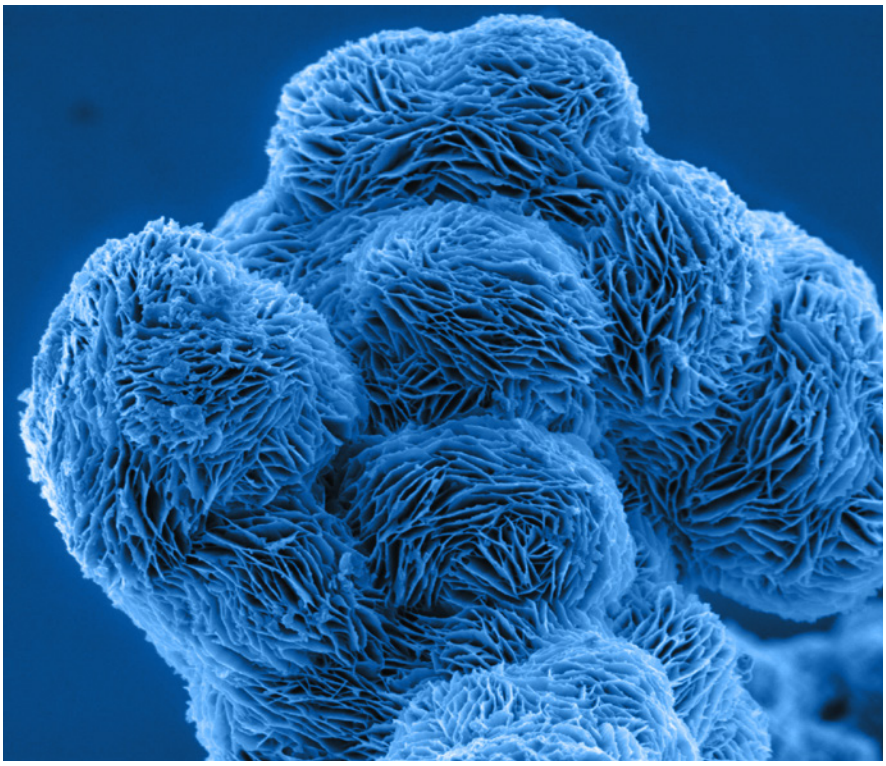
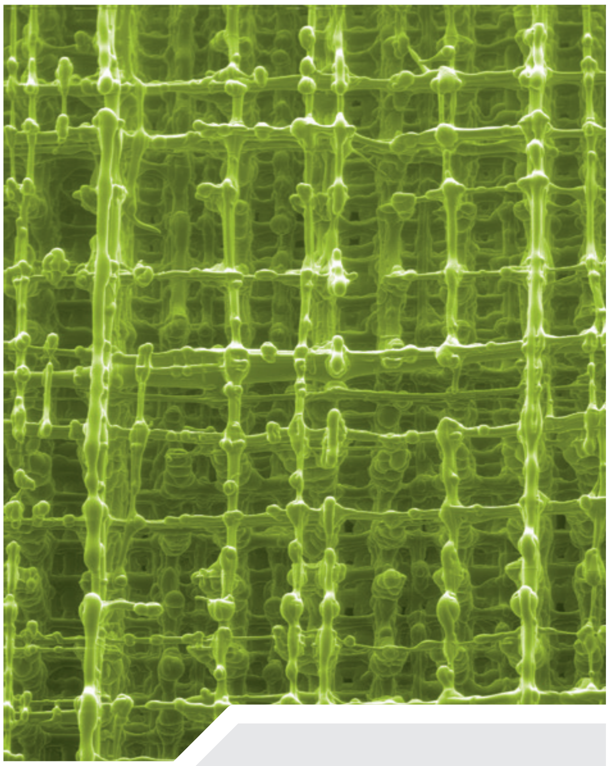
Neues Denken. Neue Materialien.





JAHRESBERICHT 2017
ANNUAL REPORT 2017

Leibniz Gemeinschaft

INM Leibniz-Institut für Neue Materialien

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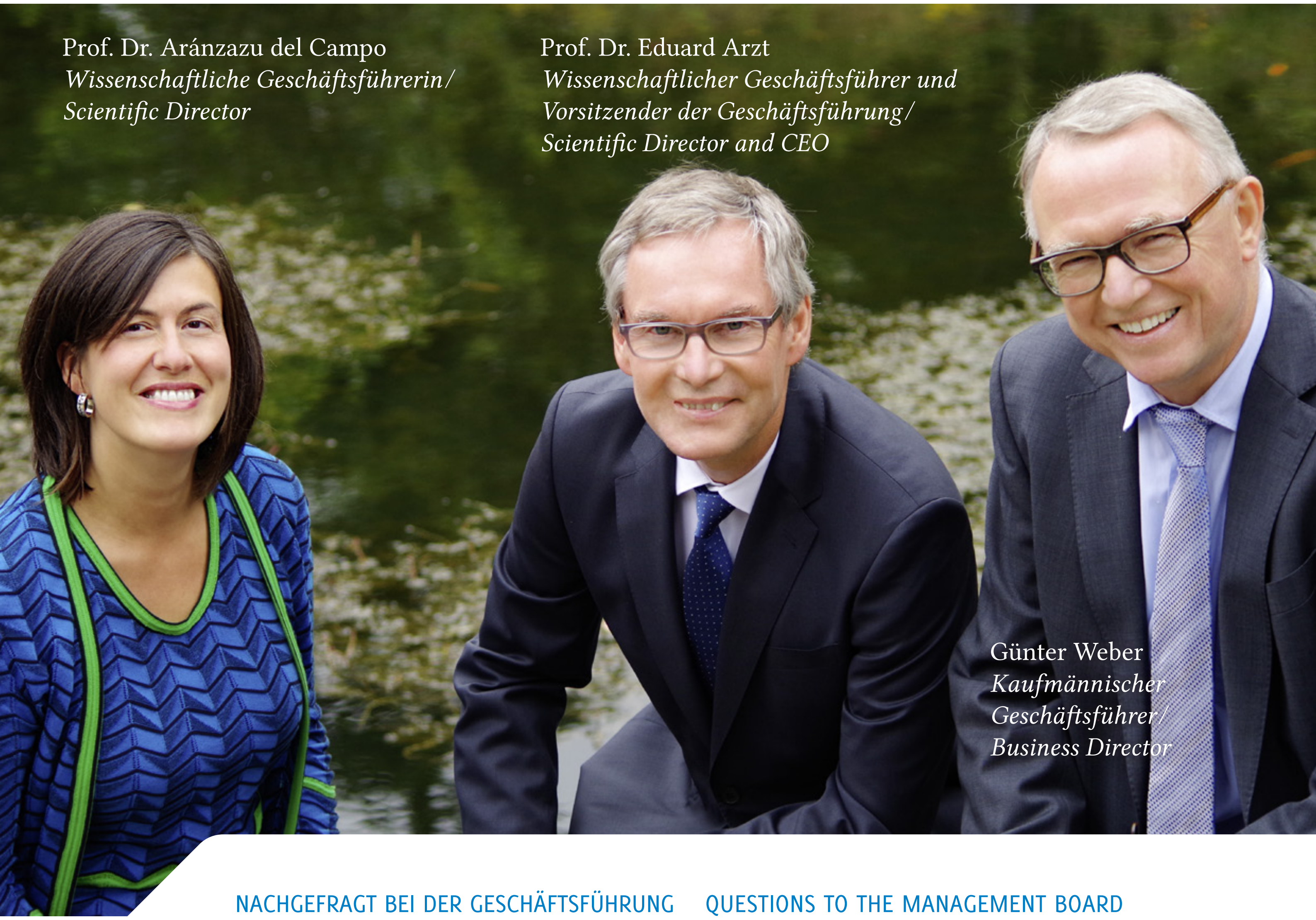


NACHGEFRAGT BEI DER GESCHÄFTSFÜHRUNG

Die Evaluierung durch die Leibniz-Gemeinschaft war sicher das wichtigste Ereignis des vergangenen Jahres am INM. Die internationale Expertenkommission hat das INM zu den „international führenden Einrichtungen im Bereich der Materialwissenschaft" gezählt. Was bedeutet Ihnen dieses Ergebnis?

E. A.: Natürlich freuen wir uns sehr über dieses hervorragende Ergebnis. Schon die letzte Evaluierung 2010 hat die Neuausrichtung des Instituts voll unterstützt, ihre erfolgreiche Realisierung wurde uns nun bestätigt. Mit seiner modernen, fächerübergreifenden Struktur ist das INM heute kaum wiederzuerkennen – es ist eine attraktive, international kompetitive und weltweit anerkannte Einrichtung der Materialforschung. Es war nicht immer leicht, alle Akteure von der Notwendigkeit dieser Änderungen zu überzeugen. Entscheidend war das vorbildliche Engagement unserer Mitarbeiterinnen und Mitarbeiter – ohne sie wäre ein solcher Erfolg nicht möglich gewesen.

QUESTIONS TO THE MANAGEMENT BOARD

The evaluation by the Leibniz Association was without a doubt the most important event of the preceding year at the INM. The international expert commission rated the INM among the "internationally leading institutions in the area of materials science". What does this outcome mean for you?

E. A.: Needless to say we are very delighted about this outstanding result. The evaluation in 2010 has already been a great support that helped with the strategic reorientation of the institute. Its successful realization has now been confirmed. With its modern, interdisciplinary structure, the INM can hardly be recognized these days as it has turned into an attractive, internationally competitive and worldwide renowned institution of materials research. It was not always easy to convince all the parties of the necessity of the changes. However, the exemplary commitment shown by our employees was decisive – without them, such a success would not have been possible.

G. W.: Und wir freuen uns sehr, dass damit dem Bund und den Ländern die uneingeschränkte Weiterfinanzierung des INM für die nächsten 7 Jahre empfohlen wird.

Im letzten Oktober hat das INM sein 30-jähriges Jubiläum gefeiert. Wie hat sich das Institut in den letzten zehn Jahren weiterentwickelt?
E. A.: Das INM verbindet heute erstklassige Grundlagen mit anwendungsrelevanten Entwicklungen. Dadurch bewegen wir uns an der Grenze des wissenschaftlich Machbaren und schaffen gleichzeitig neue Materiallösungen, etwa im Zusammenhang mit der Energiewende, der Robotik, der flexiblen Elektronik oder der Medizin.

A. d. C.: Mit dem Forschungsschwerpunkt Biogrenzflächen sind neue wissenschaftliche Ansätze für dynamische Biomaterialien entstanden. Wir beschäftigen uns dabei zunehmend mit zellbiologischen, biophysikalischen und biomedizinischen Fragestellungen. Unsere Forschung ist damit noch interdisziplinärer geworden.

Auch die Zukunftsplanung des INM überzeugte die Expertinnen und Experten. Wie sehen die Pläne aus, die ab 2020 das INM prägen sollen?
A. d. C.: Inhaltlich wird sich das INM in Richtung Digitaler und Biomedizinischer Materialien weiterentwickeln. Für unsere digitalisierte Welt werden zunehmend innovative Materialien benötigt und auch biomedizinische Materialien haben eine große Zukunft: Künstliche Gewebe werden eines Tages individuell auf Patienten anpassbar sein. Wir werden neue Nachwuchsgruppen auf diesen beiden Zukunftsgebieten etablieren. Mit der medizinischen Fakultät der Universität des Saarlandes und dem Informatik Campus Saar haben wir auf beiden Gebieten starke Partner, mit denen wir unsere Kooperation wesentlich intensivieren werden.

G. W.: Um diese Pläne umzusetzen, ist es notwendig, die Infrastruktur des INM zu erweitern. Die Evaluierungskommission hat auch unsere diesbezüglichen Planungen vorbehaltlos unterstützt. Wir sind dankbar, dass so ein Ausbau des Instituts für die neuen Forschungsrichtungen ermöglicht wird.

G. W.: And we are glad that, due to the outcome of the evaluation, the federal and regional governments received the recommendation for the unrestricted continuation of funding for the next seven years.

Last October, the INM celebrated its 30th anniversary. How has the institute developed in the last ten years?
E. A.: The INM of today combines first class basic research with application-relevant developments. By doing so, we are stretching the limits of what is scientifically feasible and, at the same time, create new material solutions, for example with regard to renewable energy turnaround, robotics, flexible electronics, or medicine.

A. d. C.: Since we have focused on the research area of biointerfaces, new scientific approaches for dynamical biomaterials have been generated. We are increasingly engaged in cell biological, biophysical, and biomedical topics. This is the reason why our research has become even more interdisciplinary.

The plans for the future of the INM also convinced the experts. What are the plans that are supposed to shape the INM from 2020 and beyond?
A. d. C.: As regards content, the INM will develop in the directions of digital and biomedical materials. Our digital world increasingly requires innovative materials and biomedical materials have a great future: Someday, artificial tissues will be adaptable to an individual patient. We will establish new junior research groups in both of these areas. The Medical Faculty of Saarland University and the Informatics Campus Saar are strong partners in both areas. We plan to significantly intensify our cooperation in these topics significantly.

G. W.: To implement these plans, it is necessary to expand the infrastructure of the INM. The evaluation commission completely agreed with our plans to do so. We are grateful that such an expansion of the institute will pave the way to the implementation of the new research fields.

GRUPPENBERICHTE / GROUP REPORTS

Eduard Arzt
Head *Functional Microstructures*

"OUR RESEARCH FIELD FOCUSSES ON PHYSICAL AND PHYSICO-CHEMICAL PROCESSES AT INTERFACES. WE DESIGN, SYNTHESIZE AND CHARACTERIZE MATERIALS AND STRUCTURES WITH HIGH DENSITIES OF SURFACES AND INTERFACES. RECENT DEVELOPMENTS INCLUDE A PROGRESSIVE SHIFT FROM SCIENTIFIC CONCEPTS TO APPLICATION."

GRENZFLÄCHENMATERIALIEN / *INTERFACE MATERIALS*

ENERGIE-MATERIALIEN / ENERGY MATERIALS

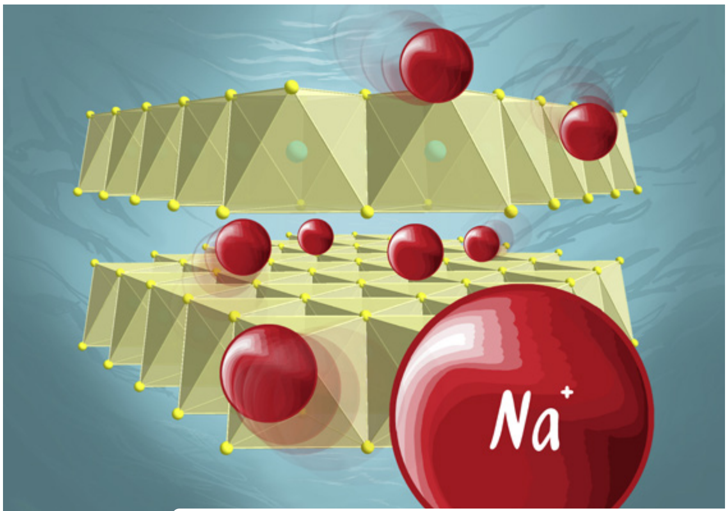
PROF. DR. VOLKER PRESSER

ZUSAMMENFASSUNG

Der Programmbereich *Energie-Materialien* entwickelt funktionale Nanomaterialien und erforscht elektroaktive Grenzflächen für elektrochemische Anwendungen zur Energiespeicherung und Wasseraufbereitung. Unsere hochporösen Kohlenstoffe und Nanokohlenstoffe (z. B. Kohlenstoffnanozwiebeln) können auf der Nanoskala mit Metalloxiden und Metallsulfiden hybridisiert werden. Wir untersuchen zudem Faraday'sche Materialien wie 2D-Metallkarbide (MXene) und Chalkogenide. Neben Superkondensatoren und Interkalationsbatterien erforschen wir redoxaktive Elektrolyte zur Entwicklung schneller Energiespeicher mit hoher Speicherkapazität. Besondere Bedeutung hat die Charakterisierung elektrochemischer Prozesse, die mit In-situ-Methoden detailliert untersucht werden. Damit reichen unsere Aktivitäten von Materialsynthese und Grundlagenforschung bis hin zu Methodenentwicklung, Zelldesign und Industriekollaborationen zur angewandten Energieforschung.

MISSION

Research in the Program Division *Energy Materials* is focused on the synthesis, characterization, and application of electroactive interfaces and functional nanomaterials. Our activities focus on electrochemical energy storage (supercapacitors, redox electrolytes, batteries) and water treatment (capacitive deionization, electrochemical desalination). Carbon materials and nanohybrids are the most important electrode materials, and we utilize non-porous carbon nanoparticles (carbon onions, carbon black) and nanoporous carbon materials (activated carbons, carbide-derived carbon, polymer-derived carbon, carbon nanofibers) to obtain electrodes for electrochemical applications. Hybridization of carbon is accomplished by implementation of nanoscale metal oxides or metal sulfides. We also investigate Faradaic materials, such as 2D metal carbides (MXene) or transition metal dichalcogenides. Redox electrolytes capitalize on the rapid charge transfer when in nanoconfined space; utilized as nanoreactors, nanoporous carbons combined with redox electrolytes enable the unique combination of battery-like energy storage while maintaining supercapacitor-like charge/discharge rates. We focus on a comprehensive array of materials characterization techniques and in situ methods to gain novel insights into electrochemical processes. Our contributions range from basic research, materials synthesis, and the refinement of testing procedures to industrial collaboration and technology development.



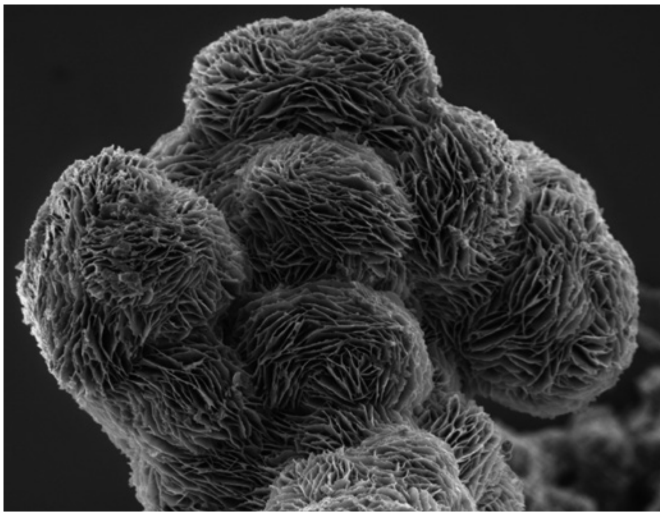


Fig. 1: Hydrothermally synthesized vanadia nanoflowers for use as electrodes for lithium and sodium ion batteries.
Fig. 2: Sodium intercalation in the crystal lattice of titanium disulfide enables energy efficient desalination of sea water.

CURRENT RESEARCH

Carbon/metal oxide nanohybrids for intercalation batteries

Many metal oxides have a high energy storage capacity, but suffer from a limited electrical conductivity. The nanoscopic hybridization of carbon and metal oxides allows combining a facile network for electron transport with a large amount of electrochemically active material via intercalation of lithium, sodium, or potassium. Our team has developed unique metal oxide / carbon nanofibers using a one-pot synthesis approach of electrospinning. We also have a broad material portfolio to synthesize well-tailored metal oxide / carbon and metal sulfide / carbon nanohybrids or nanocomposites using atomic layer deposition, hydrothermal methods, and chemical processes.

Redox electrolytes for high performance energy storage

Aqueous electrolytes are particularly attractive for energy storage devices per the fast mobility of dissolved ions and non-flammability. The use of redox-active aqueous electrolytes, such as zinc iodide, enables the continued use of activated carbon to capitalize on the vast redox activity of iodide. Yet, the fast redox processes occurring in carbon nanopores severely enhance the device power to supercapacitor-like levels.

Faradaic materials for water treatment

Capacitive deionization is an emerging technology for energy efficient water desalination, usually employing nanoporous carbon electrodes. We have demonstrated the high suitability of pseudocapacitive and battery-like electrode materials, such as 2D MXene, transition metal dichalcogenides and metal oxide / carbon nanohybrids. Our work has shown that unlike capacitive deionization, Faradaic deionization allows the desalination at high molar strength, enabling applications such as sea water treatment or mining water remediation.

OUTLOOK

Our team will continue to broaden the utilization of interfacial electrochemistry and hybrid carbon nanomaterials. We will continue to enhance our collaboration with industry for the development of high capacity energy storage devices, with strong focus on carbon/metal oxide nanohybrid materials. We will also further explore electroactive interfaces and Faradaic materials for advanced electrochemical desalination. The low energy consumption and excellent performance for the desalination of high salinity media overcomes the present-day issues of capacitive deionization and will lead to a new technology field of desalination batteries. The latter critically requires thorough understanding of the structural changes during charging/discharging and selectivity of Faradaic materials towards ionic species.

FUNKTIONELLE MIKROSTRUKTUREN / FUNCTIONAL MICROSTRUCTURES

PROF. DR. EDUARD ARZT, DR. RENÉ HENSEL

ZUSAMMENFASSUNG

Der Programmbereich befasst sich mit der experimentellen und theoretischen Untersuchung mikrostrukturierter Oberflächen, die spezielle mechanische, optische, thermische und haptische Funktionalitäten aufweisen. Vorbild für Gestalt und Funktionen der Strukturen sind Konzepte aus der belebten Natur, die auf künstliche Systeme übertragen werden. Der Fokus der laufenden Arbeiten liegt auf fibrillären, bioinspirierten Haftsystemen für die temporäre Adhäsion auf rauen, weichen und hautähnlichen Substraten sowie anwendungsrelevanten Fragestellungen. Ein Schwerpunkt besteht in der numerischen Modellierung der Spannungsverteilungen in der Kontaktfläche und der darauf aufbauenden Optimierung des Haftverhaltens. In Kooperation mit Industriepartnern werden technische Gecomer-Greifsysteme für spezifische Anwendungen entwickelt. Medizinische Implantatoberflächen werden zusammen mit der Uniklinik Homburg erforscht. Unsere Arbeiten werden von der EU (ERC Advanced Grant sowie ITN Trainee Network), einem Projekt der Leibniz-Gemeinschaft und durch Industriekooperationen gefördert.

MISSION

The Program Division *Functional Microstructures* conducts experimental and theoretical research on the fabrication and characterization of functional micro- and nanopatterned surfaces. By combining suitable morphology and materials, surface features are designed that enhance various functionalities such as mechanical, optical, thermal or haptic characteristics. Inspired by the adhesive performance of natural systems, the group mimics such mechanisms to control the adhesion of synthetic surfaces. Presently, our scope lies on the exploration of the mechanisms of contact between adhesive fibrillar structures and soft, compliant surfaces with finite roughness, such as skin. Numerical modeling of the stress distributions in the contact interface is performed to optimize the adhesion. In cooperation with industrial partners and clinicians, we currently transfer our Gecomer Technology into industrial applications and explore its potential for biomedical surfaces. Our research is funded by an ERC Advanced Grant, an EU ITN Trainee Network, a Leibniz transfer project and industrial contracts.

CURRENT RESEARCH

Advanced fibril designs – Why shape matters

Theoretical contact mechanics is essential for understanding adhesion phenomena of micropatterns. The distribution of normal stresses inside the contact area governs the adhesion performance, which can be improved by optimized fibril designs. Recently, we introduced funnel-shaped microstructures (see Highlight Article) where polymeric flaps are conically arranged. This geometry was shown to improve mechanical stability and to enable exceptionally strong adhesion. An "adhesion modeling cluster" was established with a first ERC-related workshop. In a team of international experts (R. M. McMeeking, UC Santa Barbara; N. Fleck, University of Cambridge; A. Kossa, Budapest UTE; M. Bacca, University of British Columbia), we model adhesion problems to rationally optimize designs and to discover new concepts.

Skin adhesives – Adhesion in clinical use

Skin is a challenging substrate to achieve adhesion as it is rough and compliant. In addition, the adherent has to be biocompatible to avoid irritations. Silicone-based films were tested to several rough substrates: Softer films were demonstrated to adhere better and to be less sensitive to surface roughness than stiffer films. Plasma treatment can significantly improve cellular adhesion and spreading. In first in-vivo tests, films were successfully applied to support the healing of ear drum perforations in mice (cooperation with Prof. Schick and Dr. Wenzel, UKS Homburg). Adhesive films for wearable sensors are currently under investigation in collaboration with the Saarland Informatics Campus (Prof. Steimle, UdS).

Technology transfer – Gecomer Technology on the rise

INM's Gecomer Technology has now been validated for numerous pick & place scenarios and in challenging environments. The patent base was extended to include additional effects that will be of practical use for specific applications. A roll-to-roll micropatterning process was successfully implemented in collaboration with the *InnovationCenter INM*. In a Proof-of-Concept project funded by ERC, we will take our Technology to the next level to prepare its commercialization.

OUTLOOK

Scientifically, micropatterned surfaces will continue to play a central role in INM's research portfolio. Among the fundamental aspects to be explored are, e. g., the contact mechanics in the presence of edge and misalignment effects and the mechanics of interaction with ultra-soft substrates. Additional functionalities will be introduced to improve the reliability of adhesive devices in critical applications. In cooperation with Saarland University Hospital (Prof. Schick, Homburg), biomedical prototypes will enter the stage of in-vivo testing. New functions of micropatterned surfaces such as electrical interfacing and haptic properties will be explored in future collaborations (e. g. with *Nanotribology*). Micromechanical modeling of adhesion performance will remain an important baseline to rationally optimize adhesion, e. g. for intelligent gripping devices with adjustable touch. The potential applications range from medical devices to space robotics.

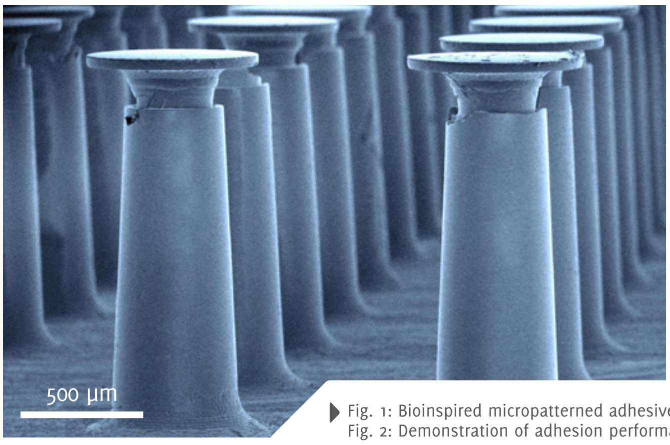


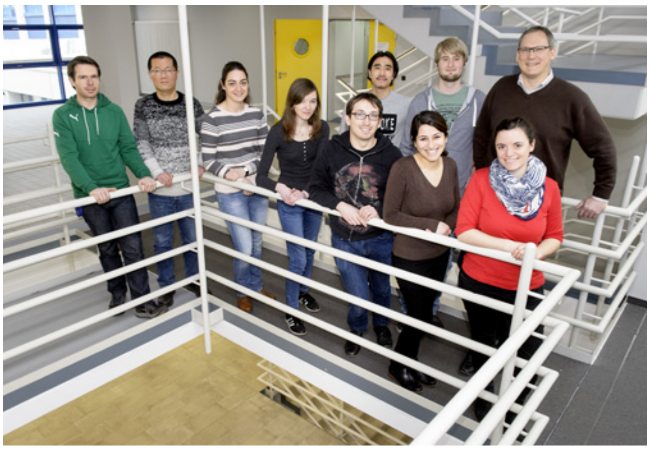
Fig. 1: Bioinspired micropatterned adhesive as platform of patented Gecomer Technology.
Fig. 2: Demonstration of adhesion performance.

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 Strukturierung und Funktionalisierung von Oberflächen und das Verständnis physikalisch-chemischer Mechanismen von Reibung und Verschleiß. Die experimentellen Projekte basieren auf unserer Expertise in der hochauflösenden Rasterkraftmikroskopie. Auch auf größeren Längenskalen werden grundlegende Experimente zu Reibung und Verschleiß durchgeführt, zum Beispiel an Polymermaterialien oder an Proben, die mit der INM-eigenen Gecomer-Technologie hergestellt wurden. Mit letzteren wurden vor allem neue Projekte zur haptischen Wahrnehmung von Materialien entwickelt. Zu den wichtigsten Ergebnissen des Jahres 2017 gehören Nachweise der elektrochemischen Schaltbarkeit von Viskosität in ionischen Flüssigkeitsfilmen sowie der Korrelation von Reibungsstimuli an der menschlichen Fingerspitze mit EEG-Signalen.



MISSION

The Program Division *Nanotribology* explores new materials with specific adhesion and friction properties. We focus on surface functionalization and on understanding the physical chemistry of friction, wear, and lubrication. The experimental projects rely on our expertise in the field of high-resolution force microscopy. Fundamental tribology experiments also address larger length scales, in particular on polymer tribomaterials and on samples produced by means of INM-manufactured Gecomer technology in collaboration with the Program Division Functional Microstructures. New projects have been initiated in the field of haptic perception of materials, where fingertip friction is explored as a key input parameter.

CURRENT RESEARCH

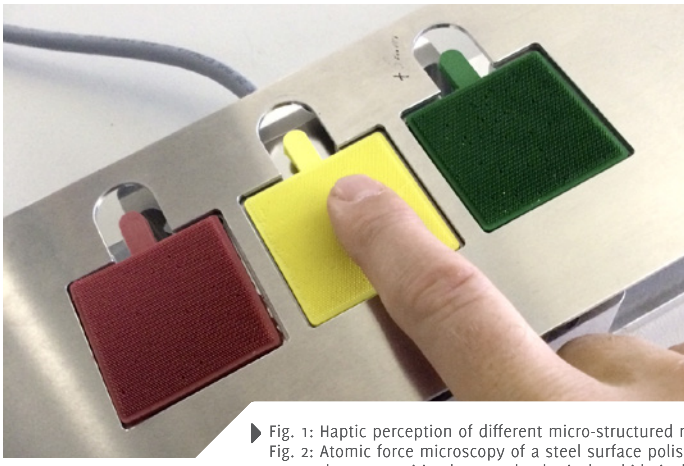
The following examples describe research results which led to publications in international research journals:

Switching viscosity in nanometer-confined ionic liquids

As a contribution to the Faraday Discussions "Chemical Physics of Electroactive Materials", we reported on a nanorheological experiment, based on atomic force microscopy in an electrochemical cell. We demonstrated that the viscosity of an ionic liquid in nanometer-scale confinement depends critically on the charge state of the confining walls. The study was performed in collaboration with Jun.-Prof. Hausen, *RWTH Aachen and Forschungszentrum Jülich.*

Understanding the rate dependence of friction by multivalent reversible bonds

In 2017, three publications in peer-reviewed journals describe the dynamics of friction caused by the cooperative action of tens of reversible macromolecular bonds. We found that the force measured for the detachment of a single molecular bond depends on the stiffness of the force sensor, an effect which reflects the dynamical rebinding of broken bonds. We also demonstrated the specific friction properties of surfaces decorated with shape-resistant polymers, which interacted by cyclodextrin-based inclusion complexes. Finally, we reported unexpected strong friction in the limit of very low sliding velocities and explained the effect with an aging of the contact between flexibly attached molecular binding sites. All publications have been prepared jointly with the Chair of Macromolecular Organic Chemistry at Saarland University.



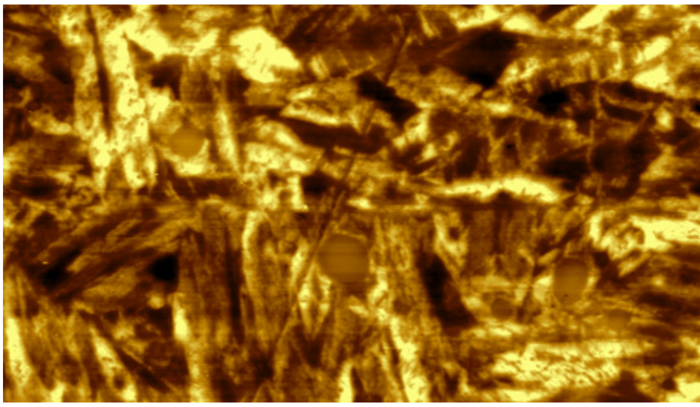


Fig. 1: Haptic perception of different micro-structured rubber samples mounted to force sensor for recording friction forces.
Fig. 2: Atomic force microscopy of a steel surface polished to nanometer roughness for lubrication experiments. Needles of the martensitic phase and spherical carbide inclusions can be distinguished.

Tribology of a Braille display and EEG correlates

Haptic perception is an emerging field of science. We have started our own projects based on psycho-physical experiments which explore the relation between physical aspects of the skin-material interaction and the individual perception thereof. Complementary to experiments involving conscious perception, we have presented results for a fingertip friction experiment, where participants took a passive role. Friction stimuli were delivered to the fingertip by means of a Braille display. EEG signal fluctuations were recorded from the scalp of participants and correlated with the friction signal. We were able to reproducibly detect event-related potential waves within 140 milliseconds after a change of friction. The novel method has significant potential for studying the influence of individual attention in haptic perception. This project is the result of a collaboration with Prof. Strauss, Systems Neuroscience & Neurotechnology Unit at Saarland University and htw saar.

OUTLOOK

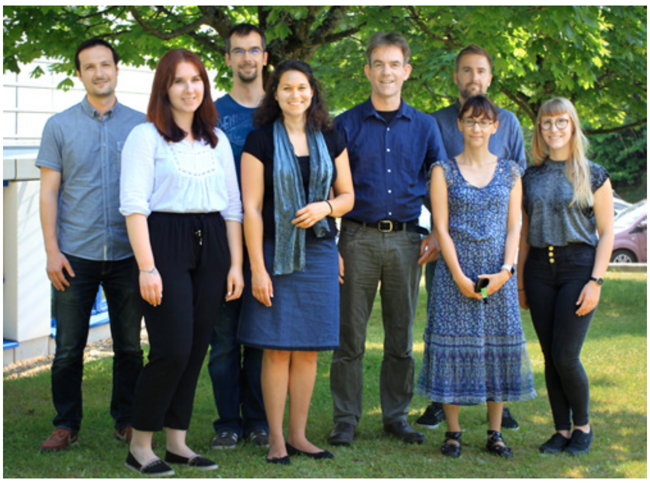
We will continue to investigate the mechanisms which link the structure and the dynamics of surfaces to friction and wear in new materials. Our current projects include studies of nanometer-scale adhesion and stiffness at the interface between hydrogels and buffer solutions in collaboration with the Program Division *Dynamic Biomaterials*, studies of scratch mechanisms in polymeric tribomaterials in collaboration with Kaiserslautern University, and studies of molecular mechanisms in liquid lubrication, including additives suggested by industrial partners. We will strengthen our activities in tribochemistry, investigating the interplay of mechanical and chemical processes in sliding contacts. Our research on haptic perception of material properties will be further developed in collaboration with the Departments of Psychology and of Computer Science at Saarland University.

INNOVATIVE ELEKTRONENMIKROSKOPIE / INNOVATIVE ELECTRON MICROSCOPY

PROF. DR. NIELS DE JONGE

ZUSAMMENFASSUNG

Eine nanometergenaue Materialcharakterisierung ist unabdingbar für die Weiterentwicklung der modernen Nanotechnologie und der Biologie. Der Programmbereich *Innovative Elektronenmikroskopie* betreibt interdisziplinäre Forschung an der Schnittstelle der Physik der Elektronenmikroskopie (EM), Biophysik, Materialwissenschaft, Zellbiologie und Bildverarbeitung. Wir entwickeln modernste Techniken im Bereich in situ Transmissions-EM (TEM) und Raster-TEM (STEM) für die Forschung an funktionellen Materialien und biologischen Systemen unter realen Bedingungen und untersuchen neue Wege für die dreidimensionale Datenaufnahme. Die Gruppe verfügt über langjährige Erfahrung mit Bildverarbeitung sowie mit der Entwicklung von Protokollen für spezifische Proteinmarkierung mit Nanopartikeln. Dem Programmbereich steht unter anderem ein hochmodernes JEOL ARM200-Elektronenmikroskop zur Verfügung. Wir haben vielfältige Forschungskooperationen mit diversen Universitäten und der Industrie.



MISSION

Nanoscale characterization is essential for the development of modern nanotechnology, energy science, biology, and biomedicine. Our Program Division conducts interdisciplinary research at the interface of physics of electron microscopy, biophysics, materials science, cell biology, and image processing being world leading in the area of liquid-phase electron microscopy. We develop state-of-the-art *in situ* transmission electron microscopy (TEM) and scanning TEM (STEM) methods for the study of functional materials and biological systems at realistic conditions, mostly using a liquid flow system. The group is also exploring new routes for 3D data acquisition using intelligent STEM and image reconstruction strategies. We have extensive experience with image processing and developing protocols for specific labeling of proteins with nanoparticles. The group houses a state-of-the-art electron microscope (ARM200, JEOL). Various collaborations exist with both academia and industry.

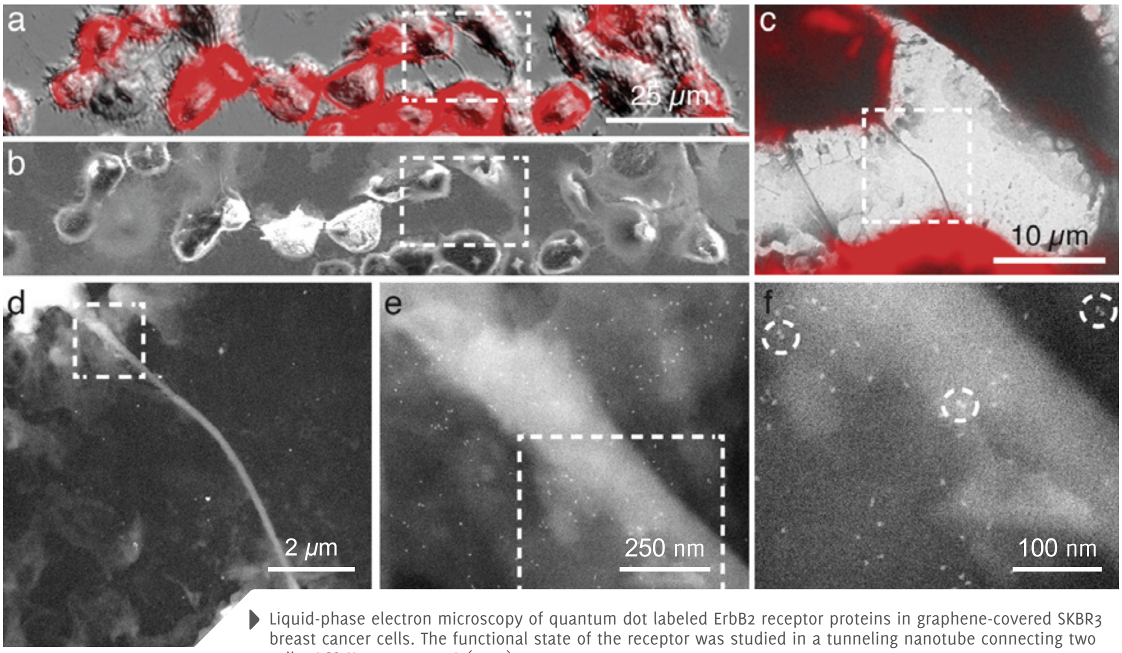
CURRENT RESEARCH

Growth factor receptors in cancer cells

We study the growth factor receptor HER2 at the single-molecule level within whole breast cancer cells in liquid, analyzing differences in protein function between individual cancer cells. A highlight was a publication on the effect of cancer drugs on small sub-populations of cells (Mol. Biol. Cell 2017). We have also developed a new way to enclose cells in liquid by covering with a graphene sheet (ACS Nano 2017). This research is conducted in collaboration with Prof. Wiemann, German Cancer Research Center, Heidelberg, and Prof. Solomayer, Saarland University Hospital, Homburg, and funded by the Else Kröner-Fresenius-Stiftung.

Stoichiometry of calcium channels

Liquid STEM is used to study the stoichiometry of Ca^{2+} channels formed by ORAI proteins in mam-



Liquid-phase electron microscopy of quantum dot labeled ErbB2 receptor proteins in graphene-covered SKBR3 breast cancer cells. The functional state of the receptor was studied in a tunneling nanotube connecting two cells. ACS Nano 11, 11108 (2017).

malian cells. The relative ratio of the various ORAI channels is highly relevant for cell function. This project is conducted together with Prof. Niemeyer, Saarland University, Homburg, and is part of the SFB Collaborative Research Center 1027 in cooperation with the Junior Research Group *Cytoskeletal Fibers*. We also cooperate with Prof. Flockerzi, Saarland University, Homburg, and published on another ion channel (J. Struct. Biol. 2017).

MULTIMAT

We are partner in the MARIE SKLODOWSKA-CURIE ACTIONS Innovative Training Network project "A multiscale approach towards mesostructured porous material design", headed by Prof. Sommerdijk, TU Eindhoven, Netherlands. Our role is to expand the application area of liquid-phase electron microscopy to image self-assembly of soft matter.

Studying the behavior of nanomaterials in liquid

Dynamic processes at the solid-liquid interface are studied with TEM and STEM at the nanoscale. We have discovered that nanoparticles in close proximity of a surface do not move as predicted by Brownian motion but many orders of magnitude slower. Various other nanoscale phenomena have been found. For example, silica nanoparticles changed their shape anisotropy under electron beam irradiation (Small 2017). We have research interactions with the Program Division Structure Formation.

3D STEM

We are innovating in 3D STEM for obtaining nanometer resolution in micrometer-thick specimens. The project is a cooperation with Dr. Dahmen, German Center for Artificial Intelligence, Saarbrücken. INM-focus projects.

Liquid-phase electron microscopy is used to study corrosion of steel covered with zinc phosphate flake-type particles in the project NANOCORR (cooperation with *Nanomers*). We also study possible interaction of integrin with HER2 in the project SOCIEB cancer cells (with *Dynamic Biomaterials*).

OUTLOOK

The IEM group is well prepared to conduct research at the international forefront of electron microscopy in the areas of biology/biophysics and materials science. Future aims are to study processes of protein complexes, to develop a Liquid STEM into a standard characterization method for membrane proteins in cells, to study HER2 in gastric cancer, to improve the time-resolution of *in situ* STEM via adaptive sampling techniques, and to develop Liquid 3D STEM.

Jiaxi Cui
Head *Switchable Microstructures*
Aránzazu del Campo
Head *Dynamic Biomaterials*

"OUR RESEARCH FIELD DEVELOPS POLYMERS AND CELLULAR MICRO-ENVIRONMENTS MIMICKING THE DYNAMIC PROPERTIES OF NATURAL TISSUES. WE USE THEM TO RECREATE CELL SCENARIOS OF BIOMEDICAL RELEVANCE. OUR RESULTS WILL CONTRIBUTE TO NEW BIOMEDICAL APPLICATIONS."

Franziska Lautenschläger
Head *Cytoskeletal Fibers*

Annette Kraegeloh
Head *Nano Cell Interactions*

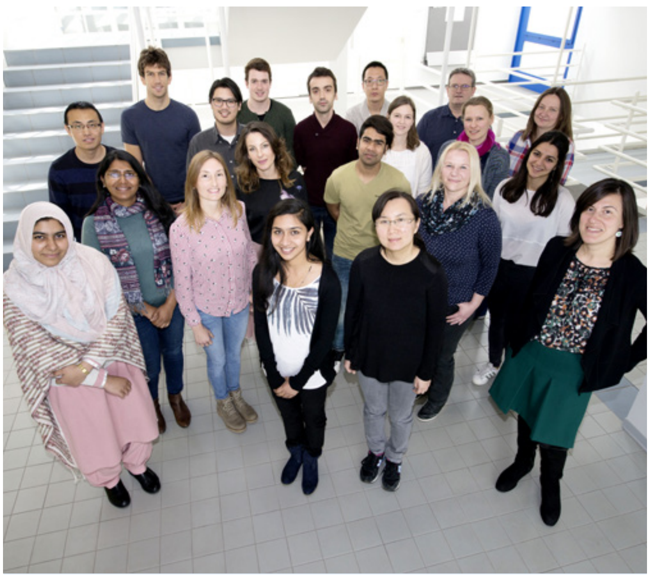
BIOGRENZFLÄCHEN / *BIO INTERFACES*

DYNAMISCHE BIOMATERIALIEN / DYNAMIC BIOMATERIALS

PROF. DR. ARÁNZAZU DEL CAMPO

ZUSAMMENFASSUNG

Der Programmbereich *Dynamische Biomaterialien* entwickelt zellinstruktive Materialien, die in der Lage sind, das zelluläre Verhalten zu steuern. Die Eigenschaften dieser Materialien ähneln den Eigenschaften der natürlichen Gerüste in Geweben. Wir nutzen synthetische Photoschalter und photoresponsive biologische Prozesse, um Materialien mit latenten Funktionalitäten zu entwickeln, die mittels Licht aktiviert werden können. Auf diese Weise können Eigenschaftsänderungen ganz nach Bedarf mit präziser räumlicher und zeitlicher Kontrolle angeschaltet, verstärkt, oder abgeschaltet werden. Diese Änderungen ahmen den evolutionären und adaptiven Charakter lebender Materie nach. Unsere dynamischen Materialien werden genutzt um spezifische Zellprozesse *in vitro* und *in vivo* zu steuern und zu untersuchen. Denkbar ist auch eine Nutzung als fortgeschrittene Gerüste für prädiktivere Gewebemodelle, als effizientere instruktive Matrizen für die Gewebetechnik und als Träger höherer Verpflanzungsverhältnisse in der Zelltherapie.



MISSION

The Program Division *Dynamic Biomaterials* develops cell-instructive materials able to guide cellular's fate. These materials resemble the properties of the natural scaffold in tissues. We exploit synthetic phototriggers and photoresponsive biological processes to design materials with latent functional levels that can be unlocked upon light exposure. Property changes can be initiated, reinforced, or terminated on demand with precise spatiotemporal control. These changes mimic the evolutionary and adaptive character of living matter. Our dynamic materials are used to guide and study specific cell processes *in vitro* and *in vivo*. They are envisioned as advanced scaffolds for more predictive tissue models, as more efficient instructive matrices for tissue engineering and carriers for higher engraftment ratios in cell therapies.

CURRENT RESEARCH

A few highlights of the research work in *Dynamic Biomaterials* follow:

Biomaterials that optoregulate matrix- and cell-cell interactions

New biofunctional hydrogels with tunable mechanical properties and ligand type were developed and applied to regulate relevant celluler processes, i. e. to accelerate differentiation or guide positioning of neuronal stem cells. Using new photoactivatable angiogenic factors and multiphoton excitation, controlled formation of blood vessel within a 3D gel in desired geometries was realized, as a first step to light-regulated angiogenesis in regenerative contexts (cooperation with UKS, Experimental Surgery). The relationship between cell-biomaterial adhesive interactions and growth factors was studied in cooperation with the Program Division *Innovative Electron Microscopy* (Focus Project 2017) and within the EU FET Project *Mechanocontrol*. Finally, biomaterials integrating matrix and cell binding signals were developed in order to recreate additional features of natural environments in artificial models, and support *in vitro* culture of scarce primary cells.

Hydrogel formation at physiological conditions and 3D Bioprinting

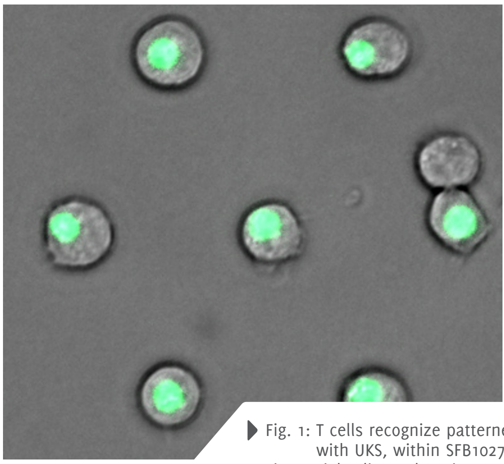
Biomaterials for cell encapsulation and for 3D bioprinting are a focus of our research. In both cases, effective chemistries for rapid crosslinking and biofunctionalization under mild conditions are necessary. The group performed fundamental research in new reactants and polymer architectures and also application-oriented research within substantial long-term cooperation projects with the cosmetic industry. One of the systems developed in the group was presented to the "Evonik Call for Research Proposals 2017" and obtained the 2nd prize. Special effort is devoted to the application of these materials as new inks for 3D bioprinting scaffolds and in cell constructs for medical applications.

Immunointeractive materials

The group strongly cooperated with Biophysics at UKS within the SFB1027 to study the role of mechanical factors in the activation of immune cells, and the design of biomaterials able to stimulate T cell responses. The nomination of Dr. Bin Qu from UKS as INM Fellow will allow additional exchange in this topic. In collaboration with *Cytoskeletal Fibers*, new tools to study the role of the cytoskeleton in this process were developed.

OUTLOOK

The development of optoregulated cellular microenvironments remains a major topic in the group. The synthetic toolbox is moving from pure organic synthesis to biochemical approaches, and from phototriggers to natural optical switches. Progress on the biomaterial side involves implementation of 3D Printable Bioinks and development of cocultures with customized environments for the different cell types. The focus of the group is currently set to the development of biomaterials supporting tissue regeneration. However, we envision to apply tissue engineering concepts to recreate biological materials in vitro, breaking the classical border between synthetic and biosynthetic approaches in biomaterials science. These efforts drive the alignment of *Biointerfaces* Research Field into Biomedical Materials, declared by INM as future perspective area in the Evaluation 2017.



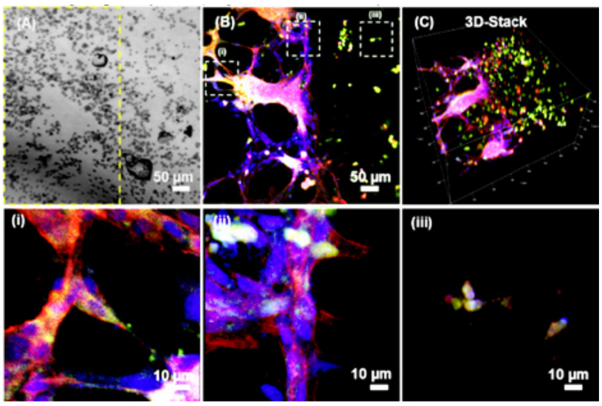


Fig. 1: T cells recognize patterned ligands on an artificial surface and get activated for killing (in cooperation with UKS, within SFB1027).
Fig. 2: Light-directed angiogenesis in a 3D gel seeded with endothelial cells.

SCHALTBARE MIKROFLUIDIK / SWITCHABLE MICROFLUIDICS

DR. JIAXI CUI

ZUSAMMENFASSUNG

Die Juniorforschungsgruppe *Schaltbare Mikrofluidik* wird durch das Projekt „Bio/Synthetische Multifunktionale Mikro-Produktionseinheiten“ im Rahmen eines Leibniz Research Clusters gefördert. Ziel der Gruppe ist es, mit neuen polymerbasierten Materialien und Herstellungsverfahren auf neue Bedürfnisse in Gebieten wie Biosynthese und Biomedizin zu reagieren. Molekulares Design, organische Synthese und modernste Technologien zur Polymerisation ermöglichen die Entwicklung klar definierter Materialien. Außerdem nutzen wir Molekulartechniken wie Selbstorganisation und molekulare Wiedererkennung zur Herstellung funktionaler Oberflächen für die Übertragung von Flüssigkeiten und zur Kontrolle von Oberflächenhaftung und Reibung. Unser nächstes Ziel besteht darin, die Polymerisationstechniken von der molekularen auf die makroskopische Ebene auszuweiten und so eine neue Art von wachsenden Polymermaterialien zu entwickeln, die simultane Kontrolle über mechanische Eigenschaften, Zusammensetzung, Größe und Form ermöglicht.

MISSION

The Program Division *Switchable Microfluidics* is supported by the project “organic/synthetic multifunctional meso-production units” of Leibniz research cluster (LRC). It aims to develop novel polymer-based materials and manufacture approaches to make switchable structural surfaces for meeting emerging needs in biosynthesis, biomedicine, and other areas. To this end, we start from molecular design and organic synthesis, apply advanced polymerization technologies to get well-defined materials, and study their properties such as mechanical strength, responsiveness to external stimuli, and dynamic behavior. We apply molecular engineering approaches including self-assembly, molecular recognition, and others, to fabricate smart surfaces for transferring liquid, as well as controlling surface adhesion and friction. On the other hand, we intend to amplify the living/controlled polymerization skills from molecular to macroscopic level to develop a new class of growing polymer materials that permits simultaneous and unprecedented levels of control over mechanical properties, composition, size, and shape of the samples.

CURRENT RESEARCH

Switchable microreactor platform

We develop switchable meso-structural surfaces as micro-reactor platforms that allow for the control of reaction pathways. The project is inspired by the compartmentalized synthetic strategy in living cells: chemical reactions initiated under defined conditions conclude at the required degree with the desired product being automatically transferred to the next reaction compartment. To mimic this, we designed a complex structure with a meso-structural surface, geometrically arranged hollow pillars and a soft actuating system to switch the channels. In 2017, we developed a class of magnet-responsive systems of this type (Fig. 1). These structures allow for liquid pumping out through the channel, triggering a reaction by bending the pillars, and collecting the product through another channel.

Earthworm-inspired low friction films

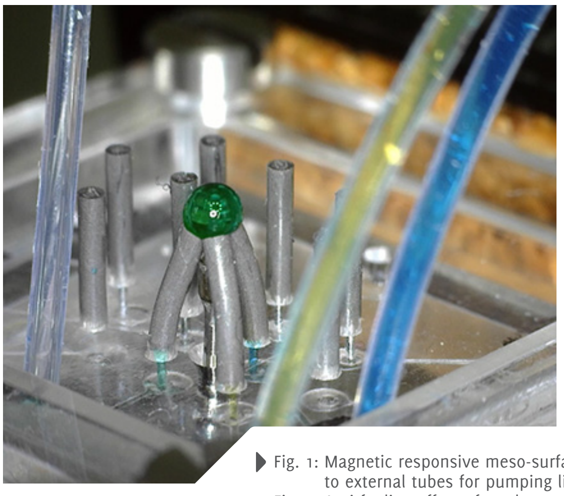
The investigation of natural systems can provide novel strategies to materials development. Earthworms exhibit the extraordinary ability to reduce friction and adhesion due to their rough skin and sustained secretion ability allowing for fast formation of a lubricant film. We designed and prepared rough polymer coatings by breath figure method. These earthworm-inspired coatings have a textured surface while storing lubricant in the bulk polymer. Under external stimuli such as normal or shear stresses, the lubricant is quickly released and forms a lubricant film, reducing friction efficiency (Fig. 2). The secretion process is site-specific and sustained. The coatings also show resistance to wear- and are self-cleaning. This strategy is promising for applications in solid environment and for biomedicine devices such as gastroscopes.

Self-reshaping hydrogels

Hydrogels from dynamic polymer networks show interesting properties such as continual deformation and self-healing. We developed a class of dynamic hydrogels consisting of two non-covalent crosslinking interactions, hydrophobic association and ion-coordination. The weak hydrophobic association is offered by the hydrophobic alkyl side chains of one comonomer while the strong ion-coordination interaction is formed through Fe(III) and another comonomer acrylic acid. These two interactions form a tough hydrogel: hydrophobic association and the ion-coordination interaction maintain the shape and strengthen the sample. With these interactions competing, a self-reshaping process is observed in the hydrogel. This strategy of competition-induced mass transfer might offer new ways to build interesting structures that could not be made in traditional ways.

OUTLOOK

We will continue the development of meso-structural surfaces with specific attention to the technologic approach on a large scale, further study the underlying mechanism of the competition between two non-covalent interactions on the control of hydrogel shape, and develop a new fashion of growing polymers by applying this concept to other polymer systems. Finally we will demonstrate their advantages compared to current technologies, such as 3D printing, and their ability to self-healing.



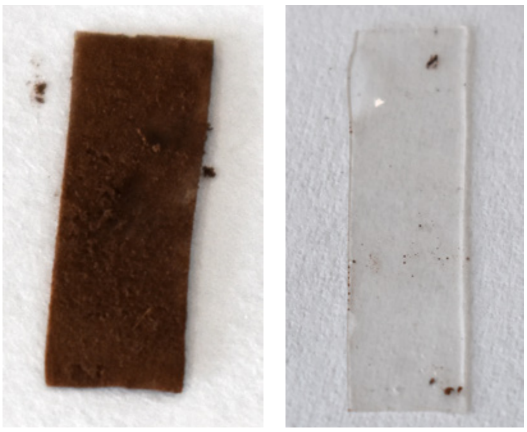


Fig. 1: Magnetic responsive meso-surface with middle magnet to control bending and hollow pillars connected to external tubes for pumping liquid solutions.
Fig. 2: Anti-fouling effect of earthworm-inspired coatings (PDMS-based gel film, right) with a normal PDMS-based coating as control (left).

ZELLSKELETALE FASERN / CYTOSKELETAL FIBERS

JUN.-PROF. DR. FRANZISKA LAUTENSCHLÄGER

ZUSAMMENFASSUNG

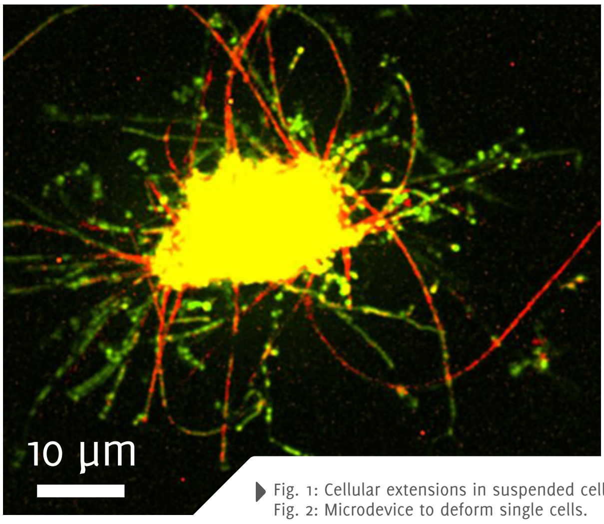
Seit Januar 2017 beschäftigt sich die Juniorgruppe *Zellskeletale Fasern* mit Polymeren innerhalb von Zellen, welche das Zytoskelett bilden. Dabei ist besonders die Dynamik und der Aufbau dieser Fasern von Interesse, zum Beispiel während Immunzellen migrieren oder Krebszellen adhärieren. Das Zytoskelett der Zelle spielt eine entscheidende Rolle für die Kommunikation zwischen Zelle und extrazellulärer Matrix oder Biomaterialien. Diese Schnittstelle ist die Basis für die enge Kooperation mit dem Programmbereich *Dynamische Biomaterialien*. Um dynamisch variierbare Umgebungen für Immunzellen zu schaffen, arbeitet die Juniorgruppe ebenfalls eng mit der Juniorforschungsgruppe *Schaltbare Mikrofluidik* zusammen. Zudem werden die mechanischen Veränderungen von Immunzellen und deren Zytoskelett nach dem Kontakt mit Nanopartikeln oder hochauflösende Aufnahmen des Zytoskelettes in Kooperationen mit den Programmbereichen *Nano Zell Interaktionen und Innovative Elektronenmikroskopie* untersucht.

MISSION

Since January 2017, the Junior Research Group *Cytoskeletal Fibers* has been investigating polymers within cells, which are forming the cytoskeleton. The group is especially interested in actin and intermediate filaments and the interaction between them as well as alterations of the cytoskeleton due to external influences. Furthermore, it is necessary to understand the dynamics and the structure of the fibers in order to understand cellular mechanisms, for example, how immune cells migrate or how cancer cells adhere to a substrate. The cytoskeleton plays a crucial role in the communication between cells and the extracellular matrix. This interface is the basis of the close collaboration with the Program Division *Dynamic Biomaterials*. In order to render the environment of immune cells variable and adaptable, the group additionally works together with the Junior Research Group *Switchable Microfluidics*. Furthermore, cytoskeletal and mechanical changes of immune cells after the contact with nanoparticles are investigated in collaboration with the Program Division *Nano Cell Interactions*.

CURRENT RESEARCH

In the beginning of 2017, the group set up the laboratory and hired new scientists while continuing their close relationship with Saarland University and tying further bonds between both institutions.



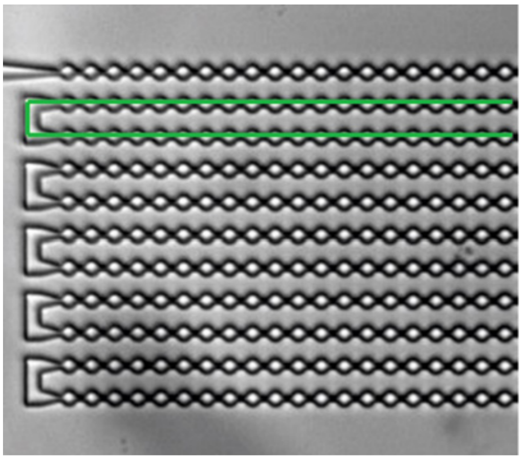


Fig. 1: Cellular extensions in suspended cells.
Fig. 2: Microdevice to deform single cells.

The group worked on a number of projects:

Investigation of the filament vimentin on the migration of immune cells

Particularly, it was tested if the lack of vimentin reduces the integrity of cells and renders cells more vulnerable to external deformation, e. g., whether cells die when migrating through very small pores.

Structure and dynamics of the actin cortex during the adhesion of cells

This project is part of the SFB 1027 and is carried out in collaboration with the Program Divisiona *Dynamic Biomaterials* and *Innovative Electron Microscopy*. Here, the group showed that the dynamics of the actin cortex measured by fluorescence recovery after photobleaching (FRAP) is different depending on the adhesion state of cells. Imaging of this cortex in high resolution was started in collaboration with the SEM facility of the INM, which resulted in images that require a thorough further quantification.

Testing of the effect of nanoparticles on the mechanical properties of immune cells

In this project (collaboration with *Nano Cell Interactions*), the group *Cytoskeletal Fibers* showed that immune cells which had been in contact with nanoparticles took longer to pass small channels with constrictions. This result strongly suggests a change in the mechanical properties of cells after nanoparticle contact.

Influence of microtubules on the adhesion of circulating tumor cells

The theoretical part of this project is performed in collaboration with Saarland University in the frame of the project SFB 1027. Within the experiments it was surprising to find microtubule extensions in suspended cell types other than circulating tumor cells. These effects will be quantified now and the influence of cytoskeletal drugs on these extensions will be tested.

OUTLOOK

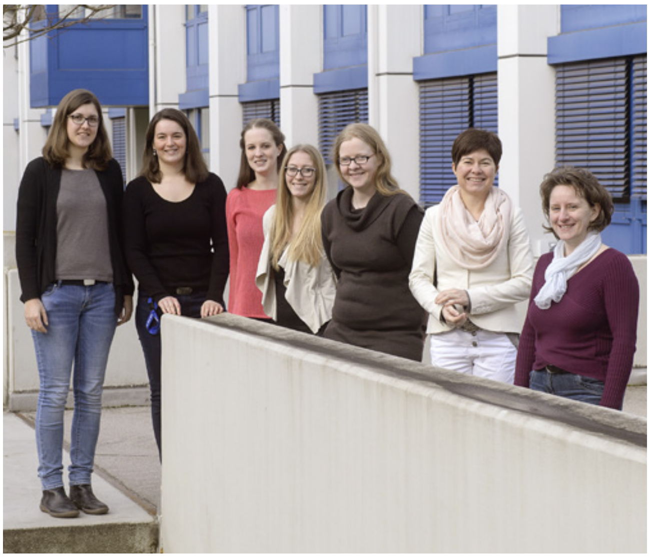
The Junior Research Group *Cytoskeletal Fibers* is well prepared to perform internationally leading research on cells, their internal cytoskeleton and its reaction towards external factors such as chemical adhesion or physical forces. In the future, the group will add further aspects to their scientific portfolio, such as the interaction of cytoskeletal elements and how they can be influenced by currently unknown natural components. The group is particularly interested in the interactions between actin and the intermediate filament vimentin. Furthermore, it will work on the effect on cytoskeletal elements when cells get strongly deformed. In collaboration with the Junior Research Group *Switchable Microfluidics*, the group plans to create cell culture conditions in which it is possible to precisely tune the time and location of a chemical release.

NANO ZELL INTERAKTIONEN / NANO CELL INTERACTIONS

DR. ANNETTE KRAEGELOH

ZUSAMMENFASSUNG

Der Programmbereich *Nano Zell Interaktionen* beschäftigt sich mit den Auswirkungen technisch hergestellter Nanoobjekte auf menschliche Zellen, um 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 Untersuchungsobjekte werden Nanopartikel aus anorganischen Materialien gezielt hergestellt und charakterisiert. Zur Lokalisation von Partikeln und Zellstrukturen werden vor allem lichtmikroskopische Techniken, zum Beispiel hoch-auflösende Stimulated Emission Depletion (STED)-Mikroskopie, eingesetzt. Zur weiteren 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 to enable safe applications of nanomaterials in technical and biomedical fields. It strives to understand how particle properties influence structure and biochemistry of the cells and to elucidate mechanisms that affect the 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 are prepared and characterized. Light microscopy techniques, for example Stimulated Emission Depletion (STED) microscopy, are used to localize particles and to analyze cellular structures. Further chemical, biochemical, and molecular biological techniques are used for the analysis of the cellular responses.

CURRENT RESEARCH

Protein-doped silica nanoparticles

Fluorescently labeled nanoparticles are useful tools for bioimaging, in particular in the field of nanosafety research. Beyond bioimaging, protein-doped silica nanoparticles constitute a promising tool in the field of intracellular protein delivery. We developed a novel approach for the preparation of green fluorescent protein (GFP) doped silica nanoparticles with a narrow size distribution. The incorporation of the protein into the silica matrix not only increased the quantum yield as compared to pure GFP, but also enhanced its photostability and resistance against thermal or enzymatic treatment. In addition, the protein doped nanoparticles seemed to achieve a higher intracellular delivery and reduced intracellular degradation as compared to the pure protein.

Morpheus – a test platform for the safety of nanomaterials

The ZIM (Central Innovation program for small and medium-sized enterprises) project "Morpheus" aims at developing a multiparametric test platform for an early hazard assessment of nanoparticles. This platform is based on 3D liver microtissue and combines the quantification of metabolic and functional markers. Current investigations aim at elucidating the effects of nanoparticles and drugs on the activity and expression of cytochromes P450 as indicators for liver function. Further efforts aim at demonstrating the use of morphology markers as indicators of nanoparticle effects on liver tissue. Combined with information on the location and metabolic activity of nanoparticles, the platform will allow a comprehensive analysis of nanoparticle effects on liver specific functions, which is interesting for pharmaceutical and food applications.

Safe nanomaterials developments

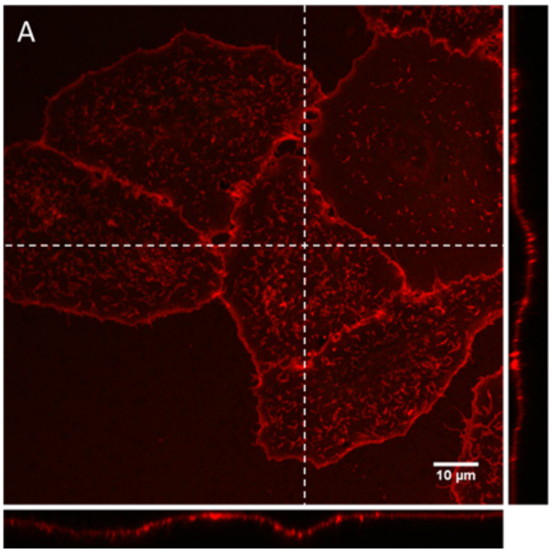
In frame of the Horizon 2020 project "NanoReg2", the group, in cooperation with the *Innovation Center INM*, is involved in safe-by-design approaches in the context of regulatory aspects. Recently, a general scheme of the application of safe-by-design and considerations of functionality and safety aspects during innovation processes, based on the "Cooper stage gate model", has been elaborated. As a basis, safe-by-design principles that are applicable to the development of nanomaterials and nanoproducts have been drafted. The safe-by-design concept aims to reduce risks of nanomaterials to human and environmental safety and health.

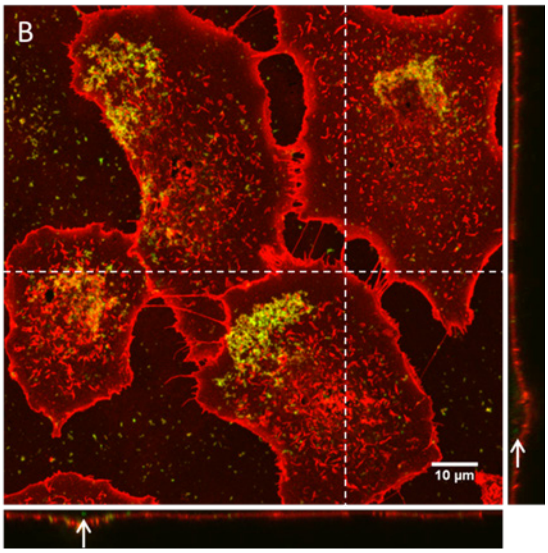
Leibniz-Research Alliance Nanosafety

Within the *Leibniz-Research Alliance for Nanosafety* coordinated by INM, the group is currently involved in studies on the mechanisms of nanomaterials toxicity, the localization of nanoparticles in tissues, the development of a microscopy-based test platform as well as the reception of nanosafety issues by the public.

OUTLOOK

A real understanding of the mechanisms involved in the generation of nanomaterial effects on cells, tissues or even human health demands understanding of the involved physical, chemical, and biological mechanisms. One important aspect is the correlation between the location of the nanomaterials and the induced response on a cellular and tissue level. Therefore, one main objective of future work is to further develop and optimize light microscopy-based testing platforms including analysis of the nanomaterial location within the cellular context. More general objectives are to contribute to the development of safe nanomaterials and to strengthen the biomedical application potential of nanomaterials.





Confocal microscopy images of A549 cells after 24 h exposure to GFP (A) and GFP-doped nanoparticles (B). Cell membrane: red; GFP: green.


Carsten Becker-Willinger
Head *Nanomers*
Peter W. de Oliveira
Head *Optical Materials*

"OUR RESEARCH FIELD DESIGNS NEW COMPOSITES WITH FUNCTIONALIZED PARTICLES THAT TUNE E. G. OPTICAL, ELECTRONIC OR PROTECTIVE PROPERTIES. OUR MATERIALS CAN REACT TO EXTERNAL STIMULI OR CHANGE THEIR PROPERTIES WHEN REQUIRED. IN COOPERATION WITH INDUSTRY, WE ADAPT AND TRANSFER THEM TO THE MARKETS."

Tobias Kraus
Head *Structure Formation*

NANOKOMPOSIT-TECHNOLOGIE / *NANOCOMPOSITE TECHNOLOGY*

NANOMERE / NANOMERS

DR.-ING. CARSTEN BECKER-WILLINGER

ZUSAMMENFASSUNG

Der Programmbereich *Nanomere* entwickelt multifunktionelle Schutzschichten, Kompaktwerkstoffe sowie Materialien für additive Fertigungsverfahren auf Basis von Kompositen mit organischen und hybriden organisch-anorganischen Matrizes sowie nano- und mikroskaligen, funktionellen Verstärkungselementen. Neue Werkstoffeigenschaften sollen auch für industrielle Anwendungen nutzbar gemacht werden. Als partikuläre und anisotrope funktionelle Füllstoffe sind keramische oder metallische Additive besonders interessant. Sie erlauben mit einer maßgeschneiderten Partikel-Matrix-Grenzfläche den Transfer festkörperphysikalischer Eigenschaften anorganischer Materialien in Polymere und Beschichtungen. Schwerpunkt der Aktivitäten sind schwermetallfreie, aktive Korrosionsschutzsysteme, feinstrukturierte Gleitlacke, Antifouling-Funktionen für Wärmetauscher, temperaturbeständige Bindemittel, transparente, selbstheilende Beschichtungen und Materialien für die additive Fertigung.

MISSION

Activities of the Program Division *Nanomers* comprise the development of functional coatings and bulks based on the polymer matrix composite concept. A strong focus is put on application oriented projects for materials used in industry. Functions of interest are corrosion protection, fine structured low friction coatings, antifouling coatings for heat-exchanger systems, temperature binders, and transparent self-healing surfaces. Fields of application are in electronics, medical applications, optics, automotive, construction, engineering as well as additive manufacturing.

CURRENT RESEARCH

Heavy metal free corrosion protection

The EU-project WELDAPRIME on development of sol-gel derived nanocomposite coatings for intermediate corrosion protection of mild steel was finalized successfully. As a follow-up, the INM focus project “Nanocorr” (with *Innovative Electron Microscopy*) started in 2017. It aims at allowing a deeper understanding of early stage steel corrosion processes in the presence of zinc-phosphate flake-type particles. This should help to design new types of heavy metal free coatings with active corrosion protection mechanisms. In parallel, the corrosion protection behavior of the flakes was investigated with Electrochemical Impedance Spectroscopy, potentiometric and standard corrosion tests. The results were presented at the TechConnect World Conference and EUROCORR 2017. A corresponding industry project on corrosion protection for steel used for metal fittings was started near the end of 2017.

BioPolyMed

The aim of the BMBF-project BioPolyMed (cooperation with the University Hospital Greifswald), which successfully passed a mid-term milestone, is the development of biodegradable catheters with anti-microbial surface modification. We were able to provide biodegradable polymer compositions that fulfill the requirements on mechanical and thermal properties as well as on biocompatibility. The last project phase should gain adjustment of the anti-microbial activity in combination with biodegradability and should lead to a catheter and a corresponding packaging foil with a great potential to minimize the risk of infection of patients in intensive care units.

Polyrotaxane based paints

The BMBF-VIP+-project Polyrotaxanlack focuses on a new class of materials to establish the concept of self-healing scratch resistant coatings as a technology platform. The approach is based on polyrotaxane based paints developed in close cooperation with Saarland University. Polyrotaxanes in combination with suitable cross-linkers and nanoparticulate additives lead to hard coatings that show complete self-healing when heated up to 90 °C. The pure polymers have been blended with organic-inorganic silane structures as well as nanoparticles in order to improve their mechanical properties while maintaining self-healing ability. (Fig. 1).

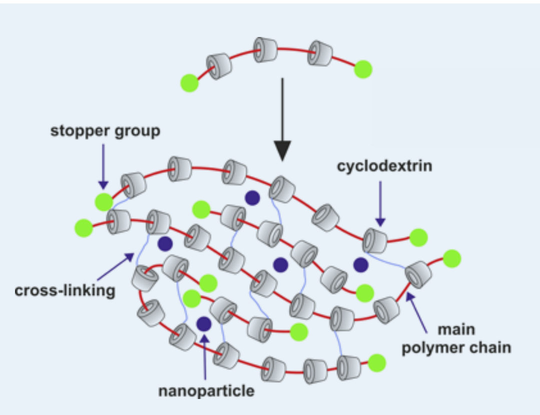
NaMiComp

The BMZ-GIZ-project NaMiComp with the University of Namibia (UNAM) focusses on the use of Namibia's locally available natural resources as a base for sustainable construction materials. Two expert visits were performed to train Namibian experts in synthesis and analytical methods and to plan a first materials research lab at UNAM as a nucleus for building up a materials science institute as a long-term goal.

In addition, an industrial development project for optimization and scale-up of a sol-gel based synthesis for inorganic pre-polymers for anti-adhesive layers used in printing machinery was performed in its final phase. The material will be transferred to production in 2018.

OUTLOOK

The polymer composite approach still has great potential to be used for tailored multifunctional coatings and bulk materials. Especially for self-healing coatings based on polyrotaxane slide-ring gels, the functionalized nanoparticles will provide the weathering ability necessary for practical use in outdoor applications. Furthermore, their addition will open new possibilities for further improving the mechanical strength of this class of materials. In addition, 3D-printable thermoplastic nanocomposites with engineering plastic matrices as well as 3D-printable hybrid materials based on reactive curing mechanisms will be developed.



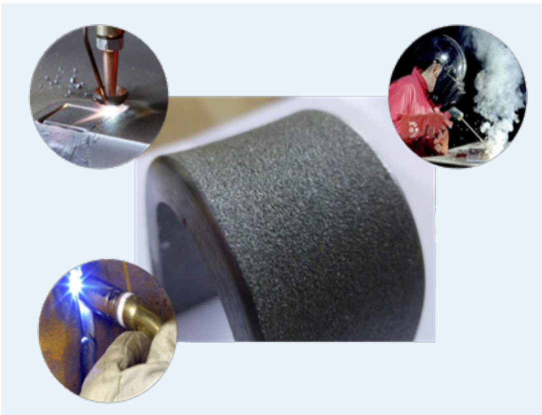


Fig. 1: Structure of the polyrotaxane based self-healing coatings: slide-ring gel with functional nanoparticles.
Fig. 2: Weldaprime – Environmentally friendly corrosion protection primer for mild steel (temporary protection) after mandrel bending test; welding, cutting and joining possible without removal of primer layer.

OPTISCHE MATERIALIEN / OPTICAL MATERIALS

DR. PETER W. DE OLIVEIRA

ZUSAMMENFASSUNG

Im Programmbereich *Optische Materialien* werden Beschichtungs- und Bulkmaterialien vorwiegend auf Nanokompositbasis entwickelt und optimiert, die ihre besonderen Charakteristika und Funktionalitäten durch die Interaktion mit elektromagnetischer Strahlung und speziell sichtbarem Licht erlangen. Der Arbeitsbereich der Gruppe reicht von Simulationsrechnungen über Materialsynthesen bis hin zur Anpassung bestehender und der Entwicklung neuer Applikations- und Strukturierungstechniken. Dabei werden Applikationsverfahren und Werkstoffe iterativ aufeinander angepasst. So werden neue Materialkonzepte entworfen, beispielsweise transparente, elektrisch leitfähige Materialien auf der Basis von Nb:TiO_2, welche über Sol-Gel Verfahren hergestellt werden. Weitere Beispiele sind dekorative, glasartige Schutzschichten oder die Herstellung leitfähiger Mikrostrukturen über die Photochemische Metallisierung mittels Stempelverfahren.

MISSION

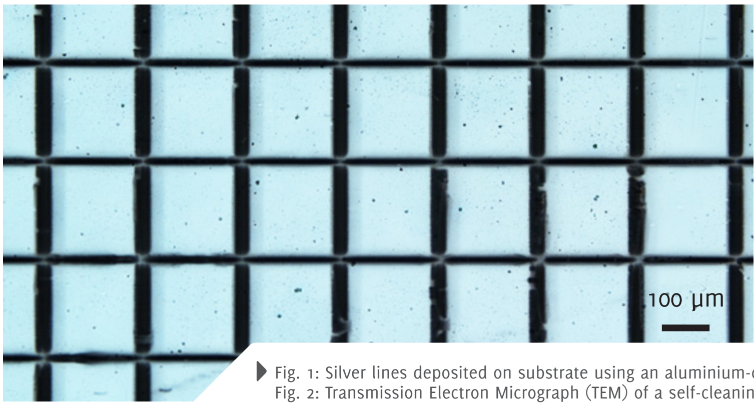
The Program Division *Optical Materials* develops and optimizes optical and electro-optical nano-composite materials for coatings and bulks, which obtain their special characteristics and functionalities through interaction with electromagnetic radiation and especially with visible light. The work area of the group ranges from simulation calculations, over materials developments, up to the adaptation of existing and the development of new application and structuring techniques. This approach opens new solutions for current material challenges. Also, we combine the requested physical properties such as refractive index, conductivity, absorption or light sensitivity with the chemistry to create new materials that fulfil the requirements of specific products and processes.

CURRENT RESEARCH

The following highlight topics were investigated in 2017:

Niobium-doped titanium dioxide nanoparticles

A new sol-gel-autoclavation process for niobium-doped titanium dioxide nanoparticles (nTNO) was developed. The nTNOs were synthesized with niobium (Nb) concentrations up to 20 wt. %. Pellets were pressed from the obtained powders and used as target for pulsed laser deposition (PLD) on borofloat substrates. Both coatings and pellets were analyzed regarding their resistivity. Pellets showed resistivities in the kΩ range, decreasing with increasing Nb concentration when measured as prepared. A treatment in air and forming gas increased the resistivity to low Ω-ranges. Furthermore, the



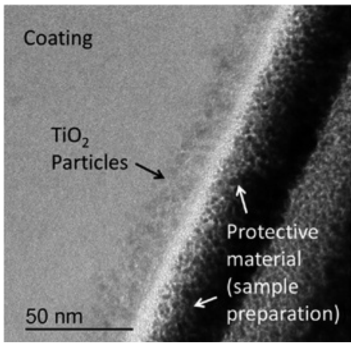


Fig. 1: Silver lines deposited on substrate using an aluminium-coated stamp (scale bar 100 µm).
Fig. 2: Transmission Electron Micrograph (TEM) of a self-cleaning coating on glass.

transmission of the TNO coatings was measured. The nTNOs will be applied in transparent conductive coatings.

Photochemical metallization

The photochemical metallization using a stamp process was further developed as an alternative for the vacuum-based processes for conductive microstructures for application as invisible circuitry for display technology and touch screens. We presented a novel method to fabricate silver microstructures on various substrates using polymer-made stamps with UV-absorbing or -blocking structured layers to screen the undesired parts of the stamp in order to have finer structures (fig. 1). This method will be further optimized for bigger stamps in order to scale up the process for application in a roll-to-roll device.

Self-cleaning coatings on glass surfaces

A spray coating procedure was developed for self-cleaning coatings on glass surfaces. The process employs a paint robot for large area application of sol-gel-materials containing hydrolyzed organo siloxanes and photocatalytic TiO_2 nano-particles. During wet coating and thermal curing, a gradient layer was formed with a SiO_2 matrix and a thin TiO_2 enriched part on top (fig. 2). The requirements for coated glass with respect to mechanical abrasion, weathering stability and classification as “class 1” self-cleaning coating (DIN 1096-5) were fulfilled by the INM material which is comparable to commercial CVD products.

OUTLOOK

The core strategy of the Program Division *Optical Materials* is the combination of optical effects, materials development and processing with a major focus on designing materials with addressable optical properties. *Optical Materials* selects application fields such as display technology, energy conversion, and active optics among others. Materials with novel optical functions like material that can be induced with virtual voxels (3D-Pixels) will increase in importance and in market potential in the coming years with regard to the increasing importance of security and information technologies. The advancement of the group’s new materials will be complemented by the adaption and development of innovative coating and printing techniques.

STRUKTURBILDUNG / STRUCTURE FORMATION

PROF. DR. TOBIAS KRAUS

ZUSAMMENFASSUNG

Der Programmbereich *Strukturbildung* erforscht die Anordnung von kolloidalen Partikeln und Polymeren und wendet sie zur Herstellung neuer Materialien aus flüssigen Vorstufen an. Partikel und Polymere werden miteinander kombiniert, um Komposit- und Hybridmaterialien mit definierten Strukturen herzustellen. Wir beobachten die Bildung von Mikrostruktur und inneren Grenzflächen während der Materialsynthese aus flüssigen Vorstufen und untersuchen, wie sich die Struktur auf die Eigenschaften auswirkt, indem wir systematisch Größe, Geometrie, Zusammensetzung und Anordnung der Komponenten variieren. So entstehen zum Beispiel transparent leitfähige Schichten aus ultradünnen Metalldrähten, Suprapartikel als Kombinationen optisch aktiver und supraparamagnetischer Nanopartikel und hybride Nanopartikel, die sich in Umweltproben eindeutig wiederfinden lassen. Für Materialien der Zukunft suchen wir nach Partikeln, die sich gezielt bewegen lassen, um die Materialeigenschaften verändern zu können.

MISSION

The Program Division *Structure Formation* investigates the assembly of colloidal particles and polymers and applies this process for the preparation of new material from liquid precursors. Particles and polymers are combined to create composite and hybrid materials with defined structures. We observe how microstructure and internal interfaces form during material synthesis. We investigate how structure affects properties by systematically varying size, geometry, composition and arrangement of the components. This leads, for example, to transparent conductive coatings from ultrathin metal wires, to supraparticles as combinations of optically active and superparamagnetic nanoparticles, and to hybrid nanoparticles that can be unambiguously detected in environmental samples. For future materials, we seek particles that can be moved to change material properties.

CURRENT RESEARCH

Self-organizing and hybrid inks for electronics

There are two great challenges in printing electronic structures from liquid inks: the printed structures have to percolate (they have to be connected throughout), and there should be no insulating layers between the conductive components after drying. We address both issues in the BMBF project *NanoSpekt* and introduced two new concepts to solve them: *Self-organizing* inks contain metal nanowires that spontaneously form percolating bundles during drying; thus, continuous conductive pathways form at small scales without the need for local intervention. *Hybrid inks* contain a hard metal nanostructure inside a soft conductive polymer shell. They form conductive films immediately after drying without the conventional sintering step because the soft polymer bridges the non-conductive gaps between the metal. Both concepts were fully established in 2016; the resulting inks and printing processes are currently adapted to different user cases and scaled up for commercial evaluation. We closely collaborate with the Program Division *Optical Materials* on this topic.

Porous and hybrid silicon structures

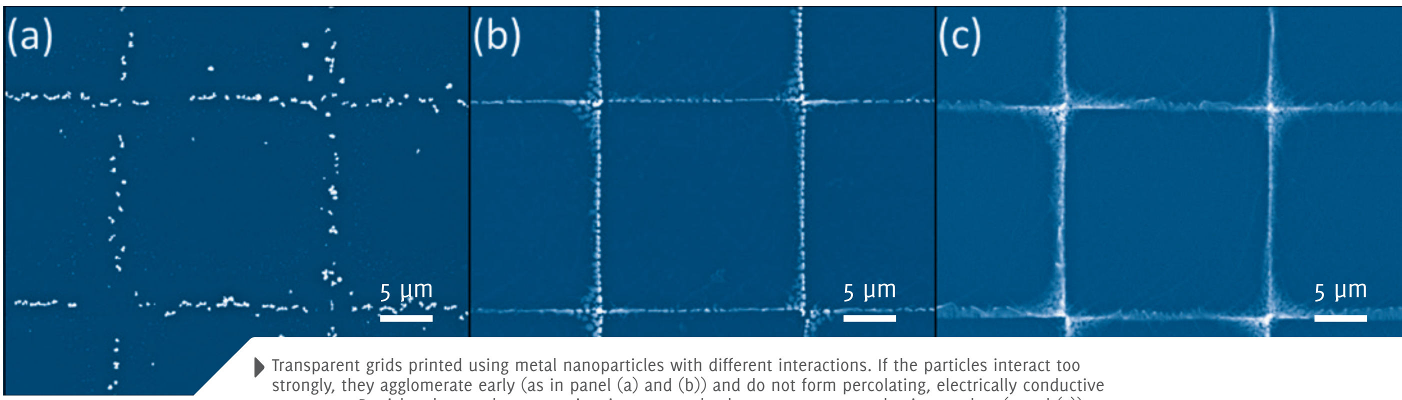
Particle-based porous films are promising materials for future application as sensors and biomaterials. We collaborate with the group of Prof. Nicolas Voelcker at the Future Industries Institute and the University of South Australia in Adelaide, an expert on the synthesis of porous silicon and its functionalization for biomedical purposes. We have developed methods to structure silicon and metal surfaces using particles that we tested as cell substrates and sensors in collaboration. The collaboration was highly successful, and we are delighted to have Prof. Voelcker as an INM Fellow starting in January 2017.

Binary supraparticles

The group has worked on the control and assembly of spherical nanoparticles inside the oil droplets of oil-in-water emulsions for several years. In 2016, we managed to arrange mixtures of two different nanoparticle types inside the same droplet and to observe the structure of the resulting binary particles (Figure). Prof. Tanja Schilling of the University of Luxembourg collaborated with us to predict the structure of the superstructures and helped us to understand how the process parameters – in particular the choice of surfactant – influenced the structure of the supraparticles. It is now possible to tune the geometry of the resulting objects between supercrystal, Janus, and core-shell particles.

OUTLOOK

The Program Division will continue to exploit colloidal mechanisms for the creation of new materials. This strategy has been very successfully applied to create new inks for printed electronics. We are currently employing the new principles to create solutions for specific technical challenges and bring them to industry. This application-oriented work has led to new fundamental questions, for example, on the stability of metal particles with dense alkyl ligands shells in organic solvents. Basic research is under way to better understand their stability, and a collaboration with Prof. Paul Mulvaney in Melbourne will help to extend it to semiconductor particles. The INM Fellowship of Prof. Nico Voelcker will allow us to intensify collaboration towards particle-based drug delivery and porous sensor materials.



Transparent grids printed using metal nanoparticles with different interactions. If the particles interact too strongly, they agglomerate early (as in panel (a) and (b)) and do not form percolating, electrically conductive structures. Particles that are less attractive, in contrast, lead to transparent conductive meshes (panel (c)).

INNOVATIONSZENTRUM INM / INNOVATIONCENTER INM

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

INM InnovationCenter

ZUSAMMENFASSUNG

Das *InnovationsZentrum INM* ist die Schnittstelle zwischen Märkten und den Technologieplattformen des INM. Im dritten Jahr seit seiner Gründung stand die Vermarktung von Gecomer-Strukturen, dekorativen Schichten und funktionellen Nanopartikeln im Fokus. Forschungs- und Entwicklungs-ergebnisse des INM wurden analysiert, Firmenpartner gesucht und kontaktiert. Neue Transfer-Projekte wurden ins Leben gerufen, die entweder aus technischen Entwicklungen „bottom up“ entstanden sind oder aus strategischen Erwägungen „top down“ als notwendig erkannt wurden. Eine intensive Zusammenarbeit mit Wissenschaftler/innen des INM stellte sicher, dass solche Projekte durch exzellente Grundlagenforschung unterstützt wurden. Das Zentrum möchte in den kommenden Jahren Standardprozesse zur Unterstützung von Innovationen etablieren und wird dazu durch das BMBF-Projekt Science4KMU gefördert. Als seine anspruchsvollste Aufgabe betrachtet es die Identifikation und Auswertung disruptiver Entwicklungen aus der Grundlagenforschung.

MISSION

The main objective of the *InnovationCenter INM* is to increase the institute's competitiveness in the acquisition of industrial projects. Therefore, the InnovationCenter INM provides support for science-to-business marketing to the scientists at INM. It develops an innovation strategy focussing on the institute's competences. Continuous evaluation of the markets provides supplemental impulses for the direction of future basic research. Based on INM's research output, the InnovationCenter helps in design and development of novel coating materials, surface structuring techniques, and processes up to pilot plant scales. R&D project partners are supported along the innovation chain from basic concepts to quality control and validation of the production process.

CURRENT RESEARCH & DEVELOPMENT

SELF-HEALING CLEARCOATS derived from cyclodextrine based polyrotaxanes are targeted in a VIP+ project funded by BMBF (co-operation with Nanomers and Prof. Wenz, Saarland University). Polyrotaxanes are developed and converted to paints for use in automotive applications. The varnishes are tested at the InnovationCenter for larger area spray coating and weatherability. In co-operation with other groups, the time and temperature dependence of the self-healing behavior and the mechanical properties are correlated with the relaxation behavior of the cross-linked polymer structures. Specimen of the lacquers showed a micro-hardness above 200 N/mm² at room temperature. Single micro-scratches on the paint surface obtained by scratch test with up to 50 g load could be healed by heating the lacquer for 1min at 100° C. (Fig. 1)

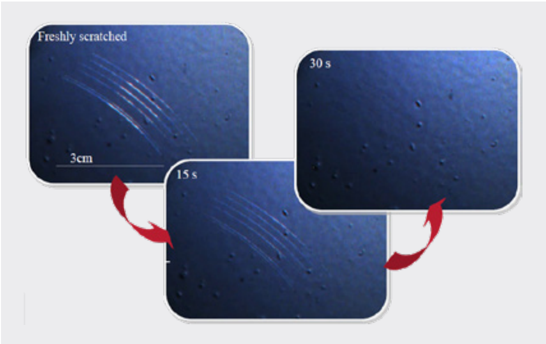


Fig. 1: Self-healing of crosslinked polyrotaxane layers at 100° C.
Fig. 2: The wipe coating machine in operation.

CONTINUOUS PARTICLE SYNTHESES IN A MICROREACTOR provide several advantages over conventional batch processes, especially smaller reaction volume, better control over reaction parameters, and particle morphology. A crucial issue in microfluidic particle synthesis is the avoidance of particle agglomeration and sedimentation. Synthesis of anatase nanoparticles was performed successfully via a solvothermal process resulting either in rods or more spherical particles depending on reaction temperature. Zirconia nanoparticles were achieved via an alcohol-thermal process with particles being amorphous.

With WIPE COATING a new application method was adapted for large glass panes (in co-operation with Optical Materials). The new method circumvents the disadvantages of other wet chemical thin layer coating methods. The coating machine is constructed from a large vertical frame where the substrate is fixed by suction. An aluminum tank with a rubber tube to seal the contact to the pane holds the coating solution. It is moved by a high precision linear drive allowing the application of optical coatings, as shown by an antireflective coating where at 98 spots on the surface of 1650 x 900 mm² a layer thickness of 93.6 ± 2.4 nm was determined. (Fig. 2)

For the fabrication of TRANSPARENT CONDUCTIVE NANOFIBERS BY ELECTRO SPINNING, a continuous process was developed and integrated into a roll-to-roll coating machine. A solution containing a titanium precursor is put into a tank. A rotating nozzleless electrospinner set-up is wetted by this spin dope. In a strong electrical field, the solution is spun to a web of nanofibers being collected continuously covering uniformly the substrate. After calcination, fibers are photochemically metallized. The coated surfaces show transmissions of 98 %, a haze of 1.13, and sheet resistances around 650 sq-1.

The *InnovationCenter* offers a wide range of ANALYTICAL SERVICES to customers from industry. INM's analytical capabilities are made available to companies, allowing them to improve the quality and competitiveness of their products.

OUTLOOK

The *InnovationCenter* is creating a culture of innovation in an internal network using the relationship between development, engineering, and industrial collaboration. An external network will be developed, tested and validated aiming to foster partnerships with industry. The Center analyses the requirements of SMEs, provides assistance in identifying funding for innovation, and manages the process. It will bring together specific teams of the institute to implement and execute projects with the required information, resources, and facilities.

Tobias Kraus

Peter W.
de Oliveira

SERVICEBEREICHE / SERVICE GROUPS

CHEMISCHE ANALYTIK / CHEMICAL ANALYTICS

DR. CLAUDIA FINK-STRAUBE

Die Servicegruppe *Chemische Analytik* verfügt über moderne Verfahren der Massenspektrometrie, Chromatographie und Atomspektrometrie. Unser Ziel ist analytischer Service für die Gruppen des INM und der Universität sowie Externe; außerdem bieten wir die Entwicklung und Validierung neuer analytischer Methoden an. Die Elementanalytik führt routinemäßig die quantitative Bestimmung nahezu aller stabilen Elemente mit ICP-OES, FL- und GF-AAS durch. Elementverteilungen im Ultraspurenbereich komplexer Proben werden mit HR-SF ICP-MS analysiert. Zur Identifizierung, Massebestimmung und Strukturaufklärung organischer Moleküle kommen GC-MS, LC-ESI-MS und LC-ESI HR-Q-TOF zum Einsatz. Daneben verfügt das Labor über gängige Aufschluss- und Extraktionsverfahren (MW, HT Aufschluss, HS, LE, SPE, SPME) zur Probenvorbereitung.

PHYSIKALISCHE ANALYTIK / PHYSICAL ANALYTICS

DR. MARCUS KOCH

Die Servicegruppe *Physikalische Analytik* bietet dem INM und externen Kooperationspartnern Untersuchungen im Bereich der Röntgendiffraktometrie und Elektronenmikroskopie an. Durch den Einsatz vielfältiger Präparations- und Abbildungsverfahren können verschiedenste Proben bis in den Nanometerbereich analysiert werden. Besonders für das Gebiet „Soft Matter“ gibt es durch Verwendung von Kryopräparation und Kryoelektronenmikroskopie neue Möglichkeiten zur Charakterisierung von Oberflächenmorphologie und innerer Struktur (Kryo-REM bzw. Kryo-TEM). Beschäftigte, die Elektronenmikroskope selbständig nutzen möchten, werden in die entsprechenden Methoden eingewiesen. Studierende und Schüler/innen erhalten im Rahmen von Praktika und Führungen Einblicke in die Elektronenmikroskopie.

ENGINEERING / ENGINEERING

DIPL.-ING. DIETMAR SERWAS

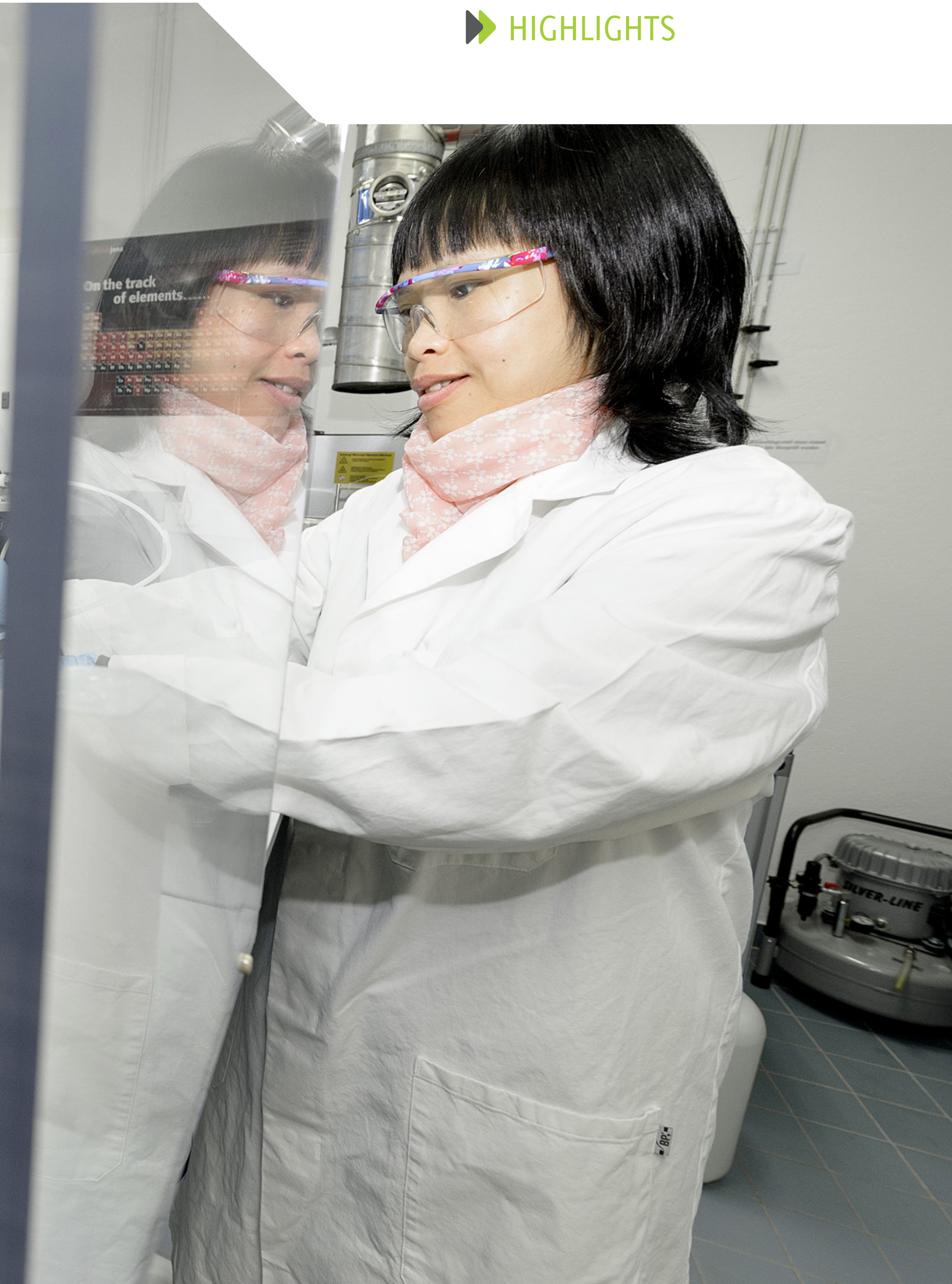
Das Hauptaufgabengebiet des Servicebereiches *Engineering* mit den Arbeitsbereichen Konstruktion, mechanische Werkstatt und Elektrowerkstatt besteht in der Entwicklung und Herstellung wissenschaftlicher Anlagen und Komponenten für Forschung und Projekte der Gruppen des INM. Die Bandbreite der Arbeiten reicht von kleinen Laborgeräten bis hin zu Pilotanlagen. Aus den Vorgaben der Forschung werden die Konstruktionen mittels der CAD-Software CATIA-V5 erstellt und in der Fertigung der INM-Werkstätten umgesetzt. Hierfür steht eine moderne Ausstattung wie ein CAM-System, eine 5-Achs-HSC-Präzisionsfräsmaschine oder eine Funkenerosionsanlage zur Verfügung. Weiterhin werden im Rahmen einer Kooperation Werkstattarbeiten für den Lehrstuhl Technische Physik der Universität des Saarlandes durchgeführt.

NTNM-BIBLIOTHEK / NTNM LIBRARY

DIPL.-BIBL. MA ELKE BUBEL

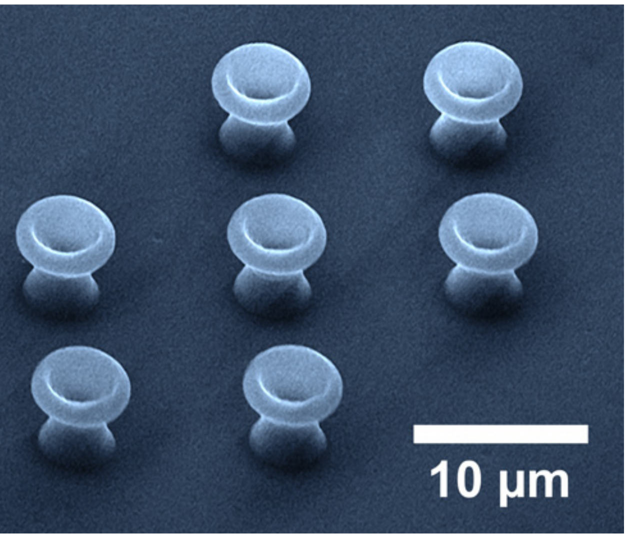
Die NTNM-Bibliothek ist die gemeinsame Bibliothek für Naturwissenschaft und Technik der Naturwissenschaftlich-Technischen Fakultät der Universität des Saarlandes und des INM – Leibniz-Institut für Neue Materialien. Sie bietet Studierenden und Angehörigen von Universität und INM sowie externen Interessierten ein bedarfsorientiertes Angebot an Print- und elektronischen Medien. Für Angehörige des INM bietet die NTNM-Bibliothek Service- und Beratungsleistungen im Bereich Wissenschaftliches Publizieren und Open Access. 2017 hat das BMBF im Rahmen seiner Förderrichtlinie des freien Informationsflusses in der Wissenschaft – Open Access einen Projektantrag der NTNM-Bibliothek zur Förderung der Sichtbarkeit von Open Access Publikationen *visOA* über einen Förderzeitraum von zwei Jahren bewilligt.

HIGHLIGHTS



NOVEL MICROSTRUCTURES FOR STRONG REVERSIBLE ADHESION

S.C.L. FISCHER, K. GROSS, O. TORRENTS ABAD, R. HENSEL AND E. ARZT
FUNCTIONAL MICROSTRUCTURES



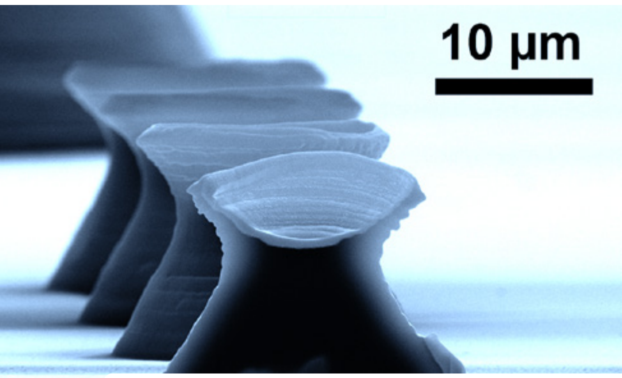


Fig. 1: Scanning electron micrograph of a funnel-shaped microstructure array.
Fig. 2: Section through the microstructure showing the funnel shape.

Reversible adhesion is the key functionality to grip, place and release objects non-destructively. Inspired by nature, micropatterned dry adhesives have been successfully developed at INM over the past decade. It is now known that the success of such adhesives critically depends on the interplay between design parameters and surface roughness, rather than on surface energy and chemistry alone.

We recently developed a new generation of adhesive structure designs, so called funnel-shaped microstructures (Fig. 1) with exceptional adhesion performance. The complex 3D structures were fabricated using two-photon and nanoimprint lithography. The diameter, the flap thickness, and the opening angle of the structures were varied systematically (Fig. 2). The adhesion of single structures was characterized using a triboindenter system equipped with a flat diamond punch. The pull-off stresses obtained reached values up to 5.6 MPa, which is higher than any values reported in literature for artificial dry adhesives. Experimental and numerical results suggest a characteristic attachment mechanism that led to intimate contact formation from the edges towards the center of the structures. Van-der-Waals interactions most likely dominate the adhesion, while contributions by suction or capillarity play only a minor role. The funnel-shaped microstructure design has been identified as a promising concept for strong and reversible adhesives. Our ongoing modeling activities on this topic are supported by R. McMeeking (UC Santa Barbara) and A. Kossa (Budapest University of Technology & Economics). The transfer into novel pick and place handling systems is under evaluation.

S. C. L. Fischer et al., Adv Mater Interfaces, 4 (2017) 1700292

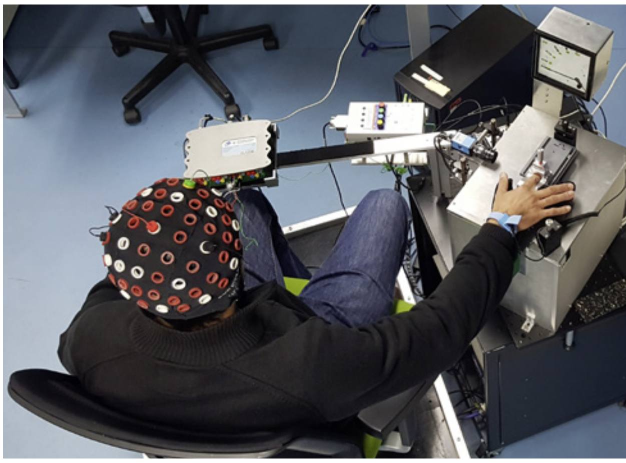
TRIBOLOGY OF A BRAILLE DISPLAY AND EEG CORRELATES

N. ÖZGÜN[A], D. J. STRAUSS[B] AND R. BENNEWITZ[A]
[A] NANOTRIBOLOGY
[B] INM FELLOW, SYSTEMS NEUROSCIENCE AND NEUROTECHNOLOGY UNIT, FACULTY OF MEDICINE, SAARLAND UNIVERSITY

When our senses detect a sudden event in our environment, intensity and time-scale of the electrophysiological response in our brain can often be observed by recording an electroencephalogram (EEG). For example, when we hear a short click, the EEG will contain a wave of electrical potential at the skull within 100 milliseconds after the click. But these so-called event-related potentials are not the only brain activity. The signal is rather part of an ongoing plethora of oscillating potentials. Statistical averaging of EEG signals recorded after many repetitions of the click will finally reveal the event-related wave. INM Fellow Daniel Strauss is an expert in advanced mathematical methods to extract event-related potentials. In a project under his supervision conducted by Novaf Özgün in the Program Division Nanotribology, we explored if a sudden change in friction at the fingertip also triggers an event-related potential in the EEG signal (Fig. 1).

The friction stimulus was delivered by a programmable Braille display, which serves as a reading device for blind computer users. The information is conveyed by patterns of millimeter-sized dots, which can be raised and lowered and which are read by sliding a fingertip across the rows of dots. We measured the change in friction when one or three lines of dots where raised under the finger of a participant (Fig. 2). Repeating the change in friction 160 times and applying the advanced averaging methods to the EEG signal, we found a significant event-related wave 80 – 150 milliseconds after the dots were raised. By demonstrating the correlation between fingertip friction force and EEG signal, we introduced a novel tool to the emerging fields of haptics, the science of perception by touch.

N. Özgün, D. J. Strauss, R. Bennewitz, Tribology Letters, 66 (2018) 16



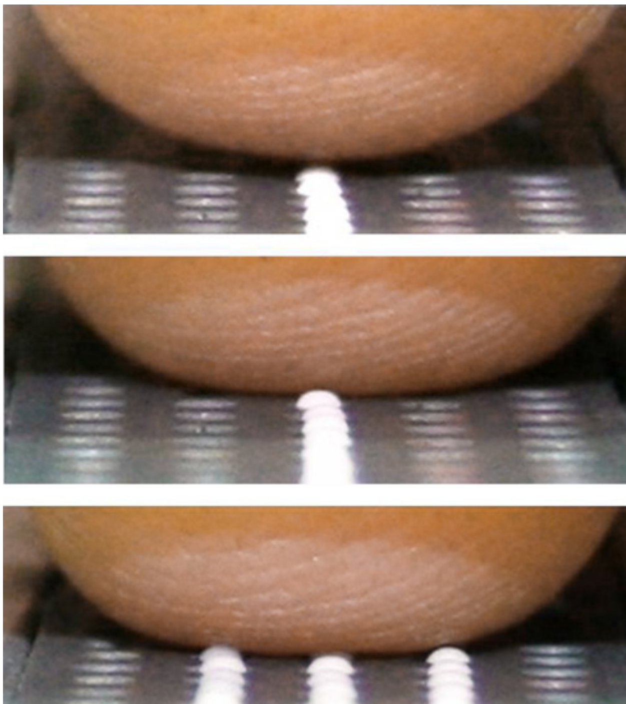


Fig. 1: Neural processes evoked by changes in friction between the fingertip and a Braille display were investigated by means of an electroencephalogram (EEG).
Fig. 2: Programmable Braille display in interaction with the finger of a participant. The friction signal depends on the strength of contact and on the number of Braille dots raised.

ELECTRON MICROSCOPY IDENTIFIES CANCER CELLS "ESCAPING" DRUG RESPONSE

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[B] GERMAN CANCER RESEARCH CENTER, HEIDELBERG
[C] INNOVATIVE ELECTRON MICROSCOPY
[D] DEPT. OF PHYSICS, SAARLAND UNIVERSITY, SAARBRÜCKEN

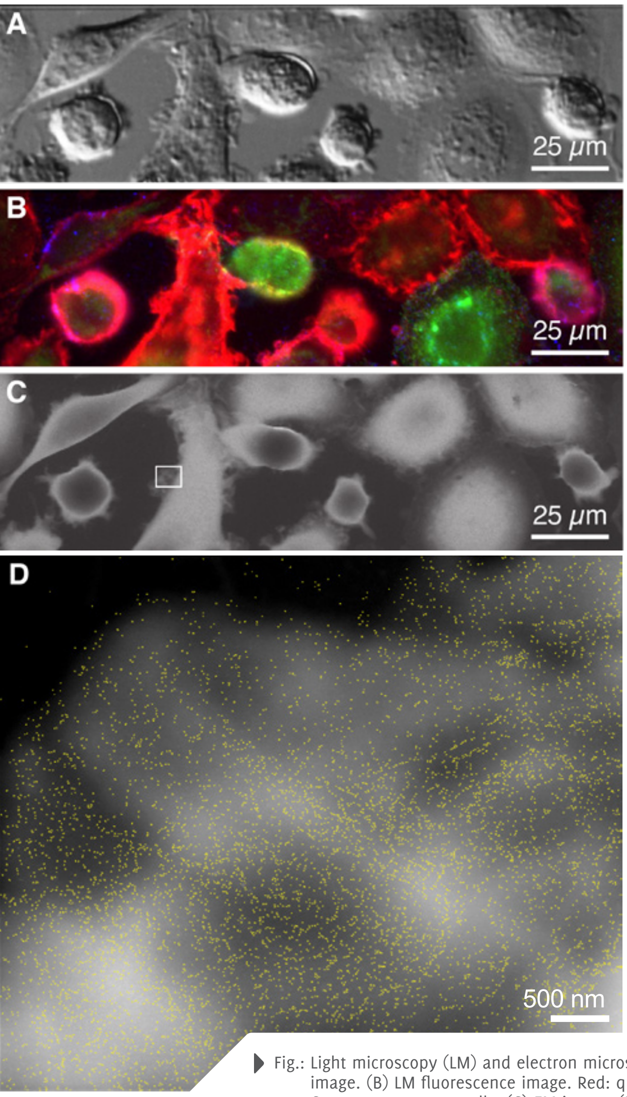


Fig.: Light microscopy (LM) and electron microscopy (EM) of breast cancer cells in liquid. (A) LM image. (B) LM fluorescence image. Red: quantum dot nanoparticles (QDs) bound to HER2. Green: cancer stem cells. (C) EM image. (D) High-resolution EM shows individual QDs.

The team of Prof. de Jonge published a groundbreaking new quantitative method for obtaining insights into the molecular responses of HER2 proteins in breast cancer cells[1]. Using this novel approach, they achieved a breakthrough. Wide-reaching implications in antibody-based therapeutics are anticipated. Breast cancer is amongst the leading causes of death for women and in particular the HER2-overexpressing form is dangerous. Antibody-based medication exists, but the disease eventually develops drug resistance for most of the patients. Despite many years of extensive research, the origin of drug resistance is still not well understood and remedies are lacking. Combining single-molecule and single-cell analysis, the team unraveled how the target molecule HER2 responds to the prescription drug trastuzumab in the bulk population of an HER2 overexpressing breast cancer cell line. Most importantly, it was discovered why rare cancer cell subpopulations remained largely irresponsive to the drug providing a possible molecular explanation for the development of drug-resistance in this type of cancer.

The new analytical method has the potential to find broad usage in cancer research leading eventually to improved cancer therapies because it effectively addresses cancer cell heterogeneity down to the single-protein level. The approach is generally applicable to study membrane protein interactions in cell biology beyond cancer research, and provides unique information for research areas in which it is important to account for cell heterogeneity, and to study protein function within the native environment of the intact plasma membrane.

[1] D. B. Peckys, U. Korf, S. Wiemann, N. de Jonge, Mol. Biol. Cell 2017, 28, 3193.

3D BIOPRINTING: AN INTEGRATIVE TECHNOLOGY TO RECONSTRUCT COMPLEX TISSUES

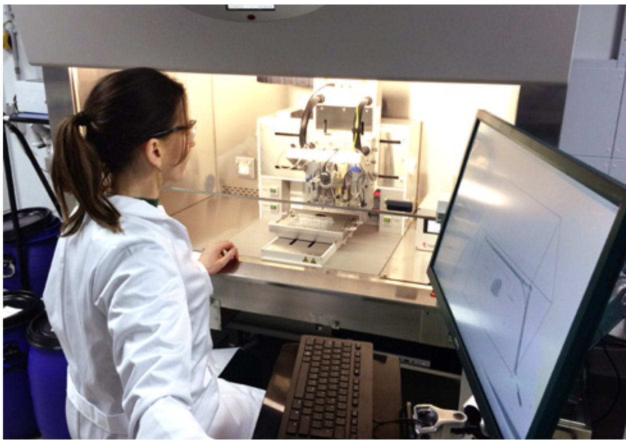
M.K. WŁODARCZYK-BIEGUN AND A. DEL CAMPO
DYNAMIC BIOMATERIALS

Tissues and organs are composed of multiple cells embedded in multicomponent matrices, and spatially organized in specialized compartments. Such compositional and structural complexity and the resulting functional performance are not captured in current in vitro models used for diagnostics, or in 3D constructs for regenerative therapies. This issue negatively impacts relevant biomedical scenarios: in vitro models display limited predictive potential for precision diagnostics and personalized therapies, cell therapies remain inefficient and unaffordable, functional engineered tissues and organs for clinical use remain an unreachable dream.

Therefore, 3D bioprinting emerges as an attractive fabrication method for reconstructing the complexity of natural tissues and their functionality. It allows integration of various cells and matrices in a single scaffold at desired combinations and lengthscales. The future of bioprinting technologies and their impact in clinical solutions relies to a great extent on the development of printable biomaterials. These should be able to encapsulate functional cells and recreate their individual and specialized microenvironments. The Program Division Dynamic Biomaterials at INM designs hydrogel-based bioinks with cell-specific signals for extrusion printing of primary cells into functional co-cultures.

Bioprinting allows easy integration of additional elements for cellular stimulation and health monitoring to implantable scaffolds and medical devices for the purpose of accelerating healing and regeneration. Printed optical fibers (Dynamic Biomaterials) and electrodes (Structure Formation) at INM will greatly expand the functionalities of printed tissues.

M.K. Włodarczyk-Biegun, A. del Campo, Biomaterials, 134 (2017) 180



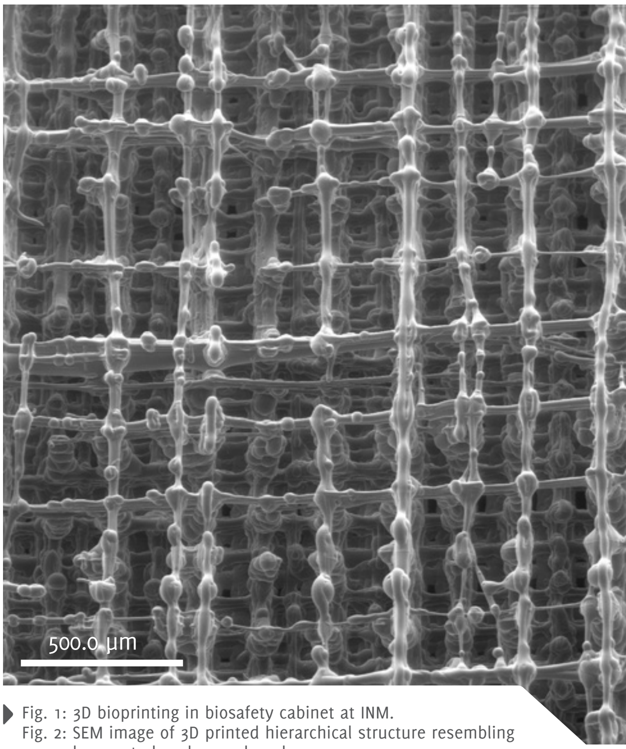


Fig. 1: 3D bioprinting in biosafety cabinet at INM.
Fig. 2: SEM image of 3D printed hierarchical structure resembling human trabecular meshwork.

NEW MATERIAL FOR THE PRODUCTION OF STEM CELLS FOR MEDICINE

D. DOBLAS AND T. KRAUS
STRUCTURE FORMATION

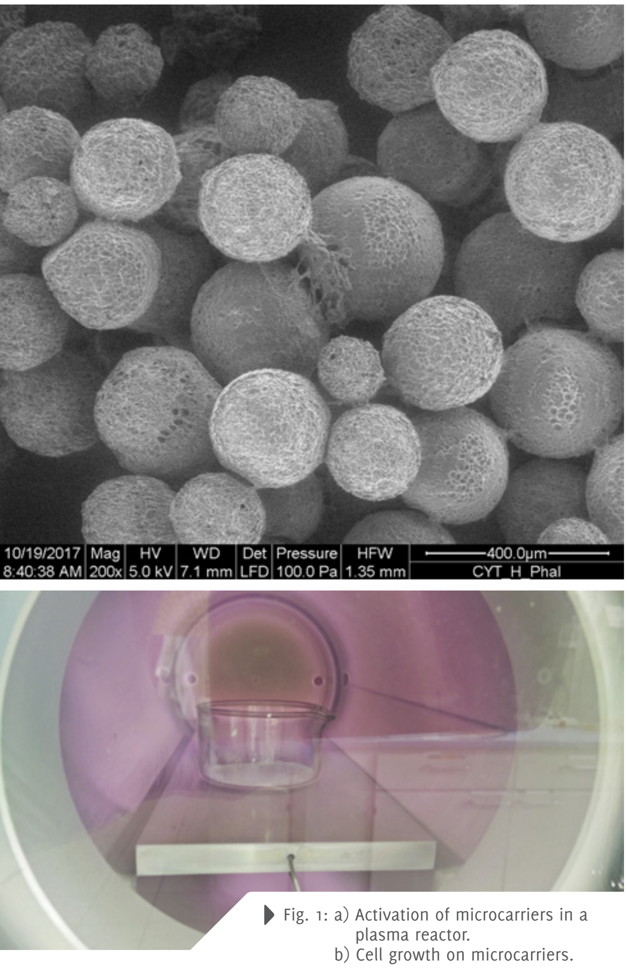


Fig. 1: a) Activation of microcarriers in a plasma reactor.
b) Cell growth on microcarriers.

Stem cells are highly promising tools for new therapies used in neurodegenerative diseases and conditions, diabetes, heart disease, and others, but the growing ("proliferation") of such cells in quantities that are sufficient for patient treatment still is extremely expensive. The IMPROVE-STEM project (**I**nterreg project developing new bio**M**aterials for **PRO**liferation and in **V**itro **E**xpansion of **STEM** cells) aims to develop an integrated set of tools necessary for the in vitro amplification of mesenchymal stem cells to promote their application in cell therapy in hospitals. Polymer microcarriers – spherical particles of about 0.15 mm – with a modified surface enable control of the adhesion/detachment of the cells. They are used in bioreactors for stem cell production that are adapted for the culture of adherent cells.

Previous studies have shown that surface modification of microcarriers can improve cell proliferation. At INM, we are developing new methods to functionalize the surface of polystyrene microcarriers for stem cell adsorption and growth. As a first step in the modification, microcarriers are activated by a plasma treatment to generate reactive groups on the surface (Figure 1a) followed by a chemical reaction that involves the formation of alkylsilane self-assembled monolayers on the surface. Preliminary tests have shown promising cell growth on this material (Figure 1b).

This project involves several universities (Liege University, Lorraine University, Kaiserslautern University) as well as research centers (LIST, INM, CNRS). The multidisciplinary consortium brings together advanced skills in materials science, bioprocess engineering, and stem cell biology that form the basis of a Platform of Excellence in the culture of mesenchymal stem cells.

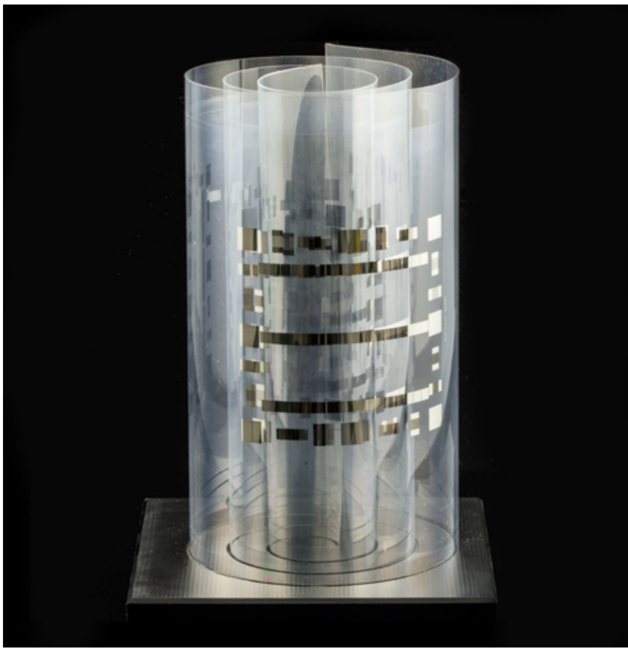
STRETCHABLE ELECTRODES FOR PRINTED ELECTRONICS

P. ROGIN, T. DÖRR, J. KAMPKA AND P. W. DE OLIVEIRA
OPTICAL MATERIALS

Fine metal structures are essential as conductors in modern electronic devices. As a specific application, capacitive touch sensors based on almost fully transparent metal mesh electrodes have emerged as an alternative to more traditional sensor structures made of transparent conductive oxides. In comparison to the latter, a metal mesh offers better performance as e. g. a higher conductivity at a lower price and better availability of raw materials. Furthermore, its mechanical flexibility facilitates the application on curved surfaces.

The photochemical metallization process developed in recent years is a cost-effective method for creating such metal structures covering large areas with features only a few microns wide. The simple process is based on direct ultraviolet light-induced deposition of silver from a suitable precursor solution onto a surface pre-coated with a nanoparticulate photocatalyst. By irradiation through a mask, fine structures such as the lines of a transparent metal mesh can be created.

The process has been developed for rigid (e. g. glass) and bendable (e. g. PET foil) substrates. The mesh electrode arrays have a net transparency (i.e., corrected for Fresnel reflection losses) exceeding 90 % and a sheet resistance below 40 /sq (anisotropic, fast axis). However, in order to cope with biaxially curved surfaces while still maintaining processability, also stretchable substrates are required. First conductive samples were produced on silicone foil. So far, the conductivity on this stretchable substrate is significantly lower than on PET and dependent on deformation – conductivity is decreased - in a partially reversible manner. Future work will aim at improving the conductivity by a thorough optimization of the interface between the substrate and the silver structure.



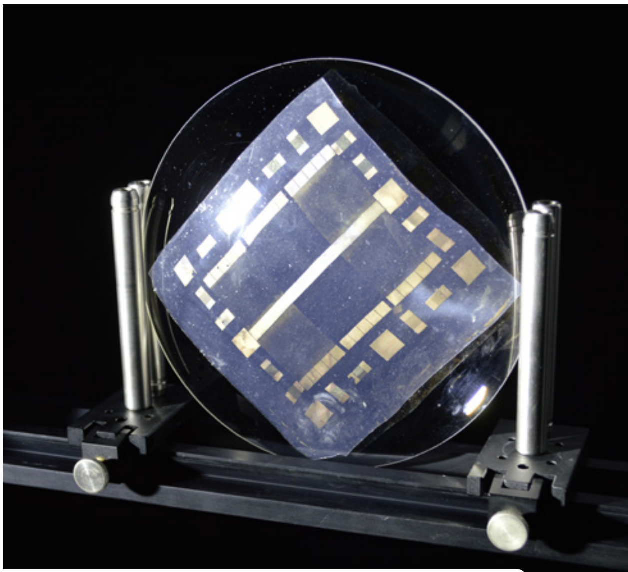
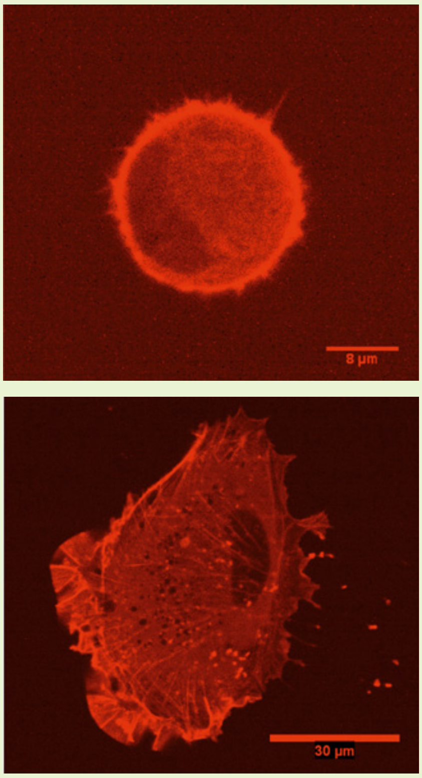
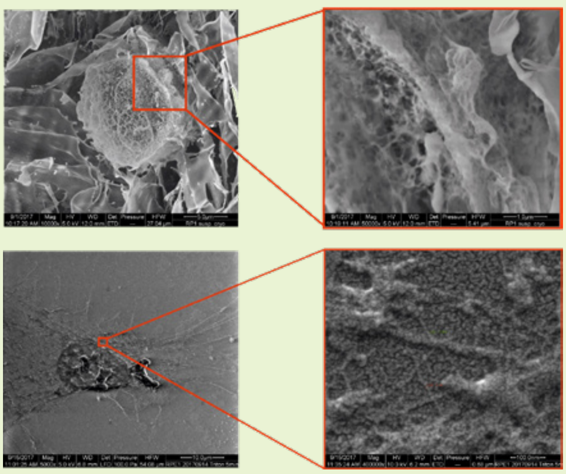


Fig. 1: PET foil coated with test structures comprising both full area coated silver patches and portions of silver mesh with various parameters.
Fig. 2: Silver structures on a PDMS foil substrate, attached to a convex lens.

ACTIN DYNAMICS OF ATTACHING CELLS

K. KAUB, D. FLORMANN, M. KOCH, E. TERRIAC AND F. LAUTENSCHLÄGER
CYTOSKELETAL FIBRES / PHYSICAL ANALYTICS





How do living cells – and their internal structures – adapt to the cellular environment, especially to different materials? To answer this question, we investigate the structure and dynamics of the actin cytoskeleton, a polymer network in cells responsible for force generation and transmission as well as for migration. First, we test the general effect of adhesion of cells on the actin cortex – the layer supporting the cell membrane. Later on, these experiments can be extended to test the effect of particular properties of the materials cells are adhering to. By labelling the actin cytoskeleton of suspended and adhered cells with fluorescent dyes, we measure the dynamics of the cortex by monitoring the exchange of actin subunits. This is achieved by photobleaching a small part of this cortex with high laser intensities and recording the recovery of the fluorescent signal. And indeed, this signal differs in suspended and adherent cells. To investigate if the structure of the cortex is the cause of these dynamical differences, we take high resolution images of the actin cortex by electron microscopy. While being standard for adhering cells, this is quite challenging for cells in suspension. To achieve this, we adopted a method where cells are frozen while suspended in a droplet. Afterwards, the whole conglomerate is broken. Some of the cells are split in the middle and the actin cortex can be visualized. These images are analyzed to get statistical data of single fiber parameters such as their thickness or the crosslinking between several fibers. Understanding cell adhesion effects on cytoskeletal fibers within cells will enable us in future to choose suitable materials to trigger or to prevent cellular processes such as the migration during tumor metastasis.

Fig. 1: Fluorescence images of the actin cortex in suspended (up) versus adherent (bottom) cells.
Fig. 2: High resolution images of the actin cortex in suspended (up) versus adherent (bottom) cells.

THREE QUESTIONS TO FRANZISKA LAUTENSCHLÄGER

Franziska is head of the Junior Research Group "Cytoskeletal Fibers" and junior professor for biophysics at Saarland University. She joined INM in January 2017.

YOUR RESEARCH GROUP INVESTIGATES THE INFLUENCE OF THE CYTOSKELETON ON THE FUNCTIONS OF CELLS. WHAT FASCINATES YOU ABOUT THIS RESEARCH TOPIC?

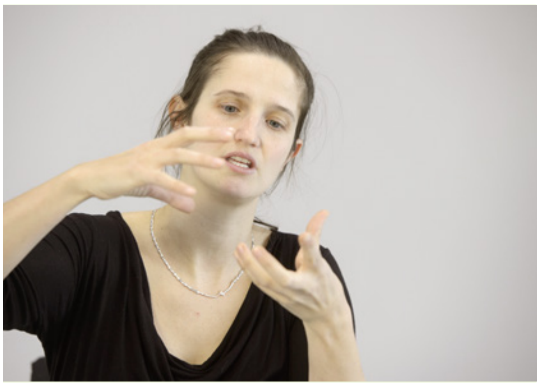
Cells per se have been known since the 17th century. Today, we know all components of cells but we still do not understand the mechanisms explaining their functions. The cytoskeleton – a polymer network in cells – plays a crucial role in the behavior of the cell such as in migration, differentiation or cell division. For me as a physicist, it is a fascinating material as such. It is the generator of forces within cells, provides their form and stiffness, is still very dynamic and influences the movements of the cells. I would love to know how that all works.

YOU WORK AT INM BUT ALSO AT SAARLAND UNIVERSITY. WHAT ARE THE ADVANTAGES FOR YOU OF COMBINING THESE TWO "WORLDS"?

Being part of both gives me more possibilities to interact: At INM, I can easily collaborate, as the groups working on "bio subjects" are very close to my research topics. Because of the funding situation, I have more scientific freedom and the infrastructure at INM is great. As a member of the University, I do more teaching, which gives me a direct contact to the students. And I am directly involved in processes shaping the future scientific landscape in my field on campus.

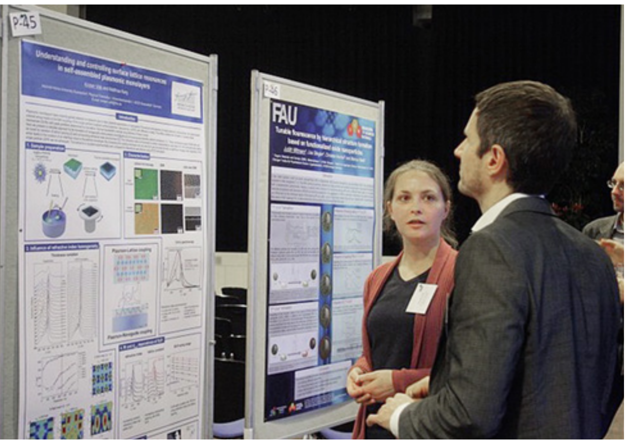
IF YOU HAD A WISH FOR YOUR RESEARCH, WHAT WOULD YOU LOVE TO ACHIEVE?

The cytoskeleton consists of three parts. One is the filament vimentin and its function is almost unknown. I would love to show its importance for the cell, to bring it to fame. It would also be great to generate insights on the behavior of the cytoskeleton which help to use it as a material outside of cells and to use it to improve life.



PARTICLE-BASED MATERIALS SYMPOSIUM 2017

T. KRAUS
STRUCTURE FORMATION



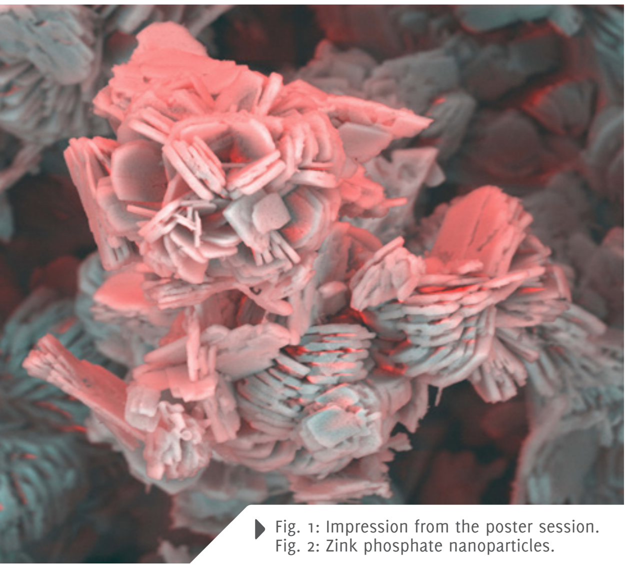


Fig. 1: Impression from the poster session.
Fig. 2: Zink phosphate nanoparticles.

Making materials with particles has proven to be both useful and versatile and is therefore practiced in Europe for very diverse purposes. The field is so interdisciplinary that even inside Germany, its proponents – e. g. working on particle-based gels for neuronal damage repair or on charge transport in semiconductor particle films for electronics - may never have met each other. The purpose of the Particle-Based Materials Symposium that Tobias Kraus organized with Alexander Kühne (Leibniz-DWI, Aachen), Robin Klupp-Taylor (Institute of Particle Technology, FAU Erlangen-Nürnberg) and Karl Mandel (Fraunhofer-ISC Würzburg) was to bring together scientists from different disciplines working in the field.

This goal was achieved entirely according to the feedback from the 80 participants. Lectures on the simulation, synthesis, characterization and application of particle-based materials covered a wide range from optical to electronic, catalytic, and biological materials; the discussions were lively and sometimes controversial. The role of definition versus functionality, mechanistic understanding of structure formation versus robust deployment for products, and the increasing relevance of "soft" materials where particles are highly useful building blocks were common themes. Excellent posters on an even wider range of topics led to intense discussions (see Figure), also between students and more senior researchers. All mingled at the conference dinner in excellent humor.

The conference helped forming a community that supports each other in technical problems and simplifies communication in particular of younger researchers. There was unanimous interest in a 2018 Workshop, and the delegates from FAU Erlangen-Nürnberg expressed their interest to organize it.

NANOSAFETY 2017

A. KRAEGELOH AND C. HARTMANN
NANO CELL INTERACTIONS

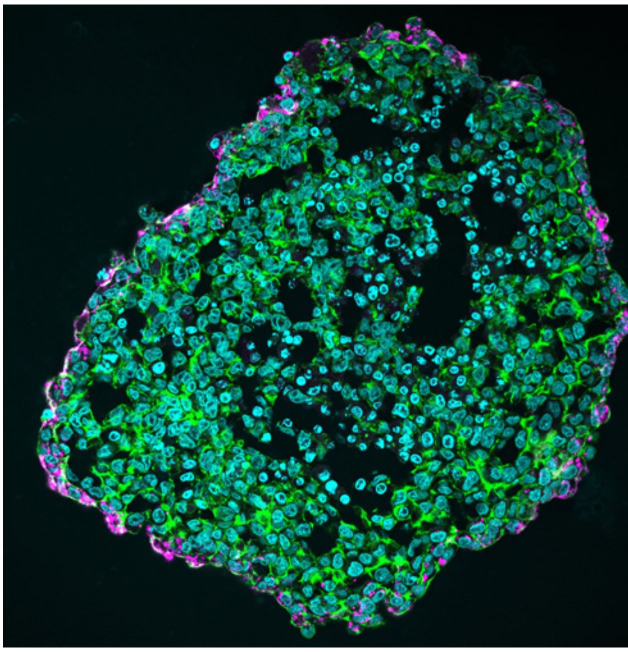


Fig. 1: Microtissue with nanoparticles.
Fig. 2: Naonosafety theme image.

From October 11–13, 2017, INM hosted the Nanosafety 2017 conference, which dealt with current topics in the field of nanosafety, ranging from environmental exposure pathways to molecular mechanisms. Located in the Saarbrücken Castle, the conference attracted 75 experts from 15 countries.

In his keynote lecture, William K. Boyes (US Environmental Protection Agency) gave an overview on a framework for evaluating the safety of nanomaterials released into the environment. This framework is aimed at guiding the development of future models and tools required to predict and avoid potential implications due to widespread use of nanomaterials and -products. The key session Safe by Design was opened by a lecture of Lutz Mädler (Leibniz Institute for Material-Oriented Technologies) on high-throughput screening methods for the evaluation of toxicological hazards and establishment of nanostructure-activity relationships. In a workshop, measures were discussed to identify and counteract potential risks early in the innovation process, to implement safe by design during industrial innovation, and to support it by "trusted environments" as information exchange platform.

As keynote speaker on Neurotoxicity, Michelle L. Block (Indiana University School of Medicine) highlighted the role of circulating factors in the impact of inhaled particles on the central nervous system. Needs for the development of tiered testing strategies, alternative in vitro tests, chronic exposure studies and studies on ageing and neurodegeneration were emphasized in a workshop.

Nanosafety 2017 was organized by the Leibniz Research Alliance Nanosafety, established and supported by the Leibniz Association. It received excellent media response. Participants were given the opportunity to submit contributions to a special issue of the journal Nanomaterials.

A LAB IN THE DESERT

C. BECKER-WILLINGER, C. JUNG, B. REINHARD AND G. WEBER

It's November: Bernd Reinhard, Carsten Becker-Willinger (Program Division Nanomers) and Günter Weber of INM travel to Namibia with representatives from the GIZ (German Association for International Cooperation). They want to forward their joint assessment with the University of Namibia (UNAM), and to take part in the //Kharas Innovation Hub. This journey is part of the NaMiComp project which aims at establishing a materials sciences institute in Namibia.

The project is underway: the first stage of the Southern Campus is under construction; showing that something is happening here at the heart of the desert, 500 km south of Windhoek. But why a materials sciences institute? The overall aim is to produce fireproof construction materials from natural resources. Despite the abundant resources available, good construction materials are rare in Namibia. Acacias cover great swathes of land and sand is right outside everyone's door. However, it will only be possible to manufacture these raw substances into valuable building materials using scientific analysis and research. This is where the INM team fits in: the team members know which skills the African scientists of tomorrow will need for this. They know what hardware is necessary for analysis and preparation, can help to plan and equip laboratories using their expertise, and can pass on their knowledge to the Namibian researchers, who have already visited the INM on several occasions.

The GIZ in Germany and Namibia support the project, as they know how to approach the industry in a targeted way, how to establish a spin-off and how to acquire investors for the necessary infrastructure, all of which is necessary to make a success of NaMiComp.

INM FELLOW GOES INTERNATIONAL

C. JUNG AND N. VÖLCKER

After studying Chemistry at Saarbrücken and Aachen and completing his postgraduate studies in the USA, Nicolas Völcker chose to pursue an academic career in Australia. At the time he had no idea what a fantastic research culture Australia has to offer. Völcker, originally from Hamburg, has been involved in research at several universities in Australia since 2001 and is now a professor at Monash University in Melbourne and the Director of the Melbourne Centre for Nanofabrication. In spite of the long travel distance, he has maintained strong links with the INM and Saarland through his past research visits and his time as a Humboldt fellow. Since 2017, he has been using the INM Fellowship to cooperate with the INM on the development of special nanoparticles, which could be used particularly to produce less toxic drugs for chemotherapy. By the end of the four-year cooperation, a joint research laboratory will have been set up to produce and test these particles.

For the excitable particles, the researchers are producing nanoparticles from metal and loading them with active molecules, such as pharmaceutical active ingredients or anti-corrosion agents. The nanoparticles are then incorporated into carriers. The active ingredients or excited particles are only able to pass through the carrier and reach the site if they are excited with electromagnetic radiation. By using excitable particles, overdosing in cancer treatment can be avoided. This concept of controlled release of active ingredients could also be transferred to protective coatings: instead of the existing method, which incorporates nanoparticles into carriers which continuously release active substances, such as metal ions, the excitable particles would make it possible to release controlled amounts as required.


INM

FAKTEN UND ZAHLEN / FACTS AND FIGURES

DAS INM IN ZAHLEN / INM IN FIGURES

DAS INM IN ZAHLEN

Im Jahr 2017 betrug der **Gesamtumsatz** des INM 22,97 Mio. Euro.

Erlöse aus der gemeinsamen Finanzierung durch den Bund und die Länder (**institutionelle Förderung**): 16,13 Mio. €,
- davon Personal- und Sachaufwendungen: 13,88 Mio. €,
- und für Investitionen: 2,25 Mio. €

Erlöse aus Drittmittelvorhaben: 6,66 Mio. €
- davon 4,29 Mio. € aus öffentlichen Projektförderungen,
- und 2,37 Mio. € aus Vereinbarungen mit Industrieunternehmen.

Sonstige betriebliche Erträge: 0,18 Mio €

Das INM hatte Ende 2017 **254 Beschäftigte** (127 m, 127 w), davon

- 88 Wissenschaftler/innen (50 m, 38 w),
- 40 Promovierende (25 m, 15 w),
- 53 Beschäftigte (27 m, 26 w) in den Bereichen Labor, Technik und Service,
- 34 Beschäftigte (9 m, 25 w) in der Verwaltung und den Sekretariaten,
- 33 Hiwis (12 m, 21 w) und 6 Auszubildende (4 m, 2 w).

INM IN FIGURES

In 2017, the **total turnover** of INM added up to 22.97 million euro.

Proceeds from the **joint financial support** by the federal government and the federal states (institutional funding): 16.13 million €,
- including expenses for personnel and materials: 13.88 million €,
- and for investments: 2.25 million €.

Proceeds from **third party funding:** 6.66 million €
- including 4.29 million € from public grants,
- and 2.37 million € from industrial contacts.

Other operating income: 0.18 million €

At the end of 2017, **254 employees** (127 m, 127 f) worked at INM including:

- 88 scientists (50 m, 38 f),
- 40 doctoral students (25 m, 15 f),
- 53 employees (27 m, 26 f) in laboratories and technical services,
- 34 employees (9 m, 25 f) in administration and secretarial offices,
- 33 graduate assistants (12 m, 21 f) and 6 apprentices (4 m, 2 f).

m = männlich, w = weiblich / m = male, f = female

KURATORIUM & WISSENSCHAFTLICHER BEIRAT / BOARD OF TRUSTEES & SCIENTIFIC ADVISORY BOARD

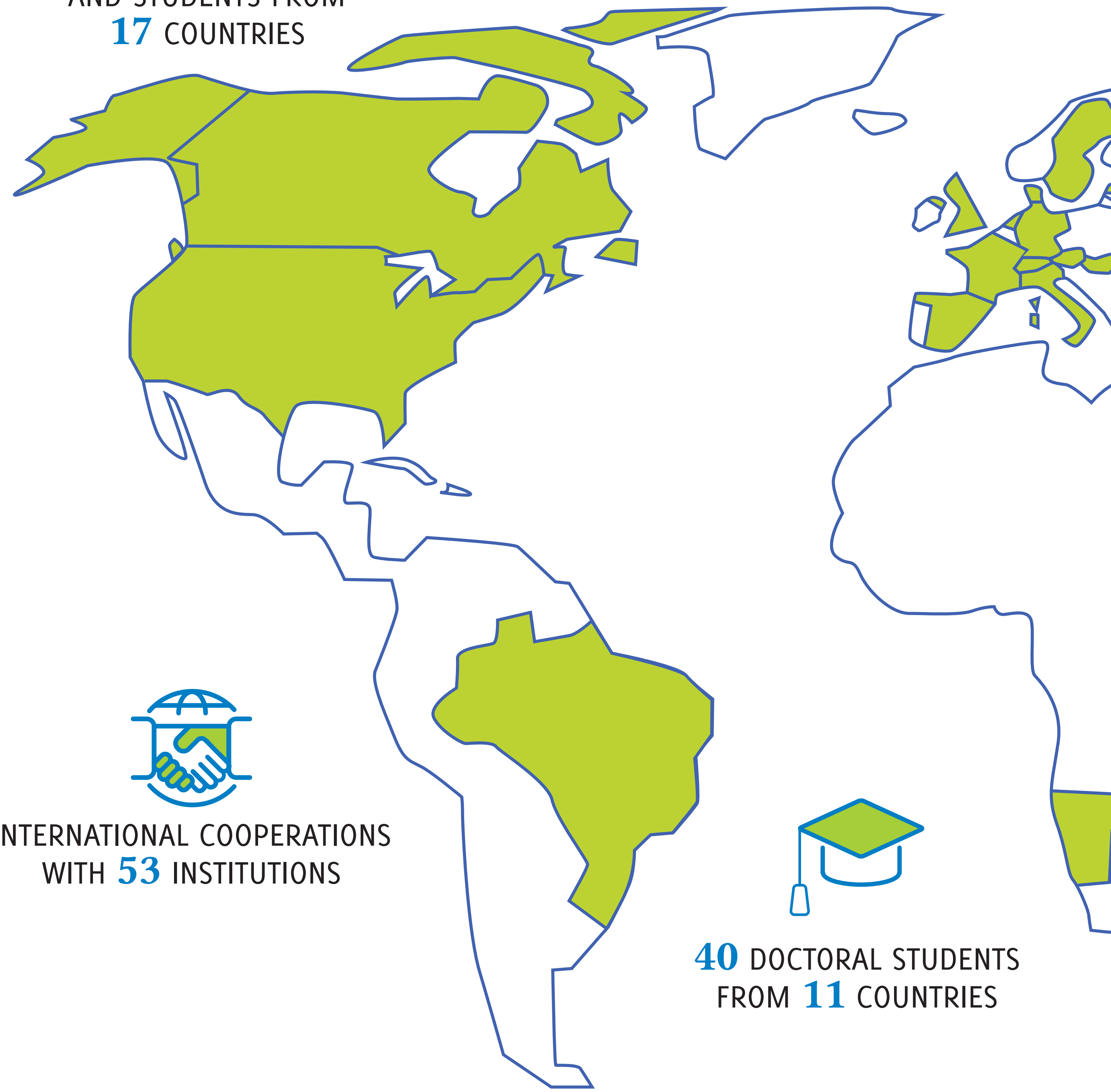
Stand / As of: 31.12.2017

MITGLIEDER DES KURATORIUMS / MEMBERS OF THE BOARD OF TRUSTEES

MITGLIEDER DES WISSENSCHAFTLICHEN BEIRATS / MEMBERS OF THE SCIENTIFIC ADVISORY BOARD

INM INTERNATIONAL

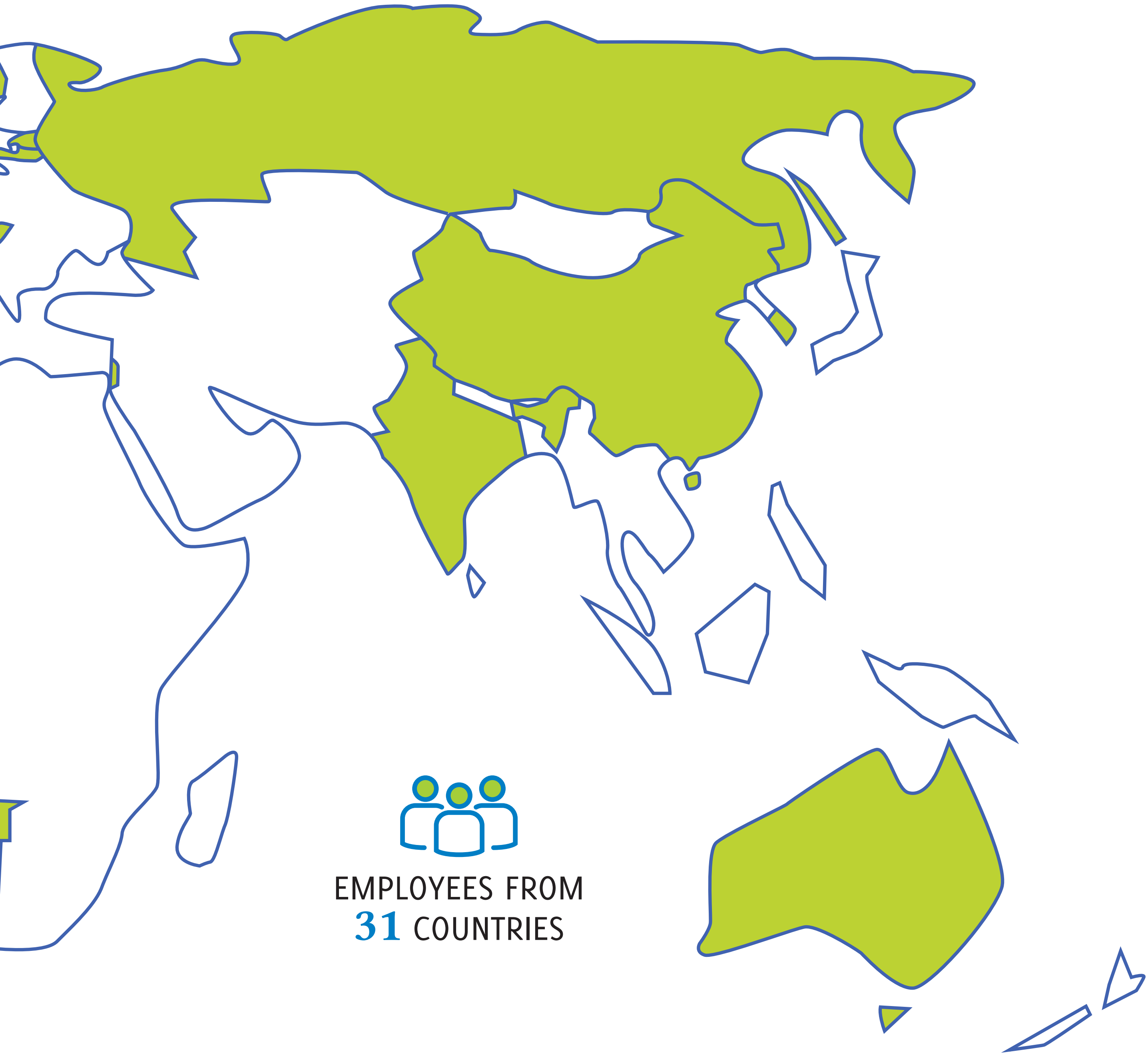
30 VISITING SCIENTISTS AND STUDENTS FROM **17** COUNTRIES



INTERNATIONAL COOPERATIONS WITH **53** INSTITUTIONS

40 DOCTORAL STUDENTS FROM **11** COUNTRIES

COOPERATIONS
WITH **33** INSTITUTIONS
IN GERMANY



EMPLOYEES FROM
31 COUNTRIES

States with institutional cooperation (not included: cooperations with industry)

DISSERTATIONEN / DOCTORAL THESES

Ali, Awadelkareem
Cyclopentanolates of Aluminium Hydride / Chloride and Synthesis & Characterization of Superhydrophobic Surfaces for Biomedical Application
Universität des Saarlandes, Saarbrücken,
Prof. Dr. M. Hammadeh

Barreau, Victoriia
Adhesion of Micropatterned Adhesives to Rough Substrates and at Elevated Temperatures
Universität des Saarlandes, Saarbrücken,
Prof. Dr. E. Arzt

Farrukh, Aleeza
Photo-Triggerable Laminin Mimetic Peptides for Directional Neural Regeneration
Johannes Gutenberg Universität, Mainz,
Prof. Dr. A. del Campo

Jochem, Aljosha-Rakim
Reference Particles for Field-Flow Fractionation
Universität des Saarlandes, Saarbrücken,
Prof. Dr. T. Kraus

Kümper, Alexander
Einfluss von kolloidalen Silikananopartikeln auf die EGFR-abhängige Signaltransduktion
Heinrich Heine Universität, Düsseldorf,
PD Dr. Klaus Unfried, Dr. A. Kraegeloh

Maurer, Johannes
Ultrathin Gold Nanowires for Transparent Electronics
Universität des Saarlandes, Saarbrücken,
Prof. Dr. T. Kraus

Támara Florez, Juan Carlos
Deposition of Metallic Copper through UV Light Irradiation
Universität des Saarlandes, Saarbrücken,
Prof. Dr. G. Kickelbick, Dr. P. W. de Oliveira

Zeiger, Marco
Next Generation Electrochemical Energy Storage with Nanocarbons and Carbon Nanohybrid Materials
Universität des Saarlandes, Saarbrücken,
Prof. Dr. V. Presser

ABSCHLUSSARBEITEN / THESES

BACHELORARBEITEN / BACHELOR THESES

Boyadzhieva, Silviya
Einfluss von Proteinadsorption, Substratrauheit, Filmdicke und Haltezeit auf die Adhäsion des Silikonelastomers SSA MG 7-9800
Universität des Saarlandes, Saarbrücken,
Prof. Dr. E. Arzt

Danner, Martin
Untersuchung der Adhäsionseigenschaften und der Biokompatibilität des Silikonelastomers SSA MG 7-9800 unter besonderer Berücksichtigung der Sauerstoffplasma-behandlung
Hochschule Kaiserslautern,
Prof. Dr. K.-H. Schäfer, Dr. K. Kruttwig

Geiger, Sophie
The Influence of Silica Nanoparticles on the Mechanical Properties of Immune Cells
Universität des Saarlandes, Saarbrücken,
Jun.-Prof. Dr. F. Lautenschläger

Kreuz, Tim
Charakterisierung alternativer Polypropylen-Typen zur Extrusion von medizinischen Mehrschichtfolien
Universität des Saarlandes, Saarbrücken,
Prof. Dr. E. Arzt

MASTERARBEITEN / MASTER THESES

Badie, Sylvain
Synthesis and Characterization of Cellular C/SiC-Composites as Starting Materials for High-Temperature Applications
Universität des Saarlandes, Saarbrücken,
Prof. Dr. V. Presser

Bettscheider, Simon
Contact Mechanics of Rigid Spherical Probes Adhering to Micropatterned Elastic Surfaces
Universität des Saarlandes, Saarbrücken,
Prof. Dr. E. Arzt

Cano Bonilla, Marina
Quantification of Gold Nanoparticle Concentration in an Evaporating Media
Universität des Saarlandes, Saarbrücken,
Prof. Dr. T. Kraus

Engel, Lukas
Additive Manufacturing, Mechanical Characterisation and FE Modelling of Auxetic Hydrogels for Biomedical Applications
Universität des Saarlandes, Saarbrücken,
Prof. Dr. E. Arzt

Engstler, Roxanne
Dynamical Crosslinked Hydrogels: Self-Healing, Mechanical Properties, and Self-Formation of Core-Shell Structure
Universität des Saarlandes, Saarbrücken,
Prof. Dr. G. Wenz, Dr. J. Cui

Fries, Peter
Influence of Actin Dynamics on Speed and Persistence of Immune Cells
Universität des Saarlandes, Saarbrücken,
Jun.-Prof. Dr. F. Lautenschläger

Hernández, Luissé
In-situ Analysis of the Detachment Kinetics of Polydimethylsiloxane Fibrillar Adhesive Arrays
Universität des Saarlandes, Saarbrücken,
Prof. Dr. E. Arzt

Lin, Hei Tung
An Optical Study of the Size Dependent Phase Behaviour of Alkanethiol Stabilized Plasmonic Nanoparticles Suitable for Optical Nanocomposites
Universität des Saarlandes, Saarbrücken,
Prof. Dr. T. Kraus

Ma, Guogiang
Self-Forming Poly(PDMS-co-urea)-Epoxy Bilayer Films: Synthesis and Mechanical Properties
Universität des Saarlandes, Saarbrücken,
Prof. Dr. E. Arzt

Massuti-Ballester, Pau
Outgassing Analysis of Different Copper Materials for Ultra-High Vacuum by Thermal Desorption Spectroscopy
Universität des Saarlandes, Saarbrücken,
Prof. Dr. T. Kraus

Priolo, Juan
Characterization of Nano-Precipitates in Microalloyed Steels by Chemical Extraction and Electron Microscopy – Comparison between the Matrix Dissolution and Carbon Replica Techniques for Nano-precipiate Extraction
Universität des Saarlandes, Saarbrücken,
Prof. Dr. C. Motz, Prof. Dr. T. Kraus

Ridder, Alexander
Synthesis, Properties and Application of Carbon Nanodots for Energy Storage
Universität des Saarlandes, Saarbrücken,
Prof. Dr. V. Presser

Tekeli, Mehmed Can
Capacitive Deionization with Intercalation-Type Materials
Universität des Saarlandes, Saarbrücken,
Prof. Dr. V. Presser

Weber, Louis Valentin
New Synthesis Methods to Integrate Nanoparticles in Thin Nanocrystalline Metallic Films for Improving Microstructural Stability
Universität des Saarlandes, Saarbrücken,
Prof. Dr. C. Motz, Prof. Dr. T. Kraus

REFERIERTE PUBLIKATIONEN / PEER-REVIEWED PUBLICATIONS

125 Publikationen
publications
davon / *including*

92 Publikationen in referierten Zeitschriften
publications in peer-reviewed journals

33 sonstige Publikationen
other publications

26 Publikationen im Open Access veröffentlicht
publications published in Open Access
davon / *including*

24 Beiträge in referierten Zeitschriften
contributions in peer-reviewed journals

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A list of all publications is available on our website
http://www.leibniz-inm.de/en/publications

GRENZFLÄCHENMATERIALIEN / INTERFACE MATERIALS

Energie-Materalien / Energy Materials

S. Choudhury, B. Krüner, P. Massuti-Ballester, A. Tolosa, C. Prehal, I. Grobelsek, O. Paris, L. Borchardt and V. Presser
Microporous novolac-derived carbon beads/sulfur hybrid cathode for lithium-sulfur batteries
J Power Sources 2017, 357, 198-208 [06.395 (2016)]
doi:10.1016/j.jpowsour.2017.05.005

S. Choudhury, M. Zeiger, P. Massuti-Ballester, S. Fleischmann, P. Formanek, L. Borchardt and V. Presser
Carbon onion-sulfur hybrid cathodes for lithium-sulfur batteries
Sustainable Energy Fuels 2017, 1, (1), 84-94 [-]
doi:10.1039/c6se00034g

V. Dargel, N. Jäckel, N. Shpigel, S. Sigalov, M. D. Levi, L. Daikhin, V. Presser and D. Aurbach
In Situ Multilength-Scale Tracking of Dimensional and Viscoelastic Changes in Composite Battery Electrodes
ACS Appl Mater Interfaces 2017, 9, (33), 27664-27675 [07.504 (2016)]
doi:10.1021/acsami.7b06243

S. Fleischmann, D. Leistenschneider, V. Lemkova, B. Krüner, M. Zeiger, L. Borchardt and V. Presser
Tailored Mesoporous Carbon/Vanadium Pentoxide Hybrid Electrodes for High Power Pseudocapacitive Lithium and Sodium Intercalation
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S. Fleischmann, A. Tolosa, M. Zeiger, B. Kruner, N. J. Peter, I. Grobelsek, A. Quade, A. Kruth and V. Presser
Vanadia-titania multilayer nanodecoration of carbon onions via atomic layer deposition for high performance electrochemical energy storage
J Mater Chem A 2017, 5, 2792-2801 [08.867 (2016)]
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S. Fleischmann, M. Zeiger, N. Jackel, B. Kruner, V. Lemkova, M. Widmaier and V. Presser
Tuning pseudocapacitive and battery-like lithium intercalation in vanadium dioxide/carbon onion hybrids for asymmetric supercapacitor anodes
J Mater Chem A 2017, 5, (25), 13039-13051 [08.867 (2016)]
doi:10.1039/c7ta02564e

N. Jäckel, V. Dargel, N. Shpigel, S. Sigalov, M. D. Levi, L. Daikhin, D. Aurbach and V. Presser
In situ multi-length scale approach to understand the mechanics of soft and rigid binder in composite lithium ion battery electrodes
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Quantitative Information about Electrosorption of Ionic Liquids in Carbon Nanopores from Electrochemical Dilatometry and Quartz Crystal Microbalance Measurements
J Phys Chem C 2017, 121, (35), 19120-19128 [04.536 (2016)]
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C. Kim, J. Lee, P. Srimuk, M. Aslan and V. Presser
Concentration-Gradient Multichannel Flow-Stream Membrane Capacitive Deionization Cell for High Desalination Capacity of Carbon Electrodes
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doi:10.1002/cssc.201700967

C. Kim, P. Srimuk, J. Lee, S. Fleischmann, M. Aslan and V. Presser
Influence of pore structure and cell voltage of activated carbon cloth as a versatile electrode material for capacitive deionization
Carbon 2017, 122, 329-335 [06.337 (2016)]
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C. Koczwara, S. Rumswinkel, C. Prehal, N. Jäckel, M. S. Elsässer, H. Amenitsch, V. Presser, N. Hüsing and O. Paris
In Situ Measurement of Electrosorption-Induced Deformation Reveals the Importance of Micropores in Hierarchical Carbons
ACS Appl Mater Interfaces 2017, 9, (28), 23319-23324 [07.504 (2016)]
doi:10.1021/acsami.7b07058

B. Krüner, C. Odenwald, A. Tolosa, A. Schreiber, M. Aslan, G. Kickelbick and V. Presser
Carbide-derived carbon beads with tunable nanopores from continuously produced polysilsesquioxanes for supercapacitor electrodes
Sustainable Energy Fuels 2017, 1, (7), 1588-1600 [- (2016)]
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B. Krüner, P. Srimuk, S. Fleischmann, M. Zeiger, A. Schreiber, M. Aslan, A. Quade and V. Presser
Hydrogen-treated, sub-micrometer carbon beads for fast capacitive deionization with high performance stability
Carbon 2017, 117, 46-54 [06.337 (2016)]
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Low Friction and High Solid-Solid Contact Ratio—A Contradiction for Laser-Patterned Surfaces?
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S. Choudhury, M. Azizi, I. Raguzin, M. Gobel, S. Michel, F. Simon, A. Willomitzer, V. Mechtcherine, M. Stamm and L. Ionov
Effect of fibrous separators on the performance of lithium-sulfur batteries
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S. Choudhury, T. Saha, K. Naskar, M. Stamm, G. Heinrich and A. Das
A highly stretchable gel-polymer electrolyte for lithium-sulfur batteries
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S. Kamerling and A. K. Schlarb
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Zeitschrift Kunststofftechnik/Journal of Plastics Technology 2017, 13, (3), 176-195 [-]
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SUPPLEMENT 2016

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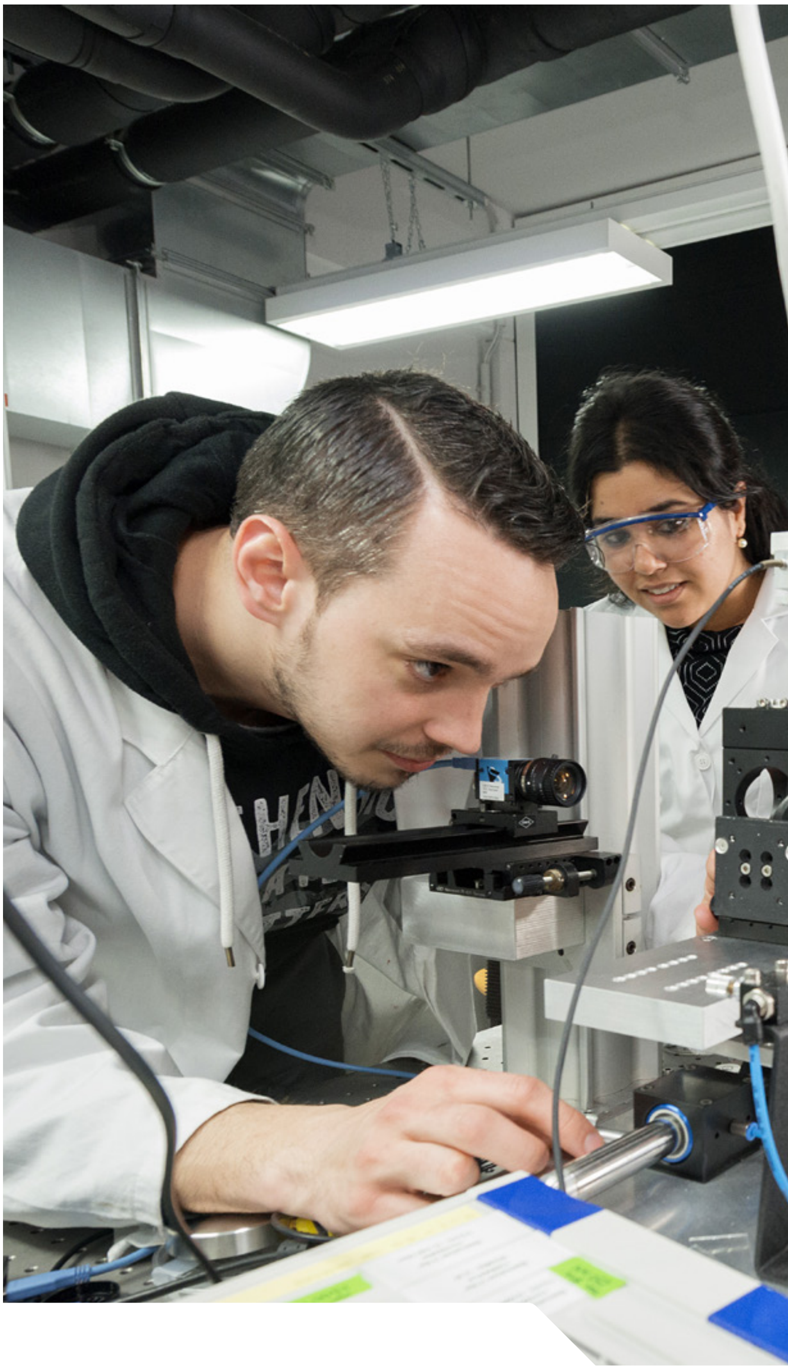

EINGELADENE VORTRÄGE / INVITED TALKS

231 Vorträge
talks
davon / *including*

82 eingeladene wissenschaftliche Vorträge
invited talks

149 sonstige Vorträge
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http://www.leibniz-inm.de/en/publications

GRENZFLÄCHENMATERIALIEN / INTERFACE MATERIALS

Energie-Materialien / Energy Materials

S. Choudhury, K. I. Ozoemena and V. Presser
Carbon-sulfur nanostructured hybrid for Li-S batteries
June 22, 2017; University of the Witwatersrand, Johannesburg <South Africa>

N. Jäckel, B. Krüner, K. L. Van Aken, M. Alhabeb, B. Anasori, F. Kaasik, Y. Gogotsi and V. Presser
Electrochemical in situ tracking of volumetric changes in two-dimensional metal carbides (MXenes) in ionic liquids
5th International Symposium on Enhanced Electrochemical Capacitors (ISEE'Cap17); July 10-14, 2017; Jena <Germany>

J. Lee and V. Presser
Charge ballance of hybrid energy storage system via vanadium and tin redox activities in aqueous solution
68th Annual Meeting of the International Society of Electrochemistry (ISE); August 27 - September 1, 2017; Providence <USA>

J. Lee, P. Srimuk and V. Presser
Redox-enabling nanoporous carbons for high-performance energy storage
Vidyasirimedhi Institute (VISTEC); July 20, 2017; Rayong <Thailand>

C. Prehal, C. Koczwara, N. Jäckel, H. Amenitsch, M. A. Hartmann, V. Presser and O. Paris
Structure and kinetics of ions in nanoporous carbon supercapacitors studied by in situ x-ray scattering and atomistic modelling
XXVI International Materials Research Congress; August 20-25, 2017; Cancun <Mexico>

V. Presser
Carbon and carbon hybrid materials for electrochemical desalination
28th International Conference on Diamond and Carbon Materials; September 3-7, 2017; Gothenburg <Sweden>

V. Presser
Redox-enabling nanoporous carbons for high performance energy storage
5th International Symposium on Enhanced Electrochemical Capacitors (ISEE'Cap17); July 10-14, 2017; Jena <Germany>

V. Presser
Electrochemical dilatometry for energy storage materials
Bavarian Center for Applied Energy Research (ZAE Bayern); November 14, 2017; Würzburg, <Germany>

V. Presser
Carbon nanomaterials
Edgar-Lüscher-Lecture; September 28, 2017; Dillingen, Saar , <Germany>

P. Srimuk, M. Aslan and V. Presser
MXene as a novel intercalation-type pseudocapacitive cathode and anode for capacitive deionization
Vidyasirimedhi Institute (VISTEC) Rayong <Thailand>;

P. Srimuk, J. Lee, M. Aslan and V. Presser
Capitalizing on Faradaic activity of carbon hybrid materials to enhance water desalination via capacitive deionization
July 20, 2017; Vidasirimedhi Institute (VISTEC), Rayong <Thailand>

Funktionelle Mikrostrukturen / Functional Microstructures

E. Arzt
Neue funktionelle Oberflächen – von den Grundlagen zur Anwendung
March 30, 2017; Hochschule Kaiserslautern <Zweibrücken, Germany>

E. Arzt
Fundamentals and applications of Gecomer technologies
Workshop Modeling and Concepts for Adhesion and Grip; March 14, 2017; Saarbrücken <Germany>

E. Arzt
Bioinspired adhesive surfaces – recent progress through new designs
March 6, 2017; Department of Mechanical and Aerospace Engineering – University of California <San Diego, Calif>

E. Arzt
Bioinspired adhesive surfaces – designs for non-smooth counter surfaces
TMS 2016, 146th Annual Meeting and Exhibition; March 1, 2017; San Diego <Calif., USA>

E. Arzt
Design maps for pianos: Visualizing limitations of instrument scaling and wire strength on sound
ICMOBT 2017: 7th International Conference on Mechanics of Biomaterials and Tissues; December 10, 2017; Marriott Waikoloa Beach <Hawaii>

E. Arzt
Verwertungsstrategie am INM
7. Transferwerkstatt, Wissens- und Technologietransfer der außeruniversitären Forschungseinrichtungen; November 17, 2017; Deutsches Zentrum für Luft- und Raumfahrt e. V. (DLR), Bonn <Germany>

E. Arzt
Bioinspired new materials – from geckos to robotics and biomedicine
Deutsche Pharmazeutische Gesellschaft DPhG-Jahrestagung 2017; September 2017, 29; Universität des Saarlandes, Saarbrücken <Germany>

E. Arzt
Mit Grips mehr Grip – bioinspirierte Haftoberflächen vom Konzept zur Anwendung
DGM-Tag 2017; September 27, 2017; Messe Dresden <Germany>

E. Arzt and A. Kraegeloh
Best practice – Leibniz Research Alliance Nanosafety
Summer School des Leibniz-Forschungsverbundes Infections 21; August 30 – September 1, 2017; Forschungszentrum Borstel, Borstel <Germany>

R. Hensel
Composite pillar structures for enhanced adhesion
DFG Nachwuchsakademie; September 25, 2017; Dresden <Germany>

R. Hensel
Bio-inspired elastomeric adhesives for novel pick-and-place concepts
3rd Polymer Sciences and Engineering Conference; October 02, 2017; Chicago <Il, USA>

R. Hensel
Bioinspired complex microstructures for strong adhesion to smooth and rough substrates
AD3PA International Workshop on Advanced 3D Patterning; October 05, 2017; Dresden <Germany>

Nanotribologie / Nanotribology

R. Bennewitz
Nanotribology – shedding light on structure, stress, deformation, chemistry, and lubricants
Workshop on Tribology with highly brilliant synchrotron radiation; March 15-17, 2017; DESY, Hamburg <Germany>

R. Bennewitz
Controlling friction by molecular interactions and electrochemical potentials
7th European Nanomanipulation Workshop; February 20-22, 2017; Jena <Germany>

R. Bennewitz
Molecular control of friction and adhesion
Seminar talk; February 2, 2017; Institute of Physics, University of Basel <Switzerland>

Innovative Elektronenmikroskopie / Innovative Electron Microscopy

N. de Jonge
Liquid-phase electron microscopy of cells and nanomaterials in liquid
Conference and Workshop on Liquid Phase Transmission Electron Microscopy; September 18-20, 2017; Eindhoven University of Technology <Eindhoven, NL>

N. de Jonge
Studying membrane proteins and drug responses in individual breast cancer cells using liquid-phase electron microscopy
August 4, 2017; Vanderbilt University School of Medicine <Nashville, TN, USA>

N. de Jonge
Membrane proteins studied in intact cells using liquid-phase scanning transmssion electron microscopy
Nature Conference on Electron Microscopy for Materials – The Next Ten Years; May 27-29, 2017; Hangzhou <China>

N. de Jonge
Studying drug responses in rare breast cancer cells using liquid-phase electron microscopy
Microscopy Characterisation of Organic-Inorganic Interfaces; February 23, 2017; London <UK>

N. de Jonge
Studying membrane proteins in cells using liquid-phase electron microscopy
Colloquium of Collaborative Research Centre 1027; January 17, 2017; Saarbrücken <Germany>

N. de Jonge
Electron microscopy of cells, membrane proteins, and nano materials in liquid
January 10, 2017; Department of Chemistry and Applied Biosciences, KIST <Saarbrücken, Germany>

N. de Jonge
Liquid-phase electron microscopy of cells and nanomaterials in liquid
Lecture for the Honoris causa ceremony; December 7, 2017; University of Lyon <Lyon, France>

N. de Jonge
Liquid-phase electron microscopy of cells and nanomaterials in liquid
Seminar in the Electron Microscopy Unit; October 23, 2017; Weizmann Institute of Science <Israel>

N. de Jonge
Single molecule and single cell analysis of HER2 receptors in breast cancer cells using liquid phase scanning transmission electron microscopy
Frontiers in Single Molecules Biophyisics 2017; October 16-18, 2017; Neve Ilan Hotel <Israel>

P. Kunnas, I. N. Dahmke and N. de Jonge
Studying soft systems with electron microscopy in liquid
Celebration of the Electron-Symposium; November 14, 2017; DESY, CFEL Hamburg

BIOGRENZFLÄCHEN / BIO INTERFACES

Dynamische Biomateralien / Dynamic Biomaterials

A. del Campo
Bioinspired adhesives for biomedical applications
in-adhesives: Symposium on Innovations in Adhesives and their Applications; February 14-15, 2017; München <Germany>

A. del Campo
Optoregulated biomaterials
Colloquia-HT2017; March 9, 2017; Oxford University <Oxford, UK>

A. del Campo
Dynamic Biomaterials
Gesellschaft Deutscher Chemiker Talks; May 18, 2017; Universität Konstanz <Konstanz, Germany>

A. del Campo
Hybrid surface patterns mimicking frog toe pad wet-adhesive design
WE-Heraeus-Seminar: Bio-inspired, Nano- and Micro-structured Surfaces: New Functionality by Material and Structure; May 29-31, 2017; Bad Honnef <Germany>

A. del Campo
Light-triggered dynamic biointerfaces
FEBS Workshop – Biological Surfaces and Interfaces: Interface Dynamics; July 2-7, 2017; Sant Feliu de Guixols <Catalonia, Spain>

A. del Campo
Bioinspired, anisotropic surface designs for wet adhesion
September 15, 2017; IMT Institute of Microstructure Technology / KIT Karlsruhe Institute of Technology Karlsruhe <Germany>

A. del Campo
Optoregulated biointerfaces
September 21, 2017; MIPS Monash Institute of Pharmaceutical Sciences, Melbourne <Australia>

A. del Campo
Light-guiding cell-materials interactions
September 22, 2017; MIME The Monash Institute of Medical Engineering, CSIRO & MCN Melbourne Centre for Nanofabrication Melbourne <Australia>

A. del Campo
Optoregulated cellular microenvironments
September 25-29, 2017; 2017 ICBNI International Conference on BioNano Innovation Brisbane <Australia>

A. del Campo
Optoregulated biomaterials to study cellular interactions
Seminario de jovenes investigadores en polimeros; October 31, 2017; Madrid <Spain>

A. del Campo
Optoregulated biointerfaces
Biological-Physical Colloquium; November 6, 2017; Technische Universität Kaiserslautern, Kaiserslautern <Germany>

A. del Campo
Optoregulated biointerfaces
15th European Conference on Organized Films (ECOF 15); July 17-20, 2017; Dresden <Germany>

E. S. Khan
Photoactivatable Hsp47: a tool to regulate collagen assembly and tumor microenvironment
Gordon Research Conference on Collagen; July 15-21, 2017; Colby-Sawyer College, New London, NH <USA>

S. Sankaran
Precision biomaterials with optoregulated functions
Symposium "Biomaterials-based approaches to personalized medicine"; March 22, 2017; Berlin <Germany>

S. Sankaran
Photoresponsive bacterial biomaterial interfaces
EMBO Physical Biology Circle Meeting; March 8-10, 2017; European Molecular Biology Laboratory (EMBL), Heidelberg <Germany>

S. Sankaran
Optoregulated living biomaterials
SFB Cell Physics; October 11-13, 2017; Saarbrücken <Germany>

M. K. Włodarczyk-Biegun
Catechol-PEG based bioinks for 3D printing and gluing
3D Printing in Science European Congress 2017; May 16-17, 2017; Hannover <Germany>

M. K. Włodarczyk-Biegun
3D Bioprinting of medical glues
Bionection 2017 – Partnering Conference for Technology Transfer in the Life Sciences 2017; October 17-18, 2017; Jena <Germany>

M. K. Włodarczyk-Biegun
3D Bioprinting of medical glues
Formnext 2017, powered by TCT Conference; November 15, 2017; Frankfurt <Germany>

Zellskeletale Fasern / Cytoskeletal Fibers

F. Lautenschläger
Microfabricated devices to investigate intermediate filaments in living cells
Meeint "When Biomaterials meet biophysics"; September 29, 2017; Erlangen <Germany>

F. Lautenschläger
Vimentin in amoeboid migration
Meeting "Perspectives on Intermediate Filament Structure and Mechanics: From Single Molecules to Cellular Assemblies"; April 07, 2017; Amsterdam <NL>

F. Lautenschläger
Intermediate filaments in cell mechanics
Summerschool: Experimental and theoretical approaches to cell mechanics; April 23 – May 06, 2017; Bangalore <India> via Skype

L. Stankevicins
The role of vimentin in leukocyte amoeboid migration
10th European meeting in Intermediate Filaments; June 14-17, 2017; Saint-Malo <France>

Nano Zell Interaktionen / Nano Cell Interactions

E. Arzt and A. Kraegeloh
Best practice – Leibniz Research Alliance Nanosafety
Summer School des Leibniz-Forschungsverbundes Infections 21; August 30 – September 1, 2017; Forschungszentrum Borstel, Borstel <Germany>

A. Kraegeloh
Nanosicherheit und Wechselwirkungen von Nanopartikeln mit Zellen
Symposium zur Lehrerfortbildung „Nanotechnologie: Potenziale und Risiken"; September 14, 2017; Universität des Saarlandes, Saarbrücken <Germany>

A. Kraegeloh, H. Peuschel, T. Ruckelshausen, J. Fleddermann, P. Herbeck-Engel and I. Tavernaro
From Nano Cell Interactions to Safe Nanomaterials
Korea-EU Nano-product Safety Symposium; May 25, 2017; Saarbrücken <Germany>

NANOKOMPOSIT-MATERIALIEN / NANOCOMPOSITE MATERIALS

Optische Materialien / Optical Materials

M. Amlung
Keynote Lecture: Development and evaluation of glass-like and glass-ceramic protection coatings for metals, steels and glasses
Advanced Ceramics and Applications IV; September 18-20, 2017; Belgrade <Serbia>

M. Amlung
Glass-like protection coatings
Seminar at "Graduate Institute of Ferrous Technology (GIFT)"; May 24, 2017; Pohang <South Korea>

M. Amlung
Development and evaluation of glass-like and glass-ceramic protection coatings for metals and alloys
Seminar at Seoul National University; November 14, 2017; National University, Seoul <South Korea>

M. Amlung
Glass-like and glass-ceramic coatings for metals and alloys
Seminar at LG Chemical, Daejeon, Korea; Daejeon <South Korea>

P. W. de Oliveira
INM and Optical Materials in general
Seminar at "Graduate Institute of Ferrous Technology (GIFT)"; May 24, 2017; Pohang <South Korea>

P. W. de Oliveira
INM in general and special themes of Optical Materials
Seminar at Seoul National University; November 14, 2017; Seoul <South Korea>

P. W. de Oliveira
Funktionalisierung von Oberflächen durch nasschemische Beschichtungsverfahren
H.F. Mark-Symposium 2017; September 7, 2017; Wien <Austria>

P. W. de Oliveira
Photokatalyse
April 27, 2017; Institut für Materialchemie, Wien <Austria>

M. Opsölder
Inorganic-organic composites "Nanomers"
Seminar at "Graduate Institute of Ferrous Technology (GIFT)"; May 24, 2017; Pohang <South Korea>

Strukturbildung / Structure Formation

L. González-Garcia
Hybrid inks of electronics
BISS 2017 – Bayreuth International Summer School on Polymer Science : "Synthetic, structural and electro-optical sutides of polymers and colloids"; July 3-7, 2017; Bayreuth <Germany>

L. González-Garcia
Self-assembly of metal nanostructures for transparent and flexible electronics
18. Wörlitzer Workshop "Self assembling layer structures"; June 19-20, 2017; Wörlitz/Dessau <Germany>

T. Kraus
Transparent electrodes with ultrathin nanowires sinter-free electrodes with hybrid inks
Beilstein Nanotechnology Symposium 2017: Nanoscale Photovoltaics ; New devices and materials; November 21-23, 2017; Potsdam <Germany>

T. Kraus
Self-assembling particles and interfaces for electronic inks
ChinaNano 2017 – 7th International Conference on Nanoscience and Technology; August 29-31, 2017; Beijing <China>

T. Kraus
Self-organizing hybrid inks for transparent, flexible, and printed electronics
ICMAT – 9th International Conference on Materials for Advanced Technologies; June 18-23, 2017; Singapore <Singapore>

T. Kraus
Order and disorder in nanoparticle superstructures
SoftComb Workshop on Non-Equiligrium Dynamics and Structure Formation; April 3-5, 2017; Tübingen <Germany>

T. Kraus
From colloidal interfaces to composite interphases
Max-Planck-Institut für Polymerforschung; February 14, 2017; Mainz <Germany>

QUERSCHNITTSBEREICH / CROSS LINKING UNIT

InnovationsZentrum INM / InnovationCenter INM

A. Kraegeloh, H. Peuschel, T. Ruckelshausen, J. Fleddermann, P. Herbeck-Engel and I. Tavernaro
From Nano Cell Interactions to Safe Nanomaterials
Korea-EU Nano-product Safety Symposium; May 25, 2017; Saarbrücken <Germany>

PROGRAMMBEREICHSUNGEBUNDEN / NOT LINKED TO A PROGRAM DIVISION

Chemische Analytik / Chemical Analytics

Y. E. Silina
The key parameters impacted surface-assisted laser desorption/ionization-mass spectrometry
4-d World Congress on Mass Spectrometry; June 18-21, 2017; London <UK>

Y. E. Silina
A droplet-based lab-on-a-chip for screening of cellular stress biochemical markers
5th International Conference on Bio-sensing Technology; May 7-10, 2017; Riva Del Garda <Italy>

Y. E. Silina
The key parameters affected LDI-MS and its application in a droplet lab-on-a-chip
November 28, 2017; Universität <Leipzig> / Institut für Analytische Chemie, AK Massenspektometrie

NTNM-Bibliothek / NTNM Library

U. Geith
Alles OPEN. Und wer zahlt die Rechnung? Finanzierungsmodelle von Open-Access-Publikationen
Informationsveranstaltung „Open Access: Anpacken!“ an der Universität des Saarlandes (UdS); September 26, 2017; Universität des Saarlandes, Saarbrücken <Germany>

AUSZEICHNUNGEN / AWARDS



Eduard Arzt
Heyn-Denkmünze, Deutsche Gesellschaft für Materialkunde (DGM). Dresden, 26.09.2017.

Roland Bennewitz
Faraday Lecture, Cambridge, UK, 10. – 12.04.2017.

Roland Bennewitz
MINT-Botschafter, Initiative „MINT Zukunft schaffen“ des Saarlandes. Saarbrücken, 08.02.2017.

Johanna Blass
Eduard-Martin-Preis, Universität des Saarlandes. Saarbrücken, 24.10.2017.

Vaishali Chopra
Best Poster Award, European Conference on Organised Films (ECOF). Dresden, 17. – 20.07.2017.

Sarah Fischer
Peebles Award for Graduate Student Research, Adhesion Society. St. Petersburg, FL, USA, 26.02. – 01.03.2017.

Sarah Fischer
Alan Gent Distinguished Student Paper Award, Adhesion Society. St. Petersburg, FL, USA, 26.02. – 01.03.2017.

Jana Fleddermann
1. Preis, Posterwettbewerb der 8th International BioNano-Med 2017, Danube University Krems. Krems, Austria, 20. – 22.03.2017.

Nicolas Jäckel
Auswahl zum 67th Lindau Nobel Laureate Meeting. Lindau, 25. – 30.06.2017.

Niels de Jonge
Doctor honoris causa, Université de Lyon, France, 07.12.2017.

Marcus Koch (mit Marieke Ahlers, Bert Laegel, Steffen Klingel, Dennis Schlehuber, Ilka Gehrke, Christina Eloo, Hans-Jörg Bart)
Outstanding Paper Award, Proceedings of the 13th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics. Portorož, Slovenia, 17. – 19.07.2017.

Günther Krämer
Best Poster Prize, 655. WE-Heraeus-Seminar on Surfaces and Interfaces of Ionic Liquids. Bad Honnef, 03. – 06.12.2017.

Julieta Paez
2nd prize, Evonik Call for Research Proposals ECRP 2017, Evonik.

Volker Presser (mit Matthew Suss, Israel)
ARCHES – Award for Research Cooperation and High Excellence in Science, Minerva-Stiftung der Max-Planck-Gesellschaft. Berlin, 29.03.2017.

Beate Reiser
2nd Poster prize, Particle-Based Materials Symposium. Saarbrücken, 09. – 10.11.2017.

Shrikrishnan Sankaran
Auswahl zum 67th Lindau Nobel Laureate Meeting. Lindau, 25. – 30.06.2017.

Marc Schöneich
Wilfried-Ensinger-Preis, Wissenschaftlicher Arbeitskreis der Universitäts-Professoren der Kunststofftechnik WAK.

Maria Villiou
Studentship, Gordon Research Conference “Molecular Insight to Understand Fracture and Adhesion”. South Hadley, MA, USA, 23. – 28.07.2017

Malgorzata Włodarczyk-Biegun
Auswahl zum Leibniz-Mentoring-Programm, Leibniz-Gemeinschaft.

Huaixia Zhao
Humboldt Research Fellowship for Postdoctoral Researchers, Alexander von Humboldt-Stiftung.

PATENTE / PATENTS

5 Patentanmeldungen
patent applications

6 erteilte Patente
granted patents

4 europäische
european

2 internationale
international

68 Patentfamilien
patent families

ERTEILTE EUROPÄISCHE PATENTE / PATENTS GRANTED IN EUROPE

Europäisches Patent Nr. 09744064.8
Titel: *„Zusammensetzung zur Herstellung optischer Elemente mit Gradientenstruktur“*
Erfinder: Peter de Oliveira, Peter König, Michael Veith, Omid Yazdani-Assl

Europäisches Patent Nr. 04739339.2
Titel: *„Zusammensetzung mit Nichtnewtonschem Verhalten“*
Erfinder: Peter de Oliveira, Martin Mennig, Helmut Schmidt

Europäisches Patent Nr. 13780171.8-1405
Titel: *„Verfahren zur Detektion von Endotoxinen und/oder 1,3-beta-D-Glucanen in einer Probe“*
Erfinder: Annette Kraegeloh, Melanie Kucki

Europäisches Patent Nr. 09801667.8
Titel: *„Verfahren und Zusammensetzung zur Herstellung optischer Elemente mit Gradientenstruktur“*
Erfinder: Peter de Oliveira, Jenny Kampka, Peter König, Annette Kraegeloh, Michael Veith

ERTEILTE INTERNATIONALE PATENTE / PATENTS GRANTED INTERNATIONALLY

US Patent Nr. 12/310,707
Titel: *„Zusammensetzung zur Beschichtung elektrischer Leiter und Verfahren zur Herstellung einer solchen Zusammensetzung“*
Erfinder: Oral Cenk Aktas, Sener Albayrak, Carsten Becker-Willinger, Michael Veith

Koreanisches Patent Nr. 1020127019809
Titel: *„Synthese von Nanopartikeln mittels ionischer Flüssigkeiten“*
Erfinder: Peter de Oliveira, Hechun Lin, Michael Veith

LEHRVERANSTALTUNGEN / TEACHING

WINTERSEMESTER 2016 / 2017

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

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

Arzt, Eduard, Kraegeloh, Annette und Mitarbeiter/innen
NanoBioMaterialien-P
Universität des Saarlandes, Praktikum, 4 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 (mit Wenz, Gerhard)
MC07: Technologie der Polymere und Komposite
Universität des Saarlandes, Vorlesung, 2 SWS

Becker-Willinger, Carsten
Non Destructive Testing: Polymer Materials Part 1
Dresden International University, Blockvorlesung, 1 SWS

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

Jonge, Niels de
Mikroskopie
Universität des Saarlandes, Vorlesung, 4 SWS

Jonge, Niels de
Experimentalphysik I: Mathematische Ergänzungen
Universität des Saarlandes, Vorlesung, 2 SWS

Kraegeloh, Annette (mit Wittmann, Christoph)
Biochemie-1
Universität des Saarlandes, Vorlesung, 2 SWS

Kraus, Tobias
Beschichtungen (Functional Coatings)
Universität des Saarlandes, Vorlesung, 2 SWS

Lautenschläger, Franziska
Einführung in die Biologie I
Universität des Saarlandes, Vorlesung, 2 SWS

Lautenschläger, Franziska (mit Ott, Albrecht)
Seminar zu aktuellen Fragen der Biophysik
Universität des Saarlandes, Seminar, 2 SWS

SOMMERSEMESTER 2017

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

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

del Campo, Aránzazu (mit Wenz, Gerhard)
Analyse von Polymeren
Universität des Saarlandes, Vorlesung, 2 SWS

del Campo, Aránzazu und Mitarbeiter/innen
Biopolymere & Bioinspirierte Polymere
Universität des Saarlandes, Vorlesung, 2 SWS

del Campo, Aránzazu und Mitarbeiter/innen
Praktikum Biomaterialien
Universität des Saarlandes, Blockpraktikum, 5 SWS

Kraegeloh, Annette und Mitarbeiter/innen
NanoBiomaterialien-2
Universität des Saarlandes, Vorlesung / Übung, 2 SWS

Kraus, Tobias
Praktikum Kolloide und Grenzflächen
Universität des Saarlandes, Praktikum, 3 SWS

Lautenschläger, Franziska
Praktikum Einführung in die Biologie
Universität des Saarlandes, Praktikum, 2 SWS

Lautenschläger, Franziska
Seminar zu aktuellen Fragen der Biophysik
Universität des Saarlandes, Seminar, 2 SWS

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

Presser, Volker (mit Wenz, Gerhard)
Smart Materials and Polymers
Universität des Saarlandes, Vorlesung, 2 SWS

WINTERSEMESTER 2017 / 2018

Arzt, Eduard, del Campo, Aránzazu
INM-Kolloquium
Universität des Saarlandes, Kolloquium, 2 SWS

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

Arzt, Eduard, Kraegeloh, Annette und Mitarbeiter/innen
NanoBioMaterialien-P
Universität des Saarlandes, Praktikum, 4 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 (mit Wenz, Gerhard)
MC07: Technologie der Polymere und Komposite
Universität des Saarlandes, Vorlesung, 2 SWS

Becker-Willinger, Carsten
Non Destructive Testing: Polymer Materials Part 1
Dresden International University, Blockvorlesung, 1 SWS

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

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

Del Campo, Aránzazu
Biomedizinische Polymere
Universität des Saarlandes, Vorlesung, 2 SWS

Jonge, Niels de
Experimentalphysik I: Mathematische Ergänzungen
Universität des Saarlandes, Vorlesung, 2 SWS

Kraegeloh, Annette (mit Wittmann, Christoph)
Biochemie-1
Universität des Saarlandes, Vorlesung, 2 SWS

Kraus, Tobias
Beschichtungen (Functional Coatings)
Universität des Saarlandes, Vorlesung, 2 SWS

Lautenschläger, Franziska
Einführung in die Biologie I
Universität des Saarlandes, Vorlesung, 2 SWS

VORTRÄGE IM INM-KOLLOQUIUM / INM COLLOQUIUM TALKS

Prof. Dr. Jens Kreisel, Luxembourg Institute of Science and Technology, Luxembourg
Mechanical deformation of functional oxides
January 17, 2017, Host: Prof. Dr. Eduard Arzt

Prof. Dr. Jürgen Steimle, Universität des Saarlandes, Saarbrücken
End-user fabrication of personalized flexible sensors
January 31, 2017, Host: Prof. Dr. Eduard Arzt

Prof. Dr. Philipp Adelhelm, Friedrich-Schiller-Universität Jena
From lithium to sodium: materials aspects of future battery concepts
February 14, 2017, Host: Prof. Dr. Volker Presser

Dr. Alexander Titz, Helmholtz-Zentrum für Infektionsforschung Saarbrücken
Carbohydrate-binding proteins as targets for anti-infectives: pseudomonas aeruginosa and its lectin lecb
April 27, 2017, Host: Prof. Dr. Aránzazu del Campo

Prof. Dr. Alexander Eychmüller, Technische Universität Dresden
Superstructures of colloidal nanocrystals
May 4, 2017, Host: Prof. Dr. Tobias Kraus

Prof. Dr. Peter Müller-Buschbaum, Technische Universität München
Polymer and hybrid nanostructures for applications with advanced scattering techniques
May 9, 2017, Host: Prof. Dr. Tobias Kraus

Dr. Mitchell Han, University Medical Center Utrecht, The Netherlands
Cadherin mechanotransduction in morphogenesis
May 15, 2017, Host: Prof. Dr. Aránzazu del Campo

Prof. Dr. Stephan Hofmann, University of Cambridge, United Kingdom
Integrated crystal growth of advanced nanomaterials: from model systems to integrated manufacturing
May 16, 2017, Host: Prof. Dr. Niels de Jonge

Prof. Dr. Myung-Han Yoon, Gwangju Institute of Science and Engineering (GIST), Korea
Solution-processed metal oxide materials for large-area flexible electronics and hydrogen energy devices
May 19, 2017, Host: Dr. Peter Oliveira

Dr. Kerstin Blank, MPI für Kolloid- und Grenzflächenforschung, Potsdam
Molecular force sensors: from molecular mechanisms towards applications in biology and materials science
May 30, 2017, Host: Prof. Dr. Roland Bennewitz

Dr. Johnny Kim, Max Planck Institute for Heart and Lung Research, Bad Nauheim
Muscle stem cells in regeneration and disease
May 31, 2017, Host: Prof. Aránzazu del Campo

Prof. Dr. Marc A. Meyers, University of California, San Diego, USA
Biological materials science: challenges and opportunities
June 6, 2017, Host: Prof. Dr. Eduard Arzt

Prof. Dr. Andrea Hodge, University of Southern California, Los Angeles, USA
Grain boundary engineering at the nanoscale
June 14, 2017, Host: Prof. Dr. Eduard Arzt

Prof. Dr. Thomas Riedl, Bergische Universität Wuppertal
Hybrid perovskite optoelectronics
July 4, 2017, Host: Prof. Dr. Tobias Kraus

Prof. Dr. Christina Scheu, MPI für Eisenforschung, Düsseldorf
Insights into the structure and properties of hydrothermally grown $Nb_3O_7(OH)$ photocatalysts and their Ti containing derivatives
July 18, 2017, Host: Prof. Dr. Volker Presser

Assoc. Prof. Dr. Attila Kossa, Budapest University of Technology and Economics, Hungary
Visco-hyperelastic modelling of polymeric foams & viscoelastic/viscoplastic characterization of thermoplastics
August 9, 2017, Host: Prof. Dr. Eduard Arzt

Prof. Dr. Muhammad Yousaf, York University, Toronto, Canada
Rewiring cell surfaces with click chemistry for applications in cell biology and tissue engineering
August 22, 2017, Host: Prof. Dr. Aránzazu del Campo

Prof. Dr. Jianjun Wang, Chinese Academy of Sciences, Beijing, China
Bioinspired materials for controlling ice formation
September 14, 2017, Host: Dr. Jiaxi Cui

Prof. Dr. Yanlei Yu, Fudan University, Shanghai, China
Photodeformable liquid crystal polymers and soft actuators
October 26, 2017, Host: Dr. Jiaxi Cui

Prof. Dr. Ulrich Stimming, University of Newcastle, United Kingdom
Analysis of molecular processes in batteries
November 7, 2017, Host: Prof. Dr. Volker Presser

Prof. Dr.-Ing. Wilhelm Schabel, Karlsruhe Institute of Technology (KIT)
Processing of functional thin films and battery electrodes
November 14, 2017, Host: Prof. Dr. Tobias Kraus

Dr. Dimitris Missirlis, Max-Planck-Institute for Medical Research & Heidelberg University
Cell-microenvironment interactions: how fibronectin conformation and substrate mechanics control fibroblast polarization & directional migration
December 7, 2017, Host: Prof. Dr. Aránzazu del Campo

Prof. Dr. Vojislav Mitić, University of Niš, Serbia
From $BaTiO_3$-ceramics to fractal nature in ceramics and materials sciences
December 8, 2017, Host: Dr. Peter W. de Oliveira

Prof. Dr. Christian Colliex, Université Paris Saclay, Orsay, France
New views on the nano-world offered by the multi-signal scanning transmission electron microscope (STEM)
December 12, 2017, Host: Prof. Dr. Niels de Jonge

Prof. Dr. Rubén Pérez, Universidad Autonoma de Madrid, Spain
Measuring the mechanical properties of biomolecules in liquids with large-scale atomistic molecular dynamics simulations
December 19, 2017, Host: Prof. Dr. Roland Bennewitz

VERANSTALTUNGEN / EVENTS

FEBRUAR

Kick-Off Veranstaltung NaMiComp
C. Becker-Willinger, A. del Campo, B. Reinhard und G. Weber (mit Univ. des Saarlandes und Univ. Namibia)
Saarbrücken, 08. – 09.02.2017

MÄRZ

Netzwerktreffen Biotechnologie
A. del Campo, N. de Jonge, M. Koch, A. Kraegeloh und M. Quilitz (mit BBZ Völklingen)
Saarbrücken, 13.03.2017

ERC-Workshop: Modeling and concepts for adhesion and grip
E. Arzt, R. Hensel und C. Hartmann (mit Univ. of California, Santa Barbara)
Saarbrücken, 14. – 17.03.2017

Biomaterials-based approaches to personalized medicine
A. del Campo (mit Leibniz Research Alliance Health Technologies, IPF Leibniz Institute of Polymer Research Dresden, DWI Leibniz Institute for Interactive Materials)
Berlin, 22.03.2017

LOPEC 2017
J. Atchison, L. Gonzáles-García, J. Mohrbacher, M. Opsölder, R. Sander und W. Seitz
München, 28. – 30.03.2017

MÄRZ

Workshop 2.0 des Forschungsverbundes Nanosicherheit
A. Kraegeloh und D. Hell
Saarbrücken, 28. – 29.03.2017

Eröffnung der neuen NTNM-Bibliothek
E. Bubel, U. Geith und C. Hartmann
Saarbrücken, 31.03.2017

APRIL

Veranstaltung für den Lions Club Heusweiler
E. Arzt, R. Hensel, A. Kraegeloh, P. William de Oliveira, M. Quilitz und A. Verch (mit Univ. des Saarlandes)
Saarbrücken, 03.04.2017

Veranstaltung für die Teilnehmenden des Workshops "Recent trends in microstructure characterization"
G. Krämer, J. Mohrbacher, M. Quilitz und A. Verch
Saarbrücken, 04.04.2017

13. Zsigmondy-Kolloquium der Deutschen Kolloid-Gesellschaft
T. Kraus und C. Hartmann (mit Univ. des Saarlandes)
Saarbrücken, 05. – 07.04.2017

Hannover Messe
J. Atchison, M. Jochum, J. Mohrbacher, M. Opsölder, R. Sander, A. Schreiber, W. Seitz und J. Staudt
Hannover, 24. – 28.04.2017

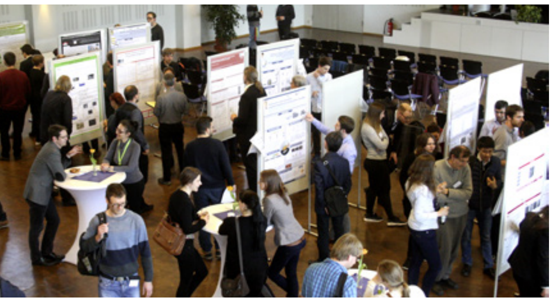
APRIL

Girls' Day 2017 – Der Blick durchs Mikroskop
I. Dahmke, G. Heppe, M. Koch, C. Sauer-Hormann, S. Siegrist und S. Zeiter-Semmet
Saarbrücken, 27.04.2017

JUNI

Besuch einer Delegation des Georgia Institute of Technology (Metz, Frankreich)
A. del Campo und M. Quilitz
Saarbrücken, 08.06.2017

Open Access – Tag der Offenen Tür der Universität des Saarlandes
E. Bubel und U. Geith
Saarbrücken, 24.06.2017



JULI

Nano Korea – International Nanotech Symposium & Exhibition
M. Amlung, S. Kim, M. Opsölder und W. Seitz
Goyang/Seoul, Korea, 12. – 14.07.2017

ERC-Workshop "Chemical Aspects on Micropatterned adhesives"
E. Arzt, R. Hensel und C. Hartmann
Saarbrücken, 20.07.2017

Veranstaltung für die Teilnehmenden der Summer School "Technology Transfer & Entrepreneurship" der Univ. des Saarlandes
R. Bennewitz, I. Dahmke, J. Fleddermann, M. Koch, J. Mohrbacher, V. Presser, M. Quilitz und C. Schmitz
Saarbrücken, 20.07.2017

SEPTEMBER

18. Jahrestagung des Arbeitskreises Bibliotheken und Informationseinrichtungen der Leibniz-Gemeinschaft
E. Bubel und U. Geith (mit Sprecherrat des AK)
Nürnberg, 14. – 15.09.2017

Veranstaltung für Teilnehmende der 5th DocMASE Summer School
M. Koch, J. Mohrbacher und M. Quilitz
Saarbrücken, 14.09.2017

Internationale Automobil-Ausstellung IAA
A. May, J. Mohrbacher, M. Opsölder und W. Seitz
Frankfurt, 14. – 24.09.2017

Veranstaltung für Teilnehmerinnen des MentoMINT-Programmes der Universität des Saarlandes
S. Fischer, M. Quilitz, C. Sauer-Hormann, C. Schmitz, J. Staudt und V. Tinnemann (mit Univ. des Saarlandes)
Saarbrücken, 20.09.2017

Veranstaltung für den Lions Club Lebach
E. Arzt, R. Hensel, T. Kraus, M. Quilitz und J. Staudt
Saarbrücken, 21.09.2017

NOVEMBER

Particle-Based Materials Symposium
T. Kraus und C. Hartmann (mit Fraunhofer Institute for Silicate Research, FAU Erlangen, Leibniz Institute for Interactive Materials)
Saarbrücken, 09. – 10.11.2017

Veranstaltung für eine Delegation aus der Provinz Jiangsu, China
M. Koch, J. Mohrbacher und M. Quilitz (mit Jiangsu Center of International Technology Transfer und Univ. des Saarlandes)
Saarbrücken, 13.11.2017

Medizintechnik-Messe Compamed
L. Engel, W. Seitz und R. Strahl
Düsseldorf, 13. – 16.11.2017

What's next? Career paths in science – and beyond. A symposium for female scientists
C. Sauer-Hormann und S. Zeiter-Semmet (mit Gleichstellungsbüro, Univ. des Saarlandes)
Saarbrücken, 16.11.2017

AUGUST

Veranstaltung für Studierende der Programme AMASE und I.DeAr der Universität des Saarlandes
J. Mohrbacher, M. Quilitz und M. Zeiger (mit Univ. des Saarlandes)
Saarbrücken, 24.08.2017

OKTOBER

BMBF Ferienpraktikum Nano- und Werkstofftechnologie 2017
G. Heppe, M. Koch, T. Müller, M. Quilitz, C. Sauer-Hormann, S. Schumacher und S. Siegrist (mit dem VDI)
Saarbrücken, 09. – 13.10.2017

Nanosafety 2017
E. Arzt, A. Kraegeloh, C. Hartmann und D. Hell (mit Leibniz-Forschungsverbund Nanosicherheit)
Saarbrücken, 11. – 13.10.2017

Cell Physics 2017
A. del Campo, N. de Jonge und F. Lautenschläger (mit Univ. des Saarlandes, SFB 1027)
Saarbrücken, 11. – 13.10.2017

30 Jahre INM
E. Arzt, A. del Campo, G. Weber und C. Hartmann
Saarbrücken, 23.10.2017

OKTOBER

Infoveranstaltung: Freier Zugang zu wissenschaftlicher Literatur
E. Bubel und U. Geith (mit Saarländische Universitäts- und Landesbibliothek)
Saarbrücken, 26.10.2017

4. LIESA-Kongress
M. Quilitz
Saarbrücken, 26.10.2017

Tagesseminar Gute Wissenschaftliche Praxis und Kommunikation, STUBE – Studienbegleitprogramm Rheinland-Pfalz/Saarland
R. Bennewitz
Saarbrücken, 28.10.2017

DAS INM IN DEN MEDIEN / INM IN THE MEDIA

Hybrid-Tinten auf der Compamed
SCHALTKREIS AUF WEICHEM UNTERGRUND
UBSTRATE
A6 Wirtschaft
Damit Forschung in Firmen ankommt
FLEXIBLE TOUCHSCREENS
Away from the Rigid Display
Research & Technology
49
olutioniert Energiespeicher
ELEKTRONIKINDUSTRIE
Smart & flexibel
Gedruckte Silberbahnen auf Folie machen biegsame und preiswerte Touchscreens möglich
Saar-Uni vergibt Stipendien für Materialwissenschaftler
Biegsame Touchscreens
Forscher der Saarland-Uni (INM) haben neue Materialien für eine Nano-Tinte entwickelt, die in Screens eingesetzt werden kann
Eduard Arzt erhält Heyn-Denkmünze der DGM
Fotochemische Metallisierung
Gebogene Touchscreens
INM Fellowship
Forschung an anregbaren Partikeln
gion
ekt zum Technologie-
saaris
automotive. saarland
d-Gemeinschaftsstand auf der IAA
Biegsame Touchscreens
ostengünstiger Inkjet-Druck
otheken, dort die Verlagskraken

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Mitte links: Hydrothermally synthesized vanadia nanoflowers for use as electrodes for lithium and sodium ion batteries. (© INM)
Mitte rechts: SEM image of 3D printed hierarchical structure resembling human trabecular meshwork. (© INM)

SAARLAND

Großes entsteht immer im Kleinen.

INM

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