften. Schwerpunkte sind nasschemische Synthesemethoden und die Nutzung funktionalisierter Nanopartikel. Der Fokus der Arbeiten liegt in der Nutzung der Konzepte für konkrete industrielle Anwendungen.

Querschnittsfeld: Das *Querschnittsfeld* fasst übergreifende Forschungs- und Entwicklungsthemen zusammen, die die Arbeiten der Forschungsfelder methodisch ergänzen. Die Schwerpunkte umfassen hochmoderne, innovative Elektronenmikroskopie, Multiskalenmodellierung und Simulation. Das *InnovationsZentrum INM* gewährleistet den Transfer der Forschungsergebnisse in die Industrie.

THE RESEARCH FIELDS OF INM

The research in the institute is grouped in three research fields and *cross-linking activities.* These research fields merge Program Divisions and Junior Research Groups with similar thematic orientation:

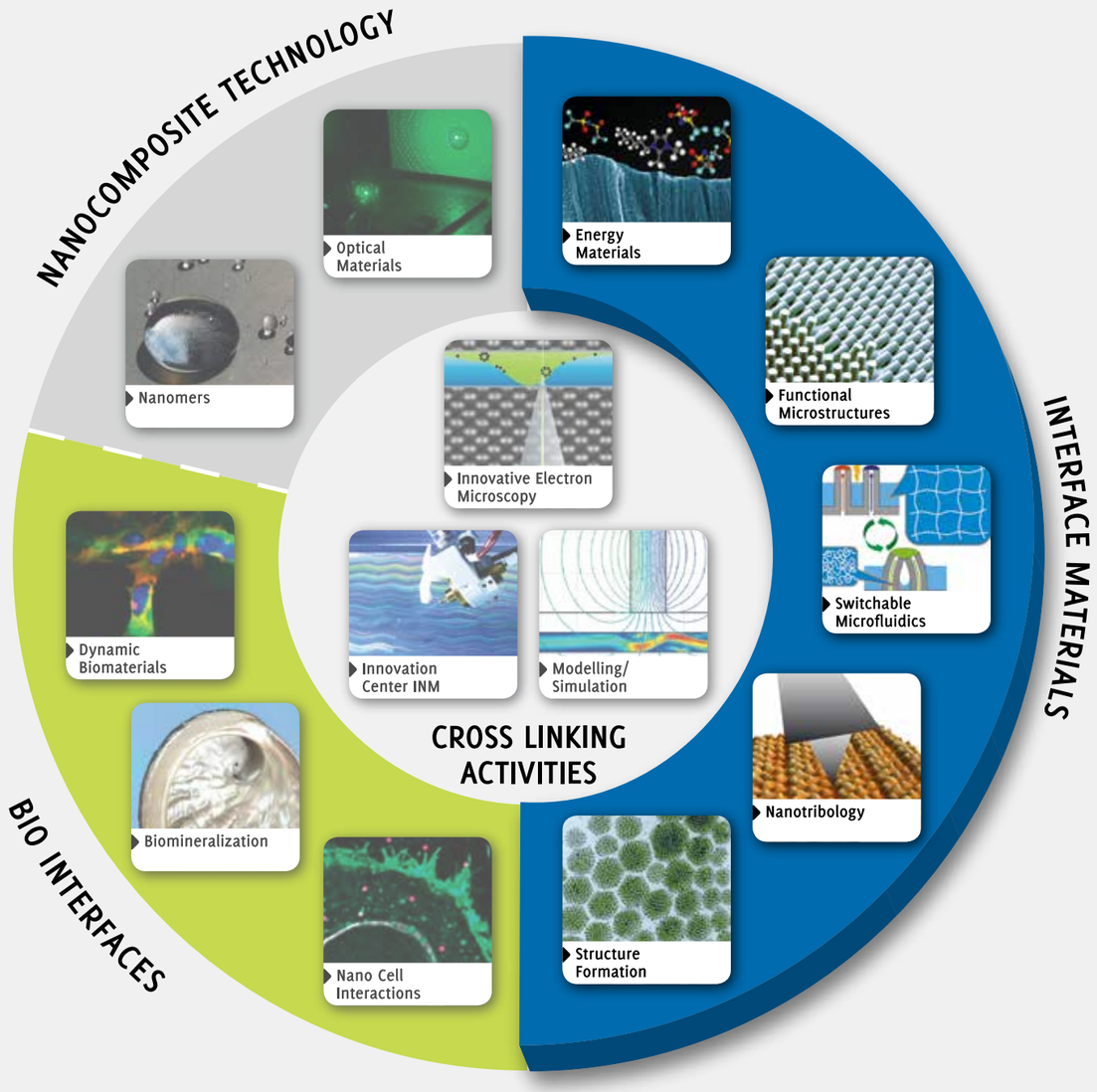
Interface Materials: The research field deals with new methods of surface and interface patterning and investigates especially physical mechanisms at surfaces. It focusses for example on new materials for energy storage, switchable tribologic and adhesive phenomena, flexible coatings for photovoltaics, and on the interaction between structured surfaces and skin.

Bio Interfaces: In this research field, the work concentrates on the interface between materials science and biology or medicine. Focus areas comprise the development of biomaterials able to trigger cell responses on demand, perspectives of resource- and environmentally friendly syntheses of materials via adapted biomineralization as well as the interaction between nanoparticles and cells, tissues and organs.

Nanocomposite Technology: The research field addresses non-metallic-inorganic hybrid materials and their functional, especially optical, tribological, and protective properties. Key aspects are wet chemical synthesis methods and the use of functionalized nanoparticles. A strong focus is on the utilization of concepts for practical applications in industry.

Cross Linking Activities: The area combines comprehensive research and development activities, which methodically complement the competencies of the research areas. Major components are up-to-date innovative electron microscopy, multiscale modeling and simulation. The *InnovationCenter INM* links INM's scientific and technological know-how with industry.

GRENZFLÄCHENMATERIALIEN / INTERFACE MATERIALS



DAS FORSCHUNGSFELD *GRENZFLÄCHENMATERIALIEN*

Das Forschungsfeld *Grenzflächenmaterialien* befasst sich mit neuen Methoden der Oberflächen- und Grenzflächenstrukturierung und erforscht insbesondere physikalische Mechanismen an Oberflächen. Im Vordergrund stehen neue Materialien zur Energiespeicherung, steuerbare tribologische und adhäsive Phänomene, flexible Schichten für Elektronik und Photovoltaik sowie Wechselwirkungen zwischen strukturierten Oberflächen und Haut.

Schwerpunktmäßig trägt dieses Forschungsfeld zu den INM-Leitthemen A (Energieanwendungen), B (Medizinische Oberflächen) und C (Tribologische Systeme) bei.

Im Herbst 2015 wurde im Zuge eines eingeworbenen Leibniz Research Clusters (LRC) die Juniorforschungsgruppe *Schaltbare Mikrofluidik* neu eingerichtet, sowie die Juniorforschungsgruppe *Schaltbare Oberflächen* nach Weggang des Leiters in den Programmbereich *Funktionelle Mikrostrukturen* integriert. Des Weiteren wurde im Dezember 2015 die Juniorforschungsgruppe *Energie-Materialien* in einen Programmbereich umgewandelt. Das Forschungsfeld besteht zum 31.12.2015 aus vier Programmbereichen und einer Juniorforschungsgruppe:

- Programmbereich *Energie-Materialien*, Leitung: Prof. Dr. Volker Presser
- Programmbereich *Funktionelle Mikrostrukturen*, Leitung: Prof. Dr. Eduard Arzt, Dr. René Hensel
- Programmbereich *Nanotribologie*, Leitung: Prof. Dr. Roland Bennewitz
- Juniorforschungsgruppe *Schaltbare Mikrofluidik*, Leitung: Dr. Jiaxi Cui
- Programmbereich *Strukturbildung*, Leitung: Dr. Tobias Kraus

THE RESEARCH FIELD *INTERFACE MATERIALS*

The research field *Interface Materials* deals with new methods of surface and interface patterning and investigates especially physical mechanisms at surfaces. It focuses for example on new materials for energy storage, switchable tribologic and adhesive phenomena, flexible coatings for photovoltaics, and on the interaction between structured surfaces and skin.

This research area contributes significantly to INM's lead topics A (energy applications), B (medical surfaces) and C (tribological systems).

Within a new Leibniz Research Cluster (LRC), a new Junior Research Group *Switchable Microfluidics* was established in autumn 2015. The Junior Research Group *Switchable Surfaces* was integrated into the Program Division *Functional Microstructures* after the leaving of the head of the group. Furthermore, the Junior Research Group *Energy Materials* was transferred into a Program Division in December 2015. The research field *Interface Materials* consists of four Program Divisions and one Junior Research Group (as of December 31, 2015):

- Program Division *Energy Materials*, Head: Prof. Dr. Volker Presser
- Program Division *Functional Microstructures*, Head: Prof. Dr. Eduard Arzt, Dr. René Hensel
- Program Division *Nanotribology*, Head: Prof. Dr. Roland Bennewitz
- Junior Research Group *Switchable Microfluidics*, Head: Dr. Jiaxi Cui
- Program Division *Structure Formation*, Head: Dr. Tobias Kraus

Mehr Informationen über das Forschungsfeld *Grenzflächenmaterialien* finden Sie hier.

More informations about the research field *Interface Materials*.

ENERGIE-MATERIALIEN / ENERGY MATERIALS

PROF. DR. VOLKER PRESSER

ZUSAMMENFASSUNG

Der Programmbereich *Energie-Materialien* erforscht und entwickelt Nanomaterialien für elektrochemische Anwendungen, wie beispielsweise zur elektrochemischen Energiespeicherung oder zur Wasseraufbereitung via kapazitiver Entionisierung. Auf der Materialseite liegt der Schwerpunkt auf Nanokohlenstoffen, hochporösen Kohlenstoffen und Hybridmaterialien, die als Pulver, Kugeln, Schäume oder Nanofasern hergestellt werden. Nanoskalige Hybridisierung wird durch die Implementierung von Metalloxiden und Oberflächengruppen erreicht. Hieraus werden auf der Anwendungsseite vor allem Elektroden für Superkondensatoren entwickelt. Ein wichtiges Ziel ist die Kombination von hoher Energie- und Leistungsdichte funktionaler Energiespeicher und deren Transfer in die Industrie. Besondere Bedeutung nimmt die Charakterisierung der elektrochemischen Phänomene ein, die mit *in-situ* Methoden detailliert untersucht werden.

Prof. Dr. Volker Presser

is head of the program division *Energy Materials* and Full Professor at Saarland University. He received his doctorate in Applied Mineralogy at the Eberhard-Karls University, Tübingen, and worked formerly as Research Assistant Professor at Drexel University, Philadelphia, USA.

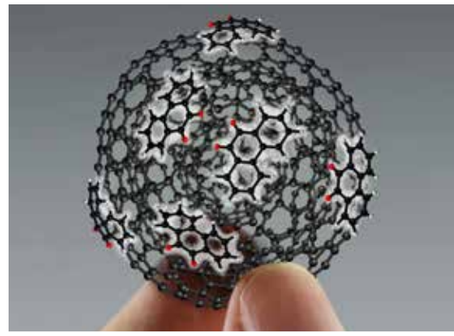
MISSION

Research in the Program Division *Energy Materials* is focused on the synthesis, characterization, and application of nanomaterials for electrochemical applications. Our activities include electrochemical energy storage (supercapacitors) and water treatment using capacitive deionization. Both applications are based on the electrical double-layer which forms at the interface between electrically charged materials and electrolytes with dissolved ionic species. Carbon nanomaterials are the most important electrode material and we utilize non-porous carbon nanoparticles and nanoporous carbons for electrochemical applications. In particular, polymer- and carbide-derived carbons are explored in complex forms (such as beads, fibers, or films). Faradaic reactions resulting from hybridization of metal oxides or functional surface groups with carbon enable to significantly increase the energy density of electrochemical capacitors. We focus on a comprehensive array of materials characterization techniques and in-situ methods to gain novel insights into electrochemical processes. Our contributions extend from basic research, materials synthesis, and the refinement of testing procedures to industrial collaboration and technology development.

CURRENT RESEARCH

Hybrid energy storage

Fast charge and discharge rates by supplying enhanced energy storage capacity can be accomplished by the use of hybrid materials, showing battery-like as well as capacitor-like properties. Particularly attractive are surface functional groups, such as quinones, which can easily be adapted to carbon surfaces by facile drop casting. Pore blocking by surface functional groups can be avoided by using nanocarbon materials with a large outer surface area, such as carbon onions. By this way, ion access to the surface is not hindered to enable combined electrostatic and redox contributions to the energy storage process.



Hybrid energy storage based on carbon onions and quinone functional surface groups.

Tracking ion electrosorption in carbon nanopores

Using small angle scattering, synchrotron radiation was used to investigate in operando the movement of ions in aqueous media within porous carbons. At high molar concentration, as used in supercapacitors, the total number of ions inside the carbon nanopores is not changing. Instead, the charge storage is accomplished by gradually changing the anion-to-cation ratio. This process of ion swapping explains the fast response of supercapacitors that is to be seen as facile ion redistribution. While preserving the total ion number, ions inside carbon nanopores get attracted closer to the pore walls as an electric potential is applied. Using synchrotron radiation, a high spatial and temporal resolution enabled tracking the signal related to different ion species in aqueous media. This work was carried out in collaboration with Prof. Paris (Montanuniversität Leoben) and conducted at ELETTRA in Trieste.

Carbon heteroatoms

Carbons suffer from a limited electrical conductivity. To overcome limited charge screening, doping carbon has emerged as an attractive approach. Interestingly, nitrogen-doped carbon, when matched to certain electrolytes, shows an unique enhancement of the capacitance, probably caused by a difference in the interfacial interaction with nitrogen-containing ionic liquids. We have demonstrated this effect for templated nitrogen-doped, carbide-derived carbons in collaboration with Prof. Kempe (Bayreuth University). Yet, nitrogen in carbon materials may not remain fully inert when transitioning to aqueous electrolytes and additional arising redox-reactions may reduce the capacitive component of total transferred charge. This may come at the price of reduced ability to desalinate water for capacitive deionization, but opens new pathways for hybrid energy storage systems. For this study we used a comprehensive set of nitrogen- and sulfur-doped carbon heteroatoms with tailored porosity in collaboration with Prof. Antonietti and Dr. Fellinger (Max Planck Institute of Colloids and Interfaces).

OUTLOOK

Our team will continue to broaden the utilization of interfacial electrochemistry and hybrid carbon nanomaterials. In particular, we will explore redox-active electrolytes for enhanced energy storage and further investigate the performance stability during capacitive deionization operation. The latter requires thorough understanding of the electrochemical reactivity of surface groups and their change over time. Another focus will be on enhancing our collaboration with industry and technology transfer.

FUNKTIONELLE MIKROSTRUKTUREN / FUNCTIONAL MICROSTRUCTURES

PROF. DR. EDUARD ARZT, DR. RENÉ HENSEL

ZUSAMMENFASSUNG

Der Programmbereich befasst sich mit der Herstellung und Charakterisierung funktionsstrukturierter Oberflächen. Durch Mikro- und Nanostrukturierung sowie gezielte Materialauswahl werden spezielle mechanische, optische, thermische und haptische Funktionalitäten erzeugt. Vorbild für Gestalt und Funktionen der Strukturen sind Konzepte aus der belebten Natur, die auf künstliche Systeme übertragen werden. Der Fokus der Arbeiten liegt auf bioinspirierten Haftsystemen (Fig. 1); im Vordergrund stehen die Interaktion Gecko-inspirierter Strukturen mit rauen, weichen und hautähnlichen Substraten und anwendungsrelevante Fragestellungen. In enger Kooperation mit der Universität des Saarlandes und Industriepartnern werden Anwendungen im Bereich medizinischer Oberflächen und technischer Greifsysteme erschlossen. Das Thema wird von der DFG (Nachwuchsakademie), der EU (ERC Advanced Grant) und in einem in 2015 eingeworbenen Projekt im Leibniz-Wettbewerbsverfahren (Kooperation mit dem *InnovationsZentrum INM*) gefördert.

MISSION

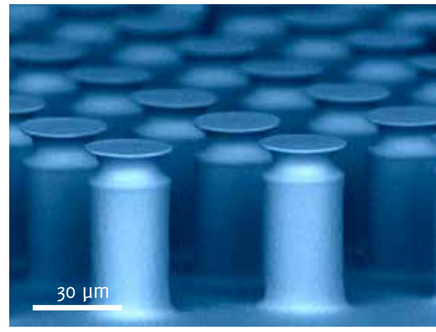
The Program Division *Functional Microstructures* conducts research in the fabrication and characterization of functional micro- and nanopatterned surfaces. Through a suitable combination of morphology and materials, surface features are fabricated that enhance various functionalities such as mechanical, optical, thermal or haptic characteristics. Inspired by the fascinating adhesive performance of natural structures, the group attempts to mimic such mechanisms to improve the adhesion of synthetic surfaces (fig. 1). Presently, our research focus lies on the mechanisms of contact between adhesive fibrillar structures and soft, compliant surfaces such as skin. In collaborative development projects with industrial partners, we investigate technological processes to promote the transfer of our Gecomer Technology into industrial applications such as robotic pick-and-place systems.

Prof. Dr. Eduard Arzt (Head)

is scientific director and CEO of INM and professor for new materials at Saarland University. After his PhD at the University of Vienna, he performed research, amongst others, at Cambridge University, Stanford University and MIT and was director at the Max Planck Institute for Metals Research, Stuttgart.

Dr. René Hensel (Deputy Head)

studied materials science at Technische Universität Dresden. He completed his doctorate at the Leibniz Institute of Polymer Research Dresden (IPF) and the Max Bergmann Center of Biomaterials Dresden (MBC). Since 2014, he has been deputy head of the Program Division *Functional Microstructures*.



Bioinspired, fibrillar adhesives provide a platform for patented Gecomer Technology.

CURRENT RESEARCH

Hierarchically patterned dry adhesives

Nature uses hierarchical fibrillar structures to mediate temporary adhesion to arbitrary substrates. In the completed DFG SPP project (1420) and in cooperation with Prof. Fleck, Cambridge University, we investigated the adhesion of artificial multilevel structures in contact with smooth and rough substrates. We found that adhesion can be dramatically affected by additional hierarchical levels but is not always beneficial. The study points to possible advantages of hierarchy for shear adhesion or non-aligned substrates.

Adhesion of composite fibrils

A novel design of bioinspired dry adhesives was introduced: fibrils composed of a thin soft material layer terminating the top face of a stiffer pillar structure. Experimental and numerical results (cooperation with Prof. McMeeking, UCSB) demonstrated that composite fibrils show improved adhesion by reducing corner stress singularities. The elasticity gradient has a similar effect as in mushroom fibrils, where a geometrical gradient improves adhesion. Composite fibril patterns promise to overcome current fabrication limitations of mushroom fibrils. A systematic variation of material and design parameters revealed that a high elastic modulus ratio between the two elastomers and a thinner soft layer improves adhesive performance.

Development towards industrial applications

INM's Gecomer Technology has increasingly been presented at high-technology fairs and exhibitions worldwide. The successful demonstration of a pick-and-place robot equipped with Gecomer gripping surfaces has produced much positive response from many industrial sectors. In collaboration with the *InnovationCenter INM*, successful development projects with industrial customers were conducted. These efforts are now intensified by a grant received in 2015 from the Leibniz Association to close the gap between science and product development (see also Highlight Article on Gecomer Technology).

OUTLOOK

The Program Division *Functional Microstructures* will continue on its path from scientific research to active technology transfer. Upscaling and validation studies and further exploration of new application fields for our Gecomer technology will increasingly dominate our work. Scientific research will focus on contact mechanisms of fibrillar structures on rough and soft substrates such as skin. In collaboration with the new Junior Research Group *Switchable Microfluidics*, new approaches for switchable adhesives will be investigated. In the field of biomedical applications, the collaboration with Saarland University Hospital (Prof. Schick, Homburg) will enter the stage of *in-vivo* testing. Micromechanical modeling of adhesion performance will remain an important baseline to rationally improve adhesion further.

NANOTRIBOLOGIE / NANOTRIBOLOGY

PROF. DR. ROLAND BENNEWITZ

ZUSAMMENFASSUNG

Der Programmbereich *Nanotribologie* forscht an der Entwicklung neuer Materialien mit besonderen adhäsiven und tribologischen Eigenschaften. Im Zentrum stehen dabei die Funktionalisierung von Oberflächen und das Verständnis der mikroskopischen Mechanismen von Reibung und Verschleiß. Unsere experimentellen Projekte basieren auf unserer Expertise in der hochauflösenden Rasterkraftmikroskopie, die wir auch im Ultrahochvakuum und in Flüssigkeiten sowie unter elektrochemischer Kontrolle betreiben. Außerdem nutzen wir neue experimentelle Methoden, zum Beispiel um die Reibung von strukturierten Proben gegen eine Fingerspitze mit den Gehirnströmen der Testperson (EEG) zu korrelieren. Zu den herausragenden Ergebnissen des Jahres 2015 gehören die Demonstration der Kontrolle von Reibung durch makromolekulare Funktionalisierung sowie die Entdeckung einer unteren, nanoskaligen Grenzlänge für die Verformung von metallischen Gläsern durch Scherbänder.

Prof. Dr. Roland Bennewitz

is the Head of the *Nanotribology* group and Honorary Professor of Experimental Physics at Saarland University. He obtained his PhD from the Freie Universität Berlin, did postdoctoral studies at the University of Basel, and held the Canada Research Chair in Experimental Nanomechanics at McGill University in Montreal.

MISSION

The Program Division *Nanotribology* explores new materials with specific mechanical surface properties. We focus on surface functionalization and on understanding the microscopic mechanisms in friction and wear. Our experimental projects rely on our expertise in the field of high-resolution force microscopy under ultra-high vacuum conditions or in liquids where the surfaces can be electrochemically controlled. Furthermore, we develop new experimental methods in the field of haptics. Our methods, results and know-how on fundamental nanotribology led to fruitful collaborations, in particular within the INM and with Saarland University. Examples are joint projects with the Program Division *Functional Surfaces* on multi-scale aspects of fibrillar adhesion, with the INM Fellow Karin Jacobs on friction in thin polymer films, and with Prof. Martin Müser from Saarland University on molecular layering in confinement.

CURRENT RESEARCH

The following examples describe research results from 2015 which resulted in publications in international research journals:

Switching adhesion and friction by light using photosensitive guest-host interactions

Friction and adhesion between two β-cyclodextrin functionalized surfaces can be switched reversibly by external light stimuli. The interaction between the cyclodextrin molecules attached to the tip of an atomic force microscope and a silicon wafer surface is mediated by complexation of ditopic azobenzene guest molecules. The strength of the friction force is reduced by illumination with UV light which reduces the complexation probability of the azobenzene group with the cyclodextrin molecules at the surfaces. Friction is restored by illumination with visible light.

Lower nanometer-scale size limit for the deformation of a metallic glass by shear transformations

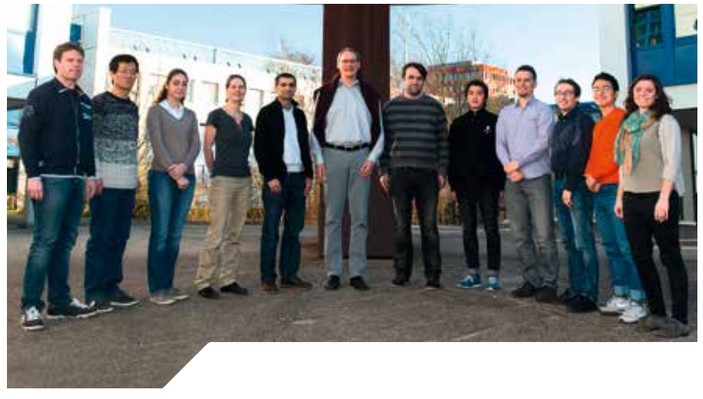
We combined non-contact atomic force microscopy (AFM) imaging and AFM indentation in ultra-high vacuum to quantitatively and reproducibly determine the hardness and deformation mechanisms of Pt(111) and a platinum-based metallic glass with unprecedented spatial resolution. Our observation of plastic deformation mechanisms of crystalline Pt(111) are consistent with the discrete mechanisms established for larger scales: plasticity is mediated by dislocation gliding. For the metallic glass, we discovered that plastic deformation at the nanometer scale is not discrete but continuous and localized around the indenter. Our results reveal a lower size limit for metallic glasses below which shear transformation mechanisms are not activated by indentation. We conclude that the energy stored in the stressed volume during nanometer-scale indentation is insufficient to account for the interfacial energy of a shear band in the glassy matrix.

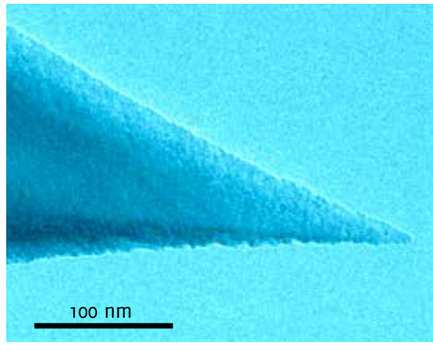
Mechanisms of friction and wear reduction by carbon fiber reinforcement of PEEK

Carbon fibers are widely used as reinforcements in poly-ether-ether-ketone (PEEK). For further optimization of these tribo-materials, we investigated the contribution and action mechanisms of carbon fiber reinforcements to the tribological performance of PEEK composites in collaboration with Prof. A. Schlarb (Kaiserslautern University). We studied carbon fibers in a PEEK composite by scratching experiments using single-asperity indenters and friction imaging using contact atomic force microscopy. Shearing dominates the friction and wear behavior of carbon fibers alone, while both shearing and plowing contribute to the overall friction of PEEK composites. The wear reduction by carbon fibers originates from their effective load-bearing capability. For the first time, fatigue of individual carbon fibers was studied.

OUTLOOK

We will continue to investigate the mechanisms which link the structure and the dynamics of surfaces to friction and wear in new materials. Our current funded projects include studies of friction and contact ageing on clean metals, and of the role of surface structure and chemistry for friction and wear in metallic glasses. A collaborative project within the INM addresses the neural response to friction against the fingertip. A project with Kaiserslautern University relates the scratch mechanisms in polymers across length scales to their macroscopic tribological responses. Finally, we aim to apply the results of our research in projects with industrial partners on molecular mechanisms in additive lubrication.





Mechanical studies at the nanometer scale require probes of the same size scale. This transmission electron microscopy image shows a typical tip used in our atomic force microscopy experiments.

STRUKTURBILDUNG / STRUCTURE FORMATION

DR. TOBIAS KRAUS

ZUSAMMENFASSUNG

Der Programmbereich *Strukturbildung* untersucht grundlegende Mechanismen der Strukturbildung aus Molekülen, Polymeren und kolloidalen Partikeln und wendet sie zur Herstellung neuer Materialien aus flüssigen Vorstufen an. Wir setzen Partikel und Polymere durch Nassbeschichten zusammen und untersuchen, wie die Eigenschaften von Komposit- und Hybridmaterialien von ihrer Mikrostruktur abhängen, indem wir systematisch Größe, Geometrie, Zusammensetzung und Anordnung der Komponenten variieren. Wir beobachten, wie Mikrostruktur und innere Grenzflächen entstehen und Materialeigenschaften bestimmen. Diese Methode wenden wir zum Beispiel auf transparent leitfähige Schichten aus metallischen Nanopartikeln für die Elektronik, Suprapartikel aus optisch aktiven Partikeln und leitfähige Komposite her. Wir suchen Partikel, aus denen sich zukünftig „aktive Nanokomposite" herstellen lassen, die mit Elektronik verbunden ihre Eigenschaften bei Bedarf ändern können.

Dr. Tobias Kraus

is a chemical engineer trained at TU Munich, MIT, and the University of Neuchâtel. He obtained his PhD at ETH Zurich and the IBM Research Laboratory. His interests span physical chemistry, surface science, and process engineering. He has been appointed Deputy Head of the *InnovationCenter INM.*

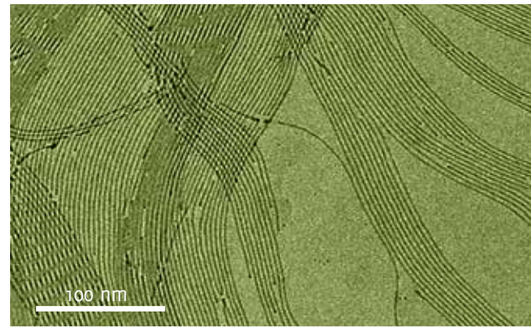
MISSION

The Program Division *Structure Formation* investigates how molecules, polymers and colloidal particles join to form structures, their fundamental processes of formation, and their application to prepare new materials. Particles and molecules are the building blocks that we assemble by liquid coating. We study how the properties of composite and hybrid materials depend on their microstructures and how to alter them by systematically varying size, geometry, chemical composition, and arrangement of the constituents. We observe how microstructures and interfaces form and affect material properties to create e. g. transparent conductive layers of metal nanoparticles for electronics, electrically conductive composites and suprapartricles composed of optically active nanoparticles. We seek particles for future "active nanocomposites" that can interface with electronics and change their properties when required.

CURRENT RESEARCH

Ultrathin nanowires for flexible electronics

The thinnest gold wires that we synthesized are only 10 gold atoms thick (ca. 1.6 nm in diameter), but many micrometers long (Figure 1). At such small diameter, gold wires appear transparent, bending easily and elastically, and seem to be ideal wires to create flexible, transparent electronics. In 2015, we demonstrated in the BMBF-project *NanoSpekt* that the wires are useful for electronics, but first we had to overcome two problems. Ultrathin gold wires break apart at room temperature. Their surface energy is so large that the wires tend to decompose into spheres, thus degrading conductivity drastically. We developed techniques to slightly coarsen



Ultrahin gold nanowires are fascinating building blocks for flexible and transparent electronics.

the wires by soft sintering in plasma. The resulting wires are thick enough to be stable but thin enough to be transparent. This step also solves the second problem of the ultrathin wires: After preparation by chemical synthesis the wires are covered with an organic shell, which is insulating and renders films of wires non-conductive. We optimized the plasma sintering such that the layers are removed and conductive links form between the wires.

Flexible X-ray detectors

Siemens is interested in X-ray detectors that are easier to produce than by current technology. We collaborated with Siemens Research and created hybrid X-ray detectors that combine materials from organic solar cells with inorganic particles. Detectors from these new materials can be sprayed and provide high resolution. The material has been presented in a *Nature Photonics* article.

Unexpected clusters of polymers and nanoparticles

Proteins form very stable dispersions. In the human body, they stay dispersed until they arrange into cell components. Uncontrolled agglomeration causes diseases. Mixtures of proteins and nanoparticles are usually less stable. Many proteins let nanoparticles agglomerate into an undefined mix of growing particles that eventually settle. Only if the concentration of proteins is very large do they stabilize certain particles and keep them in dispersion. Surprisingly, there exists an intermediate case. Studies on protein-nanoparticle interactions that we performed in collaboration with the program division *Nano Cell Interactions* showed that in certain concentration ratios, nanoparticles and proteins agglomerate only briefly and form stable hybrid clusters that then remain dispersed. This unusual intermediate case is interesting for biomedical applications of nanoparticles, but also when analyzing the fate of nanoparticles in aquifers. The results were published as an Editor's highlight in *ACS Nano.*

OUTLOOK

As spray coating of electronics is of growing interest, we started a DAAD-funded collaboration with Prof. Paul Mulvaney (Melbourne University) to spray solar cells, which will continue and expand. Spray coating high-performance materials requires understanding the behavior of particles in the sprayed droplets. Nanoparticle stability and agglomerate structure remain a core topic of the group. We are expanding the studies to a wider range of technologically relevant materials that include semiconductors.

Ultrathin gold nanowires agglomerate in an unusual way by forming bundles. Recent results show that this bundling can be used to print electronic circuitry: we use a stamp to control the bundling and to create fibers with geometries both conductive and transparent. This could enable a printing process yielding transparent flexible circuitry in a single step.

SCHALTBARE MIKROFLUIDIK / SWITCHABLE MICROFLUIDICS

DR. JIAXI CUI

ZUSAMMENFASSUNG

Die Juniorforschungsgruppe *Schaltbare Mikrofluidik* wurde 2015 eingerichtet. Sie wird durch das Projekt „Bio/Synthetische Multifunktionale Mikro-Produktionseinheiten" des Leibniz Research Clusters (LRC) gefördert. Ihr Ziel ist die Entwicklung schaltbarer strukturierter Oberflächen zur Anwendung in Gebieten wie Biosynthese, Biomedizin, Anwuchsverhinderung, Bildgebung und Adhäsion. Zu diesem Zweck entwickeln und synthetisieren wir neue intelligente Materialien, die ihre Eigenschaften wie Volumen, Form, Benetzbarkeit, optische und mechanische Eigenschaften, Adhäsion und Oberflächengeometrie in Abhängigkeit von äußeren Einflüssen ändern können. Diese Verbindungen werden über diverse Ansätze, wie z. B. Polymerisation, Selbstorganisation, molekulare Wiedererkennung oder Mischung zu responsiven Komponenten verarbeitet. Außerdem untersuchen wir die Anwendung von Nano- und Mikrotechnologien für die Herstellung neuer Materialien. Auf Basis dieser Verbindungen und Komponenten werden schaltbare Oberflächen hergestellt.

MISSION

The Junior Research Group *Switchable Microfluidics* was initiated in 2015. It is supported by the project "Organic/synthetic multifunctional meso-production units" of the Leibniz Research Cluster (LRC) and aims to develop switchable structural surfaces to meet emerging needs in biosynthesis, biomedicine, antifouling, optical imaging, adhesion, and other areas. To this end, we design and synthesize novel smart materials including both liquid and solid that can change their properties such as volume, shape, wettability, optical performance, adhesion, mechanical strength, and surface geometry under external stimuli. These compounds are fabricated into responsive components by various approaches such as polymerization, self-assembly, molecular recognition, or blend. Furthermore, we study the application of nano/microtechnologies on the fabrication of novel materials. Take advantage of these technologies, we assemble either the novel compounds or the responsive components into switchable surfaces.

Dr. JIAXI CUI

is a chemist trained at Peking University, Max-Plank-Institute for Polymer Research, Mainz, and Harvard. He received his PhD at Peking University with a dissertation on polymer chemistry and supramolecular materials. Since 2015, he has been head of the Junior Research Group *Switchable Microfluidics.*

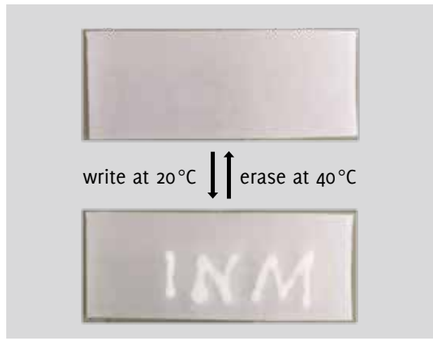
CURRENT RESEARCH

Switchable micro-reactor platform

We develop switchable meso-structural surfaces as micro-reactor platforms that permit simultaneous and unprecedented levels of control over reaction pathways. This project is inspired by the compartmentalized synthetic strategy in living cells: chemical reactions initiated under defined conditions, conclude at the required degree with desired product that can be automatically transferred to the next reaction compartment, in a programmable and precisely controlled mode. To mimic this, we design a complex structure consisting of meso-structured surface with geometrically arranged hollow pillars and soft actuating system that can switch the channels. In 2015, the first proof-of-concept that the soft actuating system is able to control the tilting of pillars was achieved. We will fabricate hollow pillars and combine soft actuating system to create the reactor platform.

Mobile surface

Liquids constitute a novel structured material to create a multifunctional surface. While most of current systems focus on inert liquids, we develop novel mobile surfaces by infusing thermo-responsive oils into porous substrates. The oils consisting of silicone and oligo(ethylene glycol) are prepared in a very green method: solvent free, at room temperature, with nearly quantitative yield, and especially, produced for direct use. They display lower critical solution temperatures (LCST) in water. We investigate the stabilization of porous polypropylene membranes to these oils and how the thermo-responsiveness of these oils switches surface wettability, optical properties, and the penetrability of fluids (i. e. water).



Mobile surface with thermo-responsive wettability.

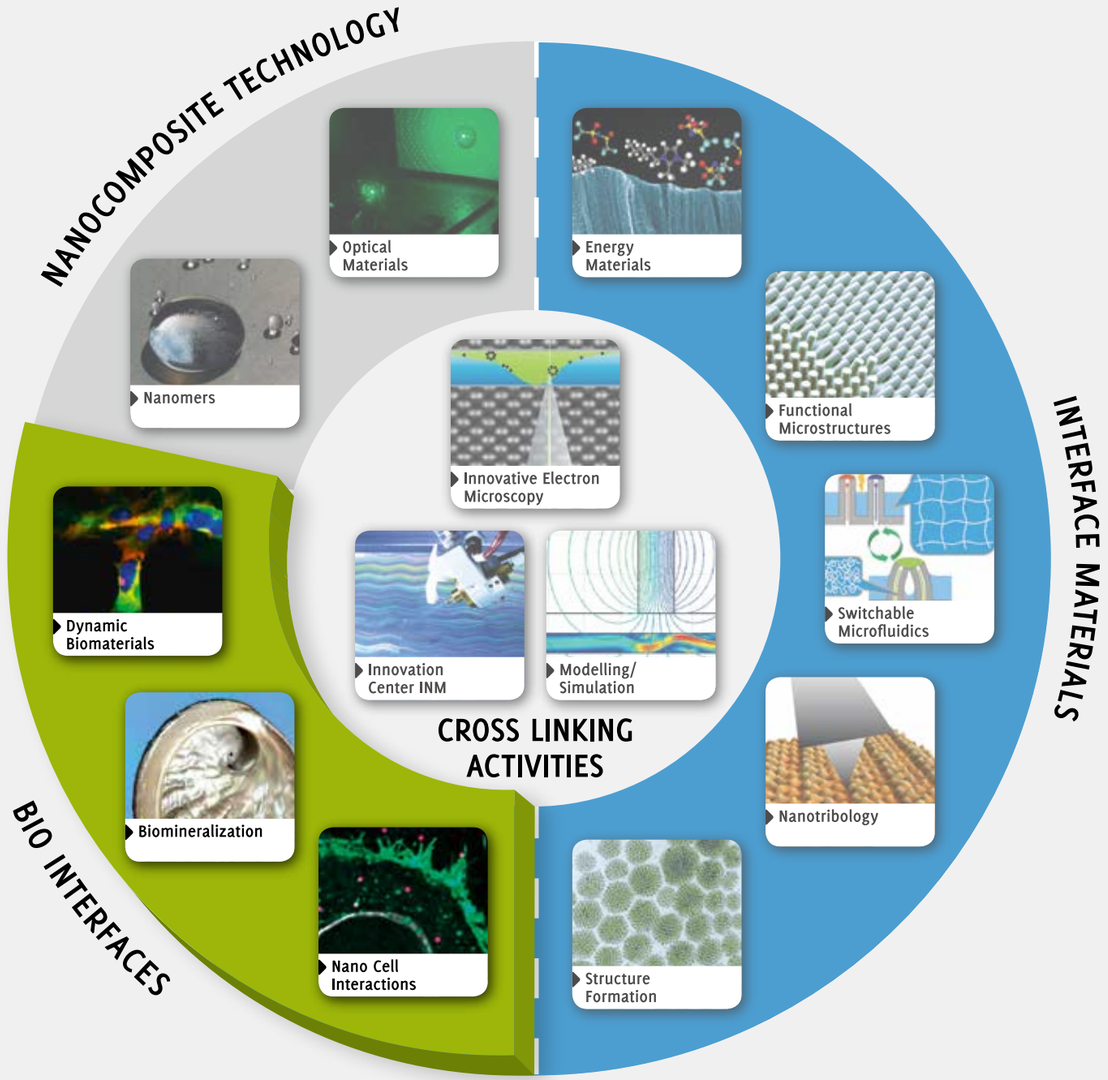
Tough hydrogel

Hydrogels are materials that consist of cross-linked polymer networks dispersed in water. They can undergo significant volume changes under external stimuli and thus constitute promising actuating systems. However, the relatively poor mechanical behavior of hydrogels remains a challenge, impeding their use in real-world applications that require mechanical integrity. We develop novel approaches for preparing tough and responsive hydrogel materials. In collaboration with the research group of Prof. Joost Vlassak, Harvard, we have designed a hierarchical system of non-covalent crosslinks that can lead to superior stretchability and damage recovery. We extend this approach to other polymer systems for special functions such as high elastic modulus, biocompatibility, biodegradability, and stimuli-responsiveness.

OUTLOOK

The group will continue the research topics on the development of actuating soft material systems and the fabrication of meso-structural surfaces with hollow pillars. We will focus on two kinds of actuating soft systems, responsive hydrogel and liquid crystal elastomer. We will seek third-party fundings to support the development of hydrogel materials in either independent or collaborative ways. Stimuli-responsive mechanisms will be integrated to the tough hydrogel systems we have developed. In parallel, we will synthesize liquid crystal monomers and apply novel approaches to fabricate them into liquid crystal elastomers in a 2.5 or 3D mode. These materials will either be used directly to prepare or integrated into meso-structural surfaces for getting primary switchable microfluidic systems that can respond to an external stimulus (i. e. light).

BIOGRENZFLÄCHEN / BIO INTERFACES



DAS FORSCHUNGSFELD *BIOGRENZFLÄCHEN*

Im Forschungsfeld *Biogrenzflächen* werden Forschungs- und Entwicklungsarbeiten betrieben, deren Themen sich auf die Schnittstelle zwischen Materialwissenschaft und Biologie bzw. Medizin konzentrieren. Schwerpunkte sind die Steuerung von Zellen durch zellinstruktive Materialien, Perspektiven der ressourcen- und umweltschonenden Herstellung von Materialien mittels adaptierter Biomineralisation sowie die Interaktionen zwischen nanopartikulären Substanzen und Zellen, Geweben und Organen.

Das Forschungsfeld trägt schwerpunktmäßig zu den INM-Leitthemen B (Medizinische Oberflächen) und D (Nanosicherheit/Nano-Bio) bei. Im Forschungsfeld wird zudem der Leibniz-Forschungsverbund Nanosicherheit koordiniert (Programmbereich *Nano Zell Interaktionen*).

Im Sommer 2015 wurde der Programmbereich *CVD/Biooberflächen* nach Weggang des Leiters aufgelöst. Im September 2015 wurde der neue Programmbereich *Dynamische Biomaterialien* unter Leitung der neuen wissenschaftlichen Geschäftsführerin des INM eingerichtet. Das Forschungsfeld besteht zum 31.12.2015 aus drei Programmbereichen:

- Programmbereich *Biomineralisation*, Leitung: PD Dr. Ingrid Weiss
- Programmbereich *Dynamische Biomaterialien*, Leitung: Prof. Dr. Aránzazu del Campo
- Programmbereich *Nano Zell Interaktionen*, Leitung: Dr. Annette Kraegeloh

THE RESEARCH FIELD *BIO INTERFACES*

In the research field *Bio Interfaces*, the research and development activities concentrate on the interface between materials science and biology or medicine. Focus areas comprise the development of biomaterials able to trigger cell responses on demand, up to cell programming, perspectives of resource- and environmentally friendly synthesis of materials by adapted biomineralization as well as the interactions between nanoparticles and cells, tissues and organs.

The research field contributes especially to INM's lead topics B (Medical surfaces) and D (Nanosafety /Nano-Bio). Furthermore, the Leibniz Research Alliance Nanosafety is coordinated within this research field (Program Division *Nano Cell Interactions*).

In summer 2015, the Program Division *CVD/Biosurfaces* was terminated after the leaving of the head of the group. In September 2015, the new Program Division *Dynamic Biomaterials*, headed by the new scientific director of INM, was established. The research field *Bio Interfaces* consists of three Program Divisions (as of December 31, 2015):

- Program Division *Biomineralization*, Head: PD Dr. Ingrid Weiss
- Program Division *Dynamic Biomaterials*, Head: Prof. Dr. Aránzazu del Campo
- Program Division *Nano Cell Interactions*, Head: Dr. Annette Kraegeloh

Mehr Informationen über das Forschungsfeld *Biogrenzflächen* finden Sie hier.

More informations about the research field *Bio Interfaces*.

BIOMINERALISATION / BIOMINERALIZATION

PD DR. INGRID M. WEISS

ZUSAMMENFASSUNG

Der Programmbereich *Biomineralisation* erforscht die Prinzipien komplex aufgebauter Materialien lebender Organismen und sucht nach neuen Möglichkeiten, diese auf technologisch herstellbare Multifunktions-Materialien zu übertragen. Im Fokus stehen dabei unterschiedlichste Biopolymere der extrazellulären Matrix und ihre Wechselwirkung mit anorganischen Komponenten. Im Laufe der Evolution wurde eine Vielzahl molekularer Wechselwirkungen optimiert, die durch Selbstassemblierung zu strukturell bevorzugten Kompositmaterialien führen. Basierend auf diesen Grundlagen lassen sich nun auch neue Wege im Hinblick auf das Design von Biogrenzflächen beschreiten. Im Jahr 2015 gelang es uns erstmals, einzelne Teilschritte im Selbstorganisationsprozess nanoskaliger Mineralkomposite zu identifizieren. Einen zukünftigen neuen Schwerpunkt unserer Forschung bildet die Etablierung und Erweiterung molekularer Werkzeuge, um die Interaktion von Geweben mit natürlichen oder künstlichen Materialien maßzuschneidern.

MISSION

The Program Division *Biomineralization* at INM combines inspiration and tools from interdisciplinary fields to investigate formation mechanisms of biological materials, such as pearls or peacock feathers. It aims at identifying the fundamental regulatory networks that can be exploited by extracellular matrix (ECM)-oriented materials science approaches using techniques established in the biointerfaces groups at INM. In 2015, we discerned for the first time, distinct initial steps in the self-assembly process of biogenic nanoparticles, which were previously isolated from the hierarchically structured and mineralized ECM. Based on understanding and manipulating such fundamental mechanisms, we hope to be able to broaden the applications of new materials in novel areas of biosciences.

CURRENT RESEARCH

Manipulating the ECM for tailored mineralization

A novel gene expression system was generated for easy manipulation of the extracellular matrix (ECM) with various biomacromolecules derived from biominerals. In liquid systems, it is difficult to gain control over mineral nucleation and growth. Therefore, the effect of novel ECM components derived from synthetic genes was studied in cell cultures grown on mineralized substrates. Depending on the amino acid composition of the foreign protein, the growth mode of the cells as well as the respective mechanical properties of the ECM deposited on the mineralized substrate varied so strongly that the performed functional screening was extremely fast and simple.

PD Dr. Ingrid M. Weiss

received her doctorate in biophysics at the TU Munich. After a postdoctoral stay at The Weizmann Institute of Science, Israel, she performed her Habilitation at the University of Regensburg, where she is Privatdozent for biochemistry since 2008, when she also became Head of the Program Division at INM.

Alignment of mineralized ECM nanoparticles

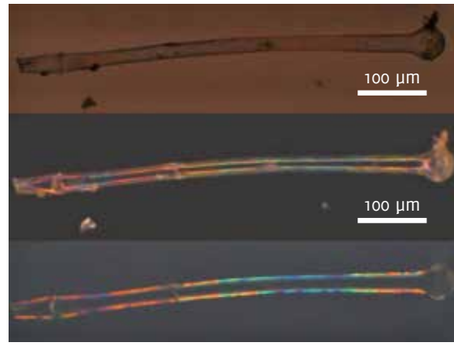
One of our strongest expertises is the investigation of hard materials of natural origin that form within or at the interface of an originally soft ECM. Aiming at understanding how an almost perfect alignment of mineral nanocrystals occurs in the ECM of some animals, we isolated the natural nanocrystals and studied their behavior in the absence of organic components in aqueous environments. The distinct steps identified for the assembly of the particles into crystallographically aligned rods, and subsequent aggregation of the rods into 3D objects, suggests a robust formation mechanism which is at least partly driven by purely inorganic recognition processes at the nano-scale *in vitro*. In contradiction to current understanding, we observed no direct involvement of proteins. Our investigations relied on high-resolution electron microscopy in scanning and transmission imaging modes, accompanied by a combination of biochemical techniques.

Optical effects in the ECM of fungi

While butterflies are well-known examples for nanostructured chitinous materials that give rise to structural colors, not very much attention is paid to the optical properties of chitinous ECM of fungi. One specific fungus is known for producing colored hyphae was investigated by using various optical methods including LC-PolScope birefringent measurements in combination with electron microscopic techniques. Several lines of evidence justify the conclusion that this fungus's specific cell wall architecture and composition produces structural colors. This work was performed in close collaboration with INM-Fellow Prof. Jacobs.

OUTLOOK

Complementary strategies are developed in close collaboration with the Program Division *Dynamic Biomaterials* to generate light-switchable biomacromolecules by protein bioengineering methods. Such fundamental knowledge will lead to new materials for advanced biomedical applications, where cell-materials interactions are tailored at the molecular and developmental scale and, thus, predictable in space and time.



Light microscopic investigation of color effects exhibited by chitinous ECM materials of fungal origin in various imaging modes. A broad range of brilliant colors is observed with crossed polarizers (bottom). Image courtesy: J. Bansemer.

DYNAMISCHE BIOMATERIALIEN / DYNAMIC BIOMATERIALS

PROF. DR. ARÁNZAZU DEL CAMPO

ZUSAMMENFASSUNG

Der Programmbereich *Dynamische Biomaterialien* entwickelt zellinstruktive Materialien, die mit Zellen kommunizieren und deren Verhalten steuern können. Mithilfe responsiver Polymere werden Gerüststrukturen hergestellt, welche die natürliche Mikroumgebung der Zelle (extrazelluläre Matrix) simulieren, einschließlich ihrer biochemischen Zusammensetzung und biophysikalischen Parameter sowie ihrer Fähigkeit, Eigenschaften mit der Zeit zu verändern. Mittels dieser Materialien untersuchen wir, inwieweit eine Zelle die Parameter eines Materials (lokale Mechanismen, Topologie, Gebundenheit) auslesen und auf deren Veränderungen reagieren kann, wie es während der Entwicklung, des Alterns oder in pathologischen Zuständen der Fall ist. Diese Informationen führen zu neuen Konzepten in Hinsicht auf Tissue Engineering und Gewebemodelle.

MISSION

The Program Division *Dynamic Biomaterials* develops instructive materials able to communicate with cells and guide their fate. Using responsive polymeric materials, we engineer artificial scaffolds that recreate the natural cellular microenvironment (extracellular matrix), including its biochemical composition and biophysical parameters, as well as its ability to change properties over time. We apply these materials to study a cell's capacity to read out materials' parameters (local mechanics, topology, confinement…) and to respond to their cues, as it happens during development, aging or in pathological states. This information leads to new biomaterial concepts and designs for tissue models and tissue engineering.

CURRENT WORK

The Program Division *Dynamic Biomaterials* joined INM in September 2015. In the following, selected research topics that lead to relevant results, publications or cooperations within the few months will be described.

New chemistries for selective biofunctionalization of hydrogels under physiological conditions

We have developed methylsulfonyl-based co-monomers for quantitative and selective coupling of thiol-derivatized biomolecules to common hydrogels used for cell culture or in biomedical applications (i.e. poly(acrylamide) or poly(2-hydroxyethyl methacrylate) gels). The comonomers do not interfere with radical polymerization reactions and can be easily incorporated into the main chain without altering the polymerisation yields and molecular weights. The biofunctionalization reaction is selective, quantitative and occurs under physiological conditions. Methylsulfonyl-functionalized gels remain biocompatible and allow selective control of cell behavior over precise ligand binding chemistry.

Engineering Laminin-containing scaffolds for neuronal differentiation

Laminin is a structural protein of the extracellular matrix with relevant functions in neuronal development. We have developed a phototriggerable laminin peptidomimetic that can be incorporated into synthetic scaffolds to support growth and differentiation of neuronal stem cells. These biomaterials allow light-directed, spatiotemporal control of axon growth and controlled design of neuronal networks on a surface or a 3D matrix. The potential of this approach to direct the formation of the layered structure of cortex during brain development will be explored in the next year in *in vitro* tests.

Bioinspired strategy to control the polymerization kinetics of catechol-based hydrogels and adhesives

Catechol-derivatized polymers allow crosslinking and adhesion to tissue at physiological conditions. However, catechol polymerization is quick and difficult to control. We have demonstrated the possibility of tuning the polymerization kinetics of catechol-prepolymers by developing catechol monomers with different substituents in the aromatic ring. By mixing precursors with different substituents, the polymerization kinetics and the final crosslinking degree were tuned on demand. These are interesting properties for the application of catecholamine-PEG gels as tissue glues or biomaterials for cell encapsulation.

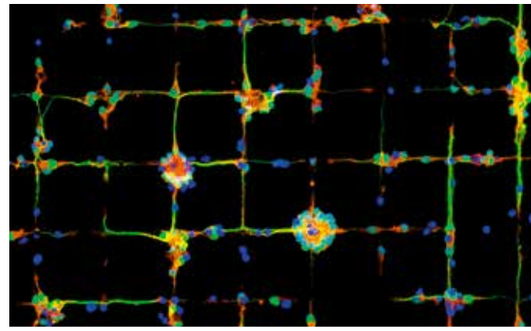
OUTLOOK

The Program Division *Dynamic Biomaterials* will continue its activities in the field of responsive materials, cell-ECM communication and bioadhesive coatings for medical and cosmetic applications. In 2016, special effort will be paid to identify and build up synergies with other groups at INM and to initiate cooperative projects. In particular, nanomechanics aspects of the ECM and artificial interpenetrating networks and their role in cellular mechanotransduction will be addressed in cooperation with the Progam Division *Nanotribology*. New biochemistry-based strategies to incorporate phototriggering units into structural proteins (collagen) to control their self-assembly and materials properties will be initiated in cooperation with the Program Division *Biomineralization.*

In parallel, cooperation with neighboring groups at UdS, UKS and Research Institutes in the Campus will be started. Cooperation projects with the surgery (Prof. Tim Pohlemann, UKS) in the field of scaffolds for regenerative medicine, with Biophysics group of Prof. Markus Hoth (UKS) in the field of materials models to investigate the inmunological synapse and the migration of T cells and with Jun.-Prof. Franziska Lautenschläger (UdS) in the field of tuning cell mechanics with dynamic biomaterial scaffolds have already started.

PROF. DR. ARÁNZAZU DEL CAMPO

joined INM as Scientific Director and Group Leader in September 2015. She is a Polymer Chemist and leads a research group in the field of Biointerfaces since 2005. Her previous appointment was as a Minerva Fellow at the Max Planck Institute for Polymer Research in Mainz (2009-15).



Neuronal Network on patterned substrates with Laminin peptidomimetics.

NANO ZELL INTERAKTIONEN / NANO CELL INTERACTIONS

DR. ANNETTE KRAEGELOH

ZUSAMMENFASSUNG

Im Programmbereich *Nano Zell Interaktionen* geht es um die Auswirkungen technisch hergestellter Nanoobjekte auf menschliche Zellen. Die Motivation hierzu ist, zu einer sicheren Anwendung von Nanomaterialien in technischen und biomedizinischen Bereichen beizutragen. Ziel ist es zu verstehen, wie bestimmte Partikeleigenschaften Struktur und Biochemie der Zellen beeinflussen, und aufzuklären, welche Mechanismen die Aufnahme und Lokalisation von Nanoobjekten vermitteln. Als Untersuchungsobjekt werden Nanopartikel aus anorganischen Materialien gezielt hergestellt und charakterisiert. Zur Lokalisation von Partikeln und Zellstrukturen werden vor allem licht-mikroskopische Techniken eingesetzt. Eine Besonderheit der Gruppe ist der Einsatz der hoch-auflösenden Stimulated Emission Depletion (STED)-Mikroskopie für diesen Zweck. Zur Analyse der Zellantwort werden darüber hinaus chemische, biochemische und molekularbiologische Techniken verwendet.

MISSION

The Program Division *Nano Cell Interactions* explores the effects of engineered nanoobjects on human cells. The motivation is to enable safe applications of nanomaterials in technical and biomedical fields by understanding how particle properties influence structure and biochemistry of the cells, and to elucidate mechanisms that affect uptake or location of nanoobjects with the purpose to pave the way for the design of safer nanomaterials. For this reason, well-defined inorganic nanoparticles (NPs) are prepared and characterized using techniques such as super-resolution Stimulated Emission Depletion (STED) microscopy which permits to localize particles and cellular structures. Further chemical, biochemical, and molecular biological techniques are employed for the analysis of the cellular responses.

CURRENT RESEARCH

Morpheus – a test platform for the safety of nanomaterials

The ZIM (Central Innovation program for SMEs) project “Morpheus” aims at developing a multiparametric test platform to be used for an early hazard assessment of nanoparticles. This test platform, based on 3D liver microtissue, combines for the first time conventional indicators of tissue damage with an analysis of morphological markers. The testing comprises quantification of metabolic as well as functional markers. Morphological markers and nanoparticle penetration into the tissue will be analyzed via light microscopy. Eventually, the project will focus on examining the influence of nanoparticles on the pharmacology of medical drugs. The ZIM project is run within the network Nanopharm and is carried out by Pharmacelsus GmbH and INM over a period of three years.

Nanoparticle effects on lung cells under mechanical strain

In the field of nanosafety, the lung plays an important role as primary organ for the entrance of nanoparticles. Lung epithelial cells are continuously subjected to mechanical strain during breathing. In lung cells, nanoparticles were shown to be associated with lamellar bodies, the structures involved in exocytosis of lung surfactant. Therefore, nanoparticles might interfere with the formation and secretion of lung surfactant. The aim of a running doctoral project is to clarify if mechanical strain modulates the uptake and effects of nanoparticles on lung epithelial cells *in vitro*. Until now, no significant influence of nanoparticles and strain on expression of surfactant protein C were measured. Regarding the influence of strain and nanoparticles on surfactant secretion, an analytical method for DPPC (Dipalmitoylphosphatidylcholine) quantification using HILIC-ESI-MS (hydrophilic liquid chromatography and electrospray mass spectrometry) was developed for this project by the service group *Chemical Analytics*.

Incorporation of proteins into silicon dioxide nanoparticles

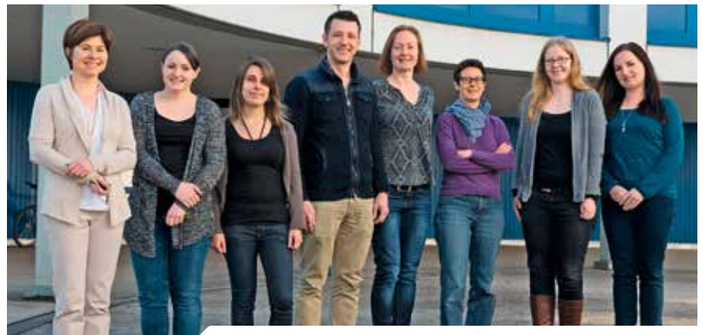
In the field of drug delivery and nanobiocatalysis, the incorporation of functional proteins and enzymes into nanoparticles is of main importance in order to enhance protein stability and therefore applicability of therapeutic protein delivery approaches. An *in situ* approach was developed enabling incorporation of functional proteins (GFP) and enzymes (ß-galactosidase) during the formation of small and well-dispersed silica nanoparticles. Leaching experiments showed that GFP was stably coupled to the particle matrix. The synthesis of core-shell nanoparticles indicated functionality of the protein even if incorporated into the inner particle core. Previous experiments using GFP labeled silica nanoparticles indicated an increased temperature resistance of incorporated GFP.

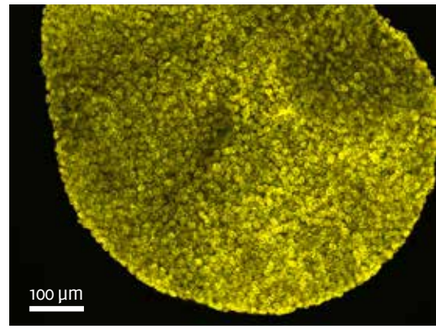
OUTLOOK

Within the Horizon 2020 project NanoRegII, the group will be involved in safe-by-design approaches related to regulatory aspects of nanosafety. One main task is to derive the safety and functionality information needed to implement a novel approach of nanomaterial development. Within a Leibniz-doctoral project in cooperation with IUF-Leibniz Research Institute for Environmental Medicine, Dusseldorf, future studies will aim to decipher particle location in relation to components involved in early signaling events initiated or influenced by nanoparticles. Within the Leibniz-Research Alliance Nanosafety coordinated by INM, the group will be involved in studies related to nanomaterials toxicity, reception of nanosafety and nanotechnology as well as safe-by-design approaches for nanomaterial development.

Dr. Annette Kraegeloh

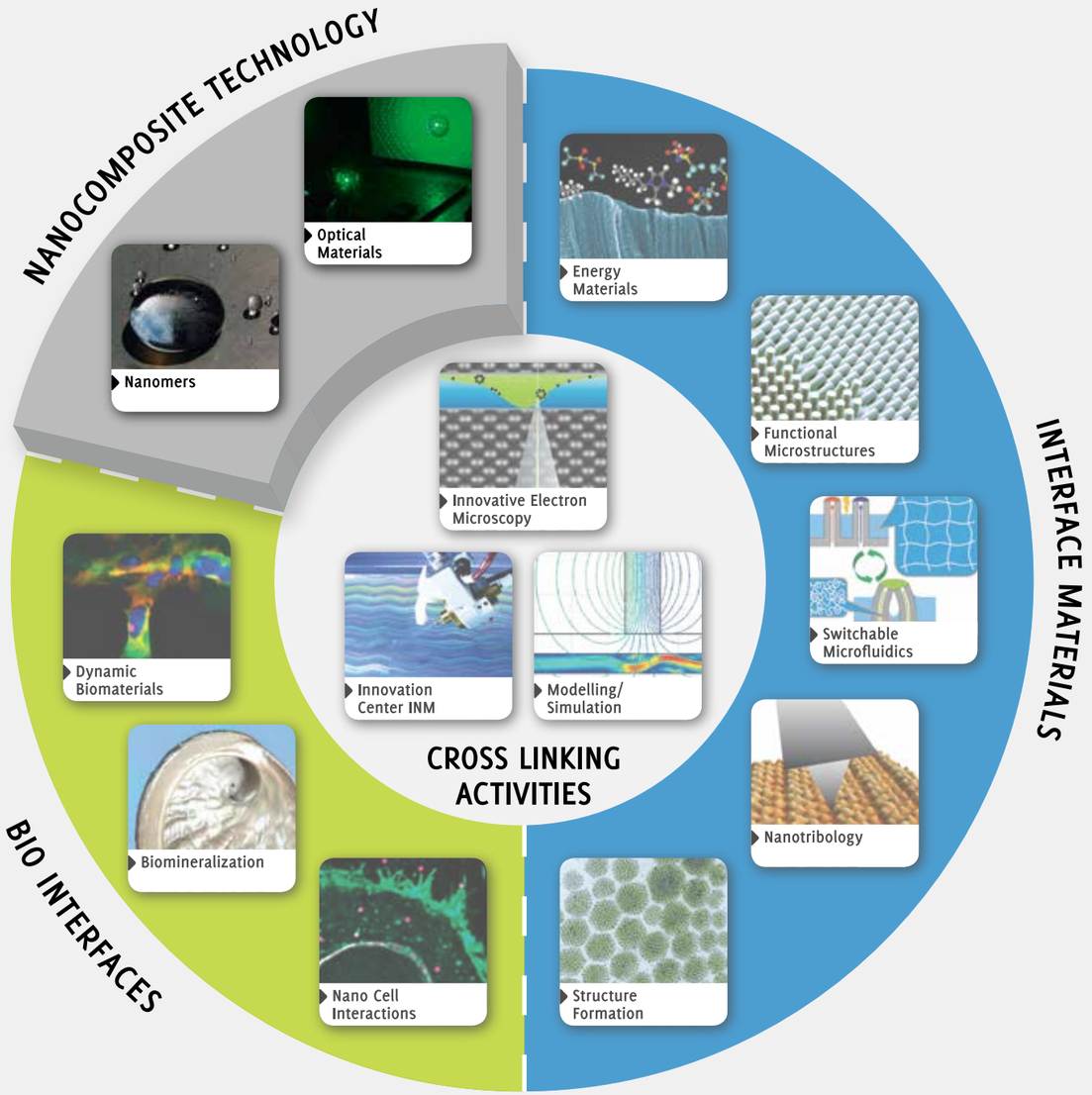
received her doctorate in biology at the University of Bonn. After joining the Life Science group at INM in 2004, she became the head of the Program Division *Nano Cell Interactions* in 2008. In 2015, she opened a habilitation procedure at Saarland University.





3D liver microtissue. The nuclei of singe cells are shown in yellow.

NANOKOMPOSIT-TECHNOLOGIE / NANOCOMPOSITE TECHNOLOGY



DAS FORSCHUNGSFELD *NANOKOMPOSIT-TECHNOLOGIE*

Das Forschungsfeld *Nanokomposit-Technologie* widmet sich nichtmetallisch-anorganischen Hybridmaterialien, vorwiegend in Form von Beschichtungen, und ihren funktionellen Eigenschaften. Schwerpunkte sind nasschemische Synthesemethoden und die Nutzung von funktionalisierten Nanopartikeln. Der Fokus der Arbeiten liegt in der Verwendung der Konzepte für industrielle Anwendungen. Die Materialien werden für den Einsatz beispielsweise in den Bereichen Elektronik, Medizintechnik, Optik, Automobil, Displays, erneuerbare Energien sowie Maschinenbau und Elektrotechnik entwickelt und optimiert.

Dieses Forschungsfeld trägt schwerpunktmäßig zu den INM-Leitthemen A (Energieanwendungen), C (Tribologische Systeme) und D (Nanosicherheit/Nano-Bio) bei. Es vertritt zudem das INM im Forschungscampus caMPlusQ, einer Gemeinschaftsinitiative der Ingenieurwissenschaften der Universität des Saarlandes und ihrer benachbarten außeruniversitären Forschungsinstitute (Programmbereich *Nanomere*).

Das Forschungsfeld *Nanokomposit-Technologie* besteht zum 31.12.2015 aus zwei Programmbereichen:

- Programmbereich *Nanomere*, Leitung: Dr. Carsten Becker-Willinger
- Programmbereich *Optische Materialien*, Leitung: Dr. Peter W. de Oliveira

THE RESEARCH FIELD *NANOCOMPOSITE TECHNOLOGY*

The research field *Nanocomposite Technology* addresses non-metallic-inorganic hybrid materials and their functional, especially optical, tribological, and protective properties. Key aspects are wet chemical synthesis methods and the use of functionalized nanoparticles. A strong focus is put on the utilization of concepts for applications in industry. The materials are developed and optimized for applications, for example, in electronics, medicine, optics, automotive, display technology, renewable energies as well as construction and electrical engineering.

This research field contributes significantly to INM's lead topics A (Energy applications), C (Tribology) and D (Nanosafety/Nano-Bio). Furthermore, it represents INM within the Forschungscampus caMPlusQ, a joint initiative of the engineering sciences at Saarland Universities and its neighboring non-university research institutes (Program Division *Nanomers*).

The research field *Nanocomposite Technology* consists of two Program Divisions (as of December 31, 2015):

- Program Division *Nanomers*, Head: Dr. Carsten Becker-Willinger
- Program Division *Optical Materials*, Head: Dr. Peter W. de Oliveira

Mehr Informationen über das Forschungsfeld *Nanokomposit-Technologie* finden Sie hier.

More informations about the research field *Nanocomposite Technology*.

NANOMERE / NANOMERS

DR.-ING. CARSTEN BECKER-WILLINGER

ZUSAMMENFASSUNG

Im Programmbereich *Nanomere* wird an polymermatrixbasierten Kompositen mit nano- und mikroskaligen Funktionselementen geforscht. Organische Polymere werden ebenso als Bindemittel eingesetzt wie hybride organisch-anorganische Matrizes. Ziel ist die Nutzbarmachung neuer Werkstoffeigenschaften für industrielle Anwendungen. Neue Beschichtungszusammensetzungen werden über nasschemische Prozesse bereitgestellt und sind mit industrieüblichen Techniken verarbeitbar. Besonders interessant sind keramische und metallische Füllstoffe, die in Kombination mit maßgeschneiderten Partikel/Matrix-Grenzflächen den Transfer physikalischer Eigenschaften anorganischer Materialien in Polymere und Beschichtungen erlauben. Neben Beschichtungen werden auch thermoplastische Kompaktwerkstoffe erzeugt, wobei schwermetallfreier Korrosionsschutz, Reibungskontrolle, antimikrobielle Wirkung und transparente, abriebfeste Gasdiffusionsbarrieren im Fokus stehen.

MISSION

The activities of the Program Division *Nanomers* comprise the development of functional coatings and bulks based on polymer-matrix composites. A strong focus is set on application-oriented projects for materials used in industry. Areas of interest are corrosion protection, control of friction, anti-microbial functionality or wear resistance combined with transparency and barrier properties. Fields of application can be found in electronics, medical devices and optics as well as in automotive, mechanical and electrical engineering.

CURRENT RESEARCH

The focus of the activities was set on corrosion protection coatings for mild steel, copper and aluminum. Within the FP7 EU-project WELDAPRIME ("Self-repairable Zinc-free Weldable Anti-corrosion Primer for the Steel Protection"), we have developed hybrid nanocomposite coatings derived from sol-gel processing, which form stable bonds to the metal surface. Incorporating nanoparticles, these hybrid coatings are more stable than the created rust because the nanoparticles act as active corrosion inhibitors equivalent to zinc. Fields of application as intermediate storage and transportation protection can be found in the automotive, construction, oil, gas or shipyard industries. At the milestone in July 2015, the project was positively assessed by the EC and can therefore be followed up in 2016.

Diffusion barrier layers based on highly structured composite materials that show excellent adhesion and abrasion resistance were used as a materials base in an industrial project concerning the protection of copper against sulfur-compound-induced corrosion phenomena. The project was successfully conducted in close co-operation with the *InnovationCenter INM*. It was finished by the end of 2015 and the material will be implemented in the production line of the customer in 2016. Demonstrators showing the obtained material performance as well as oral presentations to the topic of highly structured corrosion-protection coatings were presented at Hanover fair, TechConnect World conference (Washington) and EUROCORR 2015. Investigations on newly developed platelet-shaped metal-phosphate particulate additives were extended to prove their active corrosion-protection mechanisms in coatings, in particular on steel. The corrosion-protection behavior was investigated with standardized weathering tests, local corrosion measurements using Scanning Vibration Electrode (SVET), and integral protection capability measurements, which were carried out with Electrochemical Impedance Spectroscopy (EIS).

Another research topic dealt with abrasion-resistant low-friction coatings combining tribological coatings for dry lubrication with corrosion protection. The results of the focus project Flakelub were presented at the TechConnect World exhibition and conference and got strong resonance. Applications of these coatings are actually followed up as possibly useful for industry in mechanical engineering.

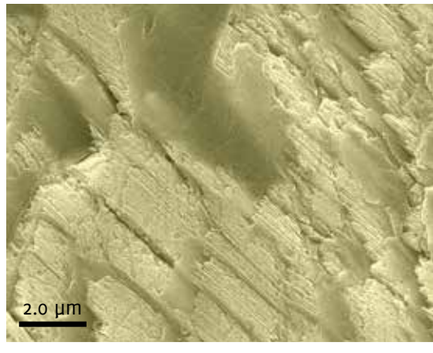
Further work on particulate additives was performed in the synthesis of high-refractive-index barium-titanate nanoparticles and functionalized copper colloids. Based on the copper-colloid technology platforms of INM, the BMBF project BioPolyMed ("Biodegradierbare polymerbasierte Einwegsysteme in der Intensivmedizin") started at the end of 2015. The project primarily aims to develop medical equipment with antimicrobial activity. To ensure its biodegradability upon disposal as waste in a reasonable timescale is one of the major challenges to be solved during the project. Further industrial applications are explored for this technology platform, following up on the knowledge created during the FP7 EU-project CuVito.

OUTLOOK

Future work in the Program Division will be concerned with hygienic, antimicrobial coatings for everyday life beyond medical applications. Two INM-patent applications filed in 2013 dealing with appropriate metal-colloid particles will be used to acquire more industrial projects, especially with SMEs. We will investigate the active corrosion-protection behavior and the influence of the degree of filling and processing parameters on the particle orientation of platelet-type fillers, in particular the anisotropic metal-phosphate particles in composites, to achieve high-barrier properties and high mechanical strength.

Dr.-Ing. Carsten Becker-Willinger

studied chemistry at the Albert-Ludwigs-Universität in Freiburg majoring in macromolecular chemistry. From 1993 to 1998, he worked at INM on his doctoral thesis on thermoplastic nanocomposites. In 2001, he became head of the Program Division *Nanomers*.



Cross section of a polymer-matrix composite containing zinc-phosphate flakes.

OPTISCHE MATERIALIEN / OPTICAL MATERIALS

DR. PETER W. DE OLIVEIRA

ZUSAMMENFASSUNG

Der Programmbereich *Optische Materialien* erforscht Beschichtungswerkstoffe mit besonderen Eigenschaften, deren Funktion auf der Wechselwirkung mit elektromagnetischer Strahlung beruht. Die Entwicklung von neuen optischen Beschichtungen umfasst Materialsynthese sowie Applikations- und Strukturierungstechniken. In nationalen und internationalen Kooperationen wurden im Jahr 2015 die folgenden Themen bearbeitet: Verbesserte Fotoabscheidung von Silber- und Kupferschichten, biokompatible und photochrome Komposite, Entwicklung neuartiger Drucktinten auf der Basis innovativer transparent leitfähiger Materialien, Entwicklung von funktionell dekorativen Beschichtungssystemen für die Oberflächenveredelung von Haushaltsgeräten, glasartige Beschichtungen mit optimierter Biokompatibilität für kardiovaskuläre Implantate sowie die Herstellung von Leuchtpartikeln mit Zusammensetzungen der Mischkristallreihe $(Y,Gd)_2O_3$:Eu (in Kooperation mit dem Programmbereich *Strukturbildung*).

DR. PETER W. DE OLIVEIRA

has been head of the Program Division *Optical Materials* since 2005. He studied physics in Brazil and came to the INM after obtaining his diploma and master's degree. He also heads the I*nnovationCenter INM.*

MISSION

The Program Division *Optical Materials* focuses on the development of composite materials for the functionalization of glass, ceramic and polymeric substrates to interact with electromagnetic radiation. Our expertise in wet chemical syntheses of organic-inorganic matrices combined with experience in the production of nanoparticles with specific chemical modifications allows the development of new optical materials for coating applications. Also, we fine-tune the chemical and physical properties of the new materials to fulfil the requirements of specific products and processes.

CURRENT RESEARCH

A number of projects on fundamental aspects of nanomaterials opened new possibilities for the development of materials for printed electronics, lighting, and energy. Building on these advanced industrial projects in the area of touch screens, glass and ceramic composites have created alternative products and/or production processes for the optical industry.

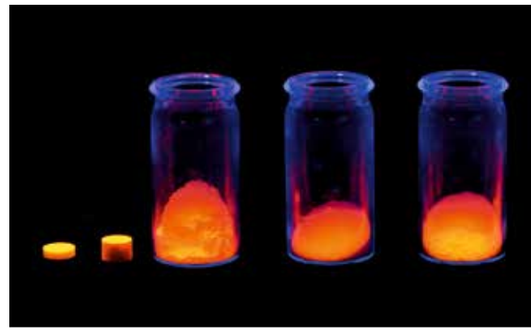
As photometallization is expected to be an alternative to expensive ITO in touch panel technology, an INM focus project was started in 2015. TiO_2 is used as the photocatalyst for the deposition of silver. For an economic process, photocatalytic activity in the visible range is important. Thus, doping of the TiO_2 photocatalyst was conducted to achieve a decrease of the band gap. Thus photocatalytic silver deposition at wavelengths up to 405 nm and a higher efficiency with UV were achieved.

The development of a flexible new material with improved optical properties for the manufacture of intraocular lenses was the subject of a 2015 successfully finished project under the ZIM scheme of the German Federal Ministry for Economic Affairs and Energy. Artificial intraocular lenses are implanted into cataract patients, where a surgical removal of the turbid lens is the only feasible way to prevent blindness. The new material can adjust to the surrounding brightness, thus reducing discomforting glare effects to the bearers.

Successfully finished in 2015 was the project "HOP-X" funded by the German Federal Ministry of Education and Research. The co-operation project focused on organic detectors for X-rays with a more favorable production route and better resolution than current detectors. The new organic detector materials are substances which absorb X-rays and convert them into visible light. The sensors can be fabricated by printing or spray coating them onto a substrate more cost-effective than the state of the art detectors. We developed and delivered nanoparticle samples of scintillator materials and also worked on the formulation of polymer composites of these scintillators (co-operation with the Program Division Structure Formation).

The new European Horizon2020 project "Infinity" was started with the target of developing a new materials base for printing transparent conductive structures. Our main goal is the replacement of Indium due to its critical raw material status. We develop alternative materials using widely available metallic elements compatible with sol-gel and printing technologies and low temperature processes to be printed on flexible substrates. New formulations will enable printing of mixed metal oxide coatings employing low-cost materials. New treatment processes to convert coated materials to high performance conductive structures at low temperature. The INM develops the materials and inks and defines the printing process.

A lasting strategic development partnership with a large industrial partner from Asia continues to result in a row of projects focusing on functional decorative coatings for the finishing of surfaces e.g. for consumer goods like large appliances and electronics. In 2015, several projects were successfully executed. The targets of the single projects were the development of coating systems with improved wear protection of the surfaces, special decorative effects or improved hardness, always together with secondary functions such as reduced fingerprint visibility or easy cleanability.

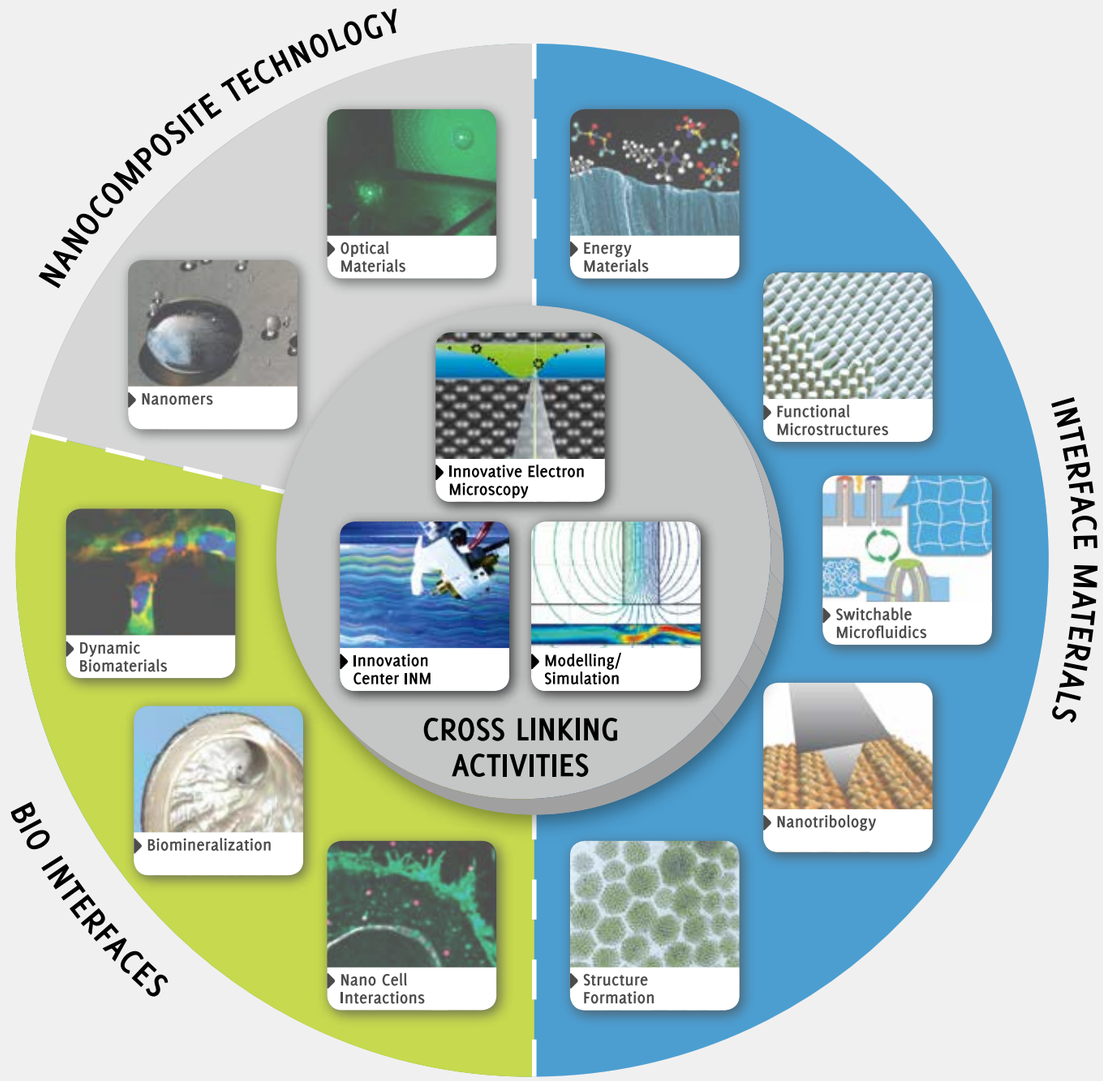


Luminescent samples of scintillator nanoparticles.

OUTLOOK

The combination of optical effects, material development and processing has been a core strategy of the Program Division *Optical Materials*. It has contributed to the sustainability of the technological platform and the balance between basic and applied research. Our long-term goal is to understand how material development can be used to access new optical effects as a basis for new products and to transfer these technologies to the market.

QUERSCHNITTSFELD / CROSS LINKING ACTIVITIES



DAS *QUERSCHNITTSFELD*

Im *Querschnittsfeld* sind übergreifende Forschungs- und Entwicklungsthemen zusammengefasst, die neben eigener Forschung die Arbeit der anderen Programmbereiche unterstützen. So wendet der Programmbereich I*nnovative Elektronenmikroskopie* die elektronenmikroskopische Methodik auf neue matrialwissenschaftliche und biologische Fragestellungen an. Die Arbeiten des Programmbereichs *Modellierung/Simulation* zielen auf Forschungsarbeiten, die methodische Beiträge zu anderen Forschungsfeldern leisten. Das *InnovationsZentrum INM* verbindet die Wissenschafts- und Technologiebasis des INM mit Industrieunternehmen. Es koordiniert Kooperationsprojekte mit der Industrie und setzt diese um. Zusätzlich bietet es Beratung und analytische Serviceleistungen an.

Das *Querschnittsfeld* besteht zum 31.12.2015 aus drei Programmbereichen:

- Programmbereich *Innovative Elektronenmikroskopie*, Leitung: Prof. Dr. Niels de Jonge
- Programmbereich *Modellierung/Simulation*, Leitung: N.N.
- Programmbereich *InnovationsZentrum INM*, Leitung: Dr. Peter W. de Oliveira, Stv. Leitung: Dr. Tobias Kraus

SERVICEBEREICHE

Die Forschungsfelder des INM werden in ihrer Arbeit von vier Servicebereichen unterstützt. Der Servicebereich *Chemische Analytik* bietet ein breites Spektrum analytischer Dienstleistungen. Der Servicebereich *Physikalische Analytik* betreibt v.a. elektronenoptische und röntgenanalytische Verfahren. Der Servicebereich *Engineering* entwickelt und stellt Anlagen und Komponenten, von kleinen Laborgeräten bis zu großen Pilotanlagen, für die Programmbereiche her. Die *Bibliothek* erbringt Serviceleistungen im Bereich Information, Dokumentation, Recherche und Dokumentlieferung.

CROSS LINKING ACTIVITIES

This area combines comprehensive research and development activities, which are supposed to methodically complement the competencies of the research fields. Among these activities, independent scientific research is of particular importance. For example the Program Division *Innovative Electron Microscopy* works on the application of electron microscopic techniques to material-related and biological problems. The work of the Program Division *Modelling/Simulation* aims at research providing a methodic contribution to other Program Divisions. The *InnovationCenter INM* links the scientific and technological basis of INM with industry. It coordinates cooperation projects with industry and implements them. Additionally, it offers consulting and analytical services.

The *Cross Linking Activities* area consists of three Program Divisions (as of December 31, 2015):

- Program Division *Innovative Electron Microscopy*, Head: Prof. Dr. Niels de Jonge
- Program Division *Modelling/Simulation*, Head: N.N.
- Program Division *InnovationCenter INM*, Head: Dr. Peter W. de Oliveira, Deputy head: Dr. Tobias Kraus

SERVICE GROUPS

Four Service Groups support the research fields of INM in their work. The Service Group *Chemical Analytics* provides analytical tools and knowledge ranging from standard characterization procedures to the development of complex new analysis routes. The Service Group *Physical Analytics* covers electron optical and x-ray analytical investigations. The Service Group *Engineering* deals with the development and construction of devices and components, from small laboratory scale equipment up to pilot plant scale devices, for the Program Divisions. The *Library* of the INM provides services in the area of information and documentation.

Mehr Informationen über das *Querschnittsfeld* finden Sie hier.

More informations about the *cross linking activities* area.

INNOVATIVE ELEKTRONENMIKROSKOPIE / INNOVATIVE ELECTRON MICROSCOPY

PROF. DR. NIELS DE JONGE

ZUSAMMENFASSUNG

Eine nanometergenaue Materialcharakterisierung ist unabdingbar für die Weiterentwicklung der modernen Nanotechnologie, der Energiewissenschaft und der Biologie. Der Programmbereich *Innovative Elektronenmikroskopie* (IEM) betreibt interdisziplinäre Forschung an der Schnittstelle von Biophysik, Zellbiologie, Bio-Nanotechnologie, Materialwissenschaft, Physik der Elektronenmikroskopie und Bildverarbeitung. Zur dreidimensionalen Atomstrukturanalyse und zur chemischen Materialanalyse sowie für die Untersuchung von biologischen Systemen und funktionellen Materialien in Flüssigkeit stehen dem Programmbereich ein hochmodernes Rastertransmissions-elektronenmikroskop (JEOL ARM200F) und weitere Mikroskope wie ein ESEM (FEI Quanta) und ein Fluoreszensmikroskop (Leica, DMI6000) zur Verfügung. Wir haben vielfältige Forschungskooperationen innerhalb des INM sowie mit verschiedenen Universitäten und der Industrie.

MISSION

Nanoscale characterization is essential for the growth of modern nanotechnology and biology. The Program Division *Innovative Electron Microscopy* (IEM) conducts interdisciplinary research at the interface of biophysics, cell biology, bio-nanotechnology, materials science, physics of electron microscopy, and image processing. The group pioneers the technology of *in situ* scanning transmission electron microscopy (STEM) of specimens in liquid. We also develop novel strategies for three-dimensional (3D) STEM. The group houses a state-of-the-art electron microscopy research facility involving aberration corrected STEM (ARM200, JEOL), environmental scanning electron microscopy (ESEM, Quanta, FEI), and fluorescence microscopy (DMI6000, Leica). Various research collaborations exist both with academia and industry. Students and users obtain high-quality training on modern electron microscopy in our group.

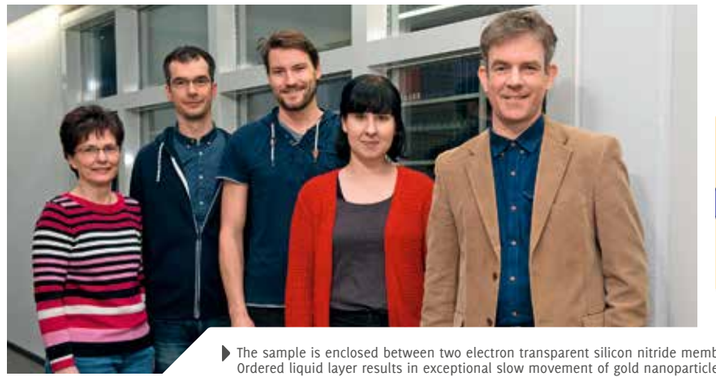
PROF. DR. NIELS DE JONGE

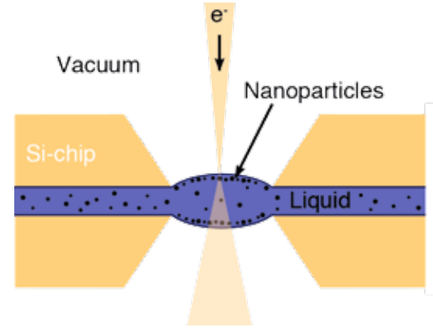
is a biophysicist working on electron microscopy (EM) of specimens in liquid, membrane proteins in cells, and three-dimensional EM. He has been head of *Innovative Electron Microscopy* since January 2012, and he is Honorary Professor of Experimental Physics at the Saarland University.

CURRENT RESEARCH

Growth factor receptors in cancer cells

Our research involves members of the epidermal growth factor receptor (EGFR) family. HER2, one of the EGFR family members, is overexpressed in certain types of breast cancer, thereby contributing significantly to dysregulated cell growth. We have studied the intra- and intercellular variation of HER2 at the single-molecule level in intact SKBR3 breast cancer cells. Of major interest is to analyze differences in protein function between individual cancer cells (cancer cell heterogeneity) and between distinct functional membrane regions within the same cell. With our approach it is possible to study the effect of cancer drugs on small sub-populations of cells, aiming to increase the effectiveness of HER2 targeting drugs.





The sample is enclosed between two electron transparent silicon nitride membranes separating the liquid from the vacuum. Ordered liquid layer results in exceptional slow movement of gold nanoparticles.

Stoichiometry of calcium channels

Liquid STEM is being used to study the stoichiometry of complexes formed by TRPV6 proteins in COS7 cells. TRPV6 proteins oligomerize into calcium-selective cation channels in the plasma membrane. TRPV6 proteins thus could be a prognostic marker for prostate- and breast cancer. However, X-ray crystallographic data is so far not available. We aim to determine the subunit stoichiometry via Liquid STEM. Such data is crucial for the understanding of ion channel function and their targeting by drugs. Several other types of calcium channels are being studied as well.

Studying the behavior of nanomaterials in liquid

TEM and STEM of liquid specimen offer unique options to study the nanometer-scale dynamic processes occurring in liquid. We have recently studied the electron beam induced electrochemistry of gold nanoparticles under varied liquid conditions, and we discovered that nanoparticles in close proximity of a surface do not move as predicted by Brownian motion but many orders of magnitude slower, possibly explained by the presence of an interface layer of ordered liquid with exceptionally high viscosity.

3D STEM

The primary method currently used for obtaining insight into the three-dimensional (3D) organization of cellular structures is tilt series transmission electron microscopy (TEM). However, its application is limited on account of the high tilt angles of up to 70°, and it is a challenge to image micrometer-thick samples containing whole cells for example. We have developed a novel 3D STEM technique for obtaining nanometer resolution on thick specimens. Aberration-corrected 3D STEM is capable of high-resolution 3D imaging without a tilt stage. We are currently improving the vertical resolution by combining focal- and tilt series STEM.

OUTLOOK

We expect several additional grants will be funded in the near future. One of our future aims is to study processes of protein complexes occurring in eukaryotic cells, to develop a new characterization method for membrane proteins in cancer cells and at the solid:liquid interface in materials science by combining liquid scanning transmission electron microscopy (STEM) with high resolution fluorescence microscopy. With this novel microscopy method we may possibly discover new phenomena that are not visible with existing microscopy methods. We expect growing activities in the biomedical field through the interaction with the Program Division *Dynamic Biomaterials*.

INNOVATIONSZENTRUM INM / INNOVATIONCENTER INM

DR. PETER W. DE OLIVEIRA, DR. TOBIAS KRAUS

ZUSAMMENFASSUNG

2014 wurde das *InnovationsZentrum INM* nach einer Neuorientierung und Neufirmierung als Verbindungsstelle zwischen dem INM und der Wirtschaft etabliert. Seine Hauptaufgabe ist der Transfer der wissenschaftlich-technischen Material- und Verfahrensbasis des INM in Handwerk und Industrie, sowohl national als auch international. Das *InnovationsZentrum INM* bietet nicht nur die Koordination und Umsetzung von Kooperationsvorhaben und Beratungsleistungen an, es offeriert zusätzlich auch Dienstleistungen für chemische und physikalische Analysen. Eine die reine Materialentwicklung begleitende Validierung und Optimierung der Produktionsprozesse ermöglicht eine kontinuierliche und effiziente Umsetzung neuer Ideen vor dem Hintergrund starken Wettbewerbs und zunehmend verkürzter Produktzyklen bei High-Tech-Produkten. Die Expertise in Wissenschaft und Ingenieurswesen sowie das breite Forschungsportfolio des INM eröffnen eine Fülle an Entwicklungsmöglichkeiten und Anknüpfungspunkten für industrielle Umsetzungen.

MISSION

The *InnovationCenter INM* (*InnovationsZentrum INM*) was established in 2014 to link INM's scientific and technological base with industry. INM's impact on industrial production depends on close links with industrial partners, and the *InnovationCenter INM* supports all Program Divisions of INM in the acquisition of industrial projects through professional science-to-business marketing. The center develops coherent innovation strategies and actively presents them at trade fairs and conferences. The *InnovationCenter INM* adapts the technology platforms of the INM to cater for the particular requirements of industry. The *InnovationCenter INM* has experienced staff, state-of-the-art facilities and equipment required for upscaling, process development, plant development, and quality assurance.

Dr. Peter W. de Oliveira

is the head of the *InnovationCenter INM*. He studied physics in Brazil and came to the INM after obtaining his diploma and master's degree. He has also headed the Program Division *Optical Materials* since 2005.

Dr. Tobias Kraus

has been head of the Program Division *Structure Formation* since 2014. Additionally, he is deputy head of the *InnovationCenter INM* and responsible for its analytical services.

The *InnovationCenter INM* links INM's scientific and technological base with industry.

CURRENT RESEARCH & DEVELOPMENT

Barrier coating for electronic parts

In 2014, a protective coating to prevent corrosion of conductor lines on electronic parts was developed and successfully scaled up. In the last step of the upscaling process, the deposition process of the coating was transferred to the industrial coating equipment of our industry partner. Fully functional electronic parts were coated during an application test with the coating systems. Those coated parts are now used for long time tests under their usual working conditions. The entire upscaling process was performed in cooperation with the Program Division *Nanomers*.

Multifunctional decorative coatings

Ceramic nanocomposite and multilayer coatings for decorative purposes and wear resistance were developed for an industrial partner. In the first step, we applied the colored coatings on flat metal substrates. Sputtering was done in our industrial scale vacuum chamber with two RF magnetrons to deposit ceramics, metals and combinations thereof. The second step consisted in the optimization of the homogeneity of the coatings and colors independent from viewing angle. Currently, we are working on homogeneous coatings on three-dimensional complex shaped parts and the improvement of the mechanical properties.

Polycarbonate (PC) with high hardness

A high surface hardness of PC is generally achieved by a hard coating applied to the surface of the respective parts. The INM investigated the increase of PC hardness by incorporating nanoparticles in the PC in order to achieve special functionalities or properties. Based on INM background results, a new concept was developed for injection molding of tough PC material. The used additives were ceramic nanoparticles. In order to achieve good compatibilities with the PC, the nano particulate additives were surface modified by organic agents. Further investigations will be done to achieve transparent instead of white opaque PC with the used particles.

Catalytic reactions

The goal of the validation and development project is the investigation of assumed properties of a group of mineral materials and, later on, an optimization of their properties. A literature review was done and numerous material samples from the project partner were analyzed. Reaction products from selected material samples and predefined compounds were analyzed with spectroscopic and chromatographic methods. Scientists from the project partner visited the INM to participate directly in the investigation and analysis and to learn about the methods.

Analytics

The *InnovationCenter INM* proactively offers analytical services to partners from industry and small and medium businesses. Our first goal is to make INM's comprehensive analytical capabilities available to companies and thus improve the quality and competitiveness of their products. We also use this opportunity to comprehend recent material challenges that companies face and suggest research and development in cooperation with the INM to meet current and future demands. Contacts in 2015 included chemical companies, paint producers, and the electronics industry.

OUTLOOK

Research at the INM during the last years has brought remarkable progress in emerging areas such as energy efficiency, printed electronics, medical surfaces, optical applications, and applications in the oil and consumer goods industries. The *InnovationCenter INM* will continue intensifying the collaboration between Program Divisions and industrial partners to successfully transfer INM's research results into innovations.

MODELLIERUNG/SIMULATION / MODELLING/SIMULATION

N.N.

ZUSAMMENFASSUNG

Die Aufgabe des Programmbereichs ist die Erstellung theoretischer Modelle und Simulationen für am INM untersuchte Materialien und Phänomene in Kooperationen mit anderen Programmbereichen und Juniorforschungsgruppen des INM. Im Jahr 2015 wurde eine Reihe theoretischer Fragestellungen durch Kooperationen mit Externen und in enger Verzahnung mit anderen Programmbereichen bearbeitet. In einer Arbeit in Kooperation zwischen Prof. Robert McMeeking (University of California), Prof. Norman Fleck (University of Cambridge) und dem Programmbereich *Funktionelle Mikrostrukturen* wurde unser Modell für die Mechanik der Ablösung von Mikrosäulen von einem Substrat erweitert. Bei Annahme einer Komposit-Struktur mit weichen Säulenenden wird ebenfalls eine Verbesserung der Spannungsverteilung und damit der Haftfestigkeit erreicht (Doktorarbeit R. Balijepalli). Die numerischen Ergebnisse sollen durch Modellexperimente validiert werden. Eine Zusammenarbeit mit dem INM Fellow Prof. Dr. Dr. Daniel Strauss (HTW Saarbrücken / Universität des Saarlandes) und dem Programmbereich *Nanotribologie* befasst sich mit der Identifizierung und Analyse hirnelektrischer Antwortpotentiale, die im Zuge tribologischer Experimente zwischen dem menschlichen Finger und unterschiedlichen Materialien gewonnen wurden.

MISSION

The Program Division is designed to develop theoretical models and simulations for materials and phenomena which are under experimental investigation at INM. Several theoretical issues were treated in close cooperation with other Program Divisions and external partners in 2015.

CURRENT RESEARCH

Numerical design of composite pillars with improved adhesion

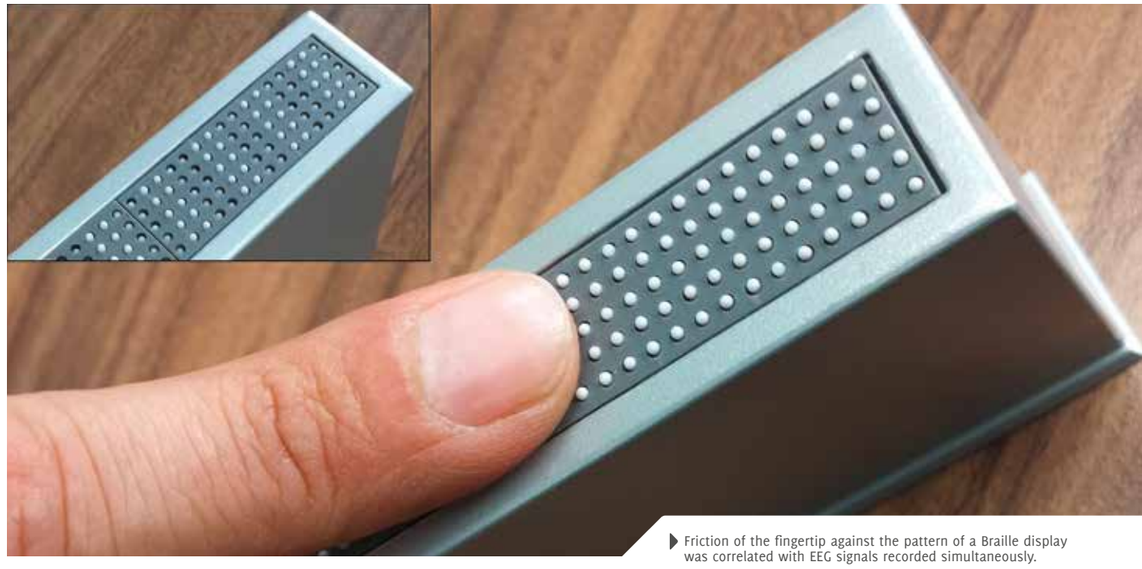
Bio-inspired fibrillar surfaces with reversible adhesion to stiff substrates were thoroughly investigated over the last decade. In this study, a novel composite fibril is proposed which consists of a soft tip layer and stiffer stalk with differently shaped interfaces (flat vs. curved) between them. A tensile stress is applied remotely on the free end of the fibril whose other end adheres to a rigid substrate. The stress distributions and the resulting adhesion of such structures are numerically investigated under plane strain (2D) and axisymmetric (3D) conditions. The stress intensities are evaluated for different combinations of layer thickness and Young's moduli. The adhesion strength values are found to increase for thinner layers and larger modulus ratios; these trends are also reflected in selected experimental results. The results of this investigation provide a new strategy for optimizing adhesion strength of fibrillar surfaces.

Haptic Human-Machine Interfaces

The tactile or haptic perception is an important sense in our interaction with the environment. However the scientific quantification of this sense has only recently become a developing field of investigation. Recent research on friction between surface materials and human skin mostly can be grouped into two topical areas: materials science and tribology studies and psychophysical investigations on tactile perception. At INM we studied neurophysiological events and evaluated whether their appearance can be correlated to tribological signals and ultimately to the surface structure. The work dealed with the extraction of neural correlates evoked by tactile stimulation of the human fingertip. We have implemented an experiment in which friction of the fingertip against the pin pattern of a Braille display was correlated with EEG signals recorded simultaneously. The programmable Braille display allowed for randomized experiments. This project was carried out in cooperation with the INM Fellow Prof. Dr. Dr. Daniel Strauss (HTW Saarbrücken / Saarland University) and the Program Division *Nanotribology*.

OUTLOOK

Modeling and simulation will remain an essential element of material optimization. We plan to continue and intensify the existing research projects. New research topics will be carried out, depending on the future staffing of the Program Division. An important goal is to establish an independent research profile which is at the same time compatible with the strategy of the experimental Program Divisions.



Friction of the fingertip against the pattern of a Braille display was correlated with EEG signals recorded simultaneously.

CHEMISCHE ANALYTIK / CHEMICAL ANALYTICS

DR. CLAUDIA FINK-STRAUBE

Die Servicegruppe *Chemische Analytik* verfügt über moderne Verfahren zur Trennung und Analyse von flüchtigen und löslichen organischen Stoffgemischen (GC-MS, LC-MS, GPC), zur Element-Analytik (ICP-MS, AAS, ICP-OES, CHNS) und zu Aufschlusstechniken für anorganische und organische Proben (Säure-/Schmelzaufschluss, Mikrowellenaufschluss, Hochdruckaufschluss). Unser Ziel ist es, analytische Dienstleistungen für alle Programmbereiche des INM, Forschungsteams der Universität und externe Auftraggeber anzubieten. In direkter Abstimmung mit den Auftraggebern werden die erforderlichen analytischen Messmethoden erarbeitet und an die konkreten Fragestellungen angepasst. Studierende und Schüler/innen können im Rahmen von Praktika einen Einblick in die Messmethodik der chemischen Analytik erhalten. 2016 passen wir unsere Techniken an die Analyse organischer Materialien und Biomoleküle an, um den Bedürfnissen des neuen Programmbereichs *Dynamische Biomaterialien* gerecht zu werden.

PHYSIKALISCHE ANALYTIK / PHYSICAL ANALYTICS

DR. MARCUS KOCH

Die Servicegruppe *Physikalische Analytik* verfügt über röntgendiffraktometrische und elektronenmikroskopische Untersuchungsverfahren, die für das INM, das universitäre Umfeld und externe Auftraggeber eingesetzt werden. Ziel ist es, einen möglichst vollständigen Überblick zu den nano- und mikrostrukturellen Eigenschaften der Materialien zu erhalten. Mit speziellen Aufbauten gelingt es zudem, Untersuchungen während Temperaturveränderungen *in situ* zu verfolgen bzw. wässrige Proben im eingefrorenen Zustand zu mikroskopieren. Darüber hinaus werden Wissenschaftler/innen in die Elektronenmikroskope eingewiesen und bei der Durchführung ihrer experimentellen Arbeiten betreut. Schüler/innen können im Rahmen von Praktika bzw. Führungen für Schulklassen einen Einblick in die Elektronenmikroskopie erhalten.

ENGINEERING / ENGINEERING

DIPL.-ING. DIETMAR SERWAS

Das Hauptaufgabengebiet des Servicebereiches *Engineering* besteht in der Entwicklung und Herstellung von wissenschaftlichen Anlagen und Komponenten für die Grundlagenforschung und Projekte der Programmbereiche des INM. Die Bandbreite der Arbeiten reicht hierbei von kleinen Laborgeräten bis hin zu Pilotanlagen. Aus den Vorgaben der Forschung werden Konzepte entwickelt und mit CATIA-V5-CAD in Konstruktionen umgesetzt, deren Fertigung in den INM-Werkstätten mit moderner Ausstattung wie CAM-System, 5-Achs-HSC-Präzisionsfräsmaschine oder Funkenerosionsanlage erfolgt. Weiterhin werden Servicearbeiten für die anderen Abteilungen des INM sowie im Rahmen einer Kooperation die Werkstattarbeiten für den Lehrstuhl „Technische Physik“ der Universität des Saarlandes durchgeführt.

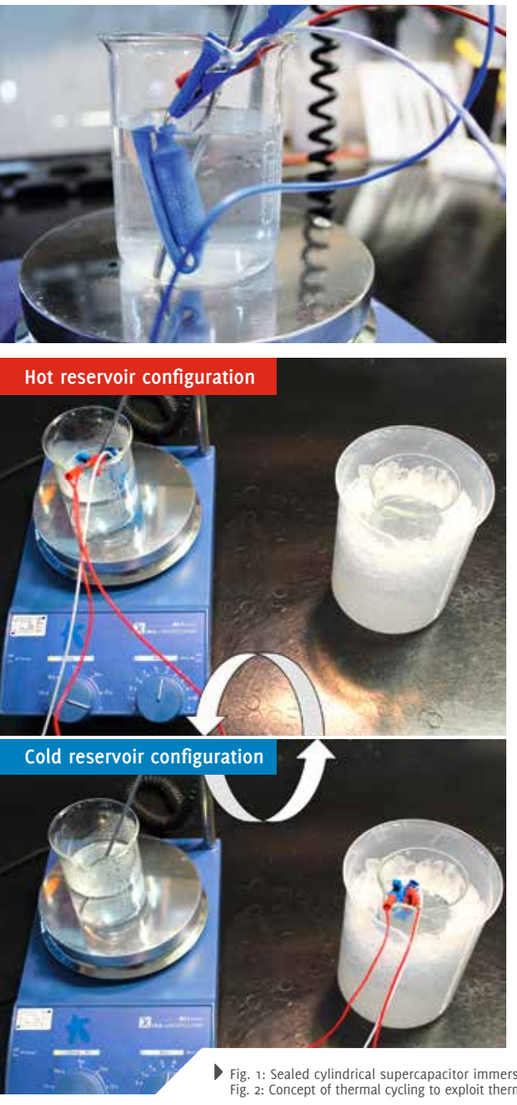
BIBLIOTHEK, INFORMATION & DOKUMENTATION / LIBRARY & INFORMATION SERVICES

DIPL.-BIBL. ELKE BUBEL

Die *Bibliothek* des INM erbringt Serviceleistungen im Bereich Information und Dokumentation. Hauptaufgaben der Bibliothek sind die Erwerbung, Erschließung und Präsentation von Print- und elektronischen Medien, die Dokumentation der INM-Publikationsdaten sowie deren Berichterstattung für Datenerhebungen, die Entwicklung von Serviceangeboten zur Umsetzung von Open-Access sowie die Administration und Redaktion aller INM-spezifischen Websites. Die *Bibliothek* ist aktiv eingebunden in den Arbeitskreis Bibliotheken und Informationseinrichtungen der Leibniz-Gemeinschaft. Die Bündelung von Ressourcen, die Schaffung von Synergieeffekten sowie Vernetzungsangebote für Bibliotheken von Leibniz-Einrichtungen sind zentrale Anliegen des Arbeitskreises.

THERMOCAPACITIVE ENERGY HARVESTING

V. PRESSER
ENERGY MATERIALS



In times of ever-increasing worldwide energy demand, innovative renewable energy sources must be explored. One highly attractive candidate is exploiting thermal energy, as it is readily available for instance in the form of waste heat. Especially low-grade waste heat is abundantly generated in industrial processes, e.g. during the operation of electronic devices or every air conditioning system. Tapping into this vast energy reservoir is highly attractive, but complicated by the low efficiency and high material costs of the state-of-the-art thermoelectric devices.

A novel approach to harvest low-grade heat and to convert it directly into electric energy is based on the use of thermocapacitive devices. They can be fabricated from cheap and sustainable materials and are highly tunable to their specific field of application. Especially at small temperature differences, they reach efficiencies close to the most efficient Carnot efficiency and can compete with thermoelectric engines. The concept of thermocapacitive energy harvesting relates to the temperature-dependency of the electrical double-layer structure. Subjecting an electrically charged carbon electrode soaked in an electrolyte to higher temperatures causes an increase in the thermal motion of electrosorbed ions. This is compensated by an increase in cell voltage, while the applied charge remains unchanged. When the system is now discharged from that enhanced voltage, additional energy is harvested in addition to the invested electric charge.

In collaboration with colleagues at Utrecht University and Johannes Gutenberg University Mainz, we have shown for the first time that the thermal voltage rise can be used directly for thermocapacitive energy harvesting. This was exemplified by employing a readily available, conventional (commercial) supercapacitor module (10 Farad). On a device level, a temperature gradient of 65 °C translates to an energy harvesting capacity of 185 mJ/g.

A Härtel, M. Janssen, D. Weingarth, V. Presser, R. van Roij
Energ Environ Sci. 8 (2015) 8, 2396-2401

Fig. 1: Sealed cylindrical supercapacitor immersed in hot water.
Fig. 2: Concept of thermal cycling to exploit thermocapacitive energy harvesting.

HIGH-TEMPERATURE DEFORMATION OF BCC METAL MICROSTRUCTURES

O. TORRENTS ABAD, E. ARZT
FUNCTIONAL MICROSTRUCTURES

Understanding mechanisms responsible for the deformation of miniaturized devices and materials has become essential to tune the mechanical properties of advanced materials. In particular, the strength of metals has been shown to increase with decreasing sample size into the nanometer scale. Metals with a body-centered cubic (BCC) crystal structure exhibit a still poorly understood size effect known to depend on temperature. For this purpose, the *Functional Microstructures* group together with researchers from the EMPA – Swiss Federal Laboratories for Materials Science and Technology, Thun (J. M. Wheeler and J. Michler) have systematically studied the size effect in tungsten (W) and tantalum (Ta) micropillars at temperatures up to 400 °C. By using a state-of-the-art mechanical tester, the microstructures were compressed inside a scanning electron microscope so that their strength and deformation behavior could be observed *in situ* (Fig. 1).

Our work shows that the size effect of these materials is magnified with increasing temperature, attaining values that are in the range of faced-centered cubic (FCC) metals. This finding is important as it suggests that the mechanisms that control the deformation of W and Ta at high temperatures are similar to those of FCC metals. We could demonstrate for the first time that the deformation of W undergoes a transition from uniform to localized deformation with increasing temperature and pillar size (Fig. 2). This observation suggests that temperature strongly influences the relative motion of line defects, i. e. edge and screw dislocations.

Overall, our study provides new insights into the deformation mechanisms of metals at the submicron scale and helps to establish a basis for the design of miniaturized BCC metal structures for applications at elevated temperature.

O. Torrents Abad, J. M. Wheeler, J. Michler, A. S. Schneider, E. Arzt
Acta Mater. 103 (2016) 483-494

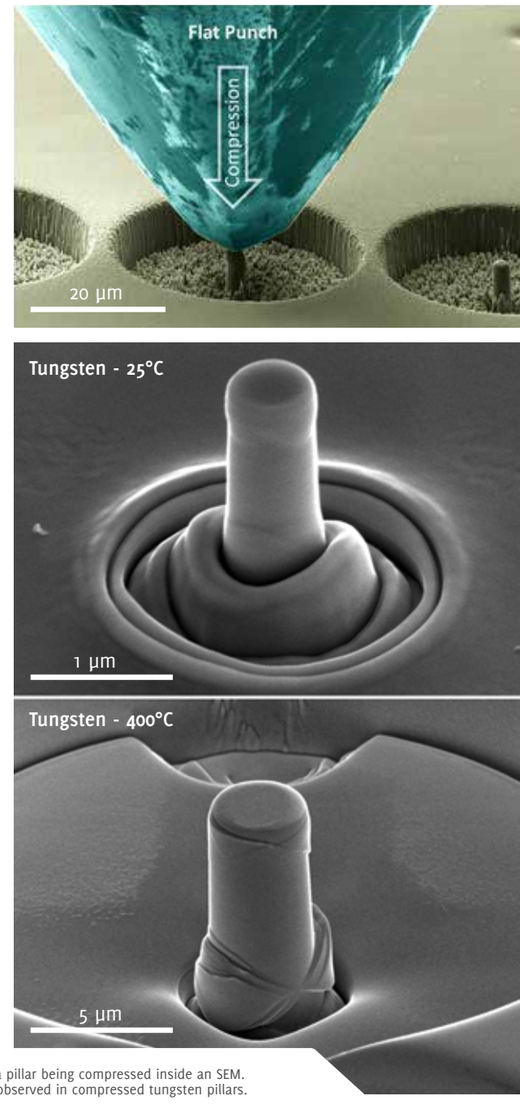
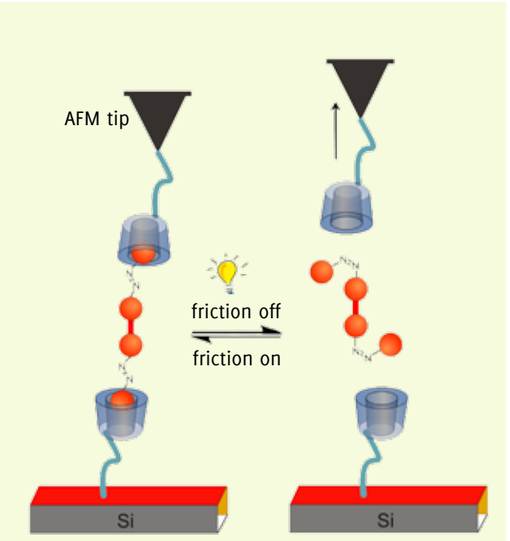
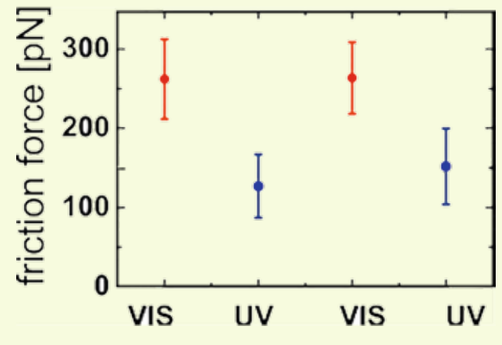


Fig. 1: Secondary electron micrograph of a pillar being compressed inside an SEM.
Fig. 2: Typical deformation morphologies observed in compressed tungsten pillars.

CONTROL OF FRICTION AND ADHESION BY MOLECULAR GUEST-HOST INTERACTIONS

J. BLASS, B. BOZNA, R. BENNEWITZ
NANOTRIBOLOGY





Macromolecular chemistry offers a number of guest-host systems, where a guest molecule forms a binding complex with a host moiety. The strength of this reversible interaction can be tuned in a wide range by variation of guests or hosts, but also by external stimuli. In collaboration with G. Wenz at Saarland University, we have adapted cyclodextrin hosts as a versatile toolkit for the control of friction and adhesion. Gold and silica surfaces are functionalized with the host molecules. Adhesion and friction between these surfaces are then controlled by connector molecules which carry guest molecules on both ends, thus binding to one host at each surface.

Atomic force microscopy experiments have proven the concept: Both adhesion and friction increase significantly when the adamantane-derived connector molecules are added to the aqueous solution. A particularly interesting observation is the collective strengthening of adhesion by multiple guest-host-guest connections. The clustering of reversible bonds leads to the effect of multivalency, in which one broken bond has a much higher probability of rebinding due to the ongoing attraction between the surfaces by the other bonds.

For the control of adhesion and friction by light stimuli, a connector molecule has been derived from azobenzene guest molecules in the group of our collaborator B. J. Ravoo at the University of Münster. The configuration of azobenzene can be reversibly switched by illumination with light of different wavelengths. While the straight configuration forms a complex with the host, the bent configuration does not fit into the cyclodextrin host cavity. We have been able to switch friction by a factor of two up and down by illumination with ultraviolet and visible light from LEDs.

J. Blass , B. L. Bozna, M. Albrecht, J. A. Krings, B. J. Ravoo, G. Wenz, R. Bennewitz
Chem. Comm. 51 (2015) 1830-1833

Fig. 1: Scheme of the molecular host-guest system with a cyclodextrin functionalized AFM tip and surface and switchable azobenzene guests.
Fig. 2: Light-responsive friction force in azobenzene guest solution.

COMPOSITE METAL PHOSPHATE – ORGANIC COATINGS FOR MILD STEEL CORROSION PROTECTION

E. PERRE, S. ALBAYRAK, C. BECKER-WILLINGER
NANOMERS

Corrosion concerns various industries from steel makers to car manufacturers and architects. Efficient corrosion protection coatings must not only provide a barrier to prevent water permeation to the metal, but also contain active additives to prevent reactions of the metallic surface with a corrosive environment. The *Nanomers* group developed organic coatings containing metal phosphate flakes to replace chromium-based coatings against mild steel corrosion.

The metal phosphate flakes in the hybrid coating not only provide an extra barrier against corrosion due to the flakes' specific morphology, but also act as active corrosion inhibitors, both cathodic and anodic. Additionally, an organic matrix was specifically developed to accommodate the metal phosphate flakes. With their controlled distribution they can be aligned parallel to the surface to provide an increased permeation pathway. The polymeric matrix was carefully selected to have a refractive index matching the flakes to render them invisible within the matrix. The coating deposition can be optimized to provide the best corrosion protection while still retaining transparency.

Synthesis of flake-shaped metal phosphate containing manganese and/or aluminum is currently developed to provide a larger range of corrosion protective additives for protecting also other types of substrates. In parallel, incorporation of the flakes in other matrices and addition of other additives is also under investigation to extend the range of functionalities that can be offered such as anti-fingerprint, hydrophobic or tribological features.

E. Perre, S. Albayrak, M. Wild, C. Becker-Willinger, EUROCORR 2015, 06.-10.09.2015, Graz
INM patent application pending

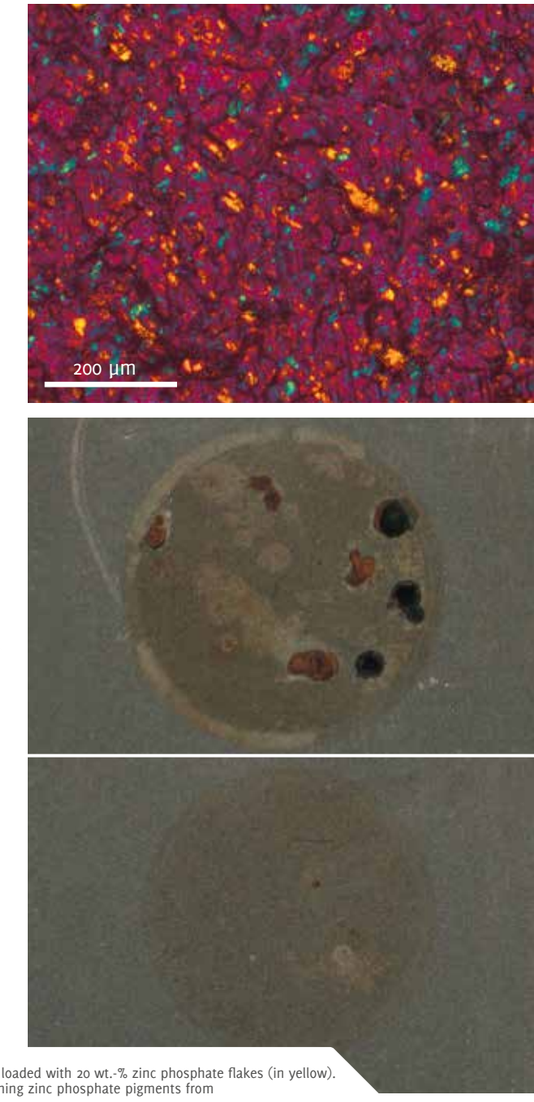
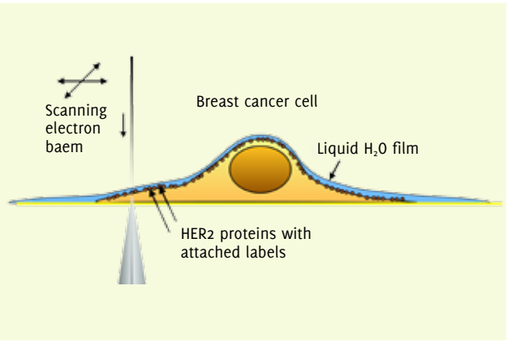
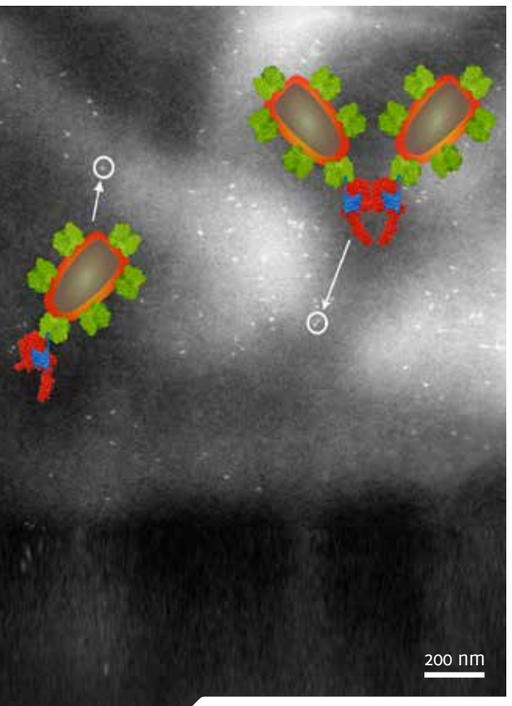


Fig. 1: Polarized light microscope image of the organic film surface loaded with 20 wt.-% zinc phosphate flakes (in yellow).
Fig. 2: Picture of mild-steel substrates coated with a matrix containing zinc phosphate pigments from
a) commercial source having undefined shape and
b) from INM with flake type shape after 105 days immersion in a corrosive electrolyte.

DISCOVERY OF A POSSIBLE REASON FOR DRUG RESISTANCE IN BREAST TUMORS

N. DE JONGE, D. PECKYS
INNOVATIVE ELECTRON MICROSCOPY





HER2 membrane proteins play a special role in certain types of breast cancer: amplified levels of HER2 drive unrestricted cell growth. HER2-tailored antibody-based therapeutics aim to prevent cancer-cell growth. Two-thirds of HER2 positive cancer patients are resistant to HER2-targeting drugs. The reason for this is not yet understood. We found that HER2 dimers appeared to be absent from a small sub-population of resting SKBR3 breast cancer cells. It seemed to be important to study this sub-population of cells with this unusual phenotype, because they could possibly have self-renewing properties resistant to HER2-antibody therapy and thus can promote new tumor growth at a later stage.

For our studies in cooperation with the German Cancer Research Center (DKFZ) in Heidelberg, we used the Liquid STEM method, which allows nanoscale studies of intact cells in a liquid environment.

We studied the local variations of HER2 membrane protein and its dimers. HER2 is a member of the human epidermal-growth-factor receptor (EGFR) family. The family members trigger cell growth signals when two of the membrane proteins are bound in a complex (dimerization). This happens usually after the binding of a small protein, the epidermal growth factor, which circulates in the blood stream and serves as a communicator to transmit signals that regulate cell growth. HER2 is special as it does not need the growth factor protein to form dimers. Thus it is capable of triggering cell growth without external regulation. In certain types of breast cancer, amplified levels of HER2 and its dimerization are known to drive unrestricted cell growth. HER2-tailored antibody-based therapeutics aim to prevent cell growth triggered by HER2 dimerization. Our novel findings were obtained as a direct consequence of the high spatial resolution of Liquid STEM and its capability to study many intact cells in liquid.

D. B. Peckys, U. Korf, N. de Jonge
Science Advances 1 (2015) e1500165

Fig.: Scheme of monitoring intact cancer cells in a liquid environment (top) with scanning electron beam screening the local distribution of HER2 protein dimers with attached labels (bottom).

GECOMER TECHNOLOGY ENTERS INDUSTRIAL DEVELOPMENT PHASE

R. HENSEL, K. MOH, P. W. DE OLIVEIRA, E. ARZT
FUNCTIONAL MICROSTRUCTURES, INNOVATIONCENTER INM

INM's Gecomer Technology (upper figure) has made another big step forward towards industrial application: Several promising collaborations with industry, especially focusing on automatic handling systems, have been conducted. Stimulated by our customers' demands regarding substrate materials, process environments and other specifications, we now fabricate new materials and fibril designs for the next generation of Gecomer Technology. Our solution provides a novel, noise-free system for handling delicate objects even in vacuum. Our energy-saving pick and place system relies on a patented attachment and detachment mechanism which enables switching of the adhesion strength purely based on contact mechanics. Hence, the switch functions without any externally applied energy, thus enabling energy conservation in production lines. Inspired by the gecko principle, a multitude of demonstrators showing the capability of the Gecomer Technology were constructed and displayed on different trade fairs in Germany (Hannover Messe, MOTEK Stuttgart) and overseas (nano tech, Japan) in 2015.

In ongoing research, the influence of surface roughness on the adhesion strength was systematically studied. The results reveal novel adhesive and non-adhesive states depending on the micropillar geometry relative to the surface roughness profile. In addition, we designed a new type of fibrillar adhesives by combining different materials within each fibril. The potential of these composite fibrils was confirmed by numerical and experimental analyses. In addition, the interaction of micropatterned surfaces with soft surfaces and skin models is being studied. First prototypes of a novel generation of skin adhesives based on the gecko principle are available (lower figure).

V. Barreau, R. Hensel, N. Guimard, A. Ghatak, R. M. McMeeking, E. Arzt
Advanced Functional Materials, accepted for publication

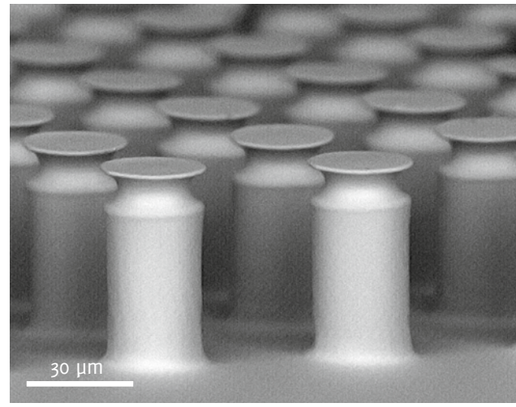
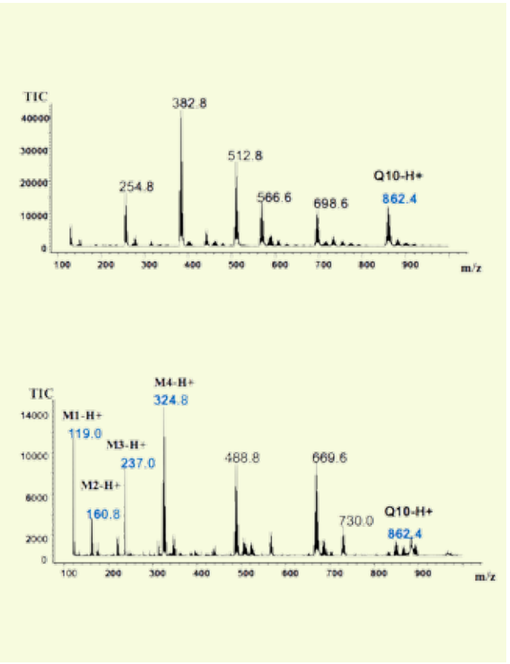
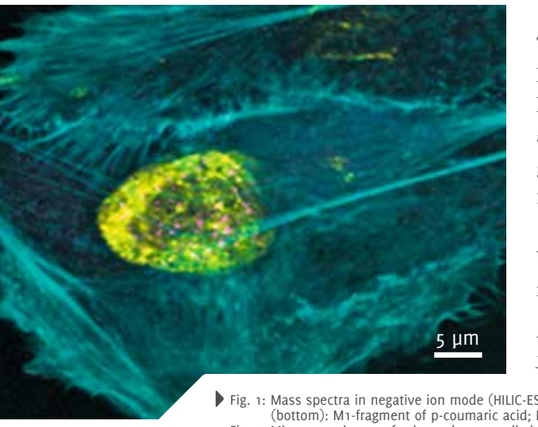


Fig.: INM's Gecomer Technology based on micropatterned fibrillar dry adhesives (top) for reversible adhesion on several delicate substrates such as skin (bottom).

P-COUMARIC ACID AS NOVEL BIOMARKER FOR QUANTIFYING HYPOXIC STRESS

Y. E. SILINA, R. G. HANSELMANN, H. PEUSCHEL, C. FINK-STRAUBE
CHEMICAL ANALYTICS, NANO CELL INTERACTIONS





In recent years, links between the risk of heart and stomach diseases, chronic inflammation and cancer with cellular hypoxia have been established. The methods to determine the degree of cellular hypoxia are often limited by insufficient sensitivity and can give false positive results for normoxic cells or fail for certain cell types such as tumor cells.

The aim of the present work was to develop a mass spectrometric assay for the quantitative determination of markers of cellular hypoxia under oxidative stress conditions. In this study, a simple and rapid technique based on hydrophilic-interaction chromatography/electrospray-ionization mass spectrometry (HILIC-ESI-MS) was used to distinguish cellular metabolic changes in primary lobar bronchial human cells triggered by hypoxia. During 168 h of hypoxia without induction of reactive oxygen species, an almost linear increase of *p*-coumaric acid levels was observed. We interpret the increasing *p*-coumaric acid concentrations during hypoxia as a result of cell damage, triggered by reduced co-enzyme Q10 levels, because the oxidative cascade was not able to supply sufficient energy. The HILIC-ESI-MS assay within *p*-coumaric acid exhibited a dynamic range from 60-610 ng/µL (R=0.999). The precision was ≤ 15 % RSD with recovery rates between 89.1 % and 93.8 %.

The increased levels of *p*-coumaric acid during hypoxia analyzed by HILIC-ESI-MS were used to determine the quantitative response of hypoxic cellular stress. Based on the concentrations of *p*-coumaric acid in the samples as a function of hypoxia time, the cells were grouped into three categories: 300-310 ng/µL = normoxic levels; 310-340 ng/µL = moderate hypoxia and > 350 ng/µl = prolonged hypoxia.

We believe that *p*-coumaric acid may be used as a novel biomarker for quantifying cellular hypoxic stress.

Y. E. Silina, C. Fink-Straube, R. G. Hanselmann, H. Peuschel, D. A. Volmer
Journal of Chromatography B 1020 (2016) 6-13

Fig. 1: Mass spectra in negative ion mode (HILIC-ESI-MS) of cellular extract before hypoxia (top) and after 48 h hypoxia / 3% O_2. (bottom): M1-fragment of p-coumaric acid; M2-p-coumaric acid; M3-O-p-coumaroyl glycerol; M4-coumaroyl hexose; M5-coenzyme Q10.
Fig. 2: Microscope image of primary human cells incubated for 8 h under hypoxic conditions (3% O_2).

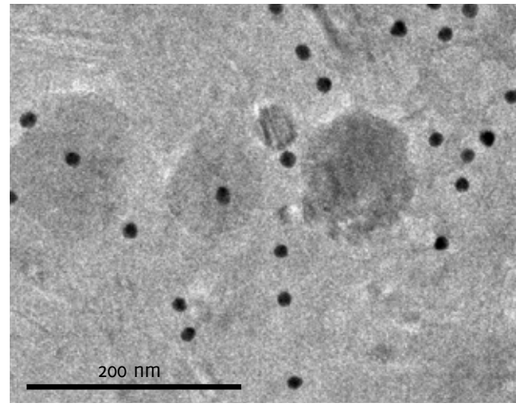
NANOPARTICLES IMAGED BY CRYOGENIC TRANSMISSION ELECTRON MICROSCOPY

M. KOCH, T. KRAUS
PHYSICAL ANALYTICS, STRUCTURE FORMATION

Nanoparticles in aqueous solution have a tendency to agglomerate due to different physicochemical properties like particle size and charge, stabilization by ligands and ionic strength of the solution. Although light optical characterization of nanoparticles solution is possible by several methods, individual nanoparticle agglomerates and very small nanoparticles cannot be resolved. In contrast to this, electron microscopy is capable to detect nanoparticles both in liquids (by Environmental Scanning or liquid Scanning Transmission Electron Microscopy) and after drying. In the first case, the resolution is limited by the Brownian motion of the nanoparticles, in the second case, the drying of the nanoparticle solution can lead to agglomeration due to the evaporation of the solvent (“coffee ring effect”).

To overcome this, cryogenic Transmission Electron Microscopy (cryo-TEM) can be used to preserve the nature of nanoparticles in solution. After plunge freezing of a thin aqueous film of nanoparticles on a holey carbon film in liquid ethane, the sample is transferred into a Gatan 914 cryo-TEM holder and imaged in a JEOL JEM 2100 LaB6 TEM at T = 100 K. Fig. 1 shows alkylthiol-stabilized gold nanoparticles after cryo-TEM preparation. Individual gold nanoparticles are embedded in a partly crystallized thin film of vitreous ice. No agglomeration of nanoparticles is visible. If the alkylthiol-stabilized gold nanoparticles are prepared by evaporation of a small droplet on a holey carbon film at room temperature, individual nanoparticle agglomerates are found by TEM at T = 298 K (Fig. 2).

Cryo-TEM preparation and imaging is advantageous for several applications, especially for nanoparticles in aqueous solutions, as shown above and biological samples. Furthermore, TEM imaging at T = 100 K is also helpful to investigate beam sensitive samples like carbon based materials, polymers or bioorganic matter. As a result, preparation and beam induced artifacts can be reduced by this method.



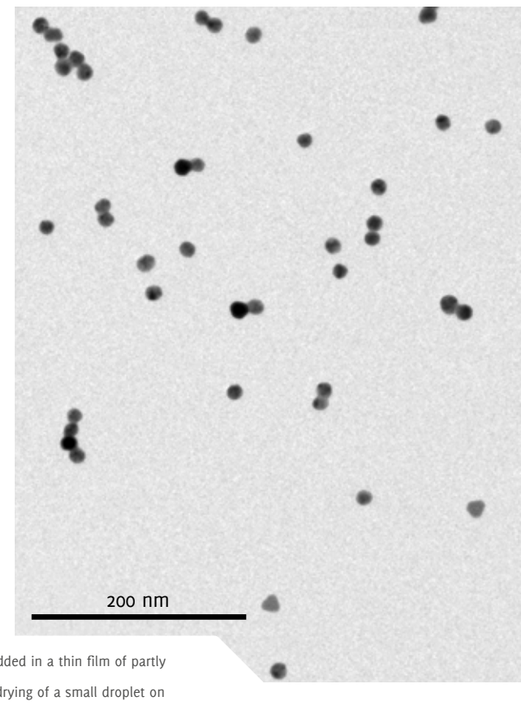


Fig. 1: TEM image of alkylthiol-stabilized gold nanoparticles embedded in a thin film of partly crystallized vitreous ice after plunge freezing at T = 100 K.
Fig. 2: TEM image of alkylthiol-stabilized gold nanoparticles after drying of a small droplet on a holey carbon film at T = 298 K.

INTERNATIONAL CONFERENCE ON CAPACITIVE DEIONIZATION & ELECTROSORPTION

V. PRESSER, C. HARTMANN
ENERGY MATERIALS

The International Conference on Capacitive Deionization & Electrosorption (CDI&E) was the first of its kind and held in Saarbrücken from October 26th-29th, 2015. This conference was initiated due to the recent enormous surge in interest in the field of water desalination by capacitive deionization (CDI). Many innovative new applications for electrosorption technologies were presented at the conference. In particular, membrane CDI, that is CDI with flow electrodes, and energy harvesting with capacitive technologies were important topics of the presentations.

The conference was organized by Volker Presser and Matthew Suss (Technion – Israel Institute of Technology, Haifa) with the logistics spearheaded by Christine Hartmann and Dominik Hell. Financially, the conference was also kindly supported by the International Society of Electrochemistry (ISE) and industrial partners. Located in the Aula of Saarland University, the conference attracted over 120 participants from academia and industry from many different countries including South Korea (19 % of attendees), Germany (17 %), the United States (11 %), the Netherlands (11 %), China (6 %), Israel (3 %), and many more. A total number of 34 oral presentations and 28 posters represented the large variety of topics within the scope of the CDI&E, ranging from fundamental aspects of interfacial electrochemistry, and materials science & engineering of advanced nanoporous materials, to industrial application and commercialization.

A flavor of the culture and history of the Saarland was provided by a visit to the Völklinger Hütte and a historic reenactment of the life in Saarbrücken of 1900. The conference also featured a half-day tutorial on the basics of capacitive deionization and electrosorption given by Maarten Biesheuvel (Wetsus, NL) and Matthew Suss. Especially noteworthy was the presence of a founding father of the field, honorary guest emeritus Prof. Dr. Bertel Kastening of the Institut für Physikalische Chemie at the University of Hamburg.

Fig. 1: Group picture of the attendees of the CDI&E 2015 conference.
Fig. 2: Impression from the conference (opening ceremony; speaker: Prof. Uwe Hartmann, Vice President Saarland University).

INM FELLOWS

Since 2012, INM has appointed selected professors from Saarland University as INM Fellows to strengthen its links to the university. At present, INM has three INM Fellows.

JANUS NANOPARTICLES

K. Abersfelder[1,2], P. W. de Oliveira[1], G. Kickelbick[2*]

Cooperation with Optical Materials group

Janus particles are a new class of nanoparticles that show two different compartments on their surface. The anisotropic particle surface may result in different reactivity, polarity, or charges of the two compartments. The surface functionalization of particles is challenging. However, a stepwise growth of different compartments during particle synthesis provides a convenient solution to obtain a Janus character. This can be achieved in an emulsion-based method of particle growth. Depending on the silane precursor, hydrolysis takes place on different positions of the emulsion droplets.

POLYMER INTERFACE DYNAMICS

J. Heppe[1,2], R. Bennewitz[1], K. Jacobs[2*]

Cooperation with Nanotribology group

Under certain conditions of functionalized materials, a thin liquid film under an external shear force can slide like a sledge rather than being sheared. The reason for this is an unusual boundary condition at the solid/liquid interface, allowing for a non-zero interfacial velocity. Whether or not this is a desired state for a film that should reduce friction, we explore in the project. For liquid droplets or film fronts, classical hydrodynamic models predict that contact-line motion requires infinite energy. Yet, common observations of moving droplets show that huge amounts of energy are unnecessary. Can we make use of this in everyday life by looking into the hydrodynamic boundary condition?

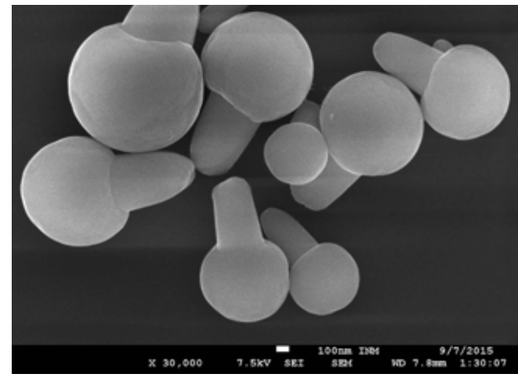
HAPTIC HUMAN-MACHINE INTERFACES

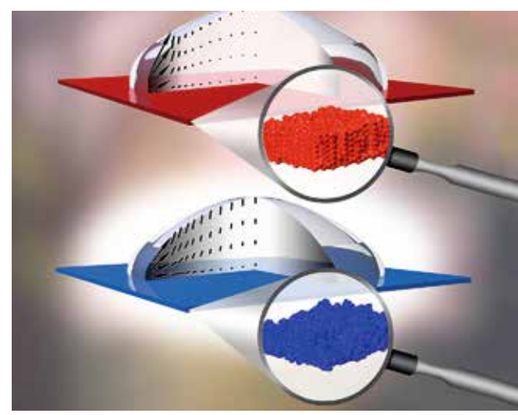
N. Özgün[1], R. Bennewitz[1], D. Strauss[2,3*]

Cooperation with Nanotribology group

Human tactile or haptic perception is a key sense in our interaction with the environment. The scientific quantification of this sense has only recently become a developing field of investigation. The project *TriboBrain* deals with the extraction of neural correlates evoked by tactile stimulation of the human fingertip. We have implemented an experiment in which friction of the fingertip against the pin pattern of a Braille display is correlated with EEG signals recorded simultaneously. The programmable Braille display allows for randomized experiments.

[1]INM
[2]Saarland University
[3]HTW Saar
*INM Fellow





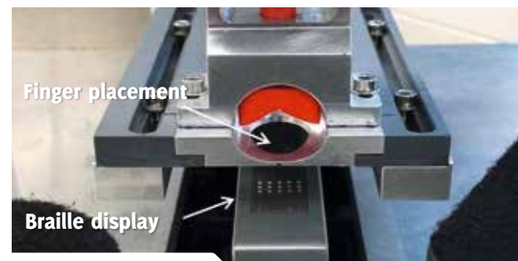
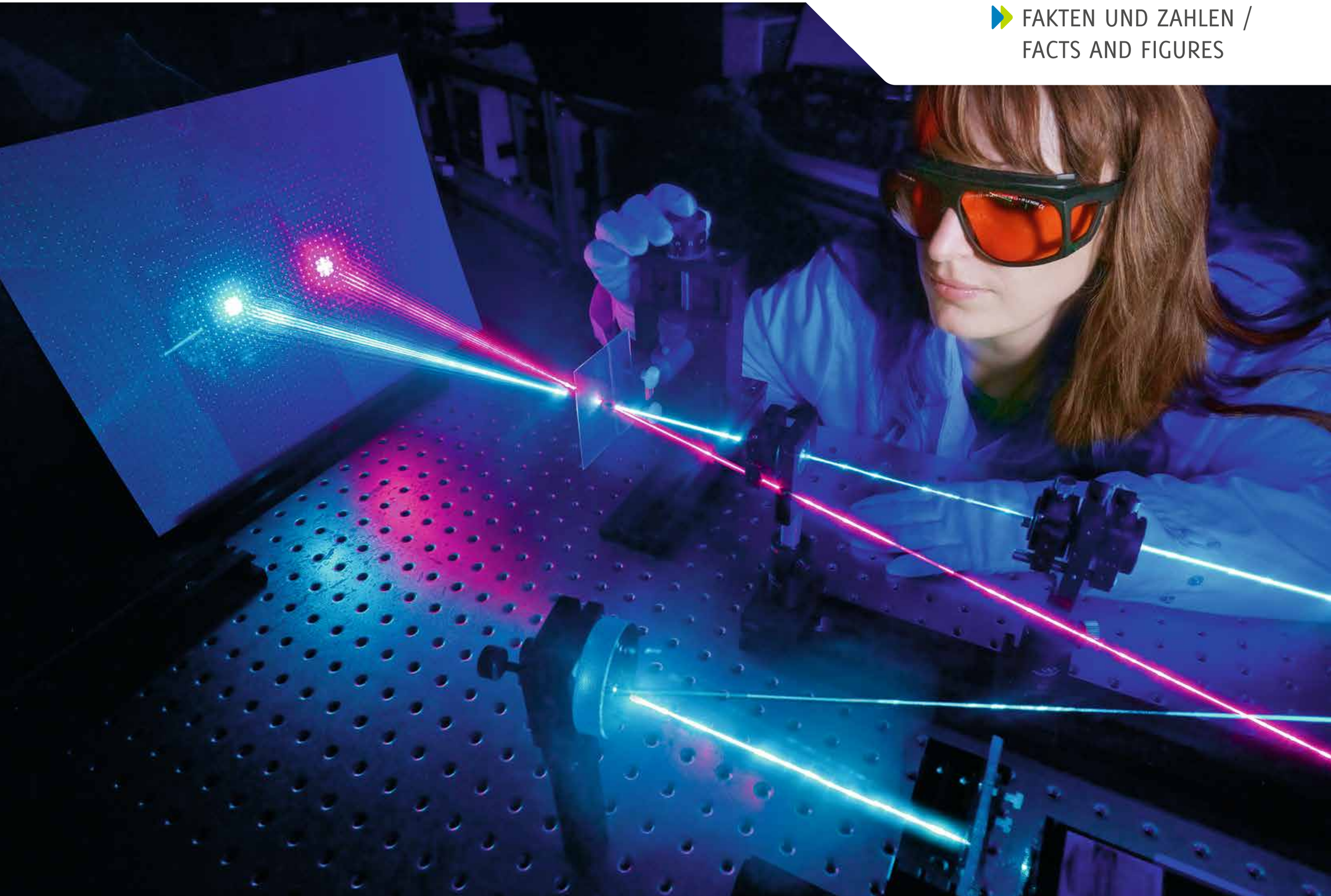


Fig. 1: SEM image of silica Janus particles consisting of two compartments from two silane precursors; first step: SiO_2 rod from TEOS, second step: aminopropyl silane (APS) sphere.
Fig. 2: Dewetting polystyrene droplets on substrates that provoke different interfacial velocities (red: low, blue: high) exhibit different flow profiles within the liquid while slowly adopting the equilibrium contact angle.
Fig. 3: Braille display for the investigation of neural response to fingertip friction.



DAS INM IN ZAHLEN / INM IN FIGURES

DAS INM IN ZAHLEN

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Erlöse aus Drittmittelvorhaben: 4,97 Mio. €
- davon 3,33 Mio. € aus öffentlichen Projektförderungen,
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Sonstige betriebliche Erträge: 0,22 Mio €

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Sethuraman, Sathyamoorthi, Indien

Srimuk, Pattarachai, Thailand

Völcker, Prof. Dr. Nicolas Hans, Australien

Weber, Dr. Eva, Deutschland

REFERIERTE PUBLIKATIONEN / PEER-REVIEWED PUBLICATIONS

Im Jahr 2015 wurden insgesamt 144 Publikationen veröffentlicht, davon 101 Publikationen in referierten Zeitschriften und 43 sonstige Publikationen.
Es wurde 67 Poster präsentiert. (Stand: 31.03.2016)
Eine Liste aller Publikationen finden Sie unter http://www.leibniz-inm.de/publikationen/

In 2015, 144 publications were published, including 101 publications in peer-reviewed journals and 43 other publications. 67 posters were shown. (As of 31.03.2016)
A list of all publications are available on our website http://www.leibniz-inm.de/en/publications/

GRENZFLÄCHENMATERIALIEN / INTERFACE MATERIALS

Energie-Materalien / Energy Materials

M. Aslan, D. Weingarth, P. Herbeck-Engel, I. Grobelsek and V. Presser
Polyvinylpyrrolidone/polyvinyl butyral composite as a stable binder for castable supercapacitor electrodes in aqueous electrolytes
J Power Sources 2015, 279, 323-333 [06.217 (2014)]

J. S. Atchison, M. Zeiger, A. M. Tolosa Rodriguez, L. M. Funke, N. Jäckel and V. Presser
Electrospinning of ultrafine metal oxide/carbon and metal carbide/carbon nanocomposite fibers
RSC Adv 2015, 5, (45), 35683-35692 [03.840 (2014)]

J. K. Ewert, D. Weingarth, C. Denner, M. Friedrich, M. Zeiger, A. Schreiber, N. Jäckel, V. Presser and R. Kempe
Enhanced capacitance of nitrogen-doped hierarchically porous carbide-derived carbon in matched ionic liquids
J Mater Chem A 2015, 3, (37), 18906-18912 [07.443 (2014)]

A. C. Forse, C. Merlet, P. K. Allan, E. K. Humphreys, J. M. Griffin, M. Aslan, M. Zeiger, V. Presser, Y. Gogotsi and C. P. Grey
New insights into the structure of nanoporous carbons from NMR, raman, and pair distribution function analysis
Chem Mater 2015, 27, (19), 6848-6857 [08.354 (2014)]

A. Härtel, M. Janssen, D. Weingarth, V. Presser and R. van Roij
Heat-to-current conversion of low-grade heat from a thermocapacitive cycle by supercapacitors
Energ Environ Sci 2015, 8, (8), 2396-2401 [20.523 (2014)]

K. Makgopa, P. M. Ejikeme, C. J. Jafta, K. Raju, M. Zeiger, V. Presser and K. I. Ozoemena
A high-rate aqueous symmetric pseudocapacitor based on highly graphitized onion-like carbon/birnessite-type manganese oxide nanohybrids
J Mater Chem A 2015, 3, (7), 3480-3490 [07.443 (2014)]

M. Oschatz, M. Zeiger, N. Jäckel, P. Strubel, L. Borchardt, R. Reinhold, W. Nickel, J. Eckert, V. Presser and S. Kaskel
Emulsion soft templating of carbide-derived carbon nanospheres with controllable porosity for capacitive electrochemical energy storage
J Mater Chem A 2015, 3, (35), 17983-17990 [07.443 (2014)]

S. Porada, P. M. Biesheuvel and V. Presser
Comment on sponge-templated preparation of high surface area graphene with ultrahigh capacitive deionization performance
Adv Funct Mater 2015, 25, (2), 179-181 [11.805 (2014)]

S. Porada, F. Schipper, M. Aslan, M. Antonietti, V. Presser and T.-P. Fellinger
Capacitive deionization using biomass-based microporous salt-templated heteroatom-doped carbons
ChemSusChem 2015, 8, (11), 1867-1874 [07.657 (2014)]

C. Prehal, D. Weingarth, E. Perre, R. T. Lechner, H. Amenitsch, O. Paris and V. Presser
Tracking the structural arrangement of ions in carbon supercapacitor nanopores using in situ small-angle X-ray scattering
Energ Environ Sci 2015, 8, (6), 1725-1735 [20.523 (2014)]

L. Reinert, M. Zeiger, S. Suárez, V. Presser and F. Mücklich
Dispersion analysis of carbon nanotubes, carbon onions, and nanodiamonds for their application as reinforcement phase in nickel metal matrix composites
RSC Adv 2015, 5, (115), 95149-95159, doi:10.1039/c5ra14310a, online: 30.10.2015 [03.840 (2014)]

N. Shpigel, M. D. Levi, S. Sigalov, O. Girshevitz, D. Aurbach, L. Daikhin, N. Jäckel and V. Presser
Non-invasive in situ dynamic monitoring of elastic properties of composite battery electrodes by EQCM-D
Angew Chem Int Edit 2015, 54, (42), 12353-12356 [11.261 (2014)]

N. Shpigel, M. D. Levi, S. Sigalov, O. Girshevitz, D. Aurbach, L. Daikhin, N. Jäckel and V. Presser
Non-invasive in-situ dynamic monitoring of elastic properties of composite battery electrodes by EQCM-D
Angew Chem 2015, 127, (42), 12530-12533 [-]

N. Souza, M. Zeiger, V. Presser and F. Mücklich
In situ tracking of defect healing and purification of single-wall carbon nanotubes with laser radiation by time-resolved Raman spectroscopy
RSC Adv 2015, 5, (76), 62149-62159 [03.840 (2014)]

M. E. Suss, S. Porada, X. Sun, P. M. Biesheuvel, J. Yoon and V. Presser
Water desalination via capacitive deionization: What is it and what can we expect from it?
Energ Environ Sci 2015, 8, 2296-2319 [20.523 (2014)]

V. P. Ting, A. J. Ramirez-Cuesta, N. Bimbo, J. E. Sharpe, A. Noguera-Diaz, V. Presser, S. Rudic and T. J. Mays
Direct evidence for solid-like hydrogen in a nanoporous carbon hydrogen storage material at supercritical temperatures
ACS Nano 2015, 9, (8), 8249-8254 [12.881 (2014)]

M. Zeiger, N. Jäckel, M. Aslan, D. Weingarth and V. Presser
Understanding structure and porosity of nanodiamond-derived carbon onions
Carbon 2015, 84, 584-598 [06.196 (2014)]

M. Zeiger, N. Jäckel, D. Weingarth and V. Presser
Vacuum or flowing argon: What is the best synthesis atmosphere for nanodiamond-derived carbon onions for supercapacitor electrodes?
Carbon 2015, 94, 507-517 [06.196 (2014)]

M. Zeiger, D. Weingarth and V. Presser
Quinone-decorated onion-like carbon/carbon fiber hybrid electrodes for high-rate supercapacitor applications
ChemElectroChem 2015, 2, (8), 1117-1127, doi:10.1002/celc.201500130, online: 26.05.2015 [- (2014)]

Funktionelle Mikrostrukturen / Functional Surfaces

C. T. Bauer, E. Kroner, N. A. Fleck and E. Arzt
Hierarchical macroscopic fibrillar adhesives: in situ study of buckling and adhesion mechanisms on wavy substrates
Bioinspir Biomim 2015, 10, (6), 066002 [02.354 (2014)]

L. Carrillo, B. Cucu, V. Bandmann, U. Homann, B. Hertel, S. Hillmer, G. Thiel and A. Bertl
High-resolution membrane capacitance measurements for studying endocytosis and exocytosis in yeast
Traffic 2015, 16, (7), 760-772, doi:10.1111/tra.12275, online: 25.02.2015 [04.350 (2014)]

G. Delaittre, N. K. Guimard and C. Barner-Kowollik
Cycloadditions in modern polymer chemistry
Accounts Chem Res 2015, 48, (5), 1296-1307 [22.323 (2014)]

M. Frensemeier, J. S. Kaiser, C. P. Frick, A. S. Schneider, E. Arzt, R. S. Fertig III and E. Kroner
Temperature-induced switchable adhesion using nickel-titanium-polydimethylsiloxane hybrid surfaces
Adv Funct Mater 2015, 25, (20), 3013-3021 [11.805 (2014)]

T. Frigge, B. Hafke, V. Tinnemann, T. Witte and M. Horn-von Hoegen
Spot profile analysis and lifetime mapping in ultrafast electron diffraction: Lattice excitation of self-organized Ge nanostructures on Si(001)
Structural Dynamics 2015, 2, (3), 035101, doi:10.1063/1.4922023, online: 05.06.2015 [-]

T. Frigge, B. Hafke, V. Tinnemann, T. Witte, B. Krenzer and M. Horn-von Hoegen
Nanoscale thermal transport in self-organized epitaxial Ge nanostructures on Si(001)
Semicond Sci Tech 2015, 30, (10), 105027 [02.190 (2014)]

S. N. Khaderi, N. A. Fleck, E. Arzt and R. M. McMeeking
Detachment of an adhered micropillar from a dissimilar substrate
J Mech Phys Solids 2015, 75, 159-183 [03.598 (2014)]

S. Mondal, M. Phukan and A. Ghatak
Estimation of solid-liquid interfacial tension using curved surface of a soft solid
P Natl Acad Sci USA 2015, 112, (41), 12563-12568 [09.674 (2014)]

C. Serrano, L. García-Fernández, J. P. Fernández-Blázquez, M. Barbeck, S. Ghanaati, R. Unger, J. Kirkpatrick, E. Arzt, L. Funk, P. Turón and A. del Campo
Nanostructured medical sutures with antibacterial properties
Biomaterials 2015, 52, 291-300 [08.557 (2014)]

P. Stoyanov, R. Merz, P. A. Romero, F. C. Wählisch, O. Torrents Abad, R. Gralla, P. Stemmer, M. Kopnarski, M. Moseler, R. Bennewitz and M. Dienwiebel
Surface softening in metal-ceramic sliding contacts: An experimental and numerical investigation
ACS Nano 2015, 9, (2), 1478-1491 [12.881 (2014)]

Nanotribologie / Nanotribology

R. Bennewitz and N. Strobach
Kann man Atome sehen? Rasterkraftmikroskopie und die Philosophie des Abbildens.
Phys J 2015, 14, (3), 37-42 [-]

J. Blass, M. Albrecht, B. L. Bozna, G. Wenz and R. Bennewitz
Dynamic effects in friction and adhesion through cooperative rupture and formation of supramolecular bonds
Nanoscale 2015, 7, (17), 7674-7681 [07.394 (2014)]

J. Blass, B. L. Bozna, M. Albrecht, J. A. Krings, B. J. Ravoo, G. Wenz and R. Bennewitz
Switching adhesion and friction by light using photosensitive guest-host interactions
Chem Commun 2015, 51, (10), 1830-1833 [06.834 (2014)]

B. L. Bozna, J. Blass, M. Albrecht, F. Hausen, G. Wenz and R. Bennewitz
Friction mediated by redox-active supramolecular connector molecules
Langmuir 2015, 31, (39), 10708-10716 [04.457 (2014)]

A. Caron and R. Bennewitz
Lower nanometer-scale size limit for the deformation of a metallic glass by shear transformations revealed by quantitative AFM indentation
Beilstein J Nanotechnol 2015, 6, 1721-1732 [02.670 (2014)]

M. Martinez Miró, M. Veith, J. Lee, F. Soldera, F. Mücklich, R. Bennewitz and O. C. Aktas
3D and 2D structural characterization of 1D Al/Al_2O_3 biphasic nanostructures
J Microsc-Oxford 2015, 258, (2), 113-118 [02.331 (2014)]

X.-Q. Pei, R. Bennewitz and A. K. Schlarb
Mechanisms of friction and wear reduction by carbon fiber reinforcement of PEEK
Tribol Lett 2015, 58, (3), 48 [01.739 (2014)]

P. Stoyanov, R. Merz, P. A. Romero, F. C. Wählisch, O. Torrents Abad, R. Gralla, P. Stemmer, M. Kopnarski, M. Moseler, R. Bennewitz and M. Dienwiebel
Surface softening in metal-ceramic sliding contacts: An experimental and numerical investigation
ACS Nano 2015, 9, (2), 1478-1491 [12.881 (2014)]

Schaltbare Oberflächen / Switchable Surfaces

J. S. Atchison, M. Zeiger, A. M. Tolosa Rodriguez, L. M. Funke, N. Jäckel and V. Presser
Electrospinning of ultrafine metal oxide/carbon and metal carbide/carbon nanocomposite fibers
RSC Adv 2015, 5, (45), 35683-35692 [03.840 (2014)]

C. T. Bauer, E. Kroner, N. A. Fleck and E. Arzt
Hierarchical macroscopic fibrillar adhesives: in situ study of buckling and adhesion mechanisms on wavy substrates
Bioinspir Biomim 2015, 10, (6), 066002 [02.354 (2014)]

D. Brodoceanu, R. Elnathan, B. Prieto-Simón, B. Delalat, T. M. Guinan, E. K. Kroner, N. H. Voelcker and T. Kraus
Dense arrays of uniform submicron pores in silicon and their applications
ACS Appl Mater Inter 2015, 7, (2), 1160-1169 [06.723 (2014)]

M. Frensemeier, E. Arzt, E. Qin, C. P. Frick and A. S. Schneider
Indentation-induced two-way shape-memory effect in aged Ti-50.9 at.% Ni
MRS Communications 2015, 5, (1), 77-82 [01.821 (2014)]

M. Frensemeier, J. S. Kaiser, C. P. Frick, A. S. Schneider, E. Arzt, R. S. Fertig III and E. Kroner
Temperature-induced switchable adhesion using nickel-titanium-polydimethylsiloxane hybrid surfaces
Adv Funct Mater 2015, 25, (20), 3013-3021 [11.805 (2014)]

P. Isla Yagüe and E. Kroner
A novel bioinspired switchable adhesive with three distinct adhesive states
Adv Funct Mater 2015, 25, (16), 2444-2450 [11.805 (2014)]

E. Kroner and C. S. Davis
A study of the adhesive foot of the gecko: Translation of a publication by Franz Weitlaner
J Adhes 2015, 91, (6), 481-487 [01.417 (2014)]

J. Purtov, M. Frensemeier and E. Kroner
Switchable adhesion in vacuum using bio-inspired dry adhesives
ACS Appl Mater Inter 2015, 7, (43), 24127-24135 [06.723 (2014)]

Strukturbildung / Structure Formation

L. González-García, S. Colodrero, H. Míguez and A. R. González-Elipe
Single-step fabrication process of 1-D photonic crystals coupled to nanocolumnar TiO_2 layers to improve DSC efficiency
Opt Express 2015, 23, (24), A1642-A1650, doi:10.1364/oe.23.0a1642, online: 03.11.2015 [03.488 (2014)]

P. Atanasova, N. Stitz, S. Sanctis, J. H. M. Maurer, R. C. Hoffmann, S. Eiben, H. Jeske, J. J. Schneider and J. Bill
Genetically improved monolayer-forming tobacco mosaic viruses to generate nanostructured semiconducting bio/inorganic hybrids
Langmuir 2015, 31, (13), 3897-3903 [04.457 (2014)]

D. Brodoceanu, R. Elnathan, B. Prieto-Simón, B. Delalat, T. M. Guinan, E. K. Kroner, N. H. Voelcker and T. Kraus
Dense arrays of uniform submicron pores in silicon and their applications
ACS Appl Mater Inter 2015, 7, (2), 1160-1169 [06.723 (2014)]

P. Büchele, M. Richter, S. F. Tedde, G. J. Matt, G. N. Ankah, R. Fischer, M. Biele, W. Metzger, S. Lilliu, O. Bikondoa, J. E. Macdonald, C. J. Brabec, T. Kraus, U. Lemmer and O. Schmidt
X-ray imaging with scintillator-sensitized hybrid organic photodetectors
Nat Photonics 2015, 9, 843-848 [32.386 (2014)]

M. E. Calvo, L. González-García, J. Parra-Barranco, A. Barranco, A. Jiménez-Solano, A. R. González-Elipe and H. Míguez
Flexible distributed bragg reflectors from nanocolumnar templates
Adv Opt Mater 2015, 3, (2), 171-175 [04.062 (2014)]

I. Dewald, O. Isakin, J. Schubert, T. Kraus and M. Chanana
Protein identity and environmental parameters determine the final physico-chemical properties of protein-coated metal nanoparticles
J Phys Chem C 2015, 119, (45), 25482-25492 [04.772 (2014)]

R. Elnathan, B. Delalat, D. Brodoceanu, H. Alhmoud, F. J. Harding, K. Buehler, A. Nelson, L. Isa, T. Kraus and N. H. Voelcker
Maximizing transfection efficiency of vertically aligned silicon nanowire arrays
Adv Funct Mater 2015, 25, (46), 7215-7225 [11.805 (2014)]

R. Elnathan, L. Isa, D. Brodoceanu, A. Nelson, F. J. Harding, B. Delalat, T. Kraus and N. H. Voelcker
Versatile particle-based route to engineer vertically aligned silicon nanowire arrays and nanoscale pores
ACS Appl Mater Inter 2015, 7, (42), 23717-23724 [06.723 (2014)]

N. A. Fleck, R. M. McMeeking and T. Kraus
Convective assembly of a particle monolayer
Langmuir 2015, 31, (51), 13655-13663 [04.457 (2014)]

J. Lacava, A. Weber and T. Kraus
Ageing of alkylthiol-stabilized gold nanoparticles
Part Part Syst Char 2015, 32, (4), 458-466 [03.081 (2014)]

J. H. M. Maurer, L. González-García, B. Reiser, I. Kanelidis and T. Kraus
Sintering of ultrathin gold nanowires for transparent electronics
ACS Appl Mater Inter 2015, 7, (15), 7838-7842 [06.723 (2014)]

S. T. Moerz, A. Kraegeloh, M. Chanana and T. Kraus
Formation mechanism for stable hybrid clusters of proteins and nanoparticles
ACS Nano 2015, 9, (7), 6696-6705 [12.881 (2014)]

R. B. Vasani, N. Janardanan, B. Prieto-Simón, A. Cifuentes-Rius, S. J. Bradley, E. Moore, T. Kraus and N. H. Voelcker
Microwave heating of poly(N-isopropylacrylamide)-conjugated gold nanoparticles for temperature-controlled display of concanavalin A
ACS Appl Mater Inter 2015, 7, (50), 27755-27764 [06.723 (2014)]

BIOGRENZFLÄCHEN / BIO INTERFACES

Biomineralisation / Biomineralization

L. Carrillo, B. Cucu, V. Bandmann, U. Homann, B. Hertel, S. Hillmer, G. Thiel and A. Bertl
High-resolution membrane capacitance measurements for studying endocytosis and exocytosis in yeast
Traffic 2015, 16, (7), 760-772, doi:10.1111/tra.12275, online: 25.02.2015 [04.350 (2014)]

M.-L. Lemloh
Biomineralization in ciliates.
Key Engineering Materials 2015, 672, 40-46 [-]

L. Šiller, S. Piticharoenphun, M.-L. Lemloh, B.R. Horrocks, B. Kaulich, A. Gianoncelli, M.R.C. Hunt, F. Brümmer, and D. Medaković
Sulphur-containing compounds as a response in sea urchins exposed to alkylated silicon nanocrystals and SiO_2-coated iron oxide nanoparticles.
Key Engineering Materials 2015, 672, 312-327 [-]

CVD/Biooberflächen / CVD/Biosurfaces

J. Lee, H. Jeon, A. Haidar, H. Abdul-Khaliq, M. Veith, O. C. Aktas and Y. Kim
Recombinant phage coated 1D Al_2O_3 nanostructures for controlling the adhesion and proliferation of endothelial cells
Biomed Res Int 2015, 2015, Article ID 909807 [01.579 (2014)]

M. Martinez Miró, M. Veith, J. Lee, F. Soldera, F. Mücklich, R. Bennewitz and O. C. Aktas
3D and 2D structural characterization of 1D Al/Al_2O_3 biphasic nanostructures
J Microsc-Oxford 2015, 258, (2), 113-118 [02.331 (2014)]

A. May, N. Agarwal, J. Lee, M. Lambert, C. K. Akkan, F. P. Nothdurft and O. C. Aktas
Laser induced anisotropic wetting on Ti–6Al–4V surfaces
Mater Lett 2015, 138, 21-24 [02.489 (2014)]

F. P. Nothdurft, D. Fontana, S. Ruppenthal, A. May, O. C. Aktas, Y. Mehraein, P. Lipp and L. Kaestner
Differential behavior of fibroblasts and epithelial cells on structured implant abutment materials: a comparison of materials and surface topographies
Clin Implant Dent R 2015, 17, (6), 1237-1249 [03.589 (2014)]

Dynamische Biomateralien / Dynamic Biomaterials

J. I. Paez, O. Ustahüseyin, C. Serrano, X.-A. Ton, Z. Shafiq, G. K. Auernhammer, M. d'Ischia and A. del Campo
Gauging and tuning cross-linking kinetics of catechol-PEG adhesives via catecholamine functionalization
Biomacromolecules 2015, 16, (12), 3811-3818 [05.750 (2014)]

Nano Zell Interaktionen / Nano Cell Interactions

M. Kroker, U. Sydlik, A. Autengruber, C. Cavelius, H. Weighardt, A. Kraegeloh and K. Unfried
Preventing carbon nanoparticle-induced lung inflammation reduces antigen-specific sensitization and subsequent allergic reactions in a mouse model
Part Fibre Toxicol 2015, 12, (1), 20, doi:10.1186/s12989-015-0093-5, online: 04.07.2015 [07.113 (2014)]

E. Hemmer, C. Cavelius, V. Huch and S. Mathur
Templating influence of molecular precursors on $Pr(OH)_3$ nanostructures
Inorg Chem 2015, 54, (13), 6267-6280 [04.762 (2014)]

J. Hoppstädter, M. Seif, A. Dembek, C. Cavelius, H. Huwer, A. Kraegeloh and A. K. Kiemer
M2 polarization enhances silica nanoparticle uptake by macrophages
Front Pharmacol 2015, 6, Article 55 [-]

S. T. Moerz, A. Kraegeloh, M. Chanana and T. Kraus
Formation mechanism for stable hybrid clusters of proteins and nanoparticles
ACS Nano 2015, 9, (7), 6696-6705 [12.881 (2014)]

H. Peuschel, T. Ruckelshausen, C. Cavelius and A. Kraegeloh
Quantification of internalized silica nanoparticles via STED microscopy
Biomed Res Int 2015, 2015, Article ID 961208 [01.579 (2014)]

NANOKOMPOSIT-MATERIALIEN / NANOCOMPOSITE MATERIALS

Optische Materialien / Optical Materials

A. Aghdaie, H. Haratizadeh, S. H. Mousavi, S. A. Jafari Mohammadi and P. W. de Oliveira
Effect of doping on structural and luminescence properties of AlN nanowires
Ceram Int 2015, 41, (2, Part B), 2917-2922 [02.605 (2014)]

M. Aslan, D. Weingarth, P. Herbeck-Engel, I. Grobelsek and V. Presser
Polyvinylpyrrolidone/polyvinyl butyral composite as a stable binder for castable supercapacitor electrodes in aqueous electrolytes
J Power Sources 2015, 279, 323-333 [06.217 (2014)]

E. Koushki, S. H. Mousavi, S. A. Jafari Mohammadi, M. H. Majles Ara and P. W. de Oliveira
Optical properties of aluminum oxide thin films and colloidal nanostructures
Thin Solid Films 2015, 592, Part A, 81-87 [01.759 (2014)]

QUERSCHNITTSBEREICHE / CROSS LINKING ACTIVITIES

Innovative Elektronenmikroskopie / Innovative Electron Microscopy

A. Bachmaier, H. Aboulfadl, M. Pfaff, F. Mücklich and C. Motz
Structural evolution and strain induced mixing in Cu–Co composites studied by transmission electron microscopy and atom probe tomography
Mater Charact 2015, 100, 178-191 [01.845 (2014)]

A. Bachmaier, M. Pfaff, M. Stolpe, H. Aboulfadl and C. Motz
Phase separation of a supersaturated nanocrystalline Cu-Co alloy and its influence on thermal stability
Acta Mater 2015, 96, 269-283 [04.465 (2014)]

M. Casavola, J. Hermannsdörfer, N. de Jonge, A. I. Dugulan and K. P. de Jong
Fabrication of Fischer-Tropsch catalysts by deposition of iron nanocrystals on carbon nanotubes
Adv Funct Mater 2015, 25, (33), 5309-5319 [11.805 (2014)]

T. Dahmen, H. Kohr, N. de Jonge and P. Slusallek
Matched backprojection operator for combined scanning transmission electron microscopy tilt- and focal series
Microsc Microanal 2015, 21, (03), 725-738 [01.877 (2014)]

T. Dahmen, H. Kohr, N. de Jonge and P. Slusallek
Reconstruction strategies for combined tilt- and focal series scanning transmission electron microscopy
Microsc Microanal 2015, 21, (Supplement S3), 2337-2338 [01.877 (2014)]

T. Frigge, B. Hafke, V. Tinnemann, B. Krenzer and M. Horn-von Hoegen
Nanoscale heat transport from Ge hut, dome, and relaxed clusters on Si(001) measured by ultrafast electron diffraction
Appl Phys Lett 2015, 106, (5), 053108 [03.302 (2014)]

T. Frigge, B. Hafke, V. Tinnemann, T. Witte and M. Horn-von Hoegen
Spot profile analysis and lifetime mapping in ultrafast electron diffraction: Lattice excitation of self-organized Ge nanostructures on Si(001)
Structural Dynamics 2015, 2, (3), 035101, doi:10.1063/1.4922023, online: 05.06.2015 [-]

J. Hermannsdörfer and N. de Jonge
Radiation damage of biological specimen in environmental electron microscopy
Microsc Microanal 2015, 21, (Supplement S3), 891-892 [01.877 (2014)]

J. Hermannsdörfer, N. de Jonge, V. Tinnemann, D. Alansary, B. A. Niemeyer, U. Korf and D. B. Peckys
Electron microscopy of labeled membrane proteins in whole eukaryotic cells in liquid
Eur Biophys J 2015, 44, (Suppl. 1), S126 [02.219 (2014)]

J. Hermannsdörfer, N. de Jonge and A. Verch
Electron beam induced chemistry of gold nanoparticles in saline solution
Chem Commun 2015, 51, (91), 16393-16396 [06.834 (2014)]

D. B. Peckys and N. de Jonge
Studying the stoichiometry of epidermal growth factor receptor in intact cells using correlative microscopy
J Vis Exp 2015, (103), e53186, doi:10.3791/53186, online: 11.09.2015 [01.325 (2014)]

D. B. Peckys, J. Hermannsdörfer, V. Tinnemann, U. Korf and N. de Jonge
Visualizing the distribution and stoichiometry of growth factor receptors in intact cells in liquid phase with correlative fluorescence and scanning transmission electron microscopy
Microsc Microanal 2015, 21, (Supplement S3), 213-214 [01.877 (2014)]

D. B. Peckys, U. Korf and N. de Jonge
Local variations of HER2 dimerization in breast cancer cells discovered by correlative fluorescence and liquid electron microscopy
Sci Adv 2015, 1, (6), e1500165, doi:10.1126/sciadv.1500165, online: 17.07.2015 [-]

D. Tilgner, M. Friedrich, J. Hermannsdörfer and R. Kempe
Titanium dioxide reinforced metal-organic framework Pd catalysts: Activity and reusability enhancement in alcohol dehydrogenation reactions and improved photocatalytic performance
ChemCatChem 2015, 7, (23), 3916-3922 [04.556 (2014)].

V. Tinnemann, D. B. Peckys and N. de Jonge
The localization of HER2 in the membrane of whole SKBR3 cells in native liquid state
Eur Biophys J 2015, 44, (Suppl. 1), S120 [02.219 (2014)]

M. W. P. van de Put, C. C. M. C. Carcouët, P. H. H. Bomans, H. Friedrich, N. de Jonge and N. A. J. M. Sommerdijk
Writing silica structures in liquid with scanning transmission electron microscopy
Small 2015, 11, (5), 585-590 [08.368 (2014)]

A. Verch, J. Hermannsdörfer and N. de Jonge
The stability of gold nanoparticles in liquid scanning transmission electron microscopy experiments studied under varied conditions
Microsc Microanal 2015, 21, (Supplement S3), 1125-1126 [01.877 (2014)]

A. Verch, M. Pfaff and N. de Jonge
Exceptionally slow movement of gold nanoparticles at a solid/liquid interface investigated by scanning transmission electron microscopy
Langmuir 2015, 31, (25), 6956-6964 [04.457 (2014)]

J. Zecevic, K. P. de Jong and N. de Jonge
Manipulating size and shape of silica nanoparticles with liquid-phase transmission electron microscopy
Microsc Microanal 2015, 21, (Supplement S3), 1129-1130 [01.877 (2014)]

InnovationsZentrum INM / InnovationCenter INM

L. Lin and A. K. Schlarb
Vibration welding of nano-TiO_2 filled polypropylene
Polym Eng Sci 2015, 55, (2), 243-250 [01.520 (2014)]

L. Lin and A. K. Schlarb
Vibration welding of polypropylene-based nanocomposites – The crucial stage for the weld quality
Compos Part B-Eng 2015, 68, 193-199 [02.983 (2014)]

L. Lin and A. K. Schlarb
Investigation on morphology and properties of melt compounded polyoxymethylene/carbon nanotube composites
J Appl Polym Sci 2015, 132, (40), 42639 [01.768 (2014)]

X.-Q. Pei, R. Bennewitz and A. K. Schlarb
Mechanisms of friction and wear reduction by carbon fiber reinforcement of PEEK
Tribol Lett 2015, 58, (3), 48 [01.739 (2014)]

A. K. Schlarb, L. Lin, D. N. Suwitaningsih and B. Suksut
Process-morphology-property-relationships of titania-filled polypropylene nanocomposites

International Journal of Civil and Structural Engineering – IJCSE 2015, 2, (2), 259-262 [-]

Modellierung/Simulation / Modelling/Simulation

M. Bacca, D. R. Hayhurst and R. M. McMeeking
Continuous dynamic recrystallization during severe plastic deformation
Mech Mater 2015, 90, 148-156 [02.329 (2014)]

M. R. Begley, C. Creton and R. M. McMeeking
The elastostatic plane strain mode I crack tip stress and displacement fields in a generalized linear neo-Hookean elastomer
J Mech Phys Solids 2015, 84, 21-38 [03.598 (2014)]

N. A. Fleck, R. M. McMeeking and T. Kraus
Convective assembly of a particle monolayer
Langmuir 2015, 31, (51), 13655-13663 [04.457 (2014)]

S. N. Khaderi, N. A. Fleck, E. Arzt and R. M. McMeeking
Detachment of an adhered micropillar from a dissimilar substrate
J Mech Phys Solids 2015, 75, 159-183 [03.598 (2014)]

M. Klinsmann, D. Rosato, M. Kamlah and R. M. McMeeking
An assessment of the phase field formulation for crack growth
Comput Method Appl M 2015, 294, 313-330 [02.959 (2014)]

PROGRAMMBEREICHSUNGEBUNDEN / NOT LINKED TO A PROGRAM DIVISION

Chemische Analytik / Chemical Analytics

H.-J. Mai, C. Lindermayr, C. von Toerne, C. Fink-Straube, J. Durner and P. Bauer
Iron and FER-LIKE IRON DEFICIENCY-INDUCED TRANSCRIPTION FACTOR-dependent regulation of proteins and genes in Arabidopsis thaliana roots
Proteomics 2015, 15, (17), 3030-3047 [03.807 (2014)]

Y. E. Silina, C. Fink-Straube, H. Hayen and D. A. Volmer
Analysis of fatty acids and triacylglycerides by Pd nanoparticle-assisted laser desorption/ionization mass spectrometry
Anal Methods 2015, 7, (9), 3701-3707 [01.821 (2014)]

Y. E. Silina, M. Koch and D. A. Volmer
Influence of surface melting effects and availability of reagent ions on LDI-MS efficiency after UV laser irradiation of Pd nanostructures
J Mass Spectrom 2015, 50, (3), 578-585 [02.379 (2014)]

Y. E. Silina, M. Koch and D. A. Volmer
Impact of analyte ablation and surface acidity of Pd nanoparticles on efficiency of surface-assisted laser desorption/ionization-mass spectrometry
Int J Mass Spectrom 2015, 387, 24-30 [01.972 (2014)]

Y. E. Silina, T. A. Kuchmenko and D. A. Volmer
Sorption of hydrophilic dyes on anodic aluminium oxide films and application to pH sensing
Analyst 2015, 140, (3), 771-778 [04.107 (2014)]

Physikalische Analytik / Physical Analytics

K. Astanina, M. Koch, C. Jüngst, A. Zumbusch and A. K. Kiemer
Lipid droplets as a novel cargo of tunnelling nanotubes in endothelial cells
Sci Rep 2015, 5, Art. nr.: 11453, doi:10.1038/srep11453, online: 22.06.2015 [05.578 (2014)]

P. Dandekar, R. Jain, M. Keil, B. Loretz, M. Koch, G. Wenz and C.-M. Lehr
Enhanced uptake and siRNA-mediated knockdown of a biologically relevant gene using cyclodextrin polyrotaxane
J Mater Chem B 2015, 3, (13), 2590-2598 [04.726 (2014)]

R. Jain, P. Dandekar, B. Loretz, M. Koch and C.-M. Lehr
Dimethylaminoethyl methacrylate copolymer-siRNA nanoparticles for silencing a therapeutically relevant gene in macrophages
MedChemComm 2015, 6, (4), 691-701 [02.495 (2014)]

Y. E. Silina, M. Koch and D. A. Volmer
Influence of surface melting effects and availability of reagent ions on LDI-MS efficiency after UV laser irradiation of Pd nanostructures
J Mass Spectrom 2015, 50, (3), 578-585 [02.379 (2014)]

Y. E. Silina, M. Koch and D. A. Volmer
Impact of analyte ablation and surface acidity of Pd nanoparticles on efficiency of surface-assisted laser desorption/ionization-mass spectrometry
Int J Mass Spectrom 2015, 387, 24-30 [01.972 (2014)]

INM Fellows / INM Fellows

T. Engel and G. Kickelbick
Furan-modified spherosilicates as building blocks for self-healing materials
Eur J Inorg Chem 2015, 2015, (7), 1226-1232 [02.942 (2014)]

Z. Mortezapouraghdam, L. Haab, F. I. Corona-Strauss, G. Steidl and D. J. Strauss
Assessment of long-term habituation correlates in event-related potentials using a Von Mises model
IEEE T Neur Sys Reh 2015, 23, (3), 363-373 [03.188 (2014)]

S. Schäfer and G. Kickelbick
Self-healing polymer nanocomposites based on Diels-Alder-reactions with silica nanoparticles: The role of the polymer matrix
Polymer 2015, 69, 357-368 [03.562 (2014)]

NACHTRAG 2014 / SUPPLEMENT 2014

Biomineralisation / Biomineralization

J. M. Kanold, M.-L. Lemloh, P. Schwendt, Z. Burghard, J. Baier, F. Herbst, J. Bill, F. Marin and F. Brümmer
In vivo enrichment of magnesium ions modifies sea urchin spicule properties
Bioinspir Biomim Nan 2014, 4, (BBN2), 111-120 [00.978 (2014)]

Innovative Elektronenmikroskopie / Innovative Electron Microscopy

K. Song, H. K. Schmid, V. Srot, E. Gilardi, G. Gregori, K. Du, J. Maier and P. A. van Aken
Cerium reduction at the interface between ceria and yttria-stabilised zirconia and implications for interfacial oxygen non-stoichiometry
Microsc Microanal 2014, 20, (Supplement S3), 420-421 [01.877 (2014)]

EINGELADENE VORTRÄGE / INVITED TALKS

Im Jahr 2015 wurden insgesamt 258 Vorträge gehalten, davon 79 eingeladene wissenschaftliche Vorträge und 179 sonstige Vorträge. (Stand: 31.03.2016)
Eine Liste aller Vorträge finden Sie unter http://www.leibniz-inm.de/publikationen/

In 2015, 258 talks were given, including 79 invited talks and 179 other talks. (As of: 31.03.2016)
A list of all talks are available on our website http://www.leibniz-inm.de/en/publications/

GRENZFLÄCHENMATERIALIEN / INTERFACE MATERIALS

Energie-Materalien / Energy Materials

S. Choudhury, M. Stamm, L. Ionov and V. Presser
Lithium-sulfur batteries: an emerging energy technology towards the smart car concept
University of Calcutta; December 23, 2015; Calcutta <India>

V. Presser
Grenzflächenelektrochemie als innovative Technologieplattform: Energie speichern, Wasser aufbereiten und mehr
Technische Universität; January 09, 2015; Dresden

V. Presser
Supercapacitors, pseudocapacitors, and flow capacitors
COST Winter Seminar Latest Developments in Electrochemical Capacitors; January 29-31, 2015; Poznan <Poland>

V. Presser
Insights into ion electrosorption with complementary in situ interfacial electrochemistry
Bar Ilan University; March 16, 2015; Ramat Gan <Israel>

V. Presser
Supercapacitors – Quo vadis?
Robert Bosch GmbH; March 18, 2015; Stuttgart

V. Presser
Supercapacitors, pseudocapacitors, and flow capacitors
Workshop on Materials Science for Energy Storage; May 11-15, 2015; Trieste <Italy>

V. Presser
Insights into ion electrosorption with complementary in situ interfacial electrochemistry
IPF – Leibniz Institute for Polymer Research; June 12, 2015; Dresden

V. Presser
Nanocarbons for electrochemical applications
ECUST – UdS Summer School on Materials Science and Chemistry; October 06-15, 2015; Saarbrücken

Funktionelle Mikrostrukturen / Functional Surfaces

E. Arzt
Bioinspirierte Oberflächen
Interdiziplinäre Vortragsveranstaltung OBERFLÄCHEN, ILEK, Universität Stuttgart, Institut für Leichtbau, Entwerfen und Konstruieren; May 07, 2015; Stuttgart

E. Arzt
Biomimetic functional surfaces: from geckos to Geckomer® technology
Seminar in Begbroke Science Forum, Oxford University Materials Department; May 21, 2015; Oxford <UK>

E. Arzt
Biomimetic functional surfaces: from geckos to Geckomer® technology
Institutskolloquium, Max-Born-Institut; May 28, 2015; Berlin

E. Arzt
New functional surfaces based on dimensional effects
Institutskolloquium, Universität Wien; June 08, 2015; Wien

E. Arzt
Novel biomimetic functional surfaces
Photonen Science Colloquium, DESY; June 12, 2015; Hamburg

E. Arzt
Bioinspired functional surfaces
UniGR & INM Workshop "Tailored Materials Interfaces"; June 29-30, 2015; Saarbrücken

E. Arzt
Innovation und Transdisziplinarität (Podiumsdiskussion)
Innovation Days 2015: Wirtschaft trifft Wissenschaft, Partnering-Konferenz und Karl Heinz Beckurts-Preisverleihung; December 09, 2015; Berlin

R. Hensel
Gecko-inspired dry adhesion systems for pick-and-place applications
Achema; June 16, 2015; Frankfurt am Main

Nanotribologie / Nanotribology

R. Bennewitz
Observing atoms at work – nanomechanics studies by force microscopy
Seminar at the Bilkent University, Department of Physics; March 11, 2015; Ankara <Turkey>

R. Bennewitz
Molecular control of nano-scale friction
ECI Conference "Advances in Lubrication V: Lubricated Contact"; April 13-17, 2015; Cadiz <Spain>

R. Bennewitz
Molecular control of friction and adhesion
Soft Matter+ Day, University of Twente; June 04, 2015; Enschede <Netherlands>

R. Bennewitz
Lubrication and wear from atomic layers to biological coatings
International Conference on Understanding and Controlling Nano and Mesoscale Friction; June 21-27, 2015; Istanbul <Turkey>

R. Bennewitz, J. Blass, B. L. Bozna, M. Albrecht and G. Wenz
Friction and adhesion controlled by supramolecular assemblies
International Tribology Conference – ITC 2015; September 14-16, 2015; Tokyo <Japan>

R. Bennewitz, A. Caron, C. Petzold and S. G. Balakrishna
Nanoscale friction on metal and graphene-covered surfaces
International Tribology Conference – ITC 2015, Satellite meeting "Friction – from atomic to geophysical scales"; September 14-16, 2015; Tokyo <Japan>

R. Bennewitz
Molekulare Kontrolle von Reibung
Karlsruher Werkstoffkolloquium, Karlsruher Institut für Technologie (KIT); November 11, 2015; Karlsruhe

J. Blass, B. L. Bozna, M. Albrecht, G. Wenz and R. Bennewitz
Controlling friction and adhesion by supramolecular assemblies
6th European Nanomanipulation Workshop; September 23, 2015; Gießen

N. Özgün, R. Bennewitz and D. J. Strauss
Relating tribological stimuli to single-trial somatosensory electroencephalographic responses: A pilot study
Workshop on "Cyclic Data Processing", Fraunhofer-Institut für Techno- und Wirtschaftsmathematik ITWM; April 10, 2015; Kaiserslautern

Schaltbare Oberflächen / Switchable Surfaces

E. Kroner
Switchable bio-inspired adhesives
SPIE Smart Structures; March 08-12, 2015; San Diego <CA, USA>

E. Kroner
Biomimicry, bioinspiration, and the San Diego Zoo
SPIE Smart Structures; March 08-12, 2015; San Diego <CA, USA>

E. Kroner
Switchable adhesives
Fachausschusssitzung des DGM-FA „Funktionalisierung von Oberflächen mittels Mikro/Nano Strukturierungsverfahren"; May 06, 2015; Saarbrücken

E. Kroner
Schaltbare Oberflächen
Institut für Mikrostrukturtechnik (IMT), KIT; May 12, 2015; Karlsruhe

Strukturbildung / Structure Formation

A.-R. Jochem, G. N. Ankah, S. Elsenberg, U. Rösch, C. Johann and T. Kraus
Ligand dependent particle losses of gold nanoparticles during Asymmetric Flow Field-Flow Fractionation
3rd Workshop on Field-Flow Fractionation – Mass Spectrometry, University of Vienna; September 05, 2015; Wien

T. Kraus
Physical chemistry of modern nanocomposites
Heinrich-Heine-Universität; April 08, 2015; Düsseldorf

T. Kraus
Transparent conductive layers through photometallization or nanoparticle assembly
Public HOP-X seminar at InnovationLab; April 09, 2015; Heidelberg

T. Kraus
Panel discussion on innovation
Technology Review – Innovatoren unter 35; July 01, 2015; Berlin

T. Kraus
Agglomerating particles into new materials
CNRS, Université Pierre et Marie Curie, Institut des Nano-Sciences de Paris (INSP); July 17, 2015; Paris <France>

T. Kraus
From nanoparticles to materials: particle agglomeration, binary supraparticles, and photovoltaic films
Kick-off Meeting in the frame of the project "DAAD Melbourne-Bayreuth – Polymer-Colloid Network"; November 30-December 04, 2015; Melbourne <Australia>

BIOGRENZFLÄCHEN / BIO INTERFACES

Biomineralisation / Biomineralization

I. M. Weiss
Bio/inorganic materials research – potential cross-links for ‚Saving Oseberg'
SAVING OSEBERG – Project Meeting, Folkemuseet; February 04, 2015; Oslo <Norway>

I. M. Weiss
Cooperative effects of enzymes involved in biomineralization
ExperiMed Symposium: Cross-roads in Musculoskeletal Regeneration,
Klinikum der Universität LMU (AUHP clinic, LMU); February 27, 2015; München

I. M. Weiss
Biomineralizing interfaces – An evolutionary view on enzymes
Interfaculty Biomineralization Seminar, The University of Tokyo; May 11, 2015; Tokyo <Japan>

I. M. Weiss
Biomineralizing interfaces
International Symposium "Hierarchical Structures and Dynamics at Soft Interfaces", Workshop at iCeMS Institute, Kyoto University; May 14, 2015; Kyoto <Japan>

I. M. Weiss
Regulatory mechanisms at hard-soft interfaces: A case study
Chemistry Department Seminar, School of Engineering, Kyoto University; June 03, 2015; Kyoto <Japan>

I. M. Weiss
On marine origins of biological materials
Marine Biosciences Department Seminar, JAMSTEC; June 11, 2015; Yokosuka <Japan>

I. M. Weiss
Biomineralization – A source of inspiration for glycotechnology
The 76th Gifu Glyco-Seminar Series, Applied Bio-Organic Chemistry, The University of Gifu; June 29, 2015; Gifu <Japan>

I. M. Weiss
Formation mechanisms of biological materials
iCeMS Seminar, iCeMS Institute, Kyoto University; June 30, 2015; Kyoto <Japan>

Dynamische Biomateralien / Dynamic Biomaterials

A. del Campo
Dynamic biointerfaces
"Biointerfaces: Cell – Material Interactions"; September 03-04, 2015; La Plata <Argentina>

M. Salierno, K. Kiefer and A. del Campo
Fibril-like environments arbitrate migratory transitions
Physics of Cancer 2015; September 07-09, 2015; Leipzig

A. del Campo
Dynamic cellular microenvironments
SFB 1027 Seminar; October 10, 2015; Saarbrücken

A. del Campo
Guiding cell interaction with biomaterials with light
Materials for Tomorrow 2015; November 03-04 2015; Chalmers <Sweden>

Nano Zell Interaktionen / Nano Cell Interactions

A. Kraegeloh
Quantification of cellular nanoparticle doses by STED microscopy
Nanosafety Workshop, University of South Australia; April 27-28, 2015; Adelaide <Australia>

A. Kraegeloh
Nanopartikel-Zell-Wechselwirkungen
Interdisziplinärer Lung-Club, Experimentelle Pneumologie und Allergologie, Universitäts-klinikum und Medizinische Fakultät des Saarlandes; February 10, 2015; Homburg

A. Kraegeloh, T. Ruckelshausen and H. Peuschel
STED microscopy to monitor nanoparticle cell interactions
10th Workshop and Conference on Advanced Multiphoton and Fluorescence Lifetime Imaging Techniques FLIM 2015, Universität des Saarlandes; June 17-19, 2015; Saarbrücken

NANOKOMPOSIT-MATERIALIEN / NANOCOMPOSITE MATERIALS

Optische Materialien / Optical Materials

J. Adam
Analysis of dispersions made of ceramic scintillator particles with different sizes and different grades of aggregation and agglomeration
International Workshop on Dispersion Analysis & Materials Testing; January 22-23, 2015; Berlin

J. Adam
Synthesis and dispersion of luminescent nano-/particles for the HOP-X project
Public HOP-X seminar at InnovationLab; April 09, 2015; Heidelberg

M. Amlung
Glasartige und Glas-Keramik Funktionsschichten auf Gläsern und Metallen
Jahrestagung des Deutschen Email Verbandes; April 19-20, 2015; Trier

M. Amlung
Nanoparticles for optics
ATCA Workshop KIST; September 14-15, 2015; Saarbrücken

M. Amlung and P. W. de Oliveira
Optical materials
Sol-Gel Science Symposium, DSM; November 12, 2015; Roosterhoeve <Netherlands>

T. S. Müller
Materials and processing for functionalized structures
German Days – 10th anniversary of the German Pavilion, Nanotech 2015, Tokyo Big Sight; January 29, 2015; Tokyo <Japan>

P. Rogin and M. Amlung
Glasartige Sol-Gel-Schicht auf Stahl als Multifunktionsbarriere
16. Wörlitzer Workshop „Isolations- und Barriereschichten für funktionelle Anwendungen"; June 15-16, 2015; Wörlitz

QUERSCHNITTSBEREICHE / CROSS LINKING ACTIVITIES

Innovative Elektronenmikroskopie / Innovative Electron Microscopy

N. de Jonge
Electron microscopy of biological specimens and nanomaterials in liquid
Universität Bayreuth, Colloquium Sonderforschungsbereich SFB 840; January 26, 2015; Bayreuth

N. de Jonge
Scanning transmission electron microscopy of whole cells and nanomaterials in liquid
Seminar: Université Paris 7 – Denis Diderot, Laboratoire Matériaux et Phénomènes Quantiques; February 11, 2015; Paris <France>

N. de Jonge
Studying growth factor receptor proteins in whole cells in liquid using scanning transmission electron microscopy
Seminar: Institut de génétique et de biologie moléculaire et cellulaire; March 20, 2015; Illkirch/Strasbourg <France>

N. de Jonge
Electron microscopy of labeled membrane proteins in whole eukaryotic cells in their native aqueous environment
Seminar: Max-Planck-Institut für Intelligente Systeme, Neue Materialien und Biosysteme, Universität Heidelberg; April 22, 2015; Heidelberg

N. de Jonge
Scanning transmission electron microscopy of biological specimens in liquid
XIVth French microscopy society conference; June 30-July 03, 2015; Nice <France>

N. de Jonge
Studying protein complexes on whole cells in liquid using scanning transmission electron microscopy
IAMNano 2015 International Workshop on Advanced and In-situ Microscopies of Functional Nanomaterials and Devices; July 08-10, 2015; Hamburg

N. de Jonge
Studying the behaviour of nanoparticles in liquid with electron microscopy
ESTEEM2 workshop on in situ TEM, Chalmers Campus; July 20-23, 2015; Gothenburg <Sweden>

N. de Jonge
Principles of transmission electron microscopy of nan liquid and application in biology and materials science
Microscopy Conference 2015; September 06-11, 2015; Göttingen

N. de Jonge
Scanning transmission electron microscopy of whole cells and nanomaterials in liquid
Opening ceremony of the Center for Surface and Nanoanalytics (ZONA), Johannes Kepler Universität; September 17, 2015; Linz <Austria>

N. de Jonge
Studying growth factor receptor proteins in whole cells in liquid using scanning transmission electron microscopy
ICMS discussion meeting, University of Technology; October 02, 2015; Eindhoven <Netherlands>

N. de Jonge
Scanning transmission electron microscopy of whole cells and nanomaterials in liquid
Seminar at the laboratory for electron microscopy, Karlsruhe Institute of Technology; October 26, 2015; Karlsruhe

N. de Jonge
STEM of intact cells and nano materials in liquid
2015 NVVM Materials Science Meeting; November 03, 2015; Eindhoven <Netherlands>

D. B. Peckys, U. Korf and N. de Jonge
Examining the heterogeneity of growth factor receptor complex formation in intact breast cancer cells in liquid state with correlative light- and electron microscopy
Microscopy Congress 2015; November 30-December 11, 2015; London <UK>

InnovationsZentrum INM / InnovationCenter INM

A. K. Schlarb, L. Lin, D. N. Suwitaningsih and B. Suksut
Process-morphology-property-relationships of titania-filled polypropylene nanocomposites
ACSM 2015; February 22, 2015; Bangkok <Thailand>

A. K. Schlarb
Welding of polymers and polymer composites
Chulalongkorn University; February 25, 2015; Bangkok <Thailand>

A. K. Schlarb and L. Lin
On the effect of filler geometry and processing on the morphology and properties of semi-crystalline thermoplastic-based nanocomposites
ICCM 2015; July 17, 2015; Chendgue <China>

A. K. Schlarb
Challenges and opportunities in thermoplastic hybrid composites
HKUST; July 20, 2015; Hong Kong

A. K. Schlarb
Status and developments in tribology of polymer composites
MITC 2015; November 17, 2015; Penang <Malaysia>

A. K. Schlarb
Polymer based hybrid materials on different length scales
Polymer Society of Thailand; November 20, 2015; Bangkok <Thailand>

PROGRAMMBEREICHSUNGEBUNDEN / NOT LINKED TO A PROGRAM DIVISION

INM Fellows / INM Fellows

G. Kickelbick
Chemisches Design von Anorganisch-Organischen Grenzflächen
GDCh-Kolloquium; January 22, 2015; Chemnitz

G. Kickelbick
Selbstheilende Hybridmaterialien: Über die Chemie an Grenzflächen
MNU Bundeskongress; March 31, 2015; Saarbrücken

G. Kickelbick
Janus nanoparticles – The art of anisotropic synthesis
Center for Interdisciplinary Nanostructure, Herbstkolloquium; October 15, 2015; Kassel

N. Özgün, R. Bennewitz and D. J. Strauss
Relating tribological stimuli to single-trial somatosensory electroencephalographic responses: A pilot study
Workshop on "Cyclic Data Processing", Fraunhofer-Institut für Techno- und Wirtschaftsmathematik ITWM; April 10, 2015; Kaiserslautern

PATENTE / PATENTS

Im Jahr 2015 erfolgten sechs Patentanmeldungen, die noch nicht offengelegt wurden. Dem Institut wurden 10 Patente erteilt. Vier Patentanmeldungen erfolgten im Rahmen einer europäischen Anmeldung in insgesamt 23 Mitgliedsstaaten, sechs Patente wurden im außereuropäischen Ausland zugeteilt. Es wurden somit 29 nationalisierte Schutzrechte im Jahr 2015 erteilt; zum Ende des Geschäftsjahres 2015 unterhielt das Institut insgesamt 73 Patentfamilien.

In 2015, INM has filed six new patent applications which are not yet published. Ten patents have been granted. Four of these patents are granted in Europe and six in foreign countries. The INM – Leibniz Institute for New Materials has 73 active patent families.

ERTEILTE EUROPÄISCHE PATENTE / PATENTS GRANTED IN EUROPE

Europäisches Patent Nr. 2459240 B1
Titel: *„Strukturierte Oberflächen für Implantate“*
Erfinder: Oral Cenk Aktas, Wolfgang Metzger, Martin Oberringer, Michael Veith

Europäisches Patent Nr. 2512650 B1
Titel: *„Verfahren zur Herstellung von eingekapselten Metall-Kolloiden als anorganische Farbpigmente“*
Erfinder: Dieter Anschütz, Peter de Oliveira, Claudia Fink-Straube, Kira Fries, Martin Mennig, Sarah Schumacher

Europäisches Patent Nr. 1709291 B1
Titel: *„Konsolidierungsmittel und dessen Verwendung zur Konsolidierung von Formkörpern und geologischen Formationen aus porösen oder partikulären Materialien“*
Erfinder: Klaus Endres, Bernd Reinhard, Helmut Schmidt

Europäisches Patent Nr. 2122419 B1
Titel: *„Verfahren zum Übertragen von Oberflächenstrukturierungen, wie Interferenzschichten, Hologrammen und anderen hochbrechenden optischen Mikrostrukturen“*
Erfinder: Peter de Oliveira, Christine Faller-Schneider, Bruno Schäfer, Michael Veith

ERTEILTE INTERNATIONALE PATENTE / PATENTS GRANTED INTERNATIONALLY

US Patent Nr. 9052588
Titel: *„Zusammensetzung zur Herstellung optischer Elemente mit Gradientenstruktur“*
Erfinder: Peter de Oliveira, Peter König, Michael Veith, Omid Yazdani-Assl

Chinesisches Patent Nr. 103328685
Titel: *„Verfahren zur Herstellung von metallischen Strukturen“*
Erfinder: Eduard Arzt, Peter de Oliveira, Karsten Moh, Sarah Schumacher

US Patent Nr. 9051470
Titel: *„Verfahren zur Herstellung dünner Filme und deren Verwendung“*
Erfinder: Peter de Oliveira, Michael Veith

US Patent Nr. 9063280
Titel: *„Verfahren zur Herstellung von Beschichtungen mit Antireflexionseigenschaften“*
Erfinder: Peter de Oliveira, Mohammad Jilavi, Sakthivel Shanmugasundaram, Michael Veith

Koreanisches Patent Nr. 101543806
Titel: *„Zusammensetzung zur Beschichtung elektrischer Leiter und Verfahren zur Herstellung einer solcher Zusammensetzung“*
Erfinder: Oral Cenk Aktas, Sener Albayrak, Carsten Becker-Willinger, Michael Veith

US Patent Nr. 9126848
Titel: *„Synthese von Nanopartikeln mittels ionischer Flüssigkeiten“*
Erfinder: Peter de Oliveira, Hechun Lin, Michael Veith

LEHRVERANSTALTUNGEN / TEACHING

WINTERSEMESTER 2014 / 2015

Aktas, Cenk
Nanomaterials: Synthesis, Properties and Applications
FH Kaiserslautern, Vorlesung, 2 SWS

Arzt, Eduard
INM-Kolloquium
Universität des Saarlandes, Kolloquium, 2 SWS

Arzt, Eduard und Mitarbeiter/innen
NanoBioMaterialien-P
Universität des Saarlandes, Praktikum, 4 SWS

Arzt, Eduard und Mitarbeiter/innen
NanoBioMaterialien-1
Universität des Saarlandes, Vorlesung / Übung, 2 SWS

Arzt, Eduard und Mitarbeiter/innen
Einführung in die Materialwissenschaft für (Studierende der) Mikrotechnologie und Nanostrukturen
Universität des Saarlandes, Vorlesung / Übung, 5 SWS

Becker-Willinger, Carsten
NDT Master: Polymer Materials Part 1
Dresden International University, Blockvorlesung, 1 SWS

Bennewitz, Roland
Gute Wissenschaftliche Praxis
Universität des Saarlandes, Blockseminar, 2 SWS

Jonge, Niels de
Elektronenmikroskopie
Universität des Saarlandes, Vorlesung / Übung, 5 SWS

Kraegeloh, Annette (mit Bernhardt, Rita, Wittmann, Christoph, Universität des Saarlandes)
Biochemie I
Universität des Saarlandes, Vorlesung, 1 SWS

Kraus, Tobias
Functional Coatings
Universität des Saarlandes, Vorlesung, 2 SWS

Weiss, Ingrid M.
Protein-/Enzymreinigung
Universität Regensburg, Kurs / Seminar, 4 SWS

SOMMERSEMESTER 2015

Aktas, Cenk
Biomedical Coatings
FH Kaiserslautern, Vorlesung, 2 SWS

Arzt, Eduard
INM-Kolloquium
Universität des Saarlandes, Kolloquium, 2 SWS

Arzt, Eduard und Mitarbeiter/innen
NanoBioMaterialien-2
Universität des Saarlandes, Vorlesung / Übung, 2 SWS

Bennewitz, Roland
Gute Wissenschaftliche Praxis
Universität des Saarlandes, Blockseminar, 1 SWS

Bennewitz, Roland
Nanomechanik
Universität des Saarlandes, Vorlesung / Übung, 4 SWS

Presser, Volker
Grundlagen der Thermodynamik
Universität des Saarlandes, Vorlesung / Übung, 4 SWS

Presser, Volker (mit Wenz, Gerhard, Universität des Saarlandes)
Smart Materials and Polymers
Universität des Saarlandes, Vorlesung, 1 SWS

Presser, Volker (mit Hempelmann, Rolf, Universität des Saarlandes)
Werkstoffe für effiziente Energienutzung
Universität des Saarlandes, Vorlesung, 1 SWS

Presser, Volker (mit Kolleg/inn/en, Universität des Saarlandes)
Praktikum I-1: Verwendung von Origin
Universität des Saarlandes, Praktikum, 0,5 SWS

WINTERSEMESTER 2015 / 2016

Arzt, Eduard
INM-Kolloquium
Universität des Saarlandes, Kolloquium, 2 SWS

Arzt, Eduard und Mitarbeiter/innen
NanoBioMaterialien-P
Universität des Saarlandes, Praktikum, 4 SWS

Arzt, Eduard und Mitarbeiter/innen
NanoBioMaterialien-1
Universität des Saarlandes, Vorlesung / Übung, 2 SWS

Arzt, Eduard und Mitarbeiter/innen
Einführung in die Materialwissenschaft für (Studierende der) Mikrotechnologie und Nanostrukturen
Universität des Saarlandes, Vorlesung / Übung, 5 SWS

Becker-Willinger, Carsten
Technologie der Polymere und Komposite
Universität des Saarlandes, Vorlesung, 1 SWS

Becker-Willinger, Carsten
NDT Master: Polymer Materials Part 1
Dresden International University, Blockvorlesung, 1 SWS

Bennewitz, Roland
Gute Wissenschaftliche Praxis
Universität des Saarlandes, Blockseminar, 1 SWS

Bennewitz, Roland
Technische Physik
Universität des Saarlandes, Vorlesung / Übung, 4 SWS

Jonge, Niels de
Elektronenmikroskopie
Universität des Saarlandes, Vorlesung / Übung, 2 SWS

Kraegeloh, Annette (mit Bernhardt, Rita, Wittmann, Christoph, Universität des Saarlandes)
Biochemie I
Universität des Saarlandes, Vorlesung, 1 SWS

Kraus, Tobias
Functional Coatings
Universität des Saarlandes, Vorlesung, 2 SWS

Weiss, Ingrid M.
Protein-/Enzymreinigung
Universität Regensburg, Kurs / Seminar, 4 SWS

VORTRÄGE IM INM-KOLLOQUIUM / INM COLLOQUIUM TALKS

Prof. Dr. Alexei Kornyshev, Imperial College London, UK
Ionic Liquids at Electrified Interfaces
January 07, 2015, Host: Jun.-Prof. Volker Presser

Dr. Heiko Wolf, IBM, Zurich Research Laboratory, Zurich, Switzerland
Microsphere Assembly in Shallow Traps – Deterministic Fabrication of Complex Particle Clusters
February 04, 2015, Host: Dr. Tobias Kraus

Ivan Litzov, Friedrich-Alexander-Universität Erlangen-Nürnberg
Design, Syntheses and Characterization of n-type Metal Oxide Semiconductors as Interface Materials for Opto-electronic Devices
February 11, 2015, Host: Dr. Tobias Kraus

Dr. Klaus Kruttwig, University of California, San Francisco, CA, USA
Novel MRI Technology for the Detection of Experimental Liver Cancer
February 12, 2015, Host: Prof. Niels de Jonge

Dr. Fabian Meder, University College of Dublin, Ireland
Biological "recognition" of nanomaterial surface chemistry – protein, virus, and cell responses to mono-, multifunctional, and surface patterned nanoparticles
February 25, 2015, Host: Dr. Elmar Kroner

Lizbeth O. Prieto López, University of Cambridge, UK
Using microfluidics to control soft adhesion
February 27, 2015, Host: Dr. Elmar Kroner

Prof. Dr. Enrico Stoll, TU Braunschweig
Active Space Debris Removal Using Biologically Inspired Materials
March 04, 2015, Host: Prof. Eduard Arzt

Dr. Aránzazu del Campo, Max-Planck-Institut für Polymerforschung, Mainz
Lichtgesteuerte Wechselwirkung von Zellen mit Biomaterialien
March 13, 2015, Host: Prof. Eduard Arzt

Dr. Ilaria de Santo, Università Federico II, Istituto Italiano di Tecnologia, Napoli, Italy
Manipulating Objects on the Micro and Nanoscale
March 23, 2015, Host: Dr. Elmar Kroner

Prof. Dr. Kevin T. Turner, University of Pennsylvania, Philadelphia, PA, USA
Adhesion and Wear in Probe-based Nanomanufacturing Processes
April 15, 2015, Host: Prof. Roland Bennewitz

Prof. Dr. Ulrich Jonas, Universität Siegen
Responsive Polymer Architectures: „Smart" Molecules for Smart Applications?
April 22, 2015, Host: Dr. Tobias Kraus

Dr. Asaph Widmer-Cooper, University of Sydney, Australia
Tuning Nanoparticle Interactions and Assembly: From Ag Polyhedra to Ligand-Mediated Interactions
April 24, 2015, Host: Dr. Tobias Kraus

Dr. Jiaxi Cui, Harvard University, Cambridge, MA, USA
When Bioinspired Ideas Meet Dynamic Polymer Materials Processes
May 05, 2015, Host: Prof. Eduard Arzt

PD Dr. Gerhard Maier, Polymaterials AG, Kaufbeuren
High Throughput Screening, Combinatorial Experimentation and Mathematical Design of Experiments for the Development of Polymer Compounds and Blends
May 06, 2015, Host: Prof. Eduard Arzt

Dr. Mihaela Delcea, Ernst-Moritz-Arndt-Universität Greifswald
What makes a self-protein to induce an immune response?
May 18, 2015, Host: Prof. Eduard Arzt

Dr. Corentin Coulais, Leiden University, The Netherlands
Soft Mechanical Metamaterials
May 20, 2015, Host: Prof. Eduard Arzt

Dr. Sebastian Aland, TU Dresden
Numerical Simulation of Coupled Fluid/Elastic Materials Using Phase Field Models
May 27, 2015, Host: Dr. René Hensel

Prof. Dr. Nicolas Vogel, Friedrich-Alexander-Universität Erlangen-Nürnberg
Exploiting Colloidal Self-Assembly: From Simple Building Blocks to Functional Materials
June 03, 2015, Host: Dr. Tobias Kraus

Prof. Dr. Ulrich Lemmer, Karlsruher Institut für Technologie (KIT), Karlsruhe
Organic Photodiodes: Fabrication, device operation and applications
June 16, 2015, Host: Dr. Tobias Kraus

Prof. Dr. Eva Olsson, Chalmers University of Technology, Gothenburg, Sweden
In Situ Electron Microscopy of Hard and Soft Matter
June 19, 2015, Host: Prof. Niels de Jonge

Prof. Dr. Sachin Singh Gautam, Indian Institute of Technology Guwahati, Assam, India
Time Integration Schemes for Dynamic Adhesive Contact Problems
June 23, 2015, Host: Prof. Eduard Arzt

Prof. Dr. Robert Danzer, Montan-Universität Leoben, Austria
Varistoren aus Zinkoxid: Mechanisches Versagen und neue physikalische Effekte
July 01, 2015, Host: Prof. Eduard Arzt

Prof. Dr. Franz Faupel, Christian-Albrechts-Universität zu Kiel
Functional Nanocomposites – From Fabrication to Function
July 15, 2015, Host: Dr. Tobias Kraus

Prof. Dr. Insu Jeon, Chonnam National University, Gwangju, Republic of Korea
Fabrication and Mechanical Analysis of Aluminum and Bioceramic Foam Materials
October 01, 2015, Host: Prof. Eduard Arzt

Dr. Emmanuelle Lacaze, CNRS – Université Pierre et Marie Curie, Paris, France
Control of nanoparticle self-assemblies using distorted liquid crystals
und
Dr. Jérôme Fresnais, Laboratoire de Physico-Chimie des Electrolytes, Colloïdes et Sciences, Paris, France
Magnetic Nanoparticles: Synthesis, Magnetic and Heating Properties
October 14, 2015, Host: Dr. Tobias Kraus

Prof. Dr. Thomas Hellweg, Universität Bielefeld
Smart Microgels and Microgel Nanoparticle Hybrids: Properties, Characterization, and Potential
October 21, 2015, Host: Dr. Tobias Kraus

Prof. Dr. Nicolas Giuseppone, Institut Charles Sadron (ICS), Strasbourg, France
Dynamic Supramolecular Polymers as Functional Materials
October 28, 2015, Host: Prof. Aránzazu del Campo

Dr. William Ronan, University of Cambridge, UK
Modelling of Cellular Biomechanics
October 30, 2015, Host: Prof. Eduard Arzt

Dr. Zheng Ling, Dalian University of Technology, China
MXenes: Synthesis, Assembly and Applications
November 09, 2015, Host: Jun.-Prof. Volker Presser

Dr. Pradip Dey, Freie Universität Berlin
Mimicking of Chondrocyte Microenvironment Using in situ Forming Dendritic Polyglycerol Sulfate (dPGS) Based Hydrogels
November 16, 2015, Host: Prof. Aránzazu del Campo

Dr. Roman Tsaryk, Max Planck Institut für molekulare Biomedizin, Münster
Regulation of Blood Vessel Formation during Development and in tissue Engineering
November 20, 2015, Host: Prof. Aránzazu del Campo

Prof. Dr. Bastian J. M. Etzold, Friedrich-Alexander-Universität Erlangen-Nürnberg
New Carbon Materials for Catalysis and Energy Related Applications
November 25, 2015, Host: Jun.-Prof. Volker Presser

Dr. Markus Valtiner, Max-Planck-Institut für Eisenforschung, Düsseldorf
Measuring Single Molecular Interaction Free Energies and Ion/Structuring at Solid/Liquid Interfaces
December 02, 2015, Host: Prof. Roland Bennewitz

Dr. Vítor Espírito Santo, Instituto de Biologia Experimental e Tecnológica (iBET), Lisboa, Portugal
Advanced Biomimetic Systems towards Cell Therapy and Disease Modeling
December 04, 2015, Host: Prof. Aránzazu del Campo

Dr. Alexander J. C. Kühne, DWI – Leibniz-Institut für Interaktive Materialien, Aachen
Self-assembled, Colloidal Conjugated Polymer Microlasers
December 10, 2015, Host: Dr. Tobias Kraus

VERANSTALTUNGEN / EVENTS

Besuch einer Delegation von Austauschstudierenden von Korea Tech
Organisation, Führung, Vorträge
Roland Bennewitz
Saarbrücken, 28.01.2015

Nano Tech 2015
Stand, Exponate
Mareike Frensemaier, Karsten Moh, Thomas Müller und Wolfram Seitz
Tokyo, Japan, 28.-30.01.2015

Research funding in Germany – an overview for female scientists
Organisation, Ausrichtung
Christina Sauer-Hormann und Silke Zeiter-Semmet (mit Universität des Saarlandes)
Saarbrücken, 24.02.2015

Besuch von Anke Rehlinger, Ministerin für Wirtschaft, Energie und Verkehr des Saarlandes
Organisation, Präsentationen
Eduard Arzt, Joachim Blau, Karsten Moh, Volker Presser, Mario Quilitz, Günter Weber und Ingrid Weiss
Saarbrücken, 25.02.2015

LOPEC – 7. Internationale Fachmesse für gedruckte Elektronik
Stand, Exponate
Thomas Müller, Michael Opsölder und Wolfram Seitz
München, 04.-05.03.2015

Besuch einer Delegation der koreanischen Advanced Technology Center Association
Organisation, Präsentation, Führung
Mario Quilitz (mit KIST Europe)
Saarbrücken, 23.03.2015

Besuch von Teilnehmern des 106. MNU Bundeskongresses
Organisation, Vortrag, Führung
Eduard Arzt, Marcus Koch, Annette Kraegeloh, Karsten Moh, Mario Quilitz, Peter Rogin und Daniel Weingarth
Saarbrücken, 30.03.2015

Hannover Messe 2015
Stand, Exponate
Joachim Blau, Marlon Jochum, Karsten Moh, Thomas Müller, Michael Opsölder, Mario Quilitz, Sabine Schmitz-Stöwe und Wolfram Seitz
Hannover, 13.-17.04.2015

Girls´ Day am INM: „Mit allen Sinnen forschen“
Organisation, Ausrichtung
Britta Abt, Claudia Fink-Straube, Christina Sauer-Hormann, Silke Siegrist und Silke Zeiter-Semmet
Saarbrücken, 23.04.2015

First Czech-German Workshop on Nanotechnology Entrepreneurship
Stand, Exponate
Mario Quilitz
Prag, Tschechische Republik, 04.-05.05.2015

Besuch von Teilnehmern des GradUS Global Programmes der Universität des Saarlandes
Organisation, Vortrag, Führungen
Roland Bennewitz und Mario Quilitz
Saarbrücken, 29.05.2015

Besuch von Teilnehmern eines Internationalen Treffens der Rotarier
Eduard Arzt, Arnaud Caron, Volker Presser und Mario Quilitz
Saarbrücken, 30.05.2015

TechConnect World
Stand, Exponate
Carsten Becker-Willinger und Wolfram Seitz
Washington D.C., USA, 15.-16.06.2015

Uni-GR – INM – Workshop “Tailored Materials Interfaces”
Organisation, Ausrichtung
Eduard Arzt, Christine Hartmann und Mario Quilitz (mit Universität der Großregion)
Saarbrücken, 29.-30.06.2015

Besuch von Prof. Matthias Kleiner, Präsident der Leibniz-Gemeinschaft
Organisation, Präsentationen
Eduard Arzt, Elke Bubel, René Hensel, Annette Kraegeloh, Karsten Moh, Mario Quilitz und Günter Weber
Saarbrücken, 03.07.2015

Tag der offenen Tür an der Universität des Saarlandes
Organisation, Vorträge, Präsentationen, Führungen
Christine Hartmann, Annette Kraegeloh, Tobias Kraus, Alexander Kümper, Karsten Moh, Mario Quilitz und Sarah Schmidt
Saarbrücken, 04.07.2015

Schülerpraktikum zur Elektronenmikroskopie für Schüler des Otto-Hahn-Gymnasiums Saarbrücken
Vortrag, Führungen, Praktikum
Niels de Jonge, Justus Hermannsdörfer, Diana Peckys und Andreas Verch
Saarbrücken, 21.07.2015

Besuch einer Delegation des Korean Research Institute on Chemical Technology, KRICT
Organisation, Präsentation, Diskussion
Eduard Arzt und Mario Quilitz (mit KIST Europe)
Saarbrücken, 23.07.2015

Besuch einer Delegation von China Electronics Tech Information Science Academy
Organisation, Präsentationen, Führung
Peter W. de Oliveira und Mario Quilitz
Saarbrücken, 08.08.2015

E-MRS Symposium “Transparent conductive materials: from fundamental understanding to applications”
Organisation
Lola Gonzáles-García, Christine Hartmann, Ioannis Kanelidis und Tobias Kraus
Warschau, Polen, 14.-18.09.2015

16. Jahrestagung des Arbeitskreises Bibliotheken und Informationseinrichtungen der Leibniz-Gemeinschaft
Organisation
Elke Bubel (mit Sprecherrat des AK Bibliotheken und Informationseinrichtungen)
Bremen, 16.-18.09.2015

IAA – Internationale Automobil-Ausstellung
Stand, Exponate
Martin Amlung, Carola Jung, Thomas Müller, Michael Opsölder, Wolfram Seitz und Günter Weber
Frankfurt, 17.-27.09.2015

BMBF Junior Investigation Workshop on Energy Research
Organisation, Ausrichtung
Volker Presser
Saarbrücken, 28.-29.09.2015

34. MOTEK – Internationale Fachmesse für Produktions- und Montageautomatisierung
Stand, Exponate
Joachim Blau, Karsten Moh und Wolfram Seitz
Stuttgart, 05.-08.10.2015

Besuch einer Delegation der Tupolew Universität von Kazan, Russland
Organisation, Präsentationen
Mario Quilitz und Günter Weber
Saarbrücken, 07.10.2015

Besuch von Teilnehmern der Korea – EU Innovation Academy
Organisation, Präsentation, Diskussionsrunde
Mario Quilitz (mit KIST Europe)
Saarbrücken, 15.10.2015

Besuch von Teilnehmern der ECUST Summer School
Organisation, Präsentation, Führung
Mario Quilitz (mit Universität des Saarlandes)
Saarbrücken, 16.10.2015

Ferienpraktikum Nano- und Werkstofftechnologie 2015
Organisation, Präsentationen, Praktika
Britta Abt, Mirko Bukowski, Aude Haettich, Gisela Heppe, Marcus Koch, Elmar Kroner, Thomas Müller, Mario Quilitz, Bernd Reinhard, Angela Rutz, Sarah Schumacher und Silke Siegrist (mit VDI / BMBF)
Saarbrücken, 19.-23.10.2015

CDI&E 2015 – International Conference on Capacitive Deionization and Electrosorption
Organisation, Ausrichtung
Christine Hartmann, Dominik Hell und Volker Presser
Saarbrücken, 26.-29.10.2015

Besuch von Teilnehmern des Mento MINT Programmes der Universität des Saarlandes
Organisation, Präsentationen, Führung
Sarah Fischer, Jennifer Jung, Julia Purtov und Mario Quilitz (mit Universität des Saarlandes)
Saarbrücken, 30.10.2015

Besuch von Mitgliedern der Stiftung der Rotarier
Vortrag, Führungen
Eduard Arzt, Annette Kraegeloh, Karsten Moh, Peter W. de Oliveira, Volker Presser und Mario Quilitz
Saarbrücken, 09.11.2015

Workshop zu Rechts- und Steuerfragen bei der Beschaffung von Print- und E-Medien
Organisation
Elke Bubel (mit Sprecherrat des AK Bibliotheken und Informationseinrichtungen)
Hamburg, 12.-13.11.2015

Workshop Forschungsverbund Nanosicherheit
Organisation
Eduard Arzt und Annette Kraegeloh
Berlin, 26.11.2015

NaMiBIND-Workshop
Organisation, Ausrichtung
Christine Hartmann, Bernd Reinhard und Ingrid Weiss
Saarbrücken, 30.11.-04.12.2015

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