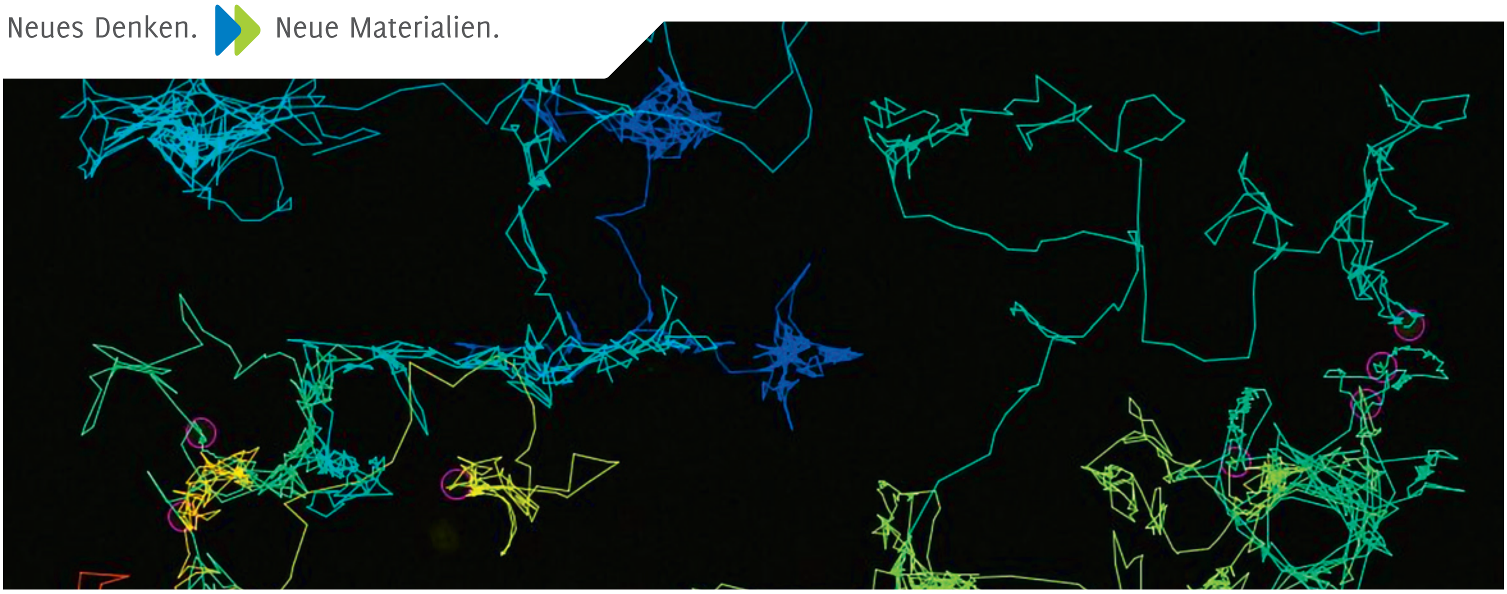
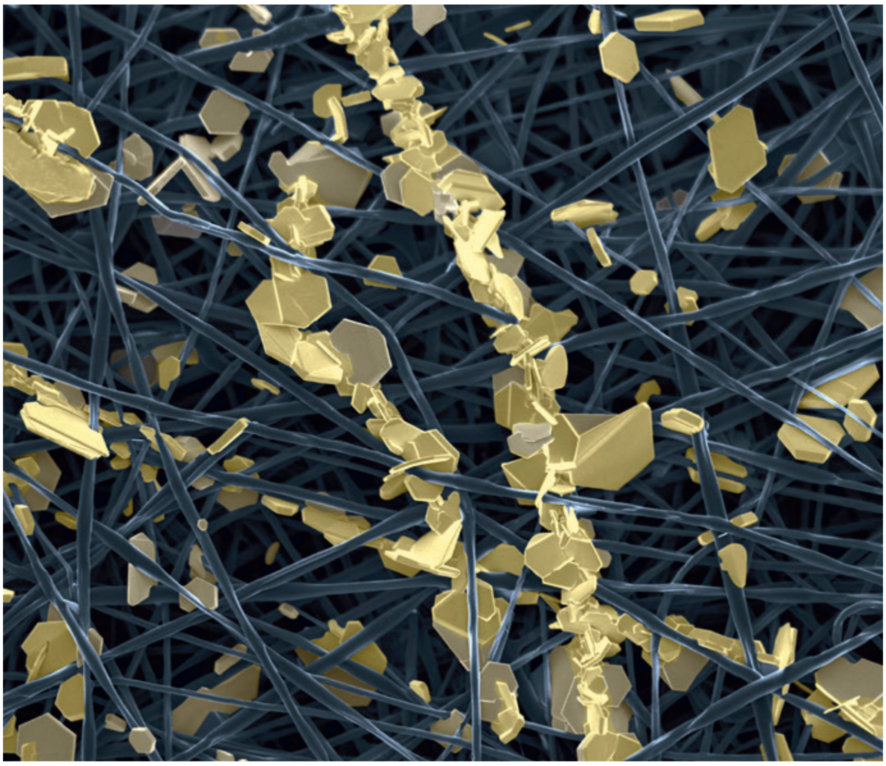
Neues Denken. Neue Materialien.





JAHRESBERICHT 2019
ANNUAL REPORT 2019

Leibniz Gemeinschaft

INM
Leibniz-Institut für Neue Materialien

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Kaufmännischer Geschäftsführer / Business Director

Prof. Dr. Aránzazu del Campo

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Prof. Dr. Eduard Arzt

Wissenschaftlicher Geschäftsführer und Vorsitzender der Geschäftsführung / Scientific Director and CEO

LIEBE FREUNDINNEN UND FREUNDE DES INM, LIEBE LESERINNEN UND LESER,

wir sind ein bisschen stolz: Erneut können wir auf ein sehr erfolgreiches Jahr am INM zurückblicken. Wieder haben unsere Publikationen einen neuen Höchststand erreicht, unsere Ergebnisse wurden in den führenden Journals unserer Fachgebiete veröffentlicht und die Einwerbung externer Mittel liegt über unseren Zielen. Dass unsere Spanne von Grundlagenforschung bis hin zu Anwendungen reicht, konnten wir nachdrücklich belegen: Die 2019 ausgegründete INNOCISE GmbH wird unsere erfolgreiche Forschung im Bereich bioinspirierter Haftsysteme in innovative Lösungen für Anwendungen in den Bereichen Robotik, Handling und Automation umsetzen.

Wie geht es weiter? Zwei Zukunftsthemen haben wir für unser Institut identifiziert: biomedizinische Materialien und Materialien für die digitale Umgebung. Viele Anforderungen der Welt von morgen werden nur mit neuen Materiallösungen umzusetzen sein. Soeben beginnen die Renovierungsarbeiten für unseren Erweiterungsbau, den wir für unsere Zukunftsthemen herrichten. Außerdem gehen wir neue strategische Kooperationen mit Medizin und Informatik ein – denn Innovationen können nur gemeinsam gelingen.

Tauchen Sie mit uns ein in die spannende Welt moderner Materialforschung. Wir freuen uns, wenn Sie das INM auch in die Zukunft begleiten.

DEAR FRIENDS OF INM, DEAR READERS,

We are a bit proud: Once again we can look back on a very successful year at INM. Our publications, again, reached a new high, our results have been published in the leading journals of our research fields and the acquisition of external funding has exceeded our goals. We were able to demonstrate that our range spans from basic research to applications: INNOCISE GmbH, founded in 2019, will leverage our successful research in the field of bio-inspired adhesive systems in innovative solutions for applications in robotics, handling and automation.

What is next? We have identified two future topics for our institute: biomedical materials and materials for the digital environment. Many of the requirements of tomorrow's world can only be met with new materials solutions. The renovation work for our extension building, which we are preparing for our future topics, has just begun. We are also entering into new strategic cooperation with partners in medicine and computer science – for only together can we create such innovations..

Delve with us into the exciting world of modern materials research. We would be pleased if you continued to accompany the INM into the future.

GRUPPENBERICHTE / GROUP REPORTS

Niels de Jonge
Head *Innovative Electron Microscopy*

Eduard Arzt
Head *Functional Microstructures*

Roland Bennewitz
Head *Nanotribology*

Volker Presser
Head *Energy Materials*

"OUR RESEARCH FIELD FOCUSES ON PHYSICAL AND PHYSICO-CHEMICAL PROCESSES AT INTERFACES. WE DESIGN, SYNTHESIZE AND CHARACTERIZE MATERIALS AND STRUCTURES WITH HIGH DENSITIES OF SURFACES AND INTERFACES. OUR RESULTS CONTRIBUTE TO NEW CONCEPTS IN HEALTH, ROBOTICS, AND RENEWABLE ENERGY."

GRENZFLÄCHENMATERIALIEN / *INTERFACE MATERIALS*

ENERGIE-MATERIALIEN / ENERGY MATERIALS

PROF. DR. VOLKER PRESSER

ZUSAMMENFASSUNG

Der Programmbereich *Energie-Materialien* erforscht elektroaktive Grenzflächen und entwickelt funktionale Nanomaterialien für elektrochemische Anwendungen zur Energiespeicherung und Wasseraufbereitung. Hochporöse Kohlenstoffmaterialien können mittels chemischer Prozesse auf der Nanoskala mit Metalloxiden und Metallsulfiden hybridisiert werden. Besonders interessant sind dabei als Materialien Kohlenstoffnanozwiebeln und Verfahren wie die Atomlagenabscheidung. Wir untersuchen zudem Faraday'sche Materialien wie zweidimensionale Karbide (MXene) und Chalkogenide. Neben Superkondensatoren sowie Lithium- und Natrium-Ionen-Batterien erforschen wir redoxaktive Elektrolyte zur Entwicklung schneller Energiespeicher mit hoher Speicherkapazität. Besondere Bedeutung hat die Charakterisierung elektrochemischer Prozesse, die mit *In-situ*-Methoden untersucht werden. Unsere Aktivitäten umfassen Materialsynthese, Grundlagenforschung, Methodenentwicklung, Zelldesign und Industriekollaborationen.

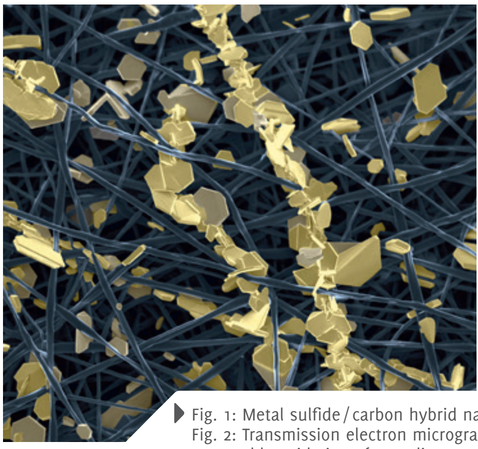
MISSION

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 and water treatment. 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 the implementation of nanoscale metal oxides or metal sulfides. We also investigate Faradaic materials, such as two-dimensional transition metal dichalcogenides or carbides (MXene). 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.

CURRENT RESEARCH

Nanohybrid materials

High-performance electrochemical materials must combine electrical conductivity with an attractive charge storage capacity. Our work on combining metal oxides and/or metal sulfides with carbon on a sub-micrometer-scale enables improved electrochemical performance. We utilize methods such as chloroxidation of carbides, sulfidation of metal oxides, and atomic layer deposition to accomplish this task. We collaborate with partners at the Technical University Darmstadt, the INP Leibniz Institute in Greifswald, and the Max-Planck Institute in Düsseldorf.



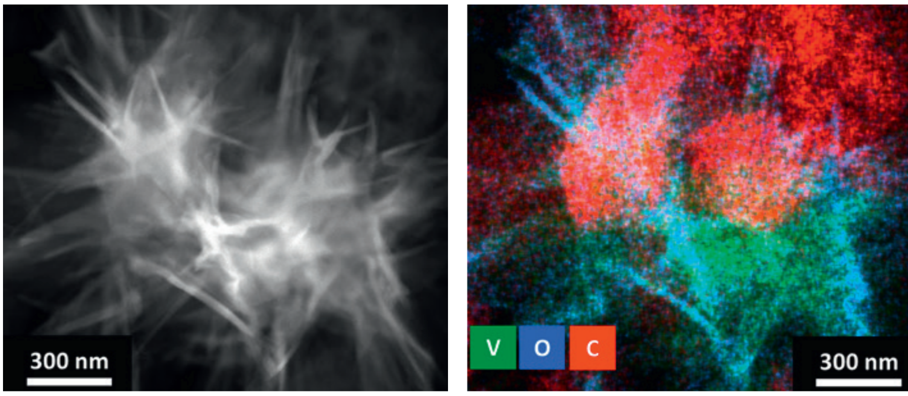


Fig. 1: Metal sulfide / carbon hybrid nanofibers obtained via electrospinning for use as high capacity electrodes in lithium-ion batteries.
Fig. 2: Transmission electron micrograph and corresponding elemental map of carbon / vanadium oxide hybrid nanomaterial obtained via chloroxidation of vanadium carbide.

Redox-active electrolytes

Redox-active electrolytes allow combining high power with high energy for electrochemical energy storage. The confinement of redox-active ions within carbon nanopores enables high charge transfer rates and, for some ions, results in weak chemisorption that makes the use of ion-exchange membranes between the electrode pair obsolete. Aqueous redox systems capitalize further on the non-flammability for enhanced safety compared to energy storage modules based on organic electrolytes. Our team has also demonstrated that redox-active electrolytes can be used for water desalination with enhanced performance by transferring the enhanced charge storage capacity to an increased ion removal ability. To enable redox-electrolytes for water desalination, our team works on the development and rigorous implementation of ceramic / polymeric ion exchange membranes.

Faradaic materials for water treatment

Capacitive deionization is a rapidly growing 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 carbides (MXene), transition metal dichalcogenides, and metal oxide / carbon nanohybrids. Our work has shown that unlike capacitive deionization, Faradaic deionization allows the ion-selective desalination at high molar strength, enabling applications such as seawater treatment or mining water remediation. We specifically focus on high-performance desalination and ion separation in the environmental setting.

Digital energy materials

In close collaboration with research partners in China and Poland, we support our experimental work by simulation of ion electrosorption processes on the nanoscale. In return, our experimental data feeds back into the simulation work to allow the correlation between prediction and actual measurement to develop next-generation electrochemical materials. In this way, we discovered the surprising permselectivity of sub-nanometer carbon pores owed to their ionophobicity. This allows a new approach to membrane-free seawater desalination with activated carbon.

OUTLOOK

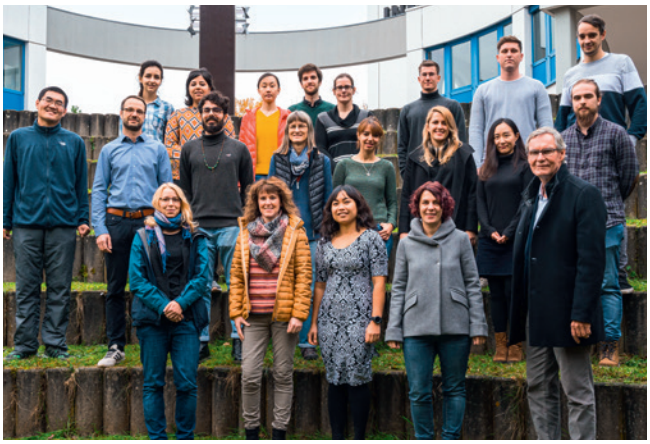
Our team will continue to broaden the utilization of interfacial electrochemistry and hybrid carbon nanomaterials. We will enhance our collaboration with industry for the development of high capacity energy storage devices, with a focus on carbon/metal oxide nanohybrid materials. In addition, we will 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 overcome 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

Mikrostrukturierte Oberflächen versprechen neue mechanische, optische und haptische Funktionalitäten. Der Programmbereich befasst sich mit der experimentellen und theoretischen Untersuchung solcher Oberflächen, deren Konzepte von Vorbildern in der belebten Natur inspiriert sind. Der Fokus der laufenden Arbeiten liegt auf fibrillären, bioinspirierten Haftsystemen für die temporäre, reversible Adhäsion. Schwerpunkte sind die Optimierung der Kontaktflächen sowie das Zusammenspiel der einzelnen Haftstrukturen anhand numerischer Modellierung und experimenteller Validierung. Neue Schwerpunkte sind Mikrostrukturen für gezielte Haftung unter Wasser und die modellmäßige Erfassung von Handhabungsmechanismen mit dem Ziel, auch „anspruchsvolle" Objekte zuverlässig zu greifen. Eine weitere erfolgversprechende Richtung ist das Design von Wundpflastern in Kooperation mit der Universitätsklinik in Homburg. Unsere Arbeiten werden von der EU (ERC Proof-of-Concept), einem Projekt der Leibniz-Gemeinschaft sowie durch Industriekooperationen gefördert.



MISSION

Micropatterned surfaces promise new mechanical, optical, and haptic functionalities. The Program Division *Functional Microstructures* conducts experimental and theoretical research on the design, fabrication and characterization of such surfaces by combining suitable morphologies and materials. Inspired by the adhesive performance of natural systems, the group mimics such mechanisms to control the adhesion of synthetic surfaces. To optimize adhesion, the stress distribution in the contact interface is modelled numerically and the statistics and interaction of individual adhesive contacts are investigated. New focal areas are the design of microstructures for controlled underwater adhesion and the theoretical evaluation of pick-and-place mechanisms with the goal to reliably handle also "challenging" objects. Another promising new direction is the design of wound adhesives for clinical application. Our research is funded by an ERC Proof-of-Concept Grant, a Leibniz project, and industrial contracts.

CURRENT RESEARCH

Strong wet and dry adhesion

While dry adhesion of micropatterned adhesives allow reliable attachment to a variety of surfaces, wet adhesion remains a challenge as capillary and van-der-Waals forces are considerably weakened under water. To gain strong adhesives that work both in air and under water, a novel microstructure design has been introduced: Cupped microstructures (Fig. 1) are the next generation of adhesive microstructures that generate strong controllable adhesion of about 1 MPa in air and under water (Fig. 2). In collaboration with Prof. Walter Federle (Univ. Cambridge, UK), design parameters were tested and adhesion mechanisms revealed – in dry conditions the adhesion is mainly based on van-der-Waals interactions, while in wet conditions the suction effect dominates. (*Wang et al., ACS Appl. Mater. Interfaces, 2019*)

Skin adhesives

Novel skin adhesives could potentially revolutionize wound healing strategies and open new avenues for human-computer interaction. New silicone-based adhesives for the treatment of ear drum perforations were developed. Due to the intrinsically low surface free energy of silicone elastomers, functionalization strategies are needed to promote the attachment and spreading of eukaryotic cells. We found that functionalization by physical protein adsorption significantly improves the cellular interaction of fibroblasts interfering with the polymeric surface without interfering in the adhesive performance, as analyzed by tack and peel tests. (*Boyadzhieva et al., Polymer, 2019*) In a new ERC Proof-of-Concept grant (STICK-2HEAL – *Innovative adhesives for ear drum healing*), the clinical potential of these materials is currently evaluated in cooperation with Prof. Bernhard Schick and Prof. Gentiana Wenzel (Saarland University Clinic). In a collaboration with the Saarland Informatics Campus (Prof. Jürgen Steimle, Saarland University), new adhesives for wearable electronics applications were developed. We analyzed their effect on human tactile perception in psychophysical experiments. (*Nittala et al., CHI 2019*)

Technology transfer & Start-up company

INM's Gecomer Technology has now been validated for numerous pick & place scenarios, even in challenging environments. The market validation was performed in an ERC Proof-of-Concept grant (SWITCH2MARKET) to prepare the founding of a spin-off company (INNOCISE GmbH, since June 2019). The spin-off now commercializes the developed technology and provides new handling solutions in cases where the new technology surpasses the state-of-the-art technologies.

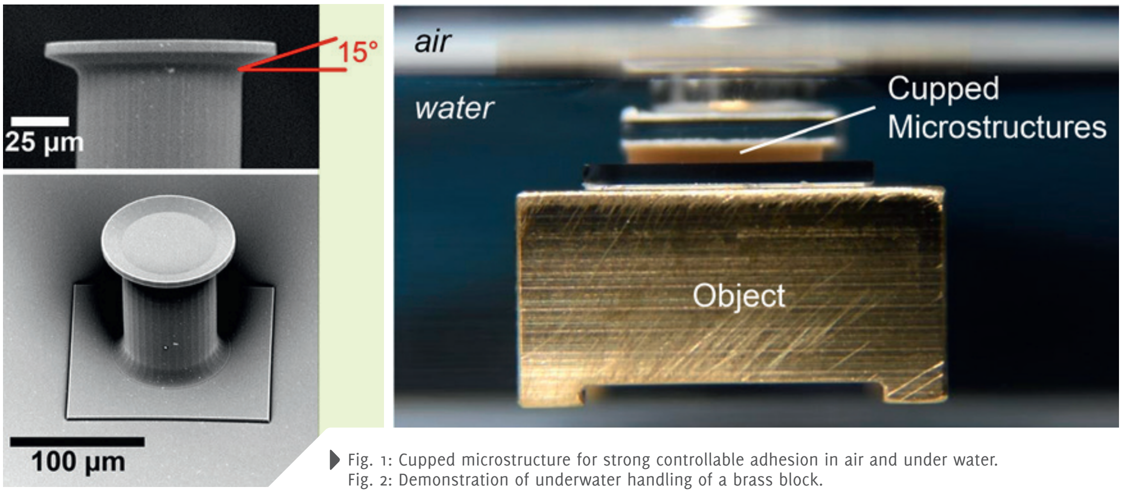


Fig. 1: Cupped microstructure for strong controllable adhesion in air and under water.
Fig. 2: Demonstration of underwater handling of a brass block.

OUTLOOK

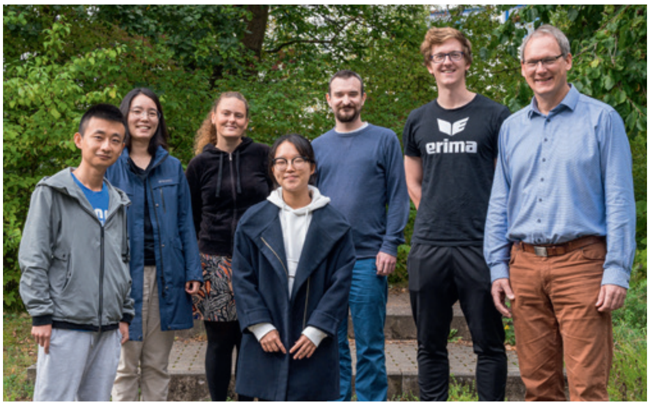
Micropatterned surfaces are a rich research field and continue to play a central role in INM's portfolio. Among the fundamental aspects to be explored are new designs including mechanical metamaterials to allow new functions and new strategies to switch adhesion. In addition, *in situ* observation of the real contact area will help to predict adhesion based on statistical learning algorithms. The potential applications range from medical devices through handling solutions to space applications.

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, die mechanische Eigenschaften wie Reibung, Verschleiß, Schmierung, Verformung und Adhäsion bestimmen. Die Systeme reichen von Graphen über Hydrogele bis hin zu mikrostrukturierten Elastomeren. Die experimentellen Projekte basieren auf unserer Expertise in der hochauflösenden Rasterkraftmikroskopie. Auch auf größeren Längenskalen werden Experimente zu Reibung und Verschleiß durchgeführt, wobei vor allem die Rolle der Reibung mit Haut in der haptischen Wahrnehmung untersucht wird. Zu den wichtigsten Ergebnissen des Jahres 2019 gehören der erfolgreiche Abschluss eines Projekts zur skalenübergreifenden Tribologie von Polymer-Stahl Kontakten, die rheologische Untersuchung ionischer Flüssigkeiten in einem nanoskaligen Spalt, sowie die Quantifizierung der molekularen Steifigkeit einzelner Quervernetzungspunkte in Hydrogelen, die auch als Biomaterial Zelladhäsion vermitteln.



MISSION

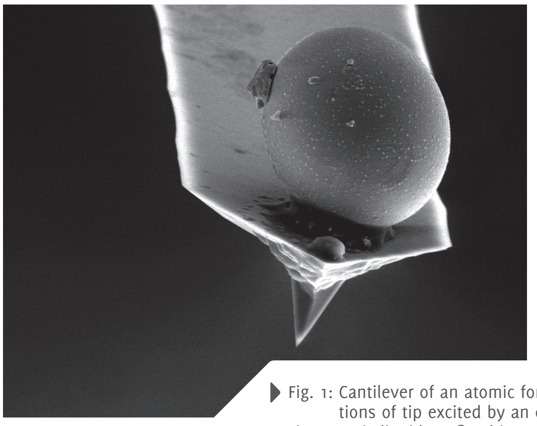
The Program Division *Nanotribology* explores new materials with specific adhesion and friction properties. We focus on surface functionalization and on understanding the physical chemistry of friction, wear, lubrication, deformation, and adhesion. Materials range from graphene over hydrogels to micro-structured elastomers. 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 in skin friction and its role in the haptic perception of materials. New projects employ single-molecule force spectroscopy in soft matter for biophysical applications.

CURRENT RESEARCH

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

Nanorheology of ionics liquids under electrochemical control

Ionic liquids are a novel class of lubricants with oil-like viscosity but a number of advantages such as low vapor pressure and electric conductivity. We have established magnetically activated Dynamic Shear Force Microscopy as a method to study the shear viscosity of ionic liquids in nanometer-sized gaps (Fig. 1). We discovered a solidification of the liquid and confirmed generic mechanisms of tunable electrolubricity (Fig. 2).



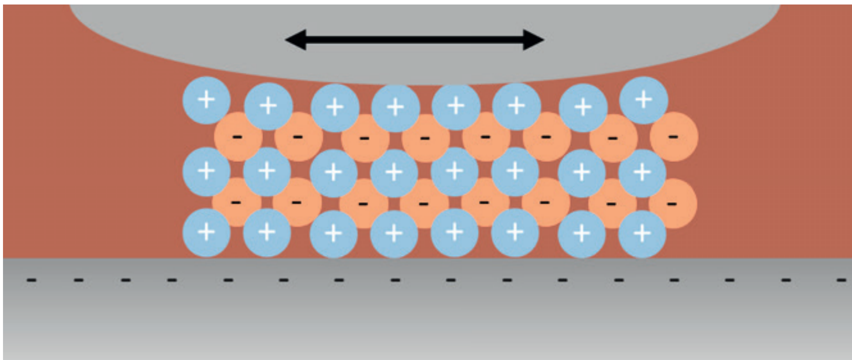


Fig. 1: Cantilever of an atomic force microscope with 20 µm hard-magnetic sphere attached. Lateral oscillations of tip excited by an external magnetic field.
Fig. 2: Ionic liquid confined in a nanometer-scale gap under the laterally oscillating tip. Liquid solidifies and ions form a cubic crystal when electrifying confining surfaces.

Nanomechanics of single crosslinks in hydrogels which mediate cell adhesion

In successful collaboration with the Program Division *Dynamic Biomaterials*, we studied the nanomechanics of hydrogels by force spectroscopy of single crosslinks. When growing cells on hydrogels, the elastic modulus of the substrate is an important parameter for the spreading of cells. This growth is mediated by protein motifs which are attached to linkers in the hydrogel. We measured the effective stiffness of the same linkers by atomic force microscopy. An analysis of the swelling behavior of the hydrogels then revealed that the molecular stiffness of individual cross-links is related to the overall elastic modulus by a factor proportional to the hydrogel's mesh size. The quantification of stiffness and deformation at the molecular length scale contributes to the discussion of mechanisms in force-regulated phenomena in cell biology.

Multi-scale tribology of the PEEK – steel contact

The final results of a collaboration with the Chair of Composite Engineering at the Technische Universität Kaiserlautern (Prof. Alois Schlarb) have been presented in a series of publications. We have introduced a novel contact mechanics model for repeated single-asperity scratches. The model takes into account the developing groove and builds a bridge between results of microscopic experiments and macroscopic materials parameters. We compared the effects of frictional and external heating on friction and wear. Finally, we have summarized our results of six different experimental techniques operating at different length scales and discussed the requirements – in particular in sample preparation – for successful multi-scale tribology projects.

OUTLOOK

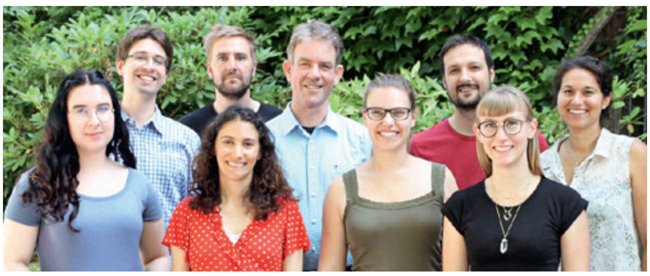
We will continue to investigate the mechanisms which link structure and dynamics of surfaces to friction and wear in new materials. Our current projects include atomic-scale friction experiments in stacks of two-dimensional materials such as graphene and MoS_2. Nanomechanical studies of hydrogels are pursued in collaboration with the Program Division *Dynamic Biomaterials*. We develop novel DNA-based materials with force sensing functions for biophysical applications. Electrochemical processes at the surface of metallic glasses are explored at the nanometer scale. Our research on haptic perception of materials will be further developed in collaboration with the Program Division *Functional Microstructures*, and the Departments of Materials Science, of Psychology, and of Computer Science at Saarland University, with the goal to reveal fundamental pathways of tactile perception through psychophysical experiments on micro-structured materials.

INNOVATIVE ELEKTRONENMIKROSKOPIE / INNOVATIVE ELECTRON MICROSCOPY

PROF. DR. DR. H. C. NIELS DE JONGE

ZUSAMMENFASSUNG

Eine nanometergenaue Materialcharakterisierung ist unabdingbar für Weiterentwicklungen in der modernen Nanotechnologie, Energiewissenschaft, der Biologie und biomedizinischer Wissenschaft. Der Programmbereich *Innovative Elektronenmikroskopie* (IEM) betreibt interdisziplinäre Forschung an der Schnittstelle der Physik der Elektronenmikroskopie (EM), Biophysik, Materialwissenschaft, Zellbiologie und Bildverarbeitung und ist weltweit führend auf dem Gebiet der Flüssigphasenelektronenmikroskopie (LP-EM). Wir entwickeln modernste Techniken im Bereich der *in situ* Transmissions-EM (TEM) und Raster-TEM (STEM) für die Forschung an funktionellen Materialien und biologischen Systemen unter realen Bedingungen. Wir untersuchen auch neue Wege für die dreidimensionale (3D) Datenaufnahme. Auch verfügen wir über langjährige Erfahrung mit Bildverarbeitung sowie mit der Entwicklung von Protokollen für spezifische Proteinmarkierung mit Nanopartikeln. Das hochmoderne Elektronenmikroskop (JEOL ARM200) ist sowohl für interne Forschung als auch für Kooperationen mit verschiedenen Universitäten und der Industrie von enormer Bedeutung.



MISSION

Nanoscale characterization is essential for the development of modern nanotechnology, energy science, biology, and biomedical sciences. The Program Division *Innovative Electron Microscopy* (IEM) conducts interdisciplinary research at the interface of physics of electron microscopy, biophysics, materials science, cell biology, and image processing. The division is world leading in the area of liquid-phase electron microscopy (LP-EM). We develop forefront *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. We are also exploring new routes for three-dimensional (3D) data acquisition using intelligent STEM- and image reconstruction strategies. In addition, we have extensive experience with image processing, and with developing protocols for specific labeling of proteins with nanoparticles. The group houses a state-of-the-art electron microscope (ARM200, JEOL). Various research collaborations exist both with academia, and industry.

CURRENT RESEARCH

Stoichiometry of calcium channels

LP-EM is used to study the stoichiometry of Ca^{2+} channels formed by ORAI proteins in mammalian cells. The relative ratio of the different ORAI channels is highly relevant for cell function. This project is conducted together with Prof. Barbara Niemeyer, Biophysics, Saarland University, and is part of the SFB Collaborative Research Center 1027.

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, thereby analyzing differences in protein function between individual cancer cells (cancer cell heterogeneity). This research is done together with Prof. Stefan Wiemann, German Cancer Research Center, Heidelberg, and Prof. Erich-Franz Solomayer, Saarland University Hospital. The project is funded by the Else Kröner-Fresenius-Stiftung.

Examining patient biopsy samples with STEM

We have started examining long-term response in Trastuzumab treated metastatic gastric- or gastroesophageal junction cancer patients via molecular HER2 surface and pathway analyses in a project together with Prof. Timo Gaiser, University Medical Centre Mannheim, funded by the Deutsche Krebshilfe.

MULTIMAT

We are partner in the MARIE SKLODOWSKA-CURIE ACTIONS Innovative Training Network (ITN) project "A multiscale approach towards mesostructured porous material design, MULTIMAT", headed by Prof. Nico Sommerdijk, Technical University of Eindhoven, The Netherlands. Our role is to expand the application area of LP-EM to image self-assembly of soft matter.

3D STEM

We are currently innovating in 3D STEM for obtaining nanometer resolution in micrometer-thick specimens. The project is in collaboration with Dr. Tim Dahmen, German Center for Artificial Intelligence, Saarbrücken. This research is funded by the DFG.

Studying the behavior of proteins and nanomaterials in liquid

A graphene liquid enclosure has been developed capable of imaging proteins in liquid, and a project funded by an industrial partner has started. Dynamic processes at the solid-liquid interface were studied with STEM at the nanoscale. We have active research interactions with the Program Division *Structure Formation*.

INM-focus projects

We have one active INM internal focus project. Herein, we study the spatial correlation between cytoskeleton and signaling active HER2 homodimers (CYHER) in a joint project with the Junior Research Group *Cytoskeletal Fibers*.

OUTLOOK

The IEM group is well situated to conduct research at the international forefront of electron microscopy both 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. Further, we aim to study HER2 in patient biopsy samples, to improve the time-resolution of *in situ* STEM via adaptive sampling techniques and to develop Liquid 3D STEM.

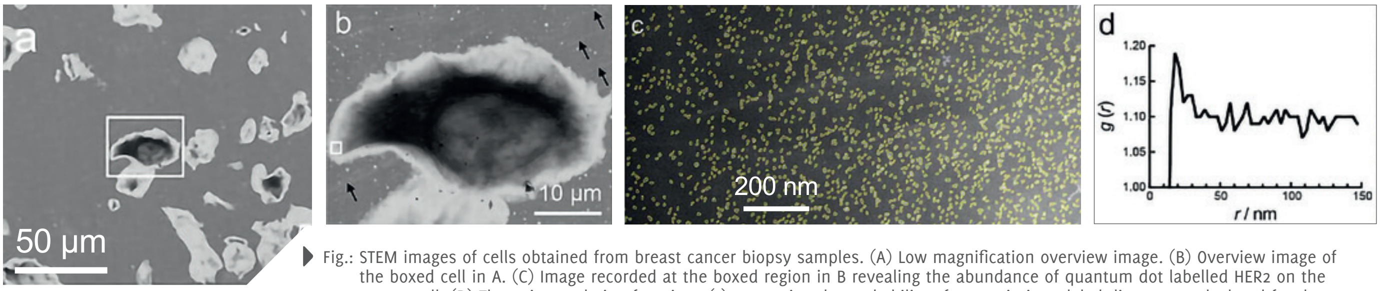
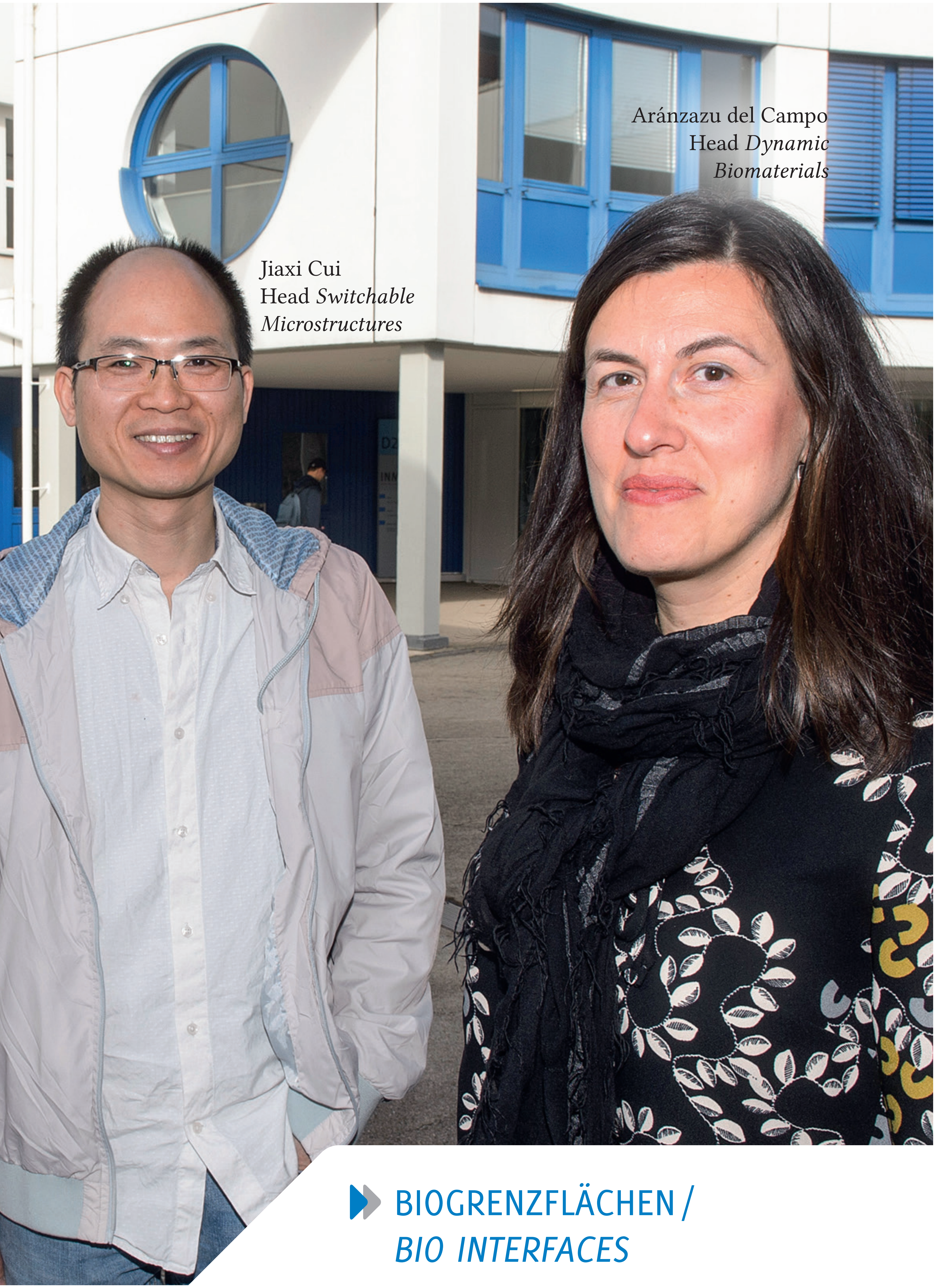


Fig.: STEM images of cells obtained from breast cancer biopsy samples. (A) Low magnification overview image. (B) Overview image of the boxed cell in A. (C) Image recorded at the boxed region in B revealing the abundance of quantum dot labelled HER2 on the cancer cell. (D) The pair correlation function g(r) measuring the probability of a certain inter-label distance r calculated for the labels shown in C. The peak at 20 nm indicates the presence of signaling active HER2 homodimers. Publication: Mol. Med. 25, 42:1-12, 2019.

Franziska
Lautenschläger
Head *Cytoskeletal
Fibers*

Annette
Kraegeloh
Head *Nano Cell
Interactions*

“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.”



Jiaxi Cui
Head *Switchable Microstructures*

Aránzazu del Campo
Head *Dynamic Biomaterials*

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, Zellwachstum zu unterstützen und das Schicksal der Zellen zu lenken. Dazu nutzen wir synthetische Phototrigger und photoresponsive biologische Prozesse, um Materialien mit latenten Funktionsstufen zu entwerfen, die mittels Lichteinwirkung angeschaltet werden können (4D-Biomaterialien). Eigenschaftsänderungen können bei Bedarf mit genauer räumlicher und zeitlicher Kontrolle eingeleitet, verstärkt oder beendet werden. Diese Veränderungen ahmen die adaptiven mechanischen und chemischen Eigenschaften der zellulären Mikroumgebung in lebenden Organismen nach. Wir entwickeln auch fortgeschrittene vernetzende Chemie zur Verkapselung biologischer Materialien mittels 3D-Drucktechniken. Zudem verwenden wir unsere Biomaterialien, um Gewebe in *In-vitro*-Kulturen und *In-vivo*-Modellen nachzubilden. Dynamische Biomaterialien sind als Gerüste für die Entwicklung prädiktiver Krankheitsmodelle sowie als instruktive Matrizes für zellbasierte Therapien gedacht.

MISSION

The Program Division *Dynamic Biomaterials* develops cell-instructive materials able to support cell growth and guide cellular's fate. We exploit synthetic phototriggers and photoresponsive biological processes to design materials with latent functional levels that can be unlocked upon light exposure (4D biomaterials). Property changes can be initiated, reinforced, or terminated on demand with precise spatiotemporal control. These changes mimic the adaptive mechanical and chemical properties of the cellular microenvironment in a living organism. We also develop advanced crosslinking chemistry for encapsulating biological materials using 3D printing technologies. Finally we apply our biomaterials to reconstruct tissues in *in vitro* cultures and *in vivo* models. Dynamic biomaterials are envisioned as scaffolds for the development of predictive disease models, and as instructive matrices for cell-based therapeutics.

CURRENT RESEARCH

Reconstructed cell-matrix and cell-cell interfaces in synthetic biomaterials

We progressed in the development of *in situ* forming hydrogels decorated with photoactivatable matrix adhesive ligands (EU funded project, *FET Mechanocontrol*) and growth factors to regulate the function of embedded cells. Hydrogel precursors are used for 3D bioprinting tissue and disease models *in vitro* (*Wlodarczyk-Biegun et al., Biofabrication, in press, Oh et al., ACS Appl Mater Interf 2019, patent filed*). We investigate the potential of these hydrogels to accelerate culture of cells to form cardiac tissue and stratified epithelium for regeneration purposes (DFG project within SPP 1782, with Univ. Clinic Cologne and Univ. Leipzig). A new DFG funded project exploiting fire-fly inspired chemistry for crosslinking at physiological conditions was initiated. We are now moving to natural ways to reconstruct tissue by stimulating cells collagen-secretion mechanism (*Khan et al., Adv Sci, 2019*). This approach allows us to reconstruct collagen fibers within tissue, including their ordered arrangement (with Eye Clinic, Saarland Univ. Clinic (UKS)).

From molecular devices to immunointeractive materials

The group closely cooperates with Biophysic groups at UKS (SFB 1027) to study how materials design can be used to regulate immune cells. In cooperation with INM Fellow Dr. Bin Qu (UKS), we developed hydrogels to trigger T cell activation. We use them as simplified *in vitro* models to understand the cooperativity between receptor organization and mechanical signals in the immune response. A dynamic synthetic biointerface able to apply forces to attached cells by means of an intercalated light-driven molecular motor has been designed in cooperation with Prof. Nicolas Guiseppone (Univ. Strasbourg). This biointerface mimics receptors at the cellular membrane which are connected to the actin cytoskeleton and subjected to forces applied by motor proteins. With the *Nanotribology* group and Bin Qu we used this biointerface to trigger T cell responses within well defined, light-regulated force ranges. On a long-term perspective, we aim to extend this methodology to 3D formats and *in vivo* studies.

Living materials for cost-effective and long term delivery of biotherapeutics

We made significant progresses and achieved substantial visibility in the emerging field of Living Materials for therapeutic applications. These are hybrid materials in which drug producing bacteria are safely encapsulated in a synthetic matrix (*Sankaran et al., Small, 2019, Sankaran et al., Adv Biosys, 2019*). Design of the matrix and processing techniques, and understanding of how bacteria growth and drug production can be optimized by the materials parameters is in our focus. In this topic we benefit from experience in microbiology and synthetic biology on our Campus. We have established institutional frameworks to strengthen the cooperation. In particular, INM, Saarland University and Helmholtz Center for Pharmaceutical Research established a Research Alliance to reinforce cooperation in this area.

OUTLOOK

We will further strengthen the topic of Living Materials: In 2020, a Leibniz Science Campus for Living Therapeutic Materials will start its activities, a postdoc of our group, Dr. S. Sankaran, will establish a new Junior Research Group on *Bioprogrammable Materials* at INM and we will host the first international conference on Living Materials. The development of cellular microenvironments to support and control cell growth and function remains a major topic in the group. The synthetic toolbox moves from organic synthesis to biochemical methods and from phototriggers to natural optical switches. Progress on biomaterial side involves implementation of 3D printable bioinks and development of co-cultures. The focus of the group is set on the development of biomaterials supporting tissue regeneration. However, we envision applying tissue engineering concepts to recreate biological materials *in vitro*, breaking the classical border between synthetic and bioengineering approaches in biomaterials science.

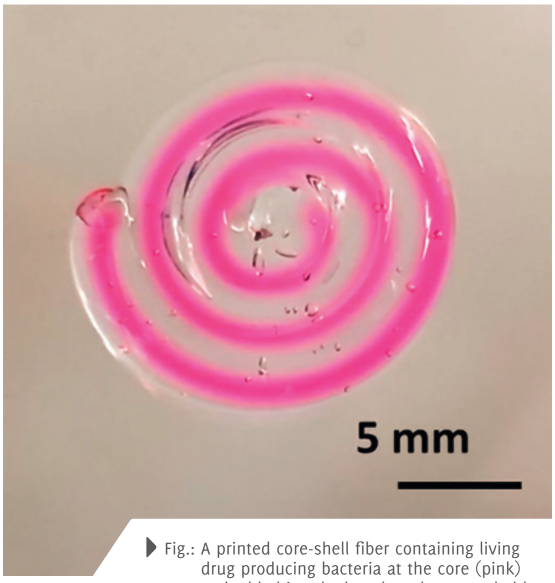


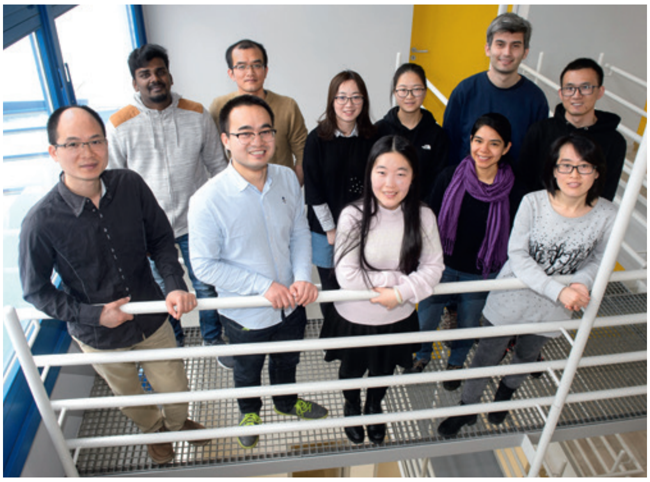
Fig.: A printed core-shell fiber containing living drug producing bacteria at the core (pink) embedded in a hydrogel, and surrounded by a containment shell that allows diffusion of nutrients and drugs, but prevents bacterial escape.

SCHALTBARE MIKROFLUIDIK / SWITCHABLE MICROFLUIDICS

DR. JIAXI CUI

ZUSAMMENFASSUNG

Die Juniorforschungsgruppe *Schaltbare Mikrofluidik* zielt darauf ab, dynamische Polymermaterialien zu entwickeln, die in der Lage sind, ihre Vernetzungsstruktur, ihre physikalischen und chemischen Eigenschaften und ihre makroskopische Geometrie zu verändern, um schaltbare Oberflächen und Biomaterialien herzustellen, die neuen Anforderungen in Biosynthese, Biomedizin und anderen Bereichen gerecht werden. Dazu entwerfen wir molekulare Strukturen, synthetisieren organische Bausteine und setzen fortschrittliche Polymerisationstechnologien ein, um definierte Materialien herzustellen und ihre Struktur-Eigenschafts-Beziehungen sowie ihre Reaktionsfähigkeit auf Stimuli zu untersuchen. An diesen dynamischen Polymersystemen wenden wir biologisch inspirierte Strategien an, um intelligente Oberflächen für die Flüssigkeitsübertragung zu schaffen, die Haftung und Reibung der Oberfläche zu steuern und heterogene Strukturen und Metamaterialien aufzubauen. Wir untersuchen auch grundlegende Mechanismen des Transports und der Umwandlung von Molekülen in dynamischen Polymernetzwerken.



MISSION

The Junior Research Group *Switchable Microfluidics* aims to develop dynamic polymer materials able to change their crosslinking structure, physical and chemical properties, and macroscopic geometry to produce switchable surfaces and biomaterials for emerging needs in biosynthesis, biomedicine, and other areas. For this purpose, we design molecular structures, synthesize organic building blocks, and apply advanced polymerization methods to prepare well-defined materials, and to investigate their structure-property relationship and stimuli-response. At these dynamic polymer systems, we apply bio-inspired strategies to create smart surfaces to transfer liquids, and to control adhesion and friction to build heterogeneous structures and metamaterials. We also investigate fundamental mechanisms of molecule transport and conversion in dynamic polymer networks.

CURRENT WORK

Enzyme-based switchable reactor

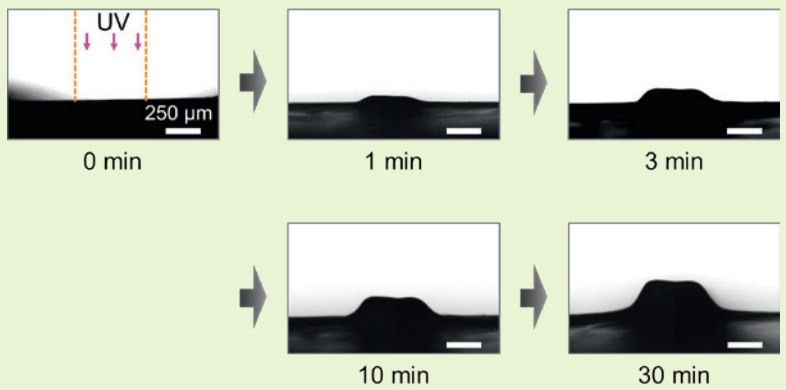
We continued developing thermo-responsive magnet nanoparticle carriers to switch the activity of enzyme catalysts to mediate biosynthesis and recycle enzymes. We developed nanoparticle carriers modified with thermo-responsive polymers via surface-initiated living/controlled polymerization. Such carriers have functional terminal groups which allow site-specific modification of enzyme catalysts. We demonstrated that the activity of the catalyst can be switched by temperature. Moreover, the thermo-responsive polymer coating can change the solubility of the carriers and thus allow efficient recycle. We collaborate with Dr. Vito Valiante, HKI Jena, to apply this system for mediating multi-enzymatic reactions. We want to improve the combined pyrone biosynthesis by developing a novel thermally-switchable, magnetically-recoverable FeO nanoparticle (NP).

Photo-guided growth of polymer materials

We develop a photo-induced regulation of localized growth of microstructures from the surface of a swollen dynamic substrate, to mimic the growth ability of living organisms. The strategy is based on the coupling of three kinds of reactions: photolysis, photopolymerization, and transesterification. The photolysis generates dissociable ionic groups to enhance the swelling ability that drives the diffusion of a nutrient containing polymerizable compositions into the irradiated region, the photopolymerization converts the polymerizable compositions into polymers, and the transesterification incorporates new-formed polymer network into original network structure. Such light-regulated growth is spatially controllable, dose-dependent, and allows modulation in size, composition, and mechanical properties of the structures (Fig. 1). We demonstrate that this technology allows to microstructure on surfaces and restores large scale surface damage.

Functional hydrogels

Designing an artificial material that can self-regulate into new and well-defined shapes without presetting permanent codes to mimic the natural systems remains a considerable challenge. To develop a fundamentally new strategy for guiding macroscopic, unidirectional shape-evolution of materials without compromising the material's integrity, we work on dynamic hydrogels with anchored acrylic ligands and hydrophobic alkyl chains (cooperation with *Dynamic Biomaterials*). We utilize various diffusion rates of water and ferric ions to create a field with a "swelling pole" and a "shrinking pole" to drive polymers to disassemble, migrate, and resettle in the targeted region. As result of these reactions, transform from solid to hollow is gained. We demonstrate this strategy is versatile in the generation of various closed hollow objects including spheres, helix tubes, and cubes with various diameters. Obtained closed hollow structures are penetrable for molecules but not for cells and thus allow to culture cells (Fig. 2). Moreover, the dynamic hydrogels are injectable, allowing us to apply 3D printing to fabricate complex hydrogel structures. We are able to create interconnected hollow networks and to further optimize this method exploiting its potential in manufacture of artificial vessels.



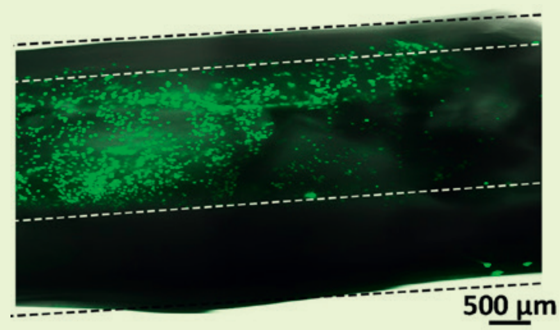


Fig. 1: Light-induced growth.
Fig. 2: Cell culture in a hollow hydrogel fiber.

OUTLOOK

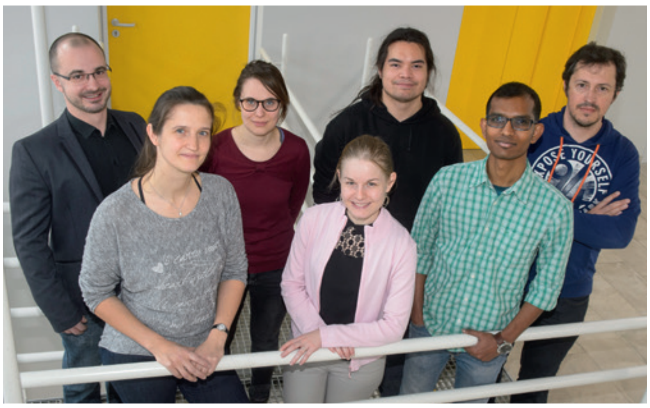
We will continue to study the underlying mechanism of photon-induced growth and to apply this method in creating microstructure on surfaces (2D) and varying the bulk properties of materials (3D). The group will focus on hierarchical dynamic behaviors of polymer networks including reversible bonding in crosslinking points, interaction between small molecules and the polymer segments in the networks, interaction of first and second networks with various polymer conformations and their contribution to macroscopic properties. These results will lead us to design self-regulated coatings that can automatically alter their properties to prevent fouling, increase adhesion, restore damage, bear loading, or reflect light.

ZELLSKELETALE FASERN / CYTOSKELETAL FIBERS

JUN.-PROF. DR. FRANZISKA LAUTENSCHLÄGER

ZUSAMMENFASSUNG

Seit 2017 untersucht die Juniorforschungsgruppe *Zellskeletale Fasern* das Zytoskelett – dies ist ein Oberbegriff für natürliche Polymere, welche in Zellen vorkommen und deren Funktionen beeinflussen. Es gibt verschiedene Arten dieser Polymertypen in Zellen. Die Gruppe *Zellskeletale Fasern* untersucht die Struktur und Dynamik sowohl einzelner Polymere (zum Beispiel Aktin) als auch deren Zusammenspiel untereinander. Des Weiteren wird der Effekt dieser Polymere auf das zelluläre Verhalten untersucht, zum Beispiel auf die Migration von Immunzellen oder die Adhäsion von Zellen an Oberflächen. Dafür werden hochauflösende Mikroskopieverfahren und Mikrofabrikationstechniken verwendet. Das Zytoskelett und dessen Rolle im zellulären System sowie die Reaktion der Polymere auf die sie umgebende Matrix bilden die Grundlage für die Kooperationen der Juniorforschungsgruppe mit mehreren Programmbereichen, wie *Dynamische Biomaterialien*, *Nano Zell Interaktionen* und *Innovative Elektronenmikroskopie*.

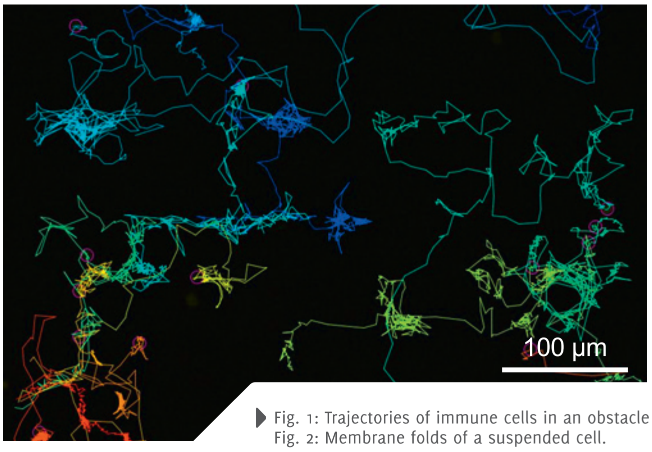


MISSION

Since January 2017 the Junior Research Group *Cytoskeletal Fibers* investigates the cytoskeleton – a polymeric structure in living cells with the potential to alter cellular functions. The fibers of the cytoskeleton are also able to adapt their structure and dynamics to external and internal stimuli, e.g. to various surrounding matrices. It's the aim of the group to understand the complexity of the cytoskeleton and the interplay of its subgroups (actin, microtubules and intermediate filaments). Finally, we aim at the concise altering of parts of the cytoskeleton in order to control cellular functions. Cytoskeletal fibers, their specific roles in cellular systems and their reaction with the surrounding matrix form the basis of the collaborations of the Junior Research Group with several Program Divisions, such as *Dynamic Biomaterials*, *Nano Cell Interactions* and *Innovative Electron Microscopy*.

CURRENT RESEARCH

The Junior Research Group is working on a number of projects, in close collaboration with the Saarland University and the Collaborative Research Center of the DFG (CRC 1027). In this context, the group just showed that actin is involved in the migration pattern of immune cells. By forming spiral actin waves immune cells generate both directed and diffuse motion, which has an influence on the searching efficiency of immune cells for pathogens. But actin is also involved in many other processes, such as in



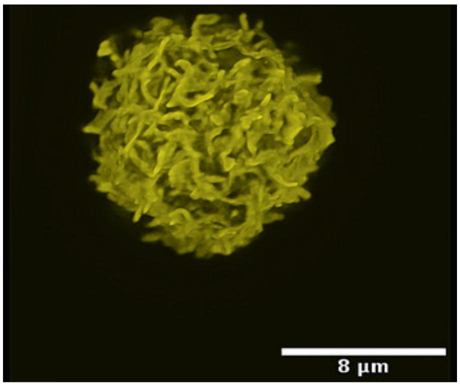


Fig. 1: Trajectories of immune cells in an obstacle parc. Each color codes one trajectory.
Fig. 2: Membrane folds of a suspended cell.

the position of active Her2 homodimers – a membrane protein which has been shown to be related to aggressive breast cancer. In order to investigate the position of this protein, the group *Cytoskeletal Fibers* and the Program Division *Innovative Electron Microscopy* teamed up and combined fluorescent microscopy of actin and electron microscopy of active Her2 homodimers.

Actin is also the main component of the cortex of cells, a structure that holds the cellular membrane and is involved in giving the cells a shape and transmitting forces. To understand this cortex, we needed high resolution images of the mesh structure of this cortex. The group achieved this goal by establishing a new protocol for the cell preparation in electron microscopy and by developing a software to quantify the mesh sizes of the obtained images. The group is now combining this structural information with dynamic parameters on the polymerization speed of the fibers which they obtain from Fluorescent Recovery After Photobleaching experiments and with cell mechanical data obtained by Atomic Force Microscopy. The imaging of the actin cortex is carried out in close collaboration with the Service Group *Physical Analytics.*

By understanding the actin cortex and its structure, the group hopes to understand how circulating tumor cells use a weakened cortex in order to form so called microtentacles – long, microtubule filled membrane extensions which enable them to reattach to the blood vessel wall. This is a process required to exit from the blood vessel into the tissue where the cells might form new metastases. If the group understands the formation of such structures, they might be able to inhibit them using specific new compounds and decrease the formation of metastases.

All components of the cytoskeleton are involved in the migration of cells. Gathering information about the cytoskeletal components inside cells enables us to qualitatively and quantitatively investigate and stimulate the migration of cells. For example, the group tests which cytoskeletal components are required to optimize search strategies of immune cells depending on the physical conditions of the surroundings. The group therefore generates a range of microenvironments with various properties and tests the ability of immune cells under particular cytoskeletal conditions to find targets. This project is carried out in collaboration with Saarland University in the framework of SFB 1027.

OUTLOOK

The Junior Research Group *Cytoskeletal Fibers* investigates the cytoskeleton and its influence on cellular functions, for example on migration. By understanding the structure and dynamics of the cytoskeletal elements and their interplay the group aims to be able to alter specific parts of the cytoskeleton so that cellular functions can be controlled. For example, we are further studying the actin cortex in healthy and cancerous cells with the aim to one day reverse cancerous changes and therewith prevent pathogenic behavior.

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 die Struktur und Biochemie der Zellen beeinflussen, und aufzuklären, welche Mechanismen die Aufnahme und Lokalisation von Nanoobjekten beeinflussen. Als Untersuchungsobjekte werden anorganische Nanopartikel hergestellt und charakterisiert. Zur Lokalisation von Partikeln und Zellstrukturen werden vor allem lichtmikroskopische Techniken eingesetzt. Eine Besonderheit der Gruppe ist die Nutzung hochauflösender Stimulated Emission Depletion (STED)-Mikroskopie für diesen Zweck. Zur weiteren Analyse der Zellantwort werden darüber hinaus chemische, biochemische und molekularbiologische Techniken eingesetzt.

MISSION

The Program Division *Nano Cell Interactions* explores the effects of engineered nano-objects 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 cells and to elucidate mechanisms that affect the uptake or location of nano-objects: Our purpose is 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 biomolecular techniques are used for the analysis of the cellular responses.

CURRENT RESEARCH

NanoS-QM

The project NanoS-QM aims at the development of quality criteria and standards for research data in the field of nanosafety research. Research data generated in this field are used for various purposes, for example for the generation and characterization of materials, for the safety testing and analysis of their biological mechanisms and impact. Such data might be further used for hazard assessment and regulation, for validation of *in vitro* assays by *in vivo* data as well as for the development of toxicologically relevant test systems. Therefore, the objectives of the project comprise

- framing and enhancement of standards and quality criteria for nanosafety research,
- development of a modular and interoperable metadata scheme for the description of heterogenous research data,

- a concept for the acquisition of metadata along the life cycle of research data considering the application of electronic lab notebooks.

The BMBF-funded project started in 2019 and is conducted in cooperation with FIZ Karlsruhe – Leibniz Institute for Information Infrastructure, IfADo – Leibniz Research Centre for Working Environment and Human Factors, Dortmund, IUF – Leibniz Research Institute for Environmental Medicine, Düsseldorf, and Leibniz Institute for Materials Engineering – IWT, Bremen. Current work includes collection of the status quo of existing quality criteria and disciplinary requirements.

NanoDopa – Dopamine-loaded nanoparticles for advanced therapy of Parkinson's disease

Parkinson's disease is a neurodegenerative disease, hallmarked by a loss of dopamine producing neurons in the brain. Treatment by application of dopamine is impeded by the blood-brain-barrier, which is impermeable for dopamine. Therefore, some current therapies are based on the application of the prodrug Levodopa, which is able to overcome this barrier and can be subsequently converted into dopamine. NanoDopa aims at the development of efficient dopamine transport into the brain. The project started in 2018 and is conducted in collaboration with Fraunhofer Institute for Biomedical Engineering and two companies in frame of the NanoPharm ZIM (Central Innovation program for SMEs) cooperation network. One main role of INM is the microscopy analysis of model brain tissue in comparison to other tissues (Fig.) in order to evaluate the transport efficiency.

OUTLOOK

In the frame of the Leibniz Research Alliance Nanosafety and together with the Department of Chemical and Environmental Engineering, University of Zaragoza, Spain, we organize the conference Nanosafety 2020 to be held in Zaragoza. Future research activities will focus on the further development and evaluation of potential applications of silicon dioxide nanoparticles, prepared within the group, in the biomedical field, more specifically for therapeutic purposes. The impact of nanomaterials on the lung will be further analyzed a) using an *in vitro* model for the alveolar lung region integrating mechanical strain, and b) using a bronchial cell model including mucus grown at the air-liquid interface. The latter investigations will be conducted in cooperation with the Institute of Biopharmacy and Pharmaceutical Technology at Saarland University. Together with external partners, the group aims at further contributing to the enhancement of research data management in the field of materials safety (for further information see the website of the InnoMatSafety consortium https://nfdi4nanosafety.de).

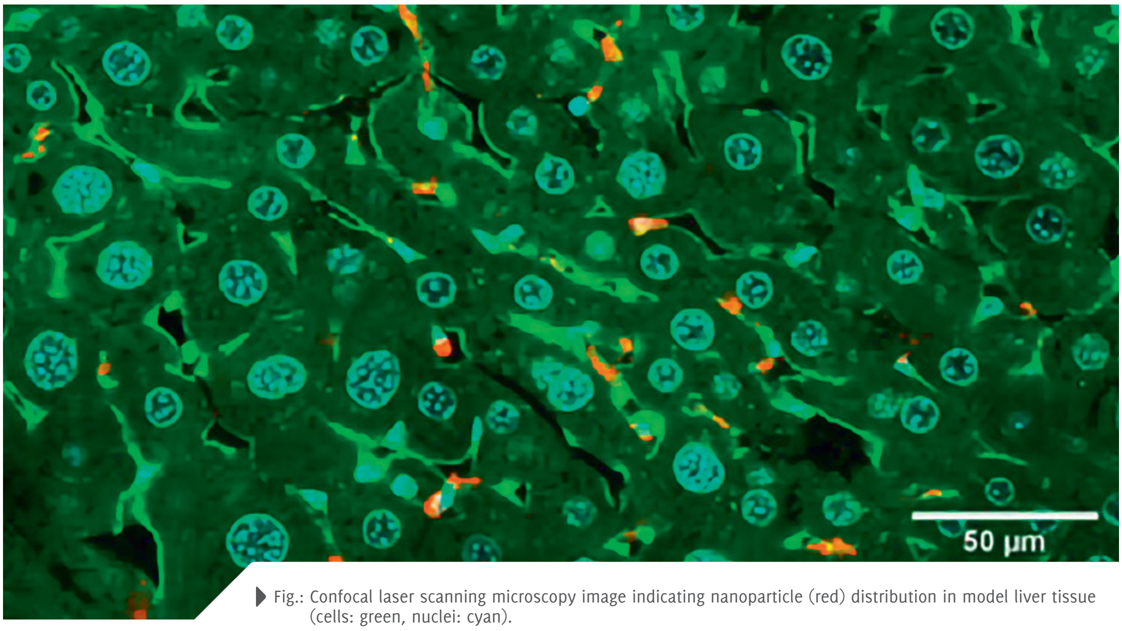


Fig.: Confocal laser scanning microscopy image indicating nanoparticle (red) distribution in model liver tissue (cells: green, nuclei: cyan).

Carsten Becker-Willinger
Head *Nanomers*

Tobias Kraus
Head *Structure Formation*

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."

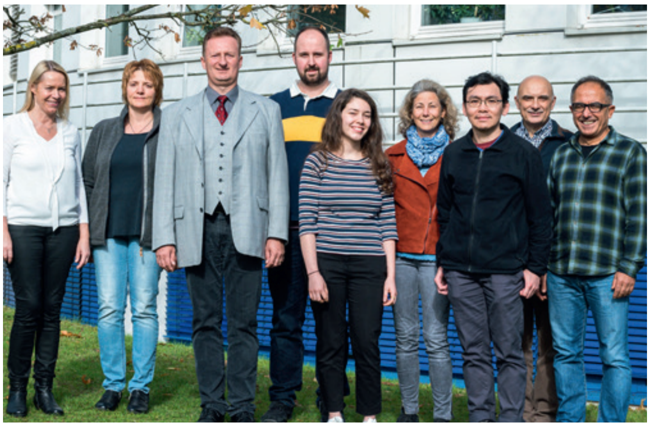
NANOKOMPOSIT-TECHNOLOGIE / *NANOCOMPOSITE TECHNOLOGY*

NANOMERE / NANOMERS

DR.-ING. CARSTEN BECKER-WILLINGER

ZUSAMMENFASSUNG

Der Programmbereich *Nanomere* entwickelt multifunktionelle Schutzschichten, Kompaktwerkstoffe und Materialien für additive Fertigungsverfahren auf Basis von Kompositen mit polymeren und hybriden Matrizes sowie nano- und mikroskaligen, funktionellen Additiven. Bei der Erzielung neuer Werkstoffeigenschaften steht der Anwendungsbezug im Vordergrund. Die funktionellen Additive können halbleitend sowie keramischer oder metallischer Natur sein. Neben kugelförmigen Partikeln werden auch solche mit plättchenförmiger Morphologie eingesetzt. Mit einer maßgeschneiderten Oberfläche versehen, erlauben die Partikel den Übertrag festkörperphysikalischer Eigenschaften anorganischer Materialien in Polymere und Beschichtungen. Schwerpunkt der Entwicklungsaktivitäten sind schwermetallfreie, aktive Korrosionsschutzsysteme für Stahl und Aluminiumlegierungen, temperaturbeständige, feuerfeste Bindemittel für Naturfaserkomposite, transparente, selbstheilende Beschichtungen und Polymerkomposit-basierte Materialien für die additive Fertigung.



MISSION

Activities of the Program Division *Nanomers* comprise the development of functional coatings and bulk materials based on a polymer matrix composite concept. A strong focus is put on application-oriented projects for industrial materials. Functions of interest are heavy metal free corrosion protection optionally with low friction, temperature stable and fire resistant binders, and transparent self-healing surfaces. Applications are in electronics, medicine, optics, automotive, construction, engineering, and additive manufacturing.

CURRENT RESEARCH

Organic-inorganic hybrid coatings for light metal alloys / ALURESIST

A new project supported by the state of Saarland (ZTS / EFRE) started in 2018 with the focus on corrosion protection coatings for fasteners made of high strength aluminum alloys. Functional nanoparticles embedded in a Nanomer-hybrid matrix are used as additives to provide active corrosion protection to coatings by releasing passivating agents. The project entered into the optimization phase to adjust the coating materials to application processes having potential for mass production.

Polymer composite coatings for corrosion protection of mild steel / HORUS

The concept for heavy metal free corrosion protection for low alloyed and mild steel is based on polymer composite coating materials containing inorganic platelets as diffusion barrier for corrosive molecules. In addition, the coatings contain flake-like particles based on zinc phosphate and manganese hydrogen phosphate to repassivate the surface in case of a damaged coating. Our concept should help to design new passive diffusion barrier coatings combined with an active corrosion protection mechanism. The active corrosion protection of the anisotropic, flake-type phosphate particles was investigated with Electrochemical Impedance Spectroscopy, potentiometry and standard corrosion tests. Results were presented at *EUROCORR 2019*. The protection mechanism was also investigated on microscopic scale together with the Program Division *Innovative Electron Microscopy* resulting in a joined publication. The polymer composite coating approach is also used in the ZIM-project HORUS to protect low alloyed construction steel against corrosive gases produced in refuse incineration plants. Within INM, the material development work in HORUS is performed together with the Program Division *Optical Materials*. Furthermore, a corresponding industry project on corrosion protection for mild steel for metal fittings was continued in 2019 and actually reached technology phase.

Transparent self-healing coatings

The BMBF-VIP+-project "*Polyrotaxanlack*" in cooperation with Saarland University was successfully finalized within 2019. Polyrotaxane based coatings, curable according to the polyurethane cross-linking mechanism, were optimized at lab scale to fulfill requirements for automotive applications. The coatings are transparent, exhibit considerable surface hardness known from conventional paints but in addition show self-healing characteristics for superficial scratches when heated up to 90 °C for only 60 s (Fig. 1). Results on the self-healing and general behavior were presented at the *SMT33 Conference on Surface Modification Technologies 2019* and a demonstrator was displayed at *Hannover fair 2019* and *IAA 2019* to get in touch with possible industrial end-users. Recently, the scaling-up process started for the polyrotaxane moieties synthesis to provide samples for industrial applications.

Fire resistant binders / NaMiComp II

The project NaMiComp II, supported by BMZ-GIZ and Saarland, in cooperation with the University of Namibia (UNAM) was finished in 2019. It resulted in the fabrication of a small demonstrator house from fire-proof fiberboards consisting of acacia shreds and inorganic so called Namibinder (Fig. 2). The Namibinder and the acacia fiberboards could for the first time be fabricated exclusively from Namibian precursors. The first application in focus of this framework is the use of the fire resistant fiberboards as construction materials for "low-cost-housing" in Namibia and other sub-Saharan African countries. The project is in line with the *Leibniz in Africa* initiative.

OUTLOOK

Material development within the group will be based on the polymer composite approach. The concept of polyrotaxanes for self-healing hard coatings will be transferred to compact materials. Reactive materials will be derived therefrom as well as transparent hybrid materials to be used for direct 3D-printing of optical elements. Polymer nanocomposites with specific mechanical and electrical properties will be developed as filaments to enable multi-material additive manufacturing.

Fig. 1: Self-healing behavior of polyrotaxane containing coatings as top-coat on painted surfaces at 90 °C.
Fig. 2: Fire-proof acacia-fiberboard demonstrator house fabricated exclusively from Namibian precursors.

OPTISCHE MATERIALIEN / OPTICAL MATERIALS

DR. PETER W. DE OLIVEIRA

ZUSAMMENFASSUNG

Die Aufgabe des Programmbereichs *Optische Materialien* ist es, neue optische und elektrooptische Verbundwerkstoffe zur Verwendung als funktionsgebende Komponente in Bulkmaterialien sowie in Beschichtungen für Glas-, Keramik-, Metall- und Polymersubstrate zu entwickeln. Diese Werkstoffe zeichnen sich durch spezifische Wechselwirkungen mit Licht bzw. elektromagnetischer Strahlung aus. Die Expertise der Gruppe liegt in der Simulation optischer Eigenschaften, der Materialsynthese, dem Design sowie der Entwicklung und Vervollkommnung neuer Auftrags-, Anwendungs- und Strukturierungstechniken. Im Berichtszeitraum konnten beispielsweise neuartige, farbintensive und dekorative Beschichtungssysteme auf der Basis von nanopartikulärem Kobaltblau, transparente leitfähige Schichten mit Hilfe des Elektrospinnens sowie eine Siebdruckpaste zum Druck transparenter E-Call-Antennen für Automobil-Verscheibungen entwickelt werden.

MISSION

The Program Division *Optical Materials* has the mission to design new optical and electro-optical composite materials to be used as functionalization agents for bulk materials and coatings on glass, ceramic, metal and polymeric substrates. Our expertise lies in the modelling of optical properties, the wet chemical syntheses of organic-inorganic matrices alongside with experience in the production of nanoparticles with specific chemical modifications. These approaches give access to new classes of materials which open new solutions for current material challenges. Therefore 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

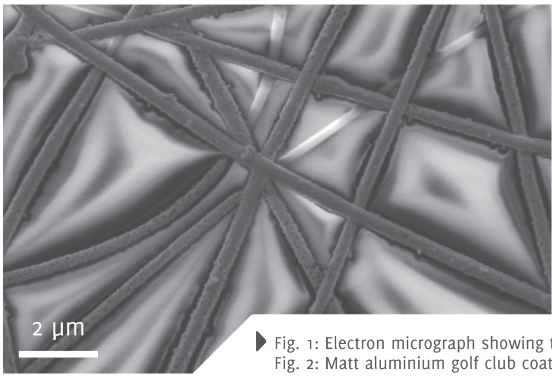
The following highlight topics were investigated in 2019:

Silver nanowire based screen printing paste for transparent antenna structures

Transparent conductive structures can be used in emergency call antennas in cars. This was the target of the project "ITECA – Integration of a transparent E-Call Antenna in a car window". The antenna has to be printed on a large scale by screen printing reaching sheet resistances below 5 Ω per Square (Ω□) and transmission values above 65 %. INM's successful approach comprises the development of the screen printing pastes by using silver nanowires and the optimization of the printing as well as the subsequent curing conditions. This work was funded by the BMWi as a ZIM-project.

Decorative cobalt blue sol-gel coatings

Stable dispersions of milled surface modified cobalt blue ($CoAl_2O_4$) particles in siloxane-based sol-gel systems were applied via spray- and dip-coating on stainless steel, glass and aircraft aluminum. Higher gloss was obtained on polished rather than on matt surfaces. Curing temperature and hardness are increased with decreasing layer thickness and color intensity. For decorative purposes, a more intense coloration is preferable. This problem was successfully solved by using a hard sol-gel-layer on top of the decorative coating. Double coated stainless steel survived more than 500 abrasive cycles with negligible scratch marks. Double coated aircraft aluminum showed no corrosion after 864 hours salt spray test.



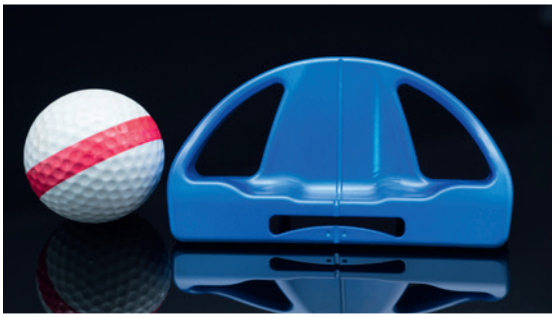


Fig. 1: Electron micrograph showing the distribution of conductive metalized electro spun fibers.
Fig. 2: Matt aluminium golf club coated with cobalt blue siloxane based sol-gel system.

Electrospinning for transparent conductive coatings

Transparent conductive coatings are widely used as electrodes in displays, touch screens, solar cells etc. and require a low sheet resistance combined with a high transmission. For wearable electronics and bendable displays flexibility of the electrode material is also needed. Electrospinning is a versatile technology to prepare very long and thin fibers. Those spun fibers generally have thicknesses well below a micrometer but lengths of some centimeters and form extended randomly oriented networks with high percolation and high transmission. Due to the randomness of the network, Moiré-Patterns for Display application can be excluded. Sheet resistance could be varied between 5 Ω□ at 80 % transmission and 650 Ω□ at 92 % transmission with haze values between 2 to 20 %. This work was executed in cooperation with the *InnovationCenter INM*.

OUTLOOK

Optical Materials centers its efforts on the design and manufacture of innovative materials with addressable optical properties. Typical examples of future research topics are the development of novel photo lacquers for additive manufacture by two-photon-lithography, the development of photonic light guides on the base of photochemically deposited amorphous metal structures, the development of transparent conductive coating materials for flexible or elastic substrate materials or the development of optical materials with extremely low refractive indices based on air-filled nano-bubbles.

Progress in new materials will be complemented by adapted innovative coating and printing techniques. Targeted application fields such as display technology, energy conversion, and active optics are among the top priorities. These targets will be achieved by intense cooperation with German and international universities and research institutes in the form of a strong cooperation network.

STRUKTURBILDUNG / STRUCTURE FORMATION

PROF. DR. TOBIAS KRAUS

ZUSAMMENFASSUNG

Der Programmbereich *Strukturbildung* erforscht die Bildung, Struktur und Eigenschaften von Materialien, in denen Metalle, Polymere, Keramiken und Biomoleküle verbunden sind. Diese Hybridmaterialien haben kolloidale Vorstufen und kombinieren Eigenschaften ihrer Komponenten. Sie können nahe der Raumtemperatur und ohne Vakuum verarbeitet werden, zum Beispiel durch Inkjet- oder 3D-Druck, um sie auf Längenskalen zwischen Nanometern und Millimetern gezielt zu strukturieren. Allerdings sind die Materialien komplexer als ihre Bestandteile, so dass ihr erfolgreicher Einsatz ausreichendes Verständnis voraussetzt. Außerdem erschwert ihre Heterogenität die Wiederverwertung. Deshalb untersuchen wir, wie sich multifunktionale Hybridmaterialien durch Wechselwirkungen ihrer Komponenten bilden, wie sie sich während ihrer Lebensdauer verändern und wie sie am Ende ihres Lebens wieder in Komponenten zerlegt werden können, um den Kreislauf zu schließen. Der Programmbereich stellt neue Hybridmaterialien für Elektronik, Optik und Sensoren her und untersucht andere Materialien in Kooperation mit Wissenschaftler/innen und Unternehmen.

MISSION

The Program Division *Structure Formation* investigates the formation, structure, and properties of materials that use metals, polymers, ceramics, and biomolecules. These hybrid materials have colloidal precursors and combine properties of their components. They can be processed close to room temperature and in air, for example using inkjet or 3D printers, to structure them at scales between nano- and millimetres. Such materials are more complex than their components, however, and their successful use requires sufficient understanding. Their heterogeneity can impede recycling. We therefore investigate how multifunctional hybrid materials form through the interaction of their components, how they change (intentionally or inadvertently) during their lifetime, and how they can be disassembled into components to close the cycle. The program division synthesizes new hybrid materials for electronics, optics, and sensors and studies other materials in cooperation with scientists and companies.

CURRENT RESEARCH

Inkjet printing electronics at home

There is an inkjet printer in almost every home, but today, it prints only graphics. Inks that can conduct electrical current could change this and enable everybody to print electronics. In 2018, we introduced "hybrid inks" that can be printed at room temperature without sintering. In 2019, we printed a light-emitting device based on fluorescent Quantum Dots using a simple consumer printer (*Yang et al., Adv. Opt. Mater., 2020*).

We teamed up with the group of Prof. Jürgen Steimle, Saarland University, a leading researcher in the field of Human-Machine-Interfaces. Together, we inkjet-printed a range of human-computer-interface devices that could be rapidly customized. The work was presented at the 2019 ACM Symposium on User Interface Software and Technology and recognized with a "Best Paper Award" (*Khan et al., Proc. 32nd ACM Sympos., 2019*, Fig. 1).

Drying inks and unexpected interactions

Little is known on the effect of increasing nanoparticle concentration on agglomeration. We developed a new experiment to provide data on this effect (*Doblas et al., Nano Lett., 2019*): a dispersion droplet is hanging in an X-ray beam and dries while its scattering is recorded. A new analysis scheme provides the changing particle concentration and indicates when the particles agglomerate. The results reveal that even small changes in the solvent type change the "solubility" of the particles (Fig. 2).

During inkjet printing, droplets dry to leave a solid material. The increasing concentration of the nanoparticles in the ink affects the structure of the final material. A synchrotron X-ray study that we published in 2019 revealed, for example, that one type of hybrid ink particles changes during drying. One part of their polymer shell segregates to the surface (*Zhang et al., Nanoscale, 2019*).

Some inks contain ultrathin metal nanowires. Such wires are much less stable than spheres and join at rather low concentrations to form "bundles". We collaborated with Prof. Martin Müser of Saarland University who simulated wires and solvent and explained this phenomenon with an entropic interaction that had not been previously reported (*Gao et al., Nano Lett., 2019*). Bundled wires share a shell of "ordered" solvent, an effect that is too weak to destabilize spheres but adds up along the wire.

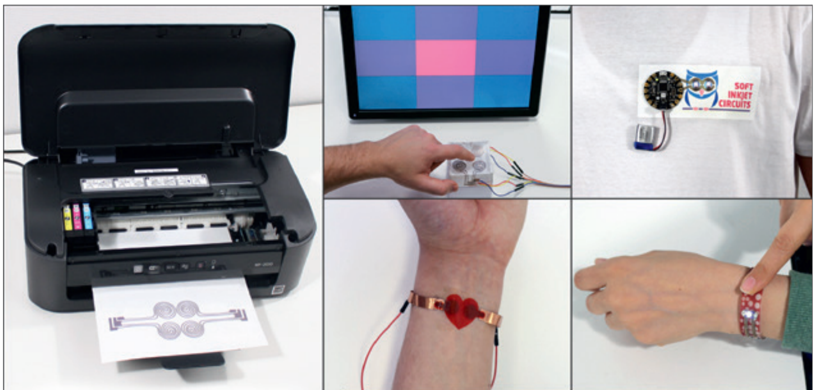
Particles in steel

Dillinger, a steel producer in Saarland, has supported the group's research on particles in steels for several years. In 2019, we were able to present two new methods that improve the understanding of such steels: a new etching protocol (*Hegetschweiler et al., J. Mater. Sci., 2019*) that provides a particle dispersion for new analysis techniques, and the use of a modern mass spectrometry technique to analyze the composition of single particles from steel (*Hegetschweiler et al., Anal Chem., 2019*).

OUTLOOK

Inks that enable the rapid production of electronics remain an important topic for the next years. The group will investigate printable materials that interact with cells and tissues, too, and combine this property with electrical conductivity and mechanical flexibility. Our hybrid concept provides an interesting opportunity: inks that can be recovered after printing.

Sustainability and price of hybrid functional materials are a second topic for the future. Many of our inks are based on gold that should be replaced with less-precious metals and prepared in processes that can be optimized. Equally important is the recovery of the metal from the printed product at the end of its life cycle.



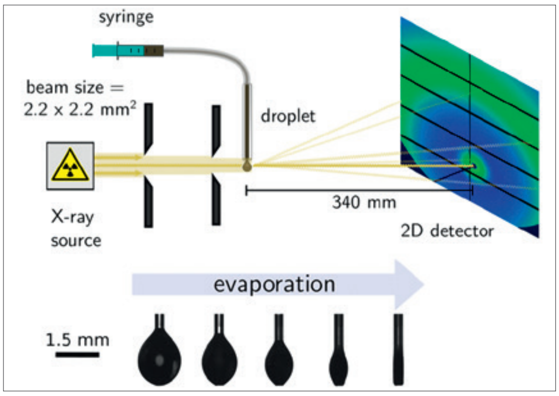


Fig. 1: Inkjet-printed human-machine interfaces. Rapid prototyping of flexible electronic devices with standard printers (left). Range of substrates incl. flexible polymers and instant tattoos.
Fig. 2: Droplet of particles in liquid pushed into an X-ray beam, where it slowly evaporates. Scattering pattern (blue & green on right) for deducing concentration of agglomeration start.

INNOVATIONSZENTRUM INM / INNOVATIONCENTER INM

DR. PETER W. DE OLIVEIRA, DR. KARSTEN MOH

ZUSAMMENFASSUNG

Das *InnovationsZentrum INM* wurde 2014 als Schnittstelle zwischen den Technologieplattformen des INM und der Industrie ins Leben gerufen. Seine wichtigste Aufgabe ist die frühzeitige Wahrnehmung und Verwertung disruptiver Erkenntnisse aus der Grundlagenforschung. Auf administrativer Seite unterstützt es die Programmbereiche des INM durch die Anbahnung und Koordination von Kooperationsvorhaben. Auf operativer Seite werden insbesondere Industrieprojekte auch personell unterstützt. Zusammen mit den Servicebereichen des INM werden darüber hinaus Dienstleistungen im Bereich der chemischen und physikalischen Analytik sowie Langzeittests angeboten. Eine Validierung und Optimierung der Produktionsprozesse, die die Materialentwicklung begleitet, ermöglicht eine umfassende und effiziente Umsetzung neuer Ideen vor dem Hintergrund starken Wettbewerbs und zunehmend verkürzter Produktzyklen bei High-Tech-Produkten. Das im Berichtszeitraum abgelaufene BMBF-Projekt Science4KMU entwickelte Standardprozesse zur Unterstützung von Innovationen in kleinen und mittleren Unternehmen (KMUs).

MISSION

The *InnovationCenter INM* was founded in 2014 as an interface between the technology platforms of INM and the industry. Its most important task is the early recognition and exploitation of disruptive findings from basic research. On the administrative side, it supports the program divisions of INM in the initiation and coordination of cooperation projects. On the operational side, industrial projects in particular also receive personnel support. Together with the service groups of INM, services in the field of chemical and physical analysis as well as long-term tests are offered. Validation and optimization of production processes accompanying the development of materials enables a comprehensive and efficient implementation of new ideas against the background of strong competition and increasingly shorter product cycles for high-tech products. The BMBF project Science4KMU, which expired in the reporting period, developed standard processes to

Fig. 1: Gecko-inspired dry adhesives for handling in vacuum.
Fig. 2: Within the project Science4KMU, we held inverse fairs in order to come into direct contact with interesting SMEs.

support innovation in small and medium-sized enterprises (SMEs).

CURRENT RESEARCH & DEVELOPMENT

Gecomer Technology

In 2019, the *InnovationCenter INM* mainly focused on further establishing the Gecomer Technology for advanced handling applications with two large industry projects in that area. One project aimed at handling extremely small devices. The other project focused on handling in vacuum, where vacuum grippers fail by nature. Both projects demanded new scientific ideas, but also engineering solutions and long-term performance testing, being ideal for a close collaboration between the *InnovationCenter INM* and the Program Division *Functional Microstructures*.

Science4KMU

The aim of the project was to improve the cooperation of research institutes in intersectional disciplines with small and medium-sized enterprises (SME) by improving the use of their innovation potential. The scope of the project covered the development of a process for identifying potential partner SMEs in two ways: Top-down with a big data-based approach, and bottom-up, based on a questionnaire for the SMEs. Both ways allow to obtain sufficient information for identifying SMEs willing to integrate innovation. This is done by using a specific classification algorithm. To establish a cooperation model, strategies for partnering between the research institute and SMEs were developed, tested and validated. The *InnovationCenter INM* will make further use of the system. In the future, the model shall be further developed into a more generalized form for transfer and to make it available as a tool box for other research institutes.

Besides executing industry and public funded projects, the *InnovationCenter* offers a wide range of INM's analytical services for our industry customers. The available facilities allow companies to improve the quality and competitiveness of their products.

OUTLOOK

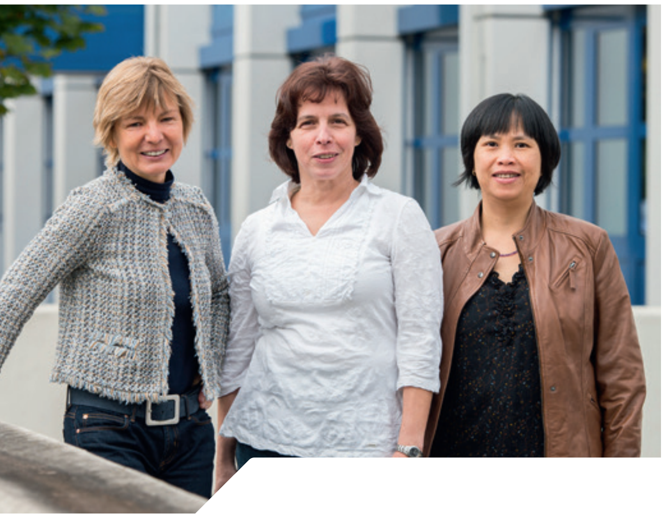
Over the last years, joint research at INM together with the supporting activities of the *InnovationCenter INM* has brought remarkable progress towards commercial use in emerging areas like printed electronics, optical applications, and new handling systems based on the Gecomer Technology. Our commitment for the future is to early identify promising research results within INM's program divisions and to enable the transfer into application by making use of our innovation-network. Besides the aforementioned areas, we will start to expand our activities into energy-related technologies and water purification, addressing two of the main future challenges.

Dr. Peter W. de Oliveira, Dr. Karsten Moh

SERVICEBEREICHE / SERVICE GROUPS

CHEMISCHE ANALYTIK / CHEMICAL ANALYTICS

DR. CLAUDIA FINK-STRAUBE



Die Servicegruppe *Chemische Analytik* nutzt moderne Verfahren zur Elementanalytik und zur Strukturaufklärung für die Materialcharakterisierung. Diese werden im Rahmen von Servicedienstleistungen für das INM, die Universität sowie Externe angeboten. Die Elementanalytik führt routinemäßig die quantitative Bestimmung nahezu aller stabilen Elemente mit ICP-OES, FL- und GF-AAS durch. Elementverteilungen im Ultraspurenbereich können mit HR-SF ICP-MS analysiert werden. Zur Identifizierung durch akkurate Massebestimmung, Größenbestimmung und Strukturaufklärung organischer Moleküle kommen GC-MS, GPC, LC-ESI-MS und LC-ESI HR-Q-TOF zum Einsatz. Gängige Aufschluss- und Extraktionsverfahren (MW, HT Aufschluss, HS, LE, SPE, SPME) zur Probenvorbereitung runden das Portfolio der chemischen Analytik ab.

PHYSIKALISCHE ANALYTIK / PHYSICAL ANALYTICS

DR. MARCUS KOCH

Die Servicegruppe *Physikalische Analytik* untersucht Proben auf vielfältige Weise mittels Elektronenmikroskopie und Röntgendiffraktometrie einschließlich eventuell notwendiger Präparationsschritte. Zielgruppen sind Wissenschaftler/innen aus dem INM, dem universitären Umfeld und Firmen im Rahmen von Servicedienstleistungen. Mit einem speziellen Rasterelektronenmikroskop (ESEM), einem Transmissionselektronenmikroskop (TEM) und einem Zweistrahlgerät (FIB) können Untersuchungen bis in den Nanometerbereich durchgeführt werden. Einige Mikroskopiertechniken können dabei *in situ* durchgeführt werden, um dynamische Prozesse (z. B. beim Heizen, Kühlen oder Gefriertrocknen) zu verfolgen. Für Studierende und Schüler/innen werden die Verfahren im Rahmen von Führungen und Praktika in anschaulicher Art demonstriert.

WERKSTATT / WORKSHOP

DIPL.-ING. KARL-PETER SCHMITT

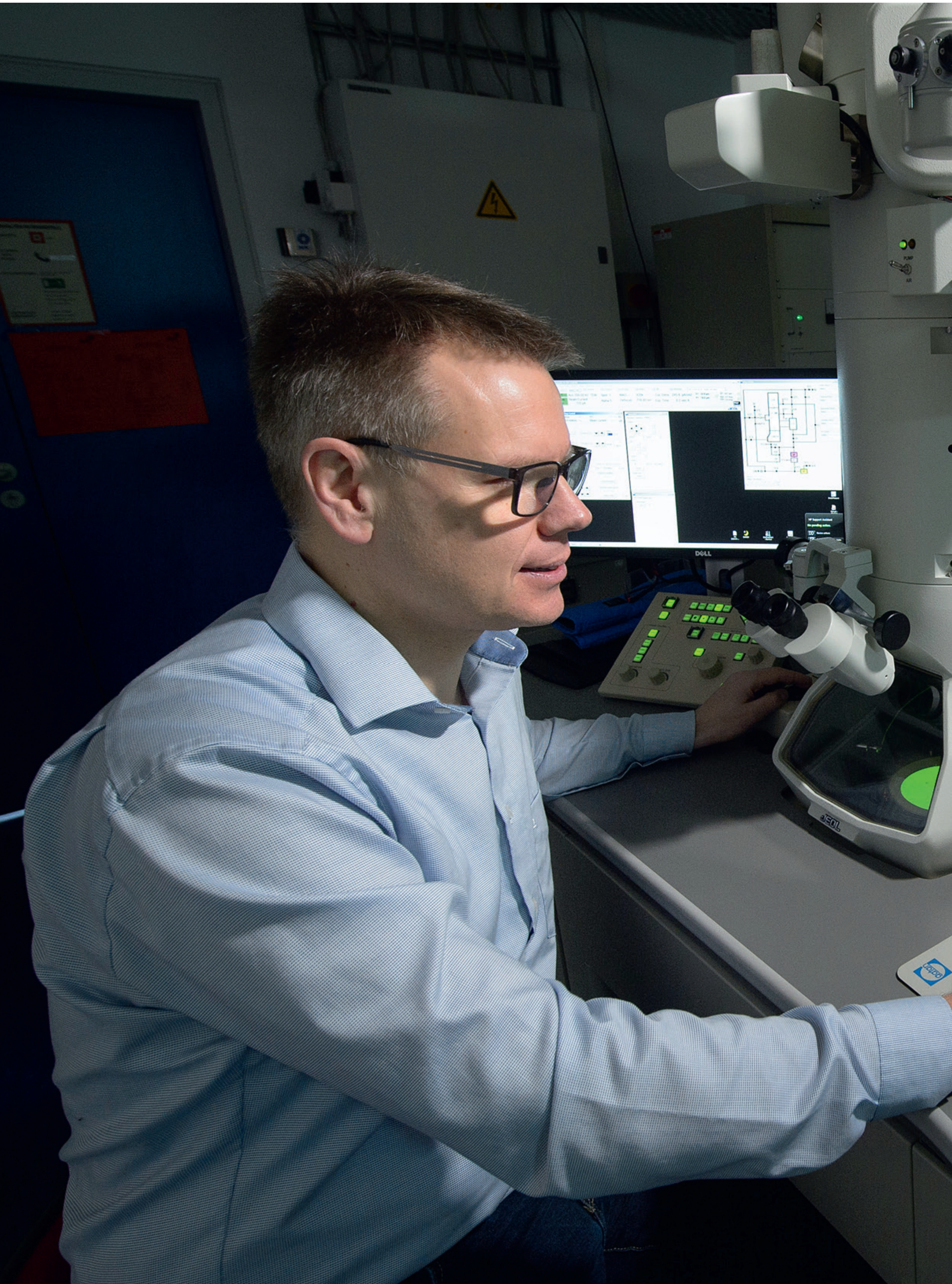
Die zentralen Aufgaben des Servicebereiches *Werkstatt* bestehen in der Entwicklung und Herstellung nichtkommerzieller Anlagen und Komponenten für Forschungs- und Entwicklungsprojekte am INM. Die Bandbreite der Arbeiten reicht dabei von Laborgeräten bis hin zu Pilotanlagen. Neben der Planung und Konstruktion werden Anlagen zudem gewartet, repariert oder nach Nutzervorgaben verändert. Die Fertigung von Werkstücken ist neben klassischen Fertigungsarten auch durch automatisierte Fertigungsprozesse möglich. Wir bieten jedes Jahr Ausbildungsstellen als Industriemechaniker/in und Elektroniker/in für Betriebstechnik an und führen Praktika für Schüler/innen durch. Im Rahmen einer Kooperation mit der Universität des Saarlandes unterstützen wir den Lehrstuhl *Technische Physik* mit Werkstattarbeiten.

NTNM-BIBLIOTHEK / NTNM LIBRARY

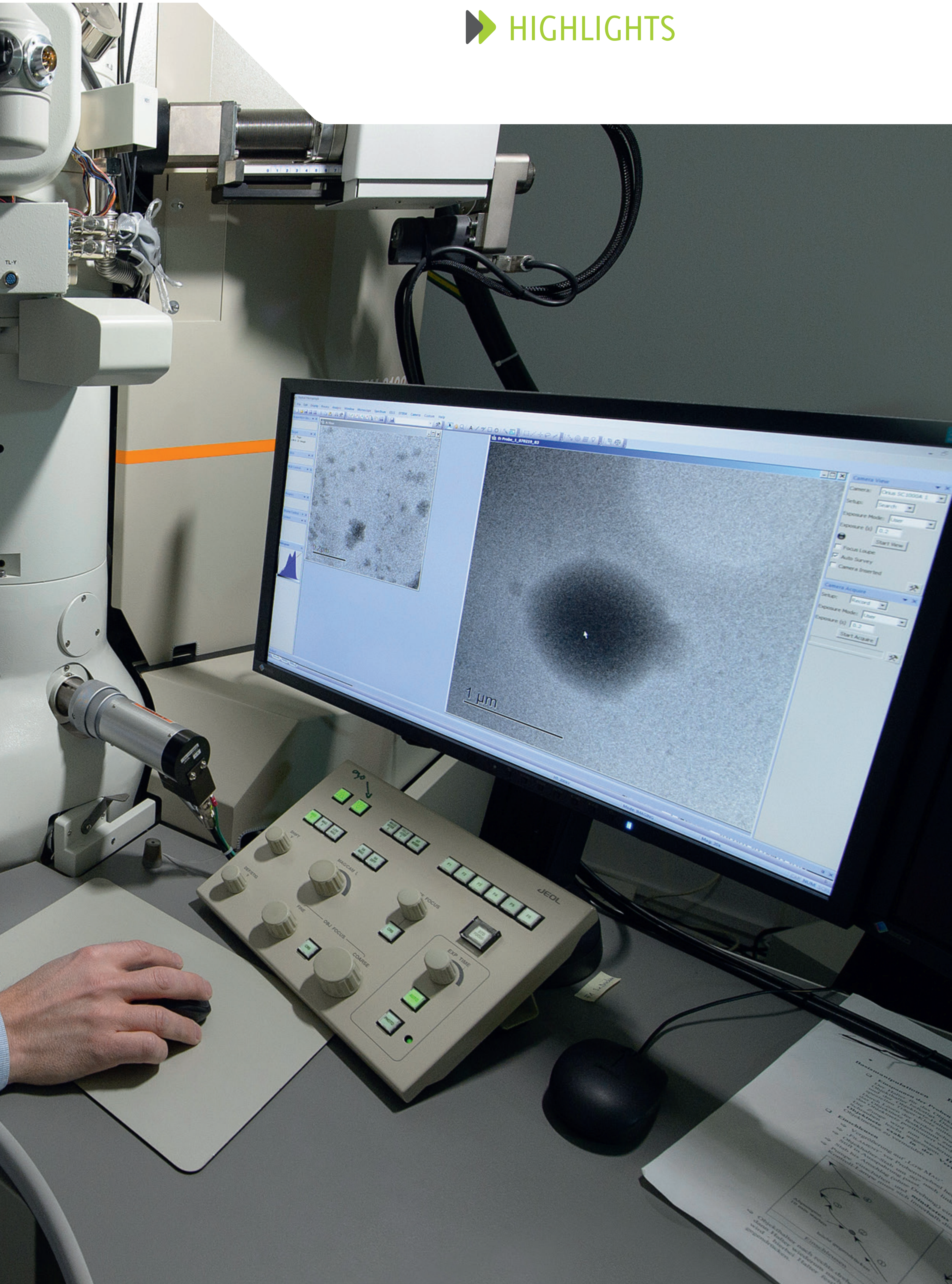
DIPL.-BIBL. MA ELKE BUBEL

NTNM CAMPUS-BIBLIOTHEK

Die NTNM-Bibliothek ist die gemeinsame Bibliothek für Naturwissenschaft und Technik des INM und der Fakultät NT der Universität des Saarlandes. Mit einem breiten Angebot an Print- und elektronischen Informationsangeboten steht sie Studierenden, Angehörigen beider Einrichtungen sowie externen Interessierten zur Nutzung offen. Für Angehörige des INM erbringt die Bibliothek forschungsnahe Informationsdienstleistungen. Sie vertritt das INM in den bibliothekarischen Arbeitskreisen der Leibniz-Gemeinschaft. Hinsichtlich wissenschaftlicher Belange wird die NTNM-Bibliothek von einem Beirat begleitet. Im Berichtsjahr wurde das vom BMBF geförderte Projekt visOA zur Sichtbarmachung von Open-Access-Publikationen erfolgreich abgeschlossen.


DELL
JEOL

HIGHLIGHTS



PHOTOACTIVATABLE HSP47: A TOOL TO REGULATE COLLAGEN SECRETION AND ASSEMBLY

ESSAK S. KHAN, SHRIKRISHNAN SANKARAN, JULIETA I. PAEZ, CHRISTINA MUTH,
MITCHELL K.L. HAN, ARÁNZAZU DEL CAMPO
DYNAMIC BIOMATERIALS

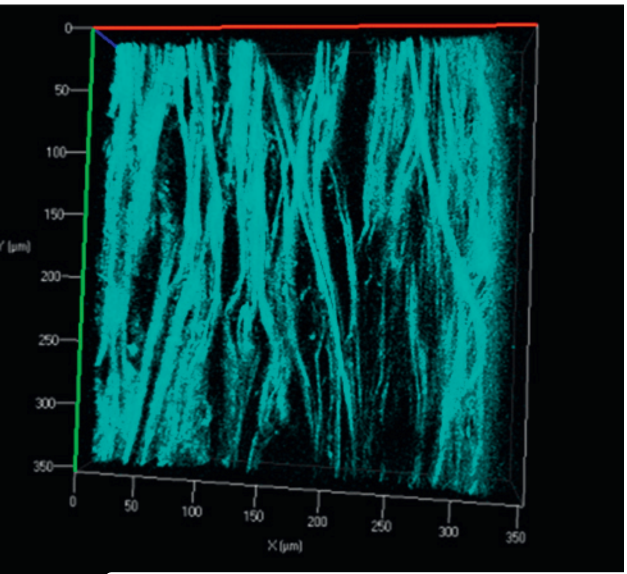


Fig.: SHG image of collagen fibers from cornea. The dimensions and alignment of the fibers are crucial to guarantee transparency and the natural curvature of the tissue. Regenerative approaches able to restore this organization are needed in certain cornea pathologies.

Collagen is the most abundant protein in our body. As a structural protein it forms hierarchical superstructures (fibers; Fig. 1) that provide mechanical stability to our tissues. Besides, collagen molecules provide important recognition sites for cells to attach, as well as binding sites for growth factors to promote cell differentiation. For these reasons, collagen is often used as scaffolding material to support tissue reconstruction. However, collagen scaffolds prepared from isolated collagen from tissues are very soft materials, do not form ordered morphologies and do not present the mechanical properties of natural collagen fibers. The assembly of collagen fibers *in vivo* is a complex process orchestrated by the cells, which cannot be mimicked by simple mixing of isolated or synthesized collagen molecules in a flask.

The Program Division *Dynamic Biomaterials* demonstrated a pathway to interfere and stimulate collagen production by living cells in damaged tissue, and is applying this approach to tissue regeneration. The collagen-specific chaperone Hsp47, a major player in collagen biosynthesis and organization, is exploited for this purpose. Exogenous supply of a photoactivatable variant of Hsp47 developed in the group allows light-regulated upregulation of collagen deposition in diseased tissues. Secreted collagen is organized by the cells into structures similar to those of natural tissue. The therapeutic potential of this approach is currently explored in cooperation with clinical partners at Saarland University. These results highlight the complexity of natural materials, and the need for multidisciplinary approaches to reconstruct them. They also evoke new and sustainable ways for the synthesis of high performance materials inspired by nature.

E.S. Khan, S. Sankaran, J.I. Paez, C. Muth, M.K.L. Han, A. del Campo, Adv Sci (2019) 6 (9), 1801982

PHOTO-INDUCED GROWTH OF MICROSTRUCTURES

JIAXI CUI
SWITCHABLE MICROFLUIDICS

Living organisms are able to create fascinating microstructures *via* a growth model. During natural growth process, nutrient is absorbed, transported and integrated into the organisms under the directive of an intrinsic code. With this capability, living organisms grow up, changing their size, strength, composition, shape, etc.

We attempted to mimic the unique abilities in synthetic materials, with special attention on controlling localized growth of microstructures from the surface of swollen substrates by light. Three kinds of reactions – photolysis, photopolymerization, and transesterification – were coupled to guide the transport of liquid compositions entrapped in the substrates, to convert polymerizable compositions in the liquids to polymers, and to reconfigure new-formed and original polymers. As a result of these reactions, microstructures can grow directly from flat substrates without any preprogramming. The developed light-induced growth approach is spatially controllable, dose-dependent, and multi-triggerable, and can be used to create rough surfaces or restore surface damage. Although the methodology was demonstrated on structuring surfaces, the mechanistic insights gained in governing the growth can be readily applied to change bulk properties of materials with regard to the capability of light to spatially trigger reactions.

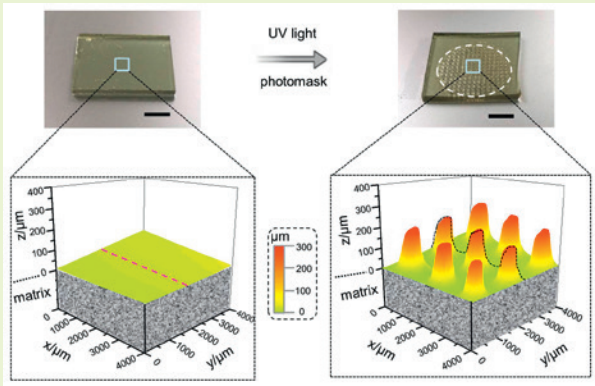


Fig.: Photo-induced growth to create microstructure on a surface.

This strategy represents not only a fundamental way to fabricate materials in which materials are integrated without any waste, but also a way of post-modification of grown materials. It also showed potential in the self-restoration of large damage and in patterning surfaces without templates. Its development will benefit areas such as transformable materials, additive manufacturing, self-healing materials, actuating systems, adaptive materials, functional surfaces etc.

L. Xue, X. Xiong, B. P. Krishnan, F. Puza, S. Wang, Y. Zheng, J. Cui, Nat Commun (2020), 11, 963

STRETCHING INFLUENCES IN-VITRO LUNG CELL RESPONSE TO NANOPARTICLES

CARMEN SCHMITZ, ANNETTE KRAEGELOH, CHRISTIANE PETZOLD
NANO CELL INTERACTIONS, LEIBNIZ-RESEARCH ALLIANCE NANOSAFETY

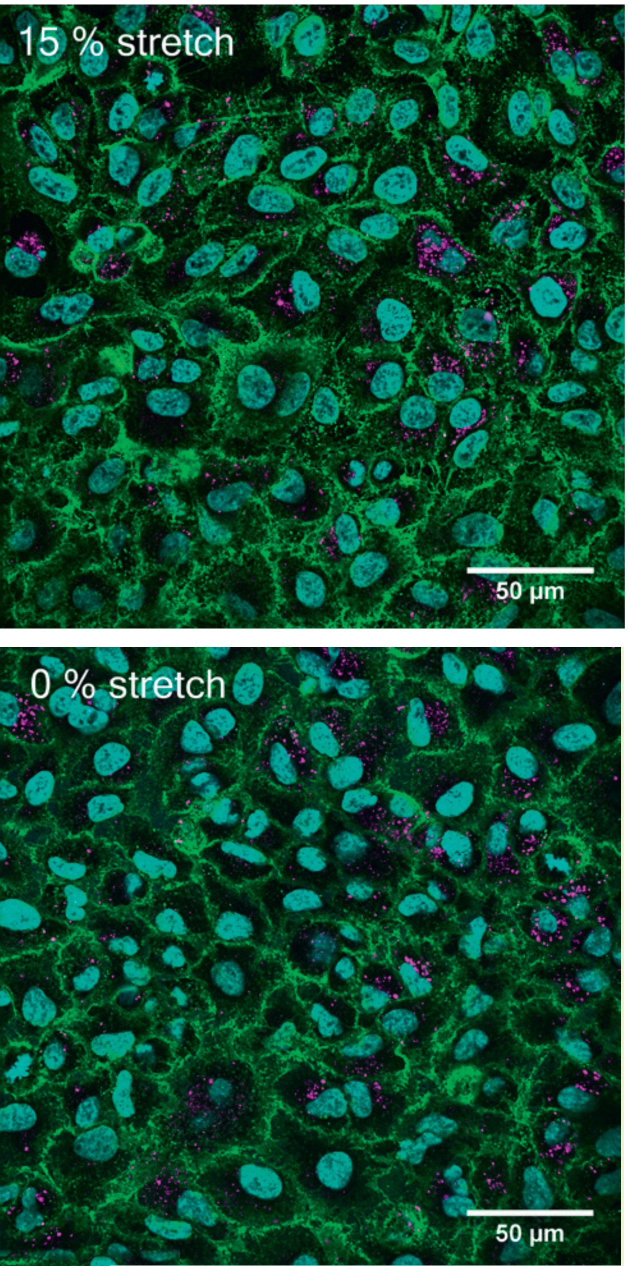


Fig.: Fluorescence microscopy images of human alveolar epithelial cells (A549) after 24 hours in culture. Stretched and non-stretched cells internalized a similar amount of silica nanoparticles (magenta). Blue: nuclei; green: cell membranes.

Nanometer-sized airborne particles – from natural sources or human-made – can reach the deep lung and cause adverse health effects. The results of in vitro testing of possible effects of nanoparticles on lung cells cannot be directly transferred to complex, living organisms. The Nano Cell Interactions group analyzed the effects of silica nanoparticles in a dynamic cell culture model that mimics specific aspects of physiological conditions in the lungs. The work was realized together with the group of Neurotoxicology and Chemosensation at IfADo, the Institute of Pharmaceutical Biology at Saarland University, and the Institute of Statistics at TU Dortmund.

Human alveolar epithelial cells (A549) were grown on flexible surfaces that were stretched to imitate the lungs' breathing movement. Those dynamically stretched cells reacted more sensitive to a treatment with silica nanoparticles than statically grown cells. Confocal fluorescence microscopy revealed that a fraction of the silica nanoparticles were taken up by the cells. Interestingly, the number of incorporated particles was similar in stretched and non-stretched cultures. Even though no acute harmful effects of the nanoparticles or the stretching alone were found, a change in the pattern of gene expression in stretched cells that had been treated with nanoparticles was detected. The activity of some genes was increased, while others were less active with the resulting gene pattern resembling the pattern known from inflammatory responses.

Further investigation of *in vitro* lung models that take into account the dynamic environment of the lungs is necessary to better predict the correlation between the *in vitro* and *in vivo* toxicity of respirable nanomaterials. Further study shall clarify which internal cellular mechanisms are responsible for the cells' more sensitive reaction to nanoparticles under dynamic conditions.

C. Schmitz, J. Welck, I. Tavernaro, M. Grinberg, J. Rahnenführer, A. K. Kiemer, C. van Thriel, J. G. Hengstler, A. Kraegeloh, Nanotox (2019) 13, 9, 1227

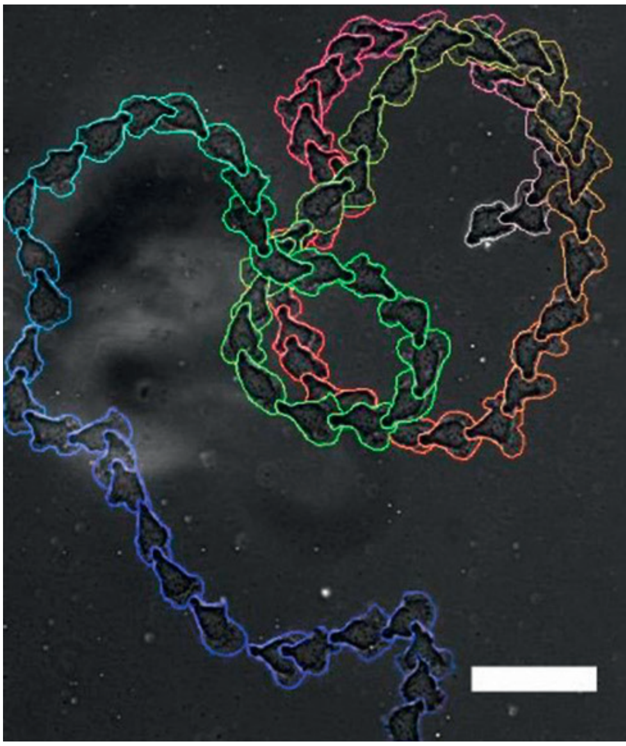
ACTIN WAVES STEERING IMMUNE CELL MIGRATION

LUIZA STANKEVICINS[A], NICOLAS ECKER[B], EMMANUEL TERRIAC[A], BIN QU[C], MARKUS HOTH[C], KARSTEN KRUSE[B], FRANZISKA LAUTENSCHLÄGER[A,C]
[A] CYTOSKELETAL FIBERS [B]UNIVERSITY OF GENEVA, SWITZERLAND [C]SAARLAND UNIVERSITY

Dendritic cells are immune cells that migrate within the human body in search of pathogens. How is such search efficient? It is already known that a combination between random, diffuse migration and straight, persistent migration is helpful in order to find a target. The group Cytoskeletal Fibers, as well as other research, have already shown various mechanisms in the past which could explain how a cell migrates persistently. However, the random part of the migration was so far thought to be simply due to noise.

The group *Cytoskeletal Fibers* and collaborators now analyzed very long trajectories of dendritic cells *ex vivo* and described their characteristic diffusive and persistent migration patterns. First, they saw that the persistent motion was not straight but on curved segments. Secondly, they provided evidence that both parts of migration (diffusive and curved) of dendritic cells could be due to the dynamical properties of one particular part of the cytoskeleton – the force-generating actin fibers. They illustrated that the actin in cells propagates in waves and is able to switch the migration mode from one to the other (e.g. from diffuse to curved) without the need for molecular noise or external polarization cues, but by altering the actin polymerization speed. The results hint at the possibility that these cells can adapt their search strategies by changing the spontaneous dynamics of their actin cytoskeleton. The work was published in Proceeding of the National Academy of Science USA.

L. Stankevicins, N. Ecker, E. Terriac, P. Maiuri, R. Schoppmeyer, P. Vargas, A. M. Lennon-Dumenil, M. Piel, B. Qu, M. Hoth, K. Kruse, F. Lautenschläger, Proc Natl Acad Sci USA (2020) 117 (2) 826



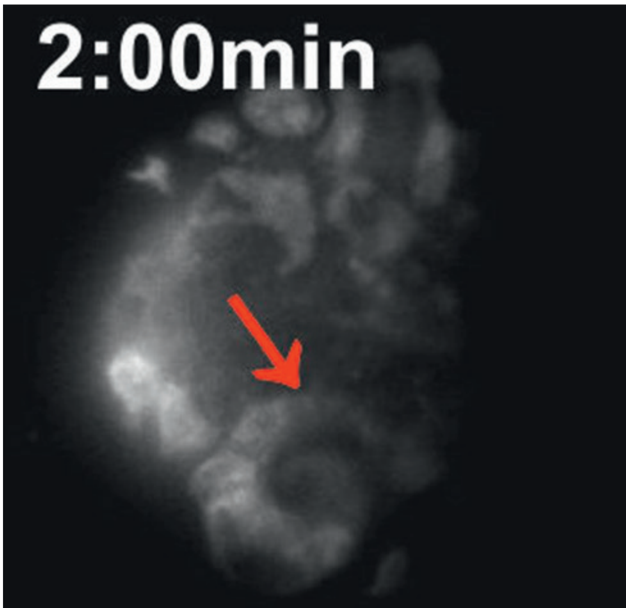
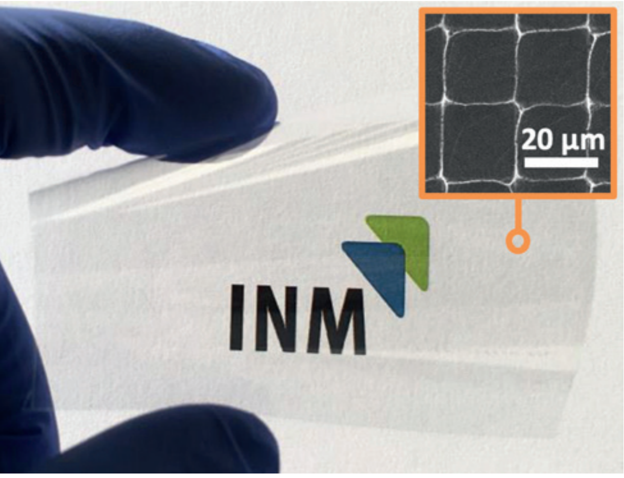


Fig. 1: Immune cell in circling motion. Scale bar 20 µm.
Fig. 2: Actin wave in immune cell.

MATERIALS FROM ULTRATHIN NANOWIRES: BETWEEN FLEXIBILITY AND STABILITY

LUKAS ENGEL, SIMON BETTSCHEIDER, TOBIAS KRAUS
STRUCTURE FORMATION



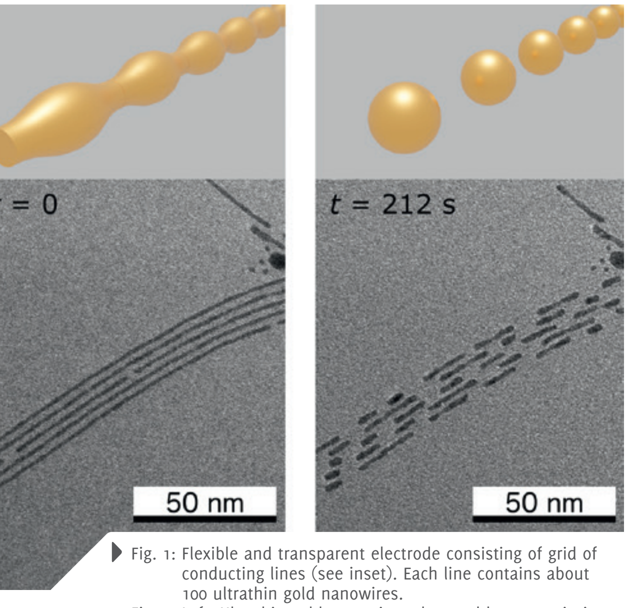


Fig. 1: Flexible and transparent electrode consisting of grid of conducting lines (see inset). Each line contains about 100 ultrathin gold nanowires.
Fig. 2: Left: Ultrathin gold nanowires observed by transmission electron microscopy and scheme of a perturbated nanowire. Right: Same nanowires break up into smaller particles when heated.

Transparent electrodes are indispensable parts of smartphones, tablets, and ticket machines. They make displays touch-sensitive and allow light to enter solar cells. Most transparent electrodes are thin, electrically conductive lines (Fig. 1) made by removing material from a continuous layer. The Program Division *Structure Formation* is working on an alternative: we synthesize ultrathin wires and make them self-assemble into suitable grids during an innovative imprinting step.

Ultrathin wires are literally ultra thin (below two nanometers) but quite long (up to several thousand nanometers). They form when we reduce metal salts in the presence of certain surface-active molecules. The wires are thin enough to remain invisible as they swim in the solvent. When the liquid dries, the wires join and form long “bundles”. We exploit the optical transparency of the wires and their tendency to form bundles when we print them to make transparent electrodes. During printing, the nanowires dry inside a stamp and form a mesh as shown in Fig. 1. The mesh is at first not electrically conductive, because each wire is covered by the surface-active molecules from synthesis insulating the metal part of the wires electrically.

Ultrathin metal wires tend to break up and form spheres (Fig. 2) which minimizes their surface energy, just as a jet of water from a watering pot does when it breaks up into droplets. It is not easy to remove the insulating molecules without damaging the wires and causing them to break up. Plasma treatment can remove the molecules, join the metal cores, and prevent disintegration. The process that we developed combines printing and plasma treatment to create highly conductive and transparent meshes.

FIRE-RESISTANT ACACIA FIBERBOARD FOR BUILDING AND CONSTRUCTION IN SUB-SAHARA AFRICA

BERND REINHARD, BUDIMAN ALI, CARSTEN BECKER-WILLINGER
NANOMERS

In a BMZ-funded cooperation project between the INM – Leibniz Institute for New Materials and the University of Namibia (UNAM), a fireproof building material made from acacia wood shreds and an inorganic binder was developed. In terms of sustainability, it consists entirely of Namibian raw materials. The composite material is characterized by excellent fire resistance and very high mechanical strength. The plates are not inflamed under exposition to a butane gas flame at 1000 °C for 1 h. The tensile and compressive strengths of the composite are in a range corresponding to that of a middle-class concrete.

The starting point for the cooperation between INM and UNAM was the fact that Namibia's biosphere is extremely threatened by undesirable invader bushes and their excessive spread with effects on biodiversity, usability of farmland and groundwater recharge. Around 30 % of the agricultural area is currently affected by the so-called "bush encroachment". The biomass in question is estimated to more than 300 million tons. Our approach was to use this vast biomass for the production of new types of composite materials for low-cost housing, aiming to substitute the dwellings made of corrugated iron or mud huts in bush where around 70 % of the rural population live.

The project is designed in a way that Namibian scientists are trained by INM scientists in the fields of materials science and chemistry. The training is based on the practical application of the fire-resistant acacia fiber boards. Parallel to the imparting of skills, a materials science laboratory is being created at UNAM and the INM is intensively involved in its planning in terms of design and equipment. In the next and final project phase, the base for the industrial production of acacia composites in Namibia will be laid.

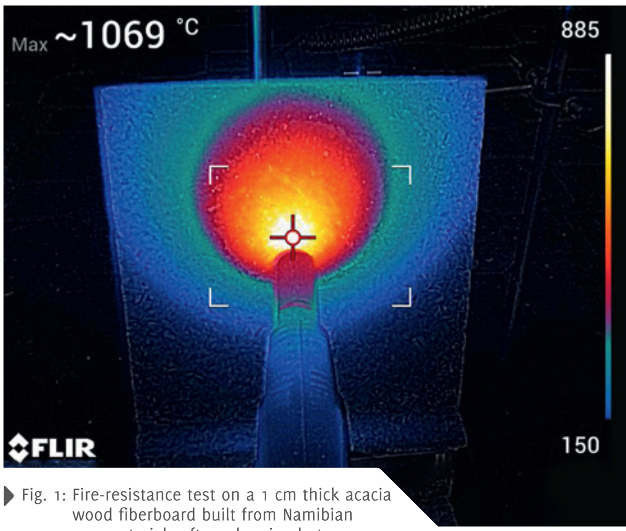


Fig. 1: Fire-resistance test on a 1 cm thick acacia wood fiberboard built from Namibian raw materials after 1 h using butane gas flame. The composite material derived from acacia shreds and inorganic binder is not burning.
Fig. 2: Infrared camera image on acacia wood fiberboard in fire resistance test after 1 h using butane gas flame. The center shows a temperature of 1069 °C whereas the backside of the 1 cm thick plate shows only 430 °C at the hottest spot.

FROM SCIENCE TO MARKET

EDUARD ARZT, MARIO QUILITZ
FUNCTIONAL MICROSTRUCTURES

INNOCISE
Precise Handling Solutions

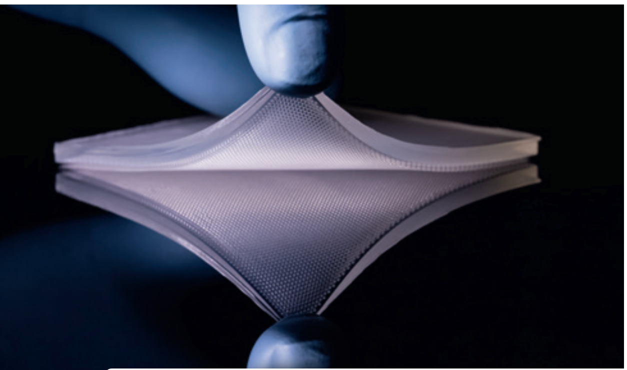


Fig.: Bio-inspired surface structures create a new adhesive technology.

The Leibniz Institute for New Materials has a strong track record in research on bio-inspired materials. The Functional Microstructures group plays a pioneering role in establishing the science of micropatterned surfaces and in creating novel adhesive functionalities. Spurred by rapidly mounting interest from industrial partners, a start-up company was founded in 2019. The objective of INNOCISE GmbH, located in downtown Saarbrücken, is to develop and commercialize innovative solutions for applications in the areas of robotics, handling and automation. The name of the new company derives from the main claim of its products: INNOvative and preCISE.

Inspired by the "gecko effect", polymer surfaces are micropatterned by different processes, down to micron dimensions, to provide reliable, glue-free adhesion to a wide variety of objects. The adhesion is optimized by computer modeling of the contact mechanisms. Most importantly, the adhesive state can be switched on and off at will and over many thousands of cycles. This functionality has created enormous interest in the automation and handling community, which is currently searching for new solutions in the context of the fully digital fabrication ("Industrie 4.0"). The products of INNOCISE exhibit several unique selling points over existing handling solutions: the technology works in a vacuum environment and can be scaled down to sensitive microcomponents. Moreover, it is fast, noise-free, and resource-efficient.

INNOCISE has demonstrated the potential of its products at several technology exhibitions worldwide. The spin-off has successfully entered into collaborations with world-leading companies to leverage its innovative technology. In addition to the currently relevant market segments, new areas of applications are appearing on the horizon, ranging from biomedical to space technology.

WORKSHOP "MATERIALS SCIENCE AND HAPTICS"

ROLAND BENNEWITZ[A], RENE HENSEL[B], EDUARD ARZT[B]
[A]NANOTRIBOLOGY [B]FUNCTIONAL MICROSTRUCTURES

The perception of materials by touch is a key element of their usability and pleasantness in everyday interaction with consumer products. While the connection between individual structural or physical parameters and certain dimensions of tactile perception has been established, an integral understanding of the perception of various materials is still to be developed. On February 21 and 22, 2019, the INM invited scientists from several European countries for a workshop on "Materials Science and Haptics".

A number of topics were covered by the invited speakers:

- The mutual influence of materials characteristics on tactile perception, in particular the role of real and perceived wetness and coldness (Astrid M.L. Kappers, Eindhoven).
- The connection between surface chemistry and fingertip friction in the haptics of materials (Mark Rutland, Stockholm).
- The combination of friction and normal forces in haptic perception and the overlap between tactile and visual inputs in the perception of materials (David Gueorguiev and Yasemin Vardar, Stuttgart).
- Partial slip of moist fingertips during object manipulation and its role in haptics (Jean-Louis Thonnard, Louvain).
- The perceptional processing of serial information from an active touch during materials exploration (Knut Drewing, Giessen).
- Engineering of a tactile display of material properties by ultrasonic friction control as a function of the finger position (Michael Wiertlewski, Delft).
- Epidermal interfaces for human-computer interaction (Jürgen Steimle, Saarbrücken).

A vivid discussion of the talks and in particular during the presentation of a number of high-level posters led to many new insights and ideas for future collaborations. The workshop was organized by Roland Bennewitz, René Hensel, and Eduard Arzt and supported by the ERC Project "Switch2Stick".

Fig.: Impressions from INM's workshop on materials science and haptics.

THREE QUESTIONS TO PROF. ROBERT M. MCMEEKING

To honor a successful and long-term cooperation, the INM and the Leibniz Association appointed Robert M. McMeeking, University of California, Santa Barbara, USA, as Leibniz Chair. The internationally renowned materials scientist is the first Leibniz Chair at INM and the first in the field of Mathematics, Natural and Engineering Sciences in the Leibniz Association.

YOU ARE AN EXPERT ON THEORETICAL MODELS OF MATERIALS BEHAVIOR. WHAT DO YOU LIKE ABOUT THIS KIND OF RESEARCH?

I am interested in the mechanical, structural and functional behavior of materials. Theoretical models for such phenomena are fascinating because of their combination of physics, engineering, applied mathematics and computation. I like to have a physical feel for what is happening to the material, but I also like to quantify what is going on, so this area is perfect for my preferred way of thinking about materials.

YOU HAVE WORKED WITH COLLEAGUES FROM INM FOR MORE THAN TEN YEARS. WHAT HAS BEEN THE HIGHLIGHT OF THIS COOPERATION SO FAR?

It has been very special to be involved in developing ideas and concepts jointly with colleagues at INM that are then put to practical use in inventions and technology by INM researchers. INM is wonderful because its range spans from basic science all the way to practical technology.

WHAT ARE YOUR CURRENT OR UPCOMING PROJECTS AT INM?

Thanks to an Alumni Award by the Alexander von Humboldt Foundation I was able to lead the development of an international network of researchers that supports INM in the area of modeling and simulation, mostly focused on bio-inspired non-chemical adhesion technologies. Among other topics, the network is working on models that help us understand how to increase adhesive strength.

More recently, colleagues at INM and I were awarded funding by the Leibniz Association for a project on systems with high adhesive strength. Sometimes the adhesion of INM's systems is so good that it is difficult to get the adhesive to let go. In MUSIGAND we will look at clever ways of getting the adhesion system to detach so that after picking up an object you can also put it down.

OPEN ACCESS AT FIRST SIGHT

UWE GEITH, THOMAS KRASS, ELKE BUBEL
NTNM LIBRARY

Libraries are key players in the practical implementation of open access offers. As part of the visOA project, the NTNM Library aims to attract attention to Open Access publications among actively publishing scientists, thereby supporting the establishment of the Open Access concept both in the reception and publication of scientific results. The fundamental concept of the project was to identify publications relevant to the scientific spectrum of the INM and already available in Open Access, to integrate them into the library's reference tools and finally to highlight them visually by means of clear and uniform identification compared to electronic media with closed access.

A further aim was to identify high-quality Open Access journals in science and technology in particular and to make them easily accessible in an attractive and user-friendly format. For that, we developed a specially programmed virtual journal display, vidijo. Vidijo can be used on all mobile devices, and its functionalities can be personalized. Vidijo will be available in its version 1.0.0 as Open Source software and will subsequently be provided for use by other libraries and information facilities.

The visOA project is supported by accompanying scientific research so that conclusions can be drawn about the effectiveness of the measures. The accompanying research comprises literature survey about the qualitative reception of scientific literature which resulted in a catalogue of criteria.

The recently completed project was funded by the Federal Ministry of Education and Research (BMBF).

https://visoa.leibniz-inm.de
https://www.vidijo.org

U. Herb, U. Geith, Information, Wissenschaft & Praxis (2020), 71 (2-3), 1-9, accepted

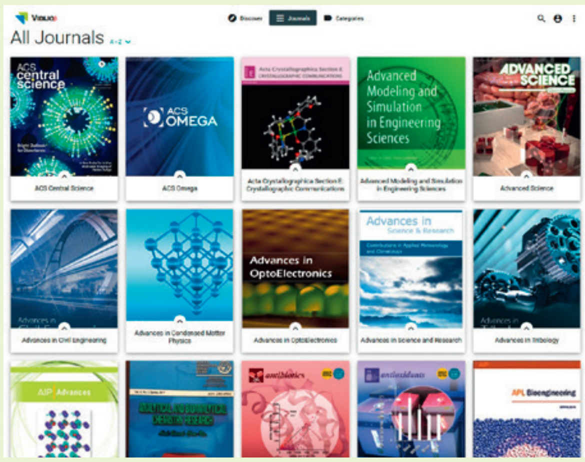


Fig.1: The Open Access Logo
Fig.2: Start page of the Vidijo tool

INM AS FAMILY-FRIENDLY EMPLOYER – RENEWED CERTIFICATE IN THE AUDIT WORKANDFAMILY

CLAUDIA FINK-STRAUBE, MARCUS KOCH, SABINE MÜLLER, CHRISTINA SAUER, SILKE ZEITER-SEMMET
PROJECT GROUP „AUDIT WORKANDFAMILY“

BETRIEBSVEREINBARUNG ZUR VEREINBARKEIT VON FAMILIE UND BERUF - PFLEGE

zwischen

INM – Leibniz-Institut für Neue Materialien gGmbH
vertreten durch deren wissenschaftliche und kaufmännische Geschäftsführung
- nachstehend „Geschäftsführung“ genannt –

und

dem Betriebsrat des INM - Leibniz-Institut für Neue Materialien gGmbH
- nachstehend „Betriebsrat“ genannt –

zur besseren Vereinbarkeit von Beruf und Familie im INM.

Fig. 1: INM’s family room.
Fig. 2: Company agreement for care of relatives.

Since 2012, INM has been certified as a family-friendly employer within the “audit workandfamily”. In 2019, the INM was awarded the renewed certificate after a successful review of the institute’s family and life-conscious measures implemented over the previous three years. With this new certificate, INM has committed itself to continue its efforts for the following three years.

With the „audit workandfamily“, INM wants to support its employees in improving their work-life balance. Main focuses are the balance of work and life with children or with relatives in need of care as well as measures for health. An important step in the review period was INM’s company agreement on the care of relatives adopted in 2018. It allows all employees of the institute to improve the flexibility of their work-life balance supporting them in their activities of taking care of family members or close relatives. With this agreement, the INM voluntarily commits itself to various measures to mitigate the financial losses of the employees concerned and to enable them to schedule time for various care obligations. Another highlight in the review period was the installation of a new family room to support the employees in cases where their regular childcare is not available. Here, the children can climb, play or draw, while the mother or father works in the same room. Also, elderly relatives can spend time here e. g. while waiting for an urgent medical appointments.

With its renewed certification, the INM strives to maintain its high standard of work-life balance by implementing further family-oriented and health-conducive measures. They include e.g. the implementation of appraisal interviews, the evaluation of needs and opportunities for mobile working, and communication of INM’s family-friendly activities.

Fig.: As part of the Leibniz Association's "Ask Leibniz" campaign, scientists from INM answered questions from society on nano-safety and water treatment. The contributions were used for a card game.


INM

FAKTEN UND ZAHLEN / FACTS AND FIGURES

DAS INM IN ZAHLEN / INM IN FIGURES

DAS INM IN ZAHLEN

Im Jahr 2019 betrug der **Gesamtumsatz** des INM 24,11 Mio. Euro.

Erlöse aus der gemeinsamen Finanzierung durch den Bund und die Länder (**institutionelle Förderung**): 18,30 Mio. €,

- davon Personal- und Sachaufwendungen: 14,85 Mio. €,
- und für Investitionen: 3,45 Mio. €

Erlöse aus Drittmittelvorhaben: 5,64 Mio. €

- davon 3,63 Mio. € aus öffentlichen Projektförderungen,
- und 2,01 Mio. € aus Vereinbarungen mit Industrieunternehmen.

Sonstige betriebliche Erträge: 0,17 Mio €

Das INM hatte Ende 2019 **247 Beschäftigte** (126 m, 121 w), davon

- 74 Wissenschaftler/innen (41 m, 33 w),
- 42 Promovierende (22 m, 20 w),
- 54 Beschäftigte (27 m, 27 w) in den Bereichen Labor, Technik und Service,
- 33 Beschäftigte (9 m, 24 w) in der Verwaltung und den Sekretariaten,
- 39 Hiwis (24 m, 15 w) und 5 Auszubildende (3 m, 2 w).

INM IN FIGURES

In 2019, the **total turnover** of INM added up to 24.11 million euro.

Proceeds from the **joint financial support** by the federal government and the federal states (institutional funding): 18.30 million €,

- including expenses for personnel and materials: 14.85 million €,
- and for investments: 3.45 million €.

Proceeds from **third party funding:** 5.64 million €

- including 3.63 million € from public grants,
- and 2.01 million € from industrial contacts.

Other operating income: 0.17 million €

At the end of 2019, **247 employees** (126 m, 121 f) worked at INM including:

- 74 scientists (41 m, 33 f),
- 42 doctoral students (22 m, 20 f),
- 54 employees (27 m, 27 f) in laboratories and technical services,
- 33 employees (9 m, 24 f) in administration and secretarial offices,
- 39 graduate assistants (24 m, 15 f) and 5 apprentices (3 m, 2 f).

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

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

Stand / As of: 31.12.2019

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saaris/saarland.innovation&standort e.V., Saarbrücken

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Universitätsklinikum des Saarlandes, Homburg

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Sony Europe Ltd., Stuttgart

Prof. Dr. Philipp Slusallek
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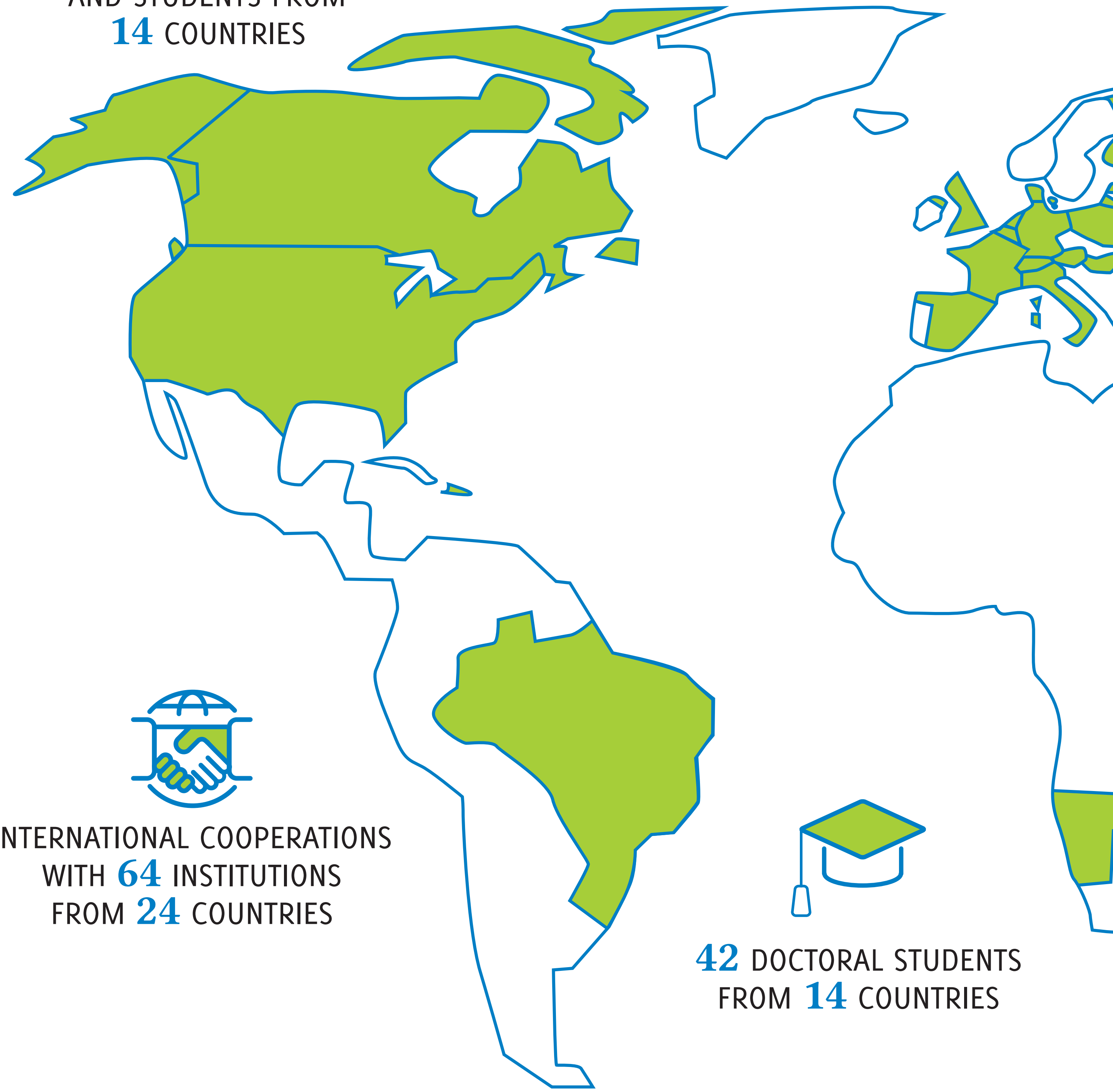
École Polytechnique Fédérale de Lausanne (EPFL), Neuchâtel, Schweiz

Prof. Dr. Nicholas D. Spencer
Eidgenössische Technische Hochschule Zürich (ETH) Zürich, Schweiz

Prof. Dr. Jürgen Steimle
Universität des Saarlandes, Saarbrücken

INM INTERNATIONAL

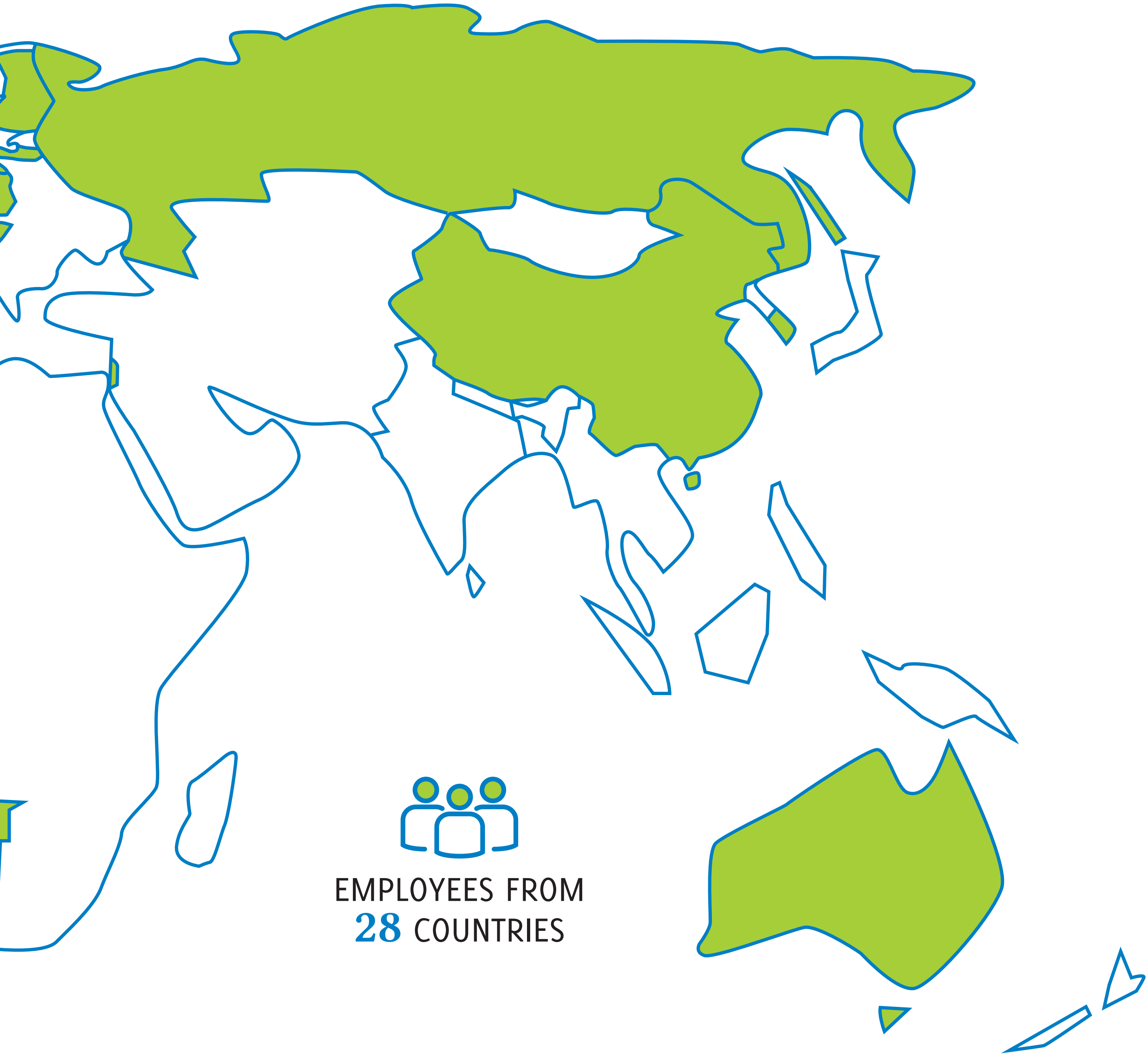
33 VISITING SCIENTISTS
AND STUDENTS FROM
14 COUNTRIES



INTERNATIONAL COOPERATIONS
WITH **64** INSTITUTIONS
FROM **24** COUNTRIES

42 DOCTORAL STUDENTS
FROM **14** COUNTRIES

COOPERATIONS
WITH **45** INSTITUTIONS
IN GERMANY



EMPLOYEES FROM
28 COUNTRIES

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

AUSZEICHNUNGEN / AWARDS

Eduard Arzt, Roland Bennewitz, Klaus Kruttwig (mit Aditya Shekhar Nittala, Jürgen Steimle, Univ. d. Saarlandes; Jaeyeon Lee, KAIST Daejeon)
CHI 2019 Honourable Mentions Award
CHI Conference on Human Factors in Computing Systems, Glasgow, UK, 04.-09.05.2019

Roland Bennewitz, Riad Sahli, Anle Wang (mit Martin Müser, Aubin Prot, Kwang-Seop Kim, Chan Kim, Univ. d. Saarlandes)
Best Work in Progress Award
IEEE World Haptics Conference, Tokyo, Japan, 09. – 12.07.2019

Simon Bettscheider
Promotionsstipendium
Studienförderwerk Klaus Murmann der Stiftung der Deutschen Wirtschaft

Shardul Bhusari
Miniproposal Funding
SFB 1027, Saarland University, Saarbrücken

René Hensel
Auswahl zum Future Leaders' Program
Science and Technology in Society (STS) forum, Kyoto, Japan, 06.-08.10.2019

Niels de Jonge
Best Software and Instrumentation Paper in Microscopy and Microanalysis for 2018
Microanalysis Society, USA

Arshad Khan, Tobias Kraus (mit Joan Sol Roo, Jürgen Steimle, Univ. d. Saarlandes)
Best Paper Award
ACM Symposium on User Interface Software and Technology (UIST) 2019, New Orleans, USA, 20. – 23.10.2019

Essak Khan
Spotlight Method of the Year
International Society of Matrix Biology

Tobias Kraus
Liesegang-Preis
Kolloid-Gesellschaft e. V., Stuttgart, 23. – 25.09.2019

Volker Presser
Fellow of the Royal Society of Chemistry
Royal Society of Chemistry, UK

Aditi Rathore
WISE – Working Internship in Science and Engineering
DAAD

Shrikrishnan Sankaran
Nature Reviews Microbiology Poster Award
VIB conference: Emerging Applications of Microbes, Leuven, Belgium, 03.-04.06.2019

DISSERTATIONEN / DOCTORAL THESES

Jessica Brunke
Nachhaltige Materialien auf Basis von Cyclodextrinen
Universität des Saarlandes, Saarbrücken
Prof. Dr. G. Wenz, Dr. C. Becker-Willinger

Tobias Dörr
Block Copolymer Derived Three-Dimensional Ordered Hybrid Materials for Energy Storage and Conversion
Universität des Saarlandes, Saarbrücken
Prof. Dr. T. Kraus, Dr. P.W. de Oliveira

Essak Khan
Optoregulation of Collagen Biosynthesis and Remodeling in Collagen Associated Diseases
Universität des Saarlandes, Saarbrücken
Prof. Dr. A. del Campo

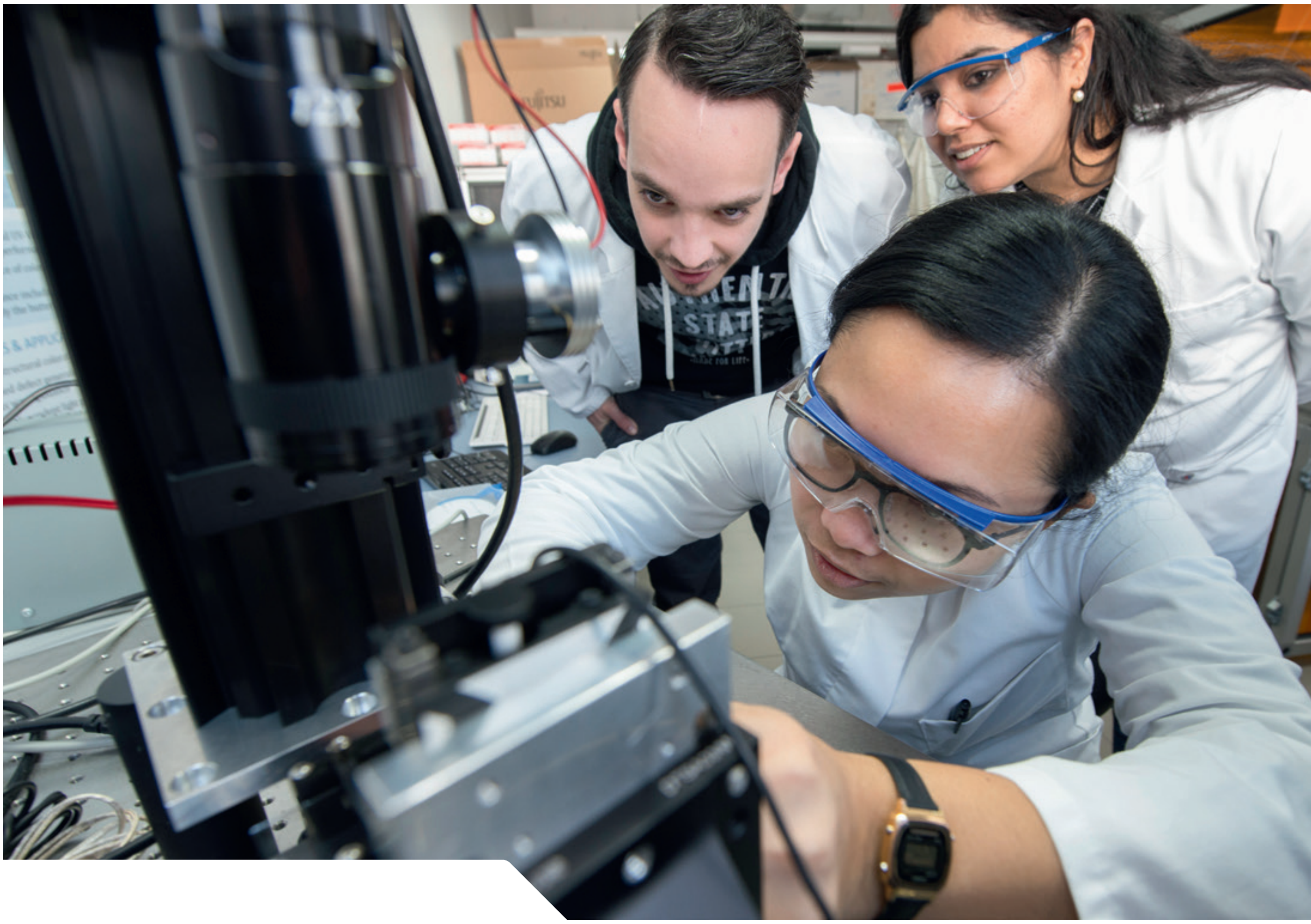
Günther Krämer
Molekulare Schmierung unpolarer und ionischer Schmiermittel im nanoskaligen Spalt
Universität des Saarlandes, Saarbrücken
Prof. Dr. R. Bennewitz

Novaf Özgün
Electroencephalographic Responses to Frictional Stimuli: Measurement Setup and Processing Pipeline
Universität des Saarlandes, Saarbrücken
Prof. Dr. D. Strauss, Prof. Dr. R. Bennewitz

Pattarachai Srimuk
Faradaic Eletrode Materials for Next-Generation Electrochemical Water Desalination
Universität des Saarlandes, Saarbrücken
Prof. Dr. V. Presser

Justine Tavera
Use of Ionic Crosslinking for Pressure-Sensitive Adhesives
Universität des Saarlandes, Saarbrücken
Prof. Dr. A. del Campo

Verena Tinnemann
Lokale und globale Ablösemechanismen in mikrostrukturierten Haftstrukturen
Universität des Saarlandes, Saarbrücken
Prof. Dr. R. Bennewitz, Dr. R. Hensel



ABSCHLUSSARBEITEN / THESES

MASTERARBEITEN / MASTER THESES

Gülseran Bozkurt
The Influence of Hydrogel Stiffness on Mono- and Co-Cultures of Primary Cells
Universität des Saarlandes, Saarbrücken
Prof. Dr. M. Hoth, Prof. Dr. A. del Campo

Lucina Kainka
The Role and Interplay of Cytoskeletal Filaments in Microtentacles
Universität des Saarlandes, Saarbrücken
Jun.-Prof. Dr. F. Lautenschläger

Francesco Kunz
Untersuchung des mikrostrukurellen Verhaltens galvanisch abgeschiedener Nanostrukturen unter äußeren Lasten
Universität des Saarlandes, Saarbrücken
Prof. Dr. T. Kraus

Jingchun Lyu
Textiles in Sliding Contact with the Human Forearm: The Effect of Hairiness, Moisture, and Material
Universität des Saarlandes, Saarbrücken
Prof. Dr. R. Bennewitz

Xing Meng
Haptic Perception of Micropatterned Elastomer Samples
Universität des Saarlandes, Saarbrücken
Prof. Dr. R. Bennewitz

Joris Pangraz
Correlations between Properties, Inkjet Printing Parameters, and the Conductivity of Metal Particle-Based Electronic Inks
Universität des Saarlandes, Saarbrücken
Prof. Dr. T. Kraus

Michael Penth
Parallele Kraftspektroskopie an hunderten von einzelnen DNA-Molekülen in einer Flusszelle
Universität des Saarlandes, Saarbrücken
Prof. Dr. R. Bennewitz

Manar Samri
Enhanced Adhesion of Smooth Silicon Films by Tuning Subsurface Stiffness
Universität des Saarlandes, Saarbrücken
Prof. Dr. E. Arzt, Dr. R. Hensel

Philipp Michael Wahl
Einfluss von Siegelprozessen auf die physikalischen Eigenschaften und die Mikrostruktur von Multilayer-Folien aus Polypropylen und thermoplastischen Elastomeren
Universität des Saarlandes, Saarbrücken
Prof. Dr. E. Arzt, Dr. R. Hensel

Chaoyu Wu
3D Printing of Biocompatible Optical Waveguides
Universität des Saarlandes, Saarbrücken
Prof. Dr. A. del Campo

Li Zhang
MoS_2-Graphene Three-Dimensional (3D) Hybrid Foam for Lithium-Ion Batteries
Universität des Saarlandes, Saarbrücken
Prof. Dr. A. del Campo, Dr. J. Cui

BACHELORARBEITEN / BACHELOR THESES

Timon Dörzapf
Influence of the Emulsification Process Parameters on the Optical Properties of Nanocomposites
Universität des Saarlandes, Saarbrücken
Prof. Dr. T. Kraus, Dr. D. Doblas Jiménez

Judith Eubel
Entwicklung und Validierung vom mikrostrukturierten Haftsystemen für die klinische Applikation
Universität des Saarlandes, Saarbrücken
Prof. Dr. E. Arzt, Dr. K. Kruttwig

Tobias Knapp
Gezielter Ligandenaustausch an ultradünnen Gold-Nanodrähten
Universität des Saarlandes, Saarbrücken
Prof. Dr. T. Kraus

Felix Kruchten
Synthese von CdSe und Bi_2S_3 Nanodrähten
Universität des Saarlandes, Saarbrücken
Prof. Dr. T. Kraus

Valeria Lemkova
Synthesis and Characterization of Niobium Oxide/Carbon Hybrid Materials for Electrochemical Energy Storage
Universität des Saarlandes, Saarbrücken
Prof. Dr. V. Presser

Maximilian Loes
Entwicklung einer Methode zur Bestimmung der Querkontraktionszahl von Elastomeren
Universität des Saarlandes, Saarbrücken
Prof. Dr. E. Arzt, Dr. R. Hensel

Moritz Schu
Acquisition and Quantitative Analysis of Cytoskeletal Actin
Universität des Saarlandes, Saarbrücken
Jun.-Prof. Dr. F. Lautenschläger

Peter Spies
Untersuchungen zur Stabilität von Halbleiter-Nanodrähten
Universität des Saarlandes, Saarbrücken
Prof. Dr. T. Kraus

Jonathan Thiemecke
Kontaktalterung von mikrostrukturierten Silikon-Haftstrukturen
Universität des Saarlandes, Saarbrücken
Prof. Dr. E. Arzt, Dr. R. Hensel

REFERIERTE PUBLIKATIONEN / PEER-REVIEWED PUBLICATIONS

166 Publikationen
publications
davon / *including*

127 Publikationen in referierten Zeitschriften
publications in peer-reviewed journals

39 sonstige Publikationen
other publications

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publications published in Open Access
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Dynamische Biomaterialien / Dynamic Biomaterials

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EINGELADENE VORTRÄGE / INVITED TALKS

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GRENZFLÄCHENMATERIALIEN / INTERFACE MATERIALS

Energie-Materialien / Energy Materials

V. Presser
A tale of two technologies: capacitive deionization and supercapacitors
6th International Symposium on Enhanced Electrochemical Capacitors (ISEE'Cap19);
May 6-10, 2019; Nantes, <FRA>

V. Presser
A tale of two technologies: capacitive deionization and supercapacitor
Materials Science and Engineering Colloquium; Saarland University;
June 4, 2019; Saarbrücken, <GER>

V. Presser
Capacitive deionization unchained
University of Manchester / National Graphene Institute;
July 17, 2019; Manchester, <GBR>

V. Presser
Nano design of electroactive materials to store energy and desalinate water
Lancaster University / Department of Chemistry and Materials Science Institute;
July 17, 2019; Lancaster, <GBR>

V. Presser
Nano design of electroactive materials to store energy and desalinate water
Institute of Physical chemistry of the Polish Academy of Sciences;
September 5, 2019; Warsaw, <POL>

V. Presser
Next-generation cell concepts for capacitive deionization using acrbon electrodes
7th German-Japanese Symposium on the Development and Technology of Carbon Materials;
September 24-26, 2019; Würzburg, <GER>

V. Presser
Electrochemical water desalination with transition metal carbides and dichalcogenides
MXene at the Frontier of the 2D Materials World, Beilstein Nanotechnology Symposium;
October 15-17, 2019; Mainz, <GER>

Funktionelle Mikrostrukturen / Functional Microstructures

E. Arzt
Biomimetic materials research – inspiration, simulation, Application
Karl Franzens Universität Graz <Graz, AUT>;
June 07, 2019

E. Arzt
On biomimetics
UCSD University of California / CMRR Center for Memory and Recording Research <San Diego, USA-CA>;
May 16, 2019

E. Arzt
Biomimetic surfaces - from inspiration to application
Mat-Science 2019: International Conference on Materials and Engineering; <San Francisco, USA-CA>;
February 18, 2019

E. Arzt
Bioinspired micropatterns – new materials for robotics and medicine
Karlsruher Werkstoffkolloquium; Karlsruher Institut für Technologie (KIT) <Karlsruhe, GER>; February 05, 2019

E. Arzt
Bioinspired materials and surfaces – from model to application
Leibniz-Institute for Solid State and Materials Research <Dresden, GER>; January 31, 2019

V. Chopra
Integration of electric fields to tune the adhesion of micropatterned adhesives
JUKNE <Cambridge, GBR>; March 20, 2019

R. Hensel
Engineering micropatterned adhesives – From single fibrils to system designs
Gordon Research Conference Science of Adhesion; <South Hadley, USA-MA>
July 22, 2019

R. Hensel
Micropatterned dry adhesives – mechanistic insights and new designs
JUKNE <Cambridge, GBR>; March 19, 2019

R. Hensel
Composite pillars with a tunable interface for adhesion to rough substrates
19. Kolloquium Gemeinsame Forschung in der Klebtechnik <Köln, GER>; February 12, 2019

K. Kruttwig
Microstructured adhesives for skin adhesion: technical realisation and implementation of a regulatory strategy
Symposium Debugging Nanobio-Interfaces to Promote Clinical Translation <Mainz, GER>; August 23-25, 2019

K. Kruttwig
Like a Second Skin: Understanding how Epidermal Devices Affect Human Tactile Perception
Mensch und Computer <Hamburg, GER>;
September 8-11, 2019

Nanotribologie / Nanotribology

R. Bennewitz, C. Petzold, M. Koch, N. Chan, S. G. Balakrishna, P. Egberts, A. Klemenz and M. Moseler
Friction mechanisms revealed by scanning force and electron microscopy
DPG-Frühjahrstagung 2019;
March 31-April 5, 2019; Regensburg, <GER>

R. Bennewitz
Molecular mechanisms of dissipation in liquids by friction force microscopy
CECAM Workshop on Interface Dynamics and Dissipation Across the Time- and Length-Scales;
May 21-23, 2019; Tel Aviv, <ISR>

R. Bennewitz
Molecular mechanisms of lubrication
Tribology-Seminar; Vienna University of Technology / Institute of Engineering Design and Product Development;
June 7, 2019; Vienna, <AUT>

Innovative Elektronenmikroskopie / Innovative Electron Microscopy

N. de Jonge
Liquid-phase electron microscopy of cells and nanomaterials in liquid
Seminar; LIST Luxembourg Institute of Science and Technology;
January 15, 2019; Belvaux, <LUX>

N. de Jonge
Electron microscopy of cells and nanomaterials in liquid
Nanophysics Seminar; Maximilians Universität München;
April 4, 2019; München, <GER>

N. de Jonge
Studying membrane proteins and drug responses at the single molecule level in whole cells using liquid-phase electron microscopy
Biologisches Kolloquium; Universität Freiburg;
May 27, 2019; Freiburg i.Br., <GER>

N. de Jonge
Liquid-phase electron microscopy of cells and nanomaterials in liquid
Scandem 2019; Conference Center Wallenberg;
June 12-14, 2019; Gothenburg, <SWE>

N. de Jonge
Proteins in whole cells studied with liquid-phase electron microscopy
MC 2019 – Microscopy Conference;
September 1-5, 2019; Berlin, <GER>

N. de Jonge
Studying membrane proteins and drug responses in individual cancer cells using liquid-phase electron microscopy
Seminar; Radbound University Medical Center;
September 19, 2019; Nijmegen, <NLD>

N. de Jonge
Studying membrane proteins and drug responses in HER2 positive cancer cells using liquid-phase electron microscopy
Scientific Seminar; Institute of Pathology;
November 18, 2019; Heidelberg, <GER>

S. Keskin
Reduced radiation damage in transmission electron microscopy of proteins in graphene liquid cells
Fritz Haber Institute of the Max Planck Society;
February 21, 2019; Berlin, <GER>

BIOGRENZFLÄCHEN / BIO INTERFACES

Dynamische Biomaterialien / Dynamic Biomaterials

A. del Campo
Increasing dimensionality in synthetic cellular microenvironments: from 1D to 4D
Curvature & Biology Workshop 2019;
February 6-8, 2019; Salzburg, <AUT>

A. del Campo
Light-regulated cellular microenvironments
Biochemisches Kolloquium; Universität Leipzig;
March 8, 2019; Leipzig, <GER>

A. del Campo
Reconstructing the cellular microenvironment with synthetic hydrogels
Invited Seminar at the Facultad de Ciencias; Universidad Autónoma de Madrid;
June 14, 2019; Madrid, <ESP>

A. del Campo
Light-driven force application to specific receptros in a living cell using molecular motors
MechanoChemBio 2019;
July 29-31, 2019; Montreal, <CAN>

A. del Campo
From dynamic to living matter: new strategies for materials design
European Summer School 2019 "Soft Matter & Smart Materials";
July 1-5, 2019; Strasbourg, <FRA>

A. del Campo
Synthetic, light-regulated cellular microenvironments
Sino-German Symposium "Cell fate and tumorigenesis: from animal models to human diseases";
September 2-9, 2019; Homburg, <GER>

A. del Campo
Living therapeutic materials
GDCh-Wissenschaftsforum Chemie 2019;
September 15-18, 2019; Aachen, <GER>

A. del Campo
Living materials: utilizing cells to program new functions
Colloquium at AMOLF NanoLab;
September 23, 2019; Amsterdam, <NLD>

J. Paez
Thiol-mediated chemistries for bioconjugation and hydrogelation: towards versatile (bio)materials
INTEC Seminar;
December 04, 2019; Santa Fe, <ESP>

J. Paez
Thiol-mediated chemistries for bioconjugation and hydrogelation: towards versatile (bio)materials
National University of Córdoba;
December 12, 2019; Cordoba, <ESP>

S. Sankaran
Living therapeutic materials
Annual Conference of the Association for General and Applied Microbiology (VAAM);
March 17-20, 2019; Mainz, <GER>

Zellskeletale Fasern / Cytoskeletal Fibers

F. Lautenschläger
Großes entsteht immer im Kleinen: Das Zytoskelett von Zellen als Bausteine des Lebens
Deutsch-Französisches Symposium: 10-jähriges Jubiläum des deutsch-französischen Bachelor of Science UdSBio;
<Saarbrücken, GER>; November 1-2, 2019

F. Lautenschläger
How do cells move and how to ovserve it
IRTG Intro Lecture des SFB 1027; <Saarbrücken, GER>;
January 15, 2019

F. Lautenschläger
Licht – mehr als nur zum Betrachten schöner Bilder
Keplerabend; Kepler Gymnasium Lebach <Lebach, GER>;
November 14, 2019

F. Lautenschläger
Mikrofabrikation für die 2D Mikroskopie zur 3D Darstellung der migrierenden Immunzellen
Interdisziplinärer Workshop „Bildgebende Diagnostik in der Hightech-Medizin" Leibniz Gesundheitstechnologien;
Medica <Düsseldorf, GER>; November 18-21, 2019

F. Lautenschläger
Vimentin provides the mechanical resilience required for amoeboid migration and protection of the nucleus
10th Annual Symposium Physics of Cancer; <Leipzig, GER>; September 25-27, 2019

Nano Zell Interaktionen / Nano Cell Interactions

A. Kraegeloh
Nanomaterial Cell Interactions
ACS Publications Forum;
September 30 – October 1, 2019; Seoul, <KOR>

A. Kraegeloh
Peer-Review: Why, How-To, and What Not To Do
ACS Publications Forum;
September 30 – October 1, 2019; Seoul, <KOR>

A. Kraegeloh
Fluorescent Silica Nanoprobes for Analysis of Nano Cell Interactions
Satellite Workshop, Seoul National University;
October 2, 2019; Seoul, <KOR>

A. Kraegeloh
Nanopartikel in der Zelle: von Akkumulation bis Entzündungsantwort
Mikrobiologisches Kolloquium, Universität Bonn;
November 22, 2019; Bonn, <GER>

NANOKOMPOSIT-MATERIALIEN / NANOCOMPOSITE MATERIALS

Optische Materialien / Optical Materials

M. Amlung
INM and InnovationCenter
Technical Meeting; Korea Institute of Machinery and Materials (KIMM)
September 24, 2019; Daejeon, <KOR>

M. Amlung
Transparent conductive oxides and photochemical silver
Technical Meeting; Institute of Machinery and Materials (KIMM);
September 9, 2019; Daejeon, <KOR>

T. S. Müller
Energieeffiziente Beschichtungen
Hannover Messe – Tech Transfer Forum;
April 03, 2019; Hannover, <GER>

Strukturbildung / Structure Formation

T. Kraus
Dynamic hybrid particles and materials
ACIS 2019 – The 9th Australian Colloid & Interface Symposium;
February 3-7, 2019; Hobart, <AUS>

T. Kraus
Printing particles: parincples & practice
Exciting Science and Nanoparticle Workshop; University of Melbourne;
February 12, 2019; Melbourne, <AUS>

T. Kraus
Particle printing: principles & practice
University of Sydney / Nano Institute;
February 15, 2019; Sydney, <AUS>

T. Kraus
Druckbare, elektrisch leitfähige Materialien mit flüssigen Vorstufen
Chemie hilft 3D-Druck;
February 19-20, 2019; Frankfurt a.M., <GER>

T. Kraus
Hybrid inks: soft ligands shells as molecular connectors in printed metal nanostructures
ChinaNano – 8th International Conference on Nanoscience and Technology;
August 17-19, 2019; Beijing, <CHN>

T. Kraus
Materials for a human-centered digital world
The Director's Forum on Nanotechnology 2019;
August 16, 2019; Beijing, <CHN>

T. Kraus
Hybrid colloids as printable materials
Kolloid-Tagung "Complex Fluids" – 49th Conference of the German Colloid Society;
September 23-25, 2019; Stuttgart, <GER>

T. Kraus
Reversible aggomeration of nanoparticles on ground and in the drop tower: x-ray and light scattering
Deutsches Zentrum für Luft- und Raumfahrt, Institut für Materialphysik im Weltraum;
December 17, 2019; Köln, <GER>

T. Kraus
Session Chair – Colloidal Stability 2
ACIS 2019 – The 9th Australian Colloid & Interface Symposium;
February 3-7, 2019; Hobart, <AUS>

PROGRAMMBEREICHSUNGEBUNDEN / NOT LINKED TO A PROGRAM DIVISION

NTNM-Bibliothek / NTNM library

U. Geith
Open-Access-Publikationen in Nachweisinstrumenten von Bibliotheken
Open Access UNBOXED; Saarland University;
November 5, 2019; Saarbruecken, <GER>

Physikalische Analytik / Physical Analytics

M. Koch
Materialdetektive ermitteln in der Zwergenwelt
Universität des Saarlandes, Tag der Offenen Tür 2019;
May 25, 2019; Saarbrücken, <GER>

R. Bennewitz, C. Petzold, M. Koch, N. Chan, S. G. Balakrishna, P. Egberts, A. Klemenz and M. Moseler
Friction mechanisms revealed by scanning force and electron microscopy
DPG-Frühjahrstagung 2019;
March 31 – April 5, 2019; Regensburg, <GER>

PATENTE / PATENTS

3 Patentanmeldungen
patent applications

14 erteilte Patente
granted patents

5 europäische
european

9 internationale
international

54 Patentfamilien
patent families

ERTEILTE EUROPÄISCHE PATENTE / PATENTS GRANTED IN EUROPE

Europäisches Patent Nr. 2367965
Titel: *„Leitfähige Beschichtungen auf ITO-Basis“*
Erfinder: Peter William de Oliveira, Sabine Heusing, Mario Quilitz, Heike Schneider, Michael Veith

Europäisches Patent Nr. 3084039
Titel: *„Verfahren zur Herstellung strukturierter metallischer Beschichtungen“*
Erfinder: Peter William de Oliveira, Tobias Dörr, Karsten Moh

Europäisches Patent Nr. 3155429
Titel: *„Spezifische Proteinmarkierung sowie Verfahren zur Identifizierung der (statistischen Verteilung der) Proteinstöchiometrie“*
Erfinder: Niels de Jonge, Diana B. Peckys

Europäisches Patent Nr. 3237764
Titel: *„Strukturierte Oberfläche mit stufenweise schaltbarer Adhäsion“*
Erfinder: Elmar Kroner, Paula Yagüe Isla

Europäisches Patent Nr. 1631523
Titel: *„Abriebfeste optische Schichten und Formkörper“*
Erfinder: Carsten Becker-Willinger, Martin Kluke, Helmut Schmidt

ERTEILTE INTERNATIONALE PATENTE / PATENTS GRANTED INTERNATIONALLY

KR Patent Nr. 10-1958511
Titel: *„Highly structured composite material and process for the manu-facture of protective coatings for corroding substrates“*
Erfinder: Carsten Becker-Willinger, Douglas Espin, Frank Hollmann, Marlon Jochum, Michael Opsölder, Sabine Schmitz-Stöwe

JP Patent Nr. 6526658
Titel: *„Formation of surface modified metal colloids“*
Erfinder: Budiman Ali, Carsten Becker-Willinger, Mirko Bukowski, Géraldine Durand, Marlon Jochum, Alan Taylor

JP Patent Nr. 6506698
Titel: *„Gegenstand mit schaltbarer Adhäsion“*
Erfinder: Eduard Arzt, Mareike Frensemeier, Jessica Kaiser, Elmar Kroner, Andreas Simon Schneider

CN Patent Nr. 105121574
Titel: *„Gegenstand mit schaltbarer Adhäsion“*
Erfinder: Eduard Arzt, Mareike Frensemeier, Jessica Kaiser, Elmar Kroner, Andreas Simon Schneider

US Patent Nr. 10,351,733
Titel: *„Komposit-Pillarstrukturen“*
Erfinder: Eduard Arzt, Sarah Fischer, René Hensel

CN Patent Nr. 107110185
Titel: *„Strukturierte Oberfläche mit stufenweise schaltbarer Adhäsion“*
Erfinder: Elmar Kroner, Paula Yagüe Isla

JP Patent Nr. 6526418
Titel: *„Antireflexionsbeschichtung“*
Erfinder: Peter William de Oliveira, Mohammad Jilavi, Peter König, Elisabete Menezes

KR Patent Nr. 102023222
Titel: *„Antireflexionsbeschichtung“*
Erfinder: Peter William de Oliveira, Mohammad Jilavi, Peter König, Elisabete Menezes

CN Patent Nr. 105829575
Titel: *„Verfahren zur Herstellung strukturierter metallischer Beschichtungen“*
Erfinder: Peter William de Oliveira, Tobias Dörr, Karsten Moh

LEHRVERANSTALTUNGEN / TEACHING

WINTERSEMESTER 2018 / 2019

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

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

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

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

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

Carsten Becker-Willinger (mit G. Wenz, Univ. d. Saarlandes)
MC07: Technologie der Polymere und Komposite
Universität des Saarlandes, Vorlesung, 2 SWS

Roland Bennewitz
Experimentalphysik IV a (Festkörperphysik I)
Universität des Saarlandes, Vorlesung / Übung, 3 SWS

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

Aránzazu del Campo und Mitarbeiter/innen
Biomedizinische Polymere
Universität des Saarlandes, Vorlesung, 2 SWS

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

Niels de Jonge und Mitarbeiter/innen
Mikroskopie
Universität des Saarlandes, Vorlesung / Praktikum, 4 SWS

Marcus Koch (mit F. Breinig, Univ. d. Saarlandes)
Zellbiologie
Universität des Saarlandes, Vorlesung, 4 SWS

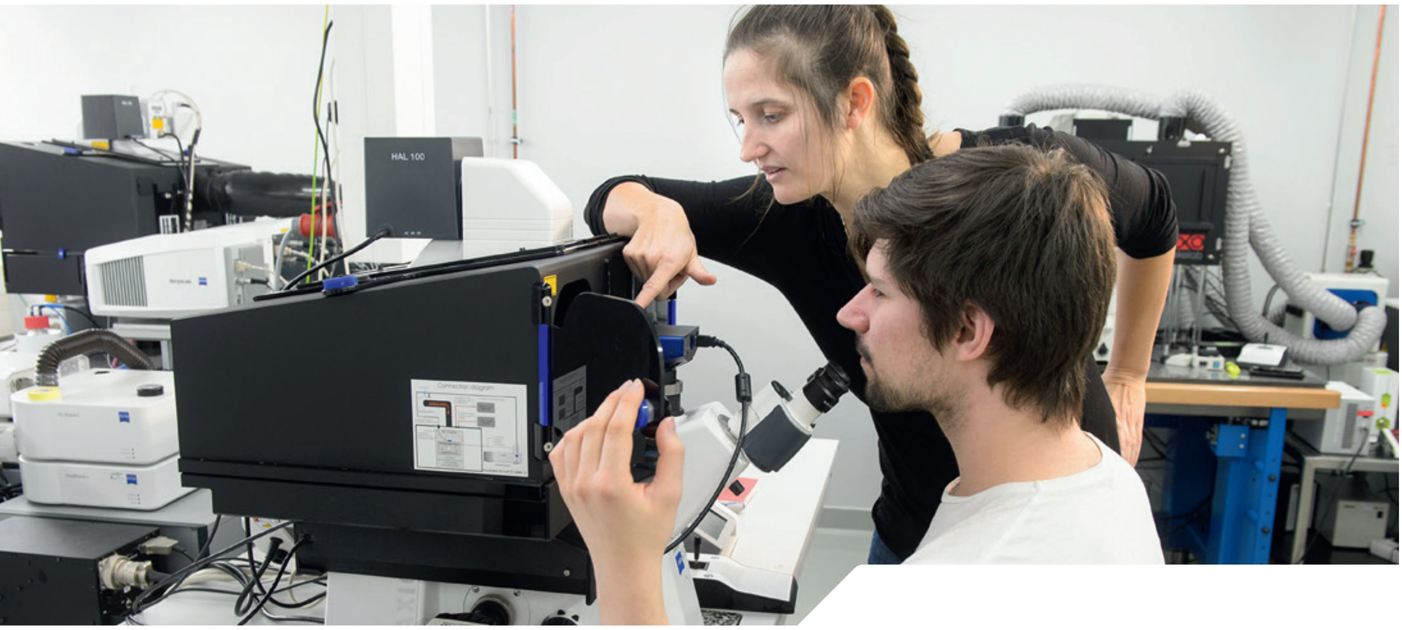
Tobias Kraus
Beschichtungen (Functional Coatings)
Universität des Saarlandes, Vorlesung, 2 SWS

Tobias Kraus
Kolloquium der Gesellschaft Deutscher Chemiker (GDCh)
Universität des Saarlandes, Kolloquium, 1 SWS

Tobias Kraus (mit G. Jung, C. Kay, H. Natter, M. Springborg, Univ. d. Saarlandes)
Masterpraktikum Physikalische Chemie
Universität des Saarlandes, Praktikum, 2 SWS

Tobias Kraus (mit G. Jung, C. Kay, H. Natter, M. Springborg, Univ. d. Saarlandes)
Vorlesung zum Pflichtmodul PC V
Universität des Saarlandes, Vorlesung, 4 SWS

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



SOMMERSEMESTER 2019

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

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

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

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

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

Tobias Kraus (mit Professor/innen der Chemie)
Gemeinsames Kolloquium der Chemie (GDCh)
Universität des Saarlandes, Kolloquium, 1 SWS

Franziska Lautenschläger
Praktikum Einführung in die Biologie (für Bachelor Plus Mint)
Universität des Saarlandes, Praktikum, 2 SWS

Franziska Lautenschläger (mit A. Ott, Univ. d. Saarlandes)
Seminar zu aktuellen Fragen der Biophysik
Universität des Saarlandes, Seminar, 2 SWS

Franziska Lautenschläger
Einführung in die Biologie II (für Bachelor Plus Mint)
Universität des Saarlandes, Vorlesung, 2 SWS

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

Volker Presser, René Hensel (mit M. Gallei, Univ. d. Saarlandes)
Smart Materials and Polymers (MC06)
Universität des Saarlandes, Blockvorlesung, 2 SWS

WINTERSEMESTER 2019 / 2020

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

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

Eduard Arzt und Mitarbeiter/innen
Einführung in die Materialwissenschaft für (Studierende der) Mikrotechnologie und Nanostrukturen
Universität des Saarlandes, Vorlesung / Übung, 4 SWS

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

Carsten Becker-Willinger
MC07: Technologie der Polymere und Komposite
Universität des Saarlandes, Vorlesung, 2 SWS

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

Roland Bennewitz
Experimentalphysik IV a (Festkörperphysik I)
Universität des Saarlandes, Vorlesung / Übung, 3 SWS

Roland Bennewitz (mit J. Kluempers, Bonn)
Good Scientific Practice and Communication
Universität des Saarlandes, 1 SWS

Aránzazu del Campo und Mitarbeiter/innen
Biomedizinische Polymere
Universität des Saarlandes, Vorlesung, 2 SWS

Marcus Koch (mit F. Breinig, Univ. d. Saarlandes)
Zellbiologie
Universität des Saarlandes, Vorlesung, 4 SWS

Tobias Kraus
Kolloquium der Gesellschaft Deutscher Chemiker (GDCh)
Universität des Saarlandes, Kolloquium, 1 SWS

Tobias Kraus (mit G. Jung, C. Kay, H. Natter, M. Springborg, Univ. d. Saarlandes)
Masterpraktikum Physikalische Chemie
Universität des Saarlandes, Praktikum, 2 SWS

Tobias Kraus (mit G. Jung, C. Kay, H. Natter, M. Springborg, Univ. d. Saarlandes)
Physikalische Chemie V (PCV)
Universität des Saarlandes, Vorlesung, 4 SWS

Tobias Kraus
Functional Coatings (Beschichtungen)
Universität des Saarlandes, Vorlesung, 4 SWS

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

Volker Presser (mit R. Hempelmann, R. Chen, D. Scheschkewitz, Univ. d. Saarlandes)
Materials for Efficient Energy Use (EnTV)
Universität des Saarlandes, Vorlesung / Praktikum, 6 SWS

VORTRÄGE IM INM-KOLLOQUIUM / INM COLLOQUIUM TALKS

Prof. Dr. Shlomo Magdassi, The Hebrew University of Jerusalem, Israel
From Gutenberg Bible to 4D Printing
08.01.2019, Host: Prof. Dr. Tobias Kraus

Dr. Benjamin Abécassis, École Normale Supérieure de Lyon, France
Self-Assembly of CdSe Nanoplatelets into Twisted Threads
15.01.2019, Host: Prof. Dr. Tobias Kraus

Dr. Karl Kadler, The University of Manchester, United Kingdom
Circadian Control of the Secretory Pathway is a Central Mechanism in ECM Homeostasis
29.01.2019, Host: Prof. Dr. Aránzazu del Campo

Prof. Dr. Jesús Merayo-LLoves, Instituto Universitario Fernández-Vega, University of Oviedo, Fundación de Investigación Oftalmológica, Spain
Plasma Rich in Growth Factor in the Regeneration of Ocular Surface
05.02.2019, Host: Prof. Dr. Aránzazu del Campo

Prof. Dr. Catherine Jones Murphy, University of Illinois at Urbana-Champaign, USA
Gold Nanocrystals: Physics, Chemistry, Biology, and Ecology
08.03.2019, Host: Prof. Dr. Tobias Kraus

Prof. Dr. Andreas Herrmann, DWI – Leibniz-Institute for Interactive Materials, Aachen, Germany
Dynamic and Functional Nanoarchitectures from DNA and Supercharged Polypeptides
12.03.2019, Host: Prof. Dr. Aránzazu del Campo

Prof. Dr. Krist V. Gernaey, Technical University of Denmark, Lyngby, Denmark
Mechanistic Models Across Scales for Bio-based production Processes
02.04.2019, Host: Dr. Marcus Koch

Dr. Lise-Marie Lacroix, Laboratoire de Physique et Chimie des Nano-objets, Toulouse, France
Elaboration of Nanostructured Materials: from a Liquid Phase Synthesis to Controlled Assembly
16.04.2019, Host: Prof. Dr. Tobias Kraus

Prof. Dr. Victorino Franco, University of Sevilla, Spain
Magnetocaloric Effect: from Energy Efficient Refrigeration to Fundamental Studies of Phase Transitions
25.04.2019, Host: Prof. Dr. Tobias Kraus

Prof. Dr. Phil Selenko, Weizmann Institute of Science, Rehovot, Israel
Looking at Proteins in Live Cells with Atomic Resolution: from Science Fiction to Science Reality
30.04.2019, Host: Prof. Dr. Niels de Jonge

Prof. Dr. Luis Liz-Marzán, CIC biomaGUNE, San Sebastián, Ikerbasque, Bilbao, Spain
Plasmonic Nanomaterials for Biosensing and Diagnostics
16.05.2019, Host: Prof. Dr. Aránzazu del Campo

Prof. Dr. Anne Kenworthy, University of Virginia School of Medicine, Charlottesville VA, USA
Membrane Domain Biogenesis and Function
21.05.2019, Host: Prof. Dr. Niels de Jonge

Prof. Dr. Robert Dryfe, The University of Manchester, United Kingdom
Electrochemical Properties of 2D Materials: from Fundamentals to Applications
24.05.2019, Host: Prof. Dr. Volker Presser

Prof. Dr. Anthony Rollett, Carnegie Mellon University, Pittsburgh PA, USA
Additive Manufacturing, 3D Printing, Porosity and Synchrotron Experiments
11.06.2019, Host: Prof. Dr. Eduard Arzt

Prof. Dr. Herbert Shea, École Polytechnique Fédérale de Lausanne, Switzerland
Elastomer-based Actuators for Wearables Haptics and Soft Robotics
18.06.2019, Host: Prof. Dr. Eduard Arzt

Prof. Dr. Mark Miodownik, University College London, United Kingdom
Towards the Design of New Sensoaesthetic Materials
25.06.2019, Host: Prof. Dr. Roland Bennewitz

Priv.-Doz. Dr. Martin Kaltenbrunner, Johannes Kepler Universität Linz, Austria
Soft Electronics and Machines
09.07.2019, Host: Prof. Dr. Tobias Kraus

Prof. Dr. Xiao Su, University of Illinois at Urbana-Champaign, USA
The Role of Charge-transfer Interactions in Electrochemical Separations: Tunability and Selectivity
20.08.2019, Host: Prof. Dr. Volker Presser

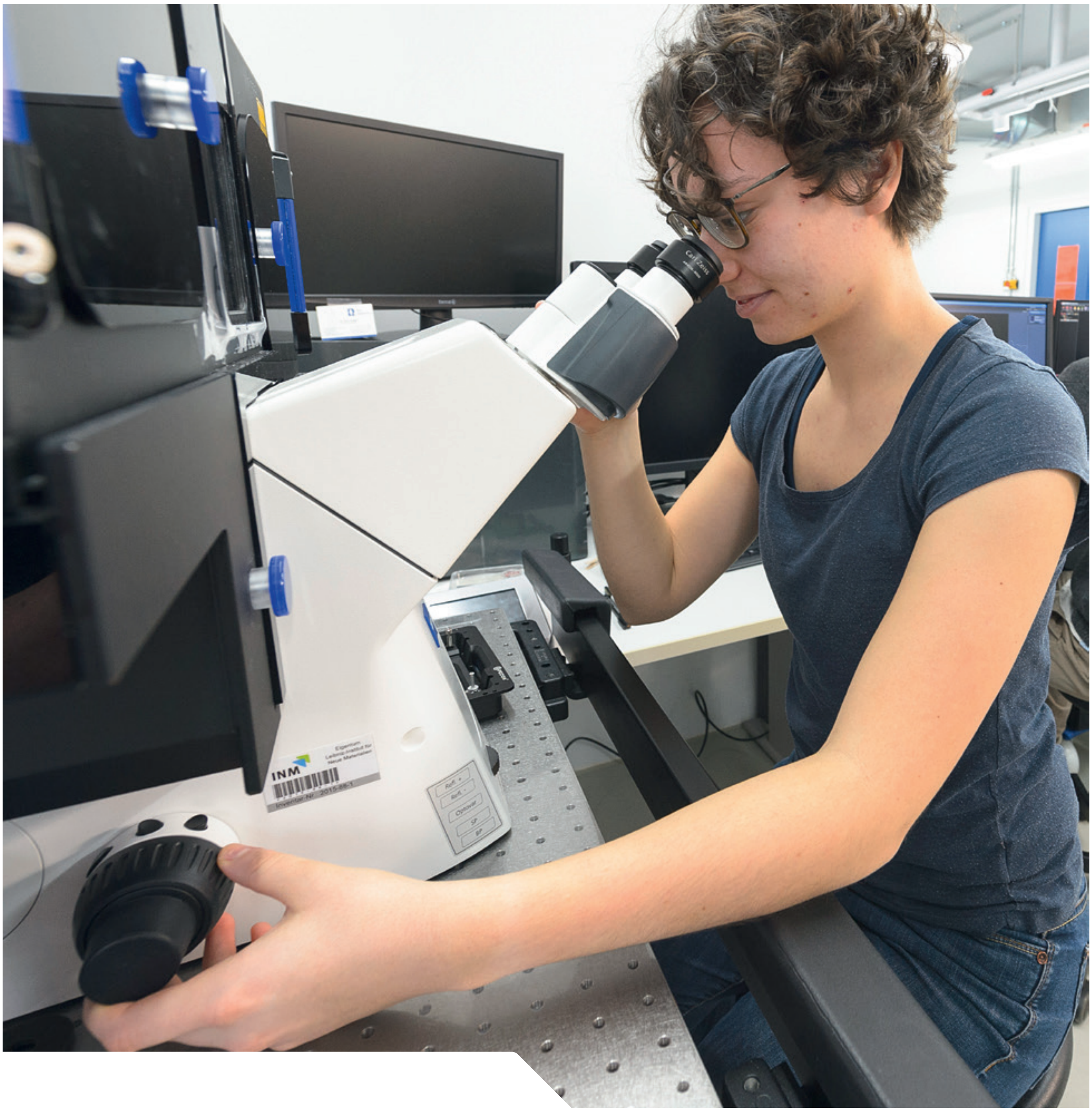
Prof. Dr. Matthias Epple, Universität Duisburg-Essen, Germany
Synthesis, Structure and Biological Applications of Bimetallic and Ultrasmall Nanoparticles
29.10.2019, Host: Prof. Dr. Tobias Kraus

Prof. Dr. Laura De Laporte, DWI – Leibniz Institute for Interactive Materials, RWTH University Aachen, Germany
Injectable Synthetic Building Blocks to Regenerate Soft Anisotropic Tissues
17.12.2019, Host: Prof. Dr. Aránzazu del Campo

Prof. Dr. Catherine Picart, Université Grenoble Alpes, Interdisciplinary Research Institute of Grenoble (IRIG), France
Biomimetic and Bioactive Coatings: From Fundamental Understanding to Pre-clinical Applications
17.12.2019, Host: Prof. Dr. Aránzazu del Campo

Prof. Dr. Seraphine V. Wegner, Max Planck Institute for Polymer Research, Mainz, University of Münster, Germany
Spatiotemporal Control over Adhesions in Synthetic Cells Using Light
17.12.2019, Host: Prof. Dr. Aránzazu del Campo

Prof. Dr. Marie Weinhart, Freie Universität Berlin, Leibniz Universität Hannover, Germany
Thermoresponsive Tissue Culture Substrates as a Tool for the Engineering of a Vascular Bed
17.12.2019, Host: Prof. Dr. Aránzazu del Campo



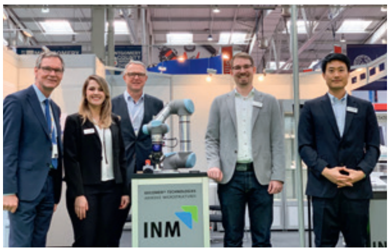
VERANSTALTUNGEN / EVENTS

JANUAR – FEBRUAR

Schülerpraktikum I
B. Abt, S. Albayrak, A. Altpeter, D. Beckelmann, P. Blach, W. M. Buhrow, J. Dollmann, R. Drumm, H. Heintz, A. Haettich, A. Jung, P. Kalmes, S. Kiefer, M. Klos, C. Muth, R. Muth, M. Penth, M. Quilitz, H. Rimbach-Nguyen, R. Sander, L. Sold, M. Sude, E. Terriac, A. Tolosa, M. Twardoch
Saarbrücken, 21.01. – 08.02.2019

nano tech 2019
M. Amlung, P. W. de Oliveira
Tokyo, Japan, 30.01. – 01.02.2019

Materials Science and Haptics
E. Arzt, R. Bennewitz, C. Hartmann, R. Hensel
Saarbrücken, 21. – 22.02.2019



MÄRZ

Roadshow des Leibniz-Forschungsverbundes Gesundheitstechnologien
A. del Campo, A. Kraegeloh, K. Kruttwig, F. Lautenschläger, M. Quilitz (mit LFV Gesundheitstechnologien)
Saarbrücken, 11.03.2019

LOPEC 2019
P. W. de Oliveira, M. Amlung, A. Escudero, T. Thai, D. J. Kang
München, 20. – 21.03.2019

Besuch des Präsidenten der Nationalversammlung der Republik Armenien
A. del Campo, N. de Jonge, M. Quilitz, G. Weber (mit Univ. des Saarlandes)
Saarbrücken, 21.03.2019

VIP + Innovationstagung Berlin
J. Brunke (mit G. Wenz, Univ. des Saarlandes)
Berlin, 26.03.2019

MÄRZ

Girls' Day: Oberflächen begreifen und verändern
M. Jochum, M. Koch, C. Sauer-Hormann, S. Siegrist, S. Zeiter-Semmet
Saarbrücken, 28.03.2019

Besuch einer Delegation des Ministeriums für Bildung & Kultur des Saarlandes
M. Koch, A. Kraegeloh, M. Quilitz, J. Staudt
Saarbrücken, 28.03.2019

APRIL

Hannover Messe
L. Barnefske, J. Brunke, D. J. Kang, G. Moreira Lana, T. Müller, H. Ollmann, T. Thai
Hannover, 01. – 05.04.2019

Printed Electronics Europe 2019
P. W. de Oliveira, A. Escudero, P. Rogin
Berlin, 10. – 11.04.2019

MAI

IEEE Workshop
E. Bubel
Saarbrücken, 07.05.2019

Tag der offenen Tür
S. Bettscheider, L. González-García, C. Hartmann, M. Koch, K. Moh, C. Petzold, V. Presser, M. Quilitz, A. Tolosa, A. Zimmermann und weitere
Saarbrücken, 25.05.2019

JUNI

Schülerpraktikum II
S. Albayrak, D. Beckelmann, A. Colbus, R. Drumm, Z. Fu, H. Heintz, R. Hensel, A. Haettich, A. Jung, P. Kalmes, A. Kleemann, C. Muth, M. Quilitz, B. Reinhard, H. Rimbach-Nguyen, A. Rutz, C. Scherrer, K. Schnellnhuber, M. Sude, E. Terriac, A. Tolosa, T. Trampert, M. Twardoch
Saarbrücken, 03.06.2019 – 21.06.2019

Jahrestreffen AK Presse der Leibniz-Gemeinschaft
C. Hartmann, C. Jung, M. Quilitz (mit Leibniz-Gemeinschaft)
Saarbrücken, 03. – 04.06.2019

JUNI

Exkursionstag für Schüler/innen der Bertha von Suttner IGS Kaiserslautern
D. Anschütz, M. Koch, B. Schäfer
Saarbrücken, 06.06.2019

Inverse Messe: Dekorative Multifunktionsbeschichtungen
M. Amlung, P. W. de Oliveira, G. Weber (mit saaris und ibo Institut für Industrieinformatik und Betriebsorganisation)
Saarbrücken, 13.06.2019

Besuch einer Delegation der Jiangsu Province VR China
A. May, M. Quilitz (mit Univ. des Saarlandes)
Saarbrücken, 24.06.2019

Praktikum zur Elektronenmikroskopie für Schüler/innen des Otto-Hahn-Gymnasium Saarbrücken
P. Blach, I. N. Dahmke, N. de Jonge, E. Ortega, T. Trampert
Saarbrücken, 25.06.2019

JULI

Besuch von Teilnehmenden der Summer School Technology Transfer & Entrepreneurship der Univ. des Saarlandes
I. N. Dahmke, K. Moh, M. Quilitz, C. Schmitz (mit Univ. des Saarlandes)
Saarbrücken, 10.07.2019

AUGUST

Besuch von Teilnehmenden des Rotary Sommercamp
E. Arzt, L. Engel, A. Kraegeloh, A. May, K. Moh, H. Ollmann, V. Presser, M. Quilitz, C. Schmitz, R. Strahl
Saarbrücken, 09.08.2019

Sommertreffen Innovationswerkstatt
E. Arzt, M. Geerkens, K. Kiefer, P. W. de Oliveira
Saarbrücken, 20.08.2019

Besuch von Studierenden aus dem Programm AMASE (EUSMAT) der Universität des Saarlandes
M. Koch, M. Quilitz
Saarbrücken, 27.08.2019

SEPTEMBER

LRC Summer School
J. Cui, L. Prieto López
Saarbrücken, 04. – 06.09.2019

AAM2019 – International Conference on Adhesion in Aqueous Media: From Biology to Synthetic Materials
E. Arzt, A. del Campo, R. Hensel, J. Paez (mit Leibniz-Institut für Polymerforschung u. a.)
Dresden, 09. – 12.09.2019

IAA – Internationale Automobil-Ausstellung
M. Amlung, J. Brunke
Frankfurt, 10.09. – 22.09.2019

5. Netzwerktreffen NanoMatFutur
C. Hartmann, T. Kraus (mit Projektträger Forschungszentrum Jülich, HIPS, Univ. des Saarlandes)
Saarbrücken, 17. – 18.09.2019

SEPTEMBER

Besuch von Teilnehmerinnen des Mento MINT-Programmes der Univ. des Saarlandes
I. Backes, P. Blach, M. Quilitz, C. Sauer-Hormann, C. Schmitz (mit Univ. des Saarlandes)
Saarbrücken, 26.09.2019

OKTOBER

Besuch von Studierenden aus den Programmen Atlantis und I.de.Ar der Universität des Saarlandes
M. Koch, M. Quilitz (mit EUSMAT, Univ. des Saarlandes)
Saarbrücken, 09.10.2019

„Studium bestehen?!“ – Coffee Lectures in der NTNM-Bibliothek
J. Marschall, L. Müller, A. Yongsap
Saarbrücken, 10., 14., 15.10.2019

DIFA – Daegu International Future Auto Expo
M. Amlung (mit saar.is, gwSaar, CISPA u.a.)
Daegu, South Korea, 17. – 20.10.2019

Jugend forscht 2019/2020 mit Schüler/innen des Geschwister-Scholl-Gymnasiums Lebach zum Thema Mikroplastik
M. Koch
Saarbrücken, 18.10., 07.11., 25.11.2019

Besuch einer Delegation des KIST Seoul, Korea
M. Quilitz
Saarbrücken, 21.10.2019

OKTOBER

Writing, presenting, networking – tools for a scientific career. A symposium for female scientists
R. Bennewitz, C. Sauer-Hormann, S. Zeiter-Semmet (mit Gleichstellungsbüro, Univ. des Saarlandes)
Saarbrücken, 24.10.2019

Workshop des Leibniz-Forschungsverbundes Nanosicherheit
E. Arzt, A. Kraegeloh, C. Petzold (mit LFV Nanosicherheit)
Saarbrücken, 29.10.2019

Workshop zur NFDI-Initiative
E. Arzt, A. Kraegeloh, C. Petzold
Saarbrücken, 30.10.2019

NOVEMBER

Medica 2019
K. Kruttwig, G. Moreira Lana
Düsseldorf, 18. – 21.11.2019

visOA, vidijo und Nachnutzung – Sichtbarmachung von Open-Access-Publikationen in den Nachweisinstrumenten einer Bibliothek
U. Geith
Saarbrücken 27.11.2019

DAS INM IN DEN MEDIEN / INM IN THE MEDIA

lektronik ohne Sintern
3V
OBERFLÄCHENTECHNIK
TECHNOLOGIE
Selbstheilender Lack lässt Kratzer wieder verschwinden
Neue Generation von Robotern
GECOMER
Packung warnt vor verdorbenem Essen
Selbstschmierend in fester Umgebung – nach dem Beispiel des Regenwurms
NEWS
Improved corrosion protection with flake-type metal-phosphate
Protezione dal processo corrosivo migliorato con p forma di scaglia di fosfato metallico
„Selbstheilender" Lack
onfish Has
Dem blauen Wasser auf der Spur
New Gecko-inspired Adhesive Patch for Treating Eardrum Injuries

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worldhaptics 2019 (S. / p. 58, Bild / Image 1)

Titelseite / *Front page*:

oben / *top*: Trajektorien von Immunzellen in einem Hindernispark. Jede Farbe kodiert eine Bewegungsbahn. / *Trajectories of immune cells in an obstacle parc. Each color codes one trajectory.* (Juniorforschungsgruppe Zytoskeletale Fasern / *Junior Research Group Cytoskeletal Fibers*)

Mitte links / *Middle left*: Durch Elektrospinnen hergestellte Metallsulfid / Kohlenstoff-Hybrid-Nanofasern zur Verwendung als Elektroden mit hoher Kapazität in Lithium-Ionen-Batterien. / *Metal-sulfide/carbon hybrid nanofibers obtained via electrospinning for use as high capacity electrodes in lithium-ion batteries.* (Programmbereich Energie-Materialien / *Program Division Energy Materials*)

Mitte rechts / *Middle right*: Vorderseite des INM / *Frontside of INM.*

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INM — Leibniz-Institut für Neue Materialien gGmbH
Campus D2 2 · 66123 Saarbrücken · www.leibniz-inm.de
Telefon: +49 (0) 681 9300-0, contact@leibniz-inm.de
Geschäftsführer: Prof. Dr. Eduard Arzt (Vorsitz),
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