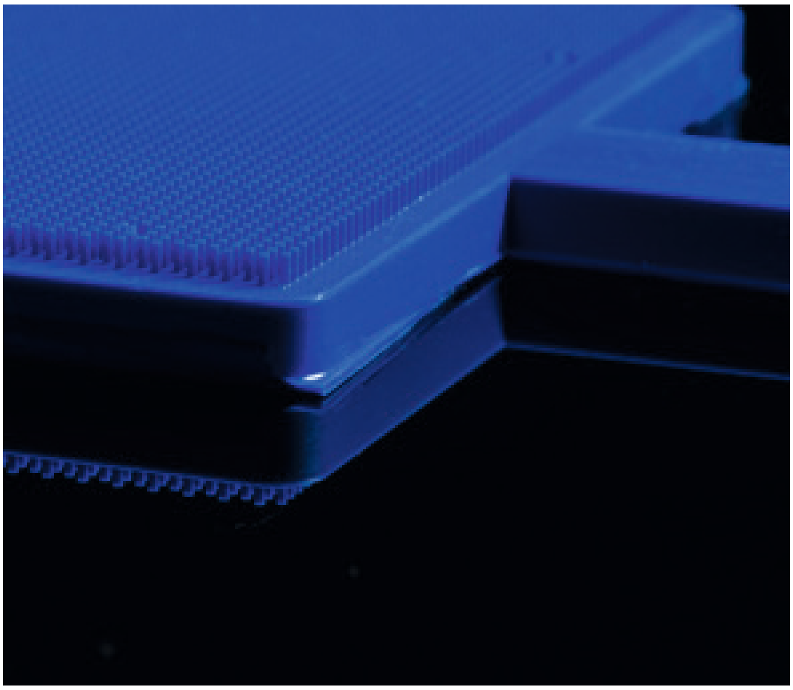
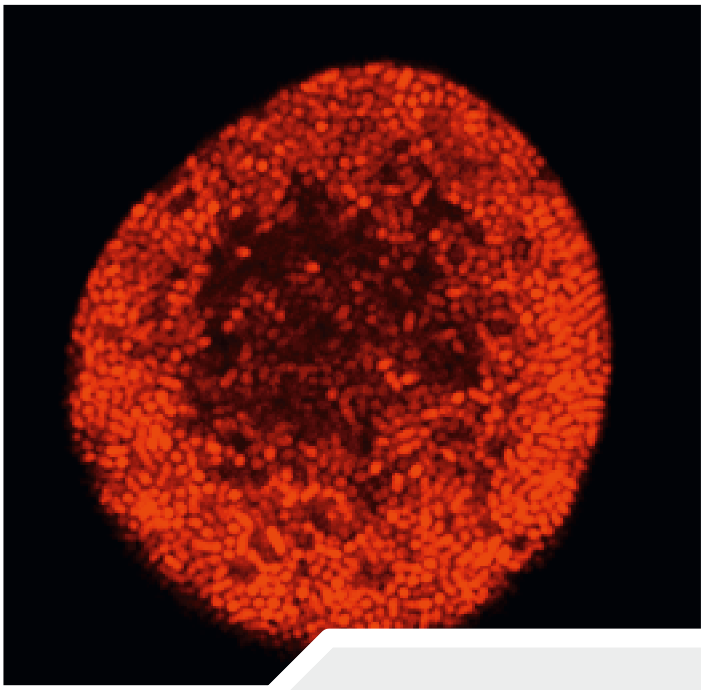
Neues Denken. Neue Materialien.





JAHRESBERICHT 2022
ANNUAL REPORT 2022

Leibniz Gemeinschaft

INM
Leibniz-Institut für Neue Materialien

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Wissenschaftliche Geschäftsführerin/ Scientific Director

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Wissenschaftlicher Geschäftsführer und Vorsitzender der Geschäftsführung/ Scientific Director and CEO

LIEBE LESERINNEN UND LESER, WILLKOMMEN ZUM JAHRESBERICHT DES INM!

Das Institut blickt wieder auf ein erfolgreiches Jahr zurück. Beispiele aus den wissenschaftlichen Highlights umfassen Technologien zur Wasserentsalzung mit Kohlenstoffelektroden, die Entwicklung medizinischer Hydrogele zur Wachstumssteuerung eingeschlossener Bakterien, oder den Einbau von maschinellem Lernen in neue Greifsysteme.

Zum Jahresende 2022 wurde Herr Professor Eduard Arzt in den Ruhestand verabschiedet. Als Wissenschaftlicher Geschäftsführer und Vorsitzender der Geschäftsführung hat er die Entwicklung des INMs in den letzten 15 Jahren maßgeblich geprägt und das Institut zu weltweiter Anerkennung geführt.

Mit Dr. Sara Trujillo und Dr. Oskar Staufer starteten zwei Nachwuchsforschende. Ihre Gruppen verstärken die Aktivitäten im Bereich Lebende Therapeutische Materialien und die Kooperation mit den Lebenswissenschaften auf dem Campus. Mit Dr. Cao Nguyen Duong erweiterte das INM seine Serviceleistungen auf dem Gebiet der Fluoreszenzmikroskopie. Prof. Niels de Jonge, seit 2012 Leiter des Programmbereiches Innovative Elektronenmikroskopie, verließ das INM, um eine leitende Position in der Industrie zu übernehmen.

Auch in diesem Jahr gab es wieder viele Auszeichnungen für INM-Mitarbeitende. Stellvertretend seien hier genannt: Prof. Volker Presser erhielt den Umwelt- und Klimaschutzpreis der Stadt Saarbrücken. Frau Kathrin Schmitt wurde der Auszubildendenpreis der Leibniz-Gemeinschaft verliehen. Für Dr. Emmanuel Pammete und Dr. Yuan Zhang war das INM wieder Gastgeber im Rahmen der Alexander-von-Humboldt-Stiftung.

Die mit Mitteln des Landes und des Bundes geförderte Umbaumaßnahme inkl. des Sondertatbestandes sind bereits erfolgreich umgesetzt. Es konnte damit für die Zukunft eine hervorragende Infrastruktur für die Forschung am INM geschaffen werden.

Wir wünschen Ihnen, dass Sie auf den folgenden Seiten Neues und Spannendes entdecken, und freuen uns, wenn Sie uns auch in Zukunft gewogen bleiben.

DEAR READERS, WELCOME TO THE ANNUAL REPORT OF THE INM!

The institute can look back on another successful year. Examples of the scientific highlights in 2022 include technologies for water desalination using carbon electrodes, the development of medical hydrogels that control bacterial growth, and the incorporation of machine learning into novel gripping systems.

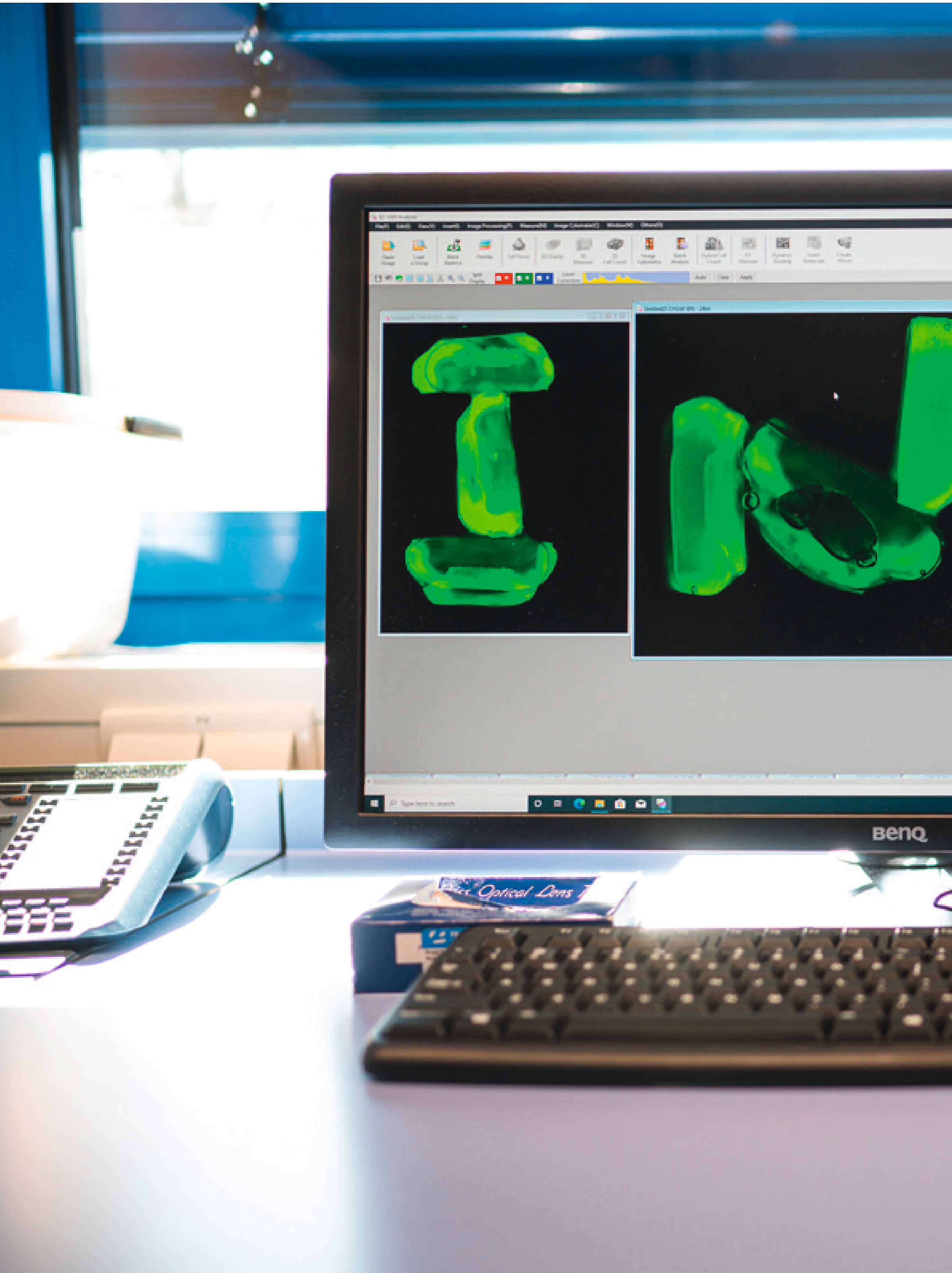
At the end of 2022, Professor Eduard Arzt retired from his position as Scientific Director and Chairman of the Management Board. Over the past 15 years, he has significantly shaped the development of INM and led the institute to worldwide recognition.

With Dr. Sara Trujillo and Dr. Oskar Staufer, two young scientists started their independent work at INM. Their groups strengthen INM's activities in the field of living therapeutic materials and the cooperation with the life sciences on the Saarland Campus. With Dr. Cao Nguyen Duong, INM expanded its services in the field of fluorescence microscopy. And Prof. Niels de Jonge, head of the successful program division Innovative Electron Microscopy since 2012, left the INM to take up a senior position in industry.

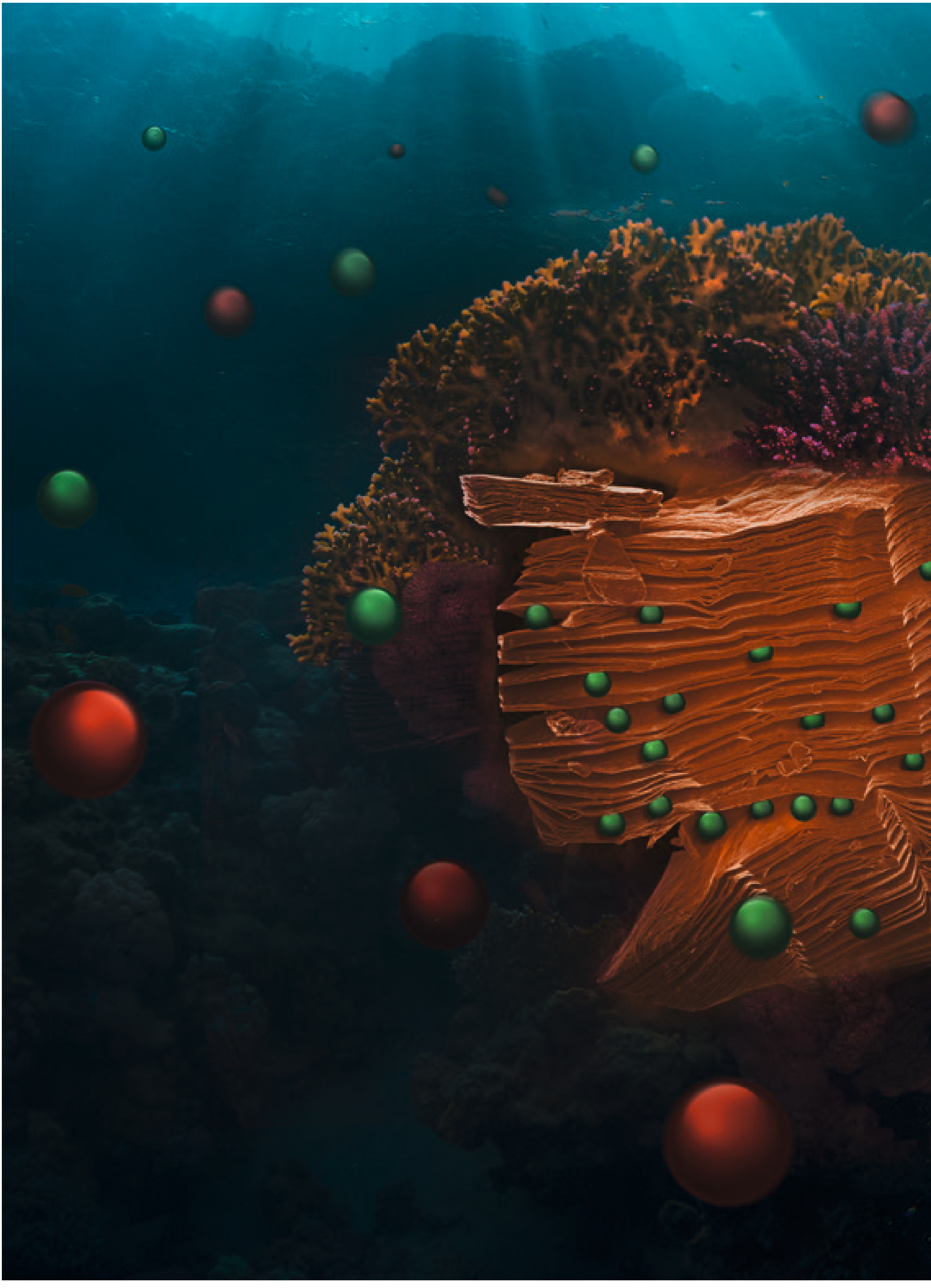
In 2022, numerous INM employees received significant honors and awards. The following are just a few examples: Prof. Volker Presser received the Environment and Climate Protection Award of the City of Saarbrücken and Kathrin Schmitt was awarded the trainee prize of the Leibniz Association. In addition, INM was once again host for Emmanuel Pammete and Yuan Zhang in the framework of the Alexander von Humboldt Fellowship Program.

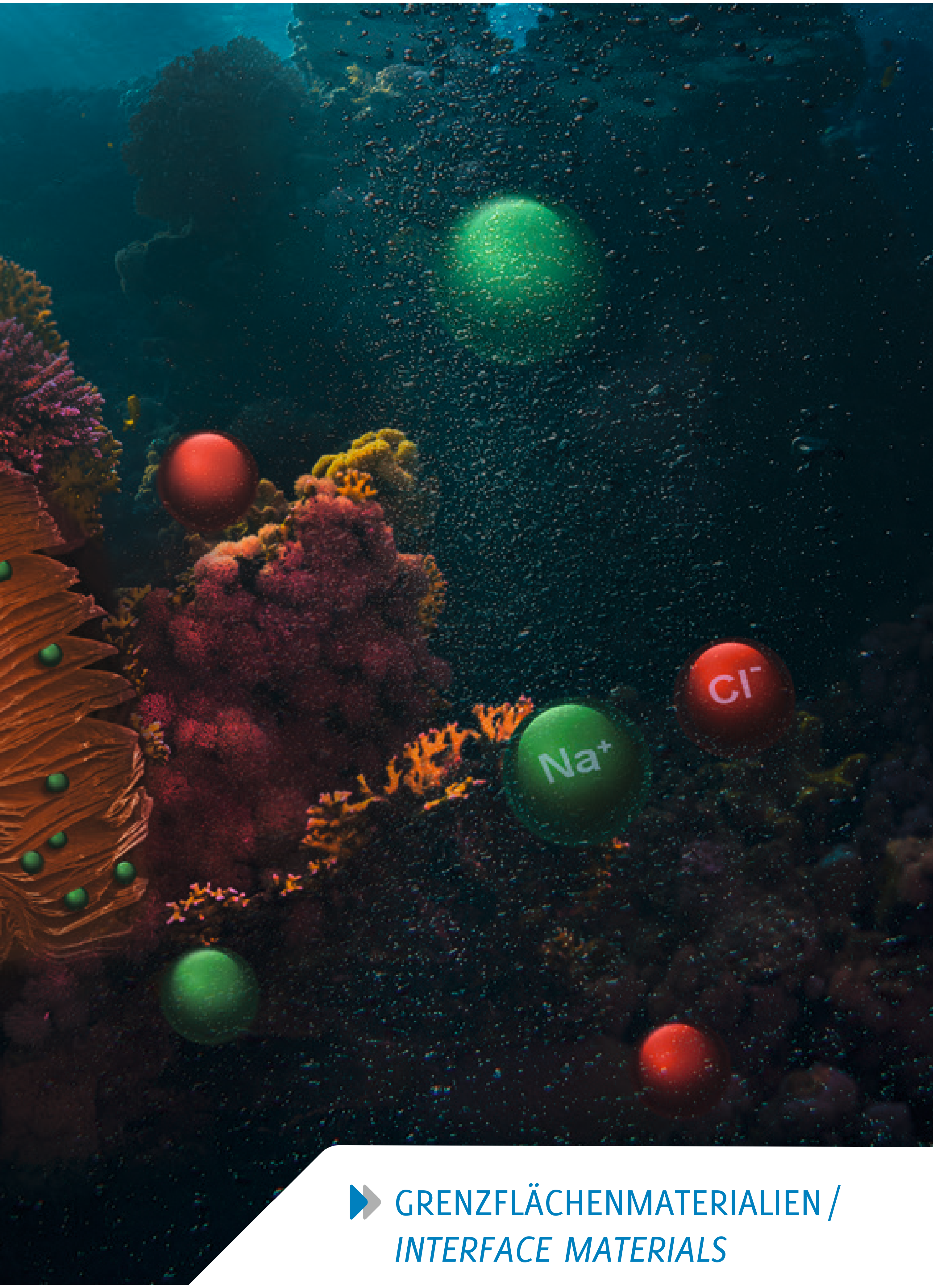
The expansion of the laboratory and office space approved and funded by the state and federal governments has been successfully implemented. With this measure INM obtains additional excellent infrastructure for future research and development.

We hope you will enjoy discovering new and exciting things on the following pages and look forward to your continued support.


BenQ
Optical Lens

GRUPPENBERICHTE / GROUP REPORTS





GRENZFLÄCHENMATERIALIEN /

INTERFACE MATERIALS

ENERGIE-MATERIALIEN / ENERGY MATERIALS

PROF. DR. VOLKER PRESSER

ZUSAMMENFASSUNG

Der Programmbereich Energie-Materialien erforscht Materialien und Technologien für eine nachhaltige Energie- und Wassernutzung. Hierzu entwickeln wir Materialien, die auf der Nanoebene Ionen und elektrische Ladung effektiv transportieren und speichern können. Wichtige Elektrodenmaterialien sind nanoporöse Kohlenstoffe, Oxide, Karbide und Sulfide. Einen besonderen Schwerpunkt bilden 2D Materialien, insbesondere MXene. Solche Materialien bilden leistungsstarke Elektroden für Superkondensatoren, Lithium-Ionen oder Natrium-Ionen Batterien zur Energiespeicherung. Die reversible Aufnahme und kontrollierte Abgabe von Ionen ermöglicht auch die Entsalzung von Meerwasser und die Ionentrennung, um Schadstoffe wie Blei abzutrennen oder Wertstoffe wie Lithium wiederzugewinnen. Für ein umfassendes Verständnis 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 materials and technologies for sustainable energy and water use. To this end, we are developing materials that can effectively transport and store ions and electrical charges at the nano level. Important electrode materials are nanoporous carbons, oxides, carbides, and sulfides. A particular focus is on 2D materials, especially MXene. Such materials make powerful electrodes for supercapacitors, lithium-ion or sodium-ion batteries for energy storage. The reversible uptake and controlled release of ions also enable the desalination of seawater and ion separation to separate pollutants such as lead or recover valuable materials such as lithium. We use various characterization methods, including in situ, for a comprehensive mechanistic understanding. In addition, we are increasingly using digital methods for predictive materials research. Our collaborations include international basic research as well as industrial projects.

CURRENT RESEARCH

Digital energy materials.

Digital methods allow us to better understand processes, and predictive tools support the development of novel nanomaterials. Digitalization is also a key tool for advancing battery production, as explored within the BMBF-funded ProZell DigiBatMat project with the Program Division *Structure Formation* and several other partners. We also use predictive tools to simulate ion transport within nanoporous carbon to create advanced supercapacitors (German-Polish

DFG Project) and high-performance seawater desalination devices (collaboration with Huazhong University of Science and Technology, Wuhan, China). 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.

Electrochemical ion separation and desalination

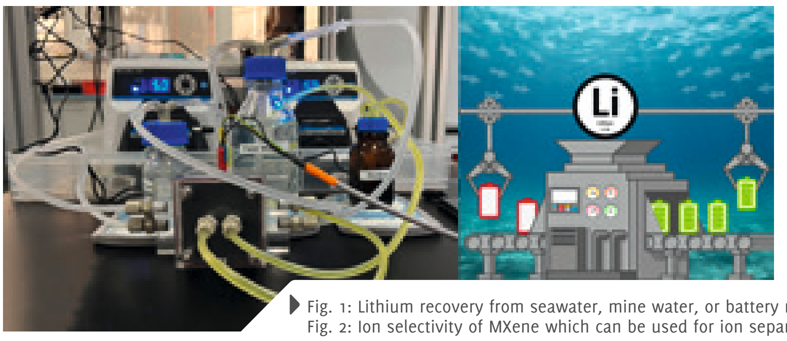
Electrochemical interfaces and materials enable triple use for energy storage, elemental recovery, and water remediation. The portfolio includes capacitive deionization (Zhang et al., Cell Rep. P. Sc., 2022), seawater batteries (Arnold et al., Small, 2022), redox flow battery desalination (Wang et al., ACS En. Lett., 2022), and fuel cell desalination (Suss et al., El. Comm., 2022). For example, drinking water can be obtained from non-selective systems based on nanoporous carbon. Removing pollutants like lead or valuable elements like lithium (Patent filed) is possible using ion-selective electrode materials. The latter mandate an intricate knowledge and design of the nanoconfinement of the target ions. Among others, we collaborate with colleagues from the IFAM Bremen, the University of Manchester, and Huazhong University of Science and Technology. Within projects funded by the RAG Foundation and EFRE, we explore lithium recovery from regional mining water within the context of hydrometallurgical battery recycling.

Next-generation batteries

Batteries need to become higher in performance, longer-lasting, easier recyclable, and based on less critical elements. High-performance lithium-sulfur pouch cell batteries are the core topic of our European project ALISA together with Swiss, Slovenian, and German partners from industry and academia. Our research extends toward post-Lithium technology, focusing on layered materials (metal oxides, MXene, 2D heterostructures). To develop sodium-ion batteries, we collaborate with German partners (SKZ, INP; BMBF) to utilize plasma-in-liquid continuous processes to obtain vanadium oxide electrodes and with Czech partners (Olomouc; DFG) to employ MXene/graphene heterostructures.

OUTLOOK

We will continue to 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 sustainable battery recycling methods. 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. In addition, more sustainable materials and processing methods will, over time, allow novel electrochemical applications and improve environmental friendliness.



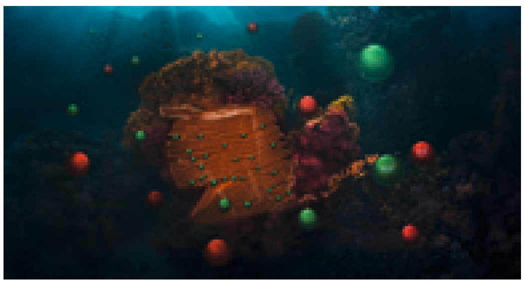


Fig. 1: Lithium recovery from seawater, mine water, or battery recycling by continuous redox-flow battery operation.
Fig. 2: Ion selectivity of MXene which can be used for ion separation and high-performance supercapacitors.

FUNKTIONELLE MIKROSTRUKTUREN / FUNCTIONAL MICROSTRUCTURES

PROF. DR. EDUARD ARZT, DR. XUAN ZHANG

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 lag dieses Jahr auf fibrillären Haftsystemen für die temporäre, reversible Adhäsion und deren Anwendung in Robotik sowie der Medizin. Zuletzt wurde das Augenmerk verstärkt auf den Ablöseprozess von miniaturisierten Objekten gelegt, für den eine neue Metastruktur entwickelt wurde. Die Integration von Maschinellem Lernen in Verbindung mit optischer Kontaktbeobachtung eröffnet den Weg zu zuverlässiger Handhabung auch von schwierigen Objekten. Im Bereich Biomedizin hat die Kooperation mit der Universitätsklinik Homburg inzwischen zu ersten Heilversuchen an geschädigten Trommelfellen im Menschen geführt.

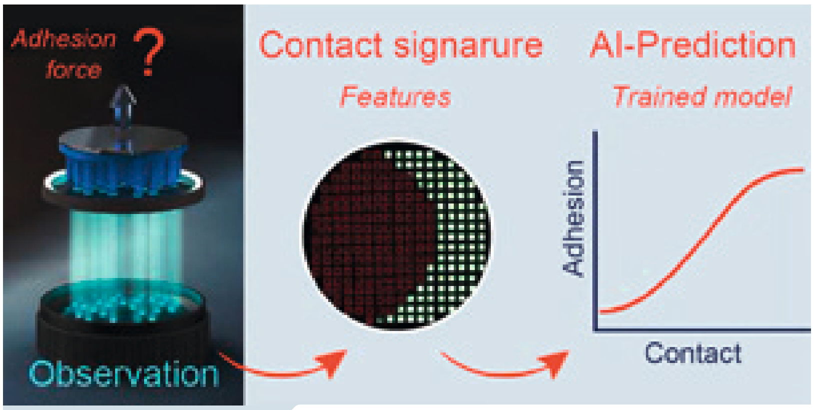
CURRENT RESEARCH

Progress in the Leibniz Competition project

In the "MUSIGAND" project, funded by the Leibniz Association, progress was made towards improved control and reliability in bioinspired handling. Several microstructure designs for reversible and switchable micro-handling were proposed: slanted fibrillar micropattern with a sliding mechanism (Wang et al., Adv Mater Interfaces, 2022); geometrically modified fibrillar pattern by tuning the contact area (Barnefske et al., Adv Mater Interfaces, 2022); and a trigger plant-inspired metastructure with snap-through instability (Zhang et al., Adv Sci, 2022). Further, a cupped microstructure inspired by the octopus was developed for underwater attachment (Wang et al., Sci Adv, 2022; J R Soc Interface, 2022). In collaboration with Prof. McMeeking, the INM-UCSB workshop "Designed materials and microstructures" was organized at the University of California, Santa Barbara, USA.

Advanced handling of micro-objects

Our bioinspired technology has been successfully demonstrated in the pick & place operations of various objects. Due to their strong adhesion to other surfaces and lack of inertial forces, the handling of micro-objects requires novel release mechanisms. Common mechanical mechanisms lose their function below a certain object mass, as the switching ratio of 2~3 is too low to release objects by gravitation or inertial effects. Inspired by the snap-through of the trigger plant in nature, a metastructure encoding the bistable curved beam was proposed with an extremely high switching ratio of ~10^4. Reversible miniaturized snap-through devices were successfully realized by micron-scale direct printing and can be applied to universal scenarios, including dry and wet environments, or smooth and rough counter surfaces (Zhang et al., Sci Adv, 2022).



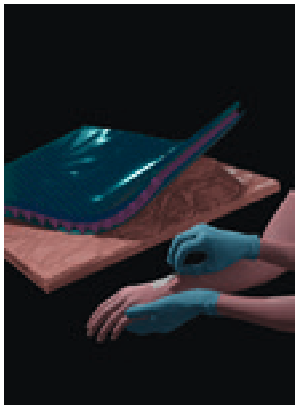


Fig. 1: Paving the path to predictive reliability of handling with bioinspired micropatterned devices: direct observation of the contact contrasts ("contact signature") by dedicated camera systems enables, in conjunction with machine learning, the prediction of the handling success for various objects (Samri et al., Materials Today, 2022).
Fig. 2: Skin adhesives: Micropatterning of film-terminated patches exhibit enhanced adhesion to soft surfaces with the roughness of human skin allowing the development of novel ear drum implants and adhesives for wearables (Moreira Lana et al., ACS Appl Mater Interfaces, 2022).

Improved adhesion of micropatterned adhesives on skin

A systematic study was conducted on the adhesion of film-terminated fibrillar microstructure to skin-like surfaces. The superior adhesion was characterized, along with moderate adhesion decay with increasing roughness when compared to unstructured samples. "First-in-human" studies were performed by our clinical partners to gain experience with such a new therapeutic strategy. Due to the glue-free adhesion based on van der Waals interactions, further potential applications are foreseen in the fields of wearable electronics and wound dressing (Moreira Lana et al., ACS Appl Mater Interfaces, 2022).

Intelligent handling by machine learning

Predicting the adhesion behavior of bioinspired fibrillar adhesives will improve the reliability of the gripping system. Here we have developed a machine-learning (ML) facilitated strategy for evaluating "contact signatures" involving transparent gripping devices and real-time optical monitoring systems. Both visual features (extracted from the recorded images) and physical features of the system (e.g., misalignment, the weight of objects, et al.) are fed as inputs into the ML algorithm. The trained networks demonstrated high accuracy in predicting the success of the subsequent handling operation (Samri et al., Materials Today, 2022).

Micropatterned adhesives in space technology

A sustainability problem faced in space exploration is the manmade satellite debris that is accumulating in the earth's orbit. Active debris removal is a future technological challenge due to its complexity and high cost. Following a recent successful validation of our fibril-patterned adhesives in capturing a free-floating target aboard the International Space Station (ISS), the latest developments and the perspectives of our technology were summarized in a review article (Ben-Larbi et al., Prog Aerosp Sci, 2022).

OUTLOOK

Over the last 15 years, the group has pioneered the paradigm of micropatterning polymeric surfaces for attaining novel mechanical functions. During this time, the topic was advanced by a combination of microfabrication, experimental and theoretical techniques and is now the basis of a rapidly developing technology. One of the major successes was the creation of the spin-off company INNOCISE GmbH in 2019. As a serendipitous result, the application of a related strategy for ear surgery was brought to fruition in collaboration with the Saarland University Clinic. The group was formally shut down at the end of 2022 with the retirement of its leader from official INM functions.

INTERAKTIVE OBERFLÄCHEN / INTERACTIVE SURFACES

PROF. DR. ROLAND BENNEWITZ

ZUSAMMENFASSUNG

Der Programmbereich Interaktive Oberflächen hat die Neuausrichtung seiner Forschungsaktivitäten, insbesondere die Ausweitung der Studien zur taktilen Wahrnehmung von Materialien, fortgesetzt. 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 Interaktionen an Oberflächen werden für 2D Materialien wie Graphen oder MoS_2, für Biomaterialien wie Hydrogele mit doppelten Netzwerken oder aber für mathematisch definierte Rauigkeiten auf Oberflächen aus dem 3D-Drucker untersucht. Die Projekte basieren auf unserer Expertise in der experimentellen Nanomechanik. Zu den wichtigsten Ergebnissen des Jahres 2022 gehört die Kraftspektroskopie an einzelnen Polymeren eines Doppelnetzwerk-Hydrogels. Ferner wurden grundlegende Erkenntnisse zur taktilen Wahrnehmung von Gecomer-Oberflächen und zum Verhältnis zwischen der affektiven Bewertung von Geschenkpapieren und der Reibung der Fingerspitze auf den Papieren gewonnen.

MISSION

The Program Division Interactive Surfaces explores new materials with specific adhesion and friction properties and investigates the function of surface materials in haptics. 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 and materials with switchable roughness. The projects draw on our expertise in experimental nanomechanics and novel skin friction experiments. Single-molecule force spectroscopy is used in soft matter for biophysical applications.

CURRENT RESEARCH

Molecular stiffness cues of interpenetrating networks

Double-network hydrogels allow tuning of their mechanical properties by combineing a host network with an interpenetrating guest network. In collaboration with the Program Division *Dynamic Biomaterials*, we established a method to study the mechanical properties of individual polymer chains in the networks using atomic force microscopy in a physiological buffer. For the first time, we have been able to address each network individually and thus quantify variations in molecular stiffness between different guest networks, even when the macroscopic mechanical properties of the double network hydrogels remain unchanged. Parallel observations of cell adhesion on the same hydrogels indicate that cell attachment proceeds effectively through a network with lower molecular stiffness when a higher ligand density is offered (Li et al., Materials Today Bio 2022).

Tactile perception of materials

Touching fibrillar surfaces elicits a wide range of affective responses, from the unpleasant sting of a stiff bristle brush to the pleasant feel of velvet. In collaboration with the Program Division *Functional Microstructures*, we used INM's Gecomer technology to fabricate a set of ordered arrays of microfibrils with varying length from different elastomer materials for a systematic study of tactile perception. We found that study participants did not discriminate material and fibril length by touch, but relied on a combined parameter, fibril bending, for their subjective assesment of perceived similarity between samples (Gedsun et al., Advanced Functional Materials 2022). We also discovered that participants could successfully judge friction differences when sliding their fingertip on Gecomer samples, except for structures smaller than 100 µm, which are only perceived by vibration stimuli (Fehlberg et al., Eurohaptics Proceedings 2022).

Ongoing projects

We are currently investigating the fascinating frictional properties of 2D materials and their heterostructures. The samples are grown in collaboration with partners in a Schwerpunktprogramm of the DFG and studied at INM using high-resolution atomic force microscopy in vacuum. The focus is on the formation of intermittent covalent bonds formed under the high local pressure of a sliding nanoscale tip. Force spectroscopy of individual polymer chains is being used in a study of the interaction of individual DNA with pores in a membrane and also in a study of the efficiency of novel light-driven molecular motors funded by the program Leibniz Wettbewerb. Materials for the future of tactile communication are being researched in a project supported by the Volkswagen Foundation. In collaboration with Charité in Berlin, we are investigating the skin as a material in the process of perception. In collaboration with neurologists at the University of Tübingen we verify the stimulus effect of switchable surface materials. A DFG-funded project is dedicated to the idea of a "tactile white", i.e. a surface that gives a minimal tactile impression but a strong impression to the touch.

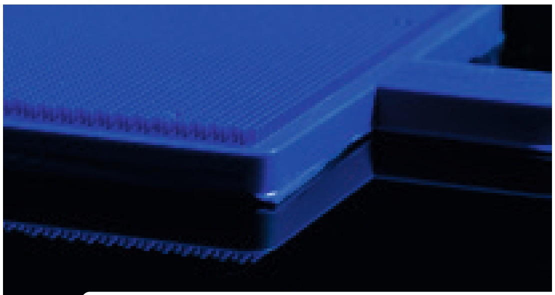
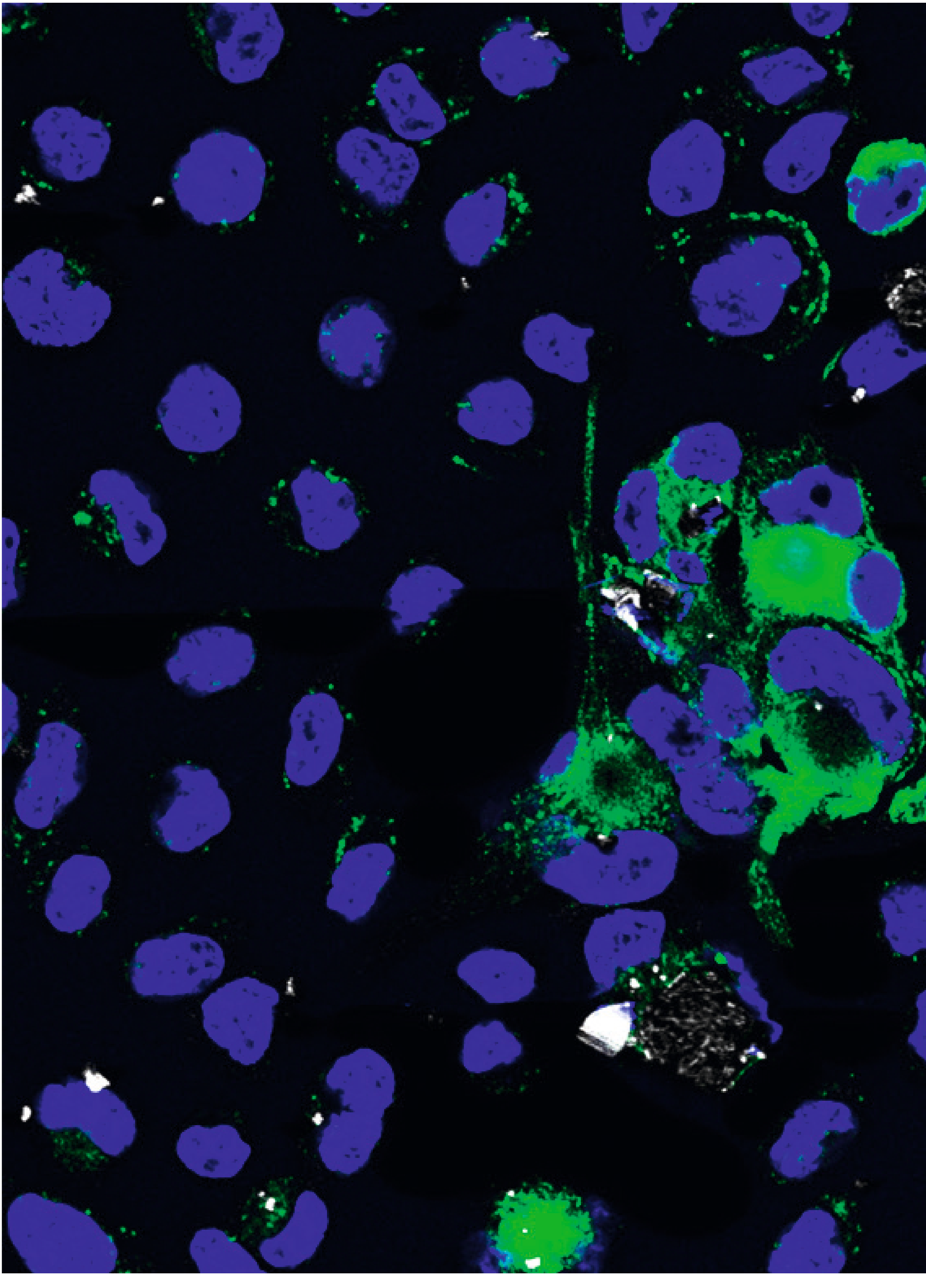
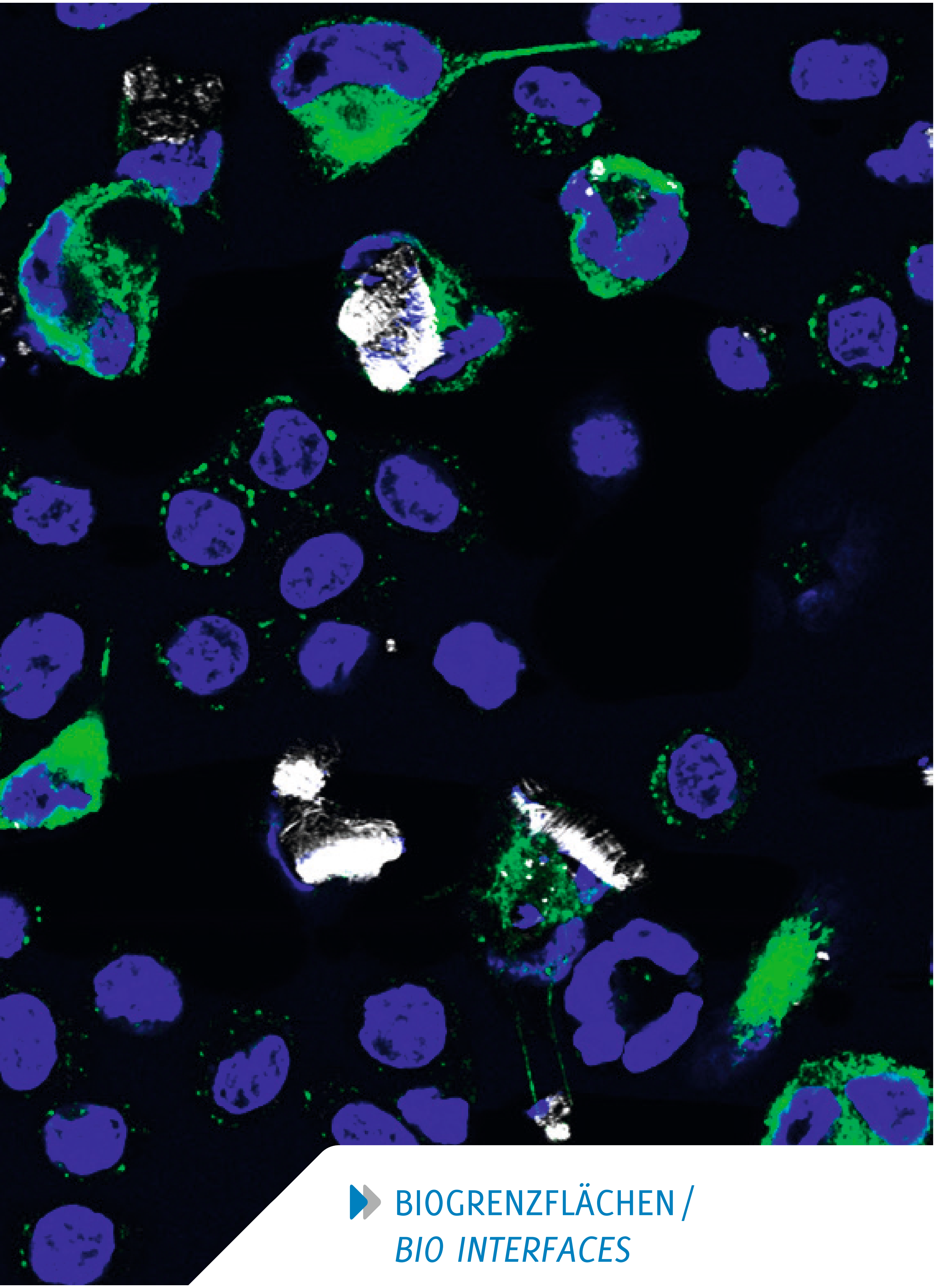


Fig.: Gecomer sample with an array of microfibrils of 400 µm in diameter. The tactile perception of these samples is dominated by the bendability of the fibrils.

OUTLOOK

We will continue to investigate the mechanisms that link structure and dynamics of surfaces to adhesion, friction, and wear in new materials. We will expand our activities in the field of soft matter nanomechanics and apply our experimental methods to dynamic biomaterials. A new class of materials, we plan to study, are living materials, whose functionality is enhanced by encapsulated bacteria. Our research on the haptics of materials is evolving to include cross-modal perception, for example, when friction signals generated by sliding touch are rendered as sound to enhance the experience of touch.





BIOGRENZFLÄCHEN / *BIO INTERFACES*

BIOPROGRAMMIERBARE MATERIALIEN / BIOPROGRAMMABLE MATERIALS

DR. SHRIKRISHNAN SANKARAN

ZUSAMMENFASSUNG

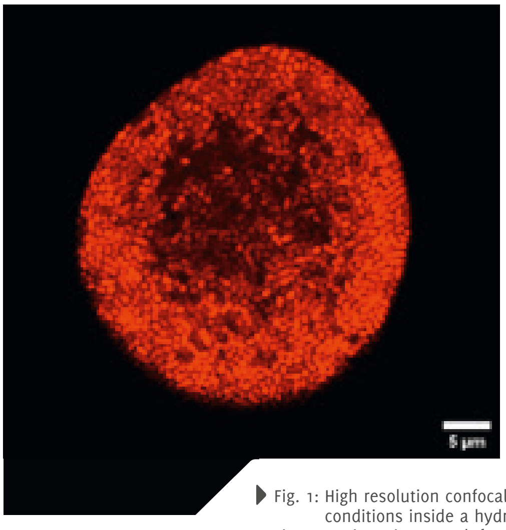
Die Juniorforschungsgruppe Bioprogrammierbare Materialien erforscht ein junges multidisziplinäres Feld, das die Gebiete der synthetischen Biologie und der Biomaterialien verbindet. Im Mittelpunkt steht die Entwicklung von Materialien mit genetisch programmierten Funktionalitäten für biosensorische Anwendungen. Sie sind in der Lage, auf Stimuli hin Wirkstoffe 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 Verbundmaterialien 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

Within the Leibniz Science Campus, we made significant progress towards the development of Living Therapeutic Materials. Together with the program division *Dynamic Biomaterials*, we created hydrogels in which engineered bacteria can be securely encapsulated. These constructs can sustain bacteria long-term and enable them to perform biosensing and drug release functions. One major highlight was the development of a Living Material that can produce and release therapeutically relevant doses of a pro-angiogenic protein initiated by light. This was able to stimulate angiogenic differentiation in vascular endothelial cells. In collaboration with Dr. Bin Qu at the UKS, we found that native immune responses to such Living Therapeutic Materials can be minimized through careful selection of the bacterial strain and encapsulation material. Along with the program division *Structure Formation*, we combined gold nanorods with heat-responsive engineered bacteria to create a system that can be controlled using near infrared light, which has high tissue penetration. This system is being combined with advances made along with the group of Prof. Rolf Mueller (HIPS)



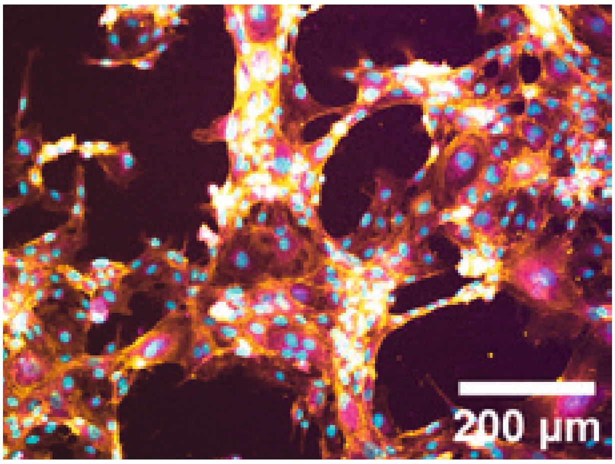


Fig. 1: High resolution confocal microscopy image of a bacterial colony grown under mechanically restricted conditions inside a hydrogel
Fig. 2: Angiogenic network formation by vascular endothelial cells induced by a pro-angiogenic protein that was released in response to light from a Living Therapeutic Material

in the development of bacteria engineered release a novel antibiotic, Darobactin, in response to heat.

We further made significant progress in engineering probiotic bacteria. We successfully engineered *E. coli* Nissle 1917 to (i) heat-responsively produce and release Darobactin and, (ii) in collaboration with Dr. Vito Valiante at Leibniz HKI, to convert low-cost cinnamic acid into the high-value flavonoid, Pinocembrin. We also established new genetic parts and methodologies to program probiotic *L. plantarum*, which are highly beneficial for health but difficult to engineer due to their limited genetic toolbox. These parts include a promoter that can drive protein expression up to 5-fold higher than previous versions and toxin-antitoxin-based plasmid retention systems that can be easily introduced to implement genetic modification without the need for antibiotics. A patent application has been filed based on these parts. We are now using them to develop stimuli-responsive genetic modules for the probiotic bacteria.

Finally, as part of our DFG funded subproject within the SFB1027 consortium, we have been studying growth, metabolic and protein production behaviour of these bacteria in hydrogels whose mechanical properties can be tuned to mimic specific domains within natural biofilms. This study is enabling us to gain a broader and deeper understanding of the biophysical principles underlying mechanosensitive behavior of bacteria in confinement. This project involves collaborations with the groups of Prof. Ludger Santen, Prof. Albrecht Ott, Prof. Karin Jacobs, Prof. Marcus Bischoff and Prof. Matthias Hannig at Saarland University.

OUTLOOK

Towards the applicability of Living Therapeutic Materials, we are developing genetic tools for remote-controlled drug release using therapeutically relevant bacteria. Over the last year, we have made significant progress in engineering bacterial strains that are beneficial to humans, positioning us at the forefront of this field. In the coming years, we will demonstrate the potential of our therapeutic bacterial devices for antimicrobial, regenerative, and immunomodulatory applications *in vitro* and *in vivo* through collaborations within the Leibniz Science Campus. To ensure the safety of these genetically modified bacteria, we will implement features including metabolic auxotrophy and kill-switches to prevent them from thriving outside the body and allow them to be terminated on demand. Additionally, we will continue to study the influence of the encapsulating materials on the bacteria to improve the performance of these living therapeutic devices. These studies and safety features will help guide the regulation of these devices for eventual testing in humans.

DYNAMISCHE BIOMATERIALIEN / DYNAMIC BIOMATERIALS

PROF. DR. ARÁNZAZU DEL CAMPO

ZUSAMMENFASSUNG

Der Programmbereich Dynamische Biomaterialien entwickelt instruktive synthetische Matrizen zur Einkapselung und als Schnittstelle zu lebenden Zellen. Wir zielen darauf ab, funktionelle in vitro Gewebemodelle und lebende Implantate für medizinische und technische Anwendungen zu entwickeln. Im Zentrum unserer Forschung stehen lichtempfindliche Moleküle und Hydrogele, die mit latenten Funktionen programmiert sind und bei Belichtung angeschaltet werden können, um Eigenschaftsänderungen und Reaktionskaskaden zu regulieren. Wir sind auch an der Kompatibilisierung synthetischer Matrizen und lebender Organismen mit Verarbeitungstechnologien wie 3D-Druck oder Mikrofluidik für zellbasierte Diagnostika und therapeutische Technologien 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. Our aim is to bioengineer functional tissues and living devices for medical and technical applications. At the core of our research are photoresponsive molecules and hydrogels programmed with latent functions that can be unlocked upon light exposure to regulate property changes and response cascades in cells. We are also interested in the compatibilization of living organisms with synthetic matrices and processing technologies like 3D printing or microfluidics towards next-generation cell-based materials and devices.

CURRENT RESEARCH

Light-actuated interfaces triggering cellular responses

The regulation of the properties of biomaterials using light is a classical topic our research. We developed mechanically active interfaces using synthetic, light-driven molecular motors and applied them to mechanically stimulate cellular responses. In cooperation with the Program Division *Interactive Surfaces*, the DWI-Leibniz Institute for Interactive Materials and the University Strasbourg (SAW Project LightAct) we are integrating force sensors to quantify the forces applied by the motor and the cells in 2D and 3D scenarios. This tool is also used for the cooperation with biophysics partners at Saarland University (SFB 1027) and at GeorgiaTech (EU Project Mechanofibrosis). To be able to operate our materials in vivo, we develop printable hydrogel optical waveguides that can guide light into the body (cooperation with *Optical Materials*). Using bioprinting technologies and multimaterial approaches, we fabricate hydrogel waveguides containing alternating

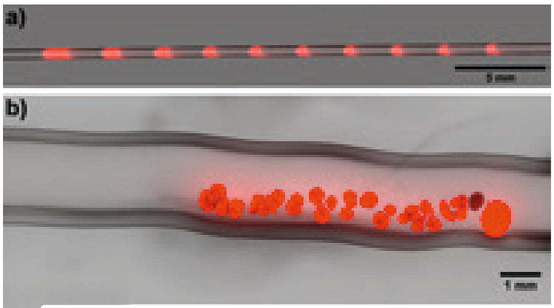


Fig.: (a) Printed segmented optical waveguide with intercalated side-emission segments. (b) Printed core-shell thread containing segments with growing bacteria colonies

guiding and scattering segments at submilimeter scale in a continuous process. These can transfer and locally deliver light at desired places along the waveguide axes (Figure 1a).

Hydrogels 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 (de Miguel et al, Macromol Biosc 2022). These characteristics make them ideal for automatized 3D cell culture and the establishment of high throughput formats for drug testing. Current projects deal with breast cancer models (EU Mechanocontrol). Technology transfer in this direction is pursued in cooperation with the *InnovationCenter INM* and in cooperation with other Leibniz Institutes (DWI, IPF, SAW Transfer project µTissues). We have incorporated design-of-experiment (DoE) methodologies to progress in data management in our projects. In cooperation with Materials-Host Interactions we demonstrated the biocompatibility of these materials in vitro and will follow-up with in vivo studies in cooperation with Saarland University.

We also develop photocrosslinkable hydrogels, and we are currently validating them for bioprinting by stereolithography in cooperation with a german industry partner (BMBF-KMU Innovative).

Materials and technologies for next-generation therapeutic delivery

A. del Campo is the spokesperson of the *Leibniz Science Campus Living Therapeutic Materials.* The group cooperates with groups at the Saarland University and the Helmholtz Institute for Pharmaceutical Research Saarland in the design of living drug eluting devices. In 2022 we quantified hydrogel property ranges that can regulate the growth and drug production of encapsulated microorganisms (Bhusari et al, Adv Sci 2022). Using multilayer designs, we fabricate living thin films able to stably retain active bacteria populations for several weeks (Bhusari et al, Biomat Adv. 2023) in cooperation with Bioprogrammable Materials. Core-shell fibers and microparticles are upcoming designs produced by automatized technologies (Figure 1b). We continue actively growing and shaping the field of Engineered Living Materials in Germany. We gathered the community in Saarbrücken (*3rd International Conference Engineered Living Materials*, see article) and organized the *Nachwuchsakademie Engineered Living Materials* (funded by DFG) at INM.

OUTLOOK

The development of cellular microenvironments for the support and control of cell growth and function with light remains a major topic. We see potential for technology transfer in the combination of our synthesis toolbox with bioprocessing technologies to be followed-up in the next years. The focus of the program division 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 die Materialeigenschaften mit Zellwechselwirkungen und Zellantworten verknüpft sind. Als Untersuchungsobjekte werden insbesondere anorganische Nanopartikel, aber auch 2D-Nanomaterialien eingesetzt und charakterisiert. Zur Lokalisation von Partikeln und Zellstrukturen werden vor allem lichtmikroskopische Techniken, wie die konfokale Laser-Raster-Mikroskopie, verwendet. 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 materials properties are linked to cell interactions and cell responses. Our purpose is to pave the way for the design of safer nanomaterials. In particular, we focus on using and characterizing inorganic nanoparticles and 2D nanomaterials. We use light microscopy techniques, such as confocal laser scanning microscopy to localize particles and analyze cellular structures. Further, we use cell-biological, biochemical, and biomolecular techniques for the analysis of cellular responses.

CURRENT RESEARCH

Leibniz Research Alliance Advanced Materials Safety

The group has obtained funding for the Leibniz Research Alliance (LRA) *Advanced Materials Safety*" (2022-2025). Prof. Andreas Fery (Leibniz Institute for Polymer Research Dresden, IPF) and Annette Kraegeloh are spokespersons of this initiative. The new alliance synergizes 12 Leibniz Institutes and further associated partners. Major goals of the alliance 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.

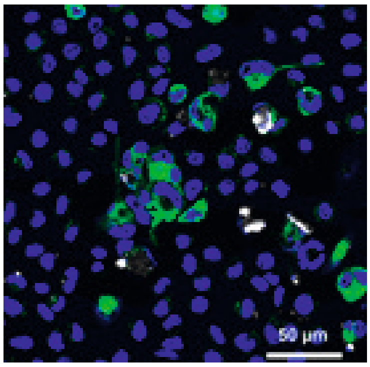


Fig. 1: Network-Meeting event of the Leibniz Research Alliance *Advanced Materials Safety*.
Fig. 2: Co-culture of lung epithelial cells (nuclei, blue) and macrophages (green) exposed to 2D-nanomaterials (white).

The core of the research program is formed by five doctoral projects, jointly supervised at several partner institutes. Two of these projects already started in 2022.

BioMXene

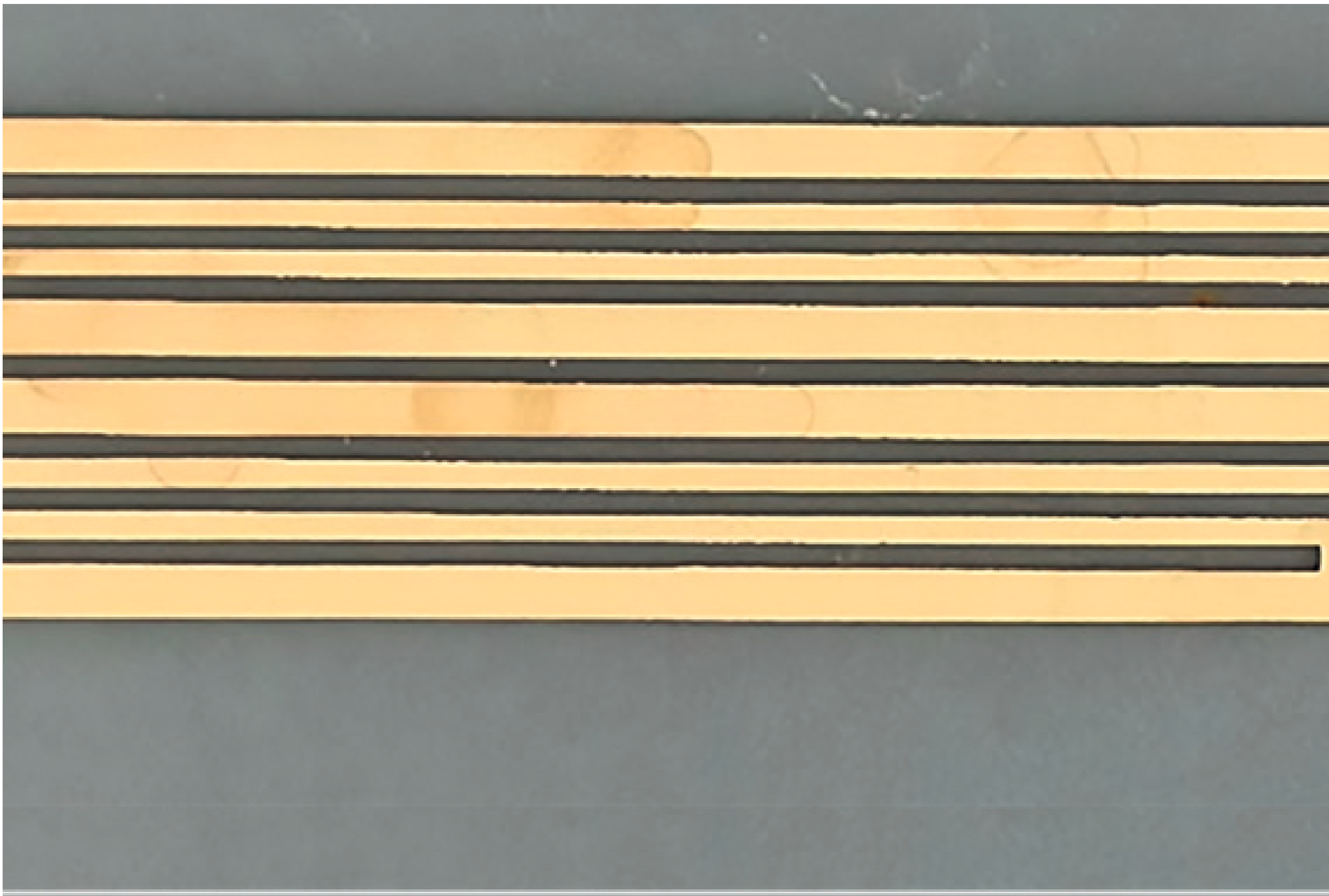
In frame of a publicly funded project (Europäischer Fonds für regionale Entwicklung), the group evaluates alternative pathways for the synthesis of 2D nanomaterials, in cooperation with *Energy Materials* and *InnovationCenter INM*. According to a Safe-by-Design approach, the aim of the project is to contribute to a sustainable synthesis of MXenes. In this context, the safety of MXenes and their precursor materials were tested by use of *in vitro* models mimicking the airways.

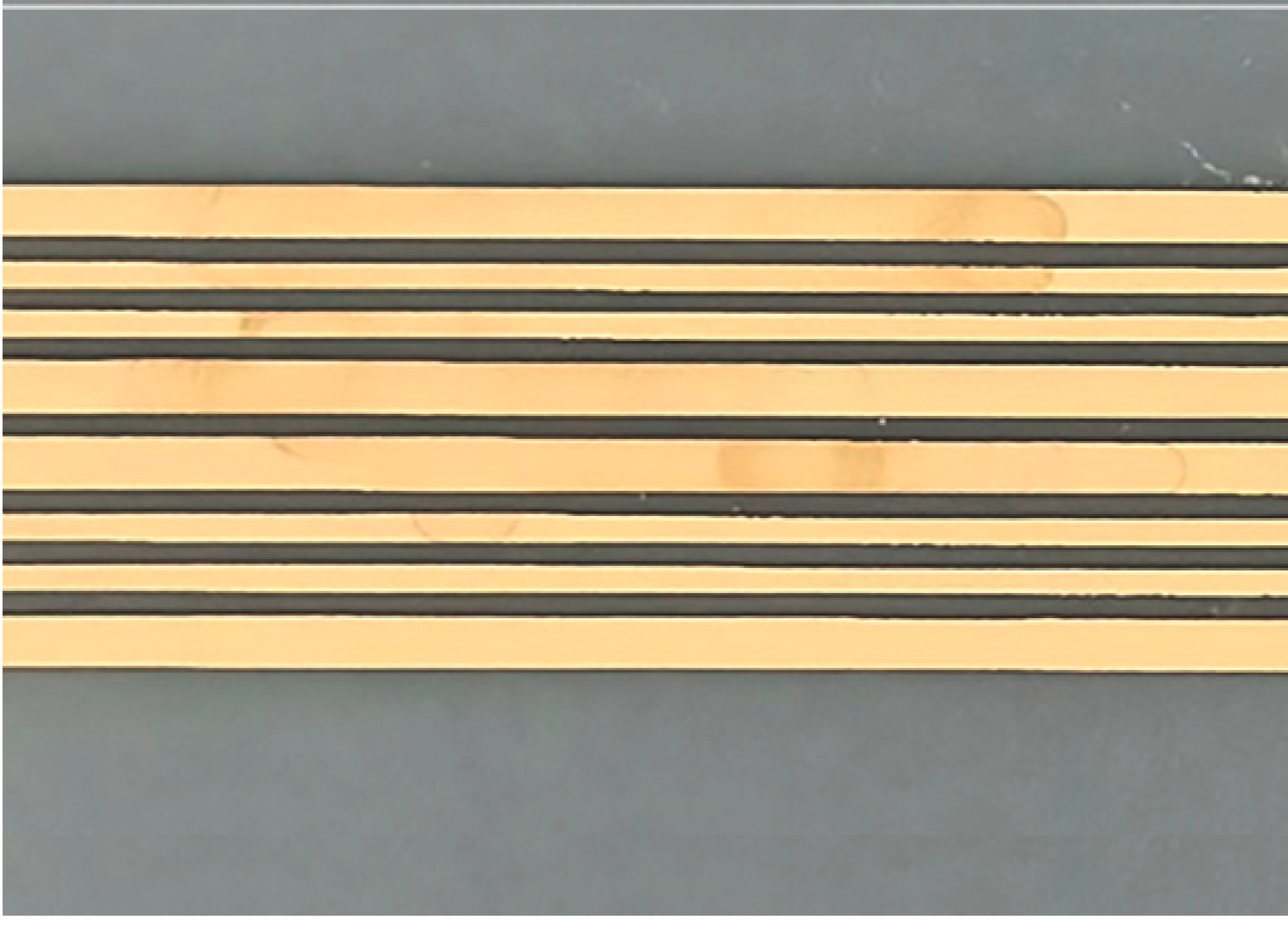
Pulmonary mucus as a barrier for particle penetration

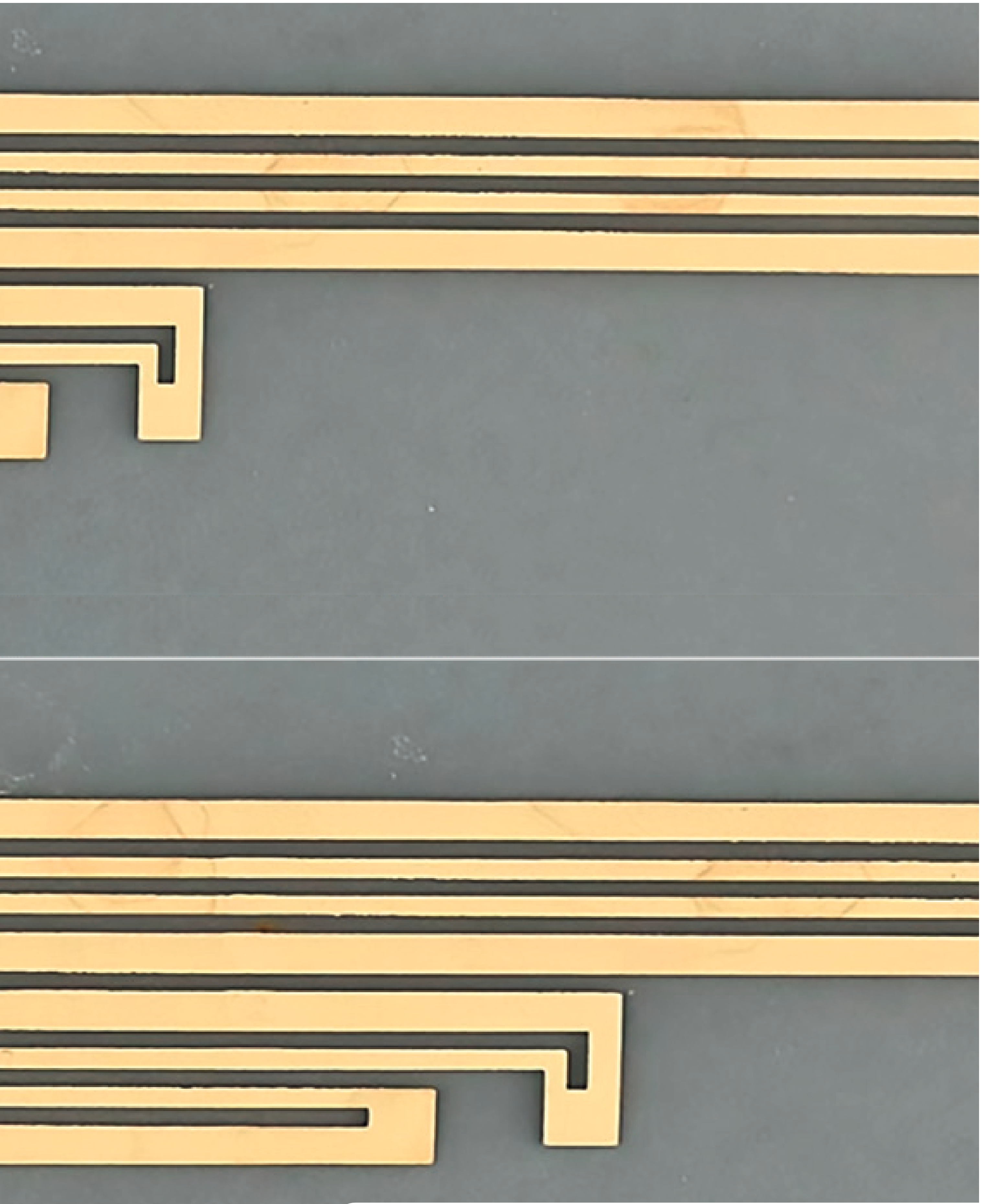
The lung is an important target organ for particulate materials that enter the human body via inhalation. In a recent study performed in cooperation with the Biopharmaceutics and Pharmaceutical Technology group at Saarland University (Prof. Marc Schneider), the barrier capacity of bronchial mucus was probed using an *in vitro* model of bronchial cells cultivated at the air-liquid interface. 500 nm particles were shown not to penetrate untreated mucus. However, mucus modulation by means of N-acetylcysteine increased particle penetration. In addition, mucus modulation also resulted in an increased particle toxicity, assumed to be initiated by direct contact between the particles and the cells. The study suggests that a reduced mucus barrier capacity might impact the safety of such therapeutic approaches. Monitoring such effects is essential for the successful development of corresponding therapies. This cooperation continues in frame of the joined doctoral project of Kristela Shehu, who is receiving funding by the German Academic Exchange Service (DAAD). The aim of her project is to develop nanostructured carriers for the treatment of bacterial infections in the lung. At INM, she has tested the antimicrobial activity of the carrier constitutents in order to identify the most effective approach. The results generated so far, allow to better understand the mode of action of the carrier formulation.

OUTLOOK

By October 2022, the program division Nano Cell Interactions was closed. The activity of the group related to the development of guidelines to assess the safety of advanced materials during their entire life cycle will be continued within the LRA *Advanced Materials Safety.*







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. Der Zusammenhang zwischen der Struktur und den rheoelektrischen Eigenschaften von Elektrofluiden steht im Mittelpunkt unserer Forschung. 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 truly 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 investigates the interplay between particle-particle friction, contact resistance, percolation, bulk resistance, and suspension viscosity to design *ad hoc* electrofluids for concrete applications.

CURRENT RESEARCH

Electrofluids with double percolation

We have adapted the concept "double percolation" from the polymer blends to the Electrofluids. The strategy is to reduce the percolation threshold, *i.e.*, the volume fraction of filler required to create a conductive network. For that, two immiscible solvents are mixed and a conductive filler with a strong affinity for one of the phases is added.

Carbon black (CB) as the conductive filler and polar/nonpolar solvent pairs as matrices such as pentyleneglycol/PDMS 100 cSt were used. The unmodified CB surface is hydrophobic thus, it tends to interact better with nonpolar solvents. Under a light microscope, we observed a clear preference of CB particles for the PDMS phase, whereas the pentylenglycol remains unfilled (Fig. 1a). The resulting electrofluids exhibited improved electrical conductivity at low CB loadings. Rheology measurements revealed that the double percolation electrofluids present an increase of the storage modulus when compared to the single solvent electrofluids, demonstrating that solvent mixtures can be used to further tailor electrofluid properties.

Stretchable conductors and strain sensors

To test their applicability as electronic components, electrofluids were encapsulated using silicon to undergo uniaxial tensile tests. Copper cables were used as connectors, thus the electrical response of the samples can be monitored in situ using a digital multimeter (Fig. 1b).

We were able to formulate electrofluids with very different behaviors; from stretchable conductors, whose electrical conductivity is retained during stretching, to sensors, whose electrical response is highly sensitive to mechanical strain. This variety of properties were achieved by controlling the structure of the 3D network that carbon black forms when dispersed in single polar (such as glycerol) or nonpolar (PDMS) solvents.

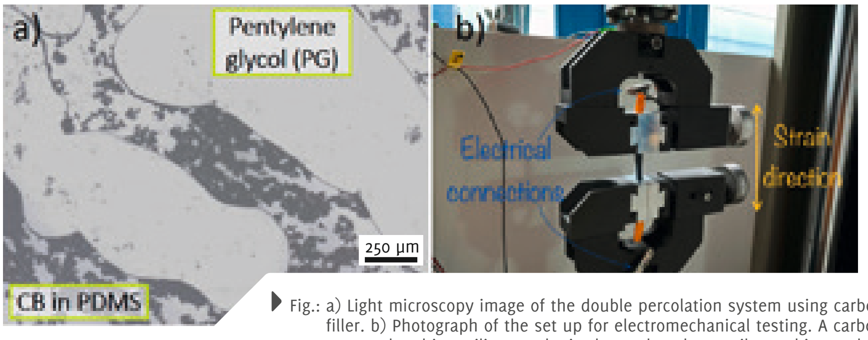
Understanding solid composites from their liquid precursors

We continued our collaboration with the program division *Structure Formation* to gain understanding of solid composites from their liquid precursors. In these composites, the network structure formed by conductive particles determines the mechanoelectrical properties. We work together to find correlations between the rheological behavior of the liquid precursor, the 3D network of the fillers, and their ultimate mechanoelectrical properties.

The role of ionic liquid (IL) molecules used as additive in CB-PDMS mixtures was investigated. Small amounts of IL resulted in softening the solid composite and reduced its conductivity slightly. Our experiments suggested that the ionic liquid interacts with the CB particles by covering their surfaces, decreasing the electrical conductivity but also, reducing the cross-linking of the PDMS softening of the composite *(Zhang et al., Adv. Mater. Technol., 2022)*.

OUTLOOK

We will expand the Electrofluid portfolio by using various filler particles. On one hand, we will explore the use of highly anisotropic particles such as carbon nanotubes. Their high aspect ratio will reduce the filler volume required to achieve electrical conductivity, while their facility to orientate under shear will impact their rheological behavior, leading to Electrofluids with novel and different mechanoelectrical properties. On the other hand, we will use metal structures such as silver spheroids, wires, and flakes. The high intrinsic conductivity of silver will lead to better conductors, however, its high density represents a challenge for the formulation of stable suspensions. We plan to chemically modify their surface to tune particle interactions and with that the formation of the connected network of the filler.



European Research Council
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Fig.: a) Light microscopy image of the double percolation system using carbon black (CB) as conductive filler. b) Photograph of the set up for electromechanical testing. A carbon black (CB) based electrofluid encapsulated in a silicone tube is clamped to the tensile machine and contacted to the digital multimeter to follow *in situ* the electrical response.

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 und mit nano- und mikroskaligen, funktionellen Additiven. Die funktionellen Additive können aus halbleitenden sowie keramischen oder metallischen Patikeln bestehen. Neben kugelförmigen Partikeln kommen auch solche mit plättchenförmiger Morphologie zum Einsatz. Mit einer maßgeschneiderten Oberfläche versehen, erlauben die Partikel den Übertrag festkörperphysikalischer Eigenschaften anorganischer Materialien auf Polymere und Beschichtungen. Bei der Entwicklung neuer Werkstoffeigenschaften steht der Anwendungsbezug im Vordergrund. Schwerpunkt der Entwicklungsaktivitäten liegen auf schwermetallfreien, aktiven Korrosionsschutzsystemen für Stahl und Aluminiumlegierungen, temperaturbeständigen, feuerfesten Bindemitteln für Naturfaserkomposite und transparenten, selbstheilenden Beschichtungen sowie Polymerkompositbasierten 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 distinct focus is set 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. The materials are applied in electronics, medicine, optics, automotive, construction, engineering and additive manufacturing.

CURRENT RESEARCH

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. The research results on the fabrication of a fiberboard plate derived from bush biomass towards the Namibian economy were presented in front of the Namibian Biomass Industry Group (N-BiG) and various stakeholders in Namibia and also in Germany. 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 a materials data sheet has been created and a marketing brochure was developed together with GIZ Namibia to enable an improved 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

Fig. 1: NaMiComp fibreboard specimen in termite resistance test after 6 months in the Namibian field (no attack by termites registered).
Fig. 2: Celebration of the joint invention of NaMiComp fibre board at UNAM including representatives from UNAM (UNAM's pro-Vice Chancellor for Research, Innovation and Development, and researchers), GIZ-Namibia and INM.

parallel to the materials development INM has contributed to capacity building in Namibia which was accompanied by support to build a materials lab at UNAM's southern campus in Keetmannshoop which was ready to start activity in March 2022.

In addition, the industry project on tribological modification of bulk polyurethane elastomers used in safety equipment was successfully performed through the optimization phase. The material was finally developed and the industry partner started to plan in-house production. The production start is envisaged for 2023.

Furthermore an industry project on development of inorganic diffusion barrier coatings for x-ray opaque dental glass particles started in autumn 2021. The complete project could be finalized successfully by the mid of 2022. The quality of the results enabled to file a new patent application and to implement the new process into the running production.

OUTLOOK

By June 2022 the Program Division *Nanomers* was closed. Know-how based on the polymer composites, inorganic binders and protective coatings has been transferred towards InnovationCenter INM to follow-up on application oriented activities.

OPTISCHE MATERIALIEN / OPTICAL MATERIALS

DR. PETER W. DE OLIVEIRA

ZUSAMMENFASSUNG

Der Programmbereich Optische Materialien sieht seine Aufgabe darin, neue optische und elektrooptische Verbundwerkstoffe durch den Einbau von Nanopartikeln, die gezielte Erzeugung von Mikro- und Nano-Poren, Imprinting oder Prägung zu entwickeln. Diese Werkstoffe zeichnen sich durch eine spezifische Wechselwirkung mit Licht bzw. elektromagnetischer Strahlung aus. Kompetenz in der Modellierung von optischen Elementen, der nasschemischer Synthese organischer und organisch-anorganischer Matrices und der Herstellung chemisch modifizierter Nanopartikel, ermöglichen die Entwicklung neuer Werkstoffe mit angepassten physikalischen Eigenschaften. Die Gruppenkompetenz liegt in der Grundlagenforschung und erstreckt sich bis zur anwendungsorientierten Forschung mit dem Ziel einer Verwertung in Zusammenarbeit mit Wissenschaft, KMUs (Kleinen und Mittleren Unternehmen) und Industrie. Die in den vergangenen beiden Jahren entwickelte neue Akquisestrategie, erwies sich als äußerst erfolgreich, da viele Industriegetriebene Projekte mit privater oder öffentlicher Förderung eingeworben werden konnten. Neben der gezielten Bindung langjähriger Partner umfasst die Akquisestrategie proaktive Schritte zur Gewinnung neuer Kooperationspartner sowie angepasste Transfermechanismen. In der Berichtsperiode wurden u. a. Komposite aus Gasblasen und Polymeren, neuartige plasmonische Materialien oder optisch-hochtransparente Glasfaserverstärkte Polymere bearbeitet.

MISSION

The Program Division Optical Materials has the mission to design new optical and electro-optical composite materials interacting with light. Structuring of inorganic, organic, or inorganic-organic hybrid materials takes place via the inclusion of nanoparticles, the generation of pores or nanobubbles or techniques like imprinting or embossing. Competence in modeling of optoelectronic components, in wet chemical processes for the synthesis of hybrid hard or soft matrices and the production of nanoparticles with chemical modifications enables the development of new materials with adapted physical properties e.g. refractive index or conductivity. The competencies of the group range from basic to applied research aiming always at utilization. A special interest lies in the cooperation with customers from academia, SMEs and industry without being completely dependent on orders. The new adopted acquisition strategy, developed in the last two years, proofed to be very successful. In addition to the targeted retention of long-term partners, it included proactive steps to acquire new partners as well as a change in the transfer mechanisms.

CURRENT RESEARCH

These highlight topics were investigated in 2022:

Coupling gratings for optical waveguides defined by silver colloids

The goal of this work is to investigate diffractive gratings composed of colloidal silver particles as a way to couple light into and out of planar waveguides. Photochemical silver deposition was used on glass substrates coated with a thin photocatalytic TiO_2 layer. Diffractive gratings consisting of Ag-colloids were created by UV-Laser interference and a nanocomposite cladding was applied as a final step. The TiO_2 layer acted as a planar waveguide, the gratings serving as elements for input and output coupling. Gratings created with low irradiation doses were suitable to characterize the waveguide properties. The modal spectrum of the waveguides was in good agreement with theoretical expectations, whereas the minimum attenuation of 3 dB/cm suggests that optimization of the microscopic homogeneity of the titanium dioxide layer is possible. This project is funded by the Federal Ministry of Education and Research in the "Wissenschaftliche Vorprojekte: Photonik und Quantentechnologien" scheme.

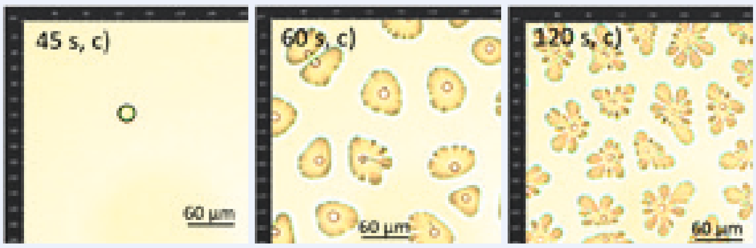

Fig. 1: Light microscope pictures flower-shaped µ-bubble forming approx. 3 µm thick coating prepared with three different heat curing times of 45s, 60s and 120s respectively.
Fig. 2: In- and out-coupling of laser light into a planar waveguide using a grating of colloidal silver nanoparticles, the sample comprises two input coupling gratings of different strength, and seven output coupling gratings.

Sol-gel as a glass fiber reinforced composite material

The aim is to develop transparent glassfiber enforced composits. Transparent, freestanding, flexible sol-gel glass fiber composites with adjustable refractive index could be synthesized. A refractive index identical to that of the glass fiber fabric was achieved on the one hand by the content of phenylsilane and on the other hand by nano-scale ZrO_2 particles. Transparency, flexibility and release were given for both approaches. In addition to the identical refractive index of the glass fiber fabric and the matrix, the matching of the Abbe number is also a condition for complete transparency.

Production of gas bubbles coatings

Target were nano-porous transparent polymer coatings to be used e.g. as antireflective coatings. Gas bubble formation in polymers was investigated by using a mixture of UV- and thermo-initiator in a two-step procedure with UV-pre-polymerization and thermal curing. The bubble size grew with increasing thermal curing duration and in thicker films. 200 µm coatings with sub-µm spherical bubbles could be obtained as well as 1-4 µm coatings with flower-shaped bubbles. Coatings with regular 50 µm ⌀ halfsphere-shaped surface holes could be prepared using an embossing mold. For the challenge in preparation of transparent sub-µm thick layers and nano-porous structure further development work is needed.

OUTLOOK

The focus of the research and development tasks of Optical Materials will continue to be on novel structured materials interacting with light. Additionally the inclusion of biological aspects in the material's development is of growing importance, featuring aspects such as biologically driven self organizing coatings. The project TRLs of these developments should reach Level 5 or above before being transfered to InnovationCenter INM. The developments 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. Optical Materials' will continue to raise industry driven co-operation projects financed by private or public resources. 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 hierarchisch zu Materialien verbinden und wie die entstehenden Strukturen ihre Eigenschaften bestimmen. Durch Streuung, Mikroskopie, systematische chemische Variation und *in situ*-Beobachtung erforschen wir grundlegende Wechselwirkungen zwischen Komponenten in Modellsystemen und ihre Auswirkungen während der Verarbeitung. Die Eigenschaften der entstehenden Materialien prüfen wir mechanisch, elektrisch und optisch. Mit dem so gewonnenen Verständnis entwickeln wir Prozesse, um Materialien für Elektronik, Optik und Sensorik auf Längenskalen zwischen Nanometern und Millimetern nahe Raumtemperatur und an Luft gezielt zu strukturieren. Nachhaltiges Wirtschaften erfordert, dass Materialien am Ende ihrer Lebensdauer wieder in nutzbare Bausteine zerlegt werden können. Daher untersuchen wir, wie sich heterogene Materialien und Materialverbunde während ihrer Lebensdauer verändern. Wir modifizieren Materialstruktur und Grenzflächen, um Lebensdauern zu erhöhen, Wiederverwendung zu ermöglichen und Recycling zu erleichtern.

MISSION

The Program Division *Structure Formation* investigates the formation of hybrid materials from complex liquids. We study how dispersed precursors join hierarchically to form materials and how emerging structures affect their properties. Scattering, microscopy, systematic chemical variation and *in situ* observation allow us to investigate fundamental interactions between components in model systems and their effects during processing. We test the properties of the resulting materials and use our insights to structure materials for electronics, optics, and sensing on length scales between nanometers and millimeters near room temperature and in air. We support the transition to a more sustainable economy and investigate how complex hybrid materials change during their lifetimes and how we can design them for reuse and recycling.

CURRENT RESEARCH

Conductive networks for soft electronics

The group investigates new electrically conductive materials for future electronics that are integrated in everyday objects, stretchable, and soft. They contain networks of nano- and microscale conductive components in insulating matrices or on surfaces. We cooperate with the *Electrofluids* Group that rheologically analyzes network structure conductivity; with Prof. Tanja Schilling (Freiburg University) to model the hierarchical structure of conductive networks, and with companies like Continental (BMBF-funded project *SensIC*) for the application of the materials. We address soft robotics in collaboration with engineers from TU Dresden (Dr. Markus Henke) and conductive networks in battery materials in collaboration with Energy Materials in the BMBF project *DigiBatMat*.

Nanocomposites in microgravity

Fragile particle networks can form during material synthesis for example when filler particles agglomerate at relatively low volume fractions. We are interested in whether gravity plays a role in such processes, for example, when using metal nanoparticles with relatively large densities that sediment. In the ARNIM projects funded by DLR, we are investigating this question in cooperation with the ZARM drop tower in Bremen and the DLR Institute for Materials Physics in Space in Cologne. We used drop tower experiments to observe how gold nanoparticles come together to form superstructures. Gravity surprisingly slows down the agglomeration, as we report in an article in Small. In late 2022, we placed our particles in the MAPHEUS sounding rocket and observed agglomeration during several minutes of microgravity.

Sensing deformation, temperature, environmental agents, and biomolecules

Deforming conductive networks can change their conductivity, effectively creating a strain sensor. We structure these and other sensors by printing electrically conductive or optically active structures and composites. Our group also creates hybrid combinations of metal particles and functionalized semiconductor polymers yield printable sensors for the detection of biomolecules. 2D-Printed temperature sensors are developed in the BMBF project *SensIC*, where we cooperate with Prof. Jasmin Aghassi-Hagmann at KIT; 3D-printed photoluminescent temperature sensors and sensors for mercury and other chemicals in the EU-funded I-Seed project with Prof. Barbara Mazzolai at IIT in Italy.

Making printed electronics recyclable

The sensors of I-Seed will remain in the environment and degrade. Other materials are integrated into electronics products that will become E-waste at the end of their lifetime. We are designing materials such that they can be extracted from waste and reused with reduced loss and energy effort. We have shown that printed hybrid conductive inks can be removed from their support in a process similar to "de-inking" in paper recycling. In a project funded by the DBU, we make screen-printed metal in electronics recyclable by minimizing the required sintering level. The EU-funded project *ReIn-E* with collaborators from Belgium aims at "in-mold" electronics with interlayers that enable separation of polymer from metal parts.

OUTLOOK

Designing materials for recyclability (as in the BMBF-funded project *AdRecBat*), increasing product longevity through materials, and the substitution of problematic raw materials are growing research activities of the group. Research creates knowledge, and its transfer to applications is increasingly aided by digital tools. We are initiating several projects that bring together knowledge and data in digital platforms. Industry participates, gets direct access to research results, and shares production data in a secure, controlled fashion.

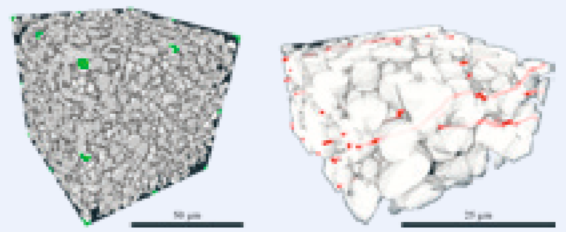

Fig. 1: A reconstructed network of conductive metal particles inside an insulating matrix. The sample was cut into very thin slides by a focused ion beam, images were taken with electron microscopy, and the structure reconstructed in 3D. The shortest possibly conductive paths are highlighted in red.

Fig. 2: A printed, stretchable electrical connector from BMBF project SensIC. The structure at the top is relaxed, the one at the bottom is stretched by 20 % but retains conductivity.

INNOVATIONSZENTRUM INM / INNOVATIONCENTER INM

DR. CARSTEN BECKER-WILLINGER, DR. PETER W. DE OLIVEIRA

INM InnovationCenter

ZUSAMMENFASSUNG

Das InnovationsZentrum INM bildet die Schnittstelle zwischen den INM-Programmbereichen und der Industrie. Insbesondere betreibt es Technologie-Scouting innerhalb des INM, um in der breitgefächerten Forschung der Programmbereiche gezielt anwendungsreife Ergebnisse zu identifizieren. Gemeinsam mit den Programmbereichen werden Strategien erarbeitet, wie der Technologiereifegrad dieser Entwicklungen auf ein Niveau gehoben werden kann, das es erlaubt, geeignete Industriepartner für Kooperationsprojekte zu gewinnen. In diesem Zusammenhang unterstützt das InnovationsZentrum INM beim Aufbau von Materialplattformen, der Realisierung von Demonstratoren und bei der Auffindung von Industriepartnern für öffentlich geförderte Projekte mit Industriebeteiligung zur Erhöhung des Technologiereifegrades. Dies dient letztlich der Initiierung, Koordination und Implementierung von direkten Industriekooperationen. In Industriekooperationen übernimmt das InnovationsZentrum INM die Aufgabe, die Umsetzung von Materialentwicklungen in den Pilotmaßstab, Materialbegleitende Validierung und Optimierung von Produktionsprozessen und ggf. modulare Automatisierung vorzubereiten. All dies ermöglicht eine umfassende und effiziente Umsetzung neuer Ideen vor dem Hintergrund starken Wettbewerbs und zunehmend verkürzter Produktzyklen bei High-Tech-Produkten. Im Berichtszeitraum lag der Schwerpunkt auf dem Transfer ökologisch und ökonomisch nachhaltiger Technologien in Richtung auf zukünftige Anwendungen.

MISSION

The Innovation Center INM is an interface between the program areas of INM and the industry. It conducts technology scouting within the INM to identify results from research in the program divisions that are ready for application, and develops strategies to raise the degree of technological maturity to a level that allows industrial cooperations. In direct cooperation with the industry, the InnovationCenter INM develops materials from the laboratory to pilot scale through scale up, material-related validation and optimization of production processes and, if necessary, modular automation. This enables a comprehensive and efficient implementation of new ideas against the background of strong competition and increasingly short product cycles for high-tech products.

CURRENT RESEARCH & DEVELOPMENT

The InnovationCenter INM currently develops natural fiber-based composites for a use as construction boards in building and furniture industry. During previous GIZ-funded cooperation project *NaMiComp* with the University of Namibia, a new type of inorganic binder with a carbon footprint improved by a factor 4 compared to concrete was developed in the program division *Nanomers*. Based on this new materials platform sustainable, fire resistant acia fiberboards could be obtained, that fulfill the requirements for the building industry. In the InnovationCenter INM larger lab size demonstrators were fabricated and the effort is widened up to produce also reed-based construction boards in the framework of future industry projects.

During the running project *Merlin* on lithium extraction from mining water InnovationCenter INM

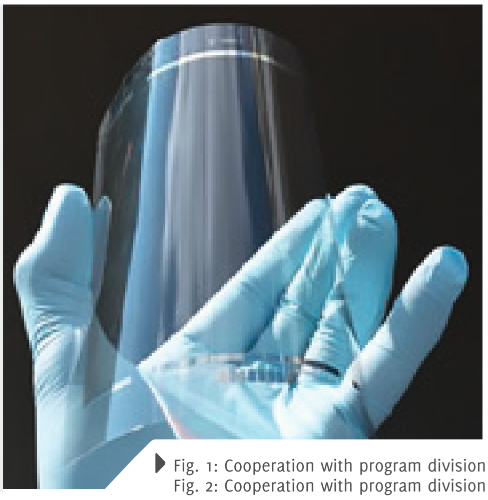

Fig. 1: Cooperation with program division Optical Materials: First step up-scaling of proximity sensor demonstrator.
Fig. 2: Cooperation with program division Energy Materials: Flow cell prototype in project “Merlin”.

started the development of a demonstrator showing the possibility of converting the capacitive deionization (CDI) principle developed in the labs of program division Energy Materials towards up-scaled continuous flow cell for lithium ion separation. The demonstrator also involves development of control technology in addition to the core capacitive separation cell set-up. The demonstrator will be used for future acquisition of industry projects concerning selective lithium extraction from natural sources that contain even higher salt concentration than mining water such as geothermal or saline water. Up-scaling of synthesis of new electrode materials and automatization of cell-assembly are currently in the conceptual phase.

A further 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 FET-Open project *Mechanocontrol* running in the program division *Dynamic Biomaterials* the InnovationCenter INM takes care about market analysis, freedom to operate analysis, IP-strategy, marketing plan, and building of demonstrators.

Three industry projects concerning transparent conductive coatings are running in cooperation with the program division *Optical Materials*. A demonstrator of transparent and conductive coating with competitive performance to indium tin oxide was realized using an electrospinning process on the roll-to-roll coating machine in the InnovationCenter to build a transparent metal mesh on a large plastic foil. The metal mesh coated foil serves as the core element for e.g. touch sensors or proximity sensors in electronic devices.

Besides executing industry and public funded projects, the InnovationCenter offers analytical services for 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 handling systems. The 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 growing innovation-network.

Dr. Carsten Becker-Willinger

Dr. Peter W. de Oliveira

SERVICEBEREICHE / SERVICE GROUPS

CHEMISCHE ANALYTIK / CHEMICAL ANALYTICS

DR. CLAUDIA FINK-STRAUBE

Die Servicegruppe *Chemische Analytik* fungiert als Dienstleister für das INM, die UdS sowie Externe. Dabei kommen atomspektrometrische (AAS, GFAAS, ICP-OES), elementaranalytische (CHNS + O) und chromatografische Verfahren (GC, Headspace-GC, HPLC mit IR, DAD, ELSD, GPC, MALLS), sowie massenspektrometrische Kopplungsmethoden (HR- SF ICP-MS, GC/MS, LC-ESI HR-Q-TOF) zum Einsatz. Die analytische Begleitung und Unterstützung interner Forschungsprojekte bis zur Qualitätskontrolle der entwickelten Materialien gelingt durch Optimierung, Entwicklung und Validierung der angewendeten Analyseverfahren inklusive Präparation (diverse Aufschluss- und Extraktionstechniken). Schüler, Azubis und Studierende erhalten einen Einblick in die Praxis chemisch-analytischer Methodik am INM.

PHYSIKALISCHE ANALYTIK / PHYSICAL ANALYTICS

DR. MARCUS KOCH

In der Servicegruppe Physikalische Analytik werden elektronenmikroskopische und röntgenanalytische Fragestellungen untersucht, die mittels Rasterelektronenmikroskopie (REM), Transmissionselektronenmikroskopie (TEM) sowie „Focused Ion Beam“ (FIB) durchgeführt werden. Für die Probenpräparation stehen unter anderem ein Ultramikrotom, eine Nanomill, ein Plunge-Freezer und verschiedene Einbett- bzw. Schleifapparaturen zur Verfügung. Im Rahmen von internen und externen Kooperationen entstehen elektronenoptische Abbildungen von flüssigen und festen Untersuchungsgegenständen aus der Physik, Chemie oder Biologie/Medizin mit einer Auflösung bis in den Nanometerbereich, um die Probenmorphologie und -zusammensetzung oder Struktur-Eigenschaftsbeziehungen zu untersuchen.

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. Außer den klassischen Fertigungsarten für den Prototypenbau steht auch die Möglichkeit einer Serienfertigung von Werkstücken durch automatisierte Fertigungsprozesse zur Verfügung. Jedes Jahr bieten wir Ausbildungsstellen als Industriemechaniker*in und Elektroniker*in für Betriebstechnik an und führen Praktika für Schüler*innen und Studierende durch.

NTNM-BIBLIOTHEK / NTNM LIBRARY

DIPL.-BIBL. MA ELKE BUBEL
(OPEN-ACCESS BEAUFTRAGTE DES INM)

NTNM CAMPUS-BIBLIOTHEK

In 2022 hat die NTNM-Bibliothek mit INMdok ein institutionelles Repositorium für die frei zugänglichen Publikationen der Wissenschaftler*innen des INM eingeführt. INMdok beruht auf der Open Source Software OPUS4 und erfüllt damit sämtliche bibliothekarischen Standards bzgl. Datenformaten, Langzeitarchivierung und Zitierfähigkeit. Neben Volltexten liefert INMdok Angaben zu lizenzrechtlichen Bestimmungen der Publikationen, Förderinformationen sowie Verweise zu den ORCID-Profilen publizierender Autor*innen. Die technische Betreuung obliegt dem Bibliotheks-service-Zentrum Baden-Württemberg. INMdok stellt neben Publish & Read Vereinbarungen, dem hybriden OA Zeitschriftenportal vidijo sowie dem DFG-Programm Open Access Publikationskosten einen weiteren Baustein zur Förderung des Open-Access Gedankens am INM dar.


New Brunswick
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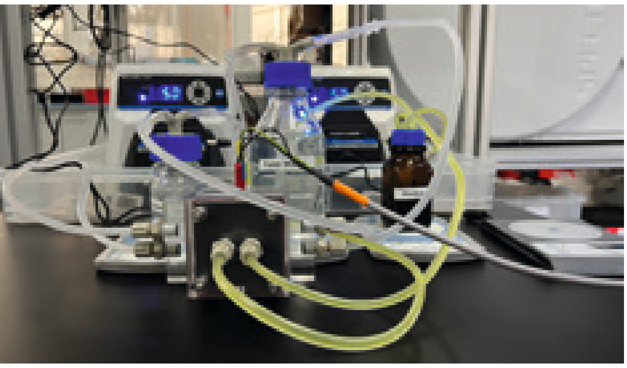
Incubator Shaker Series
NEW BRUNSWICK SCIENTIFIC

HIGHLIGHTS

ELECTROCHEMICAL LITHIUM RECOVERY FROM AQUEOUS SOLUTIONS

LEI WANG, STEFANIE ARNOLD, PANYU REN, VOLKER PRESSER
ENERGY MATERIALS



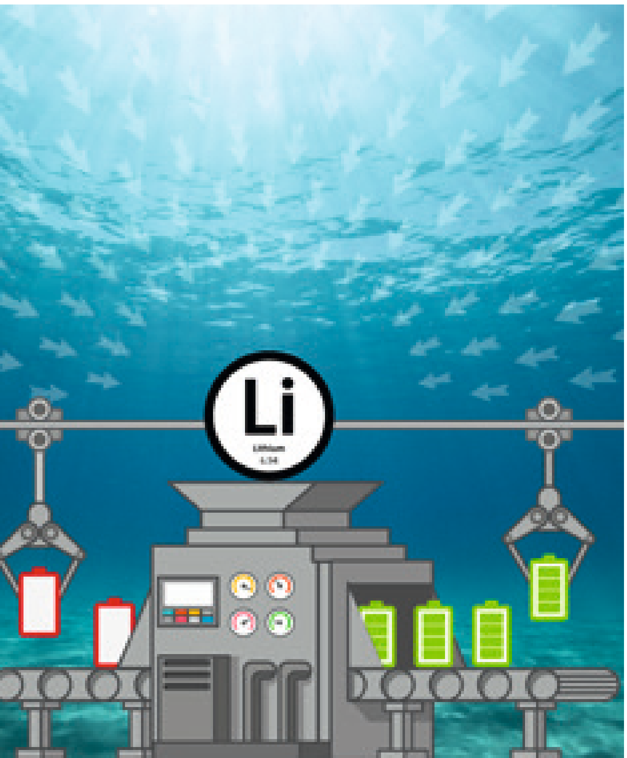


Fig. 1: Setup for continuous redox-flow-battery-like lithium-ion extraction from seawater.
Fig. 2: Our vision: direct, electrochemical sourcing lithium-ions from seawater.

One of the most critical elements for the continued eletricification, electromobility, and large-scale implementation of renewable energy sources is lithium. With the widespread use of lithium-ion batteries in electric vehicles and portable electronic devices, the demand for lithium has increased dramatically. So far, most lithium extraction methods have focused on brine and ore deposits, while the vast amount of lithium in the earth's oceans and other aqueous media remains untapped due to the significant challenges involved.

Our research team has been working to overcome these challenges and develop an efficient and cost-effective system for lithium recovery from seawater. We have developed a system that combines Li-selective ceramic membranes and a simple redox flow electrolyte. This innovative approach enables continuous lithium recovery from seawater and overcomes the limitations of electrodialysis-based systems. The lithium-extraction redox flow battery (LE-RFB) can extract dissolved lithium with a purity of 93.5% from simulated seawater, corresponding to a high Li/Mg selectivity factor of about 500.000:1. Furthermore, benefiting from a low operating voltage, only 2.5 Wh of energy consumption is required to extract 1 g of lithium.

Our research has the potential to revolutionize the lithium extraction industry by providing a cost-effective and scalable solution for recovering lithium from seawater. By tapping into this vast resource, we can help meet the growing demand for lithium while minimizing the environmental impact of lithium mining and extraction. We expect that our findings will contribute to the development of a more sustainable and efficient energy system, benefiting both industry and society as a whole.

L. Wang, S. Arnold, P. Ren, Q. Wang, J. Jin, Z. Wen, V. Presser, Redox flow battery for continuous and energy-effective lithium recovery from aqueous solution, ACS Energy Letters 7(10) (2022) 3539.

SAFE ENCAPSULATION OF BACTERIA FOR ENGINEERED LIVING MATERIALS

SHARDUL BHUSARI, SHRIKRISHNAN SANKARAN, ARÁNZAZU DEL CAMPO
DYNAMIC BIOMATERIALS & BIOPROGRAMMABLE MATERIALS

Engineered living materials (ELMs) combine living cells with non-living materials to create composites with lifelike capabilities, such as growth, self-healing, sensing, and complex biomolecule synthesis. Despite the development of ELMs for a variety of applications, little is known about the influence of the non-living materials on the living cells within them, which is needed for improving their performance and safety. So, the Program Division *Dynamic Biomaterials* and the Junior Research Group *Bioprogrammable Materials* are investigating how entrapped bacteria are affected by the mechanical properties of hydrogels, a popular carrier material.

Using hydrogels whose stiffness and compliance can be precisely tuned, the groups found that the mechanical environment greatly influences the behavior of encapsulated bacteria. When the hydrogel is soft and compliant, the cells grow along a single axis before branching out, while a stiff hydrogel restricts their growth along a single axis, causing them to cluster into dense spherical colonies. On the other hand, the highest rate of protein production occurs in hydrogels with intermediate stiffness and compliance, indicating a "sweet spot" of metabolism that balances growth and productivity.

Based on these findings, the groups developed a new encapsulation format for ELMs that greatly improves biosafety through two layers - an inner layer containing the bacteria in a hydrogel composition that ensures optimal performance and an outer layer made of a hydrogel composition that prevents the bacteria from escaping. With this construct, the groups created live biosensor devices that detect lactic acid, which can help to improve process control in the biotech industry.

The same concept is driving further developments at INM to produce ELMs for biomedical applications via 3D printing and microencapsulation.

Bhusari, S., Kim, J., Polizzi, K., Sankaran, S., del Campo, A. Biomater. Adv. 2023, 145, 213240.
Bhusari, S., Sankaran, S., del Campo, A. Adv. Sci. 2022, 9 (17), 2106026.

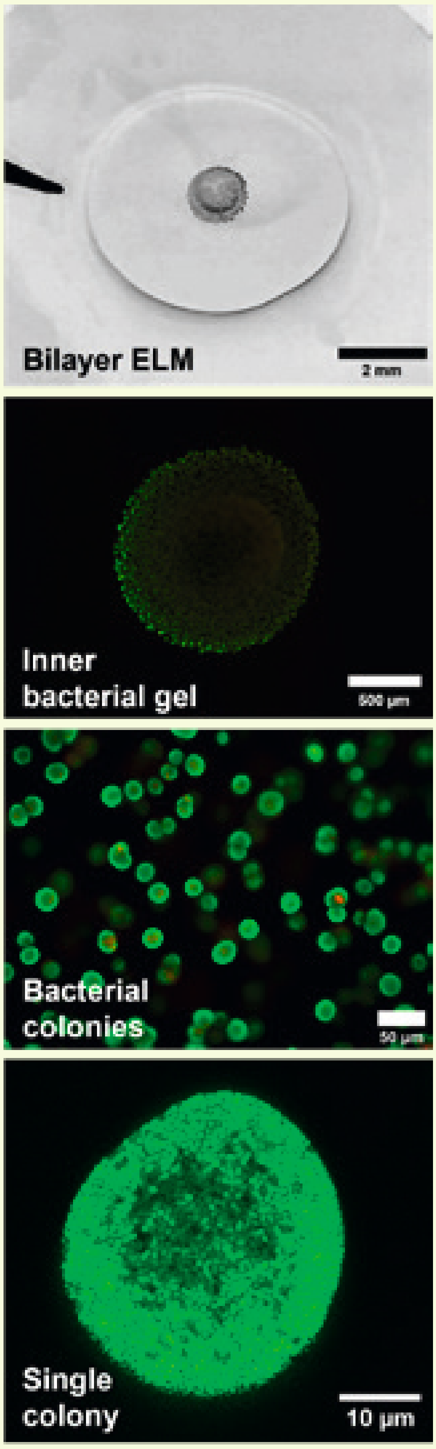


Fig.: Image of a bilyer ELM construct with the encapsulated bacterial colonies shown in green at increasingly magnified scales.

THE PAST, THE PRESENT AND THE FUTURE OF SCIENCE – PROFESSOR EDUARD ARZT IN INTERVIEW

Eduard Arzt has, as Scientific Director, been at the helm of INM for one and a half decades and has steered its fortunes in an increasingly complex and competitive scientific world. After his transitioning to the University of California in San Diego, we have asked him to tell us about his experiences: his challenges in running INM, how he chooses his research topics and how he sees science developing in the future.

YOU ASSUMED LEADERSHIP OF INM IN A DIFFICULT PHASE AND INITIATED A RE-ORIENTATION IN TERMS OF CONTENT AND ATMOSPHERE. WHAT WERE THE BIGGEST CHALLENGES?

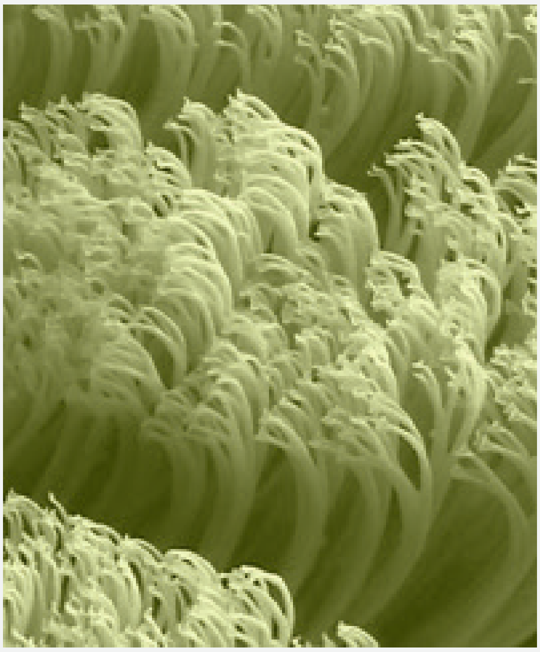
Up to 2007, INM had gone through the first "life cycle" of an institute; in the process, it had become so immersed in transfer research that it had lost contact with the scientific community. I consider myself very fortunate that in the years that followed we succeeded in revitalizing the institute by bringing in new interesting people and future-oriented scientific topics; we also developed a new style of appreciative personal interaction without which creativity cannot flourish. I benefited greatly from the fact that virtually all members of the institute were very open to the changes – in contrast to political stakeholders, whose resistance was not helpful. The subsequent success of the INM is the success of all of us.

YOUR CAREER SPANS FOUR DECADES OF SCIENTIFIC DEVELOPMENT. TO WHAT EXTENT HAS THE WAY SCIENCE IS DONE CHANGED DURING THIS TIME?

There is no doubt that science has evolved into a complex machinery over this time, which places totally new demands on scientists. Not only has the speed of development increased, but so has the complexity of research questions and the need to "sell excellence" in order to procure further funding. In addition, I deplore the increasing tyranny of metrics, which is fed by the misunderstanding that quality can be controlled by numerical indicators. I firmly believe that true science will continue to hinge on unusual, creative ideas, on deepening the understanding, and on what could be called scientific humility – as there is so much more we do not know. It will certainly be exciting to see to what extent artificial intelligence will influence this development.

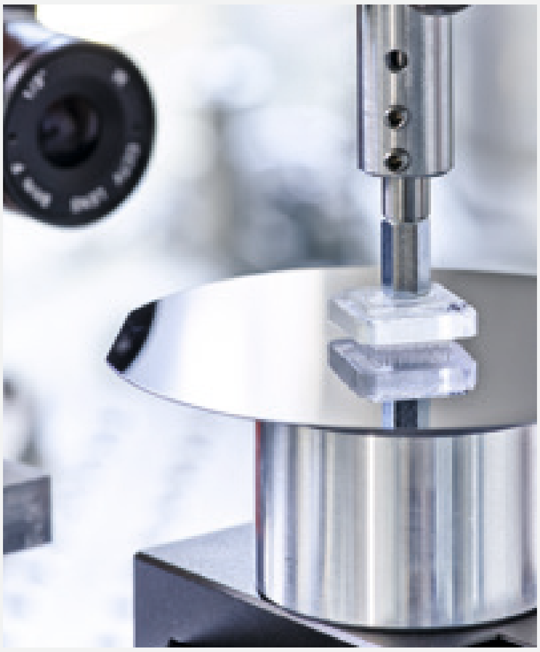
YOU HAVE WORKED IN MANY DIFFERENT FIELDS OF MATERIALS SCIENCE OVER THE COURSE OF YOUR SCIENCE CAREER. AS A SCIENTIST, HOW DO YOU ACTUALLY COME UP WITH NEW IDEAS?

Materials science is a wonderful playground for ideas, as it touches on so many areas of life. That is why I tried to tackle a completely new subject area every ten years or so. Of course, this requires some methodical "basso continuo" – in my case, the overarching concepts of microstructure and mechanical properties. Over time, my research groups succeeded in making significant contributions to, for example, high-temperature alloys, microelectronic materials, thin-film plasticity and, most recently, gecko adhesion, bioinspired robotics and ear implants. Scientists have the responsibility to protect their own creativity: I believe that immersing oneself in new topics - and, for that matter, in new environments, for example, during sabbatical stays – is enormously stimulating.



YOU HAVE NOW HANDED OVER THE INSTITUTE TO A NEW BOARD OF DIRECTORS. WHAT DO YOU EXPECT TO BE THE GREATEST CHALLENGES FOR YOUR SUCCESSORS AND HOW DO YOU VIEW INM'S PATH INTO THE FUTURE?

With Aránzazu del Campo and Wilfried Weber, an excellent leadership team is taking over the institute's management, while bringing a new, future-oriented research theme into INM. In my opinion, it will be very important to interweave the existing strengths of the institute, for example in haptic, sensor or energy materials, with the new research directions. From this, a new "DNA" of the INM must emerge again, allowing it to successfully compete in the fierce international competition. A new "life cycle" is now beginning for INM, and I trust that the new developments will follow the successful past.



INM FELLOW INVESTIGATES THE PHYSICS OF LIVING CELLS

HEIKO RIEGER

Heiko Rieger from Saarland University is the seventh Fellow of the INM. As a professor of Theoretical Physics he complements the institute's biologically oriented work with theoretical aspects.

Rieger has been Professor of Theoretical Physics at Saarland University since 1999. After completing his doctorate in theoretical physics at the University of Cologne in 1989, he spent postdoctoral stays at the University of Maryland and the University of California in Santa Cruz (both USA). In 1995 he habilitated at the University of Cologne and worked on a Heisenberg scholarship at the Jülich Research Center before moving to Saarbrücken. Visiting professorships have taken him to Tokyo Metropolitan University, École Normale Supérieure in Paris and Université Paris Sud. In 2016 he was awarded an honorary doctorate by the University of Szeged, Hungary. Rieger has been co-operating with the INM for a long time, for example in the University's Collaborative Research Center SFB 1027 *Physical Modeling of Non-Equilibrium Processes in Biological Systems*, for which he has been spokesman since 2013.

Statistical physics, theoretical biophysics and computer-aided simulations are Heiko Rieger's specialty. One of his focal points is processes in biological systems, such as the behavior of immune cells or the growth of tumor cells. Together with the Program Division *Dynamic Biomaterials*, Rieger investigates the processes at the so-called immunological synapse, the point at which immune cells come into contact with other cells, such as cancer cells. Another collaboration focuses on amoeboid cell migration, the movement of cells through complex environments like the extracellular matrix, and how it can be manipulated with light induced (optomechanical) forces. For the physicist, the application aspect is what makes this interdisciplinary cooperation so appealing: "Of course, first and foremost I want to understand how things work. But it's even nicer when something new can emerge from this understanding," Rieger emphasizes. And this is exactly what the researchers want to achieve together: The development of novel biomaterials, especially for use in therapy and medicine.

FOCUS ON NEW PEOPLE: SARA TRUJILLO MUÑOZ

Sara studied Biotechnology in Valencia (Spain) and moved to Glasgow (UK) to pursue her PhD in Biomedical Engineering in 2019. She started in Saarbrücken as postdoctoral researcher at INM in the group Dynamic Biomaterials in 2021. She is now an independent researcher within the Pharmaceutical Research Alliance Saarland (PRAS). She works on the understanding of the interactions between implanted materials and the host.

CAN YOU GIVE US AN IDEA OF WHAT MATERIAL-HOST INTERACTIONS ARE?

Biomaterials are substances which interface with biological systems to treat or replace biological functions. Biomaterials interact with cells, tissues and organs in the host, usually the patient. These are complex interactions that involve communication with various cell types and their surroundings. Therefore, their understanding is essential for designing novel, 'smarter' biomaterials to treat the patient without eliciting undesired side-effects.

WHAT FASCINATES YOU ABOUT THIS RESEARCH AREA?

I always loved how biological processes intersect and connect to achieve a greater goal. The idea of designing strategies that can affect these processes, to achieve e. g. a therapeutic outcome is really cool. There are infinite ways biomaterials can be designed to trigger a response in the body to help in healing. Even though we know a lot about these physiological processes, there is still uncertainty on how local environment will react to new therapeutic biomaterials.

YOUR PARTICIPATION IN THE PRAS IS FOR FIVE YEARS. WHAT WOULD YOU LOVE TO ACHIEVE IN THIS TIME?

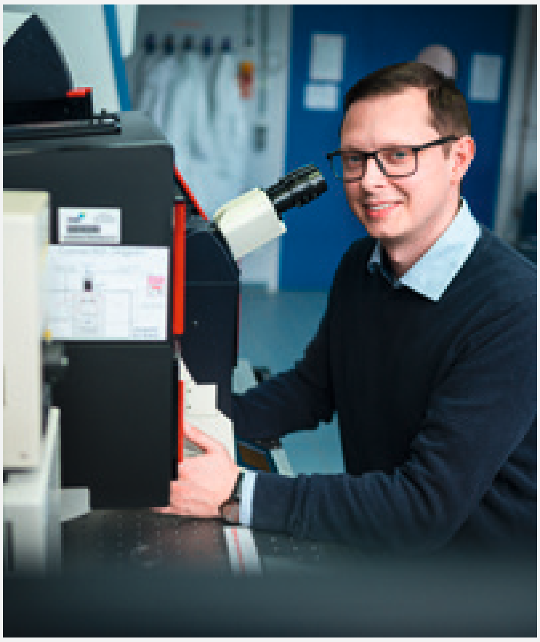
I want to contribute to our understanding about the biomaterial-tissue crosstalk and by doing so improve pre-clinical development of novel therapeutic biomaterials. My personal goal for this time is to engineer in vitro models that can help in predicting safety, compatibility and functionality of cutting-edge biomaterial systems. Also, within the PRAS, I will be able to validate these models in in vivo studies and hopefully get a more holistic view on the material-host interaction.

FOCUS ON NEW PEOPLE: OSKAR STAUFER

Oskar Staufer studied at Heidelberg University and obtained a PhD in Biology at the Max Planck Institute for Medical Research in 2020. Then he moved to the University of Oxford as a Marie Skłodowska Curie Fellow to perform postdoctoral work in immunotherapy. Since 2022 he is an independent researcher within the Pharmaceutical Research Alliance Saarland (PRAS).

CAN YOU TELL US AN IDEA OF WHAT IMMUNO-MATERIALS ARE?

Immuno-materials are designed to interact with the immune system in a controlled manner. This interaction can be aimed at eliciting an immune response, such as stimulation of the immune system, or at avoiding an immune response to reduce the likelihood of rejection of implants. The term encompasses a broad range of materials including polymers, metals and biological materials.



WHAT FASCINATES YOU ABOUT THIS RESEARCH AREA?

Immuno-materials are fascinating because of their ability to interact with the body's natural defense system in a controlled way. They offer the potential to develop more effective therapies for a variety of medical conditions. The combination of material science and immunology creates a new and exciting field of study with the potential to significantly impact human health. This is truly fascinating!

WHAT WOULD YOU LIKE TO ACHIEVE IN FIVE YEARS?

I am eager to unleash the full potential of immuno-materials and their role in regulating immunity for both therapy and research. My goal is to create a toolbox of materials mimicking the nature of the immune system, allowing us to treat diseases and to gain a deeper understanding of conditions like cancer. At the core of my passion is a desire to understand the interplay between biochemical and biophysical factors in regulating immunity. I recognize that this is a highly ambitious goal for a five-year plan. However, with the supportive environment at the INM, I am certain that we will make significant strides and exciting discoveries.

3RD CONFERENCE ON ENGINEERED LIVING MATERIALS: DESIGNED LIVING MATERIALS – FROM LAB TO APPLICATION

MARIO QUILITZ, ARÁNZAZU DEL CAMPO,
SHRIKRISHNAN SANKARAN

Still young, the research on engineered living materials is developing rapidly. Invited by the Leibniz Science Campus *Living Therapeutic Materials*, the expanding interdisciplinary community met – for the third time – in Saarbrücken, this time mostly in person. About 140 scientists from 15 countries gathered at the conference. Presented topics were: New avenues for sustainable materials production, programming material's multifunctionality in living components, new approaches to ELM processing, materials with new sensory functions, programming resilience in material's design, visions for adaptability and evolvability in ELMs, Living Therapeutic Materials, and ELM's pathway to the market.

The Third International Conference on Engineered Living Materials (ELMs) is a networking platform that attracts material scientists, synthetic biologists, biotechnologists, biophysicists and other disciplines interested in programming and creating materials with life-like capabilities. In this conference format, top scientists meet junior scientists, science meets art, and basic research meets industrial application. The program gathered representatives from academia, industry, regulatory agencies, and funding bodies to discuss the technical and environmental benefits and challenges of living materials. The conference will be organized again in 2023.

The conference was hosted by the *Leibniz ScienceCampus Living Therapeutic Materials*.

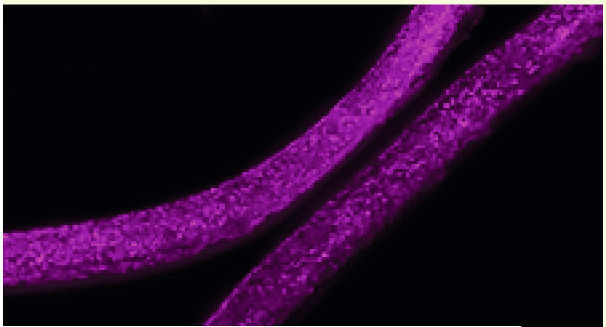
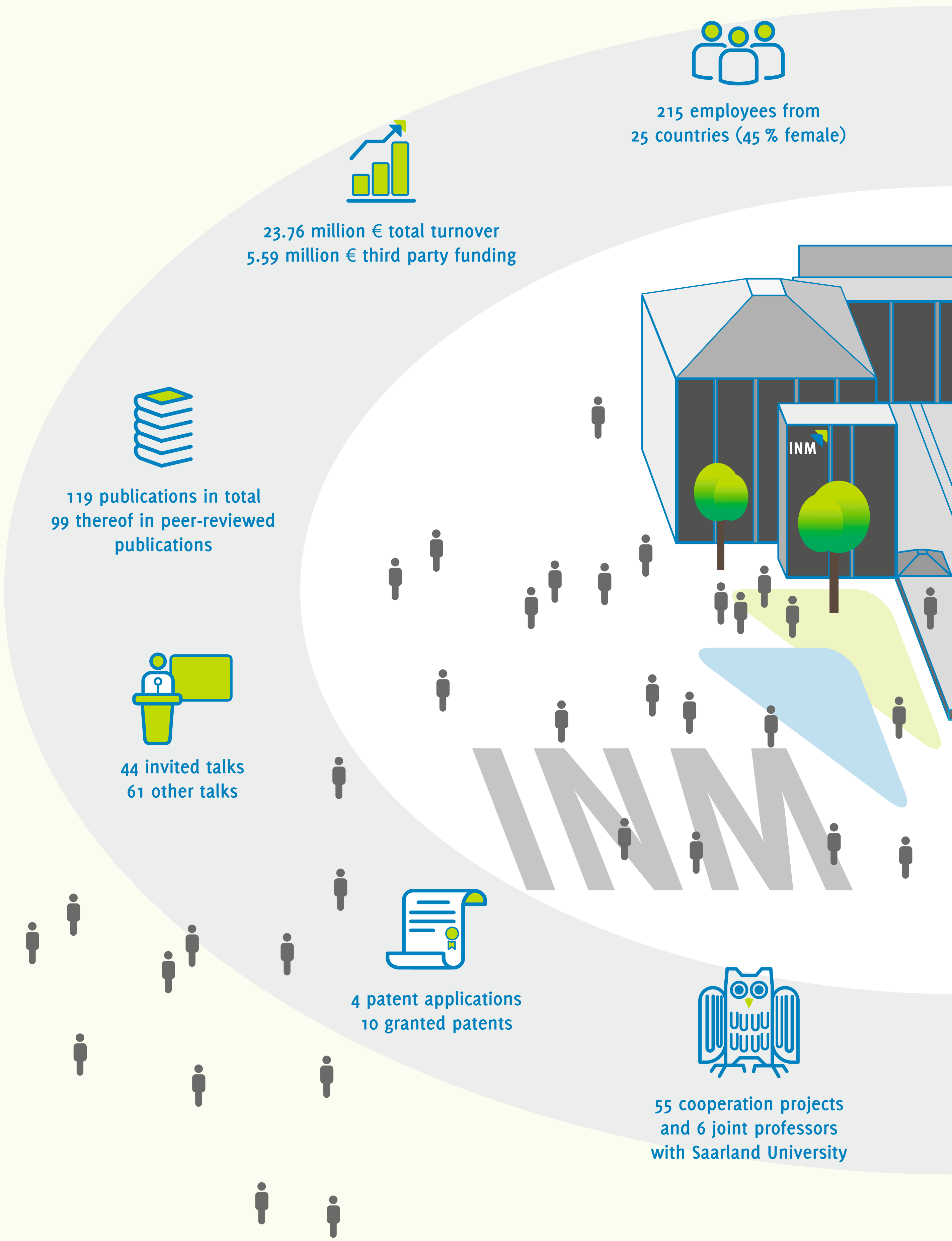


Fig. 1: The conference community in the Aula of the Saarland University.
Fig. 2: Bacterial colonies encapsulated in hydrogel, their size and shape controlled by the mechanical properties of the material.


215 employees from
25 countries (45 % female)
23.76 million € total turnover
5.59 million € third party funding
119 publications in total
99 thereof in peer-reviewed
publications
44 invited talks
61 other talks
4 patent applications
10 granted patents
55 cooperation projects
and 6 joint professors
with Saarland University
INM
INM

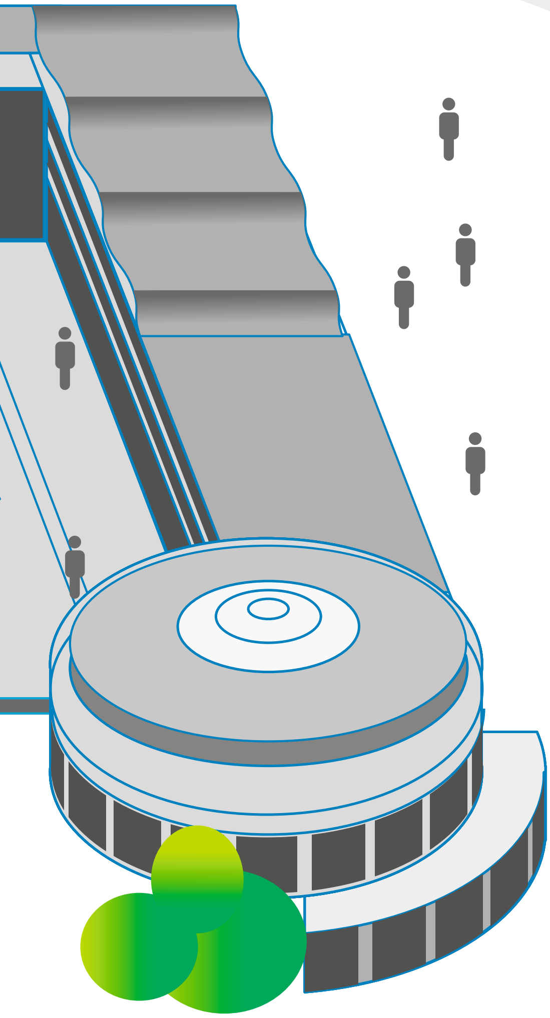
FAKTEN UND ZAHLEN 2022 / FACTS AND FIGURES 2022

101 scientists (38 % female)
thereof: 36 doctoral students (44 % female)

8 doctoral theses
4 master theses
9 bachelor theses

Teaching 46,1 weekly hours per year

26 events



Cooperations with 54 institutions in Germany

International cooperations with 47 institutions from 18 countries

AUSGEWÄHLTE PUBLIKATIONEN / SELECTED PUBLICATIONS

S. Bhusari, S. Sankaran, A. del Campo
Regulating bacterial behavior within hydrogels of tunable viscoelasticity
Advanced Science, 2022, 9, (17), 2106026

L. Wang, S. Arnold, P. Ren, Q. Wang, J. Jin, Z. Wen, V. Presser
Redox flow battery for continuous and energy-effective lithium recovery from aqueous solution
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Microgravity Removes Reaction Limits from Nonpolar Nanoparticle Agglomeration

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Tuning the Release Force of Microfibrillar Adhesives by Geometric Design

Advanced Materials Interfaces, 2022, 9, (33), 2201232

DAS INM IN ZAHLEN / INM IN FIGURES

Stand / As of: 08.03.2023

DAS INM IN ZAHLEN

Im Jahr 2022 betrug der **Gesamtumsatz** des INM 23,76 Mio. Euro.

Erlöse aus der gemeinsamen Finanzierung durch den Bund und die Länder (**institutionelle Förderung**): 18,05 Mio. €,
- davon Personal- und Sachaufwendungen: 14,28 Mio. €,
- und für Investitionen: 3,77 Mio. €

Erlöse aus Drittmittelvorhaben: 5,59 Mio. €
- davon 4,75 Mio. € aus öffentlichen Förderungen,
- und 0,84 Mio. € aus Vereinbarungen mit Industrieunternehmen.

Sonstige betriebliche Erträge: 0,11 Mio. €

Das INM hatte Ende 2022 **215 Beschäftigte** (119 m, 96 w), davon

- 65 Wissenschaftler/innen (43 m, 22 w),
- 36 Promovierende (20 m, 16 w),
- 50 Beschäftigte (27 m, 23 w) in den Bereichen Labor, Technik und Service,
- 32 Beschäftigte (10 m, 22 w) in der Verwaltung und den Sekretariaten,
- 25 Hiwis (15 m, 10 w) und 7 Auszubildende (4 m, 3 w).

INM IN FIGURES

In 2022, the **total turnover** of INM added up to 23.76 million euro.

Proceeds from the **joint financial support** by the federal government and the federal states (institutional funding): 18.05 million €,
- including expenses for personnel and materials: 14.28 million €,
- and for investments: 3.77 million €.

Proceeds from **third party funding:** 5.59 million €
- including 4.75 million € from public funding,
- and 0.84 million € from industrial contacts.

Other operating income: 0.11 million €

At the end of 2022, **215 employees** (119 m, 96 f) worked at INM including:

- 65 scientists (43 m, 22 f),
- 36 doctoral students (20 m, 16 f),
- 50 employees (27 m, 23 f) in laboratories and technical services,
- 32 employees (10 m, 22 f) in administration and secretarial offices,
- 25 graduate assistants (15 m, 10 f) and 7 apprentices (4 m, 3 f).

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

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DISSERTATIONEN / DOCTORAL THESES

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Permselective and ion-selective carbon nanopores and next-generation technologies for electrochemical water treatment
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ABSCHLUSSARBEITEN / THESES

BACHELORARBEITEN / BACHELOR THESES

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Investigation of Electrically Conductive Silver Suspensions by Rheoelectric Measurements
Fachhochschule Südwestfalen, Iserlohn
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Lokale Leitfähigkeit auf polymerstabilisierten Goldnanopartikeln
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Quantifizierung von markierten Oligonukleiotiden aus komplexen Medien
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Velocity Dependence of Fingertip Friction and its Perception
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MASTERARBEITEN / MASTER THESES

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Tossing objects with micropatterned adhesives
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DNA nano-switch to measure rupture force of biological bonds.
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Shijia Gou
Adhesion behavior of Kirigami film-terminated fibrillar microstructures
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Änderung der optischen Transparenz von dünnen metallischen Filmen durch die Absorption von elementarem Quecksilber
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Low Friction Durable Wearables for the Fingertip Made from Skin Adhesive Materials
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Surface Modification and Characterization of Silver Particles and their Use in Conductive Materials
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Silsesquioxanes as single source precursors for thin silicon suboxide films
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Untersuchung des Einflusses benetzungsfördernder und schaumvermindernder Additive auf die Beschichtungs- und Klebeeigenschaften eines wässrigen Acrylestercopolymerisats
Universität des Saarlandes
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Sakthi Vigneshwaran Subramanian Chandrasekaran
Sustainable Li-Ion Battery Electrode Synthesis and Processing: Carbon-coated Metal Sulfides derived from Prussian Blue analogues.
Universität des Saarlandes
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Varun Sai Tadimarri
Study of opto-regulated angiogenesis induction in HUVECs by bacterial hydrogels
Martin-Luther-Universität Halle-Wittenberg, Arbeit wurde angefertigt in der JFG Bioprogrammierbare Materialien
Dr. Shrikrishnan Sankaran / Prof. Dr. Franziska Seifert

Jonathan Thiemecke
Influence of the separation velocity on the detachment behavior of micropatterned dry adhesives
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Nano 2022 16th International Conference on Nanostructured Materials

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Nomination for Young Leaders Program of the STS forum 2022
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Peebles Award for Graduate Student Research
Adhesion Society, USA

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Leibniz-Auszubildendenpreis
Leibniz-Gemeinschaft

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Neuartige Silikonelastomere zur Behandlung von Trommelfellperforationen
Forschungspreis der Medizinischen Fakultät
Universität des Saarlandes 2022

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Best Poster Award
First Molecular System Engineering for Bioapplication Conference
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Energie-Materialien / Energy Materials

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Innovative Elektronenmikroskopie / Innovative Electron Microscopy

A. Bo, Y. Liu, B. Kuttich, T. Kraus, A. Widmer-Cooper and N. de Jonge
Nanoscale Faceting and Ligand Shell Structure Dominate the Self-Assembly of Non-Polar Nanoparticles into Superlattices
Advanced Materials, 2022, 34, (20), 2109093
[JIF: 32.086 (2021)]
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B. Klausfelder, P. Blach, N. de Jonge and R. Kempe
Synthesis of 3,4-Dihydro-2H-pyrroles from Ketones, Aldehydes, and Nitro Alkanes via Hydrogenative Cyclization
Chemistry – A European Journal, 2022, 28, (47), e202201307 [JIF: 05.020 (2021)]
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P. Kunnas, M.-A. Moradi, N. Sommerdijk and N. de Jonge
Strategy for optimizing experimental settings for studying low atomic number colloidal assemblies using liquid phase scanning transmission electron microscopy
Ultramicroscopy, 2022, 240, 113596 [JIF: 02.994 (2021)]
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J. Priesner, T. Kraus and N. de Jonge
Nanoscale Writing of Gold Nanoparticle Assemblies at the Liquid-Vapor Interface Using a Focused Electron Beam
Advanced Materials Interfaces, 2022, 9, (23), 2200699
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A. Zulfiqar and D. Ahmed
Solvent-free mechanochemical green synthesis of Schiff bases of tranexamic acid and study of their urease inhibitory and antioxidant activities
Asian Journal of Green Chemistry, 2022, 6, 40-47 [JIF: -]
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A. Zulfiqar, S. Azim, E. Ortega and N. de Jonge
Automated calculations for computing the sample-limited spatial resolution in (scanning) transmission electron microscopy
Ultramicroscopy, 2022, 242, 113611 [JIF: 02.689 (2022)]
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Interaktive Oberflächen / Interactive Surfaces

A. Gedsun, R. Sahli, X. Meng, R. Hensel and R. Bennewitz
Bending as Key Mechanism in the Tactile Perception of Fibrillar Surfaces
Advanced Materials Interfaces, 2022, 9, (4), 2101380
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D. Klimm, B. Szczefanowicz, N. Wolff and M. Bickermann
Phase diagram studies for the growth of (Mg,Zr):$SrGa_{12}O_{19}$ crystals
Journal of Thermal Analysis and Calorimetry, 2022, 147, 7133–7139 [JIF: 04.755 (2021)]
doi:10.1007/s10973-021-11050-4

B. Li, A. Çolak, J. Blass, M. Han, J. Zhang, Y. Zheng, Q. Jiang, R. Bennewitz and A. d. Campo
Molecular stiffness cues of an interpenetrating network hydrogel for cell adhesion
Materials Today Bio, 2022, 15, 100323 [JIF: 10.761 (2021)]
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H. Ma and R. Bennewitz
Relationship between corrosion and nanoscale friction on a metallic glass
Beilstein Journal of Nanotechnology, 2022, 13, 236-244
[JIF: 03.272 (2021)]
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BIOGRENZFLÄCHEN / BIO INTERFACES

Bioprogrammierbare Materialien / Bioprogrammable Materials

S. Bhusari, S. Sankaran and A. del Campo
Regulating Bacterial Behavior within Hydrogels of Tunable Viscoelasticity
Advanced Science, 2022, 9, (17), 2106026 [JIF: 17.521 (2021)]
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Dynamische Biomaterialien / Dynamic Biomaterials

A. Alhayek, E. S. Khan, E. Schönauer, T. Däinghaus, R. Shafiei, K. Voos, M. K. L. Han, C. Ducho, G. Posselt, S. Wessler, H. Brandstetter, J. Haupenthal, A. del Campo and A. K. H. Hirsch
Inhibition of Collagenase Q1 of Bacillus cereus as a Novel Antivirulence Strategy for the Treatment of Skin-Wound Infections
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Regulating Bacterial Behavior within Hydrogels of Tunable Viscoelasticity
Advanced Science, 2022, 9, (17), 2106026
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J. Feng, Y. Zheng, Q. Jiang, M. K. Włodarczyk-Biegun, S. Pearson and A. del Campo
Elastomeric Optical Waveguides by Extrusion Printing
Advanced Materials Technologies, 2022, 7, (10), 2101539
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M. Jin, A. Gläser and J. I. Paez
Redox-triggerable firefly luciferin-bioinspired hydrogels as injectable and cell-encapsulating matrices
Polymer Chemistry, 2022, 13, (35), 5116-5126
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Luciferin-Bioinspired Click Ligation Enables Hydrogel Platforms with Fine-Tunable Properties for 3D Cell Culture
ACS Applied Materials & Interfaces, 2022, 14, (4), 5017-5032 [JIF: 10.383 (2021)]
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G. Koçer, I. M. C. Albino, M. L. Verheijden and P. Jonkheijm
Endothelial cell spreading on lipid bilayers with combined integrin and cadherin binding ligands
Bioorganic & Medicinal Chemistry, 2022, 68, 116850
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Molecular stiffness cues of an interpenetrating network hydrogel for cell adhesion
Materials Today Bio, 2022, 15, 100323 [JIF: 10.761 (2021)]
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M. Włodarczyk-Biegun, P. Zielinski, M. Gladysz, A. Hofman, X. Wu, M. Villiou, M. Koch, A. del Campo and M. Kamperman
Melt Electrowriting enables fabrication of biommetic hierarchical scaffolds
Tissue Engineering A 2022, 28, (Suppl. 1), S362-S362
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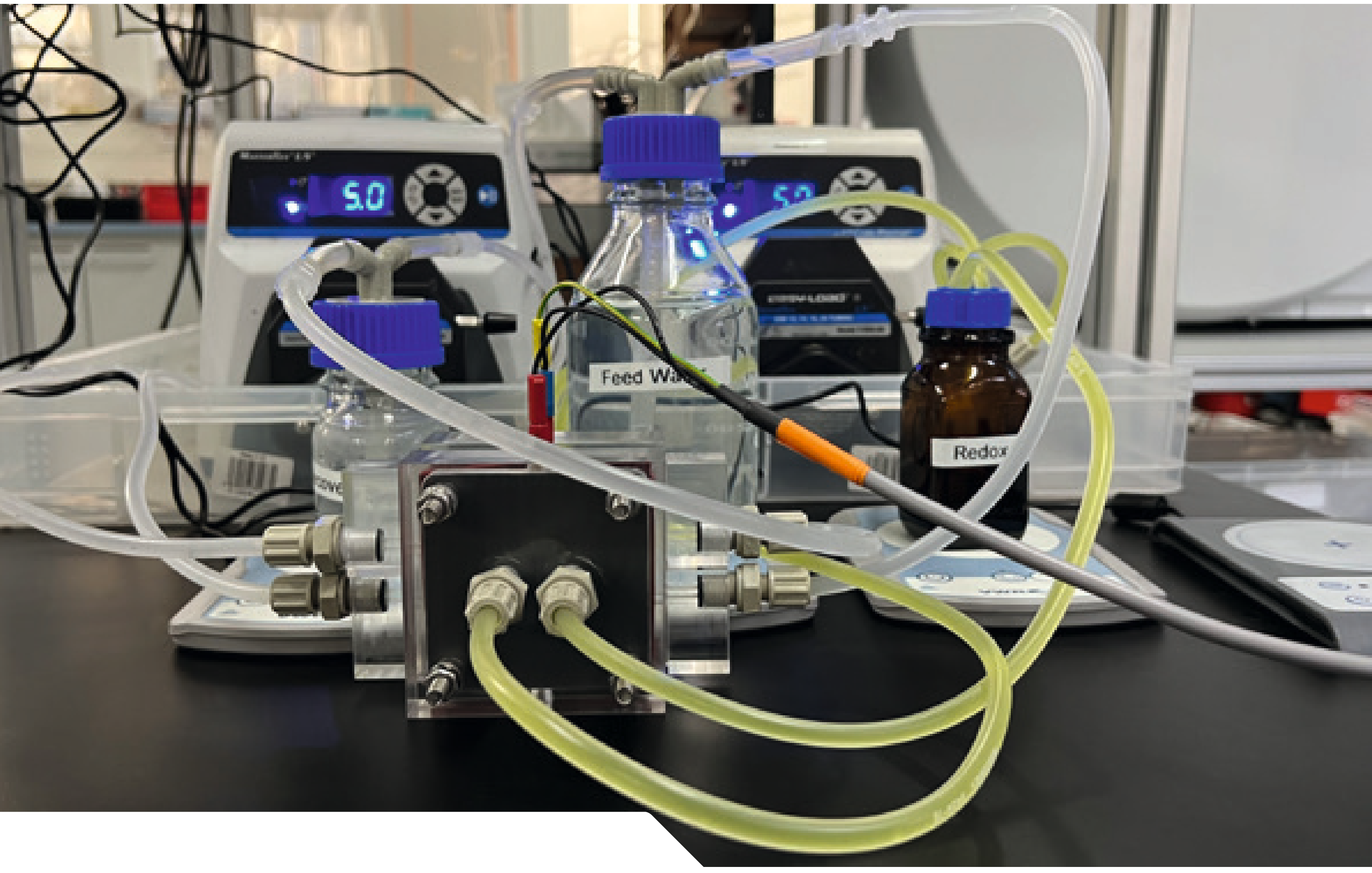

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Melt Electrowriting of Graded Porous Scaffolds to Mimic the Matrix Structure of the Human Trabecular Meshwork
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Unspecific CTL Killing Is Enhanced by High Glucose via TNF-Related Apoptosis-Inducing Ligand
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NANO ZELL INTERAKTIONEN / NANO CELL INTERACTIONS (UNTIL 09/2022)

Advanced Materials Safety (from 10/2022)

L. Elberskirch, K. Binder, N. Riefler, A. Sofranko, J. Liebing, C. B. Minella, L. Mädler, M. Razum, C. van Thriel, K. Unfried, R. P. F. Schins and A. Kraegeloh
Digital research data: from analysis of existing standards to a scientific foundation for a modular metadata schema in nanosafety
Particle and fibre toxicology, 2022, 19, (1), 1-19
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NANOKOMPOSIT-MATERIALIEN / NANOCOMPOSITE MATERIALS

Elektrofluide / Electrofluids

J. Castillo-Seoane, L. Gonzalez-Garcia, J. M. Obrero-Perez, F. J. Aparicio, A. Borrás, A. R. González-Elipe, Á. Barranco and J. R. Sanchez-Valencia
Rhodamine 6G and 800 intermolecular heteroaggregates embedded in PMMA for near-infrared wavelength shifting
Journal of Materials Chemistry C, 2022, 10, (18), 7119-7131 [JIF: 07.393 (2021)]
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Flexible and transparent electrodes imprinted from metal nanostructures: morphology and opto-electronic performance
Nanoscale Advances, 2022, 4, 3370-3380
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Flexible and transparent electrodes imprinted from Au nanowires: stability and ageing
Nanoscale Advances, 2022, 4, (18), 3940-3949
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D. Kang, L. González-García and T. Kraus
Soft Electronics by Inkjet Printing Metal Inks on Porous Substrates
Flexible and Printed Electronics, 2022, 7, 033001
[JIF: 03.588 (2021)]
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L. Zhang, D. S. Schmidt, L. González-García and T. Kraus
Microscopic Softening Mechanisms of an Ionic Liquid Additive in an Electrically Conductive Carbon-Silicone Composite
Advanced Materials Technologies, 2022, 7, (11), 2101700
[JIF: 08.856 (2021)]
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Optische Materialien / Optical Materials

L. Kócs, M. H. Jilavi, D. Beckelmann, B. Schäfer, A. May, M. Koch and P. W. de Oliveira
Water-based silica coatings: An environmentally friendly process on an industrial scale of single-layer anti-reflective coatings for large substrates
Ceramics International, 2022, 48, (3), 4165-4171
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Strukturbildung / Structure Formation

S. Bettscheider, T. Kraus and N. A. Fleck
Stabilization of ultrathin nanowires by self-assembly into bundles
Acta Materialia, 2022, 231, 117799 [JIF: 09.209 (2021)]
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Cononsolvency of thermoresponsive polymers: where we are now and where we are going
Soft Matter, 2022, 18, 2884-2909 [JIF: 04.046 (2021)]
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A precise nanoparticle quantification approach using microfluidics and single-particle tracking
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Nanoscale Advances, 2022, 4, 3370-3380
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L. Gemmer, Q. Hu, B.-J. Niebuur, T. Kraus, B. N. Balzer and M. Gallei
A block copolymer templated approach for the preparation of nanoporous polymer structures and cellulose fiber hybrids by ozone treatment
Polymer Chemistry, 2022, 13, (27), 4028-4046
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H. Hübner, B.-J. Niebuur, T. Büttner, M. Koch, B. Stühn, T. Kraus, D. Scheschkewitz and M. Gallei
Self-Assembly of Amphiphilic Carbosilane-Based Block Copolymers in Organic Media and Structure Formation in Colloidal Confinement
Macromolecules, 2022, 55, (21), 9442-9451
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Cononsolvency of the responsive polymer poly(N-isopropylacrylamide) in water/methanol mixtures: a dynamic light scattering study of the effect of pressure on the collective dynamics
Colloid and Polymer Science, 2022, 300, (11), 1269-1279
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E. Pickering, N. C. Paxton, A. Bo, B. O'Connell, M. King and M. A. Woodruff
3D Printed Tubular Scaffolds with Massively Tailorable Mechanical Behavior
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A. Pyttlik, B. Kuttich and T. Kraus
Dynamic Light Scattering on Nanoparticles in Microgravity in a Drop Tower
Microgravity Science and Technology, 2022, 34, (2), 13
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Microgravity Removes Reaction Limits from Nonpolar Nanoparticle Agglomeration
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R. Richter, M. A. M. Kamal, M. Koch, B.-J. Niebuur, A.-L. Huber, A. Goes, C. Volz, J. Vergalli, T. Kraus, R. Müller, N. Schneider-Daum, G. Fuhrmann, J.-M. Pagès and C.-M. Lehr
An Outer Membrane Vesicle-Based Permeation Assay (OMPA) for Assessing Bacterial Bioavailability
Advanced Healthcare Materials, 2022, 11, (5), 2101180
[JIF: 11.092 (2021)]
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L. Weber, J. Webel, F. Mücklich and T. Kraus
Precipitate number density determination in microalloyed steels by complementary atom probe tomography and matrix dissolution
Journal of Materials Science, 2022, 57, 12585–12599
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Advanced Materials Technologies, 2022, 7, (11), 2101700 [JIF: 08.856 (2021)]
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P. Zhang, R. Zou, S. Wu, L.-A. Meyer, J. Wang and T. Kraus
Gold Nanoprobes Exploring the Ice Structure in the Aqueous Dispersion of Poly(Ethylene Glycol)–Gold Hybrid Nanoparticles
Langmuir, 2022, 38, (8), 2460-2466 [JIF: 04.331 (2021)]
doi:10.1021/acs.langmuir.1c02783

PROGRAMMBEREICHSUNGEBUNDEN / NOT LINKED TO A PROGRAM DIVISION

Chemische Analytik / Chemical Analytics

E. V. Zolotukhina, A. Katsen-Globa, M. Koch, C. Fink-Straube, T. Sukmann, M. G. Levchenko and Y. E. Silina
The development of alginate-based amperometric nanoreactors for biochemical profiling of living yeast cells
Bioelectrochemistry, 2022, 145, 108082 [JIF: 05.760 (2021)]
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Physikalische Analytik / Physical Analytics

M. Drost, E. Diamanti, K. Fuhrmann, A. Goes, A. Shams, J. Haupenthal, M. Koch, A. K. H. Hirsch and G. Fuhrmann
Bacteriomimetic Liposomes Improve Antibiotic Activity of a Novel Energy-Coupling Factor Transporter Inhibitor
Pharmaceutics, 2022, 14, (1), 4 [JIF: 06.525 (2021)]
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Self-Assembly of Amphiphilic Carbosilane-Based Block Copolymers in Organic Media and Structure Formation in Colloidal Confinement
Macromolecules, 2022, 55, (21), 9442-9451 [JIF: 05.985 (2021)]
doi:10.1021/acs.macromol.2c01853

B. C. Huck, D. Thiyagarajan, A. Bali, A. Boese, K. F. W. Besecke, C. Hozsa, R. K. Gieseler, M. Furch, C. Carvalho-Wodarz, F. Waldow, D. Schwudke, O. Metelkina, A. Titz, H. Huwer, K. Schwarzkopf, J. Hoppstädter, A. K. Kiemer, M. Koch, B. Loretz and C.-M. Lehr
Nano-in-Microparticles for Aerosol Delivery of Antibiotic-Loaded, Fucose-Derivatized, and Macrophage-Targeted Liposomes to Combat Mycobacterial Infections: In Vitro Deposition, Pulmonary Barrier Interactions, and Targeted Delivery
Advanced Healthcare Materials, 2022, 11, (11), 2102117 [JIF: 11.092 (2021)]
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Lipid-Polymer Hybrid Nanoparticles for mRNA Delivery to Dendritic Cells: Impact of Lipid Composition on Performance in Different Media
Pharmaceutics, 2022, 14, (12), 2675 [JIF: 06.525 (2021)]
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P. Lapuhs, E. Heinrich, R. Garcia, A. Goes, N. Frank, L. Bollenbach, V. Stibane, T. Kuhn, M. Koch, A. K. Kiemer, R. Müller, K. Fuhrmann and G. Fuhrmann
The inherent antibiotic activity of myxobacteria-derived autofluorescent outer membrane vesicles is switched on and off by light stimulation
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doi:10.1039/D2NR02743G

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Yields and Immunomodulatory Effects of Pneumococcal Membrane Vesicles Differ with the Bacterial Growth Phase
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O. Metelkina, B. Huck, J. S. O'Connor, M. Koch, A. Manz, C.-M. Lehr and A. Titz
Targeting extracellular lectins of Pseudomonas aeruginosa with glycomimetic liposomes
Journal of Materials Chemistry B, 2022, 10, (4), 537-548 [JIF: 07.571 (2021)]
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E. Trenkenschuh, M. Richter, E. Heinrich, M. Koch, G. Fuhrmann and W. Friess
Enhancing the Stabilization Potential of Lyophilization for Extracellular Vesicles
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The development of alginate-based amperometric nanoreactors for biochemical profiling of living yeast cells
Bioelectrochemistry, 2022, 145, 108082 [JIF: 05.760 (2021)]
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Materialien-Host Interaktionen / Materials Host Interaction

E. Monferrer, O. Dobre, S. Trujillo, M. A. González Oliva, A. Trubert-Paneli, D. Acevedo-León, R. Noguera and M. Salmeron-Sanchez
Vitronectin-based hydrogels recapitulate neuroblastoma growth conditions
Frontiers in Cell and Developmental Biology, 2022, 10, 1-14 [JIF: 06.684 (2021)]
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INM Fellows / INM Fellows

S. Chatterjee, M. Mangeat and H. Rieger
Polar flocks with discretized directions: The active clock model approaching the Vicsek model
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A. Wysocki, A. K. Dasanna and H. Rieger
Interacting particles in an activity landscape
New Journal of Physics, 2022, 24, (9), 093013
[JIF: 03.729 (2021)]
doi:10.1088/1367-2630/ac8e8c

W. Yang, A. Denger, C. Diener, F. Küppers, L. Soriano-Baguet, G. Schäfer, A. K. Yanamandra, R. Zhao, A. Knörck, E. C. Schwarz, M. Hart, F. Lammert, L. P. Roma, D. Brenner, G. Christidis, V. Helms, E. Meese, M. Hoth and B. Qu
Unspecific CTL Killing Is Enhanced by High Glucose via TNF-Related Apoptosis-Inducing Ligand
Frontiers in Immunology, 2022, 13, 831680
[JIF: 08.786 (2021)]
doi:10.3389/fimmu.2022.831680

X. Zhou, R. Zhao, A. K. Yanamandra, M. Hoth and B. Qu
Light-Sheet Scattering Microscopy to Visualize Long-Term Interactions Between Cells and Extracellular Matrix
Frontiers in Immunology, 2022, 13, 828634
[JIF: 08.786 (2021)]
doi:10.3389/fimmu.2022.828634

Weitere / Others

Y. Chen, H. Z. Yoh, A.-R. Shokouhi, T. Murayama, K. Suu, Y. Morikawa, N. H. Voelcker and R. Elnathan
Role of actin cytoskeleton in cargo delivery mediated by vertically aligned silicon nanotubes
Journal of Nanobiotechnology, 2022, 20, (1), 406 [JIF: 09.429 (2021)]
doi:10.1186/s12951-022-01618-z

S. Deng, B. Tan, A. S. R. Chesman, J. Lu, D. P. McMeekin, Q. Ou, A. D. Scully, S. R. Raga, K. J. Rietwyk, A. Weissbach, B. Zhao, N. H. Voelcker, Y.-B. Cheng, X. Lin and U. Bach
Back-contact perovskite solar cell fabrication via microsphere lithography
Nano Energy, 2022, 102, 107695 [JIF: 19.069 (2021)]
doi:10.1016/j.nanoen.2022.107695

X. Xiong, S. Wang, L. Xue, H. Wang and J. Cui
Growing Strategy for Postmodifying Cross-Linked Polymers' Bulky Size, Shape, and Mechanical Properties
ACS Applied Materials & Interfaces, 2022, 14, (6), 8473-8481 [JIF: 10.383 (2021)]
doi:10.1021/acsami.1c23954

H. Z. Yoh, Y. Chen, S. Aslanoglou, S. Wong, Z. Trifunovic, S. Crawford, E. Lestrell, C. Priest, M. Alba, H. Thissen, N. H. Voelcker and R. Elnathan
Polymeric Nanoneedle Arrays Mediate Stiffness-Independent Intracellular Delivery
Advanced Functional Materials, 2022, 32, (3), 2104828 [JIF: 19.924 (2021)]
doi:10.1002/adfm.202104828

EINGELADENE VORTRÄGE / INVITED TALKS

223 Vorträge
talks
davon / *including*

44 eingeladene Vorträge
invited talks

179 sonstige Vorträge
other talks
davon / *including*

118 Industrievorträge

(Stand / As of 15.03.2023)

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
Electrochemical Water esalination with MXENE
2nd International MXene Conference
Philadelphia <USA, CA>
August 1 – 3, 2022

V. Presser
Nanoconfinement: the ey to Understanding Ion Electrosorption Applications
Spring Meeting of the American Chemical Society (ACS)
San Diego <USA, CA>
March 20 – 24, 2022

Y. Zhang, G. Feng and V. Presser
Permselectivity of Sub-Nanometer Carbon Pores from Prediction to Experimental Verification
7th International Symposium on Enhanced Electrochemical Capacitors (ISEE'Cap22)
Bologna <ITA>
July 11 – 17, 2022

Funktionelle Mikrostrukturen / Functional Microstructures

E. Arzt
Release with ease – bioinspired designs for placing micro-objects
TMS Annual Meeting / Nix Award Symposium (NIX III)
Anaheim <USA, CA>
March 02, 2022

E. Arzt
To stick or not to stick – how bioinspiration is changing micromanipulation
The Department of Mechanical & Aerospace Engineering Stanford S. and Beverly P. Penner Distinguished Lectures
University of California San Diego <USA, CA>
March 21, 2022

E. Arzt
To stick or not to stick – from bioinspiration to robotics and medicine
IRG-3 Meeting
University of California Santa Barbara <USA, CA>
April 8, 2022

E. Arzt
Gecomer – vom Vorbild Natur zum Start-Up
Rotary
Linz <AUT>
May 04, 2022

E. Arzt
Release with ease – challenges and bioinspired concepts for handling micro-objects
Nanobrücken
Prag <CZE>
June 06, 2022

E. Arzt
From ODS to Gecomer: a metal physicist's foray into b ioinspired innovation
INM-UCSB Workshop in the framework of the MUSIGAND project – "Designed Materials and Microstructures"
Saarbrücken <GER>
October 5, 2022

E. Arzt
Design and mechanics of adhesive microstructures – how bioinspiration is changing micromanipulation
University of California
Irvine <USA, CA>
October 20, 2022

Innovative Elektronenmikroskopie / Innovative Electron Microscopy

N. de Jonge
Liquid phase electron microscopy, fundamentals, and application to examine cancer cells
NWO Physics@Veldhoven
virtual
January 25 – 26, 2022

Interaktive Oberflächen / Interactive Surfaces

R. Bennewitz
Force microscopy of stacked 2D materials
Abschluss-Symposium Graduiertenkolleg GRK 1896
Erlangen <GER>
June 23 – 24, 2022

R. Bennewitz
Molecular force spectroscopy on dynamic biomaterials
Rudolf-Virchow-Zentrum – Center for Integrative and Translational Bioimaging
Julius-Maximilian-University of Würzburg <GER>
June 22, 2022

R. Bennewitz, M.-D. Krass, G. Krämer, H. Ma, K.-S. Kim and F. Hausen
Nanoscale friction at the solid-liquid interface: in-situ force microscopy of complex layers
WTC 2022 – 7th World Tribology Congress
Lyon <FRA>
July 10 – 15, 2022

B. Szczefanowicz, Z. Liu, G. Krämer, R. Bennewitz, T. Kuwahara, L. Mayrhofer, A. Klementz and M. Moseler
Nanoscale friction on 2D materials - from solid lubrication to covalent adhesion
Conference on "Dissipation Mechanisms in Nano/Mesoscale Tribological Systems", ICTP Trieste
Trieste <ITA>
Jay 30 – June 2, 2022

BIOGRENZFLÄCHEN / BIO INTERFACES

Bioprogrammierbare Materialien / Bioprogrammable materials

S. Sankaran, P. Dhakane, S. Bhusari, S. Dey, M. Blanch-Asensio, F. Riedel, V. S. Tadimarri and A. del Campo
Living therapeutic materials – hydrogel confined bacteria for smart drug delivery
Bharathiar University Coimbatore <IND>
May 5, 2022

Dynamische Biomaterialien / Dynamic Biomaterials

A. del Campo
Living therapeutic hydrogels
Interdisciplinary Research in POlymer Science: Birthday Colloquium of H. W. Spiess
Max-Planck-Institute for Polymer Research Mainz <GER>
November 18 – 19, 2022

A. del Campo
Mechanogpharmacology with living therapeutic hydrogels
Molecular Systems Engineering for Bioapplications (MSEB)
Heidelberg <GER>
October 19 – 21, 2022

A. del Campo
Mechanopharmacology with living therapeutic hydrogels
GRC Mltiscale Mechanochemistry and Mechanobiology, From Molecular Mechanics to Smart Materials
Ventura <USA, CA>
July 31 – August 5, 2022

A. del Campo
Hydrogels that talk to cells when lighted
Tissue Engineering and Regenerative Medicine International Society (TERMIS), European Chapter Conference
Krakow <POL>
June 28 – July 1, 2022

A. del Campo
Engineered living therapeutic materials: new concepts for sustained and sustainable drug delivery
N4M Nanoengineering for Mechanobiology
Camogli <ITA>
March 27 – 31, 2022

S. Sankaran, P. Dhakane, S. Bhusari, S. Dey, M. Blanch-Asensio, F. Riedel, V. S. Tadimarri and A. del Campo
Living therapeutic materials – hydrogel confined bacteria for smart drug delivery
Bharathiar University Coimbatore <IND>
May 5, 2022

NANO ZELL INTERAKTIONEN / NANO CELL INTERACTIONS (UNTIL 09/2022)

Advanced Materials Safety (from 10/2022)

L. Elberskirch and A. Kraegeloh
Systemic approach for the development of advanced 2D-Nanomaterials
12. Indo-German Frontiers of Engineering Symposium (INDOGFOE)
Bremen <GER>
September 29 – October 2, 2022

NANOKOMPOSIT-TECHNOLOGIE / NANOCOMPOSITE TECHNOLOGY

Elektrofluide / Electrofluids

T. Kraus, L. F. Engel, B. Reiser, S. Bettscheider and L. González-García
Hierarchical nanowire colloids and how to weave them
51st Biennial Assembly of the Geman Colloid Society
Berlin <GER>
September 28 – 30, 2022

Optische Materialien / Optical Materials

M. Amlung
INM, Innovation Center and Optical Materials
KICOX
IHK/saaris Saarbrücken <GER>
September 15, 2022

M. Amlung
INM, Innovation Center and Optical Materials
Workshop Institut für Solarenergieforschung (ISFH)
Hameln <GER>
October 25, 2022

M. Amlung
Transparent GFRP-Materials by RI-Matching
Workshop Institut für Solarenergieforschung (ISFH)
Hameln <GER>
October 25, 2022

K. Fries
Final Meeting of the Proficiency Tests on Shot Range Estimation PT-NC_2022, PT-PB-2021 and PT-PB-2020
Internationaler Schmauchspuren-Workshop
BKA <Wiesbaden, GER>
June 07, 2022

P. König, A. Schorr, S. Heusing and P. W. d. Oliveira
Flexible transparent conductive coatings by electrospinning
TechBlick : Innovationsfestival
Virtual
June 24, 2022

P. König, A. Schorr, S. Heusing and P. W. d. Oliveira
Electrospinning for transparent conductive coatings
TCM-TOEO 2022 Conference, 8th International Symposium on Transparent Conductive Materials & 12th International Symposium on Transparent Oxide and Related Materials for Electronics and Optics
Hersonissos, Heraklion <GRC>
October 16 – 21, 2022

P. Rogin, J. Kampka, K. Fries and P. W. d. Oliveira
Exploiting surface plasmon resonance for integrated optics
SPIE Photonics Europe 2022
Straßburg <FRA>
May 25, 2022

Strukturbildung / Structure Formation

T. Kraus
Electronically conductive networks of nano- and micro-particles in printed electronics, soft robotics, and batteries
Exciton Science Annual Workshop
Lorne, Victoria <AUS>
November 21 – 25, 2022

T. Kraus
Reversible interfaces for stretchable and recyclable electronics
Nanofabulous Seminar, Melbourne Centre for Nanofarbication (MCN)
Melbourne <AUS>
November 18, 2022

T. Kraus
Networks in functional materials: does gravity change their structure?
ZARM – Center of Applied Space Technology and Microgravity, Fluids and Space Engineering Seminar
Bremen <GER>
November 1, 2022

T. Kraus
Hierarchical, self-assembled particle networks in thin films and in bulk: from transparent electrodes to flexible conductors
9th World Congress on Particle Technology
Madrid <ESP>
September 18 – 22, 2022

T. Kraus
Connecting material properties to molecular structure with hierarchical networks
GDCh-Kolloquium, Friedrich-Alexander-Universität
Erlangen-Nürnberg <GER>
July 14, 2022

T. Kraus, L. F. Engel, B. Reiser, S. Bettscheider and L. González-García
Hierarchical nanowire colloids and how to weave them
51st Biennial Assembly of the Geman Colloid Society
Berlin <GER>
September 28 – 30, 2022

T. Kraus, H. Z. Yoh and Y. Chen
Digital unterstützte Forschung an komplexen Funktionsmaterialien am Beispiel der Plattform DigiBatMat
MatFo2022 – Vom Material zur Innovation 2022: Digital, Neural, Vital
Köln <GER>
November 14 – 15, 2022

InnovationsZentrum INM / InnovationCenter INM

M. Amlung
INM, Innovation Center and Optical Materials
KICOX
IHK/saaris Saarbrücken <GER>
September 15, 2022

M. Amlung
INM, Innovation Center and Optical Materials
Workshop Institut für Solarenergieforschung (ISFH)
Hameln <GER>
October 25, 2022

M. Amlung
Transparent GFRP-Materials by RI-Matching
Workshop Institut für Solarenergieforschung (ISFH)
Hameln <GER>
October 25, 2022

INM Fellow

M. H. Müser
Simulations of adhesive, viscoelastic, and randomly rough contacts: Thest of Persson theory and beyond
Adhesion Society Meeting
San Diego <USA, CA>
February 20 – 23, 2022

M. H. Müser
On the modelling of triboelectricity and stress-induced ionization
ICTP Workshop on “Dissipation mechanisms in nano/mesosclae tribological systems”
Santa Barbara <USA, CA>
May 30 – June 2, 2022

M. H. Müser
How roughness and viscoelasticity affect adhesion
INM-UC Workshop on “Designed materials and microstructures”
Santa Barbara <USA, CA>
October 6, 2022

H. Rieger
Capillary action of active matter
NSPCS2022 – Nonequilibrium Statistical Physics of Complex Systems : the 9th KIAS Conference on Statistical Physics
Seoul <KOR>
July 25 – 28, 2022

H. Rieger
Search efficiecy of chemotactic random walkers
Venice Meeting on Fluctuations in Small Coplex Systems VI
Venice <ITA>
September 5 – 9, 2022

H. Rieger
Centrosome positioning and re-positioning in immune cells
13th Physics of Cancer Symposium
Leipzig <GER>
September 28 – 30, 2022

H. Rieger
Biophysics of Killing: Immunobiophysics
ICTS program “Statistical Biological Physics: from Singel Molecules to Cell”
Bangalore <IND>
October 11 – 22, 2022

PATENTE / PATENTS

4 Patentanmeldungen
patent applications

10 erteilte Patente
granted patents

1 in Europa
in Europe

9 international
international

55 Patentfamilien
patent families

ERTEILTE EUROPÄISCHE PATENTE / PATENTS GRANTED IN EUROPE

Europäisches Patent Nr. 2125649 B1
Beschichtungszusammensetzung
Erfinder: M. Amlung, P. W. de Oliveira, M. Veith

ERTEILTE INTERNATIONALE PATENTE / PATENTS GRANTED INTERNATIONALLY

KR Patent Nr. 102402954 B1
Verfahren zur Herstellung strukturierter metallischer Beschichtungen
Erfinder: P.W. de Oliveira, T. Dörr, K. Moh

US Patent Nr. 11499967 B2
Spezifische Proteinmarkierung sowie Verfahren zur Identifizierung der (statistischen Verteilung der) Proteinstöchiometrie
Erfinder: N. de Jonge, D. B. Peckys

KR Patent Nr. 102475284 B1
Komposit-Pillarstrukturen
Erfinder: R. Hensel, S. Fischer, E. Arzt

US Patent Nr. 11286394 B1
Leitfähige Nanokomposite
Erfinder: B. Reiser, T. Kraus, L. González-Garcia, J. Maurer, I. Kanelidis

US Patent Nr. 11499264 B2
Verfahren zur Herstellung von leitfähigen Strukturen
Erfinder: P.W. de Oliveira, J. S. Atchison

KR Patent Nr. 102475289 B1
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

CN Patent Nr. 110099742 B
Herstellung von dotierten Nanopartikeln und ihre Verwendung
Erfinder: N. Müller, P. Rogin, P.W. de Oliveira, T. Müller

JP Patent Nr. 7150727 B2
Herstellung von dotierten Nanopartikeln und ihre Verwendung
Erfinder: N. Müller, P. Rogin, P.W. de Oliveira, T. Müller

KR Patent Nr. 102472064 B1
Herstellung von dotierten Nanopartikeln und ihre Verwendung
Erfinder: N. Müller, P. Rogin, P.W. de Oliveira, T. Müller

LEHRVERANSTALTUNGEN / TEACHING

WINTERSEMESTER / WINTER SEMESTER 2021/2022

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

Eduard Arzt und Mitarbeiter/innen
Einführung in die Materialwissenschaft für (Studierende der) Mikrotechnologie und Nanostrukturen
Universität des Saarlandes, Vorlesung und Übung, (virtuell), 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
Kolloide und Grenzflächen
Universität des Saarlandes, Praktikum

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

Tobias Kraus (mit G. Jung, C. Kay, 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

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

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

SOMMERSEMESTER / SUMMER SEMESTER 2022

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

R. Bennewitz
Good Scientific Practice and Communication
Universität des Saarlandes (GradUS), Blockseminar, 1 SWS

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

Aránzazu del Campo und Mitarbeiter*Innen
Praktikum Biomaterialien (Biomat P)
Universität des Saarlandes, Praktikum, 2 SWS

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

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

Tobias Kraus (mit G. Jung, C. Kay)
Vertiefungspraktikum Physikalische Chemie (PCV)
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

WINTERSEMESTER / WINTER SEMESTER 2022/2023

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

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

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

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

Carsten Becker-Willinger
Non-Destructive-Testing-Master, Modul: Polymer Materials
Dresden International University, Vorlesung / Übung, 2 SWS

Roland Bennewitz
Experimentalphysik IV a (Festkörperphysik I)
Universität des Saarlandes, Vorlesung und Übung, 3 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 (mit G. Jung, C. Kay, S. Stopkovicz, 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

Tobias Kraus
Kolloide und Grenzflächen
Universität des Saarlandes, Praktikum

Tobias Kraus (mit G. Jung, C. Kay, S. Stopkovicz, Univ. des Saarlandes)
Masterpraktikum Physikalische Chemie
Universität des Saarlandes, Praktikum, 2 SWS

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

Volker Presser
Seminar Energie-Materialien
Universität des Saarlandes, Seminar, 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

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

VERANSTALTUNGEN / EVENTS

JANUAR – FEBRUAR

Kick off Meeting des Leibniz-Forschungsverbundes Advanced Materials Safety
A. Kraegeloh, C. Petzold (mit A. Fery und den Verbundpartnern)
Virtuelles Meeting, 13.01.2022

Schülerpraktikum I
D. Beckelmann, L. Elberskirch, A. Jung, P. Kalmes, S. Kunkel, C. Lang, G. Moreira, C. Muth, H. Rimbach, S. Selzer, L. Sold, A. Weyand
Saarbrücken, 31.01. – 11.02.2022

Besuch von Ministerpräsident des Saarlandes Tobias Hans
E. Arzt, A. del Campo, G. Weber, V. Presser, S. Sankaran, M. Quilitz (mit Staatskanzlei des Saarlandes)
Saarbrücken, 02.02.2022

MÄRZ – APRIL

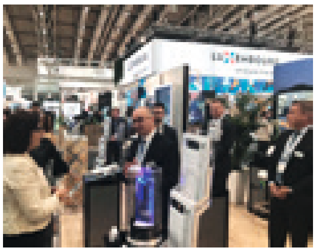
I-Seed – Towards new frontiers for distributed environmental monitoring based on an ecosystem of plant-seed-like soft robots / Mini-Symposium on Environmental Nanosensing
T. Kraus, A. Nexha
Virtuell, 17.03.2022

LOPEC – Messe für gedruckte Elektronik
S. Heusing, M. Klos
München, 23.03. – 24.03.2022

MÄRZ – APRIL

Schülerpraktikum II
D. Beckelmann, A. Haettich, K. Jost, P. Kalmes, S. Kunkel, C. Lang, A. May, R. Muth, J. Paulus, M. Quilitz, D. Schmidt, S. Selzer, S. Siegrist, L. Sold, A. Weyand
Saarbrücken, 28.03. – 08.04.2022

MAI – JUNI



Hannover Messe
C. Becker-Willinger, M. Amlung, T. Kraus, P. de Oliveira
Hannover, 03.05. – 02.06.2022

Tag der Offenen Tür der Universität des Saarlandes
X. Zhang, C. Hartmann, A. Kraegeloh, M. Koch, T. Kraus, C. Petzold, V. Presser, M. Quilitz
Saarbrücken, 21.05.2022

Leibniz ScienceCampus Summer School 2022
A. del Campo, C. Hartmann, M. Quilitz, S. Sankaran Europäische Akademie Otzenhausen
Otzenhausen, 17.06. – 19.06.2022

MAI – JUNI

DFG Nachwuchsakademie Engineered Living Materials
A. del Campo, C. Hartmann and S. Sankaran (mit Prof. W. Weber, University Freiburg)
Saarbrücken, 17.06. – 21.06.2022

3rd Engineered Living Materials Conference 2022
A. del Campo, C. Hartmann and S. Sankaran (mit Prof. W. Weber, University Freiburg)
Saarbrücken, 21.06. – 23.06.2022

Besuch der Teilnehmenden am 3. Internationalen Alumnitreffen EUSMAT der Univ. des Saarlandes
M. Quilitz (mit EUSMAT, Univ. des Saarlandes)
Saarbrücken, 30.06.2022

JULI – AUGUST

Schülerpraktikum III
D. Beckelmann, S. Brück, F. Faller, M. Fehlberg, M. Hauck, A. Jung, P. Kalmes, S. Kunkel, A. May, C. Muth, M. Quilitz, H. Rimbach, M. Samri, D. Schmidt, M. Sude
Saarbrücken, 04.07. – 15.07.2022

Besuch der Teilnehmenden der Three Korean Colleges Tour der Universität des Saarlandes
M. Koch, M. Quilitz (mit Univ. des Saarlandes)
Saarbrücken, 13.07.2022

JULI – AUGUST

Regularien-Dialog Nanotechnologie
C. Petzold, (mit J. Hermannsdörfer, Leibniz-Forschungsverbund Advanced Materials Safety mit Nano in Germany, Cluster Nanotechnologie Bayern, Norddeutsche Initiative Nanotechnologie)
Virtuell, 14.07.2022

Besuch von Studierenden aus dem Programm AMASE (EUSMAT) der Univ. des Saarlandes
K. Moh, M. Quilitz (mit EUSMAT, Univ. des Saarlandes)
Saarbrücken, 23.08.2022

SEPTEMBER

Virtual Lab Day des BMBF-VDI
M. Koch, G. Moreira-Lana, M. Quilitz (mit VDI, BMBF)
virtuell, 06.09.2022

Sitzung der Sektion D der Leibniz-Gemeinschaft
E. Arzt, A. del Campo, S. Sankaran, S. Brück, M. Quilitz (mit Leibniz-Gemeinschaft)
Saarbrücken, 08.09. – 09.09.2022

Material Science and Engineering 2020 DGM Conference C04 Advanced Particle Characterization for Material analysis and synthesis
L. Gonzalez-Garcia, T. Kraus (mit G. Salazar-Álvarez, D. Gebauer, J. Walter)
Darmstadt, 27.09. – 29.09.2022

Material Science and Engineering 2020 DGM Conference P06 Wet Processed Nanostructured Materials
L. Gonzalez-Garcia, T. Kraus (mit G. Lozano, H. Wolf)
Darmstadt, 27.09. – 29.09.202

OKTOBER – NOVEMBER

Particle Based Materials Symposium 2022 – Enhancing Sustainability
T. Kraus (Co-Organisator)
Erlangen, 06.10. – 07.10.2022

Workshop des Leibniz ScienceCampus Living Therapeutic Materials
A. del Campo, S. Sankaran, M. Quilitz
Saarbrücken, 13.10.2022

INM-UCSB Workshop Designed Materials and Nanostructures im Rahmen des Projektes MUSIGAND
E. Arzt, C. Hartmann, und weitere MA (mit UCSB)
Santa Barbara, CA, USA, 05.10. – 07.10.2022

OKTOBER – NOVEMBER

BMBF Schülerpraktikum Werkstoffferien 2022
E. Bubel, Y. Curto, L. Elberskirch, A. Haettich, J. Kasper, M. Quilitz, S. Schumacher (mit VDI, BMBF)
Saarbrücken, 24.10. – 28.10.2022

OKTOBER – NOVEMBER

Sicherheit mit Nanomaterialien – Dialog Nanotechnologie
C. Petzold, (mit J. Hermannsdörfer, Leibniz-Forschungsverbund Advanced Materials Safety mit Nano in Germany, Cluster Nanotechnologie Bayern, Norddeutsche Initiative Nanotechnologie)
Virtuell, 17.11.2022

Safe and-Sustainable-by-Design und recyclinggerechtes Design – Dialog Nanotechnologie
C. Petzold, A. Kraegeloh (Leibniz-Forschungsverbund Advanced Materials Safety mit Nano in Germany, Cluster Nanotechnologie Bayern, Norddeutsche Initiative Nanotechnologie)
Virtuell, 17.11.2022

VORTRÄGE IM INM-KOLLOQUIUM / INM COLLOQUIUM TALKS

FEBRUAR
Dr. Nguyen Duong
Spectral Imaging, FLIM-FRET and STED: Seeing is understanding
Max Planck Institute for Molecular Biomedicine, Münster
21.02.2022
Host: Prof. Dr Aránzazu del Campo

MÄRZ
Dr. Caroline Murawski
Organic LEDs as neuronal interfaces
Kurt-Schwabe-Institut für Mess- und Sensortechnik Meinsberg
14.03.2022
Host: Prof. Dr. Tobias Kraus

Dr. Can Dincer
Disposable sensors for next-generation on-site testing
Universität Freiburg
22.03.2022
Host: Prof. Dr. Aránzazu del Campo

APRIL
Dr. Oskar Staufer
Bottom-up assembly of synthetic cell-based immune microenvironments
University of Oxford
20.04.2022
Host: Prof. Dr. Aránzazu del Campo

Dr. Sara Trujillo Munoz
Materials for therapeutic delivery
INM – Leibniz Institute for New Materials
21.04.2022
Host: Prof. Dr. Aránzazu del Campo

SEPTEMBER
Prof. Dr. Tanja Schilling
Universität Freiburg
Coarse-grained models out of equilibrium
12.09.2022
Host: Dr. Lola Gonzalez-Garcia

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

LSC-SEMINARE / LSC SEMINARS

MAI 2022

Dr. B. Qu,
Universität des Saarlandes
Killing mechanisms of immune killer cells
Saarbrücken, 05.05.2022

Dr. S. Lohse,
Universität des Saarlandes
The antibacterial activities of neutrophils
Saarbrücken, 19.05.2022

JUNI 2022

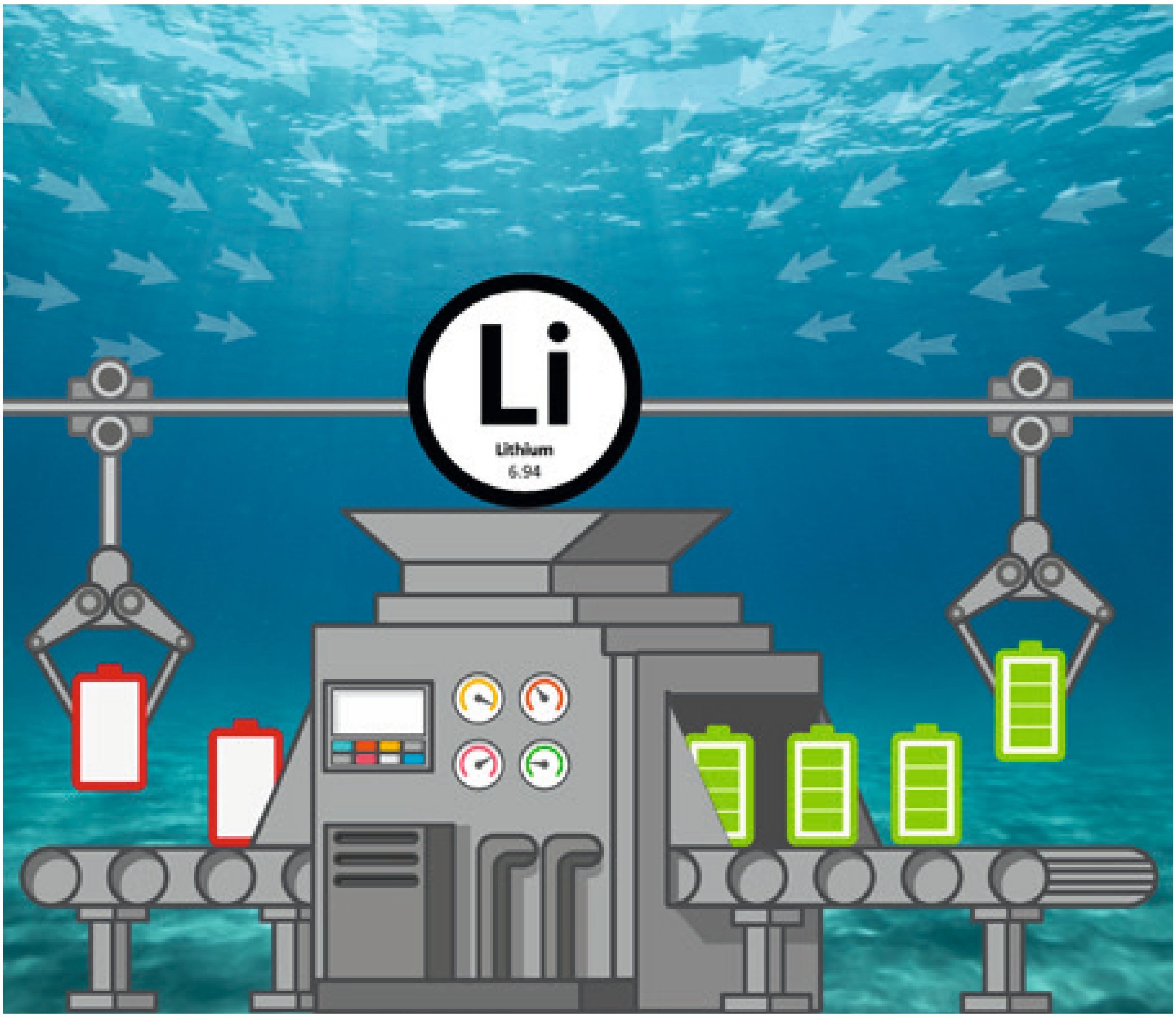
Prof. Dr. M. Laschke,
Universität des Saarlandes
In vivo analysis of implanted biomaterials
Saarbrücken, 02.06.2022

Prof. Dr. R. Bals,
Universität des Saarlandes
New therapies for diseases of the lung: Covid-19, COPD, asthma, pneumonia
Saarbrücken, 09.06.2022

JULI 2022

Prof. Dr. O. Kalinina,
Universität des Saarlandes
AI methods for predicting protein structure and drug interactions
Saarbrücken, 07.07.2022

Prof. Dr. K. Jacobs,
Universität des Saarlandes
Intermolecular and adhesive forces among bacteria and materials
Saarbrücken, 21.07.2022



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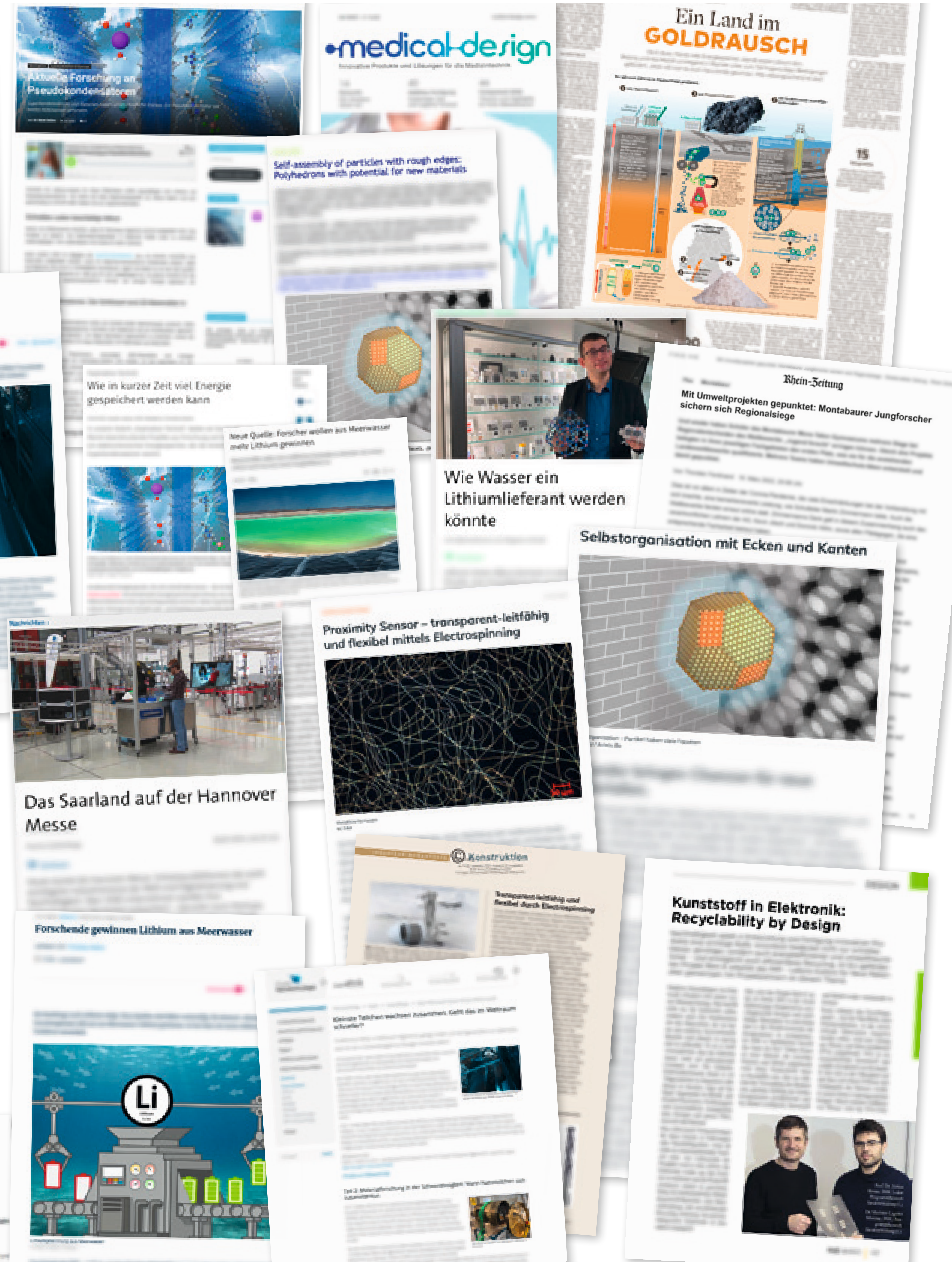

Aktuelle Forschung an Pseudokondensatoren
medical-design
Innovative Produkte und Lösungen für die Medizintechnik
Ein Land im
GOLDRAUSCH
Self-assembly of particles with rough edges: Polyhedrons with potential for new materials
Wie in kurzer Zeit viel Energie gespeichert werden kann
Neue Quelle: Forscher wollen aus Meerwasser mehr Lithium gewinnen
Wie Wasser ein Lithiumlieferant werden könnte
Rhein-Zeitung
Mit Umweltprojekten gepunktet: Montabaurer Jungforscher sichern sich Regionalsiege
Selbstorganisation mit Ecken und Kanten
Nachrichten
Das Saarland auf der Hannover Messe
Proximity Sensor – transparent-leitfähig und flexibel mittels Electrospinning
Konstruktion
Transparent-leitfähig und flexibel durch Electrospinning
Kunststoff in Elektronik: Recyclability by Design
Forschende gewinnen Lithium aus Meerwasser
Li
Kleinste Teilchen wachsen zusammen. Geht das im Weltraum schneller?

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Titelseite / *Front page*:

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

unten links / bottom left: Gecomer Probe mit einem Feld von Mikrofasern von 400 µm Durchmesser. Die taktile Wahrnehmung ist dominiert von der Biegsamkeit der Fasern. / *Gecomer sample with an array of microfibrils of 400 µm in diameter. The tactile perception of these samples is dominated by the bendability of the fibrils.*
(Programmbereich Interaktive Oberflächen, Funktionelle Mikrostrukturen / *Program Division interactive Surfaces, Functional Microstructures*)

unten rechts / bottom right: Hochauflösende konfokale Mikroskopaufnahme einer, unter mechanischer Einschränkung in einem Hydrogel gewachsenen, Bakterienkolonie. / *High resolution confocal microscopy image of a bacterial colony grown under mechanically restricted conditions inside a hydrogel.*
(JFG Bioprogrammierbare Materialien / *JRG Bioprogrammable Materials*)

SAARLAND
Großes entsteht immer im Kleinen.

INM

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