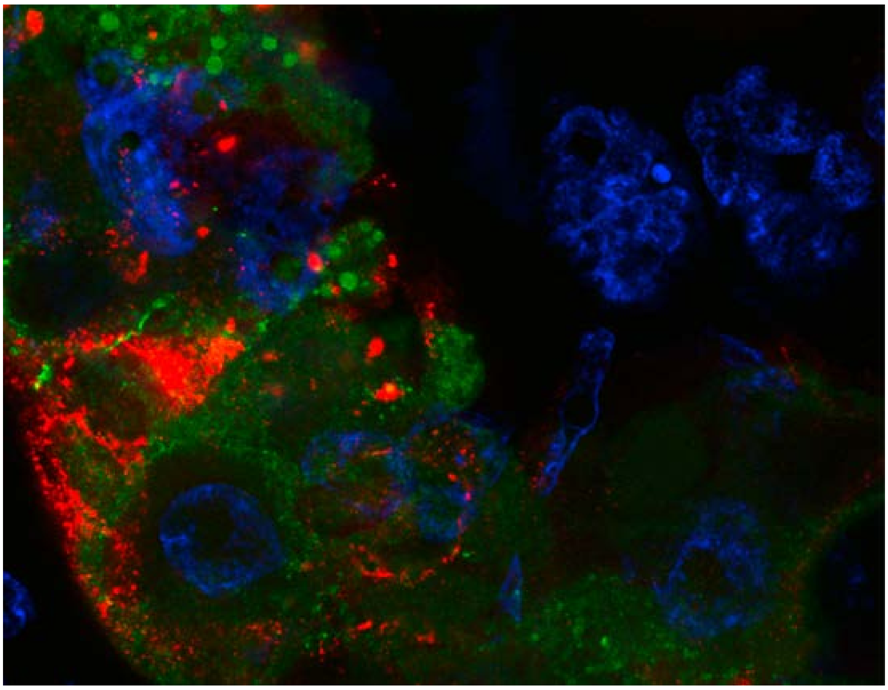
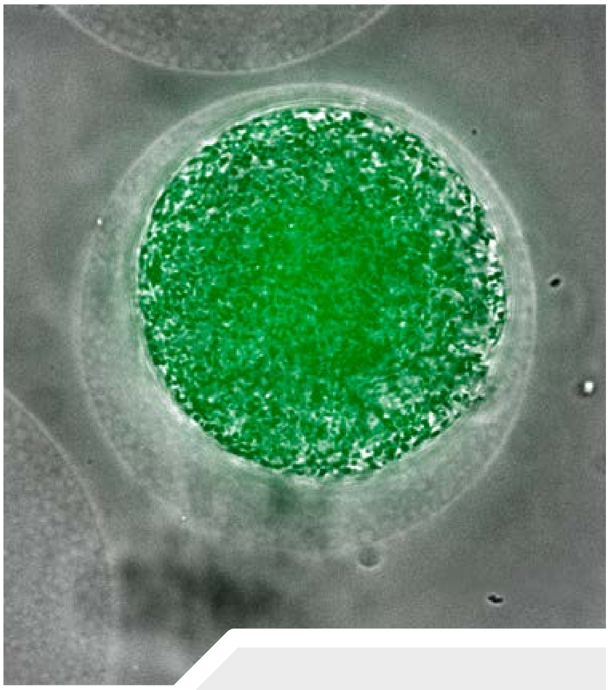
Neues Denken. Neue Materialien.





JAHRESBERICHT 2021
ANNUAL REPORT 2021

Leibniz Gemeinschaft

INM Leibniz-Institut für Neue Materialien

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Prof. Dr. Aránzazu del Campo

Wissenschaftliche Geschäftsführerin/
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Prof. Dr. Eduard Arzt

Wissenschaftlicher Geschäftsführer und
Vorsitzender der Geschäftsführung/
Scientific Director and CEO

WILLKOMMEN ZUM JAHRESBERICHT DES INM, GESCHÄTZTE LESERINNEN UND LESER,

das Institut hat trotz der notwendigen Einschränkungen wieder ein erfolgreiches Jahr hinter sich.

Unter anderem gab es folgende organisatorische Neuerungen: Gefördert durch einen ERC Starting Grant hat die neue Juniorforschungsgruppe Elektrofluide unter der Leitung von Frau Dr. Lola Gonzalez-Garcia ihre Arbeit aufgenommen.

Der vormalige Programmbereich Nanotribologie unter der Leitung von Herrn Prof. Roland Bennewitz hat seinen Namen geändert. Die Weiterentwicklung der thematischen Schwerpunkte des Programmbereiches gaben Anlass für eine Anpassung auf den Namen Interaktive Oberflächen.

Auch der vom INM koordinierte Leibniz-Forschungsverbund Nanosicherheit hat sein Themenspektrum weiterentwickelt. In seine zweite Laufzeit geht er unter dem Namen Leibniz-Forschungsverbund Advanced Materials Safety.

2021 brachte dem INM gleich zwei neue Fellows: Das INM hat den Materialwissenschaftler Prof. Martin Müser und den theoretischen Physiker Prof. Heiko Rieger, beide von der Universität des Saarlandes, zu INM-Fellows ernannt. Prof. Müsers Fokus liegt in Simulationen zur Optimierung von Haftstrukturen, Prof. Rieger untersucht Prozesse in biologischen Systemen.

Weitere Weichen für die Zukunft wurden gestellt: Von besonderer Bedeutung ist dabei das Berufungsverfahren für die Nachfolge von Herrn Professor Eduard Arzt als wissenschaftlichem Geschäftsführer. Aber auch die Baumaßnahmen im Zuge der Renovierung des Bauteils B, den das INM von der Universität des Saarlandes übernimmt, spielen eine wichtige Rolle für die Zukunft des Institutes.

Wir danken unseren Mitarbeiterinnen und Mitarbeitern für das Verständnis, die Disziplin und die Resilienz in schweren Zeiten und freuen uns, wenn Sie uns auch in Zukunft gewogen bleiben.

WELCOME TO THE ANNUAL REPORT OF THE INM, VALUED READERS,

Despite the necessary restrictions, the institute can look back on another successful year.

Among other things there were the following organizational changes: Funded by an ERC Starting Grant, the new Junior Research Group Electrofluids headed by Dr. Lola Gonzalez-Garcia startet its work.

The former program division Nanotribology under the direction of Prof. Roland Bennewitz has changed its name. The further development of the thematic priorities of the program division gave rise to an adjustment to the name Interactive Surfaces.

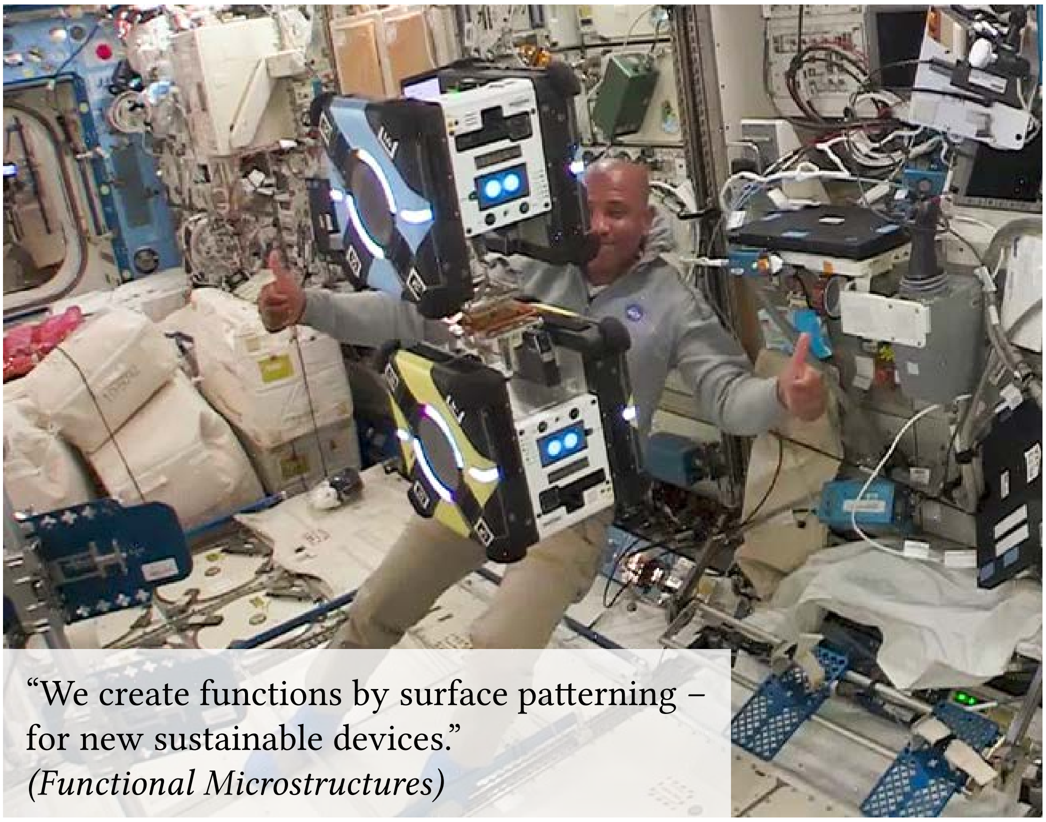
The Leibniz Research Alliance Nanosafety, coordinated by the INM, has also further developed its range of topics. It is entering its second term under the new name Advanced Materials Safety.

2021 brought two new fellows to the INM: INM appointed materials scientist Prof. Martin Müser and theoretical physicist Prof. Heiko Rieger, both from Saarland University, as INM Fellows. Prof. Müser's focus is on simulations for the optimization of adhesive structures, Prof. Rieger investigates processes in biological systems.

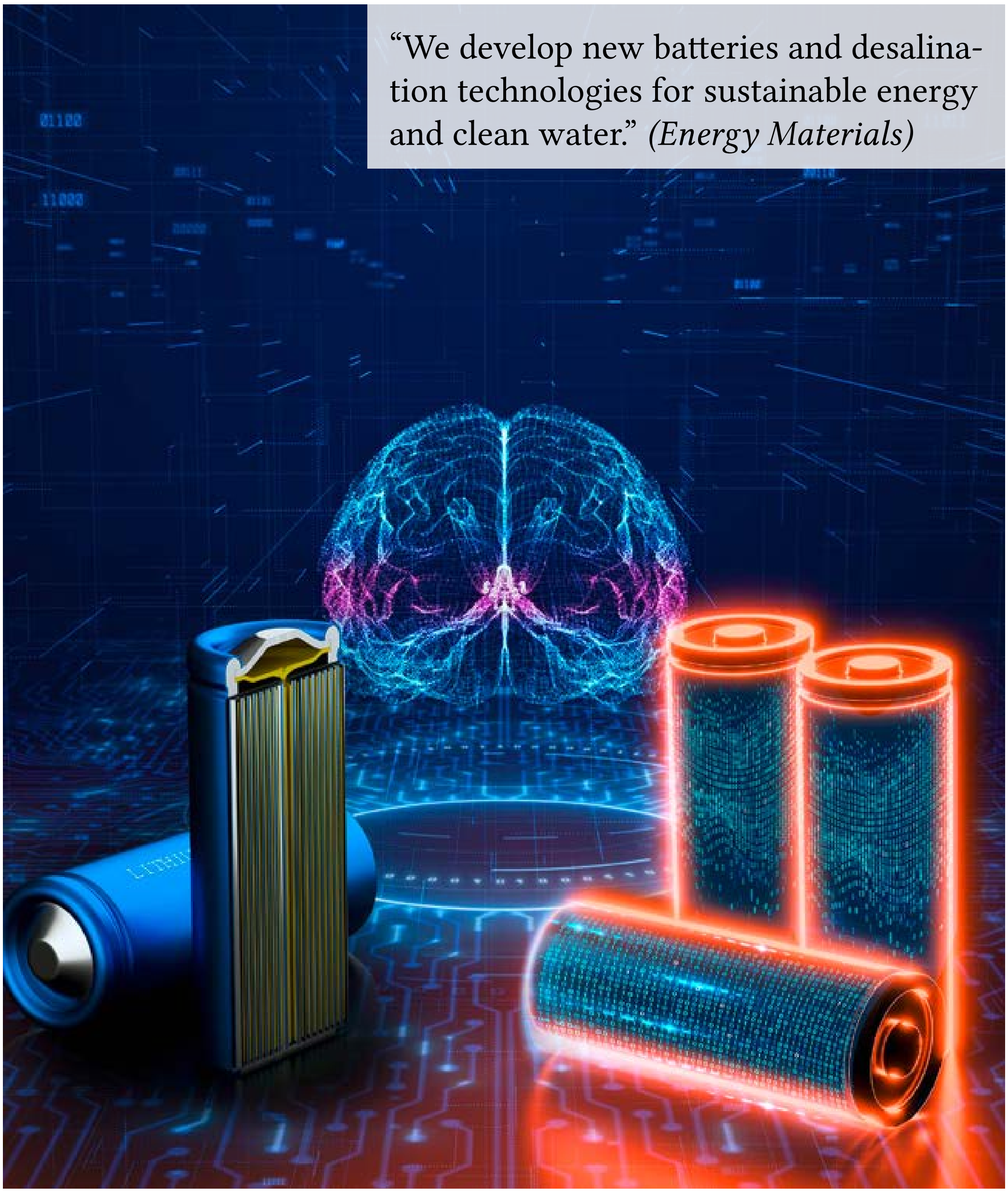
Further courses for the future have been set: Of particular importance is the appointment procedure for the successor of Professor Eduard Arzt as scientific director. Also, the construction measures during the renovation of Building B, which the INM is taking over from Saarland University, play an important role in the future of the Institute.

We appreciate our staff's understanding, dedication an resilience in difficult times and look forward to staying connected with you in the future.

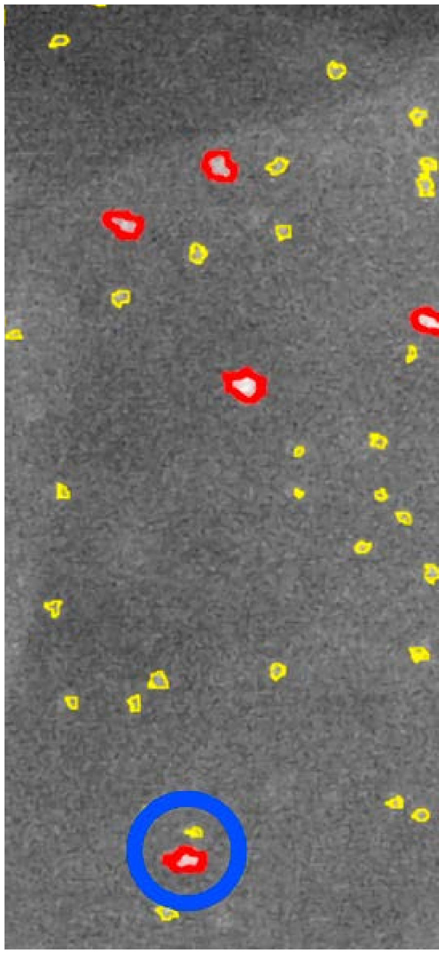
GRUPPENBERICHTE / GROUP REPORTS

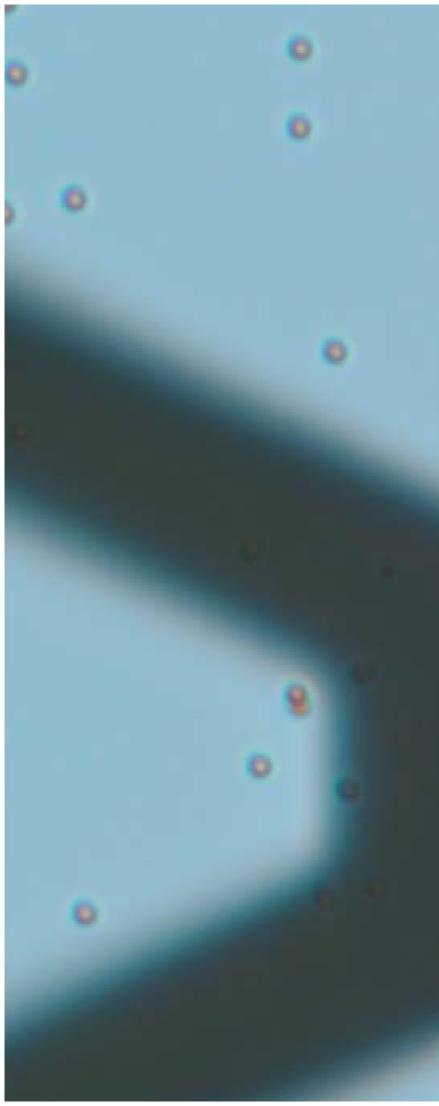


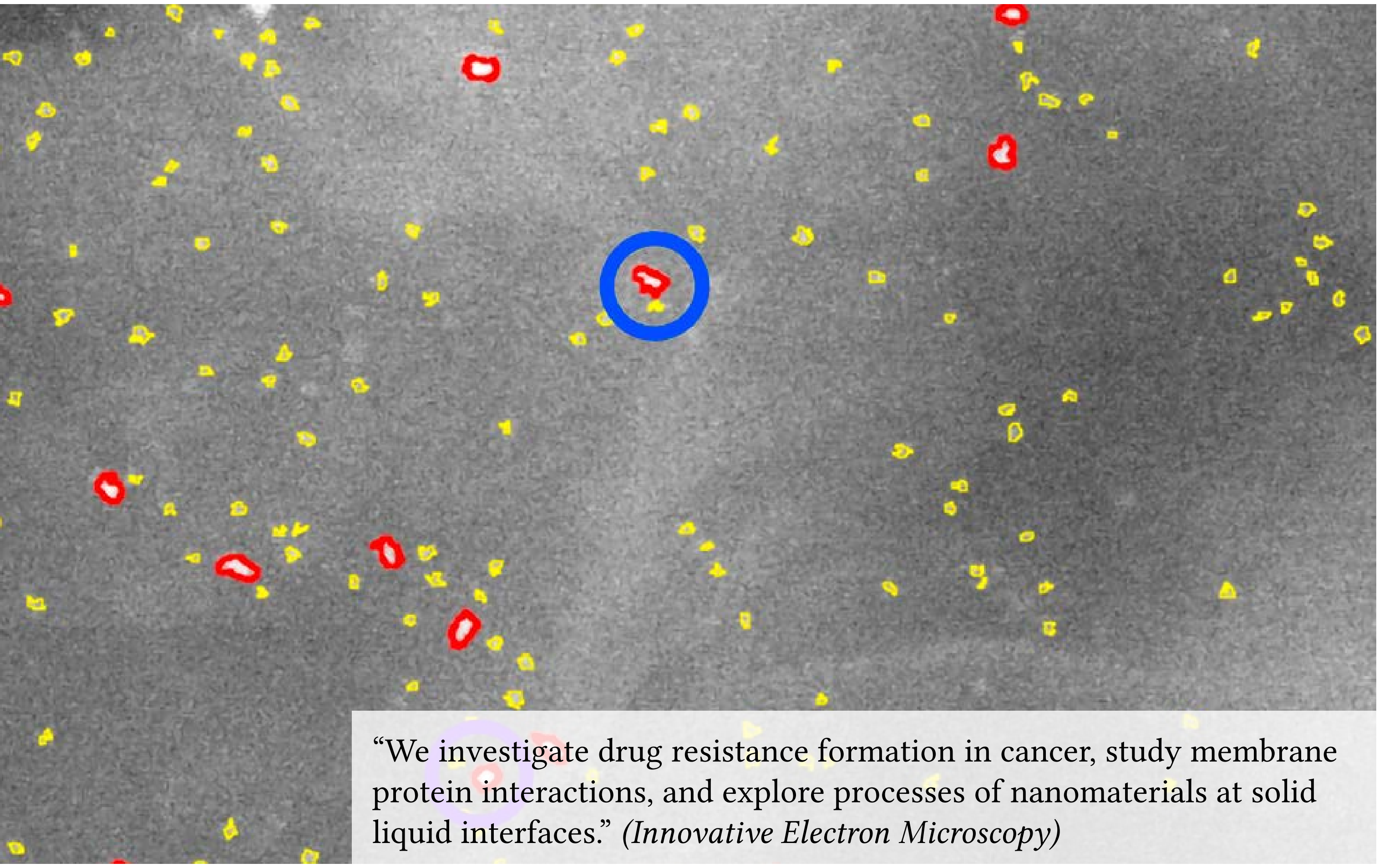
“We create functions by surface patterning – for new sustainable devices.” *(Functional Microstructures)*



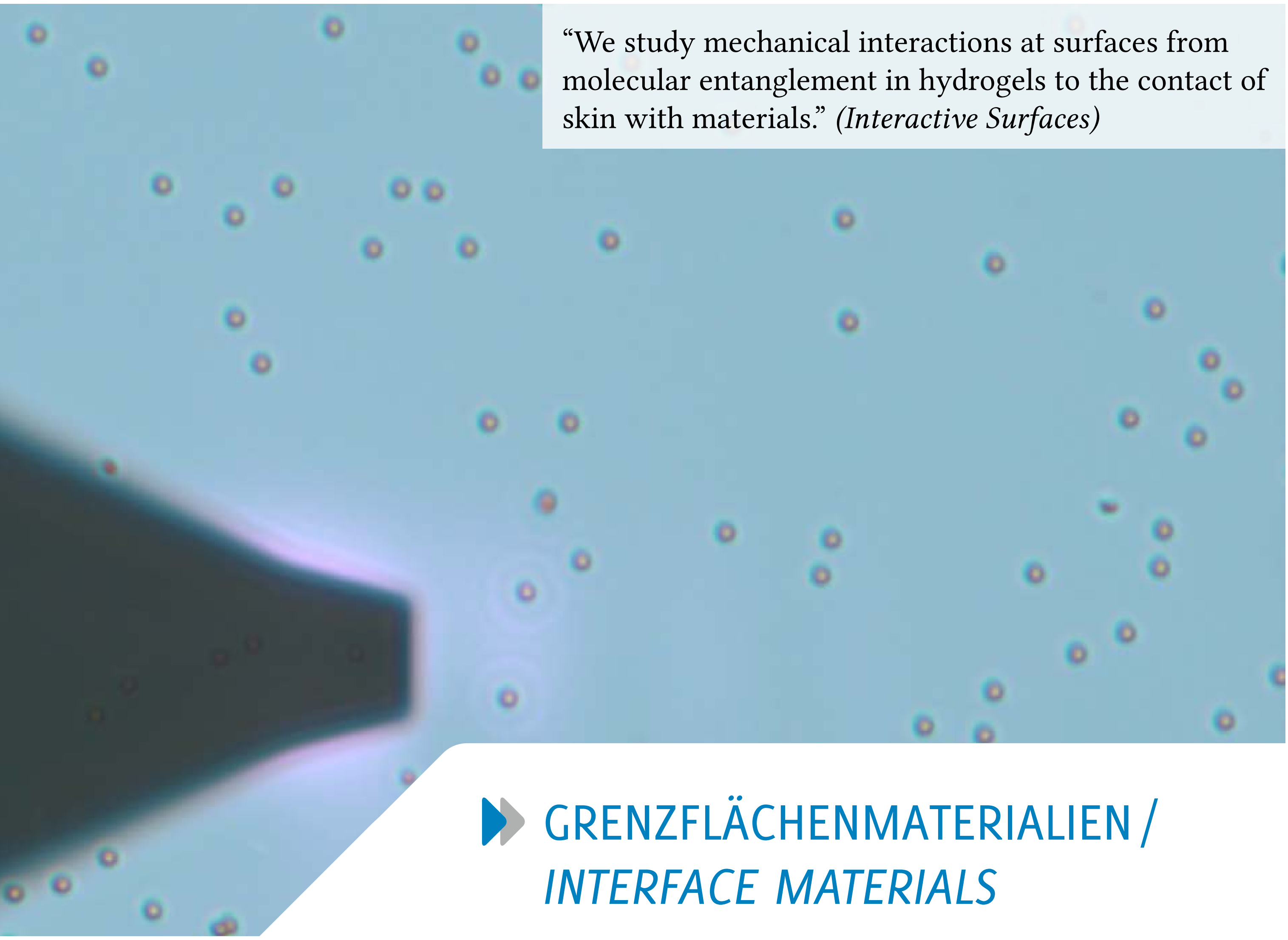
“We develop new batteries and desalination technologies for sustainable energy and clean water.” *(Energy Materials)*







“We investigate drug resistance formation in cancer, study membrane protein interactions, and explore processes of nanomaterials at solid liquid interfaces.” *(Innovative Electron Microscopy)*



“We study mechanical interactions at surfaces from molecular entanglement in hydrogels to the contact of skin with materials.” *(Interactive Surfaces)*

GRENZFLÄCHENMATERIALIEN / *INTERFACE MATERIALS*

ENERGIE-MATERIALIEN / ENERGY MATERIALS

PROF. DR. VOLKER PRESSER

ZUSAMMENFASSUNG

Der Programmbereich *Energie-Materialien* erforscht elektrochemische Methoden für nachhaltige Energie- und Wassernutzung. Solche Anwendungen erfordern Materialien, die auf der Nanoebene in Bezug auf Ionentransport und elektrische Leitfähigkeit optimiert werden. Wichtige Elektrodenmaterialien sind nanoporöse Kohlenstoffe, Oxide, Karbide und Sulfide. Einen besonderen Schwerpunkt unserer Forschung bilden MXene aufgrund ihrer chemischen Vielfältigkeit und 2D-Struktur. Diese Materialien und deren Kombination (Hybridisierung) ermöglichen leistungsstarke Batterien zur Energiespeicherung. Als Entsalzungsbatterien erlauben diese Materialien die Herstellung von Trinkwasser aus Meerwasser und die selektive Ionenentfernung, z. B. für die Lithium-Gewinnung. Für ein umfassendes Verständnis elektrochemischer Prozesse und Materialien nutzen wir vielfältige Charakterisierungsmethoden, einschließlich In-situ-Verfahren. Wir nutzen verstärkt digitale Methoden zur prädiktiven Materialforschung. Unsere Kollaborationen umfassen sowohl die internationale Grundlagenforschung als auch Industrieprojekte.

MISSION

The Program Division Energy Materials explores and develops electrochemical methods for sustainable energy and water use. Such applications require materials optimized at the nano level regarding ion transport and electrical conductivity. Important electrode materials are nanoporous carbons, oxides, carbides, and sulfides. MXenes are a particular focus of our research due to their chemical diversity and 2D structure. These materials and their combination (hybridization) enable powerful batteries for energy storage. As desalination batteries, these materials allow the production of drinking water from seawater and the selective removal of ions, for example, for lithium production. For a comprehensive understanding of electro-chemical processes and materials, we use various characterization techniques, including in-situ methods. In addition, we are increasingly using digital methods for predictive material research. Our collaborations include both international basic research and industrial projects.

CURRENT RESEARCH

Digital energy materials

Digital twinning allows not only to better understand processes and gives rise to unique ways for high-throughput analysis and predictive research; *Wang et al., Adv. Energy Mater. 2021*. That is, we can first identify optimized materials before we synthesize them in the laboratory. We use such advanced tools within the BMBF-funded ProZell DigiBatMat project together with the Program Division *Structure Formation* and several other partners. Thereby, digital twinning will allow comprehensive virtualization of batteries and their fabrication. We also use predictive tools to simulate ion transport within nanoporous carbon to create advanced supercapacitors (German-Polish DFG Project; *Breitsprecher et al.,*

Fig. 1: Predictive material science and high-throughput screening are key technologies for advanced high-entropy materials needed for high-performance batteries.
Fig. 2: Fuel-cell technology can be modified for the continued generation of electrical energy, clean water, and heat within the power-to-gas concept.

Nat. Comm. 2020) and high-performance sea-water desalination devices (collaboration with Huazhong University of Science and Technology, Wuhan, China; *Zhang et al., Cell Reports Physical Science 2022*). Fully understanding the pore size/ion size correlations and ion transport kinetics allows the controlled design of high-performance supercapacitors and ion-selective desalination devices.

Desalination batteries

We explore desalination batteries for triple-use, energy storage, elemental recovery, and water remediation (*Srimuk et al., Nat. Rev. Mater 2020*). The ability to energy-efficiently desalinate saltwater is of high importance to the generation of potable water. Yet, the selective extraction of pollutants like lead or nitrate is equally essential. Desalination batteries can also be employed as seawater batteries where low-cost, abundantly available seawater serves as the electrolyte. We implement battery-technology and fuel-cell technology for the generation of clean water not just for human consumption but also to desalinate seawater for the large-scale hydro-gen generation. We collaborate with several colleagues from IFAM Bremen, University of Manchester, Lancaster University, and University of Illinois at Urbana-Champaign. Within a project funded by the RAG Foundation, we explore lithium recovery from regional mining water, but the technology can easily be extended to other water sources, such as hydrothermal water.

Nanohybrid heterostructure materials

High-performance electrochemical materials must combine electrical conductivity with an attractive charge storage capacity (*Fleischmann et al., Chem. Rev. 2020*). To this end, we use two-dimensional materials, such as MXene, and we also develop nanoscaled hybrids of carbon, carbides, oxides, and sulfides to create high-performance lithium-ion and sodium-ion batteries. Such hybrids are obtained from various synthesis methods, including atomic layer deposition, electrospinning, hydrothermal and solvothermal processes, and chloroxidation. Three DFG projects support the research on nanohybrid heterostructures, including one so called Own Position project in which the position of a principal investigator (S. Husmann) is temporarily funded.

OUTLOOK

Our work will develop electrochemical materials with tunable ion selectivity to serve as an innovative platform for a new generation of sensors, ion separation devices, and post-lithium battery technology. This know-how will also be used to develop novel ways for sustainable battery recycling. Modeling will transition from a tool to explain processes towards a powerful predictive method to enable high throughput screening and focused experimental work in the laboratory. More sustainable materials and processing methods will, over time, allow to not only enable novel electrochemical applications but also improve upon environmental friendliness.

FUNKTIONELLE MIKROSTRUKTUREN / FUNCTIONAL MICROSTRUCTURES

PROF. DR. EDUARD ARZT, DR. RENÉ HENSEL

ZUSAMMENFASSUNG

Mikrostrukturierte Oberflächen sind evolutionäre Strategien der Natur, die in unserer Gruppe als neue Materialkonzepte erforscht, entwickelt und bis zur Anwendungsreife gebracht werden. Der Fokus unserer Arbeiten liegt auf fibrillären Haftsystemen für die temporäre, reversible Adhäsion. Aktuelle Schwerpunkte sind die statistische Analyse des Ablöseprozesses, die Integration von Maschinellem Lernen in Verbindung mit optischer Kontaktbeobachtung, sowie das Design bioinspirierter Saugmechanismen in flüssigen Medien (‚water as a glue'). Mittels numerischer Modellierung und experimenteller Validierung werden Prototypen für das kontrollierte Ablegen von Mikroobjekten entwickelt. Die angepeilten Anwendungen reichen von der Robotik über biomedizinische Wundauflagen bis zum Rückholen von Weltraumschrott. Im Vergleich zu chemischen Strategien ermöglicht das Paradigma der Mikrostrukturierung Lösungen mit hoher Ressourceneffizienz und Nachhaltigkeit.

Dr. René Hensel

Prof. Dr. Eduard Arzt

MISSION

We develop multifunctional adhesives with fibrillar micropatterns for advanced handling, robotic and medical applications. Unlike conventional adhesive systems such bioinspired designs promise highly energy-efficient and enviroment-friendly operation. Combining analytical and numerical analyses with experimental studies, our research recently focused on predicting optimal designs for dry adhesives and detachment mechanisms in wet adhesion. New topics include integration of machine-learning in robotic handling and the effect of surface roughness on adhesion at array level. Our advanced array designs target biomedical applications, wearable devices and space applications. Finally novel designs with controlled release behavior are developed for handling micro-objects. Our research is funded by the EU (ERC Proof-of-Concept Grant), Leibniz Association and industrial partners.

CURRENT RESEARCH

Progress in the Leibniz Competition project

In the "MUSIGAND" project, funded by the Leibniz Association, progress was made towards improved control and reliability in gecko-inspired handling. A strategy for predicting the gripping performance of fibrillar adhesives was developed involving real-time optical monitoring and machine learning (*Samri et al., Mater Today, 2022, Fig. 1*). Statistical analyses were conducted on adhesion strength of microfibrils in a compliant system (*Hensel et al, ACS Appl Mater Interfaces, 2021; Booth & Hensel, Appl Phys Lett, 2021*). An optimal design for mushroom-shaped fibrils was proposed on in-situ contact obversation and contact mechanics simulations (*Zhang et al, J Appl Mech, 2021*). Adhesion enhancement of micropatterned adhesives by contact aging was analysed (*Thiemecke & Hensel, Adv Funct Mater, 2021*). With Saarland University, an analytical treatment of the elasticity and adhesion of elastic films was developed (*Müller & Müser, J*

Adhes, 2022). An extensive review of our work was published in Prog Mater Sci (*Arzt et al., 2021*).

Underwater adhesion microstructures

In collaboration with Prof. Taher Saif (University of Illinois, Urbana-Champaign, USA), we proposed to alter the role of water by using cupped microstructures, inspired by aquatic animals. We developed a model for deformation-enhanced liquid suction, discussed the time evolution of the suction and investigated possible modes of detachment (*Wang et al., Sci Adv, 2022*). By introducing a cavity into the cupped microstructures, the attachment mechanism against rough surfaces was investigated (*Wang et al., Adv Funct Mater, 2021*). Understanding such underwater attachment mechanisms will allow to design microcups for underwater applications.

Handling of micro-objects

Our Gecomer Technology has been successfully demonstrated in pick & place operations of various objects. A new challenge came up in releasing micro-objects due to their strong adhesion to other surfaces. Common mechanical release mechanisms lose their function below a certain object mass, as the swiching ratio of 2~3 is too low to release objects by gravitation. A slanted fibril design was proposed with a switching ratio of up to 500. During retraction, a sliding-induced peeling from the object resulted in controlled detachment. A three-legged minitripod was fabricated for demonstration of accurate placement of superlight objects with considerable potential in advanced industrial application (*Yue et al., Adv Mater Interfaces, 2022*).

Micropatterned adhesives in application: biomedicine and space technology

Advanced micropatterned polymeric materials with soft terminated-film design have demonstrated useful adhesion to skin. Such novel skin adhesives were improved for the treatment of tympanic membrane perforations. In cooperation with Prof. Bernhard Schick and Prof. Gentiana Wenzel (Saarland University), partial recovery of hearing performance was detected immediately after applying the adhesive to mouse ears (*Moreira Lana et al., Adv NanoBiomed Res, 2021, see Highlight article*). Another promising application was validated at the International Space Station (ISS): Our fibril-patterned adhesives demonstrated a successful automated docking process. Such gripping devices are in development for the retrieval of man-made space debris in earth orbit (*Fig. 2*).

OUTLOOK

Investigations of fundamental aspects and potential applications of micropatterned surfaces, are a focus of our portfolio. Advanced fibril patterns with terminated design are fundamentally studied on the interfibril coupling effect by in-situ observation and statistical analysis. It will also accommodate more applications in biomedicine such as treatment of ear drum perforations and wearable electronics. Explored underlying mechanism in wet adhesion will lead to successful underwater adhesives. In addition, new designs based on metamaterials and micro-fabrication process are paving the way towards efficient swichable adhesives to achieve small object release.

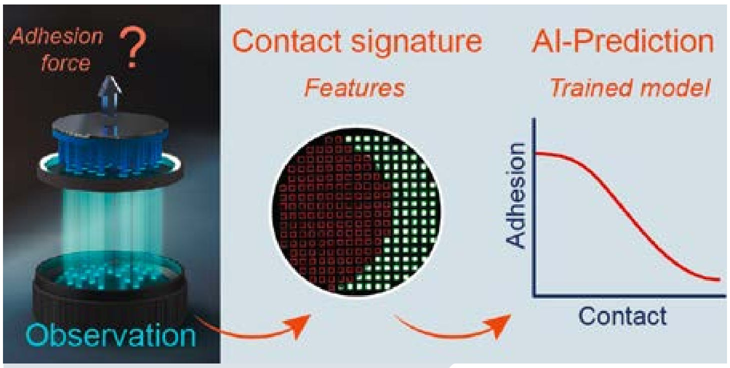


Fig. 1: Functional microstructures for intelligent gripping
Fig. 2: Demonstration of a docking process mediated by our micropatterned adhesives (International Space Station ISS)

INTERAKTIVE OBERFLÄCHEN / INTERACTIVE SURFACES

PROF. DR. ROLAND BENNEWITZ

ZUSAMMENFASSUNG

Der ehemalige Programmbereich *Nanotribologie* drückt mit seinem neuen Namen *Interaktive Oberflächen* die Neuausrichtung seiner Forschungsaktivitäten aus, insbesondere die Ausweitung der Studien zur taktilen Wahrnehmung von Materialien. Die Strukturierung und Funktionalisierung von Oberflächen und die Entwicklung des Verständnisses physikalisch-chemischer Mechanismen werden genutzt, um die mechanischen Eigenschaften von Materialien wie Reibung und Adhäsion zu bestimmen und zu nutzen. Die untersuchten Systeme reichen von zweidimensionalen Materialien über Hydrogele bis hin zu mathematisch definierten Oberflächen aus dem 3D-Drucker. Die Projekte basieren auf unserer Expertise in der experimentellen Nanomechanik. Zu den wichtigsten Ergebnissen des Jahres 2021 gehören die Etablierung eines neuen Experiments zur parallelen Kraftspektroskopie an hunderten von einzelnen Molekülen, die Anwendung dieser Methode auf einen lichtgetriebenen molekularen Motor, sowie die Aufklärung mikroskopischer Mechanismen der Reibung auf metallischen Gläsern nach elektrochemischer Oxidation.

MISSION

The Program Division *Interactive Surfaces* explores new materials with specific adhesion and friction properties and materials with a desired haptic appeal. We focus on molecular functionalization and structuring at the micrometer scale and investigate the physical chemistry of friction, wear, lubrication, deformation, and adhesion as well as the role of sliding friction in tactile perception. Materials of interest range from 2D materials over hydrogels to additively manufactured microstructures. The projects rely on our expertise in experimental nanomechanics and on novel experiments on skin friction. Single-molecule force spectroscopy is applied in soft matter for biophysical applications.

CURRENT RESEARCH

Massively parallel force spectroscopy of single molecules

The video observation of tethered particles in a microfluidic flow cell allows to quantify stretching and unbinding forces of single molecules for hundreds of molecules in parallel, providing the necessary statistics to determine relevant parameters of polymer physics and non-covalent chemistry. For example, our experiments have revealed the surprisingly small persistence length of a self-assembled DNA construct (*Penth et al. Nanoscale 2021*). In collaboration with the program division *Dynamic Biomaterials*, we have applied the novel method to quantify the forces exerted by a light-driven molecular motor, which also served as active element for cell stimulation in a dynamic biomaterial (*Zheng et al., Nature Communications 2021*). In our ongoing experiments we collaborate with colleagues in pharmaceutical sciences to quantify the unbinding forces between proteins and synthesized ligands with potential application in antibacterial drugs.

Friction mechanisms on metallic glasses after electrochemical oxidation

Metallic glasses are materials with outstanding mechanical properties. The absence of structural defects such as dislocations in a crystalline material does not only change the plastic deformation but also influences the corrosion in oxidizing electrolytes. We have explored microscopic mechanisms of friction on a metallic glass after electrochemical oxidation and found an increased friction which decayed upon repeated sliding over the same surface area. The stronger initial friction was attributed to a soft and removable layer of metal oxides and hydroxides which had precipitated at the oxidized surfaces during polarization at positive potentials (*Ma and Bennewitz, Tribology International 2021*).

Ongoing projects

Frictional properties of stacked heterostructures of 2D materials are studied by high-resolution atomic force microscopy in a vacuum environment. The project is part of a *Schwerpunktprogramm* of the DFG. and investigates chemical bonds between MoS_2 and graphene sheets which are formed intermittently under high local pressure of a sliding nano-scale tip. In collaboration with the program division *Dynamic Biomaterials* and partners in Strasbourg and Aachen, supported by the *Leibniz Association*, we explore the efficiency of novel light-driven molecular motors. The change of course in our research towards tactile perception of materials is now supported by the *Volkswagen Foundation* in two projects. In collaboration with dermatologists, we investigate the role of skin conditions for fingertip friction and for the perception of surface roughness. New materials for tactile communication through switchable surface properties are verified in collaboration with clinical neurophysiologists.

Fig.: Micron-sized beads are waiting to be picked up by the force sensor of an atomic force microscope. Each bead is tethered to the surface by a DNA molecule which is probed by force spectroscopy.

OUTLOOK

We will continue to investigate the mechanisms which link structure and dynamics of surfaces to adhesion, friction, and wear in new materials. The experiments on MoS_2 and graphene will be extended to the control of friction by applied electric potentials which address the peculiar electronic states of stacked 2D materials. Friction and adhesion of single (bio-)polymers can now be detected by high-resolution force microscopy. We will apply single-molecule techniques to explore the time dependence of self-healing processes and to further develop of novel DNA-based materials with force sensing functions for biophysical applications. After a successful proof of concept, we will employ force microscopy with colloidal probes to record mechanical signals from living materials, i.e. from bacteria encapsulated in hydrogels. Our research on haptic perception of materials will be further developed in collaboration with the Chair of Computational Materials Science, where we plan to establish design rules for a “tactile white”, i. e. a surface structure for minimal fingertip friction which leaves a weak perceptional impression upon touch.

INNOVATIVE ELEKTRONENMIKROSKOPIE / INNOVATIVE ELECTRON MICROSCOPY

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

ZUSAMMENFASSUNG

Eine nanometergenaue Materialcharakterisierung ist unabdingbar für die Weiterentwicklung der modernen Nanotechnologie und der Biologie. Der Programmbereich *Innovative Elektronenmikroskopie* (IEM) betreibt interdisziplinäre Forschung an der Schnittstelle der Physik der Elektronenmikroskopie (EM), Biophysik, Materialwissenschaft, Zellbiologie und Bildverarbeitung. Wir entwickeln modernste Techniken im Bereich *in situ* Transmissions-EM (TEM) und Raster-TEM (STEM) für die Forschung an funktionellen Materialien und biologischen Systemen unter realen Bedingungen. Auch untersuchen wir neue Wege für die dreidimensionale (3D) Datenaufnahme und verfügen über langjährige Erfahrung mit Bildverarbeitung sowie mit der Entwicklung von Protokollen für spezifische Proteinmarkierung mit Nanopartikeln. Dem Programmbereich steht ein hochmodernes Elektronenmikroskop (JEOL ARM200) zur Verfügung. Wir haben vielfältige Forschungskooperationen mit verschiedenen Universitäten und der Industrie.

MISSION

Nanoscale characterization is essential for the advancement 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 under 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

Membrane protein organization

We study the biophysical principles of how a cell organizes its functional membrane proteins in specific locations and configurations in order to regulate function. For this purpose, membrane proteins are imaged at the single molecule level using liquid-phase electron microscopy. This project is part of the Collaborative Research Center 1027 funded by the Deutsche Forschungsgemeinschaft (DFG).

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 of the German Cancer Research Center, Heidelberg, and Prof. Julia Radosa and Prof. Erich-Franz Solomayer of the Saarland University Hospital, Homburg. The project is funded by the Else Kröner-Fresenius-Stiftung.

Examining patient biopsy samples with STEM

Biopsies samples are examined from patients with gastric- or gastroesophageal junction cancer treated with Trastuzumab. HER2 dimerization levels and its heterogeneity between cancer cells are analyzed in a project together with Prof. Timo Gaiser, University Medical Centre Mannheim funded by the Deutsche Krebshilfe.

3D STEM

We develop data acquisition and digital processing (techniques/ systems?)aiming to establish three-dimensional 3D STEM with nanometer resolution in micrometers-thick specimen. The project is a collaboration with Dr. Tim Dahmen, German Center for Artificial Intelligence, Saarbrücken. This research is funded by the DFG.

Liquid 3D STEM

Combining our expertise in LP-EM and 3D STEM, the plan is to implement the capability of 3D imaging for samples in liquid. This is a joint project with Prof. Karine Masenelli-Varlot, INSA-Lyon, University of Lyon, France, funded by DFG and Agence National de la Recherche.

Studying the behavior of proteins using graphene liquid cells

A graphene liquid enclosure for imaging proteins in liquid has been developed and has led to a project funded by Bruker AXS.

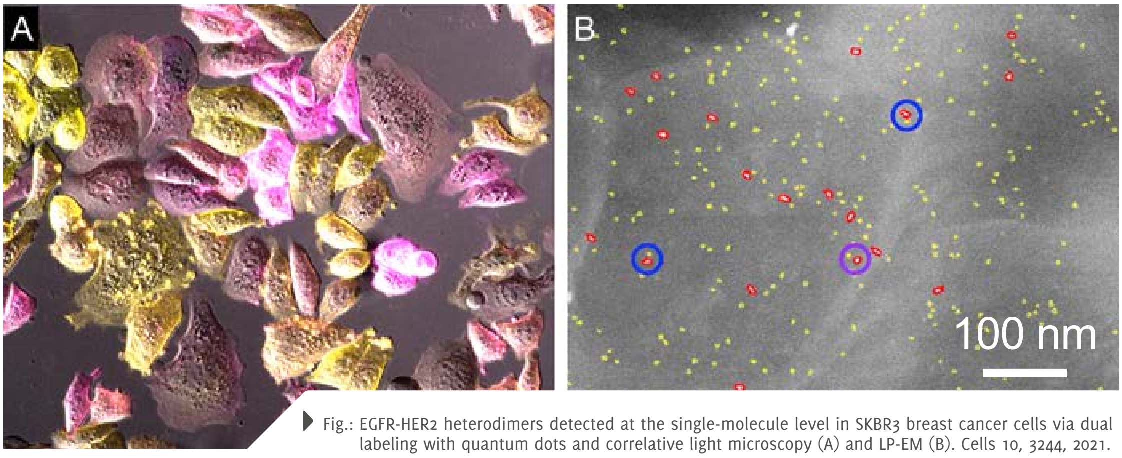


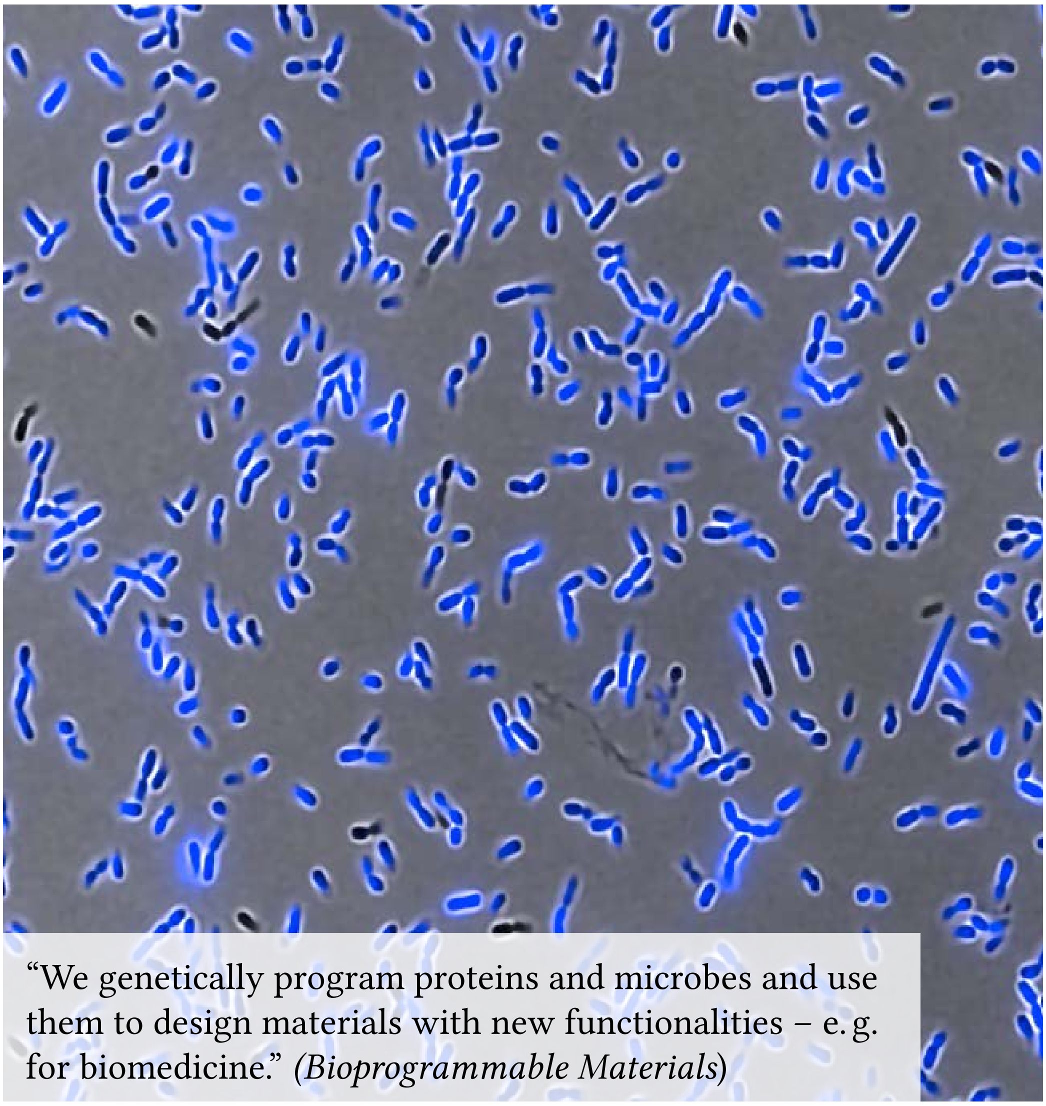
Fig.: EGFR-HER2 heterodimers detected at the single-molecule level in SKBR3 breast cancer cells via dual labeling with quantum dots and correlative light microscopy (A) and LP-EM (B). Cells 10, 3244, 2021.

Studying nanoparticles at the solid-liquid interface

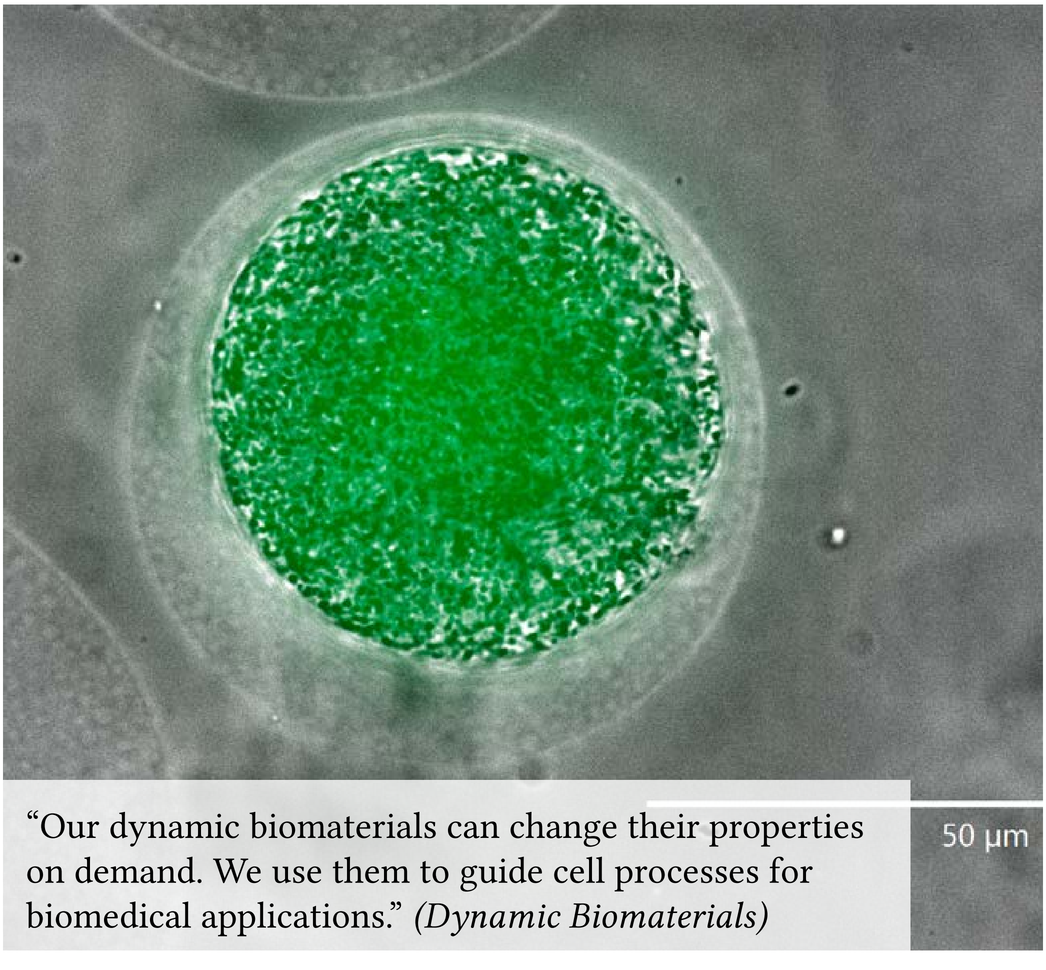
Self-assembled structures and dynamic processes of nanoparticles at the solid-liquid interface were studied with LP-EM funded by the DFG and together with the Program Division *Structure Formation*.

OUTLOOK

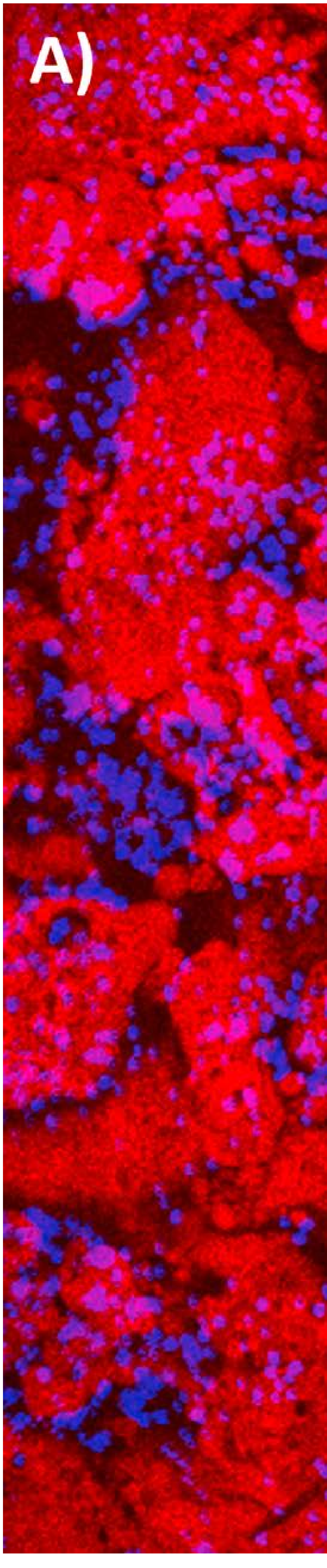
The IEM group is well situated to conduct research at the international forefront of electron microscopy both in the areas of biology/biophysics, and soft matter materials science. Future aims are to study processes of protein complexes, to develop a Liquid STEM into a standard characterization method for membrane proteins in cells, to study HER2 in patient biopsy samples, to improve the time-resolution of *in situ* STEM via artificial intelligence techniques, and to develop Liquid 3D STEM. Technology transfer to Bruker AXS will take place, supporting a planned product development.



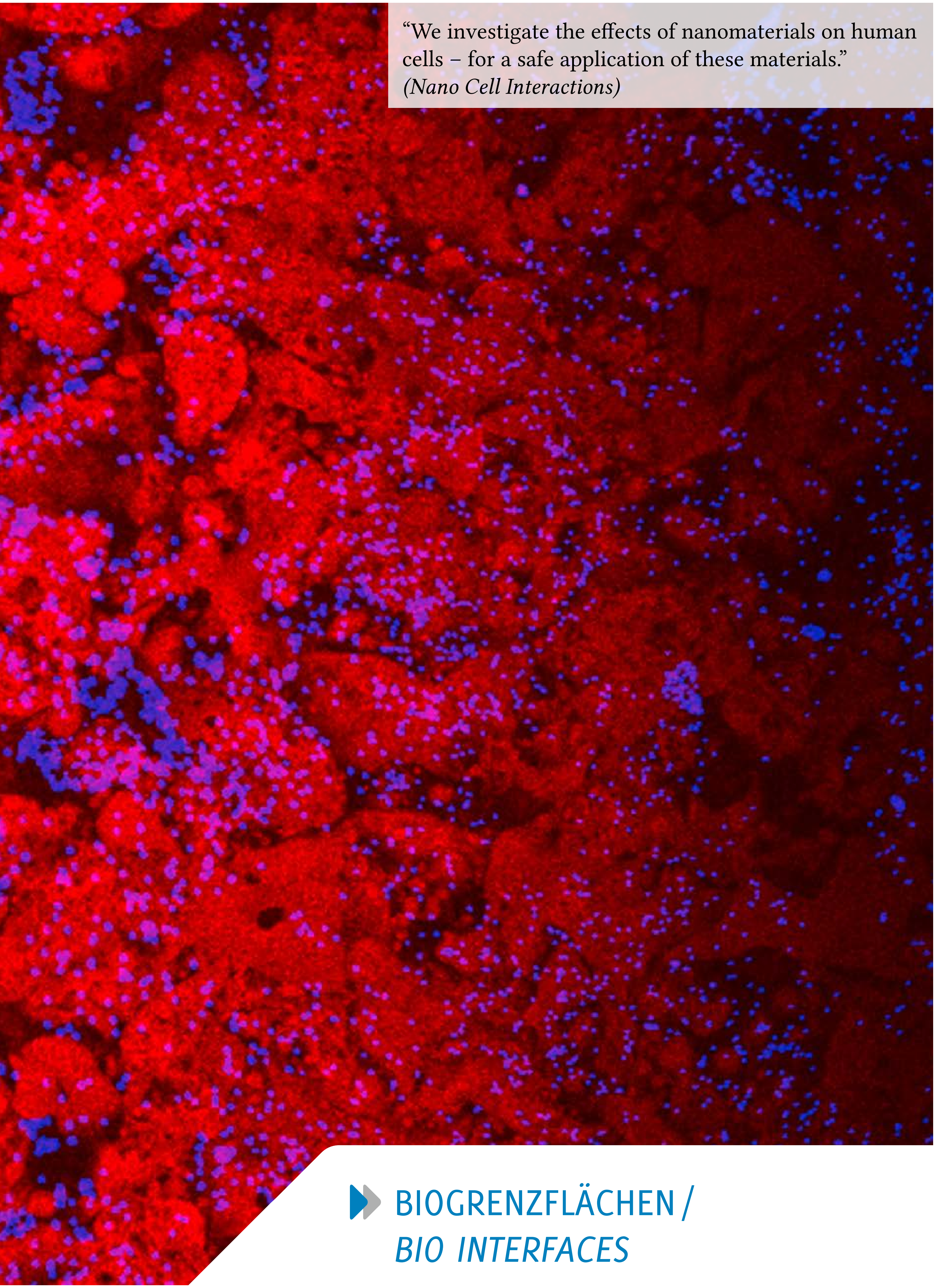
"We genetically program proteins and microbes and use them to design materials with new functionalities – e. g. for biomedicine." *(Bioprogrammable Materials)*



"Our dynamic biomaterials can change their properties on demand. We use them to guide cell processes for biomedical applications." *(Dynamic Biomaterials)*



“We investigate the effects of nanomaterials on human cells – for a safe application of these materials.”
(Nano Cell Interactions)



BIOGRENZFLÄCHEN / *BIO INTERFACES*

BIOPROGRAMMIERBARE MATERIALIEN / BIOPROGRAMMABLE MATERIALS

DR. SHRIKRISHNAN SANKARAN

ZUSAMMENFASSUNG

Die Juniorforschungsgruppe *Bioprogrammierbare Materialien* erforscht ein junges multidisziplinäres Feld, das die Gebiete der synthetischen Biologie und der Biomaterialien kombiniert. Im Mittelpunkt steht die Entwicklung von Materialien mit genetisch programmierten Funktionalitäten für biosensorische Anwendungen. Sie sind in der Lage, auf Stimuli hin Medikamente langfristig freizusetzen und das Zellverhalten zu beeinflussen. Mit Werkzeugen der synthetischen Biologie werden Proteine und Mikroben so programmiert, dass sie intelligente Funktionen erfüllen. Diese konstruierten biologischen Einheiten werden dann in entsprechend entwickelte polymere Matrizen eingebettet. Das Ergebnis sind funktionell vielseitige Kompositmaterialien mit einer großen Bandbreite an Einstellbarkeit und In-situ-Kontrollmöglichkeiten.

MISSION

The Junior Research Group *Bioprogrammable Materials* explores a young multidisciplinary field combining synthetic biology and biomaterials. It focusses on the development of materials with genetically programmed functionalities capable of biosensing, stimuli-responsive long-term drug release and manipulation of cell behavior. Synthetic biology tools are used to program proteins and microbes to perform smart functions. These engineered biological entities are then incorporated in appropriately developed polymeric matrices, resulting in composite materials with highly versatile functionalities, a wide range of tunability and *in situ* controllability.

CURRENT WORK

Living therapeutic materials

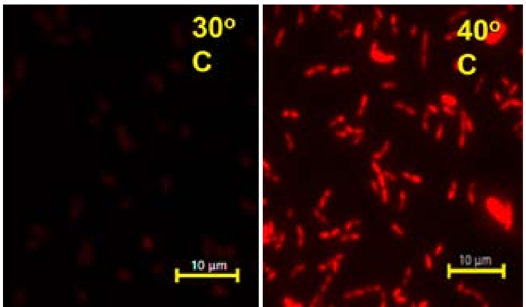
In our previous proof-of-concept work, we constructed *E. coli*-based bacterial hydrogels capable of long-term light-regulated drug release. In 2021, we demonstrated the capability of this system to stimulate angiogenic differentiation in vascular endothelial cells. Analogous to this, the DFG funded project for the light-responsive release of nerve growth factor from a bacterial hydrogel was initiated in April 2021 and is progressing rapidly. We are engineering bacteria to produce and release therapeutic flavonoids (e. g. pinocembrin) in response to food-grade chemical precursors (e. g. cinnamic acid). This project was a cooperation with Dr. Vito Valiante (Leibniz HKI, Jena), with seed funding from the Leibniz Research Alliance Bioactive Compounds and Biotechnology. We have further expanded the remote-controlled regulation capabilities of such bacterial hydrogels by encoding a thermo-responsive switch (<37 °C OFF, >39 °C ON), which would be regulatable by infrared light, focused ultrasound and even raised body-temperature during a fever. We also established new methodologies for engineering such responsive genetic circuits in more therapeutically applicable probiotics or commensals (Lactobacillus, Lactococcus, Corynebacterium). These advances are being applied in different cooperative projects with partners in the Leibniz Science Campus *Living Therapeutic Materials*. Highlights include collaborations with

(i) Program Division *Dynamic Biomaterials* where Pluronic F127 based hydrogels constructs were established for long-term, secure, and functional encapsulation of the bacteria
(ii) Program Division *Structure Formation* where gold nanorods were incorporated in the thermo-responsive bacterial gels to improve photothermal regulation efficiencies using infrared light
(iii) Prof. Rolf Müller (HIPS) where *E. coli* was engineered to thermo-responsively produce an antimicrobial agent, Darobactin
(iv) Dr. Bin Qu (UKS) where in vitro studies showed that encapsulation drastically reduces immune responses to these bacteria.

Using the possibility to tune the mechanical properties of Pluronic F127-based hydrogels, we studied the influence of viscoelastic properties on bacterial growth and functionality under confinement. This study formed the basis for a DFG funded subproject within the SFB1027 consortium to gain a broader and deeper understanding of the biophysical principles and the underlying mechanosensitive behavior of bacteria in confinement. This project was initiated since July 2021 and involves collaborations with the groups of Prof. Ludger Santen, Prof. Karin Jacobs and Prof. Marcus Bischoff at Saarland University.

OUTLOOK

To improve the scope and applicability of living therapeutic materials, we are expanding the boundaries of synthetic biology by developing genetic tools for remote-controlled drug release using therapeutically relevant bacteria. Engineering bacterial strains beneficial for humans (probiotics, commensals) is still at its infancy and our progress over the last year has strongly positioned us at the frontier of this endeavor. In the coming years we will demonstrate the applicability of our therapeutic bacterial devices for antimicrobial, regenerative and immunomodulatory applications, first *in vitro* and then in animal models through a collaboration with Prof. Matthias Laschke at the Saarland University Hospital (UKS). To ensure biocontainment of the genetically modified bacteria in these devices, safety-features including metabolic auxotrophy and kill-switches will be implemented to prevent them from thriving outside the body and terminate them on-demand. Further understanding of the influence of the encapsulating materials on the bacteria will help to improve the performance of these living therapeutic devices. These studies and features will help to shape the factors under which such devices will be regulated for eventual testing in humans.



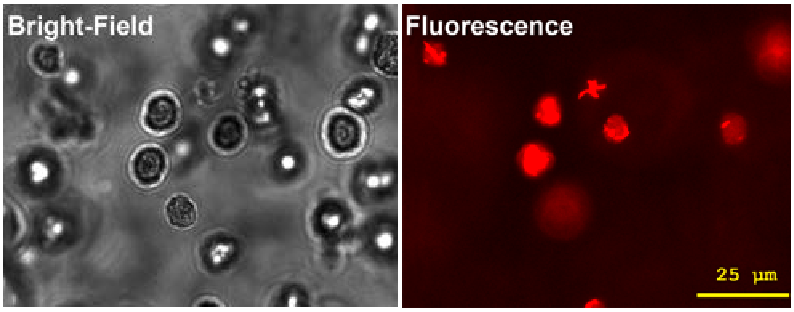


Fig. 1: Microscopy images of thermo-responsive production of a red fluorescent protein in Lactobacillus plantarum.
Fig. 2: Growth of L. plantarum as dense colonies within Pluronic F127 based hydrogels and their functional red fluorescent protein production.

DYNAMISCHE BIOMATERIALIEN / DYNAMIC BIOMATERIALS

PROF. DR. ARÁNZAZU DEL CAMPO

ZUSAMMENFASSUNG

Der Programmbereich *Dynamische Biomaterialien* entwickelt synthetische Matrizen zur Einkapselung und als Schnittstelle zu lebenden Zellen. Wir zielen darauf ab, in vitro Gewebemodelle und lebende Implantate für therapeutische Anwendungen zu entwickeln. Im Zentrum unserer Forschung stehen lichtempfindliche Moleküle, Hydrogele und Zellen, die mit latenten Funktionsniveaus programmiert sind und bei Belichtung angeschaltet werden können, um Eigenschaftsänderungen und Reaktionskaskaden zu regulieren. Wir sind auch an der Kompatibilisierung von synthetischen Matrizen und lebenden Organismen mit Verarbeitungstechnologien wie 3D-Druck oder Mikrofluidik für zellbasierte Diagnostika und therapeutische Devices der nächsten Generation interessiert. Als längerfristige Perspektive beabsichtigen wir, Konzepte aus der Geweberekonstruktion auf die Synthese nachhaltiger und belastbarer technischer Materialien zu übertragen.

MISSION

The Program Division *Dynamic Biomaterials* develops instructive synthetic matrices to encapsulate and interface with living cells. We aim to bioengineer functional tissues and living devices for medical and technical applications. Central to our research are photoresponsive molecules, hydrogels and cells programmed with latent functional levels that can be unlocked upon light exposure to regulate property changes and response cascades. We are also interested in the compatibilization of synthetic matrices and living organisms with processing technologies like 3D printing or microfluidics towards next-generation cell-based diagnostics and therapeutic devices. As longer-term perspective we intend to transfer concepts from tissue reconstruction to the synthesis of sustainable and resilient technical materials.

CURRENT RESEARCH

Light-actuated interfaces that trigger cellular responses

The regulation of material properties using light is at the core of our research. We integrate light-triggers into hydrogels to regulate the presentation of bioactive components or the mechanics of the network (*Nair et al., Adv Healthcare Materials, 2021*) and, by this means, guide the fate of embedded cells. A recent highlight is the development of mechanically active interfaces using light-driven molecular motors and the demonstration of mechanical stimulation of cell surface receptors (*Zheng et al., Nature Communications 2021*) in cooperation with the Program Division *Interactive Surfaces* and with partners at Saarland University. This work will be continued in our project within the SFB1027 in the field of mechanical stimulation of T cells. Follow-up investigations translate this design to 3D scenarios in collaboration with the

DWI-Leibniz Institute for Interactive Materials and the University Strasbourg (SAW Project LightAct), and with GeorgiaTech (EU Project Mechanofibrosis).

To transfer our light-based molecular technologies to medical scenarios, we develop printable hydrogel optical waveguides that can guide light into the body. New photocrosslinkable hydrogels are processed as core-cladding fibers by extrusion printing (*Pearson et al., Adv Funct Mater 2021*). The potential of these materials for technology transfer is explored with the Program Division *Optical Materials*.

Materials for automatized cell encapsulation and bioprinting

Our group develops hydrogels with adjustable crosslinking kinetics to facilitate automatized handling of 3D cultures. These hydrogels allow mixing of polymeric precursors and cell suspensions under low shear forces and customized regulation of gelation times between a few seconds to a few minutes for comfortable processing (*Paez et al., Biomacromolecules 2021*). These characteristics make them ideal for automatized 3D cell culture and the establishment of validated tissue models for drug testing. Technology transfer in this direction is pursued in cooperation with the *INM Innovation Center* and in cooperation with other Leibniz Institutes (DWI, IPF, *SAW Transfer project µTissues*). In a different context, photocrosslinkable hydrogels are applied in cooperation with the bioprinting industry (*BMBF-KMU Innovative*).

Materials and technologies for next-generation therapeutics

Within the *Leibniz ScienceCampus Living Therapeutic Materials* we cooperate with the group *Bioprogrammable Materials*, with Helmholtz Institute for Pharmaceutical Research Saarland and with Saarland University in the design of matrices and processing technologies to encapsulate drug producing organisms and fabricate implantable drug eluting devices. We have identified material parameters that are relevant for cell viability during processing, to control cell growth and to maximize drug production at the application site. This work should lead to the establishment of generic design rules and structure-property relationships within this new material class. We are taking an active role in establishing this emerging field (*Rodrigo-Navarro et al., Nature Materials 2021*) and in gathering the community at German (*DFG Nachwuchsakademie* Engineered Living Materials) and international (2nd International Conference Engineered Living Materials organized in February 2021, virtual) level.

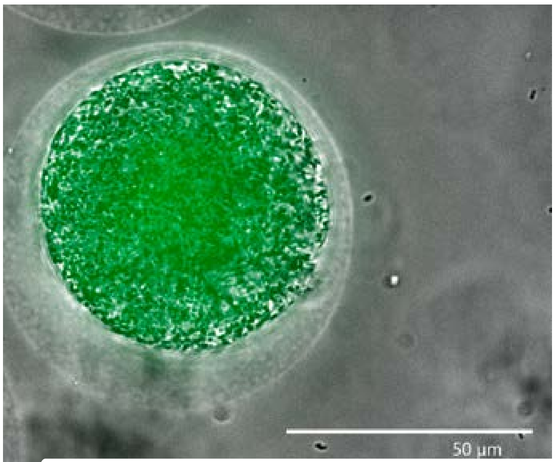


Fig.: Core-shell microparticle (Dextran/PEG) that contains functional drug-producing bacteria and controls their replication.

OUTLOOK

The development of cellular microenvironments to support and control cell growth and function with light remains a major topic in the group. We see potential for technology transfer in the combination of our synthetic toolbox with bioprocessing technologies to be followed-up in the next years. The focus of the group is expanding from the development of biomaterials supporting tissue regeneration to the application of morphogenesis concepts to recreate biological materials *in vitro*, breaking the classical border between synthetic and bioengineering approaches in materials science.

NANO ZELL INTERAKTIONEN / NANO CELL INTERACTIONS

PD DR. ANNETTE KRAEGELOH

ZUSAMMENFASSUNG

Der Programmbereich *Nano Zell Interaktionen* beschäftigt sich mit den Auswirkungen technisch hergestellter partikulärer Materialien auf menschliche Zellen, um zu einer sicheren Anwendung hochentwickelter Materialien in technischen und biomedizinischen Bereichen beizutragen. Ziel ist es zu verstehen, wie bestimmte Materialeigenschaften die Struktur und Biochemie der Zellen beeinflussen und wie dies mit der Aufnahme, Akkumulation und Zielsteuerung der Materialien zusammenhängt. Als Untersuchungsobjekte werden insbesondere anorganische Nanopartikel, aber auch 2D-Nanomaterialien eingesetzt und charakterisiert. Zur Lokalisation von Partikeln und Zellstrukturen werden vor allem lichtmikroskopische Techniken verwendet. Eine Besonderheit der Gruppe ist die Nutzung hochauflösender Stimulated Emission Depletion (STED)-Mikroskopie. Zur weiteren Analyse der Zellantwort werden darüber hinaus zellbiologische, biochemische und molekularbiologische Techniken angewandt.

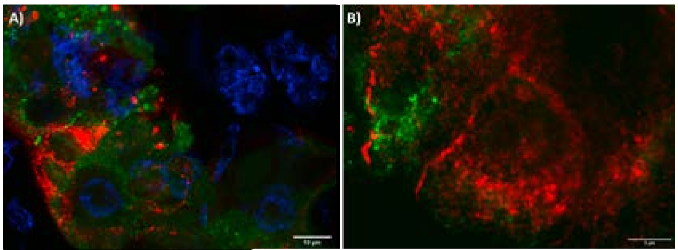
MISSION

The Program Division *Nano Cell Interactions* explores the effects of engineered particle-like materials on human cells to enable safe applications of advanced materials in technical and biomedical fields. It strives to understand how materials properties influence structure and biochemistry of cells and how these effects are linked to the uptake, accumulation, and targeting of the materials. Our purpose is to pave the way for the design of safer nanomaterials. In particular, inorganic nanoparticles and 2D nanomaterials are used and characterized. Light microscopy techniques, for example Stimulated Emission Depletion (STED) microscopy, are used to localize particles and to analyze cellular structures. Further, cell-biological, biochemical, and biomolecular techniques are used for the analysis of cellular responses.

CURRENT RESEARCH

Pulmonary mucus as a barrier for particle penetration

The lung is an important target organ for nanomaterials that enter the human body via inhalation. Human respiratory mucus, lining the airway epithelium, forms a relevant barrier to nanomaterials inhaled unintentionally as well as to particulate inhalation therapeutics applied on purpose. Mucus is a hydrogel. Its basic gel structure is made up by glycosylated mucin glycoproteins. In a recent study, the granular pattern of mucin molecules was revealed (*Meziu et al., Int. J. Pharm., 2021*). This has been taken further by studies aiming at investigating the structure and barrier properties of mucus produced *in vitro* by cells derived from the human bronchial region and cultivated at the air-liquid interface. In this context, the toxicity of various types of polystyrene nanoparticles on bronchial cells covered by differently developed mucus layers was analysed. Immature mucus layers or mucus modulation, achieved by addition of chemical agents, allowed for significantly higher particle penetration across the mucus layer and contributed to an increased particle induced toxicity. These studies have been conducted in the frame of a cooperation (involving a doctoral and a master project) between the *Nano Cell Interactions* group and the Biopharmaceutics and Pharmaceutical Technology group at Saarland University (Prof. Marc Schneider).



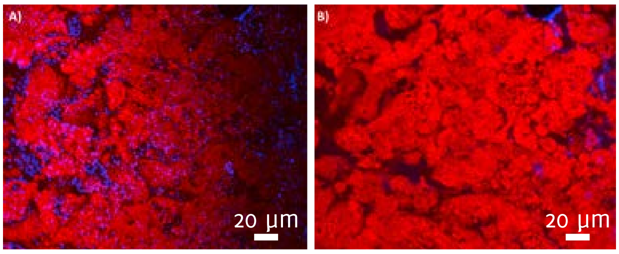


Fig. 1: In vitro secretion of mucin proteins by Calu-3 cells. MUC5AC (green) and MUC5B (red) at A) basal and B) apical regions. Cell nuclei are colored blue.
Fig. 2. Penetration of polystyrene particles (blue) through in vitro mucus (red). Sections were taken at a distance of 1 µm (A) and 5 µm (B) from the mucus top side.

Recently, Kristela Shehu obtained funding for her doctoral project by the German Academic Exchange Service (DAAD). The aim of her project, continuing the mentioned cooperation, is to develop nanostructured carriers for the treatment of bacterial infections in the lung. At INM, the safety and efficacy of these materials will be tested according to a Safe by Design approach.

Safe MXenes by Design

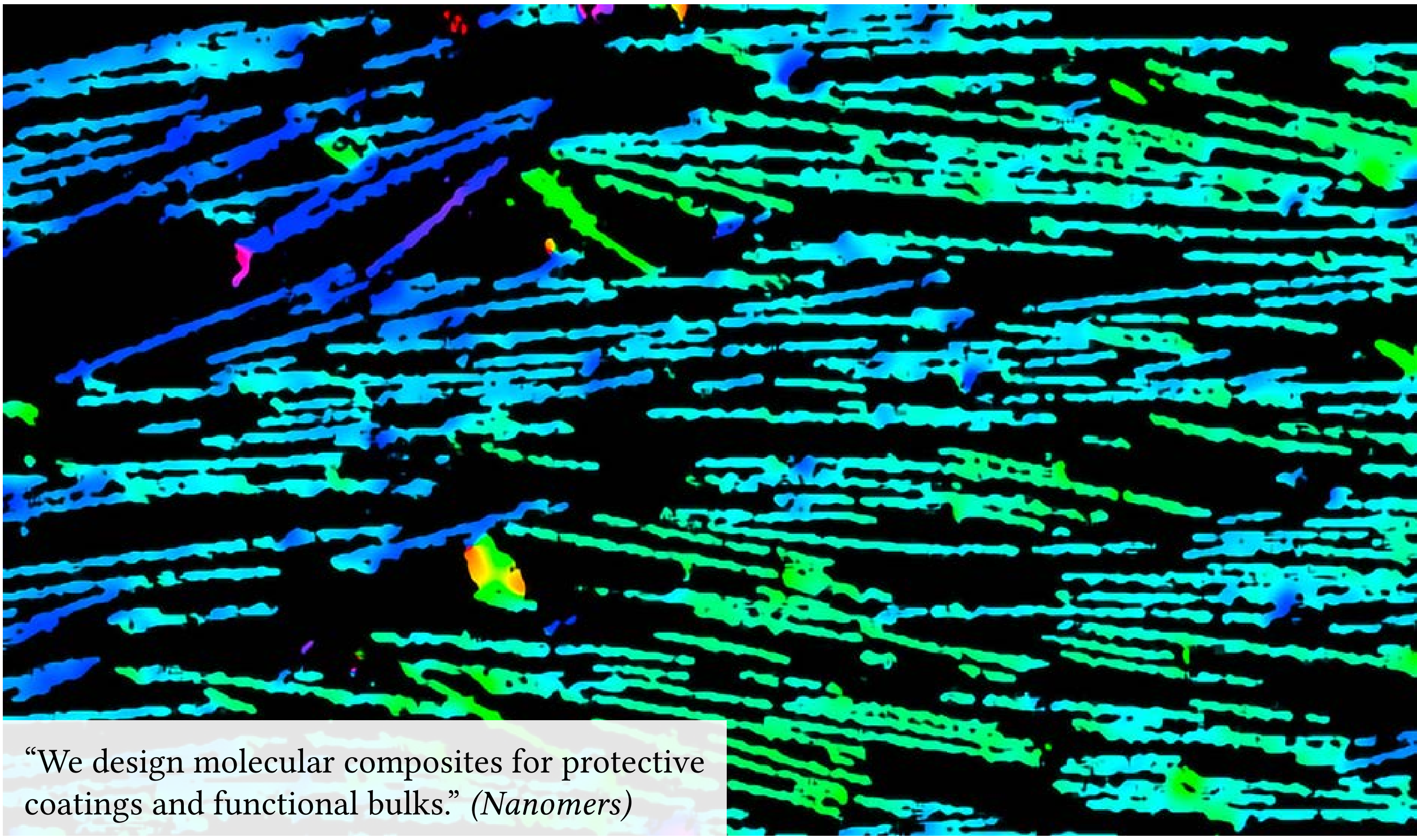
Safe by Design is also the starting point for a cooperation with the program division *Energy Materials* and the *InnovationCenter INM*. The aim is to contribute to safer and sustainable synthesis and processing of MXenes and their precursor materials. The short-term objective is to identify the impact of various types of these 2D nanomaterials on human lung cells. Currently, an *in vitro* coculture model of the lung comprising epithelial and phagocytic cells is developed that builds on previous findings and mimics mechanical strain during the breathing motion. In cooperation with the German Federal Institute for Risk Assessment (BfR), FIZ Karlsruhe – Leibniz Institute for Information Infrastructure (FIZ) and further 12 partner institutions, the group has contributed to the preparation and submission of a proposal "InnoMatSafety" in frame of the third round of calls for the National Research Data Infrastructure (NFDI). Further information can be found on the website of the InnoMatSafety consortium https://nfdi4nanosafety.de.

OUTLOOK

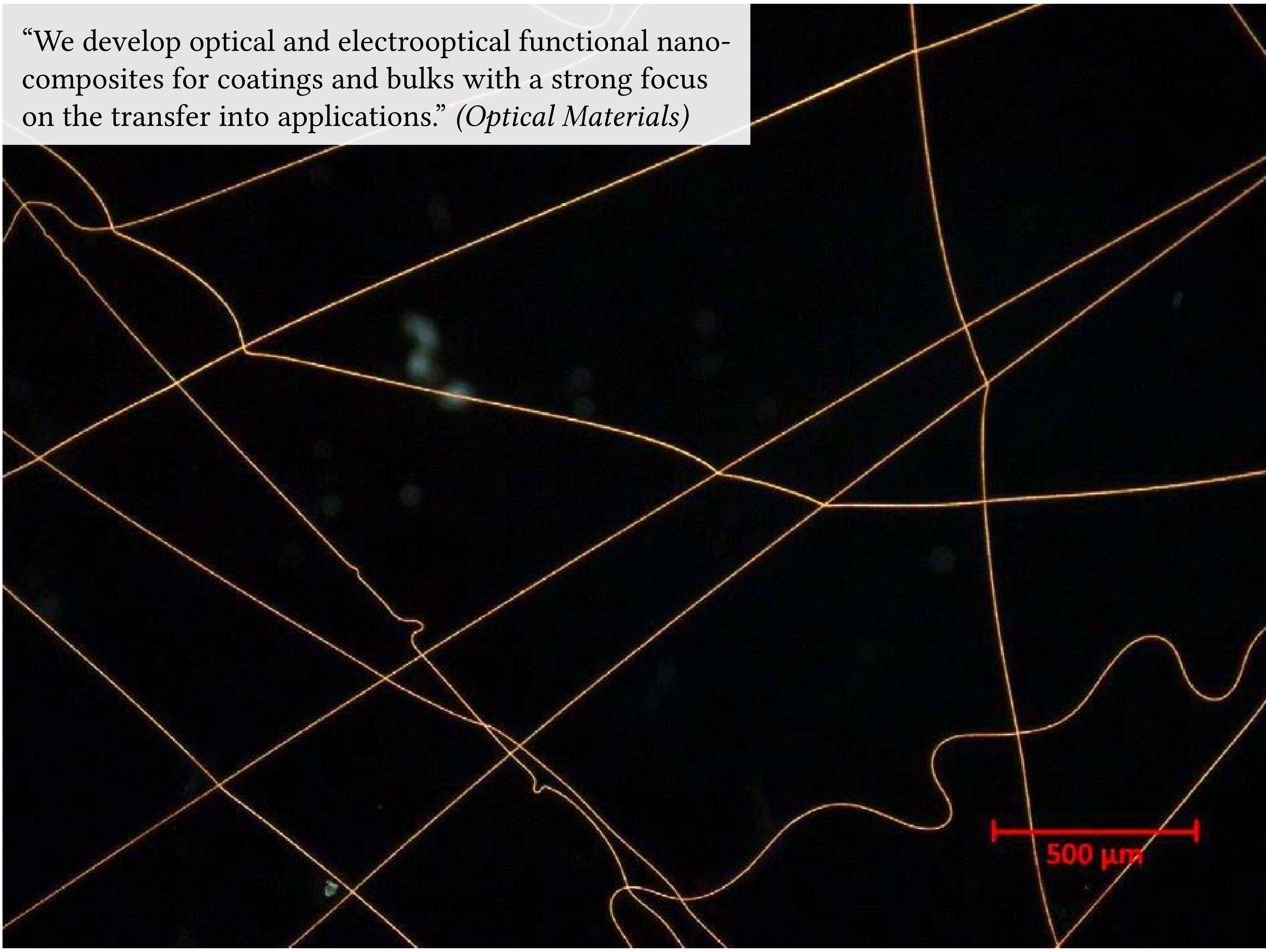
The group has successfully obtained funding for the Leibniz Research Alliance (LRA) "Advanced Materials Safety" (2022-2025). Prof. Andreas Fery (Leibniz Institute for Polymer Research) and Annette Kraegeloh are spokespersons of this initiative. The new alliance synergises 12 Leibniz institutes in addition to further associated partners. The LRA aims at establishing a holistic risk assessment approach to hierarchical hybrid materials and to provide guidelines for sustainable materials design. Major goals are:

- developing design concepts for safer and sustainable advanced materials,
- determination and prediction of the impact of advanced materials on human health and environmental organisms,
- perception and knowledge transfer regarding advanced materials and their sustainable application.

The program division Nano Cell Interactions will be discontinued in 2022 and transformed into the project group "Advanced Materials Safety".

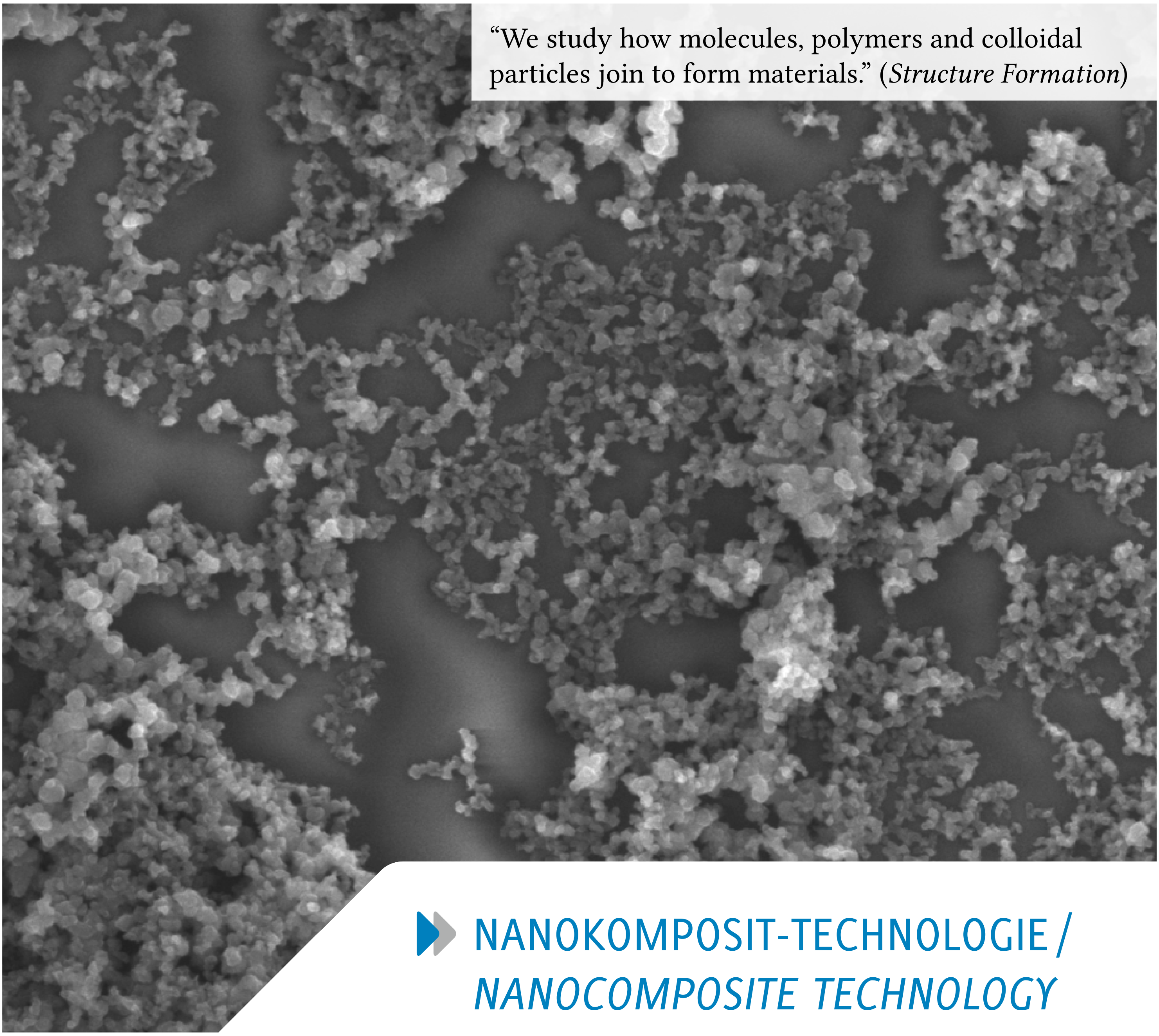


“We design molecular composites for protective coatings and functional bulks.” *(Nanomers)*



“We develop optical and electrooptical functional nano-composites for coatings and bulks with a strong focus on the transfer into applications.” *(Optical Materials)*

"We investigate highly concentrated suspensions of conductive particles in fluid matrices that conduct electrons while flowing as liquids." *(Electrofluids)*



"We study how molecules, polymers and colloidal particles join to form materials." (*Structure Formation*)

NANOKOMPOSIT-TECHNOLOGIE / *NANOCOMPOSITE TECHNOLOGY*

ELEKTROFLUIDE / ELECTROFLUIDS

DR. LOLA GONZÁLEZ-GARCÍA

ZUSAMMENFASSUNG

Die Juniorgruppe *Elektrofluide* erforscht mit Förderung der ERC flüssige Alternativen zu den herkömmlichen festen Metall- und Halbmetallmaterialien der Elektronik. Sie entwickelt damit elektronische Komponenten und robotische Aktuatoren für vollständig weiche Maschinen. „Elektrofluide" sind Suspensionen fester, leitfähiger Partikel, die Elektronentransport ermöglichen, wie Flüssigkeiten strömen und oft nicht-Newtonsches Verhalten zeigen, das wir ausnutzen. Eine ausreichende Leitfähigkeit erreichen wir durch hohe Konzentrationen von Partikeln, die bei handhabbarer Viskosität transiente leitfähige Netzwerke bilden. Im Mittelpunkt unserer Forschung steht der Zusammenhang zwischen der Struktur und den rheoelektrischen Eigenschaften von Elektrofluiden. Die Gruppe untersucht die Wechselwirkungen von Partikel-Partikel-Reibung, Kontaktwiderstand, Perkolation, Volumenwiderstand und Suspensionsviskosität, um Ad-hoc-Elektrofluide für konkrete Anwendungsfälle zu entwickeln.

MISSION

The Junior Group *Electrofluids* funded by the ERC investigates liquid alternatives to the traditional metal and semiconductor solid materials used in electronic components and robotic actuators to enable soft devices. "Electrofluids" are suspensions of solid, conductive particles that allow the electron transport while flowing as liquids and often exhibit non-Newtonian behavior, that we also exploit. We achieve sufficient conductivity using high concentrations of particles that form transient conductive networks at manageable viscosity. The connection between the structure and the rheoelectrical properties of electrofluids is at the heart of our research. The group studies the interplay between particle-particle friction, contact resistance, percolation, bulk resistance, and suspension viscosity to design *ad hoc* electrofluids for concrete applications .

CURRENT RESEARCH

Carbon-based electrofluids

Electrofluids are a new type of material that combines the percolative strategy of classical conductive composites with the new approach of using a liquid matrix, which confers the material new rheological properties (Fig.). This combination opens new possibilities for highly concentrated suspensions in the field of soft electronics. We selected carbon black (CB) as the conductive filler for our first electrofluids and fabricated suspensions with various liquids like silicones (PDMS) or glycerol. One of our focusses is to investigate the effect of the liquid's polarity on the aggregation state of the CB particles. The untreated surface of the commercial CB leads to a better dispersion in non-polar solvents than on their polar

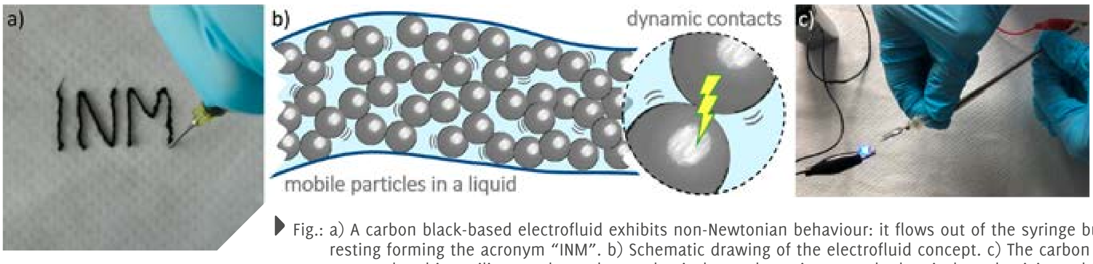


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Fig.: a) A carbon black-based electrofluid exhibits non-Newtonian behaviour: it flows out of the syringe but retains its shape at resting forming the acronym "INM". b) Schematic drawing of the electrofluid concept. c) The carbon black-based electrofluid encapsulated in a silicone tube under mechanical stretch retains enough electrical conductivity to keep a LED on.

counterparts. We exploit this behavior to tune the percolation threshold of the electrofluids and, therefore, their electrical conductivity.

Rheological and electrical properties of these materials are interrelated and depend strongly on the 3D network that the conductive filler forms in the suspension. Standard static techniques employed to elucidate 3D structures in classic composites deliver, however, limited knowledge in the case of electrofluids. Therefore, we perform *in situ* rheoelectrical measurements to analyze the structure-properties relation.

In addition to the fabrication and characterization of electrofluids, we have started to work on the material encapsulation and mechanical testing for their integration as electronic components. Various elastomers have been tested resulting in PDMS to be the most suitable for glycerol-based suspensions. We currently work on the development of a reliable protocol for the encapsulation.

Understanding solid composites from their liquid precursors

The group of *Structure Formation* uses carbon black as a conductive filler in a rubber (PDMS) to create composites that retain electrical conductivity during mechanical stretching. The structure of the network formed by the particles determines the electrical properties of the resulting material and its behavior upon mechanical stress. We collaborated with them to understand the role of ionic liquid (IL) molecules used as additive in the mixture. Little amounts of IL resulted in softening the solid composite and slightly reduced its conductivity. We studied the rheological behavior of the liquid precursors (PDMS with IL & with and without CB). Our experiments suggest that the ionic liquid interacts preferentially with the CB particles covering their surfaces increasing the contact resistance at the particle interface, which provokes the drop in the electrical conductivity of the composite. The softening of the composite is attributed to the reduced cross-linking PDMS by the presence of the IL molecules.

OUTLOOK

At this stage of the project, it is our aim to expand the portfolio of electrofluids that can be fabricated and the ranges of conductivity and viscosity that can be reached. We will create electrofluids based on metal structures according to the workplan described in the ERC Starting Grant project. Silver spheroids, wires, and flakes will be used in order to investigate the role of the particle shapes and sizes in the rheoelectrical properties of the resulting materials. The use of metals will also allow us to modify their surface with conductive polymers following a strategy developed in INM to create hybrid systems with improved electrical properties.

More complex systems will also be fabricated: at least two immiscible liquid matrices will be combined inspired by the so-called double percolation systems from polymer blends. The idea is to lower the percolation threshold of the conductive fillers since the particles will be dispersed preferentially in one of the two liquids and attracted to each other by capillary forces.

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. 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. Bei der Erzielung neuer Werkstoffeigenschaften steht der Anwendungsbezug im Vordergrund. Schwerpunkt der Entwicklungsaktivitäten sind schwermetallfreie, aktive Korrosionsschutzsysteme für Stahl und Aluminiumlegierungen, temperaturbeständige, feuerfeste Bindemittel für Naturfaserkomposite, transparente, selbstheilende Beschichtungen und Polymerkompositbasierte 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, fire resistant polymer matrix composites, temperature stable inorganic binders and transparent self-healing surfaces. Applications are in electronics, medicine, optics, automotive, construction, engineering and additive manufacturing.

CURRENT RESEARCH

Hybrid nanocomposites for corrosion protection coatings for light metal alloys / AluResist

The project AluResist supported by the state of Saarland is focused on corrosion protection coatings for fasteners made of a new high strength aluminum alloy. The last phase of the project was extended to the third quarter 2021 enabling the industrial project partner to provide fully designed fasteners built from the target alloy. The coating process was adjusted by INM to the latest fastener geometries using an application processes having potential for the use in mass production. Functional nanoparticles embedded in a Nanomer-hybrid matrix proved to exhibit active corrosion protection by releasing passivating agents. The whole development was successful so far and the results enable the industrial partner to start the planning for production implementation.

Fire resistant fibreboards from bush biomass / NaMiComp III

The project phase NaMiComp III, supported by BMZ-GIZ and Saarland in cooperation with the University of Namibia (UNAM) was completed. This third phase was dedicated to the transfer of the research results on the fabrication of a fiberboard plate derived from bush biomass towards the Namibian economy. The inorganic Namibinder developed so far and the acacia fiberboards are fabricated exclusively from Namibian precursors. The mechanical and thermal properties of fiberboards were determined at the lab scale according to the specifications for fibreboards. The results showed that the panels fulfill the highest specification and can be used in heavy duty applications in wet environment. Resistance against attack from termites is still under investigation in Namibia. 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. For this reason materials data sheet has been created and a marketing brochure was developed together with GIZ Namibia to enable better advertising in front of the local industry in Namibia and industrial companies from Germany that intend to support the planning and construction of a production line in the not too far future.

In addition, the industry project on tribological modification of bulk polyurethane elastomers used in safety equipment was successfully running through the optimization phase. The material is already developed so far that the industry partner is now starting to invest in equipment for implementing the materials fabrication process in the running production. Production start is envisaged for first half of 2022.

Furthermore an industry project on development of inorganic diffusion barrier coatings for x-ray opaque dental glass particles started in autumn 2021. The screening phase could be completed successfully and fine optimization towards use in dental adhesives will be performed in the first half of 2022.

OUTLOOK

Material development within the group will be based on the polymer composite approach. The synthesis of polyrotaxanes previously developed for self-healing hard coatings will be transfered to industry projects. Reactive materials will be derived therefrom as well as transparent hybrid materials that will be used for direct 3D-printing and stereolithography of optical elements. Polymer nanocomposites with specific mechanical and fire retardant properties will be developed as filaments for additive manufacturing of spare parts in the transportation sector. Namibinder technology will be further extended for substitution of cement based binders to derive sustainable construction materials with improved carbon footprint.

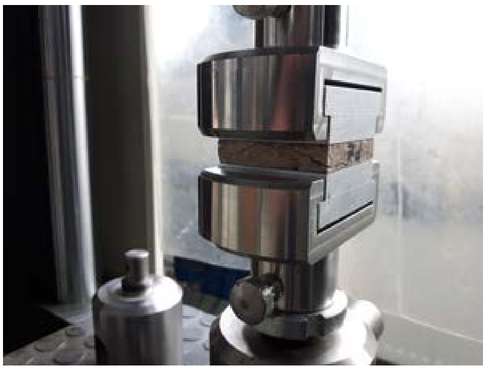




Fig. 1: Determination of mechanical properties: NaMiComp fibreboard specimen in bending and trans-verse tensile test.
Fig. 2: Tiny houses built from wood and corrugated iron sheet in Namibia to be substituted by fibre-board construction materials based on NaMiComptechnology.

OPTISCHE MATERIALIEN / OPTICAL MATERIALS

DR. PETER W. DE OLIVEIRA

ZUSAMMENFASSUNG

Der Programmbereich *Optische Materialien* erforscht die Wechselwirkung von Licht mit strukturierten Materialien. Die Strukturierung erfolgt dabei über den Einbau von Nanopartikeln, die gezielte Erzeugung von Poren, Imprinting oder Prägung. Kompetenz in Modellierung von optischen Elementen, nasschemischer Synthese organischer und organisch-anorganischer Matrices und der Herstellung chemisch modifizierter Nanopartikel ermöglichen die Entwicklung neuer Werkstoffe mit anpassten physikalischen Eigenschaften. Die Gruppenkompetenz reicht von der Grundlagenforschung, bis zur Anwendungsforschung mit dem Ziel einer Verwertung in Zusammenarbeit mit Wissenschaft, KMUs (Kleinen und Mittleren Unternehmen) und Industrie. Dies resultierte in einer neuen Akquisestrategie, die neben der gezielten Bindung langjähriger Partner auch proaktive Schritte zur Gewinnung neuer Kooperationspartner sowie gewandelte Transfermechanismen umfasst. In der Berichtsperiode wurden u. a. Nano-Luftblasen Komposite von Polymeren, neuartige plasmonische Materialien sowie berührungssensitive, weiche elektrooptische Elemente bearbeitet.

MISSION

The Program Division *Optical Materials* has the mission to design new optical and electro-optical composite materials providing interaction of light with structured materials. The structuring of inorganic, organic, or inorganic-organic hybrid materials takes place via the incorporation of nanoparticles, the targeted generation of pore structures or nanobubbles, or the use of techniques such as imprinting or embossing. Competence in modeling of optoelectronic components (Interface between electrical and optical components), in wet chemical processes for the synthesis of organic-inorganic hard and soft matrices, and the production of nanoparticles with specific chemical modifications enable the development of new materials with adapted physical properties such as refractive index or conductivity. The competencies of the group range from basic research to applied research. Their research always aims at utilization. A special interest lies in the cooperation with customers from academia, SMEs, and industry without being completely dependent on orders. This focus resulted in a reorientation of the acquisition strategy which, in addition to the targeted retention of long-term partners, also required new, proactive steps to acquire new cooperation partners as well as a change in the transfer mechanisms.

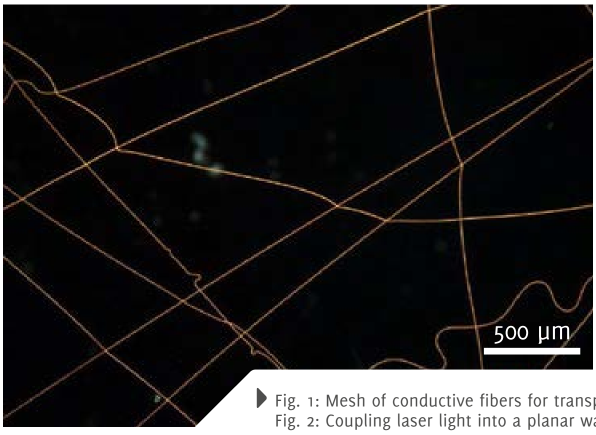
CURRENT RESEARCH

The following highlight topics were investigated in 2021:

New developments on Nanobubble-Polymer-Composites

This research on circular and low refractive index materials is targeted on transparent, stable dispersions of nano- and sub-micron-scaled air bubbles in polymers bulks. Of special interest are preferably closed nanobubbles in thin polymer composite layers to be utilized as anti-reflective coatings for polymer foils or security features. The development of a continuous roll-to-roll application process is targeted, in which a viscous, liquid coating material with the precursors for the bubble forming gas is applied so that during the curing process, the gaseous reaction product is prevented from escaping, thus forming bubbles. This project is performed in cooperation with *InnovationCentre INM*.

focusing on the application of *Optical Materials*' transparent conductive materials for touch-sensitive controls. For architecture, they aim to develop esthetic, multifunctional, modular control panels as replacements of conventional light switches. For automotive interiors, flexible control elements on foil are being developed to be integrated into 3D formed parts of the dashboard, door coverings, etc. The contact with the SME partner was established by a novel proactive process and the research is funded by the German Federal Ministry for Economics BMWi.



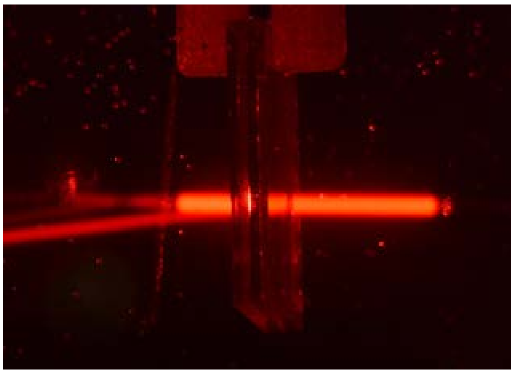


Fig. 1: Mesh of conductive fibers for transparent electrodes by electro-spinning.
Fig. 2: Coupling laser light into a planar waveguide using a grating of colloidal silver nanoparticles.

Plasmonic effects based on colloidal silver structures

This research is aimed at exploiting the plasmonic effects of silver nanoparticles for optical microstructures, such as gratings or waveguides. Surface plasmon resonance causes nanocomposites containing the particles to exhibit very characteristic features of spectral dispersion, which can be used to define wavelength-dependent refractive index and absorption profiles in a photochemical process at high resolution. The confinement of the electromagnetic field near the particle surface may enable specific effects such as enhanced nonlinear polarizability or improved sensitivity for chemical sensor applications. This research is funded by the German Federal Research Ministry BMBF.

Novel solutions for touch-sensitive control elements for architecture and automotive industry

A pair of ZIM projects with an SME partner is

OUTLOOK

The focus of the research and development tasks of *Optical Materials* will continue to be on novel structured materials interacting with light. Upcoming research topics are novel electrochromic systems with fast switching times, new refractive index adopted resins for glass fiber reinforced composite materials as robust, lightweight replacements for glass e. g. in aerospace applications or abrasion and corrosion protection layers for tools. These topics represent the group's patent strategy targeted at the exploitation of existing patent bases and the expansion by new patents into research fields being relevant to the market. Furthermore, the re-orientation of *Optical Materials*' acquisition strategy is supposed to result in the development of new instruments and sharpening the existing ones. *Optical Materials* will stay visible to industry and academia especially in application fields such as display technology, energy conversion, and active optics.

STRUKTURBILDUNG / STRUCTURE FORMATION

PROF. DR. TOBIAS KRAUS

ZUSAMMENFASSUNG

Der Programmbereich *Strukturbildung* erforscht die Bildung funktioneller Hybridmaterialien aus komplexen Flüssigkeiten. Wir untersuchen, wie sich dispergierte Metalle, Polymere, Keramiken und Biomoleküle zu Materialien verbinden und wie die entstehenden Strukturen ihre Eigenschaften bestimmen. Damit entwickeln wir Prozesse, um Materialien auf Längenskalen zwischen Nanometern und Millimetern gezielt zu strukturieren. Mit Druck-,Beschichtungstechniken und Hybridintegration können wir Materialien für Elektronik, Optik und Sensorik nah Raumtemperatur und an Luft verarbeiten. Die Eigenschaften der Materialien sind nichtlineare Kombinationen der Komponenteneigenschaften. Wir untersuchen grundlegende Wechselwirkungen zwischen Komponenten in Modellsystemen und ihre Auswirkungen während der Verarbeitung. Nachhaltiges Wirtschaften erfordert, dass Materialien am Ende ihrer Lebensdauer wieder in nutzbare Bausteine zerlegt werden können. Daher untersuchen wir, wie sich komplexe Hybridmaterialien während ihrer Lebensdauer verändern und wie Recycling durch das Materialdesign erleichtert werden kann.

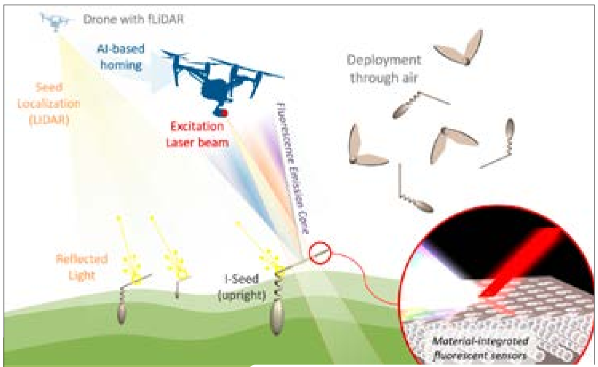
MISSION

The Program Division *Structure Formation* investigates the formation of hybrid materials from complex liquids. We study how metals, polymers, ceramics, and biomolecules join to form materials and how emerging structures affect their properties. In this way, we develop processes to specifically structure materials on length scales between nanometers and millimeters, allowing to process materials for electronics, optics and sensors by printing, coating, and hybrid integration near room temperature and in air. The properties of the materials are non-linear combinations of component properties. We investigate fundamental interactions between components in model systems and their effects during processing. Sustainable management requires that materials can be broken down into usable building blocks again at the end of their service life. Therefore, we investigate how complex hybrid materials change during their lifetimes and how recycling can be aided by materials design.

CURRENT RESEARCH

Sensor materials for sustainable robotic "I-Seeds"

Project "I-Seed" is funded by the EU (FET Proactive) and aims at artificial "seeds" that can be deployed to collect environmental data and degrade so they do not have to be recovered (https://iseedproject.eu/). Sensing of environmental parameters and their conversion into light signals are realized with a hybrid "sensor material" developed by INM. Drones deploy the seeds, detect them and transmit sensor readings (Fig. 1). The consortium links INM with soft robotics experts from Italian Institute of Technology, theoreticians modeling seed movement and design, drone-based imaging experts from Wageningen University and in Cyprus, and environmental data experts at CNR-IIA in Italy. The group at INM is developing the sensor materials. Mercury and temperature sensing are first targets. Integration into I-Seeds and the



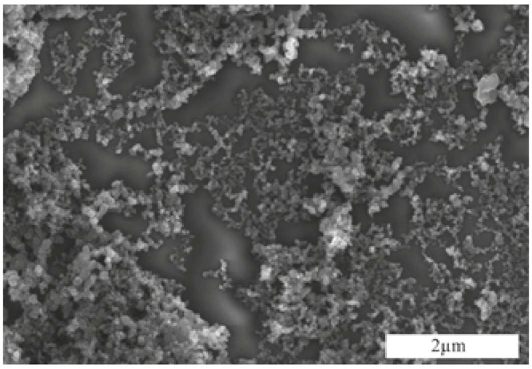


Fig. 1: Project I-Seed develops small, seed inspired robots that can be deployed through air, sense environmental parameters on ground and are read out optically by drones. (I-Seed Consortium/Italian Institute of Technology)

Fig. 2: Carbon Black networks consist of small primary particles connected in hierarchical structures. Electron micrographs enable us to reconstruct network features and correlate them with electrical properties.

choice of the optical wavelengths for readout will be done in collaboration with the partners.

Hybrid dielectrics

Is it possible to make dielectrics from gold? Not easily: dielectrics must be insulating, and gold is a good electrical conductor. Therefore, it is densely populated with mobile electrons that can be easily polarized, ideal for a dielectric with high energy storage capability. Our group solved this problem by fabricating small gold particles and electrically insulating them individually by polystyrene shells. Dispersions were then printed or coated onto electrodes and used to make capacitors with very thin dielectric layers. This new class of "hybrid dielectrics", which are printable, mechanically flexible, and can be prepared in air, was presented in *Advanced Materials*.

Carbon black networks in flexible conductors and beyond

Mechanically flexible electrical conductors are relevant for today's industry and for next generation soft robots. Current technology uses soot particles ("Carbon Black") to fill non-conductive elastomers and create conductive, flexible composites. The microstructure of these composites is highly complex because the Carbon Black has a hierarchical, fractal structure of aggregates (Fig. 2). A DFG-funded collaboration with Prof. Tanja Schilling (Uni Freiburg) and DESY lifted some of the mysteries of these composites. A joint publication in *Journal of Chemical Physics* explains that the fractal aggregates are decisive in making the composite electrically conductive; breaking them up in smaller units reduced conductivity. The project continues working on fundamental network structures fractal particles form, and on using additives to direct their structure. As Carbon Black is not the only conceivable conductive filler, we are investigating alternatives including combinations of metals, carbon, and organic semiconductors in several projects. For example, the BMBF-funded project sensIC requires stretchable conductors to be integrated into rubber hoses. The group is researching new materials with tailored combinations of components to achieve the required properties.

OUTLOOK

Research on multifunctional materials that combine various components and require multiple processing steps produces complex data. Industrial production of such materials is often challenging as properties of raw materials and minor deviations during processing affect product quality. Digitalization is a promising solution for this challenge. For example, the "DigiBatMat" project funded by BMBF and coordinated by Prof. Kraus will create the basis for digital data management of lithium-ion battery materials. It combines physicochemical and engineering knowledge about the components and their interactions with the electrical properties of the resulting batteries.

INNOVATIONSZENTRUM INM / INNOVATIONCENTER INM

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

INM InnovationCenter

ZUSAMMENFASSUNG

Das *InnovationsZentrum INM* ist die Schnittstelle zwischen den Wissensplattformen des INM und der Industrie. 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 durchgeführt und unterstützt, was aufgrund der – auch im Jahr 2021 weiterhin – besonderen Lage eine große Herausforderung darstellt. 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. Der Fokus im Berichtszeitraum lag auf dem Transfer ökologisch und ökonomisch nachhaltiger Technologien des INM in die Anwendung.

MISSION

The *InnovationCenter INM* is the interface between the knowledge-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 are executed and supported. Regarding the continuing special situation in 2021, this turned out to be challenging. 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 focus within the reporting period was on the transfer of ecologically and economically sustainable technologies of the INM into applications.

CURRENT RESEARCH & DEVELOPMENT

Energy Materials

In 2021, the *InnovationCenter INM* extended the energy research laboratory together with the Program Division *Energy Materials* and started establishing a second joint lab for battery-recycling and electrode fabrication. The idea is to bring disruptive results regarding battery materials, battery recycling, (selective) water deionization and hydrogen technology to an application relevant level. Besides the running

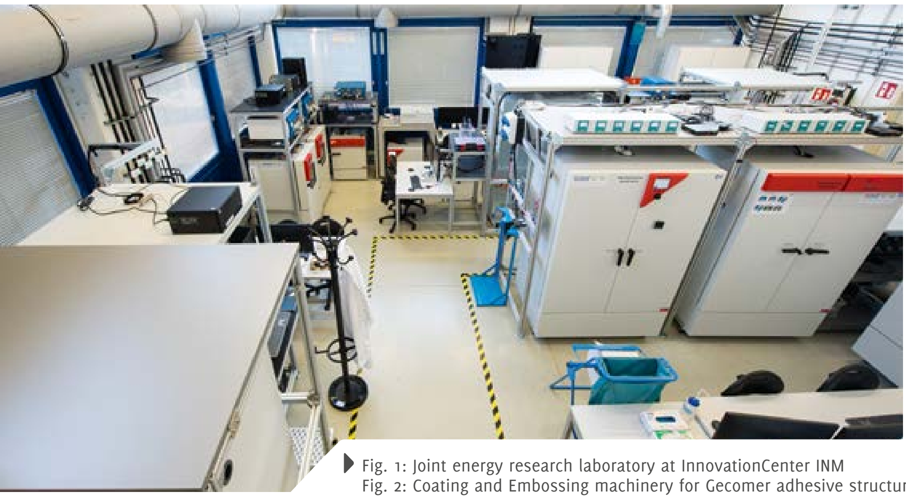


Fig. 1: Joint energy research laboratory at InnovationCenter INM
Fig. 2: Coating and Embossing machinery for Gecomer adhesive structures production

project “Merlin” on lithium extraction from mining water, we started an industry funded project on battery recycling in cooperation with and headed by the Program Division *Energy Materials*. Further project proposals (public and industry funded) where submitted with an start envisaged in 2022.

Biomedical materials

A second focus of the *InnovationCenter INM* was to prepare for the future INM initiative “Biomedical materials”. The aim is to support application oriented activities regarding hydrogels for biomedical applications. Within the EU-funded project “Mechanocontrol” (EU FET-Open, PI: Prof. del Campo), the InnovationCenter INM takes care about market analysis, freedom to operate analysis (together with patent lawyers), IP-strategy, business plan, and building of demonstrators.

Pick&Place-Technology

The aim of the industry-project “GecoSHAPE” is to develop specific Gecomer® adhesive structures and gripping tools based on them, for handling sensitive products, especially components for the assembly of lithium-ion batteries in stack design. According to the VDMA Roadmap Battery Production Equipment 2030 it is expected that future cell generations such as the lithium metal battery can be manufactured much better with stacking than with winding technologies. Another advantage of stacking over winding is better heat control or dissipation when the cell is in operation, which can ensure enhanced safety and longevity of the cell.

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. 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.

Dr. Karsten Moh

Dr. Peter W. de Oliveira

SERVICEBEREICHE / SERVICE GROUPS

CHEMISCHE ANALYTIK / CHEMICAL ANALYTICS

DR. CLAUDIA FINK-STRAUBE

Die Servicegruppe *Chemische Analytik* bietet ihre analytische Expertise als Dienstleistung für die Programmbereiche des INM, die Universität des Saarlandes sowie Externe an. Die analytische Begleitung und Unterstützung interner Forschungsprojekte bis hin zur Qualitätskontrolle der entwickelten Materialien gelingt durch moderne Analyseverfahren der Elementanalytik (CHNOS, AAS, GFAAS, ICP-OES, HR- SF ICP-MS), Chromatographie (GC, Headspace-GC, HPLC mit IR, DAD, ELSD, GPC) und Massenspektrometrie (GC/MS, LC-ESI HR-Q-TOF) inklusive Präparationsmethoden (Säure/Schmelzaufschluss, Mikrowellenaufschluss, Hochdruckaufschluss). Im Rahmen von Praktika erhalten Schüler, Azubis und Studierende einen Einblick in die Methodik chemisch-analytischer Verfahren am INM.

PHYSIKALISCHE ANALYTIK / PHYSICAL ANALYTICS

DR. MARCUS KOCH

Die Servicegruppe *Physikalische Analytik* führt schwerpunktmäßig elektronenoptische und röntgenspektralanalytische Untersuchungen durch. Dafür stehen ein Rasterelektronenmikroskop (REM), ein Transmissionselektronenmikroskop (TEM) sowie ein Zweistrahlgerät (FIB) zur Verfügung. Für eine gezielte Probenpräparation im Nanometerbereich gibt es die Ultramikrotomie, eine Nanomill und einen Plunge-Freezer. Mit Hilfe dieses Gerätes lassen sich z. B. biologische Proben oder Nanopartikellösungen schockfrieren und mittels Kryoelektronenmikroskopie untersuchen. Die zahlreichen Methoden werden in Zusammenarbeit mit Gruppen aus dem Institut und dem universitären Umfeld angewendet. Einblicke in die Techniken werden auch im Rahmen von Schüler-Praktika und Industriekooperationen gegeben.

WERKSTATT / WORKSHOP

DIPL.-ING. KARL-PETER SCHMITT

Der Servicebereich *Werkstatt* besteht aus der mechanischen Werkstatt und der Elektrowerkstatt. Beide Gruppen unterstützen die am INM durchgeführten Forschungs- und Entwicklungsprojekte in der Entwicklung und Herstellung von Anlagen und Komponenten zur Projektbearbeitung. Neben der Planung und Konstruktion werden Geräte und Maschinen zudem gewartet, repariert oder nach Nutzervorgaben modifiziert. Neben den klassischen Fertigungsarten für den Prototypenbau steht auch eine Massenfertigung von Werkstücken durch automatisierte Fertigungsprozesse zur Verfügung. Wir bieten jedes Jahr Ausbildungsstellen als Industriemechaniker*in und Elektroniker*in für Betriebstechnik an und führen Praktika für Schüler*innen durch.

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 UdS. Für Wissenschaftler*innen des INM erbringt die NTNM-Bibliothek forschungsunterstützende Dienstleistungen. 2021 wurde ein Antrag der Bibliothek im DFG-Förderprogramm „Open-Access-Publikationskosten“ bewilligt. Für die Laufzeit 2022 bis 2024 werden dem INM damit finanzielle Mittel zur Förderung von Open-Access-Publikationen zur Verfügung gestellt. Die Zuschüsse sollen zentral in der Bibliothek verwaltet werden. Ziel des Förderprogramms ist, künftig automatisiert Aussagen über Anzahl und Kosten von INM-Publikationen treffen zu können. Der Anteil der Open Access-Publikationen des INM bei Beiträgen in referierten Zeitschriften konnte von 46 % (2020) auf 49 % (2021) erhöht werden.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PRUSSIAN BLUE AND ITS DERIVATIVES: SUSTAINABLE NEXT-GENERATION BATTERIES

SAMANTHA HUSMANN, BEHNOOSH BORNAMEHR, VOLKER PRESSER, KARSTEN MOH
ENERGY MATERIALS & INNOVATION CENTER INM

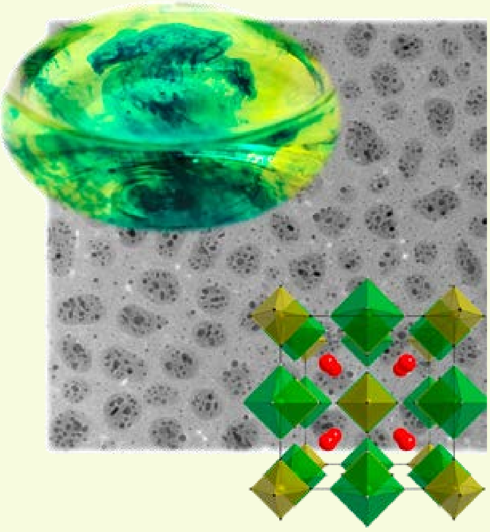


Fig. 1: Prussian blue particles and structure used as a template for high-capacity battery materials.

Developing an efficient, clean, and renewable energy grid is an urgent necessity for reaching the global climate goals. Portable and stationary rechargeable batteries are within the many energy-related technologies that require fast progress in this context. For example, batteries can still represent up to a third of electric vehicles emissions due to their manufacturing process and a lack of end-of-life management. Developing fundamentally sustainable battery materials and electrode processing is a central strategy for efficient battery recycling. One essential requirement of next-generation battery technologies is substituting costly elements like Li and Co by widely – and more evenly – available ones like Na and Fe in electrode materials. This implies the development of new energy storage materials and synthesis methods.

Prussian blue and analogues (PBA) are low-cost and environmentally friendly metal complexes. Their inherent porous structure, tuneable lattice, and stable framework capable of buffering volumetric variations make PBA ideal and versatile template materials. The DFG-funded project will explore the derivatization of copper and iron-based PBA into high-capacity metal sulfides. Morphology and composition of electrode materials have a decisive effect on battery performance. Therefore, it is fundamental to understand the PBA derivatization process to enable control over derivative characteristics. By controlling particle size, composition, and morphology, conductive and long-term electrochemically stable metal sulfides can be designed. The preparation of a low-cost, efficient battery electrode by a comparably cheap and green method and precursors is the ideal path towards sustainable and circular energy storage, which PBA templating has the potential to fulfill.

FUEL CELL DESALINATION PROVIDES CLEAN WATER FOR HYDROGEN PRODUCTION

YUAN ZHANG, KARSTEN MOH, VOLKER PRESSER
ENERGY MATERIALS & INNOVATIONCENTER INM

Hydrogen is a critical enabling element for sustainable technologies and indispensable for the decarbonization of the steel industry. However, large-scale use of hydrogen must be met by large-scale hydrogen production, for example, from water via electrolysis. Based on current technology, it is not possible to directly use the most significant water source on this planet, seawater. Therefore, the need for lowering the salinity necessitates the use of energy-efficient desalination technologies. For many years, the Program Division *Energy Materials* and the *InnovationCenter INM* have explored energy-efficient desalination technologies based on supercapacitor and battery technology. Now, we have expanded to electrocatalytic reactions by modifying a typical fuel cell.

The INM fuel cell desalination system consumes hydrogen and oxygen. However, the electrocatalytic reactions are not compensated by the flow of protons, like in a typical fuel cell. By adding a flow channel in-between the two fuel cell electrodes, the system can achieve charge compensation by continuously up-taking salt from inflowing seawater. Concurrently, the system generates an acid (HCl), a base (NaOH), and electricity in addition to a constant stream of desalted water. The latter can be fed into an electrolyzer to split the desalinated water into H_2 and O_2. Since the desalination process will consume only small amounts of the produced H_2, we can use the concept of fuel cell desalination for large-scale use of seawater for power-to-gas facilities. The byproduct of acid and base can also be used for harvesting thermal energy in addition to the generated electrical energy.

Y. Zhang, L. Wang, V. Presser, Electrocatalytic fuel cell desalination for continuous energy and freshwater generation, Cell Rep. Phys. Sci. 2(5) (2021) 100416.
M. E. Suss, Y. Zhang, I. Atlas, Y. Gendel, E. B. Ruck, V. Presser, Emerging, hydrogen-driven electrochemical water purification, Electrochem. Commun. 136 (2022) 107211.

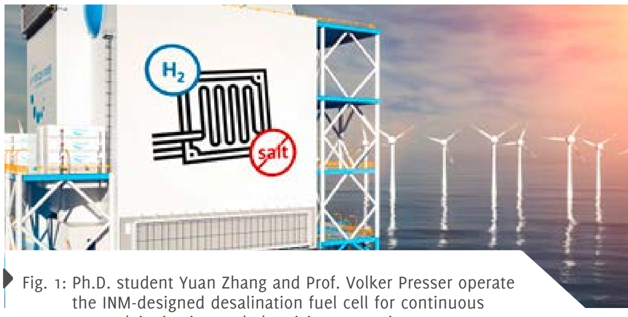
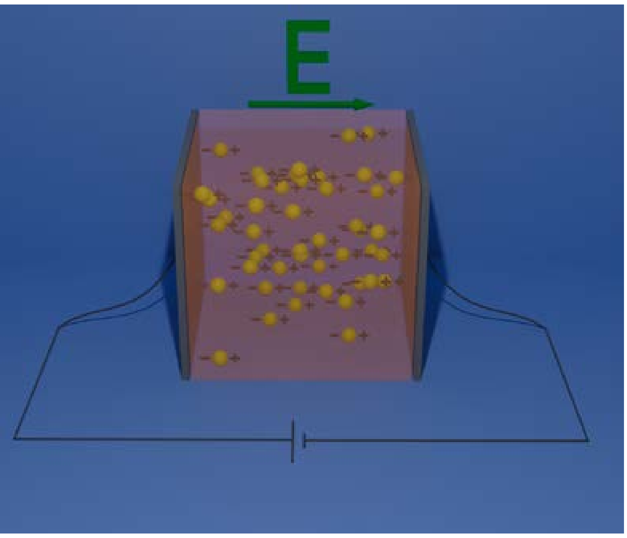


Fig. 1: Ph.D. student Yuan Zhang and Prof. Volker Presser operate the INM-designed desalination fuel cell for continuous water deionization and electricity generation.
Fig. 2: The grand vision for the fuel cell desalination technology is to be applied on large scale within the context of hydrogen production from seawater via power-to-gas.

HYBRID DIELECTRIC LAYERS: FLEXIBLE, PRINTABLE, AND TUNABLE

ROMAN BUCHHEIT, BJÖRN KUTTICH, LOLA GONZÁLEZ-GARCÍA, TOBIAS KRAUS
STRUCTURE FORMATION



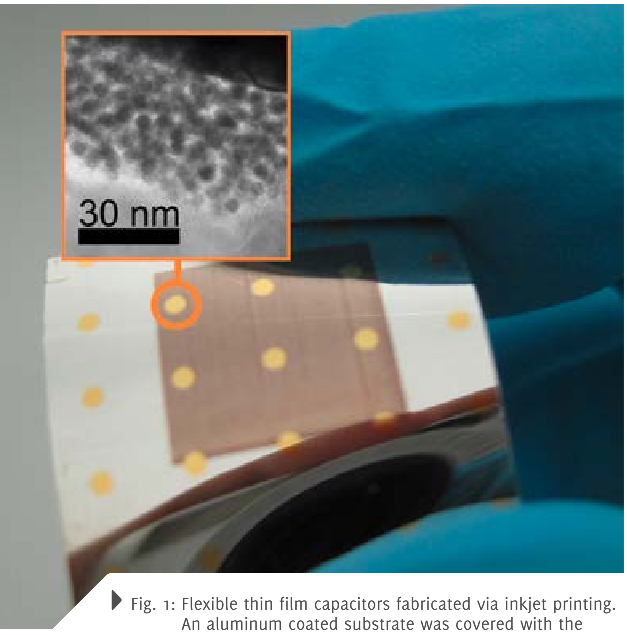


Fig. 1: Flexible thin film capacitors fabricated via inkjet printing. An aluminum coated substrate was covered with the printed dielectrics and contacted with evaporated gold (see cross section in inset).
Fig. 2: Hybrid dielectric layers consist of metallic nanoparticles with covalently bound, insulating polymer. The electrical field polarized the metal-shell interfaces, causing large dielectric constants.

Dielectric layers are crucial parts of all electronic circuitry. Hybrid dielectric materials that combine inorganic with organic components are an interesting alternative to conventional oxide or nitride layers because they can be printed, they are mechanically flexible, and their properties can be tuned in a wide range. Composites of metal nanoparticles in a polymer matrix are inherently limited: the disordered arrangement of the metal entails the risk of short-circuits. The Program Division Structure Formation has developed new class of hybrid dielectrics based on metallic nanoparticles that are individually insulated and assembled into dense films. Gold cores were covered with covalently attached polystyrene shells and deposited as films. An electric field accumulates charges at the metal-polymer interfaces, which leads to high dielectric constants and the ability to store charge in small volumes (Fig. 1).

We used the hybrid dielectric to fabricate thin film capacitors via spin coating and inkjet printing. Metal cores with diameters below 10 nm and covalently attached polymer enable ultrathin dielectric layers (below 100 nm) with comparatively high metal volume fractions. We tuned the dielectric properties by variation of the polymer shell and the metallic core size. The dielectric constant of the hybrids mainly depend on the metal's volume fraction and increase independent of the exact structure of the layer. Particle packing did affect dielectric losses. We were able to tune the order of the particle packing and found that regular packings had lower dielectric losses than random arrangements. The materials were applied to inkjet-printed mechanically flexible capacitors on aluminum coated PET foils (Fig. 2).

R. Buchheit, B. Kuttich, L. González-García, T. Kraus, Adv Mat (2021), 33 (41), 2103087

NEW FUNCTIONAL MICROSTRUCTURES ON THE PATH TO CLINICAL APPLICATION

GABRIELA MOREIRA LANA[1], RENÉ HENSEL[1], EDUARD ARZT[1],
KATHARINA SORG[2], GENTIANA WENZEL[2], BERNHARD SCHICK[2]
[1]FUNCTIONAL MICROSTRUCTURES, [2]SAARLAND UNIVERSITY MEDICAL CENTER

Functional microstructures developed at INM receive increased attention for biomedical applications: In close cooperation with the Department of Otorhinolaryngology, we developed a microstructured silicone patch for the treatment of tympanic membrane perforations. Eardrum injuries are a frequent medical condition that dramatically impacts a patients' life. Surgical procedures are costly and involve anesthesia and temporary closure of the ear canal.

Self-adhesive micropillar structures, initially developed for handling and robotics, were upgraded for adhesion to biological surfaces. Topped by a Soft Skin Adhesive (SSA) terminal layer, the film-terminated microstructure exhibits effective adhesion even to the rough surface of skin. Adhesion was evaluated against rigid substrates of various roughness and, using a specially designed tack test, against explanted mouse eardrums. The subsurface microstructure was found to also dampen any impact, protecting the sensitive membrane during surgical application. Long-term animal tests confirmed accelerated, high-quality healing of the injured eardrums with reduced scar formation. Using auditory brainstem responses (ABRs) and distortion product otoacoustic emissions (DPOAE), partial recovery of hearing performance immediately after patch application was confirmed.

The proposed material design holds great promise for improving clinical treatment of tympanic membrane perforations. Other applications of the glue-free biomedical adhesives are expected, such as skin contact in health monitoring and wearable computer interfaces. The link to our clinical collaborators produced another interesting synergy: self-adhesive films provided to the clinic substantially enhanced the transmitted amplitudes during optoacoustic stimulation – a promising approach for novel auditory prostheses.

G. Moreira Lana, K. Sorg, G. I. Wenzel, D. Hecker, R. Hensel, B. Schick, K. Kruttwig, E. Arzt, Adv. NanoBiomed Res. (2021), 1(10): 2170101.
K. Sorg, L. Heimann, G. Moreira Lana, A. Langenbucher, B. Schick, E. Arzt, G. I. Wenzel, J. Biomed. Optics (2021), 26(9): 098001

Fig. 1: Bioinspired adhesives for new treatment of eardrum perforations (top); applied patch on perforated mouse eardrum, SEM micrograph of the microstructure (bottom).

INM FELLOW INVESTIGATES ADHESIVE PHENOMENA

MARTIN MUESER

Originally from Saarbruecken, Martin Mueser received most of his academic education outside of Saarland and started his academic career overseas before returning home. In 1986 he started undergraduate studies in physics at RWTH Aachen, before he spent a year as an exchange student at INSA Lyon and finished his diploma at Saarland University. He completed his PhD in theoretical physics at Johannes Gutenberg University in Mainz, where he later completed a habilitation. He had been postdoc both at Columbia and Johns Hopkins University. From 2002, became professor in applied mathematics at University of Western Ontario in London, Canada. After a sabbatical T J Watson RC, IBM, he went to Saarland University where he holds the chair of materials simulation since 2009, also heading the computational materials physics group in Juelich Supercomputing Centre at FZ Juelich. Since 2021 he cooperates with INM as INM-fellow on pressing issues around sticky systems. His research evolves mainly around the simulation of non-equilibrium processes in hard and soft matter.

Adhesion is a well-known phenomenon with desired and unwanted effects. It makes a bandage stick to our skin inducing pain when pulled off. Despite its apparent simplicity, adhesion is surprisingly little understood. One of the difficulties in the description of adhesive systems are the complications arising from complex, multi-scale surface roughness and the coupling of surface interactions with visco-elastic properties of matter in contact. So far, combination of these two made it impossible to predict the load that pick-and-drop devices can carry and hence impeded a rational design. A first result of Mueser's INM inspired work is that the toughness of adhesive joints is largest at intermediate pull-off velocities. Mueser and coworkers at INM also managed the first real time comparison of contact formation and the following removal of a flat punch with small-scale roughness from an adhesive, viscoelastic foundation. These calculations are challenging because the dissipation impeding contact formation and destruction originate from very small scales at small times but predictions must be made for large time and length scales. The relevance of the calculations is not only scientific but matters in every-day devices and help industry to address their Monday morning problem: The sticking of hydraulic valves in production engines after machines and operators took a weekend rest.

THREE QUESTIONS TO LOLA GONZÁLEZ-GARCÍA

Lola González-García studied chemistry and materials science in Sevilla (Spain), where she also obtained her PhD degree in 2013. After that, she moved to Saarbruecken as postdoctoral researcher at INM in the program division *Structure Formation* to work with particle-based materials and focused on printing electronics. Since January 2021, she is head of the *Junior Research Group Electrofluids* at INM funded by the ERC-Starting Grant program.

CAN YOU GIVE US AN IDEA OF WHAT ELECTROFLUIDS ARE?

Electrofluids are highly concentrated suspensions of conductive particles that conduct electrons while flowing. The idea is to bring the advantages of the mechanoelectrical properties of liquid metals at the cost of classical elastomeric composites. One could think in their application in the field of truly soft robots as it would be like the “blood”, through which all the stimuli, signals, and orders are transmitted and, at the same time, can readapt to changes in geometry not altering their properties.

WHAT FASCINATES YOU ABOUT THIS RESEARCH AREA?

The system that I proposed in the ERC Starting Grant and, on which we focus the current research of the group, might sound simple at first glance. However, once one starts considering the interactions between the components and all the variables in the system, for instance the shape of the particles, the nature of the liquid, or even think in more complex combinations mixing various components, one realizes that the possibilities expand, and many open questions remain unexplored. It is exciting how, even nowadays, simple ideas hide unexplored science.

YOUR RESEARCH GROUP RECEIVES FUNDING FROM AN ERC GRANT FOR FIVE YEARS. WHAT WOULD YOU LOVE TO ACHIEVE IN THESE FIVE YEARS?

A better understanding of the Electrofluids. This short sentence probably summarizes any scientific project aim. I make research to gain a comprehensive knowledge about the materials to be able to apply them in a rational way. If I would have to put in one sentence all the milestones planned in the project, I could say that our objective is to understand the interactions between components to link the network structure and particle contacts to the rheoelectrical properties of the material for their device integration.

CISCEM 2021 – 5TH INTERNATIONAL CONFERENCE ON IN-SITU AND CORRELATIVE ELECTRON MICROSCOPY

NIELS DE JONGE AND CHRISTINE HARTMANN
INNOVATIVE ELECTRON MICROSCOPY

The 5th International Conference on In-situ and Correlative Electron Microscopy (CISCEM) was held in Paris from 8 to 10 September 2021. Despite the worldwide Corona restrictions, the hybrid format of the conference made it possible to bring together 75 on-site and 57 remote participants from 17 countries.

In the continuity of the last four conferences, the topics of CISCEM 2021 included dynamical nanoscale and atomic-scale studies of biological samples and functional materials under realistic or near realistic conditions, e. g., in gaseous environments, at elevated temperatures, and in liquid. Progress in the field benefits from the cross-fertilization of expertise and ideas obtained using the different available methods for time-resolved imaging of physical, chemical, and biological processes, thus inspiring the development of new capabilities across disciplines. Scientific questions discussed included: Can we obtain novel information about the structure and function of proteins and cells with in-situ TEM? How can we study the dynamics of beam-sensitive soft-/bio-materials? How to provide quantitative and multiscale information on nanomaterial synthesis? How can technical developments or artificial intelligence extend the time and spatial resolutions in the complex environment?

CISCEM was organized by Niels de Jonge (INM), Damien Alloyeau (CNRS / Université de Paris) and Kristian Molhave (DTU Denmark) and supported by CNRS (Conseil National de la Recherche Scientifique), the Nanoperando group and the University of Paris. Several manufacturers of microscopy systems presented their products and methods on-site. The conference abstracts were published in an online edition of the journal Microscopy and Microanalysis.

SECOND CONFERENCE ON ENGINEERED LIVING MATERIALS: THE STUFF THE FUTURE IS MADE OF

MARIO QUILITZ, SHRIKRISHNAN SANKARAN AND ARÁNZAZU DEL CAMPO
BIOPROGRAMMABLE MATERIALS, DYNAMIC BIOMATERIALS

Self-ventilating sportswear, bio-plastics that dissolve after use, or implants for the long-term and personalized delivery of drugs to the body are just a few examples of the application of so-called "living materials". These materials were the focus of the 2nd International Conference on Engineered Living Materials, which took place as a virtual event from May 4 – 7, 2021.

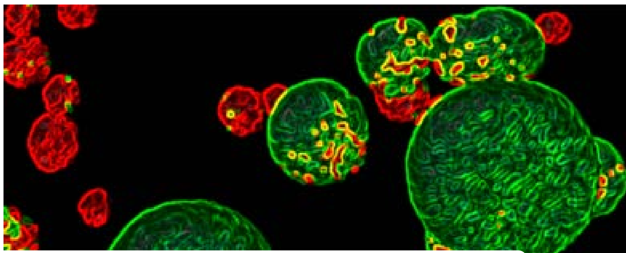
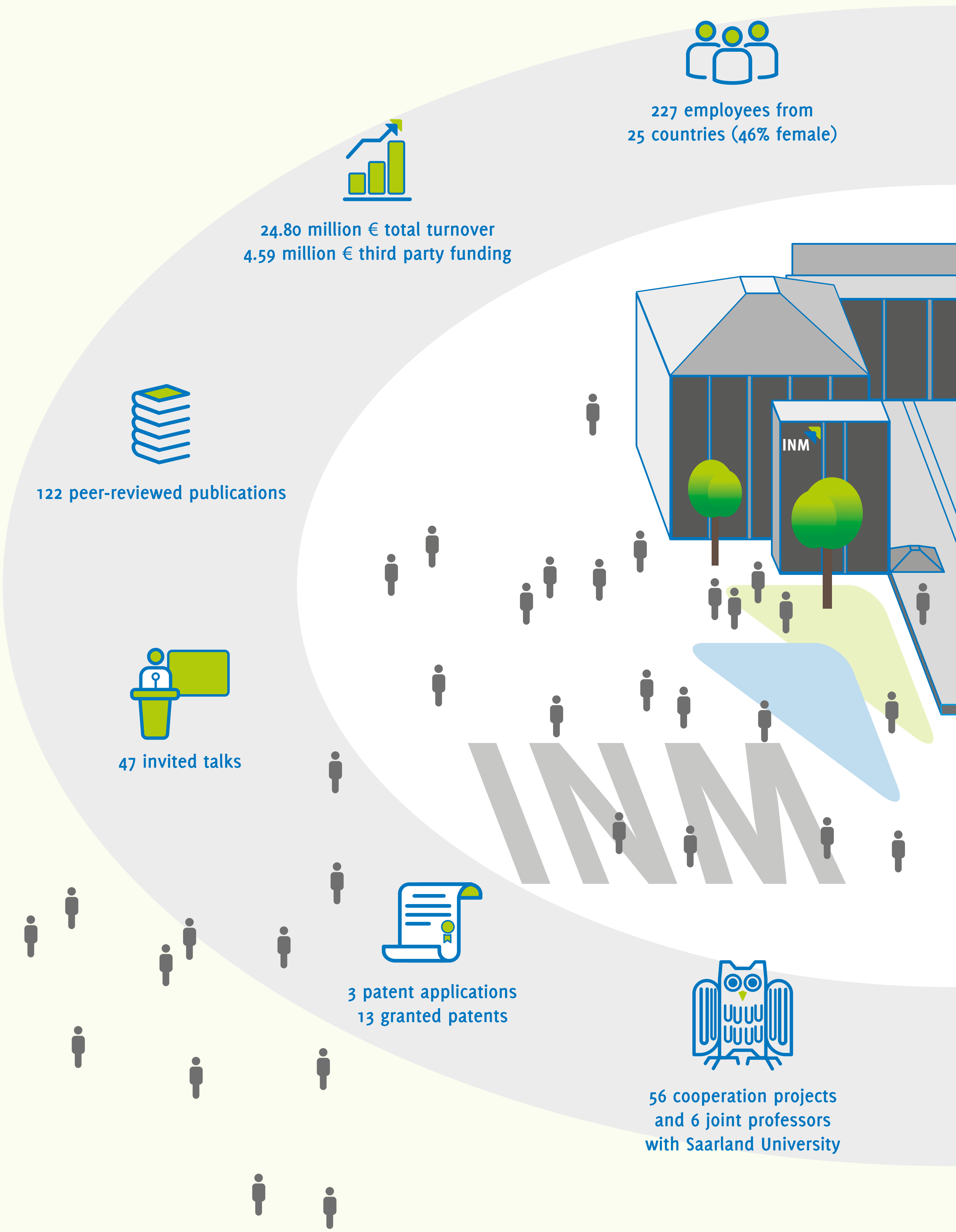


Fig.: Bacterial colonies encapsulated in hydrogel, their size and shape controlled by the mechanical properties of the material.

In February 2020, 100 experts met for the first time in Saarbrücken to shed light on the still young field of research from a wide variety of perspectives. Thanks to the possibilities now offered by the virtual world, more than 300 scientists accepted the organizers' invitation to the second conference. Materials scientists, synthetic biologists, biotechnology engineers, and biophysicists from all over the world came together to discuss the science and potential applications of the rapidly developing area. The key topics of the conference were: Bioprogrammable functions, living therapeutic materials, technical applications of engineered living materials and understanding bacteria in confinement.

The concept of Living Materials is a newly emerged paradigm. In this novel synthesis, living cells are fused into non-living matter to provide it with programmable, life-like capabilities thus creating a whole new variety of high-performance material systems. Engineered Living Materials open new routes to more sustainable material production and advanced property combinations like self-regeneration of the material after damage, flexible adaptation to environmental stimuli, or extreme longevity.

The conference was organized by the *Leibniz ScienceCampus Living Therapeutic Materials*. It was chaired by Aránzazu del Campo and Shrikrishnan Sankaran from INM together with Wilfried Weber from Freiburg University. The next conference in this successful event series will take place in June 2022.


227 employees from
25 countries (46% female)
24.80 million € total turnover
4.59 million € third party funding
122 peer-reviewed publications
47 invited talks
3 patent applications
13 granted patents
56 cooperation projects
and 6 joint professors
with Saarland University
INM
INM

FAKTEN UND ZAHLEN 2021 / FACTS AND FIGURES 2021

105 scientists (37 % female)
thereof: 39 doctoral students (49 % female)

8 doctoral theses
6 master theses
4 bachelor theses

Teaching 46,3 weekly hours per year

15 symposia, colloquia and other events

Cooperations with 51 institutions in Germany

International cooperations with 49 institutions from 19 countries

AUSGEWÄHLTE PUBLIKATIONEN / SELECTED PUBLICATIONS

I. Tavernaro, S. Dekkers, L. G. Soeteman-Hernandez, P. Herbeck-Engel, C. Noorlander, A. Kraegeloh,
Safe-by-Design part II: A strategy for balancing safety and functionality in the different stages of the
Nanoimpact (2021) 24, 100354

Q. Wang, L. Velasco, B. Breitung and V. Presser
High-Entropy Energy Materials in the Age of Big Data: A Critical Guide to Next-Generation Synthesis and Applications
Advanced Energy Materials 2021, 11, (47), 2102355

I. K. Backes, L. González-García, A. Holtsch, F. Müller, K. Jacobs, T. Kraus
Molecular Origin of Electrical Conductivity in Gold–Polythiophene Hybrid Particle Films
Journal of Physical Chemistry Letters (2020) 11, 24, 10538

R. Buchheit, B. Kuttich, L. González-García and T. Kraus
Hybrid Dielectric Films of Inkjet-Printable Core–Shell Nanoparticles
Advanced Materials 2021, 33, (41), 2103087

S. Bettscheider, B. Kuttich, L. F. Engel, L. González-García, T. Kraus
Bundling of Nanowires Induced by Unbound Ligand
The Journal of Physical Chemistry C 125 (6), 3590-3598

Y. Zheng, M. K. L. Han, R. Zhao, J. Blass, J. Zhang, D. W. Zhou, J.-R. Colard-Itté, D. Dattler, A. Çolak, M. Hoth, A. J. García, B. Qu, R. Bennewitz, N. Giuseppone and A. del Campo
Optoregulated force application to cellular receptors using molecular motors
Nature Communications 2021, 12, (1), 3580

A. Rodrigo-Navarro, S. Sankaran, M. J. Dalby, A. del Campo and M. Salmeron-Sanchez
Engineered living biomaterials
Nature Reviews Materials 2021, 6, 1175–1190

G. Moreira Lana, K. Sorg, G. I. Wenzel, D. Hecker, R. Hensel, B. Schick, K. Kruttwig and E. Arzt
Self-Adhesive Silicone Microstructures for the Treatment of Tympanic Membrane Perforations
Advanced NanoBiomed Research 2021, 1, 2100057

D. B. Peckys, D. Gaa and N. de Jonge
Quantification of EGFR-HER2 Heterodimers in HER2-Overexpressing Breast Cancer Cells Using Liquid-Phase Electron Microscopy
Cells 2021, 10, (11), 3244

E. Arzt, H. Quan, R. M. McMeeking and R. Hensel
Functional surface microstructures inspired by nature – from adhesion and wetting principles to sustainable new devices
Progress in Materials Science 2021, 119, 100778

DAS INM IN ZAHLEN / INM IN FIGURES

Stand / As of: 28.02.2022

DAS INM IN ZAHLEN

Im Jahr 2021 betrug der **Gesamtumsatz** des INM 24,80 Mio. Euro.

Erlöse aus der gemeinsamen Finanzierung durch den Bund und die Länder (**institutionelle Förderung**): 19,83 Mio. €,
- davon Personal- und Sachaufwendungen: 15,58 Mio. €,
- und für Investitionen: 4,25 Mio. €

Drittmittelerlöse: 4,59 Mio. €
- davon 4,05 Mio. € aus öffentlichen Förderungen,
- und 0,54 Mio. € aus Vereinbarungen mit Industrieunternehmen.

Sonstige betriebliche Erträge: 0,38 Mio. €

Das INM hatte Ende 2021 **227 Beschäftigte** (123 m, 104 w), davon

- 66 Wissenschaftler/innen (46 m, 20 w),
- 39 Promovierende (20 m, 19 w),
- 53 Beschäftigte (29 m, 24 w) in den Bereichen Labor, Technik und Service,
- 33 Beschäftigte (9 m, 24 w) in der Verwaltung und den Sekretariaten,
- 30 Hiwis (17 m, 13 w) und 6 Auszubildende (2 m, 4 w).

INM IN FIGURES

In 2021, the **total turnover** of INM added up to 24.80 million euro.

Proceeds from the **joint financial support** by the federal government and the federal states (institutional funding): 19.83 million €,
- including expenses for personnel and materials: 15.58 million €,
- and for investments: 4.25 million €.

Proceeds from **third party funding:** 4.59 million €
- including 4.05 million € from public funding,
- and 0.54 million € from industrial contacts.

Other operating income: 0.38 million €

At the end of 2021, **227 employees** (123 m, 104 f) worked at INM including:

- 66 scientists (46 m, 20 f),
- 39 doctoral students (20 m, 19 f),
- 53 employees (29 m, 24 f) in laboratories and technical services,
- 33 employees (9 m, 24 f) in administration and secretarial offices,
- 30 graduate assistants (17 m, 13 f) and 6 apprentices (2 m, 4 f).

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

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

Stand / As of: 31.12.2021

MITGLIEDER DES KURATORIUMS / MEMBERS OF THE BOARD OF TRUSTEES

MITGLIEDER DES WISSENSCHAFTLICHEN BEIRATS / MEMBERS OF THE SCIENTIFIC ADVISORY BOARD

DISSERTATIONEN / DOCTORAL THESES

DISSERTATIONEN / DOCTORAL THESES

Öznil Budak
Metal oxide/carbon hybrid anode materials for lithium-ion batteries
Universität des Saarlandes
Prof. Dr. G. Kickelbick

Desna Joseph
Light responsive cell-cell like biointerface using cadherin peptidomimetics
Universität des Saarlandes
Prof. Dr. A. del Campo

Thomas Kister
The stability and assembly of sterically stabilized non-polar nanoparticles
Universität des Saarlandes
Prof. Dr. T. Kraus

Haoran Ma
Nanotribology of Metallic Glasses in Corrosive Environments
Universität des Saarlandes
Prof. Dr. E. Arzt, Prof. Dr. R. Bennewitz

Zahra Mostajeran
The influence of vimentin on actin dynamics and force generation in RPE1 cells
Universität des Saarlandes
Prof. Dr. F. Lautenschläger

Julia Purtov
Bio-Inspired Photonic Surfaces by Enhanced Two-Photon Lithography
Universität des Saarlandes
Prof. Dr. E. Arzt

Fatih Puza
Fabrication of Physically Crosslinked Hydrogel Materials Good Mechanical Properties
Universität des Saarlandes
Prof. Dr. A. del Campo

Maria Villiou
Photodegradable Hydrogels for tissue gluing
Universität des Saarlandes
Prof. Dr. A. del Campo

ABSCHLUSSARBEITEN / THESES

MASTERARBEITEN / MASTER THESES

Alisa Gläser
Expanding the versatility of firefly-inspired hydrogels for cell encapsulation
Universität des Saarlandes
Prof. Dr. A. del Campo

David Iwanowitsch
System Engineering and Characterization of Carbon Black-Based Pastes Under Uniaxial Strain for Soft Electronic Applications
Hochschule Kaiserslautern, Campus Zweibrücken
Dr. L. Gonzalez

Tobias Valentin Knapp
Electrical Conductivity of Hybrid Ultrathin Gold Nanowires and Their Three-Dimensional Networks
Universität des Saarlandes
Prof. Dr. T. Kraus

Mengxiao Li
Activity of hydrogel-encapsulated cells monitored by atomic force microscopy
Universität des Saarlands
Prof. Dr. R. Bennewitz

Kristela Shehu
Modulation of in vitro mucus as a strategy to improve nanoparticle transport through mucus
Universität des Saarlandes
Arbeit angefertigt in der Gruppe Nano Zell Interaktionen am INM und Professur für Biopharmazie und Pharmazeutische Technologie, UdS
Prof. Dr. M. Schneider, PD Dr. habil. A. Kraegeloh

Therese Steudter
Photodegradable-On-Command Hydrogels: Synthesis and Characterization of Photodegradable, Hydrolytically-Stable Prepolymers
Universität des Saarlandes
Prof. Dr. A. del Campo

BACHELORARBEITEN / BACHELOR THESES

Tobias Däinghaus
Decipher the cocktail activity of photoactivatable H47Y<ONBY and small molecule collagenase inhibitors in an ex vivo skin wound infection model
Universität des Saarlandes, Saarbrücken
Prof. Dr. A. del Campo

Maja Fehlberg
Wahrnehmung von Fingerspitzenreibung gegen mikrostrukturierte Oberflächen
Universität des Saarlands
Prof. Dr. R. Bennewitz

Kim Michèle Jost
Haptische Wahrnehmung von Papier
Universität des Saarlands
Prof. Dr. R. Bennewitz

Yassine Othmane
Kinetische Untersuchungen bei der photochemischen Silberabscheidung
Universität des Saarlandes
Prof. Dr. G. Kickelbick, Dr. P. W. de Oliveira

AUSZEICHNUNGEN / AWARDS

Eduard Arzt
Adhesion Society Award for Excellence
Adhesion Society USA, 22.02.2021

Simon Bettscheider
Promotionsstipendium
Studentenförderwerk Klaus Murmann Stiftung der Deutschen Wirtschaft

Shardul Bhusari
3rd prize, Lifemat-at-a-glance Short Video Contest 2021
Leibniz Science Campus Living Therapeutic Materials, 15.10.2021

Priyanka Dhakane
1st prize, Lifemat-at-a-glance Short Video Contest 2021
Leibniz Science Campus Living Therapeutic Materials, 15.10.2021

Usama Farrukh
DAAD Fellowship
Deutscher Akademischer Auslandsdienst 2021

Samantha Husmann
Outstanding Oral Presentation
II Frontiers in Electrochemistry and Electroanalytics: Advances made by Young Female Scientists
Royal Society of Chemistry

Gülistan Kocer
Auswahl zum Leibniz-Mentoring-Programm
Leibniz-Gemeinschaft 2021

Marcus Koch
PHOENIX Pharmazie Wissenschaftspreis 2021
4. Kategorie: Pharmazeutische Technologie
(mit anderen Autoren der Publikation in Angewandte Chemie 59, 10292-10296 (2020))
Phoenix Group, 23.09.2021

Julieta Paez
Call on an Assistant Professorship
University of Twente, The Netherlands, 2021

Volker Presser
Highly Cited Researcher
Clarivate Analytics, 16.11.2021

Maria Puertas Bartolome
Julia Polak European Doctoral Award 2021
European Society for Biomaterials, 06.09.2021

Shrikrishnan Sankaran
Auswahl zur Leibniz Leadership Academy
Leibniz-Gemeinschaft

Shrikrishnan Sankaran
STS Young Leaders Program
Science and Technology in Society Forum, 05.10.2021

Xuan Zhang
Auswahl zum Leibniz-Mentoring-Programm
Leibniz-Gemeinschaft 2021

REFERIERTE PUBLIKATIONEN / PEER-REVIEWED PUBLICATIONS

156 Publikationen
publications
davon / *including*

122 Publikationen in referierten Zeitschriften
publications in peer-reviewed journals

34 sonstige Publikationen
other publications

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

60 Beiträge in referierten Zeitschriften
contributions in peer-reviewed journals

(Stand / As of 31.03.2022)

Eine Liste aller Publikationen finden Sie unter
http://www.leibniz-inm.de/publikationen

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

GRENZFLÄCHENMATERIALIEN / INTERFACE MATERIALS

Energie-Materalien / Energy Materials

S. Arnold, L. Wang, Ö. Budak, M. Aslan, P. Srimuk and V. Presser
Antimony alloying electrode for high-performance sodium removal: how to use a battery material not stable in aqueous media for saline water remediation
Journal of Materials Chemistry A 2021, 9, (1), 585-596
[JIF: 12.732 (2020)]
doi:10.1039/D0TA09806J

A. K. Boehm, S. Husmann, M. Besch, O. Janka, V. Presser and M. Gallei
Porous Mixed-Metal Oxide Li-Ion Battery Electrodes by Shear-Induced Co-assembly of Precursors and Tailored Polymer Particles
ACS Applied Materials & Interfaces 2021, 13, (51), 61166-61179 [JIF: 09.229 (2020)]
doi:10.1021/acsami.1c19027

Ö. Budak, P. Srimuk, M. Aslan, H. Shim, L. Borchardt and V. Presser
Titanium niobium oxide $Ti_2Nb_{10}O_{29}$ /carbon hybrid electrodes derived by mechanochemically synthesized carbide for high-performance lithium-ion batteries
ChemSusChem 2021, 14, (1), 398-407 [JIF: 08.928 (2020)]
doi:10.1002/cssc.202002229

A. Frank, T. Gänsler, S. Hieke, S. Fleischmann, S. Husmann, V. Presser and C. Scheu
Structural and chemical characterization of MoO_2 /MoS_2 triple-hybrid materials using electron microscopy in up to three dimensions
Nanoscale Advances 2021, 3, (4), 1067-1076
[JIF: 04.553 (2020)]
doi:10.1039/D0NA00806K

P. G. Grützmacher, S. Suarez, A. Tolosa, C. Gachot, G. Song, B. Wang, V. Presser, F. Mücklich, B. Anasori and A. Rosenkranz
Superior Wear-Resistance of $Ti_3C_2T_x$ Multilayer Coatings
ACS Nano 2021, 15, (5), 8216-8224 [JIF: 15.881 (2020)]
doi:10.1021/acsnano.1c01555

Z. Liang, C. Zhao, W. Zhao, Y. Zhang, P. Srimuk, V. Presser and G. Feng
Molecular Understanding of Charge Storage in MoS_2 Supercapacitors with Ionic Liquids
Energy & Environmental Materials 2021, 4, (4), 631-637
[JIF: 15.122 (2020)]
doi:10.1002/eem2.12147

P. A. Maughan, S. Arnold, Y. Zhang, V. Presser, N. Tapia-Ruiz and N. Bimbo
In Situ Investigation of Expansion during the Lithiation of Pillared MXenes with Ultralarge Interlayer Distance
The Journal of Physical Chemistry C 2021, 125, (38), 20791-20797 [JIF: 02.781 (2020)]
doi:10.1021/acs.jpcc.1c05092

M. Salihovic, J. Schoiber, A. Cherevan, C. Rameshan, G. Fritz-Popovski, M. Ulbricht, S. Arnold, V. Presser, O. Paris, M. Musso, N. Hüsing and M. S. Elsaesser
Hybrid carbon spherogels: carbon encapsulation of nano-titania
Chemical Communications 2021, 57, (32), 3905-3908 [JIF: 06.222 (2020)]
doi:10.1039/D1CC00697E

D. B. Schüpfer, F. Badaczewski, J. Peilstöcker, J. M. Guerra-Castro, H. Shim, S. Firoozabadi, A. Beyer, K. Volz, V. Presser, C. Heiliger, B. Smarsly and P. J. Klar
Monitoring the thermally induced transition from sp^3-hybridized into sp^2-hybridized carbons
Carbon 2021, 172, 214-227 [JIF: 09.594 (2020)]
doi:10.1016/j.carbon.2020.09.063

M. Tian, M. J. Lennox, A. J. O'Malley, A. J. Porter, B. Krüner, S. Rudić, T. J. Mays, T. Düren, V. Presser, L. R. Terry, S. Rols, Y. Fang, Z. Dong, S. Rochat and V. P. Ting
Effect of pore geometry on ultra-densified hydrogen in microporous carbons
Carbon 2021, 173, 968-979 [JIF: 09.594 (2020)]
doi:10.1016/j.carbon.2020.11.063

L. Wang, K. Frisella, P. Srimuk, O. Janka, G. Kickelbick and V. Presser
Electrochemical lithium recovery with lithium iron phosphate: what causes performance degradation and how can we improve the stability?
Sustainable Energy & Fuels 2021, 5, (12), 3124-3133 [JIF: 13.281 (2020)]
doi:10.1039/D1SE00450F

L. Wang, Y. Zhang, K. Moh and V. Presser
From capacitive deionization to desalination batteries and desalination fuel cells
Current Opinion in Electrochemistry 2021, 29, 100758_1-9 [JIF: JIF 07.271 (2020)]
doi:10.1016/j.coelec.2021.100758

Q. Wang, L. Velasco, B. Breitung and V. Presser
High-Entropy Energy Materials in the Age of Big Data: A Critical Guide to Next-Generation Synthesis and Applications
Advanced Energy Materials 2021, 11, (47), 2102355 [JIF: JIF 29.368 (2020)]
doi:10.1002/aenm.202102355

T. Winter, M. Bitsch, F. Müller, S. Voskian, T. A. Hatton, K. Jacobs, V. Presser and M. Gallei
Redox-Responsive 2-Aminoanthraquinone Core–Shell Particles for Structural Colors and Carbon Capture
ACS Applied Polymer Materials 2021, 3, (9), 4651-4660 [JIF: 08.097 (2020)]
doi:10.1021/acsapm.1c00746

T. Winter, A. Boehm, V. Presser and M. Gallei
Dye-Loaded Mechanochromic and pH-Responsive Elastomeric Opal Films
Macromolecular Rapid Communications 2021, 42, (1), 2000557 [JIF: 05.471 (2020)]
doi:10.1002/marc.202000557

T. Winter, W. Haider, A. Schießer, V. Presser, M. Gallei and A. Schäfer
Rings and Chains: Synthesis and Characterization of Polyferrocenylmethylene
Macromolecular Rapid Communications 2021, 42, (9), e2000738 [JIF: 05.471 (2020)]
doi:10.1002/marc.202000738

Y. Xiong, F. Yu, S. Arnold, L. Wang, V. Presser, Y. Ren and J. Ma
Three-Dimensional Cobalt Hydroxide Hollow Cube /Vertical Nanosheets with High Desalination Capacity and Long-Term Performance Stability
Research 2021, 2021, 9754145 [JIF: -]
doi:10.34133/2021/9754145

Y. Zhang, J. Peng, G. Feng and V. Presser
Hydration shell energy barrier differences of sub-nanometer carbon pores enable ion sieving and selective ion removal
Chemical Engineering Journal 2021, 419, 129438 [JIF: 13.273 (2020)]
doi:10.1016/j.cej.2021.129438

Y. Zhang, L. Wang and V. Presser
Electrocatalytic fuel cell desalination for continuous energy and freshwater generation
Cell Reports Physical Science 2021, 2, (5), 100416_1-9 [JIF: -]
doi:10.1016/j.xcrp.2021.100416

Funktionelle Mikrostrukturen / Functional Microstructures

M. Areyano, J. A. Booth, D. Brouwer, L. F. Gockowski, M. T. Valentine and R. M. McMeeking
Suction-Controlled Detachment of Mushroom-Shaped Adhesive Structures
Journal of Applied Mechanics 2021, 88, (3), 031017_1-8 [JIF: 02.671 (2020)]
doi:10.1115/1.4049392

E. Arzt and B. Cantor
70^{th} Anniversary Volume: Preface
Progress in materials science 2021, 120, 100820 [JIF: 39.580 (2020)]
doi:10.1016/j.pmatsci.2021.100820

E. Arzt, H. Quan, R. M. McMeeking and R. Hensel
Functional surface microstructures inspired by nature – from adhesion and wetting principles to sustainable new devices
Progress in Materials Science 2021, 119, 100778
[JIF: 39.580 (2020)]
doi:10.1016/j.pmatsci.2021.100778

S. Bettscheider, D. Yu, K. L. Foster, R. M. McMeeking, E. Arzt, R. Hensel and J. A. Booth
Breakdown of continuum models for spherical probe adhesion tests on micropatterned surfaces
Journal of the Mechanics and Physics of Solids 2021, 150, 104365 [JIF: 05.471 (2020)]
doi:10.1016/j.jmps.2021.104365

J. A. Booth and R. Hensel
Perspective on statistical effects in the adhesion of micropatterned surfaces
Applied Physics Letters 2021, 119, 230502 [JIF: 04.190 (2020)]
doi:10.1063/5.0073181

M. Ciavarella, G. Cricri and R. McMeeking
A comparison of crack propagation theories in viscoelastic materials
Theoretical and Applied Fracture Mechanics 2021, 116, 103113 [JIF: 04.017 (2020)]
doi:10.1016/j.tafmec.2021.103113

M. Ciavarella, A. Papangelo and R. McMeeking
Crack propagation at the interface between viscoelastic and elastic materials
Engineering Fracture Mechanics 2021, 257, 108009
[JIF: 04.406 (2020)]
doi:10.1016/j.engfracmech.2021.108009

R. Hensel, J. Thiemecke and J. A. Booth
Preventing Catastrophic Failure of Microfibrillar Adhesives in Compliant Systems Based on Statistical Analysis of Adhesive Strength
ACS Applied Materials & Interfaces 2021, 13, (15), 19422–19429 [JIF: 09.229 (2020)]
doi:10.1021/acsami.1c00978

M. A. Meyers and H. Quan
The rhythms of nature inspiring art and science
Matter 2021, 4, (10), 3089-3091 [JIF: 15.589 (2020)]
doi:10.1016/j.matt.2021.09.010

G. Moreira Lana, K. Sorg, G. I. Wenzel, D. Hecker, R. Hensel, B. Schick, K. Kruttwig and E. Arzt
Self-Adhesive Silicone Microstructures for the Treatment of Tympanic Membrane Perforations
Advanced NanoBiomed Research 2021, 1, 2100057 [JIF: -]
doi:10.1002/anbr.202100057

M. Samri, A. Kossa and R. Hensel
Effect of Subsurface Microstructures on Adhesion of Highly Confined Elastic Films
Journal of Applied Mechanics 2021, 88, (3), 031009
[JIF: 02.671 (2020)]
doi:10.1115/1.4049182

K. Sorg, L. Heimann, G. Moreira Lana, A. Langenbucher, B. Schick, E. Arzt and G. I. Wenzel
Optoacoustically induced auditory brainstem responses in the mouse model enhanced through an absorbing film
Journal of Biomedical Optics 2021, 26, (9), 098001 [JIF: 03.170 (2020)]
doi:10.1117/1.JBO.26.9.098001

S. Sukhomlinov and M. H. Müser
On the viscous dissipation caused by randomly rough indenters in smooth sliding motion
Applied Surface Science Advances 2021, 6, 100182
[JIF: 06.707 (2020)]
doi:10.1016/j.apsadv.2021.100182

Y. Wang and R. Hensel
Bioinspired Underwater Adhesion to Rough Substrates by Cavity Collapse of Cupped Microstructures
Advanced Functional Materials 2021, 31, (31), 2101787
[JIF: 18.808 (2020)]
doi:10.1002/adfm.202101787

W. Yang, C. J. Ruestes, Z. Li, O. T. Abad, T. G. Langdon, B. Heiland, M. Koch, E. Arzt and M. A. Meyers
Micro-Mechanical Response of Ultrafine Grain and Nanocrystalline Tantalum
Journal of Materials Research and Technology 2021, 12, 1804-1815 [JIF: 05.039 (2020)]
doi:10.1016/j.jmrt.2021.03.080

Z. Yin, B. Chen, X. E. Cao, B. Ying, H. Quan, C. Wang, Y. Ye, X. Mi, C. Yan, Y. Ding, S. Zhang, A. Bahmani, A. Dalaq, X. Li, X. Shang, K. Nan and Y. Yang
Young martlets: Exploring the world of academia and beyond
Matter 2021, 4, (5), 1434-1436 [JIF: 15.589 (2020)]
doi:10.1016/j.matt.2021.04.012

X. Zhang, Y. Wang, R. Hensel and E. Arzt
A Design Strategy for Mushroom-Shaped Microfibrils with Optimized Dry Adhesion: Experiments and Finite Element Analyses
Journal of Applied Mechanics 2021, 88, (3), 031015_1-23
[JIF: 02.671 (2020)]
doi:10.1115/1.4049183

Innovative Elektronenmikroskopie / Innovative Electron Microscopy

D. Alloyeau, K. S. Mølhave and N. de Jonge
Introduction to the Proceedings of CISCEM 2021 – the 5th Conference on In-Situ and Correlative Electron Microscopy
Microscopy and Microanalysis 2021, 27, (S2), 1-2
[JIF: 04.127 (2020)]
doi:10.1017/S1431927621013003

S. Azim, L. A. Bultema, M. B. de Kock, E. R. Osorio-Blanco, M. Calderón, J. Gonschior, J.-P. Leimkohl, F. Tellkamp, R. Bücker, E. C. Schulz, S. Keskin, N. de Jonge, G. H. Kassier and R. J. D. Miller
Environmental Liquid Cell Technique for Improved Electron Microscopic Imaging of Soft Matter in Solution
Microscopy and Microanalysis 2021, 27, 44-53 [JIF: 04.127 (2020)]
doi:10.1017/S1431927620024654

A. Bo and N. de Jonge
In-situ Observation of Nanoparticle Self-Assembly Formation and Migration at the Solid-Liquid-Gas Interface
Microscopy and Microanalysis 2021, 27, (S2), 31-32
[JIF: 04.127 (2020)]
doi:10.1017/S1431927621013155

A. Bo, B. Kuttich, T. Kraus and N. de Jonge
In Situ Observation of Gold Nanoparticles Self-assembly at the Solid-Liquid Interface Using Liquid-Phase STEM
Microscopy and Microanalysis 2021, 27, (S1), 2226-2227
[JIF: 04.127 (2020)]
doi:10.1017/S1431927621008023

S. Keskin and N. de Jonge
Electron diffraction of graphene-covered protein crystals at room temperature
Microscopy and Microanalysis 2021, 27, 2902-2903
[JIF: 04.127 (2020)]
doi:10.1017/S1431927621010126

S. Keskin and N. de Jonge
Electron Diffraction of Graphene-covered Catalase Crystals
Microscopy and Microanalysis 2021, 27, (S2), 13-14
[JIF: 04.127 (2020)]
doi:10.1017/S1431927621013064

S. Keskin, C. Pawell and N. de Jonge
Verification of water presence in graphene liquid cells
Micron 2021, 149, 103109 [JIF: 02.251 (2020)]
doi:10.1016/j.micron.2021.103109

M. Klarner, P. S. Blach, H. Wittkämper, N. de Jonge, C. Papp and R. Kempe
Key Parameters for the Synthesis of Active and Selective Nanostructured 3d Metal Catalysts Starting from Coordination Compounds – Case Study: Nickel Mediated Reductive Amination
ChemCatChem 2021, 13, (14), 3257-3261 [JIF: 05.686 (2020)]
doi:10.1002/cctc.202100562

P. Kunnas and N. de Jonge
Optimizing Experimental Parameters and Lateral Resolution in LP-EM for Imaging Low-Z Colloids Using Monte Carlo Simulations
Microscopy and Microanalysis 2021, 27, (S2), 93-94
[JIF: 04.127 (2020)]
doi:10.1017/S1431927621013465

Q. Liu, A. Bo, H. Zhan, L. Kou and Y. Gu
Revealing the Mechanical Bending Mechanisms of Single-Crystalline Rutile TiO_2 Nanowires Near Room Temperature: Implications for Nanostructured Semiconductors
ACS Applied Nano Materials 2021, 4, (10), 10354-10359
[JIF: 05.097 (2020)]
doi:10.1021/acsanm.1c01864

Q. Liu, Y. Nie, J. Shang, L. Kou, H. Zhan, Z. Sun, A. Bo and Y. Gu
Exceptional Deformability of Wurtzite Zinc Oxide Nanowires with Growth Axial Stacking Faults
Nano Letters 2021, 21, (10), 4327-4334 [JIF: 11.189 (2020)]
doi:10.1021/acs.nanolett.1c00883

E. Ortega, C. Boothroyd and N. de Jonge
The influence of chromatic aberration on the dose-limited spatial resolution of transmission electron microscopy
Ultramicroscopy 2021, 230, 113383 [JIF: 02.689 (2020)]
doi:10.1016/j.ultramic.2021.113383

E. Ortega and N. de Jonge
Resolution Models for Energy-Filtered TEM Imaging over Thick Liquid or Amorphous Layers
Microscopy and Microanalysis 2021, 27, (S1), 802-803
[JIF: 04.127 (2020)]
doi:10.1017/S1431927621003184

E. Ortega, D. Nicholls, N. D. Browning and N. de Jonge
High temporal-resolution scanning transmission electron microscopy using sparse-serpentine scan pathways
Scientific Reports 2021, 11, (1), 22722 [JIF: 04.379 (2020)]
doi:10.1038/s41598-021-02052-1

D. B. Peckys, D. Gaa, D. Alansary, B. A. Niemeyer and N. d. Jonge
Supra-Molecular Assemblies of ORAI1 at Rest Precede Local Accumulation into Puncta after Activation
International Journal of Molecular Sciences 2021, 22, (2), 799 [JIF: 05.923 (2020)]
doi:10.3390/ijms22020799

D. B. Peckys, D. Gaa and N. de Jonge
Quantification of EGFR-HER2 Heterodimers in HER2-Overexpressing Breast Cancer Cells Using Liquid-Phase Electron Microscopy
Cells 2021, 10, (11), 3244 [JIF: 06.600 (2020)]
doi:10.3390/cells10113244

D. B. Peckys, D. Gaa, F. Weinberg and N. de Jonge
Liquid-Phase Electron Microscopy for Studying the Interaction of Two Membrane Protein Species in Overexpressing Cancer Cells
Microscopy and Microanalysis 2021, 27, (S2), 7-8
[JIF: 04.127 (2020)]
doi:10.1017/S1431927621013039

INTERAKTIVE OBERFLÄCHEN / INTERACTIVE SURFACES

H. Ma and R. Bennewitz
Nanoscale friction and growth of surface oxides on a metallic glass under electrochemical polarization
Tribology International 2021, 158, 106925
[JIF: 04.872 (2020)]
doi:10.1016/j.triboint.2021.106925

M. Penth, K. Schnellnhuber, R. Bennewitz and J. Blass
Nanomechanics of self-assembled DNA building blocks
Nanoscale 2021, 13, 9371-9380 [JIF: 07.790 (2020)]
doi:10.1039/D0NR06865A

Y. Zheng, M. K. L. Han, R. Zhao, J. Blass, J. Zhang, D. W. Zhou, J.-R. Colard-Itté, D. Dattler, A. Çolak, M. Hoth, A. J. García, B. Qu, R. Bennewitz, N. Giuseppone and A. del Campo
Optoregulated force application to cellular receptors using molecular motors
Nature Communications 2021, 12, (1), 3580
[JIF: 14.919 (2020)]
doi:10.1038/s41467-021-23815-4

BIOGRENZFLÄCHEN / BIO INTERFACES

Bioprogrammierbare Materialien / Bioprogrammable Materials

A. Rodrigo-Navarro, S. Sankaran, M. J. Dalby, A. del Campo and M. Salmeron-Sanchez
Engineered living biomaterials
Nature Reviews Materials 2021, 6, 1175–1190
[JIF: 66.308 (2020)]
doi:10.1038/s41578-021-00350-8

Dynamische Biomaterialien / Dynamic Biomaterials

J.-C. Escolano, A. V. Taubenberger, S. Abuhattum, C. Schweitzer, A. Farrukh, A. del Campo, C. E. Bryant and J. Guck
Compliant Substrates Enhance Macrophage Cytokine Release and NLRP3 Inflammasome Formation During Their Pro-Inflammatory Response
Frontiers in Cell and Developmental Biology 2021, 9, (682), [JIF: 06.684 (2020)]
doi:10.3389/fcell.2021.639815

D. W. Müller, S. Lößlein, E. Terriac, K. Brix, K. Siems, R. Moeller, R. Kautenburger and F. Mücklich
Increasing Antibacterial Efficiency of Cu Surfaces by targeted Surface Functionalization via Ultrashort Pulsed Direct Laser Interference Patterning
Advanced Materials Interfaces 2021, 8, (5), 2001656
[JIF: 06.147 (2020)]
doi:10.1002/admi.202001656

R. V. Nair, A. Farrukh and A. del Campo
Light-Regulated Angiogenesis via a Phototriggerable VEGF Peptidomimetic
Advanced Healthcare Materials 2021, 10, (14), 2100488
[JIF: 09.933 (2020)]
doi:10.1002/adhm.202100488

J. I. Paez, A. de Miguel-Jiménez, R. Valbuena-Mendoza, A. Rathore, M. Jin, A. Gläser, S. Pearson and A. del Campo
Thiol-Methylsulfone-Based Hydrogels for Cell Encapsulation: Reactivity Optimization of Aryl-Methylsulfone Substrate for Fine-Tunable Gelation Rate and Improved Stability
Biomacromolecules 2021, 22, (7), 2874–2886
[JIF: 06.988 (2020)]
doi:10.1021/acs.biomac.1c00256

S. Pearson, J. Feng and A. del Campo
Lighting the Path: Light Delivery Strategies to Activate Photoresponsive Biomaterials In Vivo
Advanced Functional Materials 2021, 31, (50), 2105989
[JIF: 18.808 (2020)]
doi:10.1002/adfm.202105989

M. Puertas-Bartolomé, A. Mora-Boza and L. García-Fernández
Emerging Biofabrication Techniques: A Review on Natural Polymers for Biomedical Applications
Polymers 2021, 13, (8), 1209 [JIF: 04.329 (2020)]
doi:10.3390/polym13081209

M. Puertas-Bartolomé, M. K. Włodarczyk-Biegun, A. del Campo, B. Vázquez-Lasa and J. San Román
Development of bioactive catechol functionalized nanoparticles applicable for 3D bioprinting
Materials Science and Engineering: C 2021, 131, 112515
[JIF: 07.328 (2020)]
doi:10.1016/j.msec.2021.112515

A. Rodrigo-Navarro, S. Sankaran, M. J. Dalby, A. del Campo and M. Salmeron-Sanchez
Engineered living biomaterials
Nature Reviews Materials 2021, 6, 1175–1190
[JIF: 66.308 (2020)]
doi:10.1038/s41578-021-00350-8

J. Zhang, R. Zhao, B. Li, A. Farrukh, M. Hoth, B. Qu and A. del Campo
Micropatterned soft hydrogels to study the interplay of receptors and forces in T cell activation
Acta Biomaterialia 2021, 119, 234-246 [JIF: 08.947 (2020)]
doi:10.1016/j.actbio.2020.10.028

R. Zhao, X. Zhou, E. S. Khan, D. Alansary, K. S. Friedmann, W. Yang, E. C. Schwarz, A. del Campo, M. Hoth and B. Qu
Targeting the Microtubule-Network Rescues CTL Killing Efficiency in Dense 3D Matrices
Frontiers in Immunology 2021, 12, (3309), 729820
[JIF: 07.561 (2020)]
doi:10.3389/fimmu.2021.729820

R. Zhao, X. Zhou, E. S. Khan, D. Alansary, K. S. Friedmann, W. Yng, E. C. Schwarz, A. del Campo, M. Hoth and B. Qu
Targeting the Microtubule-network to improve CTL killing capacity in dense 3D matrices
European Journal of Immunology 2021, 51, 46
[JIF: 05.532 (2020)]
doi:10.1002/eji.202170200

Y. Zheng, M. K. L. Han, R. Zhao, J. Blass, J. Zhang, D. W. Zhou, J.-R. Colard-Itté, D. Dattler, A. Çolak, M. Hoth, A. J. García, B. Qu, R. Bennewitz, N. Giuseppone and A. del Campo
Optoregulated force application to cellular receptors using molecular motors
Nature Communications 2021, 12, (1), 3580 [JIF: 14.919 (2020)]
doi:10.1038/s41467-021-23815-4

Nano Zell Interaktionen / Nano Cell Interactions

E. Meziu, M. Koch, J. Fleddermann, K. Schwarzkopf, M. Schneider and A. Kraegeloh
Visualization of the structure of native human pulmonary mucus
International Journal of Pharmaceutics 2021, 597, 120238
[JIF: 03.061 (2020)]
doi:10.1016/j.ijpharm.2021.120238

I. Tavernaro, S. Dekkers, L. G. Soeteman-Hernandez, P. Herbeck-Engel, C. Noorlander and A. Kraegeloh
Safe-by-Design part II: A strategy for balancing safety and functionality in the different stages of the innovation process
Nanoimpact 2021, 24, 100354 [JIF: 05.316 (2020)]
doi:10.1016/j.impact.2021.100354

NANOKOMPOSIT-MATERIALIEN / NANOCOMPOSITE MATERIALS

Elektrofluide / Electrofluids

S. Bettscheider, B. Kuttich, L. F. Engel, L. González-García and T. Kraus
Bundling of Nanowires Induced by Unbound Ligand
The Journal of Physical Chemistry C 2021, 125, (6), 3590-3598 [JIF: 04.173 (2020)]
doi:10.1021/acs.jpcc.0c10919

R. Buchheit, B. Kuttich, L. González-García and T. Kraus
Hybrid Dielectric Films of Inkjet-Printable Core–Shell Nanoparticles
Advanced Materials 2021, 33, (41), 2103087
[JIF: 30.849 (2020)]
doi:10.1002/adma.202103087

F. Coupette, L. Zhang, B. Kuttich, A. Chumakov, S. V. Roth, L. González-García, T. Kraus and T. Schilling
Percolation of rigid fractal carbon black aggregates
The Journal of Chemical Physics 2021, 155, (12), 124902
[JIF: 03.488 (2020)]
doi:10.1063/5.0058503

A. Escudero, L. González-García, R. Strahl, D. J. Kang, J. Drzic and T. Kraus
Large-Scale Synthesis of Hybrid Conductive Polymer–Gold Nanoparticles Using "Sacrificial" Weakly Binding Ligands for Printing Electronics
Inorganic Chemistry 2021, 60, (22), 17103-17113
[JIF: 05.165 (2020)]
doi:10.1021/acs.inorgchem.1c02350

Strukturbildung / Structure Formation

H. Alhmoud, D. Brodoceanu, R. Elnathan, T. Kraus and N. H. Voelcker
A MACEing silicon: Towards single-step etching of defined porous nanostructures for biomedicine
Progress in Materials Science 2021, 116, 100636
[JIF: 39.580 (2020)]
doi:10.1016/j.pmatsci.2019.100636

H. Alhmoud, D. Brodoceanu, R. Elnathan, T. Kraus and N. H. Voelcker
Reprint of: A MACEing silicon: Towards single-step etching of defined porous nanostructures for biomedicine
Progress in Materials Science 2021, 120, 100817
[JIF: 39.580 (2020)]
doi:10.1016/j.pmatsci.2021.100817

C. Appel, B. Kuttich, T. Kraus and B. Stühn
In situ investigation of temperature induced agglomeration in non-polar magnetic nanoparticle dispersions by small angle X-ray scattering
Nanoscale 2021, 13, 6916 [JIF: 07.790 (2020)]
doi:10.1039/D0NR08434D

J. Bareuther, M. Plank, B. Kuttich, T. Kraus, H. Frey and M. Gallei
Temperature Variation Enables the Design of Biobased Block Copolymers via One-Step Anionic Copolymerization
Macromolecular Rapid Communications 2021, 42, (8), 2000513 [JIF: 05.471 (2020)]
doi:10.1002/marc.202000513

S. Bettscheider, B. Kuttich, L. F. Engel, L. González-García and T. Kraus
Bundling of Nanowires Induced by Unbound Ligand
The Journal of Physical Chemistry C 2021, 125, (6), 3590-3598 [JIF: 04.173 (2020)]
doi:10.1021/acs.jpcc.0c10919

S. Bettscheider, D. Yu, K. L. Foster, R. M. McMeeking, E. Arzt, R. Hensel and J. A. Booth
Breakdown of continuum models for spherical probe adhesion tests on micropatterned surfaces
Journal of the Mechanics and Physics of Solids 2021, 150, 104365 [JIF: 05.471 (2020)]
doi:10.1016/j.jmps.2021.104365

A. Bo, B. Kuttich, T. Kraus and N. de Jonge
In Situ Observation of Gold Nanoparticles Self-assembly at the Solid-Liquid Interface Using Liquid-Phase STEM
Microscopy and Microanalysis 2021, 27, (S1), 2226-2227
[JIF: 04.127 (2020)]
doi:10.1017/S1431927621008023

R. Buchheit, B. Kuttich, L. González-García and T. Kraus
Hybrid Dielectric Films of Inkjet-Printable Core–Shell Nanoparticles
Advanced Materials 2021, 33, (41), 2103087
[JIF: 30.849 (2020)]
doi:10.1002/adma.202103087

F. Coupette, L. Zhang, B. Kuttich, A. Chumakov, S. V. Roth, L. González-García, T. Kraus and T. Schilling
Percolation of rigid fractal carbon black aggregates
The Journal of Chemical Physics 2021, 155, (12), 124902
[JIF: 03.488 (2020)]
doi:10.1063/5.0058503

R. Elnathan, A. W. Holle, J. Young, M. A. George, O. Heifler, A. Goychuk, E. Frey, R. Kemkemer, J. P. Spatz, A. Kosloff, F. Patolsky and N. H. Voelcker
Optically transparent vertical silicon nanowire arrays for live-cell imaging
Journal of Nanobiotechnology 2021, 19, (1), 51
[JIF: 10.435 (2020)]
doi:10.1186/s12951-021-00795-7

A. Escudero, L. González-García, R. Strahl, D. J. Kang, J. Drzic and T. Kraus
Large-Scale Synthesis of Hybrid Conductive Polymer–Gold Nanoparticles Using "Sacrificial" Weakly Binding Ligands for Printing Electronics
Inorganic Chemistry 2021, 60, (22), 17103-17113
[JIF: 05.165 (2020)]
doi:10.1021/acs.inorgchem.1c02350

D. A. H. Fuchs, H. Hübner, T. Kraus, B.-J. Niebuur, M. Gallei, H. Frey and A. H. E. Müller
The effect of THF and the chelating modifier DTHFP on the copolymerisation of β-myrcene and styrene: kinetics, microstructures, morphologies, and mechanical properties
Polymer Chemistry 2021, 12, (32), 4632-4642
[JIF: 05.582 (2020)]
doi:10.1039/D1PY00791B

A. Hegetschweiler, A.-R. Jochem, A. Zimmermann, J. Walter, T. Staudt and T. Kraus
Colloidal Analysis of Particles Extracted from Microalloyed Steels
Particle & Particle Systems Characterization 2021, 38, (7), 2000236 [JIF: 03.310 (2020)]
doi:10.1002/ppsc.202000236

F. A. Jung, M. Schart, L. Bührend, E. Meidinger, J.-J. Kang, B.-J. Niebuur, S. Ariaee, D. S. Molodenskiy, D. Posselt, H. Amenitsch, C. Tsitsilianis and C. M. Papadakis
Highly Tunable Nanostructures in a Doubly pH-Responsive Pentablock Terpolymer in Solution and in Thin Films
Advanced Functional Materials 2021, 31, (32), 2102905
[JIF: 18.808 (2020)]
doi:10.1002/adfm.202102905

T. Kraus
Ionic glue
Nature Chemistry 2021, 13, pages 925–926
[JIF: 21.687 (2020)]
doi:10.1038/s41557-021-00782-3

T. Liu, X. Chen, E. Tervoort, T. Kraus and M. Niederberger
Design and Fabrication of Transparent and Stretchable Zinc Ion Batteries
ACS Applied Energy Materials 2021, 4, (6), 6166-6179
[JIF: 06.024 (2020)]
doi:10.1021/acsaem.1c00958

O. Meili-Borovinskaya, F. Meier, R. Drexel, M. Baalousha, L. Flamigni, A. Hegetschweiler and T. Kraus
Analysis of complex particle mixtures by asymmetrical flow field-flow fractionation coupled to inductively coupled plasma time-of-flight mass spectrometry
Journal of Chromatography A 2021, 1641, 461981
[JIF: 04.759 (2020)]
doi:10.1016/j.chroma.2021.461981

S. Müssig, B. Kuttich, F. Fidler, D. Haddad, S. Wintzheimer, T. Kraus and K. Mandel
Reversible magnetism switching of iron oxide nanoparticle dispersions by controlled agglomeration
Nanoscale Advances 2021, 3, (10), 2822-2829 [JIF: 04.553 (2020)]
doi:10.1039/D1NA00159K

B.-J. Niebuur, L. Chiappisi, F. A. Jung, X. Zhang, A. Schulte and C. M. Papadakis
Nanoscale disintegration kinetics of mesoglobules in aqueous poly(N-isopropylacrylamide) solutions revealed by small-angle neutron scattering and pressure jumps
Nanoscale 2021, 13, (34), 13421-13426 [JIF: 07.790 (2020)]
doi:10.1039/D1NR02859F

B.-J. Niebuur, H. Hegels, M. Tena-Solsona, P. S. Schwarz, J. Boekhoven and C. M. Papadakis
Droplet Formation by Chemically Fueled Self-Assembly: The Role of Precursor Hydrophobicity
The Journal of Physical Chemistry B 2021, 125, (49), 13542-13551 [JIF: 02.991 (2020)]
doi:10.1021/acs.jpcb.1c08034

A. S. Nittala, A. Karrenbauer, A. Khan, T. Kraus and J. Steimle
Computational design and optimization of electro-physiological sensors
Nature Communications 2021, 12, (1), 6351
[JIF: 14.919 (2020)]
doi:10.1038/s41467-021-26442-1

D. Rauber, F. Philippi, B. Kuttich, J. Becker, T. Kraus, P. Hunt, T. Welton, R. Hempelmann and C. W. M. Kay
Curled cation structures accelerate the dynamics of ionic liquids
Physical Chemistry Chemical Physics 2021, 23, 21042-21064 [JIF: 03.676 (2020)]
doi:10.1039/D1CP02889H

J. Webel, L. Weber, E. Vardo, D. Britz, T. Kraus and F. Mücklich
Particle encapsulation techniques for atom probe tomography of precipitates in microalloyed steels
Ultramicroscopy 2021, 223, 113219 [JIF: 02.689 (2020)]
doi:10.1016/j.ultramic.2021.113219

P. R. Yadav, M. H. Rizvi, B. Kuttich, S. R. Mishra, B. S. Chapman, B. B. Lynch, T. Kraus, A. L. Oldenburg and J. B. Tracy
Plasmon-Coupled Gold Nanoparticles in Stretched Shape-Memory Polymers for Mechanical/Thermal Sensing
ACS Applied Nano Materials 2021, 4, (4), 3911–3921
[JIF: 05.097 (2020)]
doi:10.1021/acsanm.1c00309

InnovationsZentrum INM / InnovationCenter INM

A. Escudero, L. González-García, R. Strahl, D. J. Kang, J. Drzic and T. Kraus
Large-Scale Synthesis of Hybrid Conductive Polymer-Gold Nanoparticles Using "Sacrificial" Weakly Binding Ligands for Printing Electronics
Inorganic Chemistry 2021, 60, (22), 17103-17113
[JIF: 05.165 (2020)]
doi:10.1021/acs.inorgchem.1c02350

I. Tavernaro, S. Dekkers, L. G. Soeteman-Hernandez, P. Herbeck-Engel, C. Noorlander and A. Kraegeloh
Safe-by-Design part II: A strategy for balancing safety and functionality in the different stages of the innovation process
Nanoimpact 2021, 24, 100354 [JIF: 05.316 (2020)]
doi:10.1016/j.impact.2021.100354

L. Wang, Y. Zhang, K. Moh and V. Presser
From capacitive deionization to desalination batteries and desalination fuel cells
Current Opinion in Electrochemistry 2021, 29, 100758_1-9 [JIF: JIF 07.271 (2020)]
doi:10.1016/j.coelec.2021.100758

PROGRAMMBEREICHSUNGEBUNDEN / NOT LINKED TO A PROGRAM DIVISION

Chemische Analytik / Chemical Analytics

S. Kar, H.-J. Mai, H. Khalouf, H. Ben Abdallah, S. Flachbart, C. Fink-Straube, A. Bräutigam, G. Xiong, L. Shang, S. K. Panda and P. Bauer
Comparative Transcriptomics of Lowland Rice Varieties Uncovers Novel Candidate Genes for Adaptive Iron Excess Tolerance
Plant and Cell Physiology 2021, 62, (4), 624-640 [JIF: 04.927 (2020)]
doi:10.1093/pcp/pcab018

Physikalische Analytik / Physical Analytics

M. Amne Elahi, M. Koch, J. Bardon, F. Addiego and P. Plapper
Failure mechanism analysis based on laser-based surface treatments for aluminum-polyamide laser joining
Journal of Materials Processing Technology 2021, 298, 117318 [JIF: 05.551 (2020)]
doi:10.1016/j.jmatprotec.2021.117318

M. A. Elahi, M. Koch and P. Plapper
Evaluation of the joint based on different surface conditions for aluminum-polyamide laser welding
Journal of Laser Applications 2021, 33, (1), 012036 [JIF: 01.636 (2020)]
doi:10.2351/7.0000326

D. A. Flormann, M. Schu, E. Terriac, D. G. Thalla, L. Kainka, M. Koch, A. K. B. Gad and F. Lautenschläger
A novel universal algorithm for filament network tracing and cytoskeleton analysis
The FASEB Journal 2021, 35, (5), e21582 [JIF: 05.191 (2020)]
doi:10.1096/fj.202100048R

A. Katsen-Globa, A. Schulz, N. Pütz, M. Koch, Y. Kohl, A. W. Schneider-Ickert, T. Velten and Y. E. Silina
Toward Alginate-Based Membrane Technology for High Performance Recovery of Heavy Metals in Cells
ACS Applied Bio Matererials 2021, 4, (3), 2558-2569 [JIF: 02.570 (2020)]
doi:10.1021/acsabm.0c01559

M. Koch, N. Apushkinskaya, E. V. Zolotukhina and Y. E. Silina
Towards hybrid one-pot/one-electrode Pd-NPs-based nanoreactors for modular biocatalysis
Biochemical Engineering Journal 2021, 175, 108132 [JIF: 03.978 (2020)]
doi:10.1016/j.bej.2021.108132

A. O. Konakov, N. N. Dremova, I. I. Khodos, M. Koch, E. V. Zolotukhina and Y. E. Silina
One-Pot Synthesis of Copper Iodide-Polypyrrole Nanocomposites
Chemosensors 2021, 9, (3), 56 [JIF: 03.398 (2020)]
doi:10.3390/chemosensors9030056

S. M. Lombardo, N. Günday Türeli, M. Koch, M. Schneider and A. E. Türeli
Reliable release testing for nanoparticles with the NanoDis System, an innovative sample and separate technique
International Journal of Pharmaceutics 2021, 609, 121215 [JIF: 05.875 (2020)]
doi:10.1016/j.ijpharm.2021.121215

E. Meziu, M. Koch, J. Fleddermann, K. Schwarzkopf, M. Schneider and A. Kraegeloh
Visualization of the structure of native human pulmonary mucus
International Journal of Pharmaceutics 2021, 597, 120238 [JIF: 03.061 (2020)]
doi:10.1016/j.ijpharm.2021.120238

L. Müller, T. Kuhn, M. Koch and G. Fuhrmann
Stimulation of Probiotic Bacteria Induces Release of Membrane Vesicles with Augmented Anti-inflammatory Activity
ACS Applied Bio Materials 2021, 4, (5), 3739–3748 [JIF: 02.570 (2020)]
doi:10.1021/acsabm.0c01136

L. Reinke, M. Koch, C. Müller-Renno and S. Kubik
Selective sensing of adenosine monophosphate (AMP) over adenosine diphosphate (ADP), adenosine triphosphate (ATP), and inorganic phosphates with zinc(ii)-dipicolylamine-containing gold nanoparticles
Organic & Biomolecular Chemistry 2021, 19, (17), 3893-3900 [JIF: 03.876 (2020)]
doi:10.1039/D1OB00341K

M. Schu, E. Terriac, M. Koch, S. Paschke, F. Lautenschläger and D. A. Flormann
Scanning electron microscopy preparation of the cellular actin cortex: A quantitative comparison between critical point drying and hexamethyldisilazane drying
PloS one 2021, 16, (7), e0254165-e0254165 [JIF: 03.240 (2020)]
doi:10.1371/journal.pone.0254165

C. Schütz, D.-K. Ho, M. M. Hamed, A. S. Abdelsamie, T. Röhrig, C. Herr, A. M. Kany, K. Rox, S. Schmelz, L. Siebenbürger, M. Wirth, C. Börger, S. Yahiaoui, R. Bals, A. Scrima, W. Blankenfeldt, J. C. Horstmann, R. Christmann, X. Murgia, M. Koch, A. Berwanger, B. Loretz, A. K. H. Hirsch, R. W. Hartmann, C.-M. Lehr and M. Empting
A New PqsR Inverse Agonist Potentiates Tobramycin Efficacy to Eradicate Pseudomonas aeruginosa Biofilms
Advanced Science 2021, 8, (12), 2004369
[JIF: 16.806 (2020)]
doi:10.1002/advs.202004369

D. Thiyagarajan, B. Huck, B. Nothdurft, M. Koch, D. Rudolph, M. Rutschmann, C. Feldmann, C. Hozsa, M. Furch, K. F. W. Besecke, R. K. Gieseler, B. Loretz and C.-M. Lehr
Spray-dried lactose-leucine microparticles for pulmonary delivery of antimycobacterial nanopharmaceuticals
Drug Delivery and Translational Research 2021, 11, (4), 1766-1778 [JIF: 04.617 (2020)]
doi:10.1007/s13346-021-01011-7

W. Yang, C. J. Ruestes, Z. Li, O. T. Abad, T. G. Langdon, B. Heiland, M. Koch, E. Arzt and M. A. Meyers
Micro-Mechanical Response of Ultrafine Grain and Nanocrystalline Tantalum
Journal of Materials Research and Technology 2021, 12, 1804-1815 [JIF: 05.039 (2020)]
doi:10.1016/j.jmrt.2021.03.080

INM Fellows / INM Fellows

P. Jung, X. Zhou, S. Iden, M. Bischoff and B. Qu
T cell stiffness is enhanced upon formation of immunological synapse
eLife 2021, 10, e66643 [JIF: 08.140 (2020)]
doi:10.7554/eLife.66643

Y. Liu, R. Zhao, B. Reda, W. Yang, M. Hannig and B. Qu
Profiling of cytokines, chemokines and growth factors in saliva and gingival crevicular fluid
Cytokine 2021, 142, 155504 [JIF: 03.861 (2020)]
doi:10.1016/j.cyto.2021.155504

S. Sukhomlinov and M. H. Müser
On the viscous dissipation caused by randomly rough indenters in smooth sliding motion
Applied Surface Science Advances 2021, 6, 100182
[JIF: 06.707 (2020)]
doi:10.1016/j.apsadv.2021.100182

D. Vesperini, G. Montalvo, B. Qu and F. Lautenschläger
Characterization of immune cell migration using microfabrication
Biophysical Reviews 2021, 13, 185-202 [JIF: 04.911 (2020)]
doi:10.1007/s12551-021-00787-9

J. Zhang, R. Zhao, B. Li, A. Farrukh, M. Hoth, B. Qu and A. del Campo
Micropatterned soft hydrogels to study the interplay of receptors and forces in T cell activation
Acta Biomaterialia 2021, 119, 234-246 [JIF: 08.947 (2020)]
doi:10.1016/j.actbio.2020.10.028

R. Zhao, X. Zhou, E. S. Khan, D. Alansary, K. S. Friedmann, W. Yang, E. C. Schwarz, A. del Campo, M. Hoth and B. Qu
Targeting the Microtubule-Network Rescues CTL Killing Efficiency in Dense 3D Matrices
Frontiers in Immunology 2021, 12, (3309), 729820
[JIF: 07.561 (2020)]
doi:10.3389/fimmu.2021.729820

Y. Zheng, M. K. L. Han, R. Zhao, J. Blass, J. Zhang, D. W. Zhou, J.-R. Colard-Itté, D. Dattler, A. Çolak, M. Hoth, A. J. García, B. Qu, R. Bennewitz, N. Giuseppone and A. del Campo
Optoregulated force application to cellular receptors using molecular motors
Nature Communications 2021, 12, (1), 3580
[JIF: 14.919 (2020)]
doi:10.1038/s41467-021-23815-4

J. Zhu, W. Yang, X. Zhou, D. Zöphel, L. Soriano-Baguet, D. Dolgener, C. Carlein, C. Hof, R. Zhao, S. Ye, E. C. Schwarz, D. Brenner, L. P. Roma and B. Qu
High Glucose Enhances Cytotoxic T Lymphocyte-Mediated Cytotoxicity
Frontiers in Immunology 2021, 12, 10 [JIF: 07.561 (2020)]
doi:10.3389/fimmu.2021.689337

H. Zou, W. Yang, G. Schwär, R. Zhao, D. Alansary, E. C. Schwarz, B. A. Niemeyer and B. Qu
High glucose regulates Ca^{2+} influx in cytotoxic T lymphocytes
European Journal of Immunology 2021, 51, 171
[JIF: 05.532 (2020)]
doi: 10.1002/eji.202170200

Weitere / Others

Y. Abdalla, M. Luo, E. Mäkilä, B. W. Day, N. H. Voelcker and W. Y. Tong
Effectiveness of porous silicon nanoparticle treatment at inhibiting the migration of a heterogeneous glioma cell population
Journal of Nanobiotechnology 2021, 19, (1), 60
[JIF: 10.435 (2020)]
doi:10.1186/s12951-021-00798-4

V. E. Collier, W. B. Xu, R. M. McMeeking, F. W. Zok and M. R. Begley
Recession of BN coatings in SiC/SiC composites through reaction with water vapor
Journal of the American Ceramic Society 2021, 105, (1), 498-511 [JIF: 03.784 (2020)]
doi:10.1111/jace.18052

T. Fischer, I. Winter, R. Drumm and M. Schneider
Cylindrical Microparticles Composed of Mesoporous Silica Nanoparticles for the Targeted Delivery of a Small Molecule and a Macromolecular Drug to the Lungs: Exemplified with Curcumin and siRNA
Pharmaceutics 2021, 13, (6), 844 [JIF: 06.321 (2020)]
doi:10.3390/pharmaceutics13060844

D. A. Flormann, C. Anton, M. O. Pohland, Y. Bautz, K. Kaub, E. Terriac, T. E. Schäffer, J. Rheinlaender, A. Janshoff, A. Ott and F. Lautenschläger
Oscillatory Microrheology, Creep Compliance and Stress Relaxation of Biological Cells Reveal Strong Correlations as Probed by Atomic Force Microscopy
Frontiers in Physics 2021, 9, (472), 711860_1-12
[JIF: 03.560 (2020)]
doi:10.3389/fphy.2021.711860

A. Kossa and R. M. McMeeking
Bending of a Nitinol cantilever and its fatigue performance
Extreme Mechanics Letters 2021, 42, 101083
[JIF: 04.567 (2020)]
doi:10.1016/j.eml.2020.101083

A. Kossa and R. M. McMeeking
The Effect of an Implanted Filter on Valsalva-Compression and Respiratory-Compression of the Inferior Vena Cava
Journal of Elasticity 2021, 145, 383–408 [JIF: 2.085 (2020)]
doi:10.1007/s10659-021-09850-8

M. Lazar and H. O. K. Kirchner
Generalised plane strain embedded in three-dimensional anisotropic elasticity
Philosophical Magazine 2021, 101, (24), 2584-2598
[JIF: 01.864 (2020)]
doi:10.1080/14786435.2021.1981553

T. Nizolek, T. Pollock and R. McMeeking
Kink band and shear band localization in anisotropic perfectly plastic solids
Journal of the Mechanics and Physics of Solids 2021, 146, 104183 [JIF: 05.471 (2020)]
doi:10.1016/j.jmps.2020.104183

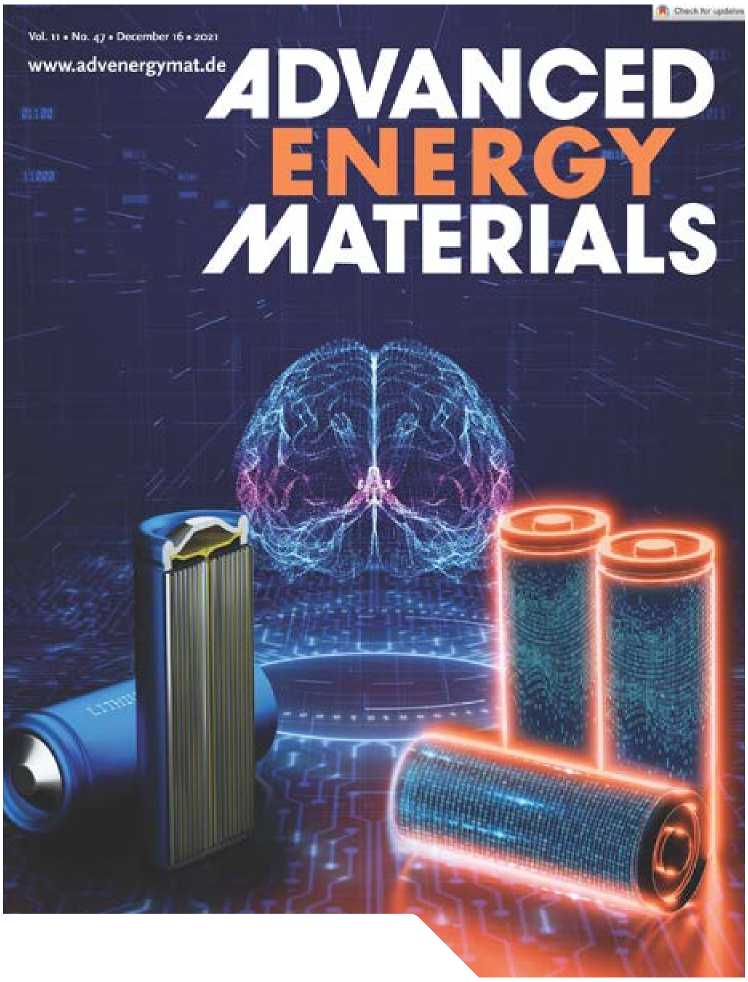
D. G. Thalla, P. Jung, M. Bischoff and F. Lautenschläger
Role of Extracellular Vimentin in Cancer-Cell Functionality and Its Influence on Cell Monolayer Permeability Changes Induced by SARS-CoV-2 Receptor Binding Domain
International Journal of Molecular Sciences 2021, 22, (14), 7469 [JIF: 05.923 (2020)]
doi:10.3390/ijms22147469

M. Veith, F. Sahin, S. Nadig, V. Huch and B. Morgenstern
Transformations of the polycyclic Alumosiloxane $Al_2(OSiPh2OSiPh2O)_3$ into new Polycycles and Co(II) and In(III) derivatives of $(Ph2SiO)_8[Al(O)OH]_4$
Zeitschrift für anorganische und allgemeine Chemie 2021, 647, (18), 1709-1720 [JIF: 01.240 (2020)]
doi:10.1002/zaac.202100126

S. Wang, H. Wang, P. Zhang, L. Xue, J. Chen and J. Cui
Folding fluorescent probes for self-reporting transesterification in dynamic polymer networks
Materials Horizons 2021, 8, (5), 1481-1487
[JIF: 13.266 (2020)]
doi:10.1039/D0MH02024A

S. Wang, L.-L. Xue, X.-Z. Zhou and J.-X. Cui
"Solid-Liquid" Vitrimers Based on Dynamic Boronic Ester Networks
Chinese Journal of Polymer Science 2021, 39, 1292-1298
[JIF: 03.603 (2020)]
doi:10.1007/s10118-021-2592-1

X. Xiong, L. Xue, L. Yang, S. Dong and J. Cui
Bio-inspired semi-infused adaptive surface with reconfigurable topography for on-demand droplet manipulation
Materials Chemistry Frontiers 2021, 5, (14), 5382-5389
[JIF: 06.482 (2020)]
doi:10.1039/D1QM00399B



SUPPLEMENT ZUM JAHRESBERICHT 2020 / SUPPLEMENT TO THE ANNUAL REPORT 2020

153 Publikationen
Publications
davon / *including*

126 Publikationen in referierten Zeitschriften
publications in peer-reviewed journals

27 sonstige Publikationen
other publications

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

59 Beiträge in referierten Zeitschriften
contributions in peer-reviewed journals

Strukturbildung / Structure Formation

F. Philippi, D. Rauber, B. Kuttich, T. Kraus, C. W. M. Kay, R. Hempelmann, P. A. Hunt and T. Welton
Ether functionalisation, ion conformation and the optimisation of macroscopic properties in ionic liquids
Physical Chemistry Chemical Physics 2020, 22, (40), 23038-23056 [JIF: 03.676 (2020)]
doi:10.1039/D0CP03751F

PROGRAMMBEREICHSUNGEBUNDEN / NOT LINKED TO A PROGRAM DIVISION

Weitere / Others

Y. Chen, S. Aslanoglou, T. Murayama, G. Gervinskas, L. I. Fitzgerald, S. Sriram, J. Tian, A. P. R. Johnston, Y. Morikawa, K. Suu, R. Elnathan and N. H. Voelcker
Silicon-Nanotube-Mediated Intracellular Delivery Enables Ex Vivo Gene Editing
Advanced Materials 2020, 32, (24), 2000036 [JIF: 30.849 (2020)]
doi:10.1002/adma.202000036

S. Husmann, A. J. G. Zarbin and R. A. W. Dryfe
High-performance aqueous rechargeable potassium batteries prepared via interfacial synthesis of a Prussian blue-carbon nanotube composite
Electrochimica Acta 2020, 349, 136243 [JIF: 06.901 (2020)]
doi:10.1016/j.electacta.2020.136243

T. Lé, G. Bidan, F. Billon, M. Delaunay, J.-M. Gérard, H. Perrot, O. Sel and D. Aradilla
Deciphering the Influence of Electrolytes on the Energy Storage Mechanism of Vertically-Oriented Graphene Nanosheet Electrodes by Using Advanced Electrogravimetric Methods
Nanomaterials 2020, 10, (12), 2451 [JIF: 05.076 (2020)]
doi:10.3390/nano10122451

R. M. McMeeking, M. Ciavarella, G. Cricrì and K.-S. Kim
The Interaction of Frictional Slip and Adhesion for a Stiff Sphere on a Compliant Substrate
Journal of Applied Mechanics 2020, 87, (3), [JIF: 02.671 (2020)]
doi:10.1115/1.4045794

R. Sahli, J. Hem, C. Crauste-Thibierge, F. Clément, D. R. Long and S. Ciliberto
Relaxation time of a polymer glass stretched at very large strains
Physical Review Materials 2020, 4, (3), 035601 [JIF: 03.989 (2020)]
doi:10.1103/PhysRevMaterials.4.035601

EINGELADENE VORTRÄGE / INVITED TALKS

340 Vorträge
talks
davon / *including*

47 eingeladene Vorträge
invited talks

293 sonstige Vorträge
other talks
davon / *including*

241 Industrievorträge

(Stand / As of 21.03.2022)

Eine Liste der eingeladenen sowie ausgewählter sonstiger Vorträge finden Sie unter http://www.leibniz-inm.de/publikationen

For a list of invited talks and selected other presentations, please visit http://www.leibniz-inm.de/en/publications

GRENZFLÄCHENMATERIALIEN / INTERFACE MATERIALS

Energie-Materialien / Energy Materials

V. Presser
Battery science and technology: going digital and going green
COP26 : United Nations Climate Change Conference, Glasgow <GBR>
virtual
November 4, 2021

V. Presser
Boldly go into the unknown
DFG-Nachwuchsakademie Keramische Werkstoffe: Von den Grundlagen zur Anwendung <Saarbrücken, GER>
virtual
May 7, 2021

V. Presser
Electrochemical desalination: synergy of energy storage, water remediation, and elemental recovery
Missouri University of Science and Technology, La Rolla <USA>
virtual
March 5, 2021

V. Presser
Electrochemical water desalination with MXene
262th National Meeting & Exposition of the American Chemical Society (ACS)
virtual
August 22 – 26, 2021

V. Presser
Ion mining: electrochemical extraction of ions from mine water and other aqueous media
Materials Week 2021
virtual
September 7 – 9, 2021

V. Presser
Lithium: the element enabling energy storage
Jung-DGM ; Deutsche Gesellschaft für Materialkunde
virtual
November 11, 2021

Funktionelle Mikrostrukturen / Functional Microstructures

E. Arzt
Scaling of bioinspired surface micropatterns for gripping applications
NRW Nano-Conference
virtual
April 21 – 23, 2021

E. Arzt
Pick-and-place by switchable microstructures: a sustainable handling
MRS Spring Meeting
virtual
April 19, 2021

E. Arzt
Designing with gaps – functional surfaces for sustainable gripping
EML Webinar
virtual
May 19, 2021

E. Arzt
Functional micropatterned surfaces – a sustainable materials paradigm
Johannes Kepler Universität Linz <Linz, AUT>
May 26, 2021

E. Arzt
Adhesive surface microstructures inspired by nature – now coming of age?
44th Annual Meeting, The Adhesion Society, Award Lecture
virtual
February 22 – 25, 2021

E. Arzt
Gecomer – Vom Vorbild Natur zum Start-Up
Rotary Club
Saarbrücken <GER>
April 7, 2021

R. Hensel
Bio-inspired micropatterned adhesives – a multiscale problem to optimize grip
Technion, Israel Institute of Technology, Department of Materials Science and Engineering
Haifa <ISR>
March 4, 2021

R. Hensel
Adhesives in space – Opportunities and Challenges
in-adhesives
virtual
June 08, 2021

R. Hensel
Switchable Micropatterned Adhesives for Microhandling Under Dry and Wet Conditions
Nanoscribe User Meeting 2021
Virtual
September 09, 2021

Innovative Elektronenmikroskopie / Innovative Electron Microscopy

N. de Jonge
Liquid phase electron microscopy
University of Vienna: Opening lecture for kickoff meeting of ONEM project
Wien <AUT>
virtual
February 5, 2021

N. de Jonge
Liquid phase electron microscopy, fundamentals, and +applications to study soft matter and cancer cells
Frontiers of Science Conference
Braga <POR>
virtual
September 27, 2021

N. de Jonge
Liquid phase electron microscopy, fundamentals, application to study membrane proteins in whole cells, and soft matter
BIST Symposium on Microscopy
Barcelona <ESP>
June 17 – 18, 2021

N. de Jonge
Liquid-Phase Electron Microscopy for Soft Matter Science and Biology
MRS Spring Meeting
Seattle <WA, USA>
virtual
April 18, 2021

N. de Jonge
Membrane proteins studied within whole cells via liquid phase electron microscopy
LiveNan.org
virtual
September 15, 2021

N. de Jonge
Prospects and challenges of dynamic liquid phase electron microscopy
Online seminar "Imaging Chemical Dynamics by Liquid Cell (Scanning) Transmission Electron Microscopy" of MDPI's journal
virtual
May 3, 2021

Interaktive Oberflächen / Interactive Surfaces

R. Bennewitz
Fingertip friction and tactile perception of materials
Virtual Workshop on "The sense of touch: interplay between action and perception & underlying body representations" University of Gießen
virtual
September 30 – October 8, 2021

R. Bennewitz
Friction force microscopy of shear planes at the electrochemical interface
116th AGEF Symposium on Triboelectrochemistry
Bonn <GER>
September 22 – 24, 2021

R. Bennewitz and G. Krämer
Ordering of nanometer-confined liquids and experimental nanolubrication
Conference on Nanolubrication
Durham <GBR>
July 15 – 16, 2021

R. Bennewitz
Single-molecule force spectroscopy of dynamic biomaterials
NanoTech Poland; 11th International edition of the NanoTech Poland
Virtual
June 9 – 11, 2021

J. Blass, R. Bennewitz, M. Albrecht and G. Wenz
Tuning friction and adhesion through cooperativity effects of supramolecular bonds
Conference on Nanolubrication
Durham <GBR>
July 15 – 16, 2021

BIOGRENZFLÄCHEN / BIO INTERFACES

Dynamische Biomaterialien / Dynamic Biomaterials

A. del Campo
Biomaterial designs for light-drive blood vessel growth (angiogenesis)
The International Chemical Congress of Pacific Basin Societies
Honolulu <HI, USA> virtual
December 16 – 21, 2021

A. del Campo
Force application to cells with light-driven synthetic molecular motors
DGZ International Meeting 2021 – Life in Between – The Cell Biology of Interfaces
virtual
September 27 – 29, 2021

A. del Campo
Light-responsive hydrogels that talk to cells
3rd International Symposium of Transregio 67 "Frontiers in Biomaterials Science"
virtual
July 9 – 10, 2021

A. del Campo
Printed optical waveguides to brin g light into the body
2nd Optogenetic Technologies and Applications Conference
Virtual
December 5 – 7, 2021

NANOKOMPOSIT-TECHNOLOGIE / NANOCOMPOSITE TECHNOLOGY

Nanomere / Nanomers

C. Becker-Willinger
FORUM 3D-DRUCK Saarwirtschaft – Komposit für den 3D-Druck
saaris / Ministerium für Wirtschaft, Arbeit, Energie und Verkehr <Saarbrücken, GER>
virtual
February 25, 2021

C. Becker-Willinger
FORUM Leichtbau Saarwirtschaft – Leichtbau als Schlüsseltechnologie; Flammengeschützte Bauplatte aus namibischen Ressourcen
Ministerium für Wirtschaft, Arbeit, Energie und Verkehr <Saarbrücken, GER>
virtual
April 27, 2021

C. Becker-Willinger
Keramische Leiterplatten aus Cu-Kolloiden
virtual – Saarbrücken <GER>
July 19, 2021

C. Becker-Willinger
Oberflächenmodifizierung von dentalem Glas
Schaan <LIE>
September 13, 2021

C. Becker-Willinger, B. Reinhard, M. Jochum, B. Ali, H. Stuurmann, L. Naomas and E. Naomab
Standard Bank Biomass Fair Namibia: Fireproof Acacia fiberboard from 100 % Namibian ressources for building and construction
N-BIC
virtual – Otjiwarongo <NAM>
June 3, 2021

C. Becker-Willinger, M. Twardoch, S. Albayrak and M. Jochum
Nanomer coatings containing manganese hydrogen phosphate particles for corrosion protection on mild steel
EUROCORR 2021
virtual
September 20 – 24, 2021

M. Twardoch, S. Albayrak, M. Jochum and C. Becker-Willinger
Investigation of the corrosion protection ability of Nanomer powder coatings containing new porous Zic phosphate flake type particles on mild steel
EUROCORR 2021
virtual
September 20 – 24, 2021

Optische Materialien / Optical Materials

M. Amlung
Glass-like protection coatings
Industrievortrag international
March 15, 2021

P. W. d. Oliveira
Optische Materialien
Saarland Universität <Saarbrücken, GER>
March 22, 2021

P. W. d. Oliveira
Production of Nanobubbles by UV light
Industrievortrag International
March 15, 2021

P. W. d. Oliveira
Electrospinning for Touch Sensor
Industrievortrag international
March 15, 2021

P. W. d. Oliveira
Transparent Electrode Production by Photo-Metallization
Industrievortrag international
March 15, 2021

P. W. d. Oliveira
ITO Ink-jet for printed electronics
Industrievortrag International
March 15, 2021

Strukturbildung / Structure Formation

T. Kraus
Directing the structure and electronics of printed hybrid films
nanoGe Fall Meeting 2021
virtual
October 22, 2021

T. Kraus
Making and recycling of particle-based materials: from controlled agglomeration to circular functional materials
AC-Kolloquium ; Universität Duisburg-Essen <GER>
virtual
April 26, 2021

T. Kraus
Structure formation in multi-scale materials: from liquid precursors to electronics, batteries, and sensors
Online Seminar Serie "Materials and Energy: Challenges and Opportunities"; Universität Duisburg-Essen <GER>
virtual
November 18, 2021

InnovationsZentrum INM / InnovationCenter INM

M. Amlung
Glass-like protection coatings
Industrievortrag international
March 15, 2021

P. W. d. Oliveira
InnovationsZentrum
Université <Lyon, FRA>
March 8, 2021

P. W. d. Oliveira
Production of Nanobubbles by UV light
Industrievortrag International
March 15, 2021

P. W. d. Oliveira
Electrospinning for Touch Sensor
Industrievortrag international
March 15, 2021

P. W. d. Oliveira
Transparent Electrode Production by Photo-Metallization
Industrievortrag international
March 15, 2021

P. W. d. Oliveira
ITO Ink-jet for printed electronics
Industrievortrag International
March 15, 2021

PATENTE / PATENTS

3 Patentanmeldungen
patent applications

13 erteilte Patente
granted patents

5 in Europa
in Europe

8 international
international

54 Patentfamilien
patent families

ERTEILTE EUROPÄISCHE PATENTE / PATENTS GRANTED IN EUROPE

Europäisches Patent Nr. INM-341
Highly structured composite material and process for the manufacture of protective coatings for corroding substrates
Erfinder: C. Becker-Willinger, F. Hollmann, M. Jochum, M. Opsölder, S. Schmitz-Stöwe, D. Espin

Europäisches Patent Nr. INM-355
Gegenstand mit schaltbarer Adhäsion
Erfinder: A. Schneider, E. Kroner, J. Kaiser, M. Frensemeier, E. Arzt

Europäisches Patent Nr. INM-381
Verfahren zur Herstellung von strukturierten Oberflächen
Erfinder: B. Reiser, J. Kampka, K. Moh, T. Kraus, L. González-García, I. Kanelidis, P. W. de Oliveira, J. Maurer

Europäisches Patent Nr. INM-376
Komposit-Pillarstrukturen
Erfinder: R. Hensel, S. Fischer, E. Arzt

Europäisches Patent Nr. INM-384
Verfahren zur Herstellung von leitfähigen Strukturen
Erfinder: P. W. de Oliveira, J. S. Atchison

ERTEILTE INTERNATIONALE PATENTE / PATENTS GRANTED INTERNATIONALLY

JP Patent Nr. INM-355
Gegenstand mit schaltbarer Adhäsion
Erfinder: A. Schneider, E. Kroner, J. Kaiser, M. Frensemeier, E. Arzt

JP Patent Nr. INM-376/JP
Komposit-Pillarstrukturen
Erfinder: R. Hensel, S. Fischer, E. Arzt

JP Patent Nr. INM-378/JP
Leitfähige Nanokomposite
Erfinder: B. Reiser, T. Kraus, L. González-García, J. Maurer, I. Kanelidis

US Patent Nr. INM-381/US
Verfahren zur Herstellung von strukturierten Oberflächen
Erfinder: B. Reiser, J. Kampka, K. Moh, T. Kraus, L. González-García, I. Kanelidis, P. W. de Oliveira, J. Maurer

AU Patent Nr. INM-381/AU
Verfahren zur Herstellung von strukturierten Oberflächen
Erfinder: B. Reiser, J. Kampka, K. Moh, T. Kraus, L. González-García, I. Kanelidis, P. W. de Oliveira, J. Maurer

JP Patent Nr. INM-384/JP
Verfahren zur Herstellung von leitfähigen Strukturen
Erfinder: P. W. de Oliveira, J. S. Atchison

US Patent Nr. INM-386/US
Vorrichtung mit einer strukturierten Beschichtung zur Verwendung als Implantat zur Behandlung von Trommelfellperforationen und zur Zellkultivierung
Erfinder: E. Arzt, S. Fischer, K. Kruttwig, R. Hensel, B. Schick, G. Wenzel

US Patent Nr. INM-391/US
Herstellung von dotierten Nanopartikeln und ihre Verwendung
Erfinder: N. Müller, P. Rogin, P. W. de Oliveira, T. Müller

LEHRVERANSTALTUNGEN / TEACHING

WINTERSEMESTER / WINTER SEMESTER 2020/2021

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NanoBioMaterialien 1
Universität des Saarlandes, Vorlesung, 2 SWS

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INM-Kolloquium
Universität des Saarlandes, Kolloquium, 2 SWS

Eduard Arzt und Mitarbeiter/innen
Einführung in die Materialwissenschaft für (Studierende des) Systems Engineering,
Vorlesung und 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

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

Roland Bennewitz (mit I. Weyand, Saarbrücken)
Gute wissenschaftliche Praxis und Kommunikation
Universität des Saarlandes (GradUS), Blockseminar, 1 SWS

Aránzazu del Campo, Shrikrishnan Sankaran und Mitarbeiter*innen
Biomedizinische Polymere
Universität des Saarlandes, Vorlesung, 2 SWS

Marcus Koch (mit F. Breinig, Univ. des Saarlandes)
Zellbiologie
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, M. Springborg, Univ. des Saarlandes)
Advanced Topics in Physical Chemistry (PC 06)
Universität des Saarlandes, Vorlesung, 4 SWS

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

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Tobias Kraus
Vertiefungspraktikum Werkstoffchemie (WCV)
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Volker Presser (mit R. Hempelmann, D. Scheschkewitz, Univ. des Saarlandes)
Materials for Efficient Energy Use (EnTV)
Universität des Saarlandes, Vorlesung, 2 SWS

SOMMERSEMESTER / SUMMER SEMESTER 2021

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

Roland Bennewitz (mit J. Klümpers, Bonn)
Good Scientific Practice and Communication, SS 2021
Universität des Saarlandes (GradUS), Blockseminar, 1 SWS

Aránzazu del Campo, Shrikrishnan Sankaran
Biopolymere & Bioinspirierte Polymere (BioPol)
Universität des Saarlandes, Vorlesung, 2 SWS

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Tobias Kraus
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Universität des Saarlandes, Kolloquium, 2 SWS

Tobias Kraus (mit G. Jung, C. Kay)
Vertiefungspraktikum Physikalische Chemie (PCV), SS 2021
Universität des Saarlandes, Praktikum, 2 SWS

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

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

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

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Einführung in die Materialwissenschaft für (Studierende des) Systems Engineering
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Gute wissenschaftliche Praxis und Kommunikation
Universität des Saarlandes (GradUS), Blockseminar, 1 SWS

Niels de Jonge
High resolution light- and electron microscopy
Universität des Saarlandes, Vorlesung und Übung, 4 SWS

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

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Advanced Topics in Physical Chemistry (PC 06)
Universität des Saarlandes, Vorlesung, 4 SWS

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Tobias Kraus
Vertiefungspraktikum Werkstoffchemie (WCV)
Universität des Saarlandes, Praktikum, 2 SWS

Volker Presser (mit R. Hempelmann, D. Scheschkewitz, Univ. des Saarlandes)
Materials for Efficient Energy Use (EnTV)
Universität des Saarlandes, Vorlesung, 2 SWS

Annette Kraegeloh (mit C. M. Lehr, M. Schneider, T. Vandamme et al.)
Introduction to Drug Delivery and NanoBiomedicine
Universität des Saarlandes, Strasbourg University, 1 SWS

VERANSTALTUNGEN / EVENTS

APRIL

Hannover Messe Digital Edition
Industrial Transformation
P. de Oliveira and M. Amlung
virtuell, 12. – 16.04.2021

MAI

Engineered Living Materials Conference
A. d. Campo, C. Hartmann and S. Sankaran (mit Prof. W. Weber, University Freiburg)
virtuell, 04. – 07.05.2021

JUNI

Ausstellungseröffnung: Bunt – Klein – Überall. Mikroplastik vom Fluss ins Meer
E. Bubel
Saarbrücken, 11.06.2021

Tag der offenen Tür der Universität des Saarlandes
E. Arzt, C. Hartmann, A. Kraegeloh, T. Kraus, V. Presser and M. Quilitz
virtuell, 26.06.2021

AUGUST

Virtueller Besuch von Studierenden aus dem Programm AMASE (EUSMAT) der Univ. des Saarlandes (mit Univ. des Saarlandes)
M. Koch, G. Moreira-Lana and M. Quilitz,
virtuell, 23.08.2021

Schülerpraktikum I
J. Blau, F. Faller, P. Kalmes, G. Moreira Lana, M. Quilitz, M. Samri, S. Selzer, L. Sold and A. Weyand
Saarbrücken, 23. – 27.08.2021

LSC-SEMINARE / LSC SEMINARS

DEZEMBER 2021

Dr. J. Hegemann, HIPS
Microbiota-protective features of commensal bacteria producing RiPP natural products
Saarbrücken, 02.12.2021

Dr. M. Rodriguez Estevez, Universität des Saarlandes
Discovering new natural drugs and biosynthetic gene clusters through heterologous expression
Saarbrücken, 16.12.2021

JANUAR 2022

Prof. Dr. C. Wittmann, Universität des Saarlandes
Metabolism – making living materials alive
Saarbrücken, 13.01.2022

Dr. S. Sankaran, INM
Genetic sensors and switches – Making living materials smart
Saarbrücken, 20.01.2022

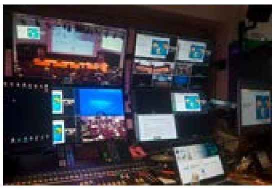
Prof. Dr. T. Kraus, INM, Universität des Saarlandes
Transport of molecules and heat in living materials
Saarbrücken, 20.01.2022

FEBRUAR 2022

Prof. Dr. A. del Campo, INM, Universität des Saarlandes
Materials and processing technologies to fabricate ELMs
Saarbrücken, 03.02.2022

lifemat

SEPTEMBER



Conference on In-Situ and Correlative Electron Microscopy – CISCEM 2021
N. d. Jonge and C. Hartmann (mit Prof. K. Mølhave, Technical Univ. of Denmark, Dr. D. Alloyeau, Univ. Paris Diderot)
Paris, 08. – 10.09.2021

SEPTEMBER

Virtual Lab Day des BMBF-VDI – Vorveranstaltung zum BMBF Schülerpraktikum Werkstoffferien 2021
M. Koch, M. Quilitz and A. Zimmermann (mit VDI, BMBF)
virtuell, 14.09.2021

DPG "SKM" Symposium Hybrid Nanomaterials: From Novel Physics and Multi-Scale Self-Organization to Functional Diversity on the Device Scale (SYHN)
T. Kraus (mit TU Hamburg)
30.09.2021

OKTOBER

Workshop des Leibniz ScienceCampus Living Therapeutic Materials
A. d. Campo, S. Sankaran
Saarbrücken, 14.10.2021

BMBF Schülerpraktikum Werkstoffferien 2021
Y. Brasse, L. Elberskirch, K. Fries, M. Koch, M. Quilitz, S. Schumacher, G. Moreira Lana, T. Müller, S. Siegrist and A. Zimmermann (mit VDI, BMBF)
Saarbrücken, 18. – 22.10.2021

Experten Workshop "Description standards and Minimum Information Table for digital research data in nanosafety"
A. Kraegeloh, C. Petzold, L. Elberskirch und externe Partner
virtuell, 26.10.2021

NOVEMBER

Schülerpraktikum II
M. Koch, M. Quilitz, C. Sauer-Hormann and A. Zimmermann
virtuell, 01. – 05.11.2021

Schülerpraktikum III
S. Arnold, W. Buhrow, F. Faller, A. Jung, P. Kalmes, S. Kunkel, C. Lang, G. Moreira Lana, M. Quilitz, H. Rimbach, M. Samri, K. Schellnhuber, S. Selzer and A. Weyand
Saarbrücken, 02. – 12.11.2021

Particle-Based Materials Symposium 2021
T. Kraus and C. Hartmann (mit Prof. Dr. G. Garnweitner, TU Braunschweig , Prof. Dr. R. Klupp Taylor, FAU Erlangen-Nürnberg, Prof. Dr. A. Kühne, Ulm University, Prof. Dr. K. Mandel, FAU Erlangen-Nürnberg, Prof. Dr. D. Segets, University Duisburg-Essen, Prof. Dr. N. Vogel, FAU Erlangen-Nürnberg)
virtuell, 30.11.2021

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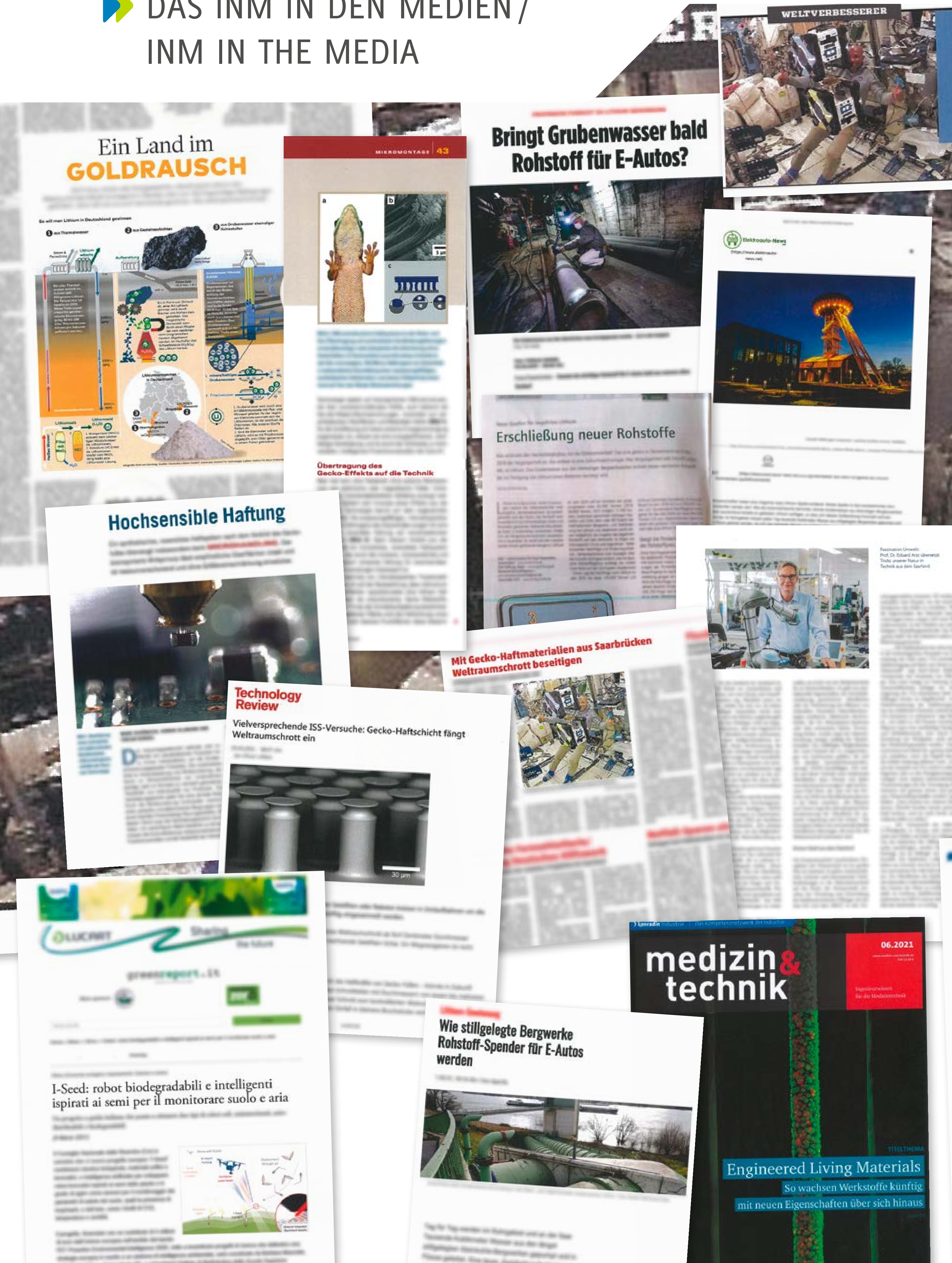


GECKOS GEGEN WELTRAUMSCHROTT
Bergbau-Altlast Grubenwasser soll zum Lithiumlieferanten werden
Grubenwasser soll zum Lithiumlieferanten werden
Biosignale präzise messen mit wenigen Mausklicks: Informatiker erleichtern die Positionierung von Elektroden am Körper
UNIVERSITÄT DES SAARLANDES
Saar-Grubenwasser soll Lieferant von Lithium werden
DIE LINDE
Neuer Ansatz zur Entsalzung von Meerwasser mit Wasserstoff
350 µm
500 µm
Microhandling in der Photonik
Nachrichten
Forderung nach Investitionen in Batterie-Recycling
Haftung ausgeschlossen? Nicht mit dem INM und Prof. Martin Müser!
I-Seed, robot che si muovono come semi per il monitoraggio del terreno
„Aktive Nanokomposite könnten anzeigen, wenn Lebensmittel verdorben sind"
Die Brennstoffzelle, die gleichzeitig Energie erzeugen und Meerwasser entsalzen kann
A) Protonen-Austausch-Membran-Elektrolyseur
B) Entsalzungs-Brennstoffzelle
Meerwasser
Frischwasser
Bild 1: Prinzip der Wasserstoffproduktion in einer PEM-Elektrolysezelle
Bild 2: Prinzip der FCD (Fuel Cell Desalination)-Zelle
Bild 3: Testzelle in der Laboranlage
Lithium aus Grubenwasser
E-Mobilität: Grubenwasser soll zum Lithiumlieferanten werden
GLÜCK AUF

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Istituto ltaliano di Technologia (IIT) (S. / *p.* 33, links / *left*)
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Phoenix group (S. / *p.* 56, Bild / *image* 1)
TU Braunschweig (S. / *p.* 6 oben / *top*, 11, rechts / *right*)

Titelseite / *Front page*:

oben / *top*: Außenansicht des INM / *Exterior view of INM.*

Mitte links / *Middle left*: In-vitro-Sekretion von Muzinproteinen durch Calu-3-Zellen. MUC5AC (grün) und MUC5B (rot) in A) basalen und B) apikalen Regionen. Zellkerne sind blau gefärbt. / *In vitro secretion of mucin proteins by Calu-3 cells. MUC5AC (green) and MUC5B (red) at A) basal and B) apical regions. Cell nuclei are colored blue.*
(Programmbereich Nano Zell Interaktion / *Program Division Nano Cell Interaction*)

Mitte rechts / *Middle right*: Kern-Hülle-Mikropartikel (Dextran/PEG), das funktionelle arzneimittelproduzierende Bakterien enthält und deren Replikation steuert. / *Core-shell microparticle (Dextran/PEG) that contains functional drug-producing bacteria and controls their replication.*
(Programmbereich Dynamische Biomaterialien / *Program Division Dynamic Biomaterials*)

SAARLAND

Großes entsteht immer
im Kleinen.

INM

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auch als interaktives Blätter-PDF.

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