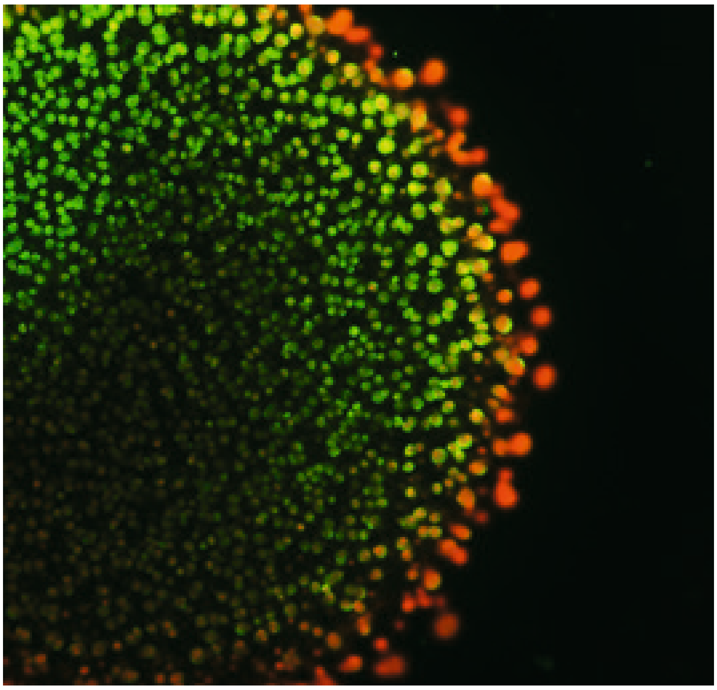
Neues Denken. Neue Materialien.



JAHRESBERICHT 2023
ANNUAL REPORT 2023

Leibniz Gemeinschaft

INM
Leibniz-Institut für Neue Materialien

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Michael Marx

Kaufmännischer Geschäftsführer/ Business Director

Prof. Dr. Aránzazu del Campo

Wissenschaftliche Geschäftsführerin und Vorsitzende der Geschäftsführung/ Scientific Director and CEO

Prof. Dr. Wilfried Weber

Wissenschaftlicher Geschäftsführer/ Scientific Director

LIEBE LESERINNEN UND LESER, WILLKOMMEN ZUM JAHRESBERICHT DES INM!

Das INM blickt auf ein erfolgreiches Jahr 2023 zurück. Wissenschaftliche Highlights wie die Entwicklung von lebenden therapeutischen Materialien, die die Bildung neuer Blutgefäße unterstützen oder Kontaktlinsen kontinuierlich feucht halten, von Materialien, die ihre physikalischen Eigenschaften selbst messen und anpassen, von selbstkorrigierenden Spiegeln für große optische Teleskope sind nur einige Beispiele aus dem breitgefächerten Forschungsportfolio des INM. Aus finanzieller Sicht hat sich die Drittmittelbilanz des INM erfreulich entwickelt. Dabei wurden auch neue Wege zur Kooperation mit Industriepartnern beschritten, die in einer neuen Technologietransferstrategie mündeten.

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

The INM looks back on a successful 2023. Scientific highlights such as the development of living therapeutic materials that support the formation of new blood vessels or keep contact lenses continuously moist, materials that measure and adjust their physical properties themselves or self-correcting mirrors for large optical telescopes are just a few examples from the INM's wide-ranging research portfolio. From a financial perspective, the INM's third-party funding balance has developed positively. New ways of cooperating with industrial partners were also explored, resulting in a new technology transfer strategy.

Personell gab es 2023 einige Veränderungen: Zum Jahresbeginn übernahm Professorin Aránzazu del Campo den Vorsitz der Geschäftsführung. Im März nahm Professor Wilfried Weber seine Arbeit als Wissenschaftlicher Geschäftsführer des INM und als Leiter der neuen Forschungsabteilung Materialorientierte Synthetische Biologie auf. Mit dem Ruhestand unseres kaufmännischen Geschäftsführers Günter Weber übernahm Michael Marx die kommissarische Leitung und wurde schließlich im Dezember zum Kaufmännischen Geschäftsführer ernannt. Auch für die Etablierung neuer Forschungsgruppen wurden 2023 wichtige Weichen gestellt und Vorarbeiten geleistet.

Bereits Mitte des Jahres begannen die Vorbereitungen zur Evaluierung des INM im Juni 2024. Im Zuge dieser Vorbereitungen erfolgte sowohl intern als auch mit den Gremien eine umfassende Entwicklung der Strategie für die nächsten sieben Jahre. Dabei konnten das wissenschaftliche Profil des Instituts geschärft, neue Zukunftsthemen identifiziert und neue Kooperationsfelder erschlossen werden. In diesem Strategieprozess wurden vier Arbeitsgruppen zu den Themen Digitalisierung, Diversität, Sichtbarkeit und Energieeinsparung ins Leben gerufen.

2023 war auch ein Jahr des Beginns neuer Großprojekte. Hierbei wäre beispielhaft das DFG-geförderte Schwerpunktprogramm (SPP) 2451 „Lebende Materialien mit adaptiven Funktionen“ zu nennen, dessen Koordination Aránzazu del Campo innehat, und das das INM mit Partnern in München, Heidelberg und Golm verbindet. Auch für den seit 2020 erfolgreich arbeitenden Leibniz ScienceCampus „Lebende Therapeutische Materialien“ wurden vor Kurzem die Mittel für eine Fortsetzung des Projektes um weitere vier Jahre bewilligt.

Auch auf der Ebene der Forschungsgruppen gab es erfolgreiche Einwerbungen von Mitteln. Hier seien exemplarisch die Förderung der Forschung von Dr. Oskar Staufer und seiner Immuno-Materialien-Gruppe aus dem Emmy-Noether-Programm und der von Wilfried Weber mitgebrachte ERC Grant STEADY genannt.

Weitere Einblicke in Neues und Spannendes aus dem INM bieten Ihnen die nachfolgenden Seiten. Wir freuen uns über Ihr Interesse.

There were some changes in staff in 2023: At the beginning of the year, Professor Aránzazu del Campo was appointed Chair of the Management Board. In March, Professor Wilfried Weber took up his position as Scientific Director of the INM and as Head of the new research department Materials Synthetic Biology. After the position of the Business Director became vacant in February 2023, Michael Marx took over as authorized representative and was finally appointed Business Director in December. Important groundwork was also laid for the establishment of new research groups.

Preparations for the evaluation of the INM in June 2024 began in the middle of the year. In the course of these preparations, a comprehensive strategy development for the next seven years took place both internally and with the committees. This enabled the Institute's scientific profile to be sharpened, new future topics to be identified and new fields of cooperation to be developed. In this process strategy, four working groups were set up on the topics of digitalization, diversity, visibility and energy saving.

2023 was also a year in which new major projects were launched. One example of this is the DFG-funded Priority Program (SPP) 2451 "Living Materials with Adaptive Functions", which is coordinated by Aránzazu del Campo and connects the INM with partners in Munich, Heidelberg and Golm. The Leibniz ScienceCampus "Living Therapeutic Materials", which has been operating successfully since 2020, was also recently granted funding to continue the project for a further four years.

Funding was also successfully acquired at the research group level. One example of this is the funding for the research of Dr. Oskar Staufer and his research group Immuno Materials from the Emmy Noether Program.

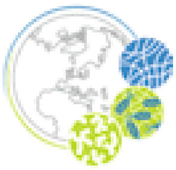
We hope that you discover a new and exciting information in this report and we would be pleased if you would continue to support us in the future.

SCIENTIFIC PROFILE OF INM – DAS WISSENSCHAFTLICHE PROFIL DES INM

INM VISION

A better world through new materials.
Eine bessere Welt dank neuer Materialien.

INM MISSION



We explore new materials from chemical and living components that overcome frontiers in functionality, performance, and sustainability.
We design our materials to drive sustainable technologies and solve societal and technological challenges in synergy with academic and industrial partners.

Wir erforschen neue Materialien aus chemischen und lebenden Komponenten, um Grenzen in Bezug auf Funktionalität, Leistungsfähigkeit und Nachhaltigkeit zu überwinden.
Wir entwickeln unsere Materialien, um nachhaltige Technologien voranzutreiben und gesellschaftliche und technologische Herausforderungen in Synergie mit akademischen und industriellen Partnern zu meistern.

INM DEPARTMENTS AND GROUPS – ABTEILUNGEN UND GRUPPEN DES INM

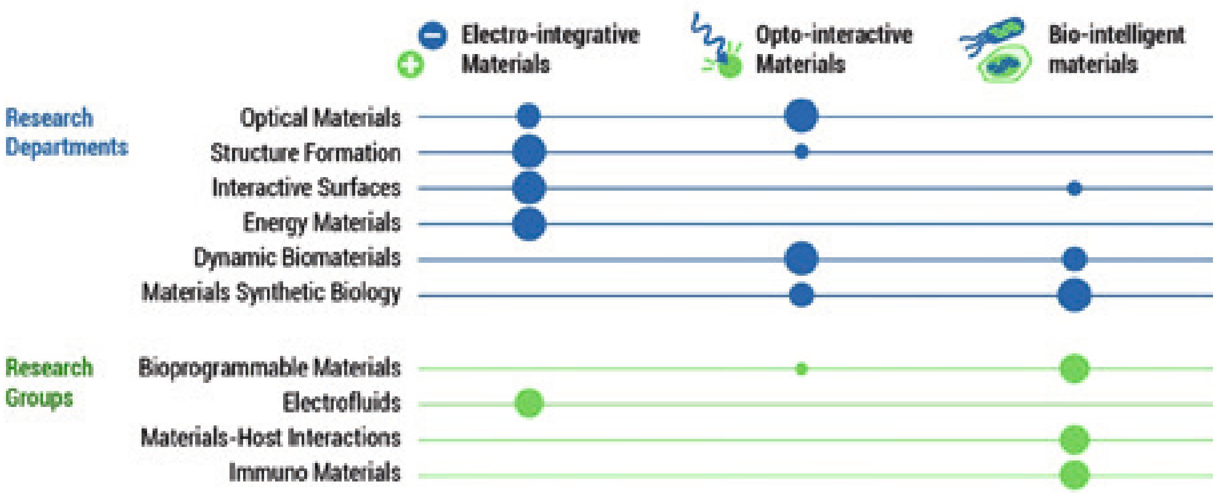
COMPETENCE AREAS OF INM – KOMPETENZFELDER

INM has identified three competence areas in which it aims for strategic leadership:

- Opto-interactive materials: We develop materials that modulate light behavior, or that are modulated upon interaction with light.
- Electro-integrative materials: We develop materials that integrate high-density ion management and stimulus-responsive conductivity.
- Bio-intelligent materials: We design materials that can instruct biological systems and program living organisms to interface materials and augment their properties.

Das INM hat drei Kompetenzbereiche identifiziert, in denen es eine strategische Führungsrolle anstrebt:

- Opto-interaktive Materialien: Wir entwickeln Materialien, die das Verhalten von Licht verändern oder die durch Interaktion mit Licht moduliert werden.
- Elektro-integrative Materialien: Wir entwickeln Materialien, die ein effizientes Ionenmanagement und eine auf Reize reagierende Leitfähigkeit integrieren.
- Bio-intelligente Werkstoffe: Wir entwickeln Materialien zur Steuerung biologischer Systeme und programmieren lebende Organismen, um mit Materialien zu interagieren und deren Eigenschaften zu erweitern.



GRUPPENBERICHTE / GROUP REPORTS

BIOPROGRAMMIERBARE MATERIALIEN / BIOPROGRAMMABLE MATERIALS

DR. SHRIKRISHNAN SANKARAN

ZUSAMMENFASSUNG

Die Forschungsgruppe *Bioprogrammierbare Materialien* nutzt die Synthetische Biologie, um genetisch programmierte Funktionalitäten in Materialien für biomedizinische Anwendungen einzubringen. Die Gruppe steht im Mittelpunkt der Biomaterialforschung des INM, die sich auf „lebende therapeutische Materialien“ konzentriert, und entwickelt Technologien zur Herstellung intelligenter und reaktionsfähiger Materialien mit gentechnisch veränderten Komponenten. Sie konzentriert sich auf zwei Hauptforschungsbereiche: (i) die Entwicklung probiotischer Bakterienstämme für die ferngesteuerte Synthese und Freisetzung von Arzneimitteln, und (ii) Untersuchungen zum Verständnis von Verhaltensänderungen von Bakterien, die in Polymermatrizen eingeschlossen sind.

MISSION

The Bioprogrammable Materials research group uses synthetic biology to introduce genetically programmed functionalities into materials for biomedical applications. The group is at the heart of INM's biomaterials research, which focuses on the development of “living therapeutic materials” and expands the toolbox for producing smart/responsive materials with genetically modified components. The group focuses on two main research areas: (i) the development of probiotic bacterial strains for remotely controlled synthesis and delivery of drugs, and (ii) studies to understand behavioural changes of bacteria encapsulated in polymer matrices.

CURRENT WORK

In 2023, we greatly progressed in programming probiotic bacteria, E. coli Nissle 1917 (Mutaflor®) and *Lactiplantibacillus plantarum* WCFS1, to produce and secrete several bioactive compounds. The *E. coli* strain was engineered to produce a novel antibiotic, Darobactin, in response to heat (coop. Prof. Rolf Mueller, HIPS), a pro-angiogenic protein and a high-value flavonoid, Pinocembrin, (coop. Dr. Vito Valiante, Leibniz HKI) in response to light. As *L. plantarum* has a poorly equipped genetic toolbox, we first expanded it by discovering super strong promoters (Fig. 1), a highly efficient repressor, and antibiotic-free plasmid retention systems (Dey et al., Microb. Biotech., 2023). We then used these tools to engineer this strain to produce Elafin for protease inhibition, and Nerve growth factor for neuronal regeneration and demonstrated their bioactivity. Many of these genetic parts are in patent applications and are being shared on request with scientific (Prof. Sarah Lebeer, Uni. Antwerp Belgium; Dr. Rachit Agarwal, IISc India; Dr. Liangliang Hao, Boston University USA; Dr. Ceren Özkul Koçak, Hacettepe University Turkey) and industry (CCBio UK) partners.

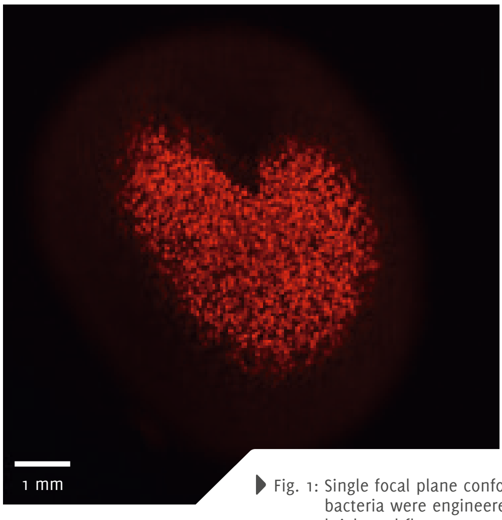
The promoter sequences are being used by Prof. Rahmi Lale (NTNU Norway/Syngens) to train their AI-based tools for identifying more high-performance promoters for *L. plantarum*. Finally, these genetic toolbox expansion strategies are being applied to enable programming of *Corynebacterium mastitidis*, a beneficial commensal of the eye surface.

The programmed bacteria are used to develop self-replenishing drug delivery devices termed Living Therapeutic Materials (LTMs). In 2023, we reported LTMs releasing the bioactive compounds pro-angiogenic protein YCQ (Dhakane et al., Adv. Funct. Mater., 2023) and the flavonoid Pinocembrin (Riedel et al., Front. Bioeng. Biotech., 2023) (Fig. 2). With the research department *Structure Formation*, infrared-activatable bacterial hydrogels containing photothermal converting nanorods were created (Basaran et al., Biomater. Adv., 2023). With the research department *Dynamic Biomaterials*, thin-film LTMs were created that ensured secure bacterial containment and which were used to develop a living lactate biosensor (coop. Karen Polizzi, Imperial College London) (Bhusari et al., Biomater. Adv., 2023). The thin-film LTMs also formed the basis for assessing immune responses *in vitro* in collaboration with Dr. Bin Qu, UkS (Yanamandra et al., Biomater Adv., 2023).

Finally, in our SFB1027 subproject, we are studying growth, metabolic and protein production behaviour of probiotic *E. coli* and *L. plantarum* in hydrogels whose mechanical properties can be tuned to mimic domains in natural biofilms. By measuring the metabolic heat released by the bacteria in confinement (coop. Rolf Mueller, HIPS) we found that mechanical restrictions in these hydrogels influence *E. coli* much more strongly than *L. plantarum*. This also correlates with growth rate and colony morphology determined by confocal microscopy. With Prof. Ludger Santen, UdS, these results are used to develop a computational simulation to gain key biophysical insights into the process.

OUTLOOK

The progress over the last year has established our ability to engineer therapeutic functions in probiotic bacteria and create functional LTMs. In the coming years, the development of LTMs will progress towards the transfer of this technology. For this, we will further demonstrate the potential of these LTMs 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 material containing them. Additionally, we will continue to study the influence of the encapsulating materials on the bacteria to improve the performance of LTMs. These studies and safety features will help guide the regulation of these devices for eventual testing in humans.



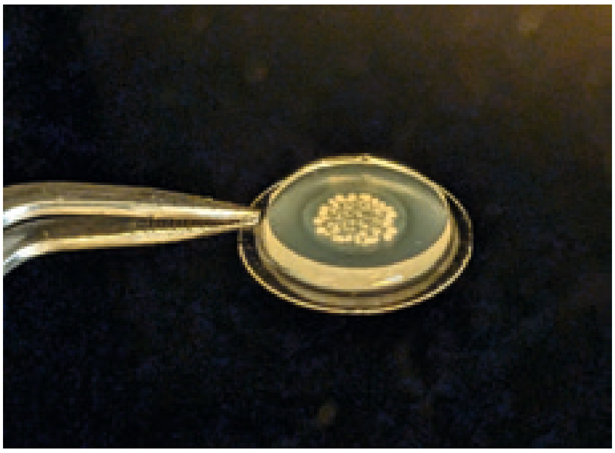


Fig. 1: Single focal plane confocal microscopy image of *L. plantarum* colonies growing in an alginate bead. The bacteria were engineered to express a fluorescent protein with our super strong promoter, resulting in bright red fluorescence.
Fig. 2: Photo of an LTM containing flavonoid-producing *E. coli* Nissle 1917 growing as colonies after secure encapsulation in a PVA-based bilayer hydrogel.

DYNAMISCHE BIOMATERIALIEN / DYNAMIC BIOMATERIALS

PROF. DR. ARÁNZAZU DEL CAMPO

ZUSAMMENFASSUNG

Die Forschungsabteilung *Dynamische Biomaterialien* entwickelt synthetische Mikroumgebungen mit programmierter Bioaktivität und Mechanik, um lebende Zellen einzukapseln und zu instruieren. Wir untersuchen, wie lebende und nicht lebende Materie auf verschiedenen Ebenen interagieren und wie diese Interaktionen genutzt werden können, um zelluläre Funktionen zu steuern und letztendlich therapeutische Vorteile zu erzielen. Die Gruppe verfügt über wichtige Kompetenzen in den Bereichen Hydrogelsynthese, Photoschalter, Biofabrikationstechnologien und Zellbiologie. Wir arbeiten eng mit synthetischen Biologen, Biophysikern, Arzneimittelentwicklern und Klinikern auf dem Saarland Campus zusammen.

MISSION

The Research Department *Dynamic Biomaterials* develops synthetic microenvironments with programmed bioactivity and mechanics to encapsulate and instruct living cells. We study how living and non-living matter interact at different levels, and how these interactions can be exploited to direct cellular functions and ultimately result in therapeutic advantages. The group has major competences in hydrogel synthesis, phototriggers, biofabrication technologies, and cell biology. We closely cooperate with synthetic biologists, biophysicists, drug developers and clinicians in the Saarland Campus.

CURRENT RESEARCH

Self-replenishable Living Therapeutic Devices for zero-waste therapeutics

We develop hydrogels and processing technologies to functionally and safely encapsulate engineered biofactories. The living hydrogels self-produce and release targeted biotherapeutics while they retain the active organism long term. These hydrogels are conceived as drug delivery implants for zero-waste pharmacology. We work on (i) the understanding of the material requirements for long term bioactivity and safety of the biofactories, and (ii) the design and processing of functional devices by automated and upscalable biofabrication methods. Our first prototype is a living drug eluting contact lens (Fig. 1) with self-lubrication properties by continuous release of hyaluronic acid (Adv Mater 2024). The idea has been patented and the group is evaluating opportunities for technology transfer. This research is part of the *Leibniz ScienceCampus Living Therapeutic Materials* (coordinator: A. del Campo).

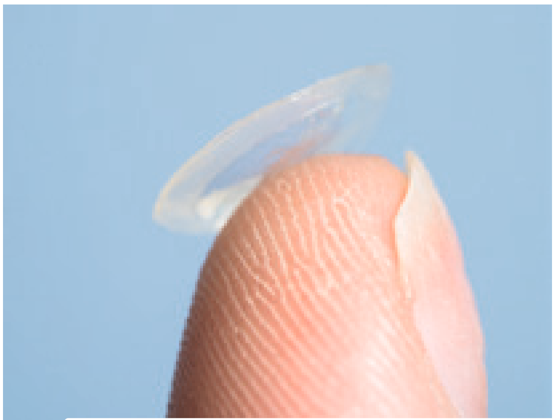


Fig. 1: Laboratory prototype of a self-lubricating contact lens containing biofactories of hyaluronic acid.

Printed hydrogel waveguides for optopharmacology

The regulation of biological processes through light-triggerable materials or optogenetically engineered organisms requires light transport inside the body and customization of the emission zone to the application site. We develop inks and multimaterial printing processes to fabricate soft hydrogel waveguides with customized side emission profiles. We use alternating inks with waveguiding or emitting segments along the printed scaffold. In this field, we cooperate with the Research Department *Optical Materials* at INM. Multiaxial designs allow us to integrate additional functions (i. e. biofactories for drug delivery) in the printed device.

Understanding how nature creates hierarchical surface patterns with distinct functions in cornified tissues

Epithelial cells develop apical protrusions to fulfill diverse functions in natural tissues, i. e. microvilli in intestinal epithelium for absorption or stereocilia in cochlear hair cells for mechanosensing in the human body. The hairy structure on the lizard's toe pad skin is another example of apical protrusions with adhesive functions. These structures have the capability to self-renew and restore function. In the last years, we have investigated the mechanism by which epithelial cells develop adhesive apical structures in lizard skin. We discovered a primary role of cytoskeletal structures (F-actin and microtubules) as templating structural elements for the development of the hierarchical surface morphology, which is stabilized by keratins and corneus beta proteins during the cornification stage (Adv Sci 2024). Our results contribute to the understanding of surface pattern regeneration in a natural tissue and may inspire future concepts to bioengineer self-renewable patterned surfaces.

OUTLOOK

The development of synthetic microenvironments for the encapsulation and control of cell growth and function remains our major topic. We will continue crossing the classical border between synthetic and bioengineering approaches in materials science. With the foundation of the Priority Programm Engineered Living Materials with Adaptive Functions by the DFG in 2024 (coordinator: A. del Campo), we will continue building and developing the scientific community in this field. The exploration of our technologies in the field of living therapeutic materials towards technology transfer and entrepreneurship will get more attention in the coming year.

ELEKTROFLUIDE / ELECTROFLUIDS

JUN.-PROF. DR. LOLA GONZÁLEZ-GARCÍA

ZUSAMMENFASSUNG

Die Forschungsgruppe *Elektrofluide* erforscht – gefördert von dem 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.

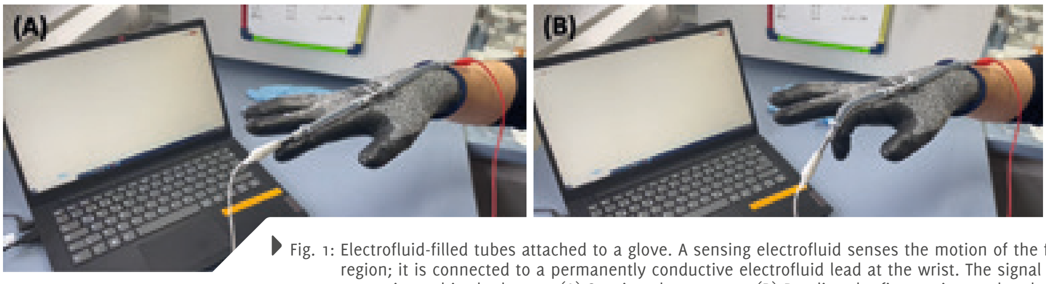
MISSION

The Research Group *Electrofluids* funded by the ERC, investigates liquid alternatives to the traditional metal and semiconductor solid materials used in electronic components and robotic actuators to enable soft devices. "Electrofluids" are suspensions of solid conductive particles that allow the electron transport while flowing as liquids and often exhibit non-Newtonian behaviour, 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 based on Carbon Nanotubes

Carbon nanotubes are broadly used in the field of conductive composites as conductive fillers due to their high aspect ratio. We prepared electrofluids with Multiwalled Carbon Nanotubes (MWCNTs). We observed two main transitions when increasing the MWCNT content: first, the sample becomes conductive, but if flows; secondthen, increasing the concentration, the electrofluid becomes rigid and the oscillatory rheology shows a gel-like behavior. This means that the electrical and the mechanical networks are formed at different percolation thresholds: 0.046 wt % MWCNT and 0.17 wt % MWCNT in glycerol, respectively.



European Research Council
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Fig. 1: Electrofluid-filled tubes attached to a glove. A sensing electrofluid senses the motion of the finger region; it is connected to a permanently conductive electrofluid lead at the wrist. The signal changes are registered in the laptop. (A) Sensing glove at rest. (B) Bending the finger triggers the electrical response.

In the framework of an internship program with the Instituto Tecnológico de Monterrey, we have studied the influence of the surface chemistry of the MWCNTs in the rheoelectrical properties of the electrofluids. We have used carboxyl-functionalized MWCNTs. Interestingly, the mechanical and the electrical percolation thresholds are, in this case, swapped respect to the non-functionalized MWCNTs. The mechanical network appears at a lower concentration of MWCNTs than the electrical network. This filler has the potential to develop electrofluids with (bio) chemical sensing capabilities.

Demonstrator of stretchable conductors and strain sensors

We created a glove that combines a strain sensor in the finger and a stretchable, stable conductor at the wrist by using two electrofluids, whose only difference is the liquid matrix (Fig. 1). The electrofluid at the finger is composed of 9 vol % Carbon Black (CB) in PDMS and serves as a sensor, i. e., the electrical signal changes significatively when the finger moves; while the one at the wrist is composed of 9 vol % CB in glycerol and it serves as a stable conductor to transport the electrical signal from the sensor. We attribute the different behavior observed for these two electrofluids to the network structure formed in the different solvents. Glycerol is polar and the CB aggregates tend to agglomerate even at relatively low concentrations, forming a strong network, while in the non-polar PDMS, CB aggregates are easier to disperse and the network formed allows for larger distortions, causing larger changes in the electrical signal.

Electrofluids based on MXenes

We started a collaboration with the research department *Energy Materials* to create electrofluids using MXenes at different delamination and exfoliation levels and understand the rheoloelectrical properties of these materials when suspended in liquid matrices. MXenes are 2D materials with interesting electrical properties that can serve as conductive filler for electrofluids. We found an unusual strain thickening behavior of the electrofluids using the precursor material (MAX) and the delaminated MXenes. In both cases, at concentrations above the percolation threshold, the storage modulus presents a peak (stronger in the case of delaminated MXenes) at high deformations, concomitantly the electrical resistance signal drops. This phenomenon was not found, however, in the electrofluids produced with exfoliated MXenes.

OUTLOOK

We will expand the *Electrofluids* portfolio by using 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.

Electrofluid reutilization and particle recovery will be addressed in the next years in order to develop more sustainable electrofluids.

Device integration of electrofluids is a challenge that we will tackle by using advanced rheology and 3D printing “on” and “in” encapsulating materials. This will allow to create complex structures that broaden the application field of electrofluids.

ENERGIE-MATERIALIEN / ENERGY MATERIALS

PROF. DR. VOLKER PRESSER

ZUSAMMENFASSUNG

Die Forschungsabteilung *Energie-Materialien* entwickelt elektrochemische Materialien für Energiespeicherung, innovative Wassertechnologien und ökologisches Recycling. Unsere Materialien transportieren und speichern Ionen sowie elektrische Ladungen effektiv über verschiedene Längenskalen. Wir fokussieren auf nanoporöse Kohlenstoffe, Oxide, Carbide und Sulfide sowie deren Hybride. Unser Workflow umfasst Materialsynthese, umfassende Materialcharakterisierung, elektrochemisches Benchmarking und In-situ-Analyse. Ein Schwerpunkt liegt auf 2D-Materialien wie MXene und MBene, die in Superkondensatoren und Natrium- und Lithium-Ionen-Batterien der übernächsten Generation eingesetzt werden können. Diese Materialien ermöglichen auch elektrochemische Entsalzung und Ionenrückgewinnung aus Wasser. Wir nutzen vielfältige Charakterisierungsmethoden für tiefgreifendes Verständnis und setzen auf digitale Techniken in der prädiktiven Materialforschung. Unsere Kooperationen reichen von internationaler Grundlagenforschung bis zu industriellen Projekten.

MISSION

The Research Department *Energy Materials* pioneers electrochemical materials for sustainable energy storage, innovative water technologies, and eco-friendly recycling solutions. We develop materials that can effectively transport and store ions and electrical charges over several length scales. Important electrode materials are nanoporous carbons, oxides, carbides, and sulphides as well as their hybrids. A key feature is our streamlined workflow from material synthesis, comprehensive structural and chemical material characterization to electrochemical benchmarking and complementary in situ analysis. A particular focus is on 2D materials, especially MXene and MBene, which enable rapid charge/discharge of supercapacitors and next-next-generation sodium- and lithium-ion batteries. The reversible uptake and controlled release of ions also enable desalination of seawater and ion separation to capture pollutants such as lead or recover valuable materials such as lithium (Fig. 1). We use various characterization methods, including in situ, for a comprehensive mechanistic understanding (Fig. 2). In addition, we are increasingly using digital methods for predictive materials research and digital twinning of battery research. Our collaborations include international basic research as well as industrial projects.

CURRENT RESEARCH

Electrochemical ion separation for desalination, ion recovery, and battery recycling

Electrochemical interfaces and materials are central to a triple application: energy storage, elemental recovery, and water remediation. Our portfolio includes a range of technologies (Torkamanzadeh et al., Cell Rep. P. Sc., 2023) to recover valuable components (Ahn et al., Ind. Eng. Chem. 2023) or remove pollutants (Wang et al., Nano Research, 2023). We use a range of materials, such as abundantly available carbon nanomaterials, low-cost metal oxides, and advanced 2D nanostructures with tailored ion selectivity. The use of ion-selective electrode materials is crucial for these processes and requires a detailed understanding and design of nanoconfinement specific to target ions. Our collaborative efforts include partnerships with esteemed colleagues from the University of Manchester, the Technion, and the Warsaw University of Technology. Our current focus specifically addresses the use of low-energy ion separation in the recycling of lithium-ion batteries to recover valuable elements, such as cobalt, nickel, and lithium in a more environmentally friendly way.

Next-next-generation batteries

Advancing battery technology towards next-next generation materials is crutial to achieve higher performance, extended longevity, better recyclability, and less dependence on critical elements. As part of the European project ALISA, we are focusing on high-performance batteries with lithium-sulfur pouch cells. In this project we are working together with Swiss, Slovenian, and German partners from industry and science. Our research also explores post-lithium technologies, with a particular focus on layered materials such as advanced metal oxides, MXene, MBene, and 2D heterostructures. For metal oxide electrode materials, we are researching continuous synthesis via the microjet reactor (UdS collaboration) and plasma-in-liquid processes (SKZ, INP; BMBF). Additionally, we are working with Czech partners (Czech Advanced Technology and Research Institute; DFG) on the development of MXene/graphene heterostructures. We are also researching carbon/metal oxide spherogels for high-performance lithium-ion batteries with Austrian colleagues (Paris Lodron Universität Salzburg, DFG) and novel lithium-ion battery anode materials together with industry.

OUTLOOK

We are advancing our research and development efforts in the field of electrochemical materials, focusing in particular on enhancing ion selectivity features for water applications. This endeavor is central in establishing a robust platform for the next generation of sensor technologies, ion separation devices, and innovative post-lithium battery systems. Our expertise in this domain is also important for the formulation of novel, sustainable methods for battery recycling. In addition, we are implementing data science to advance our research workflow and to enable predictive material science for energy materials. Furthermore, our commitment to sustainability is reflected in our ongoing efforts to integrate more environmentally responsible materials and processing techniques. This approach is central not only for the development of new electrochemical applications, but also to enhancing the environmental sustainability of these technologies.

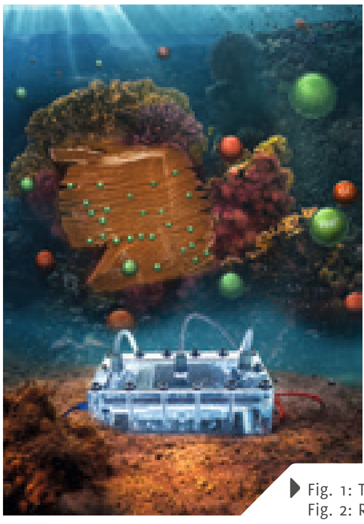


Fig. 1: Tailored electrochemical ion management for elemental harvesting and pollutant removal.
Fig. 2: Research in the energy/water nexus laboratory.

IMMUNO-MATERIALIEN / IMMUNO MATERIALS

DR. OSKAR STAUFER

ZUSAMMENFASSUNG

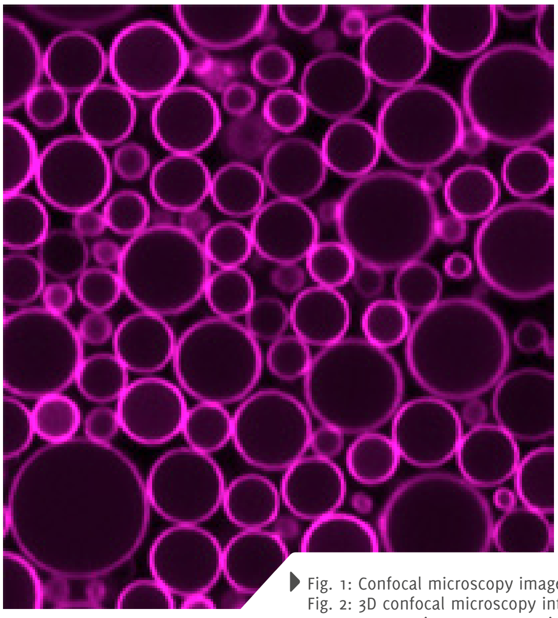
Die Forschungsgruppe *Immuno-Materialien* wurde im November 2022 am INM-Leibniz-Institut für Neue Materialien im Rahmen der pharmazeutischen Forschungsallianz Saarland gegründet und wird seit November 2023 im Rahmen des Emmy Noether Programms der Deutschen Forschungsgemeinschaft gefördert. Die Gruppe kombiniert Expertisen in der bottom-up-synthetischen Biologie und der zellulären Immunologie zur Entwicklung neuer Biomaterialien im Anwendungsbereich der Immuntherapie. Schwerpunkte sind die Entwicklung künstlicher Partikel zur gezielten Aktivierung von Immunzellen sowie die Entwicklung neuer Methoden, um physikalische und chemische Signale in der Tumormikroumgebung zu messen. Seit der Gründung konnte die Gruppe emulsionsbasierte künstliche Immunzellen entwickeln und diese hinsichtlich ihrer biophysikalischen und biochemischen Eigenschaften sowie ihres Potenzials zur Aktivierung von T-Zellen charakterisieren. Außerdem konnten erste 3D-Hybrid-Zellkultursysteme etabliert werden, um Krebs-Immuninteraktionen in Pankreastumoren zu untersuchen.

MISSION

The research group engineers emulsion-based biomimetic materials for fabrication of synthetic cell components to advance knowledge in immunology and develop new therapeutic approaches. In the lines of INM's core mission, we apply (lipids) and living (T cells) building blocks, to engineer functionalities at the interface of living and non-living matter over different length scales (molecules to tissues).

CURRENT WORK

In 2023, our research advanced significantly in creating biomimetic particles with immune properties. We successfully developed oil-in-water emulsions with micrometer-sized droplets, enabling lipid bilayer deposition on their surfaces (Fig. 1). Our team developed charge-driven deposition strategies and bio-orthogonal functionalization methods using immune-active ligands for these droplets. Collaborating with Prof. Hermann Eichler and Dr. Eva Schwarz (Saarland University (SU) Medical Center), we isolated human primary T cells and stimulated their ex vivo activation and expansion with our droplet technology. Intriguingly, we discovered that our droplets could differentiate a unique T cell phenotype, less susceptible to immune inhibition in cancer therapy. Extensive characterization revealed that these cells secrete regulatory cytokines like IL4 and IL10. Our investigations showed that the specific conjugation of stimulatory ligands on the droplets was key to expanding these promising phenotypes. This underscores the potential of carefully designed hybrid particles, combining artificial polymers and recombinant proteins, to create novel immunotherapeutic



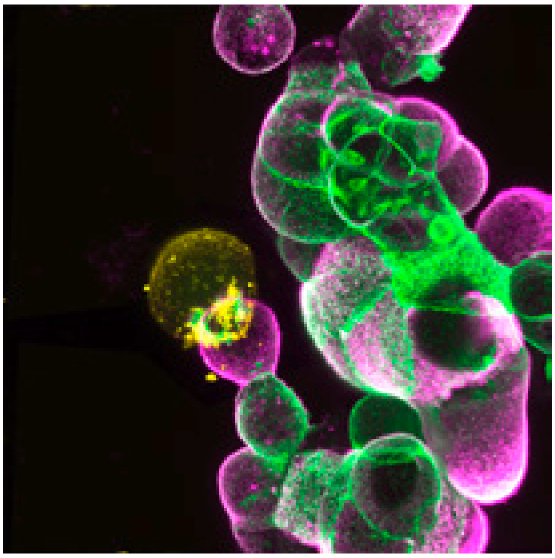


Fig. 1: Confocal microscopy image of oil-in-water emulsion-based synthetic cells
Fig. 2: 3D confocal microscopy introduction of a synthetic immune cells (yellow) making contact with a pancreatic cancer organoid stained for cellular membrane (magenta) and the actin cytoskeleton (green).

compounds. This venture, further supported in its biophysical implication by collaboration with Prof. Franziska Lautenschläger (SU) and Prof. Markus Hoth (SU Medical center), marks a substantial advancement in lipid bilayer research.

Further, we are constructing artificial tumor immune microenvironments within 3D cell culture systems (Fig. 2), in partnership with Prof. Stephen Mann from the University of Bristol and supported by the Emmy Noether Program of the German Science Foundation (DFG). This approach, also based on our droplet technology, will provide new means to understand the dynamic interplay between the immune system and cancer, particularly in three-dimensional contexts. We have successfully cultured 3D models of pancreatic and breast cancer cells, and developed protocols for integrating droplet-based synthetic cells into these cultures through self-assembly. These protocols allow us to create hybrid 3D cultures, part living and part synthetic, to systematically study cancer immune adaptation processes. Together, these projects demonstrate the dynamic, collaborative essence of our research, pushing frontiers in lipid bilayers, tumor microenvironments, and microfluidic technologies. With four additional team members joining, we are further focusing on developing synthetic cell-based sensors for 3D cancer cultures and pioneering synthetic lymph nodes as a novel vaccination technology.

OUTLOOK

Our research is evolving towards enhancing artificial cell systems for controlled stimulation and modulation of immunological environments in vitro. This approach will help us to decipher signaling mechanisms in tumor immune microenvironments and their response to immunotherapy. Additionally, we will focus on the development of artificial lymph nodes to study chemotherapy resistance based on adhesion in acute lymphatic leukemia. Through mimics of such complex biological processes in controlled settings, our goal is to unravel the intricacies of drug resistance. A major aspect of our future work includes refining artificial cell systems to serve as sensors and effectors in 3D cell cultures. This dual role is anticipated to deepen our understanding of cell interactions and behaviors in a more naturally representative three-dimensional environment. As these systems advance in sophistication, we'll increasingly apply them in functionally relevant and therapeutic studies. A prime objective is using an artificial tumor immune microenvironment for predictive analysis of bispecific antibody therapy efficacy. This method could impact on cancer therapy evaluation and refinement, leading to more precise and effective treatments. In essence, our research aims to leverage artificial cell systems for new insights into cancer therapy and drug resistance, contributing significantly to the evolution of personalized and more effective treatment methods.

INTERAKTIVE OBERFLÄCHEN / INTERACTIVE SURFACES

PROF. DR. ROLAND BENNEWITZ

ZUSAMMENFASSUNG

Die Forschungsabteilung *Interaktive Oberflächen* nutzt die Strukturierung und Funktionalisierung von Oberflächen und das Verständnis physikalisch-chemischer Mechanismen, um die mechanischen Eigenschaften von Materialien wie Reibung und Adhäsion zu bestimmen und in Anwendung zu bringen. Die Interaktionen an Oberflächen werden für 2D Materialien wie Graphen oder MoS_2, für Biomaterialien wie Hydrogele oder für mathematisch definierte Rauigkeiten auf Oberflächen aus dem 3D-Drucker untersucht. Die Projekte basieren auf unserer Expertise in der experimentellen Nanomechanik und neuartigen Experimenten im Bereich der haptischen Wahrnehmung von Materialien. Zu den wichtigsten Ergebnissen des Jahres 2023 gehört der Nachweis von dreidimensionalen kovalenten Bindungen auf dem 2D-Material Graphen bei Reibung unter sehr hohem Druck. Bei der Untersuchung der Rolle von Hautfeuchte für die Berührungswahrnehmung von Materialien wurde eine kristalline Form des Harnstoffs in der Hautoberfläche entdeckt.

MISSION

The Research Department 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 micro-structures and materials with switchable roughness. The projects draw on our expertise in experimental nanomechanics and novel tactile perception experiments. Single-molecule force spectroscopy is used in soft matter for biophysical applications.

CURRENT RESEARCH

Molecular friction mechanisms on hetero-structures of 2D materials

2D materials are considered excellent solid lubricants due to their in-plane strength and the absence of chemical interactions normal to their surface. However, we have observed a transition to a regime of higher friction above a pressure threshold. The combination of high-resolution force microscopy with atomistic modelling by our collaborators at the University of Freiburg revealed a transition from a two-dimensional (sp^2) to a three-dimensional (sp^3) configuration which leads to covalent bonding between graphene and the sliding probe tip. Essentially, we observe an intermittent transformation of graphene/SiC(0001) into diamond, which causes higher friction (Szczefanowicz *et al.*, Phys. Rev. Res. 2023). For stacks of MoS_2 layers on graphene, friction depends critically on the bending flexibility of the 2D material, leading to less adhesive friction on multiple layers with increased bending stiffness (Fig. 1, *Liu et al.*, Nanoscale 2023).

Skin physiology and tactile perception of materials

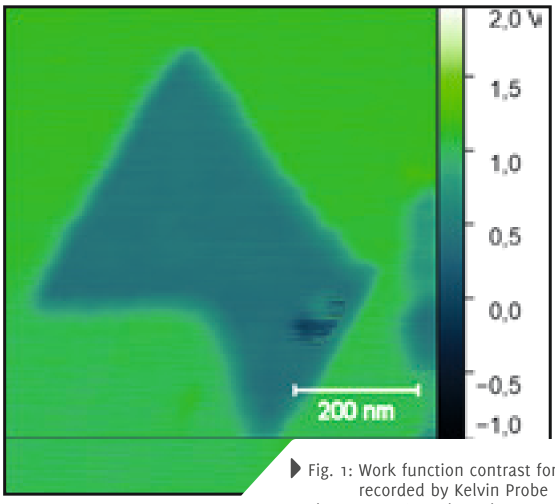
In a large collaborative project supported by the *Volkswagen Foundation*, we explore materials for the future of tactile communication. Skin physiology is prerequisite to understand the tactile perception of materials. Key parameters are the moisture of the horny layer (*stratum corneum*) covering the finger pad and the density of mechanoreceptors in the skin. In collaboration with the *Center of Cutaneous Physiology at the Charité University Hospital* in Berlin we have combined tactile perception studies with physiological characterization. Our approach of looking at skin as a material in contact mechanics led to the discovery of crystalline urea dendrimer structures in the *stratum corneum* of participants, which affect the skin moisture and thus finger pad mechanics (Fig. 2, Infante et al., Exp. Dermatology 2023). Our extensive optical microscopy survey of study participants also allowed us to present a method for quantifying the density of Meissner corpuscles, which stimulate the perception of grip and slip of materials (Infante et al., Int. J. Mole. Science 2023).

ONGOING PROJECTS

The mechanical properties of soft matter are result of fluctuations of polymers in the material's network. In our nanomechanics projects, we explore these mechanisms by force spectroscopy on individual polymer chains at the surface of soft matter. One example is the interaction of a single fluctuating DNA with pores in a membrane. Another example is the quantification of efficiency for a light-driven molecular motor in collaboration with the Research Department *Dynamic Biomaterials*. Materials for the future of tactile communication are developed in the project supported by the Volkswagen Foundation, where we investigate the influence of skin care on tactile perception. We also verify the tactile stimulus of switchable surface roughness by EEG experiments. A DFG-funded project is dedicated to the idea of a "tactile white", i. e. a surface material that gives a minimal tactile impression. Finally, we perform explorative projects on the small-scale mechanics of engineered living materials in collaboration with the *Bioprogrammable Materials* and the *Materials Synthetic Materials* groups.

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.



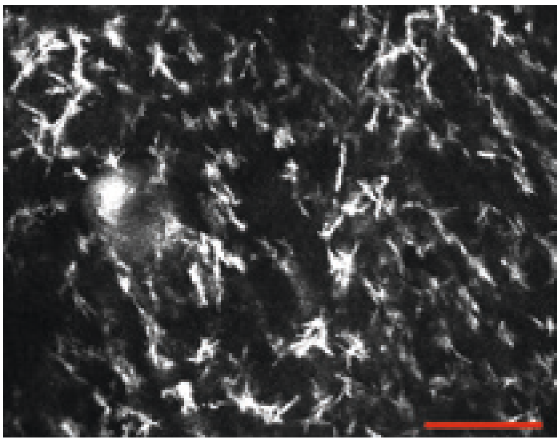


Fig. 1: Work function contrast for triangular monolayer island of MoS_2 grown on graphene/SiC(0001), recorded by Kelvin Probe Force Microscopy.
Fig. 2: Laser Scanning Microscopy of the finger pad showing urea crystallites, which affect the moisture and thus the contact mechanics of the skin (scale bar 100 μm).

MATERIALIEN-HOST INTERAKTIONEN / MATERIALS-HOST INTERACTIONS

DR. SARA TRUJILLO

ZUSAMMENFASSUNG

Die Forschungsgruppe *Materialien-Host Interaktionen* erforscht, wie sich Therapien auf der Grundlage von Biomaterialien auf Zellen und Gewebe auswirken. Sie konzentriert sich auf die Entwicklung von Gewebemodellen und Methoden, mit denen sich die Wahrscheinlichkeit der Sicherheit und Wirksamkeit dieser neuen Therapien bestimmen lässt. Wir verwenden hochdurchsatz- und automatisierbare Techniken wie Proteom-arrays und high-content-imaging, um die Reaktion des Wirts zu bewerten. Außerdem validieren wir in-vitro-Ergebnisse anhand von in-vivo-Modellen. Wir konzentrieren uns auf die Entwicklung von Hornhaut-Modellen für die Bewertung von okulären Therapien und Modellen zur Untersuchung von entzündlichen und angiogenen Prozessen. Unter den biomaterialbasierten Therapien, die wir untersuchen, arbeiten wir an lebenden therapeutischen Materialien, da diese Klasse von Materialien neue Herausforderungen und Sicherheitsrisiken mit sich bringen, die wir angehen wollen.

MISSION

The Research Group Materials-Host Interactions explores how biomaterials-based therapies affect cells and tissues. It focusses on the development of tissue models and methodologies capable of assessing and determining the likelihood of safety and efficacy of these new therapies. We use high-throughput and automatable techniques such as proteome arrays and high-content imaging to evaluate host responses. We also validate results obtained in vitro using in vivo models. We focus on the development of cornea models for the evaluation of ocular therapies and models to examine inflammatory and angiogenic processes. Among the biomaterial-based therapies we are investigating, we work on living therapeutic materials (LTMs) as this class of materials present new challenges and safety risks that we aim to tackle.

CURRENT WORK

During the first year of this group, we have made significant progress towards the development of methodologies to assess safety of Living Therapeutic Materials (LTMs). As a part of our DFG NWA project and in collaboration with the research department *Dynamic Biomaterials* we are looking at LTM stability in physiological conditions and assessing the toxicity of the by-products released by the LTMs over time using stromal and immune cells. We are comparing responses triggered by gram-negative bacteria and gram-negative genetically modified bacteria that do not produce lipopolysaccharide, one of the major pyrogenic molecules of gram-negatives.
Furthermore, we are also developing methodologies

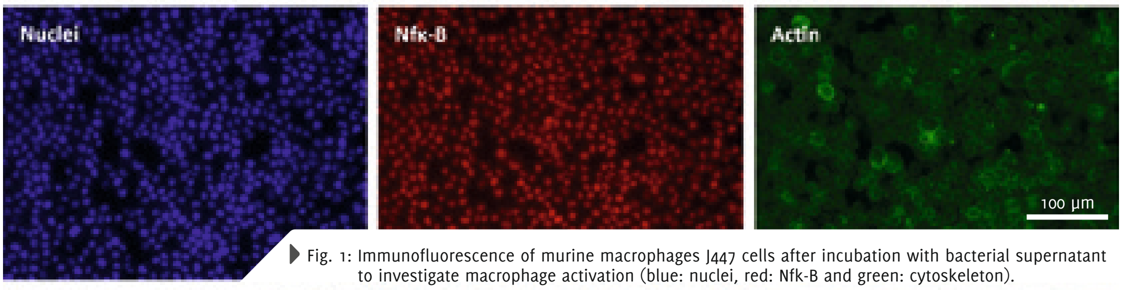


Fig. 1: Immunofluorescence of murine macrophages J447 cells after incubation with bacterial supernatant to investigate macrophage activation (blue: nuclei, red: Nfk-B and green: cytoskeleton).

for the rapid assessment of compatible conditions to culture both LTM and tissue models in vitro. This work aims to bridge the gap between the fast-growing bacteria used in LTMs and the highly demanding culture conditions of our mammalian tissue models. To do this, we have established a 96-well plate methodology in which we are able to study the viability, growth and recombinant protein production of LTMs in different cell culture media and temperatures in parallel. With this information we can select the most compatible conditions for both LTM and mammalian cells to be able to investigate their interactions in vitro.

In collaboration with the Research Group *Bioprogrammable Materials*, we are developing an in vitro assay using macrophages to study inflammation processes triggered by the use of genetically modified bacteria. This assay will help us understand how inflammation is triggered and if we can reduce it using various anti-inflammatory molecules delivered by bacteria.

Finally, we are starting to develop our first cornea model, which we aim to establish by culturing corneal stromal cells embedded in a collagen hydrogel together with corneal epithelial cells deposited on the apical side of the hydrogel and corneal endothelial cells seeded on the basal side of the hydrogel. Up to now, we are culturing our corneal fibroblasts and selecting the best collagen hydrogel conditions for encapsulation.

OUTLOOK

We are working towards the applicability of Living Therapeutic Materials by developing tissue models and in vitro assays for assessing their safety and efficacy. Our tools and methodologies are designed to assay biomaterial-based therapies or drug delivery systems in vitro with a few modifications if necessary to adapt to the biomaterial. During our first year, we have made significant progress in the development of methods to understand how Living Therapeutic Materials can co-exist in vitro with mammalian cells. We have also gained insights into their safety thresholds, and we are starting to focus on specific models such as the cornea tissue. We aim to model the three cellular layers of the human cornea, not only the most external epithelial layer that is normally used. By doing so, we will be able to study how ocular drugs interact and penetrate all the layers, being able to study not only toxicity but also absorption rate. With this model we also aim to improve permeability studies as they are normally assayed only with the epithelial layer or with cow corneas. Finally, this model can be further advanced by modelling diseases such as dry eye diseases or Fuch's dystrophy or include immune corneal resident cells to understand better how the inflammatory process in the cornea progresses into cancer therapy and drug resistance, contributing significantly to the evolution of personalized and more effective treatment methods.

MATERIALORIENTIERTE SYNTHETISCHE BIOLOGIE / MATERIALS SYNTHETIC BIOLOGY

PROF. DR. WILFRIED WEBER

ZUSAMMENFASSUNG

Die Forschungsabteilung *Materialorientierte Synthetische Biologie* fokussiert auf die Entwicklung und Anwendung von biohybriden und lebenden Materialien, die multimodale externe Signale wahrnehmen, diese Signale prozessieren und eine maßgeschneiderte strukturelle oder funktionelle Reaktion auslösen. Der Schlüssel zu diesen Eigenschaften ist die funktionelle Integration von biohybriden Schaltern und programmierten Zellen mit Polymeren oder anorganischen Oberflächen. Ein besonderer Schwerpunkt liegt auf molekularen optogenetischen Technologien zur Programmierung der Eigenschaften und Funktionen von Zellen und Materialien durch Licht. Hierbei werden quantitative mathematische Modelle eingesetzt, um geeignete Designparameter effizient zu identifizieren. Unsere Forschung fokussiert auf drei Anwendungsbereichen: (i) Stimulus-responsive und informationsverarbeitende biohybride Materialen, (ii) Technologien zur Kontrolle des Interfaces zwischen Zellen und deren Umgebung und (iii) *Engineered Living Materials*.

MISSION

In our research department *Materials Synthetic Biology* we focus on the development and application of biohybrid and living materials that sense multimodal external signals, process these signals according to fundamental computational operations and trigger a tailored structural or functional response. To these aims, we functionally integrate synthetic biology-derived biohybrid switches and cells with polymers or inorganic surfaces. We particularly focus on molecular optogenetics for programming the properties and functions of cells and materials using light. We apply quantitative mathematical models to efficiently identify suitable design parameter sets. Our research focussses on three areas of application: (i) Stimulus-responsive and information-processing biohybrid materials, (ii) Engineering the cell-material interface and, (iii), engineered living materials.

CURRENT RESEARCH

Our inspiration is the ability of organisms and the materials they are made of to adapt to dynamic environmental conditions. This adaptivity is based on the cells' ability to sense environmental information, to process and integrate this information with genetic programs and to finally produce a targeted response. In our research, we engineer nature's molecular sensing, processing, and actuation machinery to precisely control the function and properties of cells and materials. We apply these newly developed technologies in various fields of fundamental and applied research.

Stimulus-responsive and information-processing biohybrid materials

We develop and apply stimulus-responsive and information-processing biohybrid materials systems. To this aim, we functionally couple synthetic biological molecular sensors and switches to polymer materials. By wiring these switches according to topologies inspired by electronic circuits, we engineer materials that perform fundamental computational operations. To quantitatively understand the interaction of the different switches and to efficiently sample the design parameter space for optimization, we apply quantitative mathematical models. In a recent study (*Mohsenin et al., Adv. Funct. Mater.*), we describe PenTag, a biorthogonal mechanism for covalent coupling of proteins to polymers and other chemical molecules. We apply this technique to covalently label proteins, to synthesize biohybrid, stimulus-responsive hydrogels (Fig. 1) and to build a biomolecular circuit emulating the function of a binary encoder. In complementary work (*Mohsenin et al., Adv. Mater.*), we wired engineered biological switches via polymer materials to yield a binary 2-input, 4-output decoder, a fundamental motif in information processing. Such information-processing materials will be used to construct multi-input sensors with inherent analysis and information-processing capacity.

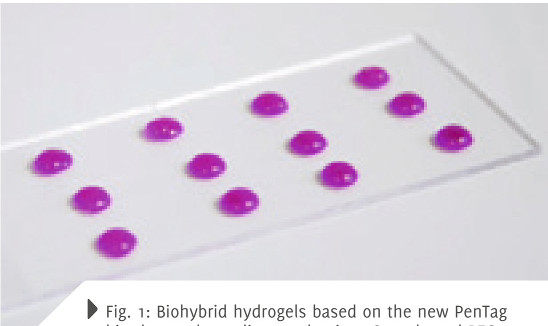


Fig. 1: Biohybrid hydrogels based on the new PenTag biorthogonal coupling mechanism. Star-shaped PEG was crosslinked by the fluorescent protein mCherry fused to the PenTag-motif on each terminus.

Engineering the cell-material interface

We are developing technologies for interfacing cells with their synthetic environment. For example, we developed a material-genetic interface which directly links the expression of a (therapeutic) transgene to the integrity of the hydrogel encapsulating the cell. To this aim, we engineered a receptor that is activated by an intact hydrogel whereas hydrogel disintegration triggered receptor deactivation (*Jerez-Longres et al., Biomater. Adv.*). Such technologies will further be developed as safety switches in living therapeutic materials.

Engineered Living Materials

In work funded by the *ERC Advanced Grant STEADY*, we engineer biomolecular sensors and actuators that change the material properties of the ELM in response to defined input signals. Based on such fundamental technologies, we develop ELMs towards application as construction materials. Within the European *LoopOfFun* consortium funded by the *European Innovation Council* (EIC), which is coordinated by our group, we contribute synthetic biology technologies for the synthesis of fungal-based materials (https://www.loop-of-fun.eu). In the *DELIVER* project funded by the *Carl-Zeiss-Foundation*, we program bacteria for the formation of 3D-structured wood-based materials. To efficiently sample the design parameter space, we apply automated synthesis and data-driven optimization of the material properties.

OUTLOOK

In our future research we will continue to work on both, fundamental and application-driven research on ELMs. Whereas the work around the ERC Advanced Grant STEADY will focus on developing fundamental design rules for ELMs and establishing gene-material correlations, we will in parallel strive towards promoting our research towards application in the context of structural and functional ELMs with application fields in construction, biosensing, or therapeutics.

OPTISCHE MATERIALIEN / OPTICAL MATERIALS

DR. PETER W. DE OLIVEIRA

ZUSAMMENFASSUNG

Optical Materials (OM) ist eine technologieorientierte Forschungsabteilung des INM. Unser Fokus liegt auf der Entwicklung, von der Grundlagenforschung bis hin zu Produkten aus Metamaterialien, Beschichtungsverfahren und Sensoren für optische und elektrooptische Anwendungen. Ein weiterer Schwerpunkt liegt in der Erforschung der Wechselwirkung von Licht und strukturierten Materialien mit angepassten physikalischen Eigenschaften. Mit dem Ziel, Impulse für neue Materialklassen zu setzen, wurde im letzten Jahr unter anderem an der Weiterentwicklung von Nano-Luftblasen-Verbundwerkstoffen, dem Up-Scaling von neuartigen elektrisch leitfähigen transparenten Bauelementen auf Basis des Elektro-spinning-Verfahrens und der Entwicklung von Bestandteilen für elektrische verformbare Spiegelelementen gearbeitet. Die geht von der Grundlagenforschung aus und strebt stets eine Validierungsorientierung in Zusammenarbeit mit Wissenschaft, Industrie und speziell KMUs an. Dabei wurde die resultierende, neue Akquisestrategie, welche Marktanalysen, proaktive Schritte zur Gewinnung neuer Kooperationspartner und veränderte Transfermechanismen umfasst, weiter präzisiert.

MISSION

The mission of the technology-oriented research department *Optical Materials* is to develop metamaterials, coating processes and sensors for optical and electro-optical applications and to research the interaction of light and structured materials with adapted physical properties from basic research to products. The aim of providing impetus for new material classes is based on inorganic, organic or inorganic-organic hybrid materials which are structured by incorporating nanoparticles, creating pores or nanobubbles or using techniques such as coating or embossing. Expertise in the modeling of optoelectronic components, the synthesis of hybrid hard or soft matrices using wet-chemical processes and the production of chemically modified nanoparticles enable the development of new materials with adapted physical properties, e.g. refractive index or conductivity. The group's expertise ranges from basic research to applied research with the aim of utilization and validation cooperation with science, industry and especially SMEs. The new acquisition strategy developed in recent years, which includes market analyses, proactive steps to gain new cooperation partners and modified transfer mechanisms, has been further sharpened.

CURRENT RESEARCH

These highlight topics were investigated in 2023:

Up-Scaling of electrospinning-set-up for transparent conductive coatings

The successful work on electrospinning of electrically conductive coatings was continued in 2023, both internally as well as a part of a ZIM project. Further activities relate the development of an ink that is suitable for an industrial process and allows subsequent copper plating to improve conductivity. Furthermore, a new, commercial electrospinning system was purchased and installed, which is integrated into a roll-to-roll coating system at the INM with a working width of 1 m (Fig. 1). As part of a ZIM project, the proof of concept of the suitability of these coatings for large-format touch-sensitive sensors for displays was achieved.

Elements for electroactive polymer actuators for new lightweight, hybrid and self-correcting mirrors – Live Mirror

In the framework of this project to demonstrate the potential for new remote sensing capabilities from the ground and from space by intelligent mirrors, one task is the contacting of electro active polymers that can sense variations and respond in real-time, and are able to hold their induced response while subject to an applied DC electric field. OM is developing novel 3-D printable inks for electrical contacts and conducting paths that will lead to cost-effective and lightweight integrated optoelectronic systems. (Fig. 2, Funded as a Horizon European Pathfinder project GAP-101099220 Live Mirror)

Light induced nano-gas-bubble formation in polymers

The porous transparent polymer materials developed in recent years were further developed in the reporting period. The aim of the work was to optimize the formation of gas bubbles in the polymer. For this purpose, mixtures of UV and thermal polymerization starters were used in a two-phase process consisting of initial UV irradiation and subsequent thermal treatment. The size of the nanobubbles could be influenced specifically by varying the thermal curing. The layer thicknesses of the materials could be adjusted in the range from a few to several hundred micrometers. The work will continue in the future; a dissertation is scheduled to begin in 2024. The aim is to produce nano-porous, highly transparent layers with a thickness of less than one micrometer and the corresponding application processes. The layers can be used as anti-reflective coatings.

OUTLOOK

Optical Materials' focus of the research and development tasks will continue to be on novel structured materials that interact with light. In addition, the inclusion of biological aspects in material development is becoming increasingly important, such as biologically driven self-organizing coatings. The project TRLs should reach level 5 or higher before being transferred to the *Innovation Center INM*. The developments represent the Group's patent strategy, which aims to use existing patent bases and expand them into market-relevant research fields through new patents. The continuation of *Optical Materials'* adjusted acquisition strategy is expected to lead to growing interest in industry-oriented cooperation projects financed by private or public funds. Optical materials will remain visible to industry and science, particularly in application areas such as display technology, energy conversion and active optics.

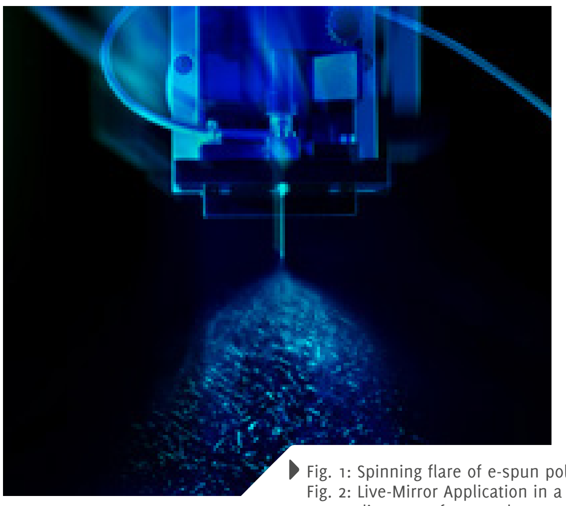


Fig. 1: Spinning flare of e-spun polymer fibers for the fabrication of electrically conductive coatings.
Fig. 2: Live-Mirror Application in a possible future telescope with an assembly of 17 mirrors with a diameter of 5 m each.

STRUKTURBILDUNG / STRUCTURE FORMATION

PROF. DR. TOBIAS KRAUS

ZUSAMMENFASSUNG

Die Forschungsabteilung *Strukturbildung* erforscht, wie sich dispergierte Partikel und Moleküle hierarchisch zu Materialien verbinden, wie die entstehenden Strukturen ihre Eigenschaften bestimmen, und wie sie sich wieder trennen. Durch Streuung, Mikroskopie, systematische chemische Variation und *in situ*-Beobachtung erforschen wir grundlegende Wechselwirkungen zwischen Komponenten. Die Eigenschaften der entstehenden Materialien prüfen wir mechanisch, elektrisch und optisch. Mit dem so gewonnenen Verständnis entwickeln wir Prozesse, um Materialien für weiche Elektronik, Robotik, Optik und Sensorik auf Längenskalen zwischen Nanometern und Millimetern nahe Raumtemperatur und an Luft gezielt zu strukturieren. Multifunktionalität, Haltbarkeit und „Recyclability by Design“ sind dabei typische Ziele. Materialien und Produkte werden so gestaltet, dass sie am Ende ihrer Lebensdauer wieder in nutzbare Bausteine zerlegt werden können. Wir modifizieren Materialstruktur und Grenzflächen, um Lebensdauern zu erhöhen, Wiederverwendung zu ermöglichen und Recycling zu erleichtern.

MISSION

The Research Department *Structure Formation* investigates how dispersed particles and molecules join hierarchically to form materials, how emerging structures affect their properties, and how they split again. Scattering, microscopy, systematic chemical variation and *in situ* observation allow us to investigate fundamental interactions between components. We test the properties of the resulting materials and use our insights to structure materials for soft electronics, robotics, optics, and sensors on length scales between nanometers and millimeters near room temperature and in air. Multifunctionality, durability and "recyclability by design" are typical goals. Materials and products are designed such that they can be split into useful building blocks at the end of their life time. We modify material structure and interfaces to increase life times, enable reuse, and simplify recycling.

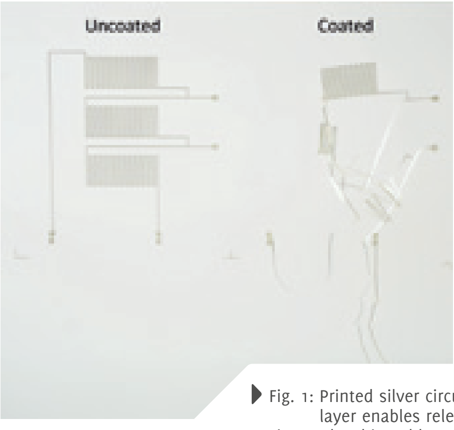
CURRENT RESEARCH

Environmental sensing with biodegradable "robots"

The group has created sensor materials that optically react to environmental parameters. In 2023, we used them for temperature-sensing "robots" in the EU-funded project "I-Seed". The group of Prof. Barbara Mazzolai at IIT in Italy 3D-printed bioinspired, seed-like objects from our materials. They fly with the wind, settle on soil, and sense surface temperature. First field tests in 2023 demonstrated good stability and strong emission. The INM group currently develops additional sensor materials that can sense mercury and other chemicals. We collaborate with *Materials Synthetic Biology* towards new sensor materials that contain living cells and specifically sense complex analytes.

Design-for-recycling of printed electronics and batteries

How can we design electronic materials such that they are easier to recycle? The group is investigating



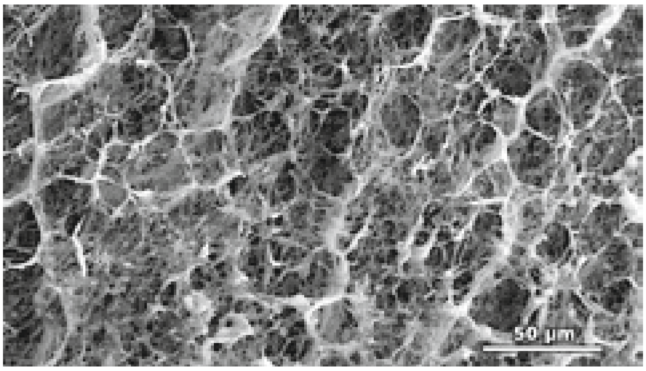


Fig. 1: Printed silver circuits without (left) and with (right) a separation layer developed in project ReIn-E. The layer enables release and recycling of the silver.
Fig. 2: Ultrathin gold nanowires assembled into networks with gel-like properties. The structure reminds of polymers but retains some properties of the metal core, for example, a dark red color.

this question for in-mold electronics in EU-project ReIn-E, for screen-printable conductive pastes in a DBU-funded project with a German SME, and for batteries in the BMBF-funded AdRecBat with Fraunhofer-ISC and the University of Erlangen-Nuremberg. In 2023, we found that polymer "separation layers" enable recycling (Figure 1) without reducing the reliability of in-mold electronics. We now extend this concept to recover silver from printed electronics.

Self-assembly from conductive composites to polymers and ionic liquids

We collaborate with colleagues around the world to create material functionality and recyclability by tuning their structure. In 2023, we worked with Dr. Debmalya Roy (DAAD visiting scholar) and DESY on the structures in conductive composites, on self-assembling polymers with Prof. Markus Gallei of Saarland University, and with colleagues from England on ionic liquids. Surprising similarities emerged: Figure 2 shows ultrathin nanowires with metal cores that we can now assemble into networks that resemble polymer gels both microscopically and in material properties.

Many economically relevant nanoparticles are quasi-spherical, apolar, and handled in solvents. In 2023, we published on their stability in solvent mixtures. Molecular simulation with Dr. Asaph Widmer-Cooper in Sydney explained why the content of polar solvents (such as hexanol) has a non-linear effect on stability, while mixtures of apolar solvents followed simple rules. Our results are relevant for collaborations with *Electrofluids*, where we use solvents to tune the structure of flowable conductive networks.

Digital materials research: batteries, microstructures, and recycling

The materials in lithium ion batteries are complex; the relations between raw materials, processing, and battery performance is a core challenge of the industry. Our strategy towards its understanding is data-based: we extended our collaboration with the BMBF-funded platform Material Digital, colleagues at TU Braunschweig, FH Aalen, companies, and *Energy Materials*. We developed a platform in the BMBF project *DigiBatMat* and developed an ontology of battery production processes to structure battery material data. Starting in 2023, we use it in project *DaMaStE* to assess on the role of carbon additives in batteries.

OUTLOOK

Our first "bio-hybrid" material, in 2023 in collaboration with *Dynamic Biomaterials* and *Bioprogrammable Materials*, combines a hydrogel with plasmonic gold nanorods and bacteria. It enables the optical activation of protein production with a laser. The nanorods act as an interface that absorbs laser light, locally increase temperature, and induce protein secretion. We will extend this approach with the Engineered Living Materials community at INM and beyond. At the same time, we will increasingly use "biofeeds" – material components formed by organisms – and study how they can be assembled into high-performance materials, with a focus on soft electronics.

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-Forschungsabteilungen und der Industrie. Insbesondere betreibt es Technologie-Scouting im INM, um in der breitgefächerten Forschung gezielt anwendungsreife Ergebnisse zu identifizieren. In diesem Zusammenhang unterstützt es die Gruppen beim Aufbau von Materialplattformen, bei der Realisierung von Demonstratoren für Messeauftritte und bei der Auffindung von Industriepartnern. Gemeinsam mit den Programmbereichen werden Strategien erarbeitet, wie der Technologiereifegrad dieser Entwicklungen auf ein Niveau angehoben werden kann. Dies dient der Initiierung, Koordination und Implementierung von direkten Industrie-Kooperationen in denen das InnovationsZentrum INM die Umsetzung von Materialentwicklungen in den Pilotmaßstab, Materialbegleitende Validierung und Optimierung von Produktionsprozessen vorantreibt. Vor dem Hintergrund eines starken Wettbewerbs am Markt und zunehmend kürzer Produktzyklen bei der Industrie soll durch die Möglichkeiten am InnovationsZentrum eine umfassende und rasche Umsetzung von Innovationen in Richtung auf den Markt realisiert werden.

Dr. Carsten Becker-Willinger

Dr. Peter W. de Oliveira

MISSION

The *Innovation Center INM* is an interface between the research departments of INM and the industry. In particular, it conducts technology scouting within INM in order to identify results from the wide range of research in the research units that are ready for application. As part of ongoing industrial cooperation, the *InnovationCenter INM* takes on the task of preparing the implementation of material developments from the laboratory to pilot scale through suitable scale up, material-related validation and optimization of production processes. Against the background of strong competition on the market and increasingly shorter product cycles in the industry, the opportunities at the *InnovationCenter INM* are intended to enable comprehensive and rapid implementation of innovations towards the market.

CURRENT RESEARCH & DEVELOPMENT

The current projects performed at *InnovationCenter INM* in cooperation with the INM program divisions comprise the optimization of the so-called Namibinder technology in the direction of sustainable alternative inorganic binders that can substitute cement in classical cement bonded wood fiber boards. The fiber boards with Namibinder have a carbon footprint improved by a factor four compared to concrete. During an industry project the new binder and the resulting composite fiber boards are optimized concerning the processing times and curing temperatures to finally allow mass production of large area boards suitable for building and construction industry. In another industry project new nanoparticulate additives based on yttrium doped

Fig. 1: Cooperation with research dept. *Energy Materials*: Flow-cell demonstrator in project "Merlin".
Fig. 2: Cooperation with research dept. *Optical Materials*: Realization of proximity sensor demonstrator.

zirconia were developed that allow to increase the electrical partial discharge stability of epoxy resin-based insulators. The improved performance of the nanocomposite materials allows to reduce the insulation layer thickness by about 50 % compared to the benchmark with only minor increase in material costs.

An industry project has been performed on the chemical up-scaling of a sol-gel based synthesis for the production of novel porous silicon carbide and silicon oxygen carbide systems that are used to fabricate new types of electrodes (anodes). The industry partner has launched a technology transfer project together with the *InnovationCenter INM*. On the other hand, an up-scaled continuous flow-cell for lithium-ion separation based on the capacitive deionization (CDI) principle developed during the "RAG-Merlin" project was realized including appropriate control technology that allows to perform production relevant extraction experiments for future acquisition of industry projects (Fig. 1).

Transparent and conductive coating based on cost saving transparent silver meshes were produced by continuous electrospinning integrated in roll-to-roll process on plastic foil using coating machine in the *InnovationCenter* in cooperation with *Optical Materials*. The metal mesh coated foil serves as the core element for e.g. touch sensors or proximity sensors in electronic devices (Fig. 2). Furthermore, a new materials basis for handling of micro-diodes basis adapted to production process and scaled-up to relevant technical size. In a third project a specific adsorption coating for heat exchangers was optimized and transferred to production. The corresponding industry partner is currently producing the coating material in a quantity of about 100 t per year.

Accompanying projects to support the technical day to day work are performed in cooperation with INM's Project Support & Technology Transfer department. In the BMBF project InnoLeit a legally sustainable transfer strategy for the INM is developed. In practical use cases several SME industry partners have been identified from previous contract research projects at INM that are currently supported to transfer the lab and technical results into their running production. In addition, the *InnovationCenter INM* is participating in a joint DFG project (Patents4Science) together with other Leibniz institutes (FIZ, INP, IWT) on the topic "Building an information infrastructure for the use of patent knowledge in science". The use case in the framework of this project for INM is set on "Battery Materials". The first phase is running until the mid of 2025.

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 sustainable building materials derived from synthetic biology. The commitment for the future is to early identify promising research results within INM's research departments and to enable the transfer into application by making use of our growing innovation-network.

SERVICEBEREICHE / SERVICE GROUPS

CHEMISCHE ANALYTIK / CHEMICAL ANALYTICS

DR. CLAUDIA FINK-STRAUBE

Die Servicegruppe *Chemische Analytik* bietet analytische Dienstleistungen für alle Programmbereiche des INM, die Universität sowie Externe an. Die analytische Begleitung und Unterstützung interner Forschungsprojekte bis hin zur Qualitätskontrolle entwickelter Materialien gelingt durch moderne Analyseverfahren der Elementanalytik (AAS, CHNOS GFAAS, ICP-OES), Chromatographie (GC, HS/SPME-GC, HPLC, GPC/MALLS) und Kopplungsverfahren mit Massenspektrometrie (GC/MS, LC-ESI HR-Q-TOF) inklusive Präparationsmethoden (diverse Aufschluss- und Extraktionsverfahren: Säure/Schmelze, Mikrowelle, Hochdruck, SPE). In regelmäßigen Praktika werden Schüler, Azubis und Studierende in die Methodik chemisch-analytischer Verfahren am INM eingeführt.

PHYSIKALISCHE ANALYTIK / PHYSICAL ANALYTICS

DR. MARCUS KOCH

Die Servicegruppe Physikalische Analytik ist für alle Mitarbeiterinnen und Mitarbeiter aus dem INM und dem universitären Umfeld Anlaufstelle bei elektronenmikroskopischen und röntgenanalytischen Fragestellungen. Die Proben können mit Hilfe eines Plunge-Freezers, einer Nanomill, eines Ultramikrotoms, eines Zweistahlgerätes (FIB) und verschiedener Sputter- bzw. Metallbeschichtungsanlagen sowie Schleif- und Einbettapparaturen in vielfältiger Weise vorbereitet werden. Als Untersuchungsmethoden stehen die Rasterelektronen- und Transmissionselektronenmikroskopie zur Verfügung, die Einblicke in Materialaufbau und -zusammensetzung von flüssigen und festen Proben bis in den Nanometerbereich ermöglichen. Wie das genau funktioniert, wird auch im Rahmen von Führungen oder Praktika gezeigt.

FLUORESZENZMIKROSKOPIE/ FLUORESCENCE MICROSCOPY

DR. CAO NGUYEN DUONG

Die Servicegruppe Fluoreszenzmikroskopie unterstützt Forscher am INM und externe Nutzer mit modernsten Bildgebungsverfahren (Widefield, Total Internal Reflection Fluorescence (TIRF), Laser Scanning Confocal, Two-Photon, Light-sheet, High-throughput Imaging, Photomanipulation und Photopatterning). Wir begleiten die Nutzer während des gesamten Prozesses der mikroskopischen Bildgebung: Planung eines Projekts, Probenvorbereitung, Auswahl und Einsatz des Mikroskops, Bildverarbeitung und Visualisierung sowie Datenmanagement. Darüber hinaus veranstalten wir einen Fluoreszenzmikroskopie-Kurs und organisieren Bildanalyse-Workshops, um den Nutzern zu helfen, sich mit den theoretischen Grundlagen vertraut zu machen und die richtige, eigenständige Nutzung komplizierter Mikroskope und mikroskopischer Anwendungen zu erlernen.

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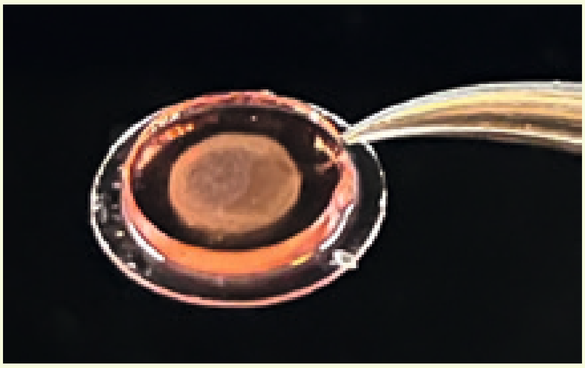
Die NTNM-Bibliothek ist die gemeinsame wissenschaftliche Bibliothek des INM-Leibniz-Institutes für Neue Materialien und der Naturwissenschaftlich-Technischen Fakultät der Universität des Saarlandes. Für Angehörige des INM bietet die Bibliothek ein breites Spektrum an elektronischen Medien. Sie organisiert für das Institut die Teilnahme an den DEAL-Verträgen mit Wiley, SpringerNature und Elsevier sowie zahlreichen weiteren Konsortialverträgen für die Nutzung elektronischer Datenbank- und Zeitschriftenpakete. Die Bibliothek unterstützt das Open Access Publizieren durch Beratung, die Bereitstellung von Publikationsinfrastruktur (INMdok, Transformationsverträge) sowie Finanzierungsmöglichkeiten (DFG-Projekt OA-Publikationskosten).

HIGHLIGHTS

LIGHT-REGULATED PRO-ANGIOGENIC ENGINEERED LIVING MATERIALS

PRIYANKA DHAKANE, VARUN SAI TADIMARRI AND SHRIKRISHNAN SANKARAN
BIOPROGRAMMABLE MATERIALS



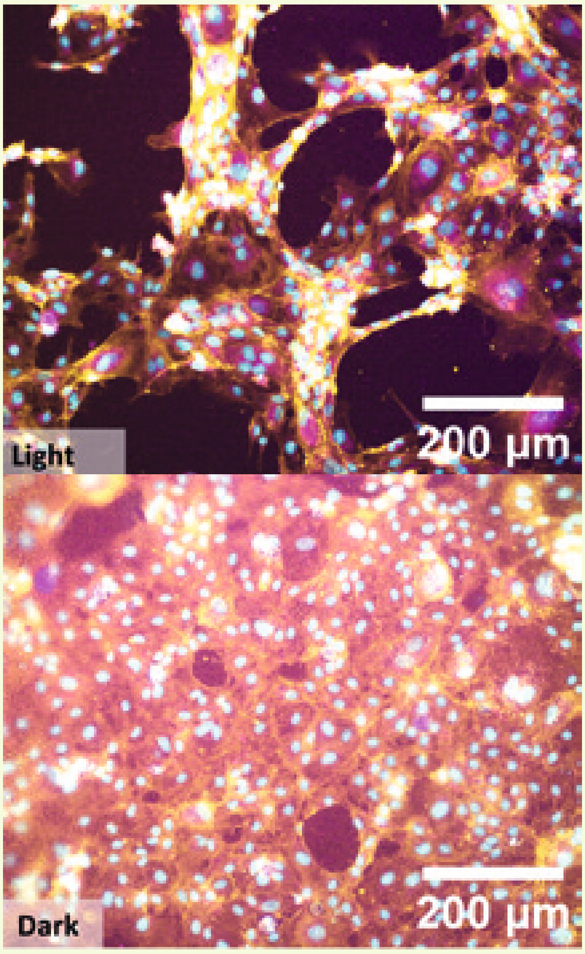


Fig. 1: Bilayer hydrogel ELM with inner bacterial layer (hazy) surrounded by protective hydrogel layer.
Fig. 2: Angiogenic network formation induced in vascular endothelial cells by light-induced growth factor production for ELMs.

The use of growth factors to drive healing of tissues is a cornerstone of regenerative medicine. On the other hand these proteins are often expensive, unstable and need to be carefully dosed to avoid serious side effects like tumor formation. Addressing these challenges, the Research Group *Bioprogrammable Materials* has developed an Engineered Living Material (ELM) capable of on-site production and delivery of a pro-angiogenic growth-factor mimetic protein in a manner that can be regulated by light. In this innovative strategy, engineered bacteria are securely encapsulated in bilayer hydrogels that support their activity and drug release but physically prevent them from escaping from this confinement. The bacteria are programmed to synthesize and secrete a vascular endothelial growth factor (VEGF)-mimetic peptide in response to light exposure. It is shown that the ELM can be switched ON in the light and OFF in the dark and that the amount of protein released can be controlled by the intensity of the light used. Furthermore, the released VEGF-mimetic protein was able to induce angiogenesis in vascular endothelial cells, proving its bioactivity.

In this ELM approach, drug delivery is achieved by packing the material with drug-producing bacterial biofactories. This ensures that the drug is freshly produced when needed, thereby overcoming long-term drug stability issues in the body. Furthermore, it circumvents the need to externally produce, purify and store the drug, and thus potentially lowering the cost of its delivery. The ability to control local dosage by light can help to limit the occurrence of unwanted side-effects. Thus, by blending materials and living cells with engineered functionalities, this study paves the way for innovative treatments that could transform the landscape of regenerative medicine.

P. Dhakane, V. S. Tadimarri, S. Sankaran, Light-Regulated Pro-Angiogenic Engineered Living Materials, Adv. Funct Mater, (2023) 33, (31), 2212695.

IRON HYDROXIDE REGENERATION AND UPCYCLING FOR HEAVY METAL EXTRACTION

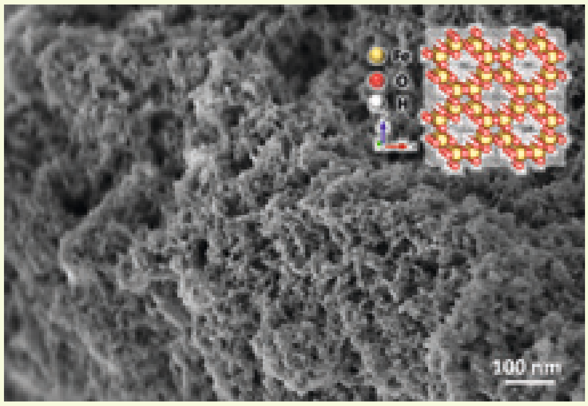
LEI WANG, LEXANE DELIGNIERE, SAMANTHA HUSMANN AND VOLKER PRESSER
ENERGY MATERIALS

Heavy metal pollution poses a significant environmental issue, necessitating effective remediation techniques. Our work demonstrates the selective extraction of heavy metals, particularly lead (Pb^{2+}), using iron hydroxide (FeOOH) as a sorbent (Fig. 1). The research explores enhancing FeOOH's adsorption capacity and its regeneration by applying external charges. Traditional adsorption methods often struggle with the synthesis and regeneration of high-performance sorbents. FeOOH, known for its environmental friendliness and low-cost production, presents a promising alternative, particularly for electrochemical ion removal (Fig. 2).

FeOOH electrodes have a chemical Pb^{2+} uptake capacity of 20 mg/g without charging. This capacity nearly doubles to 42 mg/g upon applying a voltage of -0.2/+0.8 V, with a desorption of 70-80 %. Over 35 cycles, FeOOH maintains superior selectivity towards Pb^{2+} in contrast to Co^{2+} and Ni^{2+}, with a purity of 97±3 % in the extracts. This high selectivity is attributed to the lower activation energy required for Pb^{2+} sorption. Additionally, the capacity retention rates of approximately 80 % after 5 cycles and about 50 % after 35 cycles are comparable to those achieved by chemical regeneration methods.

Importantly, we demonstrate the ability to use industrially exhausted granular iron hydroxide as the electrode material, demonstrating a Pb^{2+} uptake capacity of 37 mg/g, highlighting its practical applicability. This research shows the feasibility of continued use of FeOOH and even upcycling of spent and otherwise discarded FeOOH, contributing to exploring next-generation environmental remediation.

L. Wang, L. Deligniere, S. Husmann, R. Leiner, C. Bahr, S.J. Zhang, C. Dun, M.M. Montemore, M. Gallei, J.J. Urban, C. Kim, V. Presser, Selective Pb2+ removal and electrochemical regeneration of fresh and recycled FeOOH, Nano Res 16(7) (2023) 9352-9363.



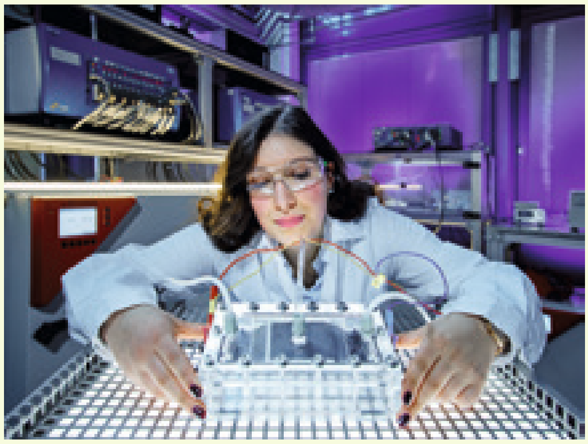


Fig. 1: Microstructure and crystal structure of iron hydroxide.
Fig. 2: Cell for electrochemical lead removal.

A BIOHYBRID MATERIALS CIRCUIT WITH BINARY DECODER FUNCTIONALITY

HASTI MOHSENIN AND WILFRIED WEBER
MATERIALS SYNTHETIC BIOLOGY

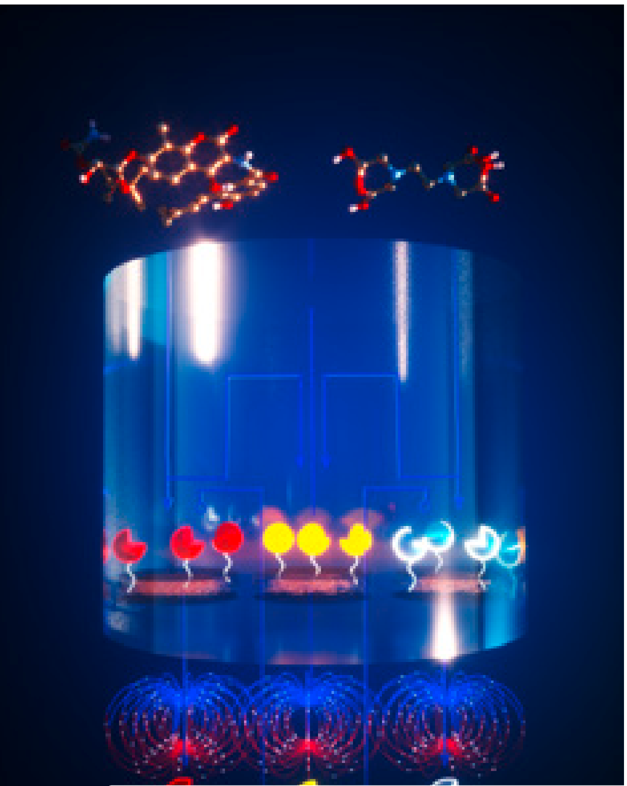


Fig. 1: Biohybrid materials that communicate with each other via diffusible inhibitory or activating signals are assembled in a circuit topology inspired by an electronical binary 2-input/4-output decoder.

In our research we aim at the development of information-processing biohybrid materials. The design of these materials relies on the functional integration of synthetic biology-based sensors and actuators with polymer materials to modules performing fundamental computational operations. By connecting the individual modules according to topologies inspired from electrical engineering, we assemble circuits of biohybrid materials that perform information-processing operations.

In this study, we developed a binary 2-input/4-output biomolecular decoder by the connection of individual material modules the activity of which could either be activated or repressed by small molecules or proteases. In order to assemble the individual modules and to optimize the performance of the overall circuit, we followed iterative design-build-test-learn cycles. Within the cycles, we applied ordinary differential equation-based mathematical models to quantitatively analyze the performance of each individual component as well of the whole system assembly. By sampling the design parameter space in silico, we identified operational setpoints yielding a functional overall circuit design as demonstrated by subsequent experimental validation.

The individual components of this system can modularly be exchanged and combined to yield different circuit topologies similar to the assembly of electronical circuits based on standardized individual building blocks such as transistors or resistors. For example, the modules in our circuit can be exchanged to respond to different input (drugs, toxins, biomarkers). Such modularity and the integrated information-processing capability will further be advanced towards developing intelligent sensor systems that sense multimodal input parameters and compute a meaningful response by interpreting the different input signals.

H. Mohsenin, H. J. Wagner, M. Rosenblatt, S. Kemmer, F. Drepper, P. Huesgen, J. Timmer, W. Weber. *Adv. Mater.* *2024*, e2308092.

SENSOR MATERIALS FOR FLUORESCENT ARTIFICIAL SEEDS FOR ENVIRONMENTAL SENSING

ALBENC NEXHA, THOMAS KISTER AND TOBIAS KRAUS
STRUCTURE FORMATION

Monitoring environmental parameters is required for the remediation of contaminated land, and to address challenges of climate change.[1] Current sensors are based on electronics that are costly, bulky and generate "e-waste".

In the project *i-Seed* (https://iseedproject.eu/) we develop new sensor technologies for wireless environmental monitoring inspired by nature. The partners have developed self-deployable, degradable artificial seeds inspired from plants which fly with the wind. The seeds contain fluorescent materials in a degradable polymer. These "sensor materials" developed at INM lend them two functionalities: the seeds respond to near infrared (NIR) excitations with strong emissions that enables finding them, and a sensor response that can be read out from a small distance to measure environmental parameters.

We prepared functional biocompatible, 3D-printed artificial seeds (Fig. 1 (A)) together with Istituto Italiano di Tecnologia (IIT). They were inspired by samara seeds (*i. e. Acer campestre*) and can measure temperatures with a resolution of 1 K.[2] The seeds are made from printable composites where polylactic acid or cellulose were filled with non-toxic rare-earth doped, upconverting particles. The particles absorb light at 980 nm due to the sensitizer Yb^{3+} and convert it into bright green emissions due to the activator Er^{3+}. Multiple emissions can be produced to enable ratiometric readout from the sensors (Fig. 1 (B)).

A drone equipped with wireless controller released the seeds.[2] Seeds were distributed in an area that is a function of height and wind. The drones uses fLiDAR (fluorescence Light Detection and Ranging) to read out the emissions of the particles from up to 4 meters. Our current seeds measure the temperature of topsoil.[2] We currently extend them to measure other parameters such as mercury concentration and humidity.

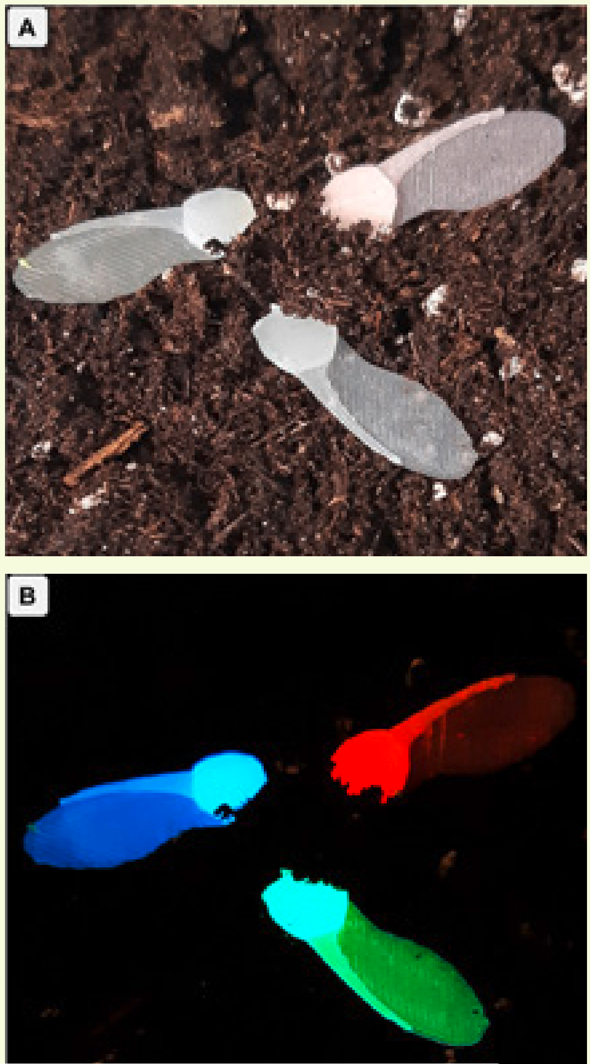


Fig.: i-Seeds that respond to temperature in (A) daylight and (B) the dark, as exited with NIR.

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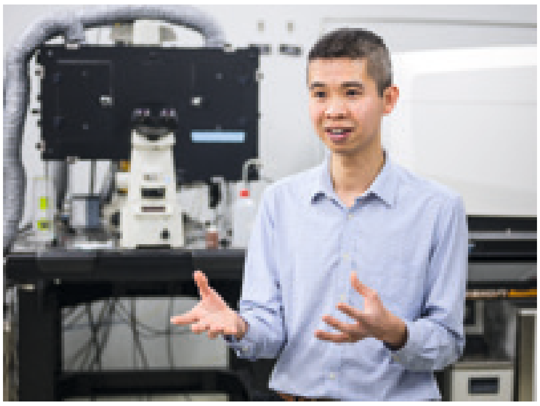
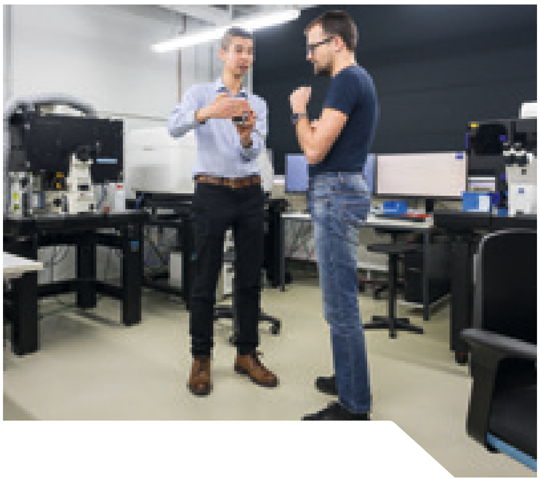
1 "Framework for sustainable wireless sensor network based environmental monitoring" in Sustainability 2022, 14, 8356, by Ridha Ouni and Kashif Saleem
2 "A printed luminescent flier inspired by plant seeds for eco-friendly physical sensing" in Science Advances 2023, 9, 46, eadi8492, by Kliton Cikalleshi, Albenc Nexha, Thomas Kister, Marilena Ronzan, Alessio Mondini, Stefano Mariani, Tobias Kraus, Barbara Mazzolai.

FOCUS ON NEW PEOPLE: CAO NGUYEN DUONG

Cao Nguyen Duong completed his studies at the University of Münster and earned a PhD in Biology from the Max Planck Institute for Molecular Biomedicine in 2020, specializing in Spectral Imaging. Subsequently, he conducted postdoctoral research with a focus on STED Super-Resolution Microscopy. Since 2023, he has been leading the Service Group *Fluorescence Microscopy* at INM.





HOW DOES THE SERVICE GROUP *FLUORESCENCE MICROSCOPY* HELP THE INM RESEARCH COMMUNITY ADVANCE THEIR RESEARCH?

The Service Group *Fluorescence Microscopy* facilitates research advancement by offering comprehensive support throughout imaging projects. From project consultation to hands-on training, image processing, and data storage, we provide end-to-end assistance. Our cutting-edge facilities feature exclusive technologies such as photomanipulation, wide-field, TIRF, confocal, multiphoton, and light sheet microscopes, enabling high-resolution imaging of dynamic processes. We also actively share our expertise through annual lectures and workshops, promoting collaboration within the research community.

WHAT TASKS DO YOU UNDERTAKE WITHIN THE SERVICE GROUP *FLUORESCENCE MICROSCOPY*, AND WHICH ASPECT OF YOUR ROLE BRINGS YOU THE MOST SATISFACTION?

As the manager of the service group, I stay updated on the latest microscopy advancements through conferences, webinars, and demos. I provide consultation to microscopy users, conduct training sessions, troubleshoot instrumentation issues, and organize imaging seminars and workshops. I am also involved in challenging imaging projects and contribute to writing method descriptions for publications.

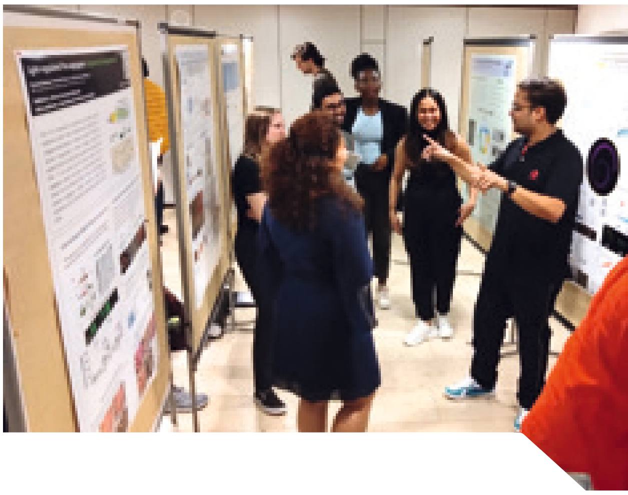
One of the most rewarding aspects of my role is the chance to educate and train enthusiastic microscopy users. This opportunity enables me to advocate for improving rigor, transparency, and reproducibility in research.

WHAT IS THE NEXT FOCUS OF THE SERVICE GROUP *FLUORESCENCE MICROSCOPY*?

Looking ahead, we are poised to tackle new challenges with enthusiasm within INM and the broader community. Efforts are underway to enhance our data infrastructure for handling large datasets of high-throughput imaging more efficiently. Additionally, we are in the process of implementing new AI features and software for image analysis, which could significantly broaden our ability to analyze complex datasets effectively.

LSC LIFEMAT SUMMER SCHOOL 2023

SHRIKRISHNAN SANKARAN AND ARANZAZU DEL CAMPO
LEIBNIZ SCIENCE CAMPUS LIVING THERAPEUTIC MATERIALS



The field of Living Therapeutic Materials (LTMs) combines synthetic biology, materials science and medicine to develop self-regulated and self-replenishing drug delivery systems for long-term and personalized administration of biopharmaceuticals. To expose early career scientists working in this field to global perspectives and advances, the Leibniz Science Campus LifeMat organized a Summer School in July 2023, covering the following four topics – (i) Programming the living, (ii) Microbe-material interactions, (iii) Therapeutic application scenarios and (iv) Biosafety. The program included inspiring lectures by global leaders in synthetic biology (e. g., Prof. Tae Seok Moon, Univ. Washington), materials science (e. g., Prof. Karine Glinel, UC Louvain) and innovative startups (ZBiotics USA, CCBio UK) who are pioneering different facets of the field. The participants freely interacted with these experts in the lunch and dinner sessions and shared their own achievements in highly interactive poster sessions.

While the Summer School was for the students of the LSC, a limited number of seats were opened to external students from around the world working on this topic. This helped bolster the connections between the LSC and the global community, even leading to new active collaborations. The program culminated in an enthusiastic session of LTM pitches, for which the participants were organized in random teams the previous day and developed novel LTM strategies for adressing chronic diseases. The teams prepared and presented 5-min pitches on LTMs they would develop to treat one of the diseases to a jury of selected scientific and industry-based speakers. This session and the interactive feedback from it acted to drive home the vital concepts and experiences the participants had learnt through the course.

SYNTHETIC CELLS: A MATERIAL SCIENCE APPROACH TO CANCER RESEARCH

OSKAR STAUFER
IMMUNO MATERIALS

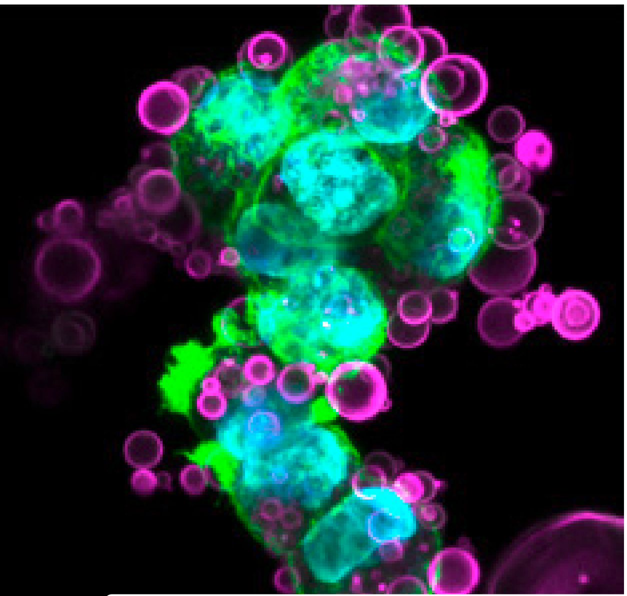


Fig.: Microscopy image of a 3D pancreatic cancer cell culture (green and cyan) surrounded by synthetic immune cells (magenta).

Cancer cells can deceive the immune system by altering their biochemical makeup and physical properties, such as adhesiveness and tissue stiffness. However, existing research methods fall short of simultaneously examining these changes to fully grasp cancer cells' adaptation strategies. The Immuno Materials Group leads a groundbreaking research project aimed at uncovering the elusive tactics cancer cells employ to evade the immune system's defenses. This six-year initiative, funded with € 2.4 million from the Emmy Noether program by the German Research Foundation (DFG), seeks to deepen our understanding of cancer cell behavior. Our work stands at the crossroads of immunology and materials science, aiming to revolutionize the understanding of cancer cell behavior.The project addresses this gap by developing synthetic 'fake immune cells' and integrating them into 3D tumoroids. This innovative approach allows for the distinct analysis of biochemical and mechanical stimuli within the tumor microenvironment, paving the way for a deeper understanding of cancer's complexities.

We benefit from collaboration with the Pharmaceutical Research Alliance Saarland, which includes the Helmholtz Institute for Pharmaceutical Research Saarland (HIPS) and Saarland University (UdS). Their combined expertise in therapeutic research and biophysics significantly enhances the project's capacity to explore the interplay between cancer cells and their surroundings.

Our research highlights INM's commitment to address societal challenges through interdisciplinary research. The integration of immunology with materials science not only enriches the INM's diverse research portfolio but also aligns with its mission to develop innovative solutions to health-related issues, marking a significant step forward in the fight against cancer.

SPP 2451 ENGINEERED LIVING MATERIALS WITH ADAPTIVE FUNCTIONS

ARANZAZU DEL CAMPO
DYNAMIC BIOMATERIALS

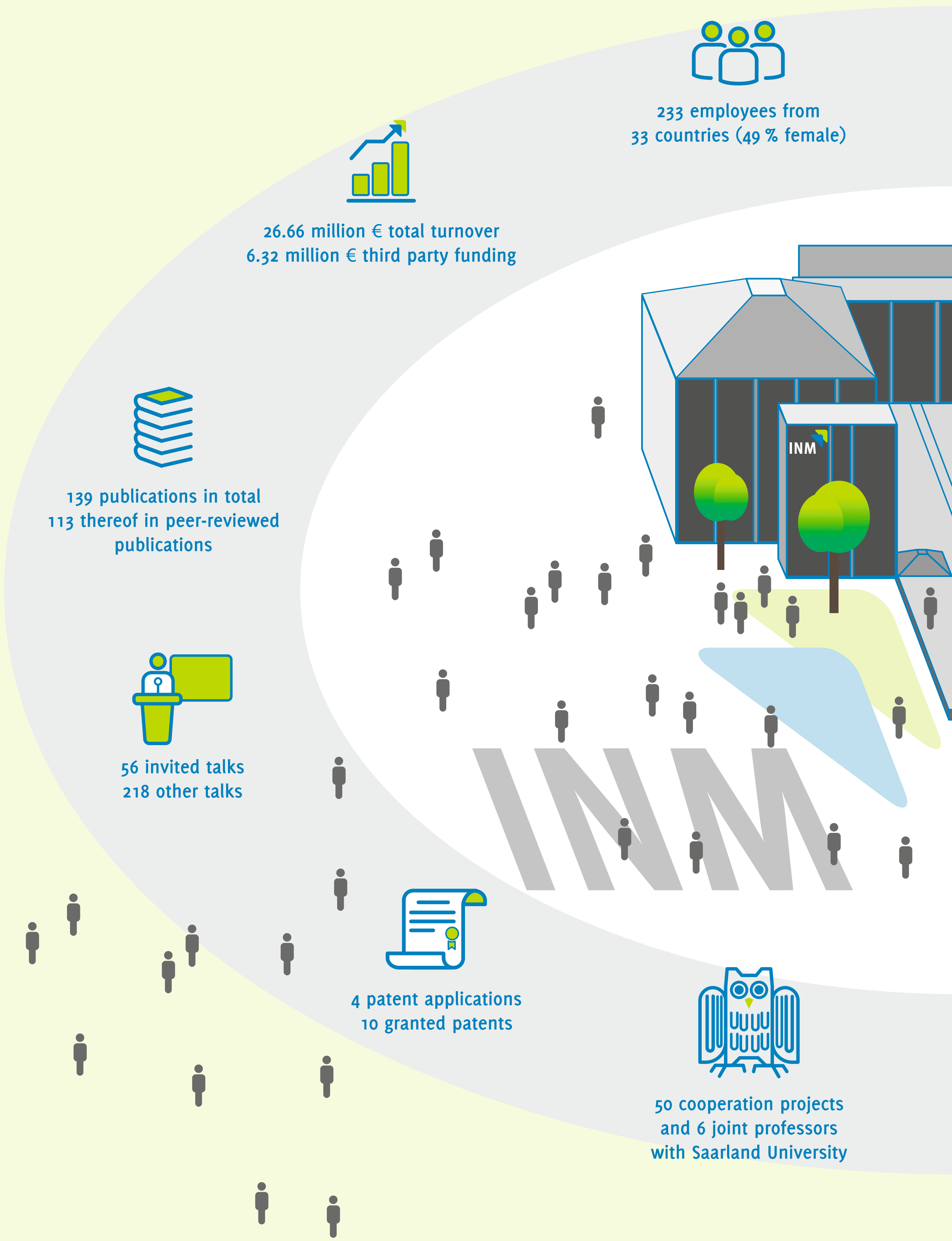
Fig. 1: Preparation workshop for SPP 2451: View into the audience.
Fig. 2: View to the stage

In March 2023, the Senate of the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) established the Priority Programme *Engineered Living Materials with Adaptive Functions* (SPP 2451). The programme will run for six years and is leaded by Prof. Aranzazu del Campo (coordinator). Prof. Wilfried Weber is a member of the Programm Committee, together with Prof. Peter Fratzl (MPI Colloids, Golm), Prof. Christine Selhuber-Unkel (University Heidelberg), and Prof. Cord Zollfrank (Technical University Munich in Straubing).

Natural living materials grow following information stored in their genetic code. They also undergo continuous and autonomous re-modelling in response to external factors and adapt their performance to new solicitations. Such properties are desirable in many technical materials, but they are extremely difficult to realize with non-living matter. In the SPP Engineered Living Materials with Adaptive Functions, new materials with programmable and adaptive capabilities will be realized by combining living organisms with materials in a synergistic way. Materials with advanced property combinations like responsiveness to multiple factors, resilience or evolvability are envisioned.

To unfold the potential of the synergistic engineering of non-living and living components, researchers in materials science and in biology/bioengineering need to work together. These communities met in Saarland Campus in July 2023 to develop ideas within the SPP2451 towards solving fundamental scientific questions in the Engineered Living Materials field: How can materials be designed to allow sustained cellular survival and function? How can synthetic biology tools be interfaced with materials? How can processing technologies be made compatible with living cells? Which parameters and methods are required to characterize the dynamic behavior of ELMs? What are the requirements for the standardized scale-up of ELM production? What are the potential risks and mitigation strategies for responsible application of ELMs in the future?

In January 2024, the SPP applicants defended their proposals in front of an international committee set by the DFG in an evaluation session in the Saarland Campus. 15 projects with at least two collaborating partners were recommended for funding. The first meeting of the SPP community will take place at INM in September 2024.

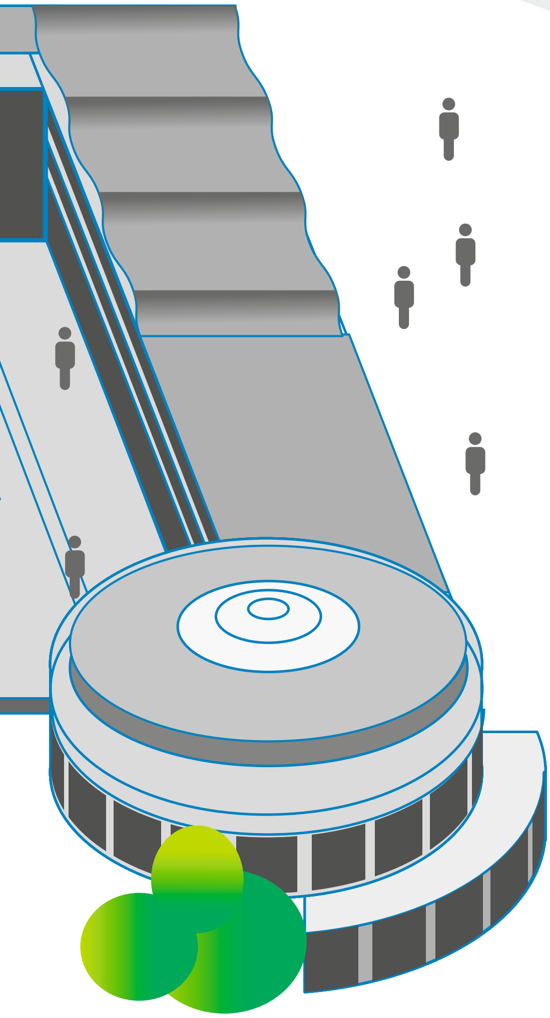

233 employees from
33 countries (49 % female)
26.66 million € total turnover
6.32 million € third party funding
139 publications in total
113 thereof in peer-reviewed
publications
56 invited talks
218 other talks
INM
4 patent applications
10 granted patents
50 cooperation projects
and 6 joint professors
with Saarland University

FAKTEN UND ZAHLEN 2023 / FACTS AND FIGURES 2023

125 scientists (45 % female)
thereof: 57 doctoral students (49 % female)

9 doctoral theses
11 master theses
2 bachelor theses

Teaching 42.8 weekly hours per year



27 events

Cooperations with 56 institutions in Germany

International cooperations with 53 institutions from 21 countries

as of 28.03.2024

AUSGEWÄHLTE PUBLIKATIONEN / SELECTED PUBLICATIONS

F. Riedel, M. Puertas Bartolomé, L. L. Teruel Enrico, C. Fink-Straube, N. C. Dong, F. Gherlone, Y. Huang, V. Valiante, A. del Campo and S. Sankaran

Engineered living materials for the conversion of a low-cost foodgrade precursor to a high-value flavonoid

Frontiers in Bioengineering and Biotechnology, 2023, 11, doi:10.3389/fbioe.2023.1278062

E. Pameté, L. Köps, F. A. Kreth, S. Pohlmann, A. Varzi, T. Brousse, A. Balducci and V. Presser

The Many Deaths of Supercapacitors: Degradation, Aging, and Performance Fading

Advanced Energy Materials, 2023, 13, (29), 2301008 doi:10.1002/aenm.202301008

A. K. Yanamandra, S. Bhusari, A. del Campo, S. Sankaran and B. Qu

In vitro evaluation of immune responses to bacterial hydrogels for the development of living therapeutic materials

Biomaterials Advances, 2023, 153, 213554 doi:10.1016/j.bioadv.2023.213554

P. Dhakane, V. S. Tadimarri and S. Sankaran

Light-Regulated Pro-Angiogenic Engineered Living Materials

Advanced Functional Materials, 2023, 33, (31), 2212695 doi:10.1002/adfm.202212695

Z. Liu, B. Szczefanowicz, J. M. J. Lopes, Z. Gan, A. George, A. Turchanin and R. Bennewitz

Nanoscale friction on MoS_2/graphene heterostructures

Nanoscale, 2023, 15, (12), 5809-5814 doi:10.1039/D3NR00138E

K. Cikalleshi, A. Nexha, T. Kister, M. Ronzan, A. Mondini, S. Mariani, T. Kraus and B. Mazzolai
A printed luminescent flier inspired by plant seeds for eco-friendly physical sensing
Science Advances, 2023, 9, (46), 14, doi:10.1126/sciadv.adi8492

C. Jerez-Logres, M. Gómez-Matos, J. Becker, M. Hörner, F.-G. Wieland, J. Timmer and W. Weber
Engineering a material-genetic interface as safety switch for embedded therapeutic cells
Biomaterials Advances, 2023, 150, 213422
doi:10.1016/j.bioadv.2023.213422

K. Cortacero, B. McKenzie, S. Müller, R. Khazen, F. Lafouresse, G. Corsaut, N. Van Acker, F.-X. Frenois, L. Lamant, N. Meyer, B. Vergier, D. G. Wilson, H. Luga, O. Staufer, M. L. Dustin, S. Valitutti and S. Cussat-Blanc
Evolutionary design of explainable algorithms for biomedical image segmentation
Nature communications, 2023, 14, 7112
doi:10.1038/s41467-023-42664-x

J. Drzic, A. Escudero, L. González-Garcia and T. Kraus
Sacrificial ligand route to hybrid polythiophene-silver nanoparticles for sinter-free conductive inks
Inorganic chemistry frontiers, 2023, 10, (5), 1552-1560
doi:10.1039/D2QI02722D

P. Ren, M. Torkamanzadeh, X. Zhang, M. Twardoch, C. Kim and V. Presser
*Conductive carbon additives:
Friend or foe of capacitive deionization with activated carbon?*
Carbon, 2023, 2013, 118191
doi:10.1016/j.carbon.2023.118191

M. Hörner, J. Becker, R. Bohnert, M. Banos, C. Jerez-Longres, V. Mühlhäuser, D. Härrer, T. Wang Wong, M. Meier and W. Weber
A Photoreceptor-Based Hydrogel with Red Light-Responsive Reversible Sol-Gel Transition as Transient Cellular Matrix
Advanced Materials Technologies, 2023, 8, (16), 2300195
doi:10.1002/admt.202300195

DAS INM IN ZAHLEN / INM IN FIGURES

Stand / As of: 11.03.2024

DAS INM IN ZAHLEN

Im Jahr 2023 betrug der **Gesamtumsatz** des INM 26,66 Mio. Euro.

Erlöse aus der gemeinsamen Finanzierung durch den Bund und die Länder (**institutionelle Förderung**): 20,21 Mio. €,

- davon Personal- und Sachaufwendungen: 15,03 Mio. €,
- und für Investitionen: 5,18 Mio. €

Erlöse aus Drittmittelvorhaben: 6,32 Mio. €

- davon 4,20 Mio. € aus Förderungen für die Grundlagenforschung und anwendungsbezogene Forschung
- und 2,12 Mio. € aus Förderungen mit Industriekooperationen.

Sonstige betriebliche Erträge: 0,14 Mio. €

Das INM hatte Ende 2023 **233 Beschäftigte** (119 m, 114 w), davon

- 68 Wissenschaftler/innen (40 m, 28 w),
- 57 Promovierende (29 m, 28 w),
- 48 Beschäftigte (25 m, 23 w) in den Bereichen Labor, Technik und Service,
- 31 Beschäftigte (10 m, 21 w) in der Verwaltung und den Sekretariaten,
- 21 Hiwis (10 m, 11 w) und 8 Auszubildende (5 m, 3 w).

INM IN FIGURES

In 2023, the **total turnover** of INM added up to 26.66 million euro.

Proceeds from the **joint financial support** by the federal government and the federal states (institutional funding): 20.21 million €,

- including expenses for personnel and materials: 15.03 million €,
- and for investments: 5.18 million €.

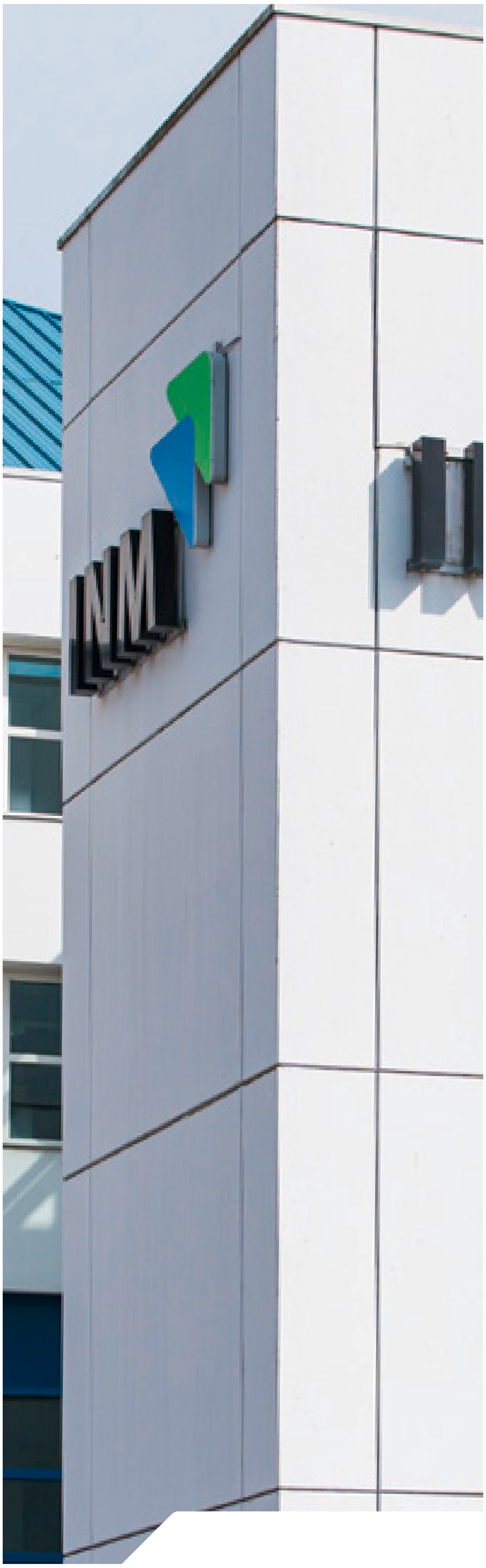
Proceeds from **third party funding:** 6.32 million €

- including 4.20 million € from funding for basic and applied research
- and 2.12 million € from funding within the framework of industrial cooperations.

Other operating income: 0.14 million €

At the end of 2023, **233 employees** (119 m, 114 f) worked at INM including:

- 68 scientists (40 m, 28 f),
- 57 doctoral researchers (29 m, 28 f),
- 48 employees (25 m, 23 f) in laboratories and technical services,
- 31 employees (10 m, 21 f) in administration and secretarial offices,
- 21 graduate assistants (10 m, 11 f) and 8 apprentices (5 m, 3 f).



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

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

Stand / As of: 31.12.2023

MITGLIEDER DES KURATORIUMS / MEMBERS OF THE BOARD OF TRUSTEES

MITGLIEDER DES WISSENSCHAFTLICHEN BEIRATS / MEMBERS OF THE SCIENTIFIC ADVISORY BOARD

DISSERTATIONEN / DOCTORAL THESES

DISSERTATIONEN / DOCTORAL THESES

Stefanie Arnold
Next generation (hybrid) battery materials at the water/energy/recycling nexus
Universität des Saarlandes
Prof. Dr. Volker Presser

Behnoosh Bornamehr
Derivatization and design of transition metal oxides and sulfides for advanced and sustainable battery technology
Universität des Saarlandes
Prof. Dr. Volker Presser

Shardul Bhusari
Functional and safe encapsulation of Escherichia coli in Pluronic hydrogels for engineered living materials
Universität des Saarlandes
Prof. Dr. Aránzazu del Campo

Hasti Mohsenin
Development of Stimuli-Responsive and Information-Processing Biohybrid Materials and Diagnostic Tools by Protein Engineering and Synthetic Biological Design Concepts
Albert-Ludwigs-Universität Freiburg
Prof. Dr. Wilfried Weber

Gabriela Moreira Lana
Bioinspired microstructured adhesives for medical applications
Universität des Saarlandes
Prof. Dr. Eduard Arzt

Manar Samri
Monitoring bioinspired fibrillar grippers by contact observation and machine learning
Universität des Saarlandes
Prof. Dr. Eduard Arzt

Bartosz Szczefanowicz
Nanotribological Properties of van der Waals Heterostructures
Universität des Saarlandes
Prof. Dr. Roland Bennewitz

Divyendu Goud Thalla
Secretion Of Vimentin And Its Influence On Cellular Functionality
Universität des Saarlandes
Prof. Dr. Franziska Lautenschläger

Lei Wang
Faradaic Materials and Processes for the Electrochemical Separation
of Alkali and Alkaline Earth Metal Ions
Universität des Saarlandes
Prof. Dr. Volker Presser

ABSCHLUSSARBEITEN / THESES

BACHELORARBEITEN / BACHELOR THESES

Alina Sophie Bauer
Entwicklung und Charakterisierung von in vitro Reptilien-hautkulturen
Universität des Saarlandes
Prof. Dr. Aránzazu del Campo

Florence Schmerber
Electrostatic Actuation of Surface Roughness for Tactile Perception Studies of Fingertip Friction
Universität des Saarlandes
Prof. Dr. Roland Bennewitz

MASTERARBEITEN / MASTER THESES

Xue Bai
Strechable temperature sensors
Universität des Saarlandes
Prof. Dr. Tobias Kraus

Sanjana Balaji Kuttae
Computational and Experimental Characterization of Optogenetic Systems in E. coli
Universität des Saarlandes
Prof. Dr. Volkhard Helms, Dr. Shrikrishnan Sankaran

Aya Bennouk
Mercury Sensors
Universität des Saarlandes
Prof. Dr. Tobias Kraus

Niclas Hautz
Effect of water on electromechanical properties of polymer-based carbon black composites
Universität des Saarlandes
Jun.-Prof. Dr. Lola Gonzalez-Garcia, Prof. Dr. Tobias Kraus

Mokhamad Khamdan
Encapsulation of bacteria in 3D printed Pluronic Hydrogels
Universität des Saarlandes
Prof. Dr. Aránzazu del Campo

Sergio Lago Garrido
Fabrication and rheoelectrical characterization of conductive pastes
Escuela Técnica Superior de Ingeniería Universidad de Huelva, Huelva, Spain
Jun.-Prof. Dr. Lola González-García, Prof. Dr. María José Martín Alfonso

Olayinka Simon Okunoye
Influence of hysteresis on temperature-induced gold-nanoparticle agglomeration and redispersing
Universität des Saarlandes
Prof. Dr. Tobias Kraus

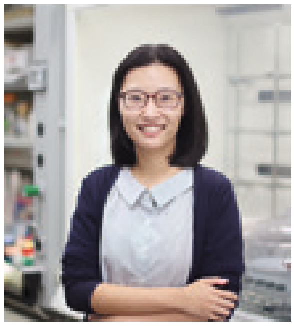
Lucas Schon
Koloniebildung in Hydrogel eingeschlossener Bakterien
Universität des Saarlandes
Prof. Dr. Roland Bennewitz

Alina Patricia Wilk
Engineering a probiotic lactobacilli to produce and secrete Nerve Growth Factor and test its bioactivity
Universität des Saarlandes
Prof. Dr. Aránzazu del Campo, Dr. Shrikrishnan Sankaran

Jiarui Zhang
Evaluation of biological routes to generate sustainable materials
Universität des Saarlandes
PD Dr. Annette Kraegeloh, Prof. Dr. Lienkamp

Xiao Zhang
Hybrid silver and carbon black filled PDMS composites for strechable electronics
Universität des Saarlandes
Prof. Dr. Tobias Kraus

AUSZEICHNUNGEN / AWARDS



Behnoosh Bornamehr
Award Open Science Reporting
Saarland University

Anna Burgstaller
Poster Prize
European Biophysical Societies' Association (EBSA) Conference 2023

Lola Gonzalez-Garcia
Nano Series Innovation Award 2023
Nano Series 2023 Conference

Seonki Hong
DGIST (Daegu Gyeongbuk Institute of Science and Technology, Daegu, Korea)
Humboldt Research Fellowship for Experienced Researchers
Alexander von Humboldt Foundation

Tobias Kraus
Outstanding Reviewer for Nanoscale
Nanoscale Journal

Gabriela Moreira Lana
Dr.-Eduard-Martin-Preis 2023
Universitätsgesellschaft des Saarlandes

Volker Presser
Highly Cited Researcher
Clarivate

Kordula Schellnhuber
Best Speaker Award – 2^{nd} place
8^{th} European Nanomanipulation Workshop

Kristela Shehu
Best Oral Presentation
Controlled Release Society, Local chapter Germany

Kristela Shehu
(Jury) Posterpreis (Best Poster)
Advanced Materials Safety 2023, Saarbrücken, Germany

Syed Tauqir Ali Sherazi
COMSATS University Islamabad
Georg-Forster-Forschungsstipendium
Alexander von Humboldt Foundation

Oskar Staufer
DECHEMA Zukunftsforum Biotechnologie
DECHEMA

Delvina Japhet Tarimo
Humboldt Research Fellowship
Alexander von Humboldt Foundation

Mohammad Torkmanzadeh
Award Open Science Reporting
Saarland University

REFERIERTE PUBLIKATIONEN / PEER-REVIEWED PUBLICATIONS

139 Publikationen
Publications
davon / *including*

113 Publikationen in referierten Zeitschriften
publications in peer-reviewed journals

26 sonstige Publikationen
other publications

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

72 Beiträge in referierten Zeitschriften
contributions in peer-reviewed journals

(Stand / As of 20.03.2024)

BIOPROGRAMMIERBARE MATERIALIEN / BIOPROGRAMMABLE MATERIALS

P. Dhakane, V. S. Tadimarri and S. Sankaran
Light-Regulated Pro-Angiogenic Engineered Living Materials
Advanced Functional Materials, 2023, 33, (31), 2212695
[JIF: 19.000 (2022)]
doi:10.1002/adfm.202212695

S. Dey, M. Blanch-Asensio, S. B. Kuttae and S. Sankaran
Novel genetic modules encoding high-level antibiotic-free protein expression in probiotic lactobacilli
Microbial Biotechnology, 2023, 16, (6), 1264-1276
[JIF: 05.700 (2022)]
doi:10.1111/1751-7915.14228

M. Blanch-Asensio, S. Dey and S. Sankaran
In vitro assembly of plasmid DNA for direct cloning in Lactiplantibacillus plantarum WCSF1
PLOS ONE, 2023, 18, (2), e0281625 [JIF: 03.240 (2022)]
doi:10.1371/journal.pone.0281625

A. K. Yanamandra, S. Bhusari, A. del Campo, S. Sankaran and B. Qu
In vitro evaluation of immune responses to bacterial hydrogels for the development of living therapeutic materials
Biomaterials Advances, 2023, 153, 213554
[JIF: 07.900 (2022)]
doi:10.1016/j.bioadv.2023.213554

S. Basaran, S. Dey, S. Bhusari, S. Sankaran and T. Kraus
Plasmonic stimulation of gold nanorods for the photothermal control of engineered living materials
Biomaterials Advances, 2023, 147, 213332
[JIF: 07.900 (2022)]
doi:10.1016/j.bioadv.2023.213332

F. Riedel, M. Puertas Bartolomé, L. L. Teruel Enrico, C. Fink-Straube, N. C. Dong, F. Gherlone, Y. Huang, V. Valiante, A. del Campo and S. Sankaran
Engineered living materials for the conversion of a low-cost foodgrade precursor to a high-value flavonoid
Frontiers in Bioengineering and Biotechnology, 2023, 11,
[JIF: 06.064 (2022)]
doi:10.3389/fbioe.2023.1278062

S. Bhusari, J. Kim, K. Polizzi, S. Sankaran and A. del Campo
Encapsulation of bacteria in bilayer Pluronic thin film hydrogels: A safe format for engineered living materials
Biomaterials Advances, 2023, 145, 213240
[JIF: 07.900 (2022)]
doi:10.1016/j.bioadv.2022.213240

DYNAMISCHE BIOMATERIALIEN / DYNAMIC BIOMATERIALS

S. Bhusari, J. Kim, K. Polizzi, S. Sankaran and A. del Campo
Encapsulation of bacteria in bilayer Pluronic thin film hydrogels: A safe format for engineered living materials
Biomaterials Advances, 2023, 145, 213240
[JIF: 07.900 (2022)]
doi:10.1016/j.bioadv.2022.213240

A. d. Miguel-Jiménez, B. Ebeling, J. I. Paez, C. Fink-Straube, S. Pearson and A. del Campo
Gelation Kinetics and Mechanical Properties of Thiol-Tetrazole Methylsulfone Hydrogels Designed for Cell Encapsulation
Macromolecular Bioscience, 2023, 23, (2), 2200419
[JIF: 04.600 (2022)]
doi:10.1002/mabi.202200419

F. Riedel, M. Puertas Bartolomé, L. L. Teruel Enrico, C. Fink-Straube, N. C. Dong, F. Gherlone, Y. Huang, V. Valiante, A. del Campo and S. Sankaran
Engineered living materials for the conversion of a low-cost foodgrade precursor to a high-value flavonoid
Frontiers in Bioengineering and Biotechnology, 2023, 11,
[JIF: 06.064 (2022)]
doi:10.3389/fbioe.2023.1278062

S. Trujillo, J. Y. Kasper, A. D. Miguel-Jimenez, B. Abt, A. Bauer, J. A. Mekontso Ngaffo, S. Pearson and A. del Campo
Cytocompatibility evaluation of PEG-methylsulfone hydrogels
ACS Omega, 2023, 8, (35), 32043-32052 [JIF: 04.100 (2022)]
doi:10.1021/acsomega.3c03952

R. Vandeberg, P. Grysan, C. Sion, M. K. Wodarczyk-Biegun, E. Lentzen, J. Bour, S. Krishnamoorthy, E. Olmos and C. Grandfils
Dextran-based matrix functionalization to promote WJ-MSCs amplification: synthesis and characterization
International Journal of Polymeric Materials and Polymeric Biomaterials, 2023, 72, (4), 285-295
[JIF: 03.200 (2022)]
doi:10.1080/00914037.2021.2006657

A. K. Yanamandra, S. Bhusari, A. del Campo, S. Sankaran and B. Qu
In vitro evaluation of immune responses to bacterial hydrogels for the development of living therapeutic materials
Biomaterials Advances, 2023, 153, 213554
[JIF: 07.900 (2022)]
doi:10.1016/j.bioadv.2023.213554

ELEKTROFLUIDE / ELECTROFLUIDS

R. Buchheit, B.-J. Niebuur, L. González-Garcia and T. Kraus
Surface polarization, field homogeneity, and dielectric breakdown in ordered and disordered nanodielectrics based on gold-polystyrene superlattices
Nanoscale, 2023, 15, (16), 7526-7536 [JIF: 06.700 (2022)]
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J. Drzic, A. Escudero, L. González-Garcia and T. Kraus
Sacrificial ligand route to hybrid polythiophene-silver nanoparticles for sinter-free conductive inks
Inorganic chemistry frontiers, 2023, 10, (5), 1552-1560
[JIF: 07.000 (2022)]
doi:10.1039/D2QI02722D

L. F. Engel, L. Gonzalez-Garcia and T. Kraus
Consolidation and performance gains in plasma-sintered printed nanoelectrodes
Nanoscale Advances, 2023, 5, 4124-4132
[JIF: 04.700 (2022)]
doi:10.1039/D3NA00293D

ENERGIE-MATERALIEN / ENERGY MATERIALS

M. Abdirahman Mohamed, S. Arnold, O. Janka, A. Quade, J. Schmauch, V. Presser and G. Kickelbick
Continuous wet chemical synthesis of Mo(C,N,O)x as anode materials for Li-ion batteries†
Journal of Materials Chemistry A, 2023, 23, (11), 19936-19954 [JIF: 14.511 (2022)]
doi:10.1039/D3TA03340F

D. Ahn, S. Kim, P. Ren, V. Presser and C. Kim
Redox flow desalination for tetramethylammonium hydroxide removal and recovery from semiconductor wastewater
Journal of Industrial and Engineering Chemistry, 2023, 118, 147-154 [JIF: 06.100 (2022)]
doi:10.1016/j.jiec.2022.10.053

B. Bornamehr, H. El Gaidi, S. Arnold, E. Pameté and V. Presser
Surfactant stabilization of vanadium iron oxide derived from Prussian blue analog for lithium-ion battery electrodes
Sustainable Energy & Fuels, 2023, 7, (18), 4514-4524
[JIF: 05.600 (2022)]
doi:10.1039/D3SE00854A

B. Bornamehr, M. Gallei, S. Husmann and V. Presser
Mechanically Stable, Binder-Free, and Free-Standing Vanadium Trioxide/Carbon Hybrid Fiber Electrodes for Lithium-Ion Batteries
Advanced Sustainable Systems, 2023, 7, (2), 2200373
[JIF: 07.100 (2022)]
doi:10.1002/adsu.202200373

B. Bornamehr, V. Presser, A. J. G. Zarbin, Y. Yamauchi and S. Husmann
Prussian blue and its analogues as functional template materials: control of derived structure compositions and morphologies
Journal of Materials Chemistry A, 2023, 11, 10473-10492
[JIF: 11.900 (2022)]
doi:10.1039/d2ta05901g

D. Bury, M. Jakubcza, M. A. K. Purbayanto, M. Birowska, A. Wójcik, D. Moszczynska, K. Eisawi, K. Prenger, V. Presser, M. Naguib and A. M. Jastrzebska
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Chemical Science, 2023, 14, (37), 10340-10346
[JIF: 08.400 (2022)]
doi:10.1039/D3SC03240J

EHEMALIGE WISSENSCHAFTLICHE EINHEITEN / FORMER SCIENTIFIC UNITS

ADVANCED MATERIALS SAFETY

A. Beyant-Friedrich, A. Kraegeloh and S. J. Sturla
A Virtual Issue of Chemical Research in Toxicology in Celebration of the International Day of Women and Girls in Science
Chemical Research in Toxicology, 2023, 36, 123-128
[JIF: 04.100 (2022)]
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E. Meziu, K. Shehu, M. Koch, M. Schneider and A. Kraegeloh
Impact of mucus modulation b N-acetylcysteine on nanoparticle toxicity
International journal of Pharmaceutics X, 2023, 6, 100212
[JIF: doi:10.1016/j.ijpx.2023.100212

S. Miyamoto, D. Naisbitt and A. Kraegeloh
Women in Toxicology Special Issue
Chemical Research in Toxicology, 2023, 36, 1439-1439
[JIF: 04.1 (2022)]
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FUNKTIONELLE MIKROSTRUKTUREN / FUNCTIONAL MICROSTRUCTURES

A. Kossa, R. Hensel and R. M. McMeeking
Adhesion of a cylindrical punch with elastic properties that vary radially
Mechanics research communications, 2023, 130, 104123
[JIF: 02.400 (2022)]
doi:10.1016/j.mechrescom.2023.104123

C. Müller and M. H. Müser
Analytical and numerical results for the elasticity and adhesion of elastic films with arbitrary Poisson's ratio and confinement
The Journal of Adhesion, 2023, 99, (4), 648-671
[JIF: 02.200 (2022)]
doi:10.1080/00218464.2022.2038580

C. Müller and M. H. Müser
How short-range adhesion slows down crack closure and contact formation
The Journal of Chemical Physics, 2023, 159, (24), 234705_1-7 [JIF: 04.4 (2022)]
doi:10.1063/5.0174379

C. Müller, M. H. Müser, G. Carbone and N. Menga
Significance of elastic coupling for stresses and leakage in frictional contacts
Physical Review Letters, 2023, 131, 156201
[JIF: 09.185 (2022)]
doi:10.1103/PhysRevLett.131.156201

C. Müller, M. Samri, R. Hensel, E. Arzt and M. H. Müser
Revealing the coaction of viscous and multistability hysteresis in an adhesive, nominally flat punch: A combined numerical and experimental study
Journal of the Mechanics and Physics of Solids, 2023, 174, 105260 [JIF: 05.300 (2022)]
doi:10.1016/j.jmps.2023.105260

INNOVATIVE ELEKTRONENMIKROSKOPIE / INNOVATIVE ELECTRON MICROSCOPY

C. Bauer, F. Müller, S. Keskin, M. Zobel and R. Kempe
A Highly Active Cobalt Catalyst for the General and Selective Hydrogenation of Aromatic Heterocycles
Chemistry – A European Journal, 2023, 29, (30), e202300561 [JIF: 04.300 (2022)]
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A. Bo, T. Kraus and N. de Jonge
Temperature-Dependent Coalescence of Individual Nonpolar Gold Nanoparticles in Liquid
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T. Maclucas, P. Grützmacher, S. Husmann, J. Schmauch, S. Keskin, S. Suarez, V. Presser, C. Gachot and F. Mücklich
Degradation analysis of tribologically loaded carbon nanotubes and carbon onions
npj Materials degradation 2023, 7, (31), 1-31
[JIF: 05.100 (2022)]
doi:10.1038/s41529-023-00346-5

PROGRAMMBEREICHSUNGEBUNDEN / NOT LINKED TO A PROGRAM DIVISION

CHEMISCHE ANALYTIK / CHEMICAL ANALYTICS

J. Hornbergs, K. Montag, J. Loschwitz, I. Mohr, G. Poschmann, A. Schnake, R. Gratz, T. Brumbarova, M. Eutebach, K. Angrand, C. Fink-Straube, K. Stühler, J. Zeier, L. Hartmann, B. Strodel, R. Ivanov and P. Bauer
SEC14-GOLD protein PATELLIN2 binds IRON-REGULATED TRANSPORTER1 linking root iron uptake to vitamin E
Plant Physiology, 2023, 192, (1), 504-526
[JIF: 07.400 (2022)]
doi:10.1093/plphys/kiac563

A. d. Miguel-Jiménez, B. Ebeling, J. I. Paez, C. Fink-Straube, S. Pearson and A. del Campo
Gelation Kinetics and Mechanical Properties of Thiol-Tetrazole Methylsulfone Hydrogels Designed for Cell Encapsulation
Macromolecular Bioscience, 2023, 23, (2), 2200419
[JIF: 04.600 (2022)]
doi:10.1002/mabi.202200419

F. Riedel, M. Puertas Bartolomé, L. L. Teruel Enrico, C. Fink-Straube, N. C. Dong, F. Gherlone, Y. Huang, V. Valiante, A. del Campo and S. Sankaran
Engineered living materials for the conversion of a low-cost foodgrade precursor to a high-value flavonoid
Frontiers in Bioengineering and Biotechnology, 2023, 11,
[JIF: 06.064 (2022)]
doi:10.3389/fbioe.2023.1278062

Y. E. Silina, C. Fink-Straube, M. Koch and E. V. Zolotukhina
A rapid in vitro electrochemical screening of extracellular matrix of Saccharomyces cerevisiae by palladium nanoparticles-modified electrodes
Bioelectrochemistry, 2023, 149, 108283 [JIF: 05.000 (2022)]
doi:10.1016/j.bioelechem.2022.108283

Y. E. Silina, E. V. Zolotukhina, M. Koch and C. Fink-Straube
A tandem of GC-MS and electroanalysis for a rapid chemical profiling of bacterial extracellular matrix
Electroanalysis, 2023, 35, (11), e202300178
[JIF: 03.00 (2022)]
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FLUORESZENZMIKROSKOPIE / FLUORESCENCE MICROSCOPY

I. Noordstra, M. Díez Hermoso, L. Schimmel, A. Vonfim-Melo, D. Currin-Ross, C. Nguyen Duong, J. M. Kalappurakkal, r. G. Morris, D. Vestweber, S. Mayor, E. Gordon, P. Roca-Cusachs and A. S. Yap
An E-cadherin-actin clutch translates the mechanical force of cortical flow for cell-cell contact to inhibit epithelial cell locomotion
Developmental Cell, 2023, 58, (18), [JIF: 11.8 (2022)]
doi:10.1016/j.devcel.2023.06.011

PHYSIKALISCHE ANALYTIK / PHYSICAL ANALYTICS

Y. Curto, M. Koch and G. Kickelbick
Chemical and Structural Comparison of Different Commercial Food Supplements for Silicon Uptake
Solids, 2023, 4, (1), 1-21 [JIF: 04.09 (2022)]
doi:10.3390/solids4010001

F. Hartmann, M. Bitsch, B.-J. Niebuur, M. Koch, T. Kraus, C. Dietz, R. W. Stark, C. R. Everett, P. Müller-Buschbaum, O. Janka and M. Gallei
Self-Assembly of Polymer-Modified FePt Magnetic Nanoparticles and Block Copolymers
Materials, 2023, 16, 5503 [JIF: 03.400 (2022)]
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F. Hartmann, B.-J. Niebuur, M. Koch, T. Kraus and M. Gallei
Synthesis and microphase separation of dendrimer-like block copolymers by anionic polymerization strategies
European Polymer Journal, 2023, 187, [JIF: 06.000 (2022)]
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E. Heinrich, O. Hartwig, C. Walt, A. Kardani, M. Koch, L. Pouralebi Jahromi, J. Hoppstädter, A. K. Kiemer, B. Loretz, C.-M. Lehr and G. Fuhrmann
Cell-Derived Vesicles for Antibiotic Delivery-Understanding the Challenges of a Biogenic Carrier System
Small, 2023, 19, (25), 2207479 [JIF: 13.300 (2022)]
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H. Hübner, B.-J. Niebuur, O. Janka, L. Gemmer, M. Koch, T. Kraus, G. Kickelbick, B. Stühn and M. Gallei
Crystalline Carbosilane-Based Block Copolymers: Synthesis by Anionic Polymerization and Morphology Evaluation in the Bulk State
Macromolecular Chemistry and Physics, 2023, 224, (3), 2200178 [JIF: 02.500 (2022)]
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F. Kern, T. Kuhn, N. Ludwig, M. Simon, L. Gröger, N. Fabis, E. Aparicio-Puerta, A. Salhab, T. Fehlmann, O. Hahn, A. Engel, V. Wagner, M. Koch, K. Winek, H. Soreq, I. Nazarenko, G. Fuhrmann, T. Wyss-Coray, E. Meese, V. Keller, M. W. Laschke and A. Keller
Ageing-associated small RNA cargo of extracellular vesicles
RNA Biology, 2023, 20, (1), 482-494 [JIF: 04.100 (2022)]
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M. Koch, A. Katsen-Globa, E. V. Zolotukhina and Y. E. Silina
Testing of yeast cells damage using hydrogen peroxide spiking and Pd-NPs-based electrodes and impact of oxidoreductase presence on electrochemical read-out
Biochemical Engineering Journal, 2023, 195,
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S. Lee, S. Nasr, S. Rasheed, Y. Liu, O. Hartwig, C. Kaya, A. Boese, M. Koch, J. Herrmann, R. Müller, B. Loretz, E. Buhler, A. K. H. Hirsch and C.-M. Lehr
Proteoid biodynamers for safe mRNA transfection via pH-responsive nanorods enabling endosomal escape
Journal of Controlled Release, 2023, 353, 915-929
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Y. E. Silina, C. Fink-Straube, M. Koch and E. V. Zolotukhina
A rapid in vitro electrochemical screening of extracellular matrix of Saccharomyces cerevisiae by palladium nanoparticles-modified electrodes
Bioelectrochemistry, 2023, 149, 108283 [JIF: 05.000 (2022)]
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A tandem of GC-MS and electroanalysis for a rapid chemical profiling of bacterial extracellular matrix
Electroanalysis, 2023, 35, (11), e202300178
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E. V. Zolotukhina, E. V. Butyrskaya, M. Koch, P. Herbeck-Engel, M. G. Levchenko and Y. E. Silina
First principles of hydrazine electrooxidation at oxide-free and oxide-based palladium electrodes in complex media
Physical Chemistry Chemical Physics, 2023, 25, (14), 9881-9893 [JIF: 03.300 (2022)]
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INM FELLOWS

S. Chatterjee, M. Mangeat, C.-U. Woo, H. Rieger and J. D. Noh
Flocking of two unfriendly species: The two-species Vicsek model
Physical Review E, 2023, 107, 024607-1 - 024607-7
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M. Karmakar, S. Chatterjee, M. Mangeat, H. Rieger and R. Paul
Jamming and flocking in the restricted active Potts model
Physical Review E, 2023, 108, (1), 014604
[JIF: 02.707 (2022)]
doi:10.1103/PhysRevE.108.014604

H. Meyer and H. Rieger
Alignment interaction and band formation in assemblies of autochemorepulsive walkers
Physical Review E, 2023, 108, (3), 034604
[JIF: 01.789 (2022)]
doi:10.1103/PhysRevE.108.034604

C. Müller and M. H. Müser
Analytical and numerical results for the elasticity and adhesion of elastic films with arbitrary Poisson's ratio and confinement
The Journal of Adhesion, 2023, 99, (4), 648-671
[JIF: 02.200 (2022)]
doi:10.1080/00218464.2022.2038580

C. Müller, M. H. Müser, G. Carbone and N. Menga
Significance of elastic coupling for stresses and leakage in frictional contacts
Physical Review Letters, 2023, 131, 156201
[JIF: 09.185 (2022)]
doi:10.1103/PhysRevLett.131.156201

C. Müller, M. Samri, R. Hensel, E. Arzt and M. H. Müser
Revealing the coaction of viscous and multistability hysteresis in an adhesive, nominally flat punch: A combined numerical and experimental study
Journal of the Mechanics and Physics of Solids, 2023, 174, 105260 [JIF: 05.300 (2022)]
doi:10.1016/j.jmps.2023.105260

A. Wang and M. H. Müser
Is there more than one stickiness criterion?
Friction, 2023, 11, 1027-1039 [JIF: 06.800 (2022)]
doi:10.1007/s40544-022-0644-3

WEITERE / OTHERS

M. Arricca, L. Cabras, M. Serpelloni, C. Bonanno, R. M. McMeeking and A. Salvadori
A coupled model of transport-reaction-mechanics with trapping, Part II: Large strain analysis
Journal of the Mechanics and Physics of Solids, 2023, 181, 105424 [JIF: 05.300 (2022)]
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C. Bonanno, M. Serpelloni, M. Arricca, R. M. McMeeking and A. Salvadori
Actin based motility unveiled: How chemical energy is converted into motion
Journal of the Mechanics and Physics of Solids, 2023, 175, 105273 [JIF: 05.300 (2022)]
doi:10.1016/j.jmps.2023.105273

V. S. Deshpande and R. M. McMeeking
Models for the Interplay of Mechanics, Electrochemistry, Thermodynamics, and Kinetics in Lithium-Ion Batteries
Applied Mechanics Reviews, 2023, 75, (1), 010801 [JIF: 14.300 (2022)]
doi:10.1115/1.4056289

A. Kossa, M. T. Valentine and R. M. McMeeking
Analysis of the compressible, isotropic, neo-Hookean hyperelastic model
Meccanica, 2023, 58, 217-232 [JIF: 02.700 (2022)]
doi:10.1007/s11012-022-01633-2

Y. Kwon, S. E. Seo, J. Lee, S. Berezvai, J. Read de Alaniz, C. D. Eisenbach, R. M. McMeeking, C. J. Hawker and M. T. Valentine
3D-printed polymer foams maintain stiffness and energy dissipation under repeated loading
Composites Communications, 2023, 37, 101453 [JIF: 08.000 (2022)]
doi:10.1016/j.coco.2022.101453

S. S. Shishvan, N. A. Fleck, R. M. McMeeking and V. S. Deshpande
Vacancy diffusion and its consequences for void growth at the interface of a stripping metal electrode and solid electrolyte
Electrochimica Acta, 2023, 467, [JIF: 06.600 (2022)]
doi:10.1016/j.electacta.2023.143081

S. S. Shishvan, N. A. Fleck, R. M. McMeeking and V. S. Deshpande
Cracking and associated volumetric expansion of NMC811 secondary particles
Journal of Power Sources, 2023, 588, 233745 [JIF: 9.2 (2022)]
doi:10.1016/j.jpowsour.2023.233745

A.-R. Shokouhi, Y. Chen, H. Z. Yoh, T. Murayama, K. Suu, Y. Morikawa, J. Brenker, T. Alan, N. H. Voelcker and R. Elnathan
Electroactive nanoinjection platform for intracellular delivery and gene silencing
Journal of Nanobiotechnology, 2023, 21, 273 [JIF: 10.200 (2022)]
doi:10.1186/s12951-023-02056-1

T. Zhang, M. Sotoudeh, A. Groß, R. M. McMeeking and M. Kamlah
3D microstructure evolution in Na_xFePO_4 storage particles for sodium-ion batteries
Journal of Power Sources, 2023, 565, 232902 [JIF: 09.200 (2022)]
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R. Zhao, A. K. Yanamandra and B. Qu
A high-throughput 3D kinetic killing assay
European Journal of Immunology, 2023, 53, 2350505 [JIF: 5.400 (2022)]
doi:10.1002/eji.202350505

X. Zhou, Y. Zheng, H. Zhang, L. Yang, Y. Cui, B. P. Krishnan, S. Dong, M. Aizenberg, X. Xiong, Y. Hu, J. Aizenberg and J. Cui
Reversibly growing crosslinked polymers with programmable sizes and properties
Nature Communications, 2023, 14, 3302 [JIF: 17.69 (2021)]
doi:10.1038/s41467-023-38768-z

EINGELADENE VORTRÄGE / INVITED TALKS

274 Vorträge
talks
davon / *including*

56 eingeladene Vorträge
invited talks

55 sonstige Vorträge
other talks

und

163 Industrievorträge

(Stand / As of 20.03.2024)

DYNAMISCHE BIOMATERIALIEN / DYNAMIC BIOMATERIALS

A. del Campo
Soft, side emitting optical fibers by multimaterial printing
MRS Fall Meeting & Exhibit
Bostton <USA-MA>
November 26 - December 1, 2023

A. del Campo
Optoactivatable hydrogels that talk to cells: photochemistry from a biomaterials user perspective
Graduiertenkolleg on Light Control : Final Symposium
Oestrich-Winkel <GER>
October 4-6, 2023

A. del Campo
Living therapeutic materials: self-replenshable drug depots
XI JIP 2023 on Science & Polymers
Alicante <ESP>
October 2-5, 2023

A. del Campo
Living therapeutic hydrogels: drug depots with self-repenishing function
AFPB 2023 Annual Conference Advanced Functional Polymers for Medicine 2023
Barcelona <ESP>
June 7-9, 2023

A. del Campo
Living therapeutic materials: self-replenishable drug depots
Annual Meeting of the Belgian Polymer Group
Houffalize <BEL>
May 22, 2023

A. del Campo
Material design criteria for living therapeutic devices
MRS Spring Meeting & Exhibition
San Francisco <USA-CA>
April 10-14, 2023

ELEKTROFLUIDE / ELECTROFLUIDS

L. Gonzalez-Garcia
Particle suspensionsl for flexible, conductive materials
IEEE Sweden Section Chapter Colloquium
Stockholm <SWE>
September 15, 2023

L. González-García
Direct nanoimprinting of metal nanostructures: a route toward flexible, transparent electrodes
2nd Annual Conference on Global Nanotechnology (NanoSeries2023)
Madrid <ESP>
June 19-21, 2023

ENERGIE-MATERALIEN / ENERGY MATERIALS

V. Presser
Electrochemical ion management and nanomaterial design for the energy/water research nexus
74th Annual Meeting of the International Society of Electrochemistry (ISE)
Lyon <FRA>
September 3-8, 2023

V. Presser
Continuous and intermittent direct electrochemical lithium extraction
6th International Conference on Battery deionization & electrochemical separation
Taipei <TWN>
July 2-6, 2023

V. Presser
MXENE and Hybrid Electrodes for High Performance Energy Storage
2nd German-French Summer Workshop on high power devices
Nantes <FRA>
June 19-23 2023

V. Presser
Electrochemical lithium-ion extraction
Dutch Institute for Fundamental Energy Research
Virtual
July 13, 2023

IMMUNO MATERIALIEN / IMMUNO MATERIALS

O. Staufer
Towards Bottom-up Assembly of Viral Replication Cycles
Build-a-cell Seminar
Virtual
February 6, 2023

O. Staufer
Bottom-up assembly of synthetic intracellular organelles
Polish Astrobiology Society Meeting
virtual
December 1-3, 2023

O. Staufer
Building immunity from the bottom up
ERC ATTACK Consortium : Annual meeting
Freinsheim <GER>
October 22-25, 2023

O. Staufer
Bootom-up assembly of artificial 3D tissues
DECHEMA Zukunftsforum Biotechnology
Aachen <GER>
2023

O. Staufer
Building immunity from the bottom up
European Materials Research Society : Autumn Meeting
Warsaw <POL>
September 18-21, 2023

O. Staufer
Augenblick für Forschung
Daimler und Benz Stiftung
Ladenburg <GER>
2023

O. Staufer
Bottom-up assembly of synthetic tissues
SynCell 2023
Minneapolis <USA-MN>
May 22-24, 2023

O. Staufer
Synthetic SARS-CoV-2 virions
IMM-PACT Symposium
Freiburg i.Br. <GER>
May 12, 2023

O. Staufer
Immuno-Materials: Immunizing the future
Minimal Biology Workshop
Bristol <GBR>
November 6-7, 2023

O. Staufer
Artificial Tumor Immune Microsenvironments
International Synthetic Biology Workshop
Darmstadt <GER>
March 20-22, 2023

INTERAKTIVE OBERFLÄCHEN / INTERACTIVE SURFACES

R. Bennewitz
Friction and surface materials – from graphene and hydrogels to micropillars and fingertips
Texas A&M University (TAMU)
College Station <USA-TX>
April 17, 2023

R. Bennewitz, M. Fehlberg, K. M. Jost, S. Saikumar and V. H. P. Infante
Role of fingertip friction in the tactile perception of surface materials
MRS Spring Meeting
San Francisco <USA-CA>
April 10-24. 2023

MATERIAL-HOST INTERAKTIONEN / MATERIAL HOST INTERACTION

S. Trujillo
Materials for therapeutic delivery
Molecular Systems Engineering and Advanced Materials
Heidelberg <GER>
April 12, 2023

MATERIALORIENTIERTE SYNTHETISCHE BIOLOGIE / MATERIALS SYNTHETIC BIOLOGY

W. Weber
Programming Materials with Synthetic Biology
International Synthetic Biology Workshop
Technische Universität Darmstadt <GER>
March 22, 2023

W. Weber
Molecular Optogenetics – Programming Cells and Materials with Light
Young Invesitgator Symposium
Universitätsklinikum des Saarlandes, Homburg Saar <GER>
April 21, 2023

W. Weber
Synthetic biology-inspired deisgn of materials
Kolloquium der Fachrichtung Materialwissenschaft und Werkstofftechnik
Universität des Saarlandes, Saarbrücken <GER>
May 09, 2023

W. Weber
Directed Evolution of Materials
Forum Experiment! 2023
Volkswagen-Stiftung, Xplanatorium Hannover <GER>
May 23-24, 2023

W. Weber
Lebende Materialien
Absolventenfeier MWWT
Universität des Saarlandes, Saarbrücken <GER>
May 26, 2023

W. Weber
Biobased and Living Materials
Strategieseminar des DWI – Leibniz-Institut für Interaktive Materialien e.V. Aachen
Abdij Rolduc, Kerkrade <NLD>
June 13 2023

W. Weber
Lebende Materialien – ein neues Paradigma in den Materialwissenschaften
Wissenschaftsforum des MINT-Campus
Alte Schmelz, St. Ingbert <GER>
July 11, 2023

W. Weber
Synthetic Biology-inspired design of advanced materials
Summer School Ryon Rhein-Main-Universities
Merck Innovation Center, Darmstadt <GER>
September 4, 2023

W. Weber
Molecular Optogenetics – Programming Cells and Materials with Light
Syn-Bio Meeting
Ben-Gurion University of the Negev, Beer-Sheva <ISR>
September 12, 2023

W. Weber
Programming materials with synthetic biology
German Association of Synthetic Biology (GASB) Conference
Freiburg i.Br. <GER>
September 18, 2023

W. Weber
Programming Cells and Materials with Light
Optogenetics Meeting 2023
Universität Göttingen, Landhotel am Rothenberg, Volpreishausen <GER>
October 4, 2023

W. Weber
Programmng Cells to Assemble New Materials from Waste- and Byproducts
Sitzung Themennetzwerk Materialwissenschaften und Werkstofftechnik der acatech
BAM Berlin Adlershof <GER>
October 9, 2023

W. Weber
Molecular Optogenetics – Programming Cells with Light
ATTACK Symposium
Freinsheim <GER>
October 24, 2023

W. Weber
Antibodies – from bench to bedside
Vorlesung
ETH Zürich , Basel <CHE>
November 1, 2023

W. Weber
Making New Materials with Synthetic Biology
Vorlesung
ETH Zürich, Basel <CHE>
November 8, 2023

W. Weber
Programming Cells and Materials with Synthetic Biology
Fakultäts-Symposium
Universität des Saarlandes, Saarbrücken <GER>
November 15, 2023

W. Weber
Molecular Optogenetics – Programming Cells and Biomaterials with Light
Maxime Dahan Symposium
Institut Curie Research Center Paris <FRA>
December 15, 2023

STRUKTURBILDUNG / STRUCTURE FORMATION

T. Kraus
Reversible interfaces for reusable and recyclable components
Johnson Matthey
Reading <GBR>
December 11, 2023

T. Kraus
Solubility, reversibility, and recycling: designing circular materials via interfaces
Albert-Ludwigs-Universität Freiburg:
Physikalisches Kolloquium
Freiburg i. Br. <GER>
November 27, 2023

T. Kraus
Reversibility in particle self-assembly, soft conductors, and circular electronic materials
University of Basel / Department of Chemistry
Basel <CHE>
June 2, 2023

T. Kraus
Reversible interfaces for soft and circular materials
18th Dresen Polymer Discussion: From particulate building blocks to functional soft matter assemblies
Meissen <GER>
May 21-24, 2023

T. Kraus
Reversibility in agglomeration and self-assembly: when are nanoparticles a dispersion, when a solution?
Nanoassembly 23, Kavli Institute
Santa Barbara <USA-CA>
April 24, 2023

EHEMALIGE WISSENSCHAFTLICHE EINHEITEN / FORMER SCIENTIFIC UNITS

Advanced Materials Safety

A. Kraegeloh
Safe by Design – ein Konzept für sichere und nachhaltige Nanomaterialien
Dialog Nanotechnologie, Nachhaltige und kreislauffähige Produktentwicklung
virtual
April 27, 2023

A. Kraegeloh
Sichere Anwendung von Nanomaterialien
X Jahre später "Nanotechnologie, Neuroenhancement, Klimawissenschaften
Volkswagen Stiftung Hannover <GER>
March 21, 2023

A. Kraegeloh
Focus on material cell interactions
Retreat des Instituts für Physikalische Chemie und Physik der Polymere
Leibniz-Institut für Polymerforschung <Schmiedeberg>
September 25, 2023

A. Kraegeloh
Seeing is more than believing: How bioimaging contributes to understand advanced materials-cell interactions
Advanced Materials Safety 2023
Saarbrücken <GER>
November 8-10, 2023

PROGRAMMBEREICHSUNGEBUNDEN / NOT LINKED TO A PROGRAM DIVISION

Physikalische Analytik / Physical Analytics

M. Koch
Scanning electron microscopy (SEM) preparation and imaging techniques to visualize cell-material interaction on hydrogels and thermoplastic printed scaffold
Microscopy Conference MC 2023
Darmstadt <GER>
February 26 - March 02, 2023

M. Koch
Metallauflagen am Retabel von Schlosss Tirol - Materialanalytik und kunsttechnologische Einordnung
Tagung "Das Retabel von Schloss Tirol"
Innsbruck <AUS>
April 20-21, 2023

INM Fellows

H. Rieger
Biophysics of killing, theory and experiment
Biophysik Kolloquium
Universität Göttingen <GER>
April 11, 2023

H. Rieger
Non-Markovian and Collective Search Strategies in biological systems
STATPHYS 28
University of Tokyo <JPN>
August 7-11, 2023

H. Rieger
Flocking of two unfriendly species: The two-species Vicsek model
Transport Phenomena and Fluctuations in Small Complex Systems
Buenos Aires <ARG>
December 11-15, 2023

PATENTE / PATENTS

4 Patentanmeldungen
patent applications

10 erteilte Patente
granted patents

1 in Europa
in Europe

9 international
international

57 Patentfamilien
patent families

ERTEILTE EUROPÄISCHE PATENTE / PATENTS GRANTED IN EUROPE

Europäisches Patent Nr. INM-391
Titel: „Herstellung von dotierten Nanopartikeln"
Erfinder: N. Müller, P. Rogin, P. W. de Oliveira, Th. Müller

ERTEILTE INTERNATIONALE PATENTE / PATENTS GRANTED INTERNATIONALLY

CA Patent Nr. INM-374/CA
Titel: „Method for producing anisotropic zinc phosphate particles and zinc metal mixed phosphate particles and use thereof"
Erfinder: S. Albayrak, C. Becker-Willinger, D. Bentz, E.M. Perre

KR Patent Nr. INM-374/KR
Titel: „Method for producing anisotropic zinc phosphate particles and zinc metal mixed phosphate particles and use thereof
Erfinder: S. Albayrak, C. Becker-Willinger, D. Bentz, E.M. Perre

JP Patent Nr. INM-374/JP
Titel: „Method for producing anisotropic zinc phosphate particles and zinc metal mixed phosphate particles and use thereof "
Erfinder: S. Albayrak, C. Becker-Willinger, D. Bentz, E.M. Perre

US Patent Nr. INM-386/US
Titel: „Device having a structured coating for adhering to other surfaces"
Erfinder: E. Arzt, S. Fischer, K. Kruttwig, R. Hensel, B. Schick, G. Wenzel

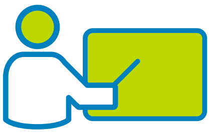
CN Patent Nr. INM-398/CN
Titel: „Double-sided reversible adhesive structure"
Erfinder: E. Arzt, R. Hensel, K. Moh

JP Patent Nr. INM-398/JP
Titel: „Double-sided reversible adhesive structure"
Erfinder: E. Arzt, R. Hensel, K. Moh

US Patent Nr. INM-398/US
Titel: „Double-sided reversible adhesive structure"
Erfinder: E. Arzt, R. Hensel, K. Moh

JP Patent Nr. INM-400/JP
Titel: „Conductive materials made of Nb-doped TiO_2*-particles"*
Erfinder: P.W. de Oliveira, J. Staudt

US Patent Nr. INM-400/US
Titel: „Conductive materials made of Nb-doped TiO_2*-particles"*
Erfinder: P.W. de Oliveira, J. Staudt



LEHRVERANSTALTUNGEN / TEACHING

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, 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 (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
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

Annette Kraegeloh (mit C.M. Lehr, M. Schneider, Univ. des Saarlandes)
Introduction to Drug Delivery and NanoBiomedicine
Universität des Saarlandes, Strasbourg University, 2 SWS

SOMMERSEMESTER / SUMMER SEMESTER 2023

Annette Kraegeloh und INM Kolleg*innen
NanoBioMaterialien-2
Universität des Saarlandes, Vorlesung, 2 SWS

Roland 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

Tobias Kraus
Vertiefungspraktikum Werkstoffchemie (WCV)
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

Volker Presser
Seminar Energie-Materialien
Universität des Saarlandes, Seminar, 2 SWS

Lola González-García
Printing of Functional Materials
Universität des Saarlandes, Seminar, 2 SWS

WINTERSEMESTER / WINTER SEMESTER 2023 / 2024

Lola González-García, Tobias Kraus
NanoBioMaterialien 1
Universität des Saarlandes, Vorlesung, 2 SWS

Eduard Arzt und Mitarbeiter/innen
Einführung in die Materialwissenschaft für (Studierende der) Mikrotechnologie und Nanostrukturen
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Lola González-García, Tobias Kraus und Mitarbeiter/innen
NanoBioMaterialien-P
Universität des Saarlandes, Praktikum, 4 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

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Advanced Topics in Classical Physical Chemistry (PC 03)
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)
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Universität des Saarlandes, Praktikum, 2 SWS

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

Volker Presser
Seminar Energie-Materialien
Universität des Saarlandes, Seminar, 2 SWS

Lola Gonzalez-Garcia
Material Science Master Praktikum
Universität des Saarlandes, Praktikum, 3 SWS

VERANSTALTUNGEN / EVENTS

JANUAR – FEBRUAR

Kick off Meeting des LFV Advanced Materials Safety
A. Kraegeloh, C. Petzold (mit A. Fery und den Verbundpartnern)
Virtuelles Meeting, 13.01.2023

Besuch einer Gruppe Studierender der Uni Metz-Nancy aus Forbach
I. Blaya Pons, G. Moreira, H. Quan, M. Quilitz, K. Sorg, X. Zhang
Saarbrücken, 23.01.2023

Schülerpraktikum I
D. Beckelmann, A Haettich, M. Jilavi, A. Jung, P. Kalmes, S. Kunkel, C. Muth, R. Muth, F. Riedel, H. Rimbach, D. Schmidt
Saarbrücken, 23.01. – 03.02.2023

JANUAR – FEBRUAR

Besuch der Teilnehmenden der Korean Winter School der Universität des Saarlandes
M. Koch, M. Quilitz (mit Universität des Saarlandes)
Saarbrücken, 31.01.2023

Nanotech 2023 – International Nanotechnology Exhibition and conference
C. Becker-Willinger, Th. Müller, M. Amlung, M. Klos
Tokyo, 01.02. - 03.02.2023

Wissenschaftliches Kolloquium zur Verabschiedung von Prof. Eduard Arzt
R. Bennewitz, A. del Campo, C. Hartmann (mit Universität des Saarlandes)
Saarbrücken, 13.02.2023

MÄRZ – APRIL

LOPEC
S. Heusing
München, 01.03. – 02.03.2023

Schülerpraktikum II
D. Beckelmann, S. Brück, A. Haettich, M. Hauck, P. Kalmes, T. Knapp, S. Kunkel, A. May, I. Melnyk, C. Muth, M. Quilitz, F. Riedel, S. Trujillo Munoz
Saarbrücken, 20.03. – 31.03.2023

European Coatings Show
M. Amlung, C. Becker-Willinger, M. Jilavi
Nürnberg, 28.03. – 30.03.2023

MÄRZ – APRIL

Besuch des französischen Generalkonsuls Sebastien Girard am INM
M. Koch, T. Kraus, E. Pamete, M. Quilitz
Saarbrücken, 12.04.2023

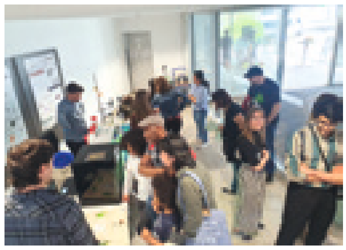
Hannover-Messe 2023
M. Amlung, C. Becker-Willinger, S. Blum, Y. Brasse, Th. Müller, S. Selzer, B. Reinhard
Hannover, 17.04. – 21.04.2023

Girls' Day
S. Siegrist, S. Zeiter-Semmet
Saarbrücken, 27.04.2023

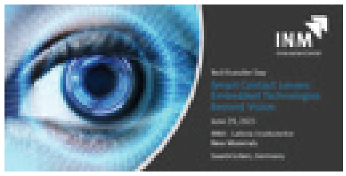
MÄRZ – APRIL

Online-Veranstaltungsreihe "Dialog Nanotechnologie" Topic: Nachhaltige und kreislauffähige Produktentwicklung
C. Petzold für den Leibniz Forschungsverbund Advanced Materials Safety
Virtuell, 27.04.2023

MAI – JUNI



Tag der Offenen Tür der Universität des Saarlandes
Y. Brasse, A. del Campo, C. Hartmann, A. Kraegeloh, M. Koch, T. Kraus, A. Nexha, C. Petzold, V. Presser, M. Quilitz, S. Sankaran, S. Trujillo
Saarbrücken, 13.05.2023

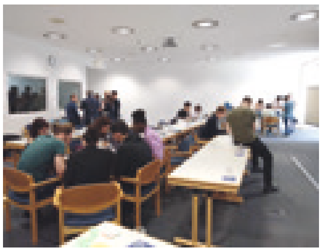


Tech Transfer Day- Smart Contact Lenses
A. del Campo, P. W. de Oliveira
Saarbrücken, 29.06.2023

JULI – AUGUST

Netzwerktreffen nanoInk 2023
S. Heusing, T. Kraus, P. W. de Oliveira
Saarbrücken, 04.07.2023

LSC Summer School on Engineered Living Materials 2023
A. del Campo, S. Sankaran, W. Weber
Europäische Akademie Otzenhausen
Nonnweiler, 03. – 05.07.2023



JULI – AUGUST

Preparatory Workshop of the SPP 2451 Engineered Living Materials with adaptive functions
A. del Campo, T. Kraus, S. Sankaran, W. Weber
Saarbrücken, 10. – 11.07.2023

Onlinediskussion der Veranstaltungsreihe "Dialog Nanotechnologie" Topic: Upscaling
C. Petzold für den Leibniz Forschungsverbund Advanced Materials Safety
Virtuell, 29. 07.2023

Seminar on Research Data Management
R. Bennewitz
Saarbrücken, 11.08.2023

NOVEMBER

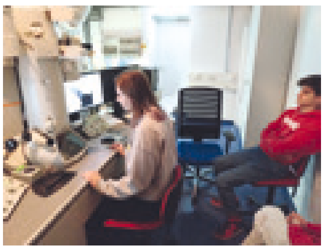
Besuch von Schülergruppen vom Gymnasium Merzig an der UdS und Aninstituten
M. Quilitz (mit Universität des Saarlandes)
Saarbrücken, 07.11.2023

Advanced Materials Safety Conference 2023
A. Kraegeloh, C. Petzold (mit A. Fery und den Verbundpartnern)
Saarbrücken, 08.11. – 10.11.2023

Besuch von Teilnehmenden der Advanced Materials Safety Conference 2023
M. Quilitz
Saarbrücken, 09.11.2023

Seminar on Good Scientific Practice
R. Bennewitz, L. Gonzalez-Garcia
Saarbrücken, 30.11.2023

SEPTEMBER – OKTOBER



Virtual Lab Day des BMBF-VDI
M. Koch, M. Quilitz (mit VDI, BMBF)
virtuell, 08.09.2023

BMBF Schülerpraktikum Werkstoffferien 2023
S. Arnold, K. Fries, A. Haettich, A. Kraegeloh, Th. Mueller, M. Quilitz, S. Schumacher, K. Sorg, Th. Steudter (mit VDI, BMBF)
Saarbrücken, 23.10. – 27.10.2023

SEPTEMBER – OKTOBER

Besuch von der Universidad Technologia de Monterrey, Mexico
M. Quilitz
Saarbrücken, 23.10.2023

INM – KOLLOQUIEN / INM – COLLOQUIA

JANUAR

Prof. Dr. Christian Kübel
Advanced Electron Microscopy in Materials Research
Karlsruhe Institute of Technology (KIT)
24.01.2023
Host: Prof. Dr. Tobias Kraus

MAI

Dr. Nathalie Bock
Convergence of ECM-based biomaterials and biomimetic culture methods for mineralization and humanization of bioengineered in vitro and in vivo bone models
Queensland University of Technology (QUT)/ Australia
23.05.2023
Host: Prof. Dr. Aranzazu del Campo, Prof. Dr. Bergita Ganse (Saarland University Medical Center)

JUNI

Prof. Dr. Jang-Ung Park
Soft Bioelectronics using Liquid Metals
Yonsei University, Dept. of Materials Science and Engineering, Seoul, South Korea
30.06.2023
Host: Prof. Dr. Aranzazu del Campo

Prof. Dr. Haider Butt
Additive Manufacturing of multifunctional conatct lenses and optical devices
Khalifa University of Science and Technology, Mechanical Engineering, Abu Dhabi, UAE
30.06.2023
Host: Prof. Dr. Aranzazu del Campo

Dr. Reza Shaebani
Designing filamentous meta materials and active smart solids
Dept. of Theoretical Physics and Center for Biophysics, Saarland University, Saarbrücken
30.06.2023
Host: Prof. Dr. Aranzazu del Campo

DEZEMBER

Prof. Dr. Jan P. Lagerwall
Application opportunities from Anti-Counterfeiting to Disease Testing enabled by the unique optics of Cholesteric Spherical Reflectors
University of Luxembourg
05.12.2023
Host:
Prof. Dr. Tobias Kraus

LSC VORTRÄGE, KOLLOQUIEN DES LSC / LSC TALKS, COLLOQUIA OF THE LSC

JANUAR

Dr. Morgan Delarue
Cell Growth under Mechanical Pressure
Universite Toulouse, team MILE, LAAS-CNRS, France
31.01.2023
Host: Prof. Dr. Aranzazu del Campo

APRIL

Prof. Dr. Tae Seok Moon
Systems and Synthetic Biology: Constructing smart and programmable Microbes to adress Global Problems
Washington University, St. Louis, USA
03.04.2023
Host: Prof. Dr. Wilfried Weber, Dr. Shrikrishnan Sankaran

OKTOBER

Prof. Dr. Ryosuke Kojima
Engineering extracellular vesicles for their delivery application and comprehensive biological understanding
Graduate School of Medicine, University of Tokyo, Japan
12.10.2023
Host:
Prof. Dr. Wilfried Weber

DAS INM IN DEN MEDIEN / INM IN THE MEDIA


Wilfried Weber wird Geschäftsführer des INM und Uni-Professor

Elektronik im Kunststoff wiederverwerten

Electrospinning macht leitfähige Strukturen flexibel, transparent und kostengünstig

Als Saarbrücken

Alexandra ist beste Fachangestellte für Mediendienste

INM auf der LOPEC:

Dr. Wurres und der Gecko-Effekt

Jenseits des Tellerrands warten Erkenntnisse

800 000 Euro für Nachhaltigkeitsprojekte des INM

Fluoreszierende künstliche Samen überwachen Bodentemperatur mithilfe von Drohnen

Projekt will Batterie-Design auf Recycling ausrichten

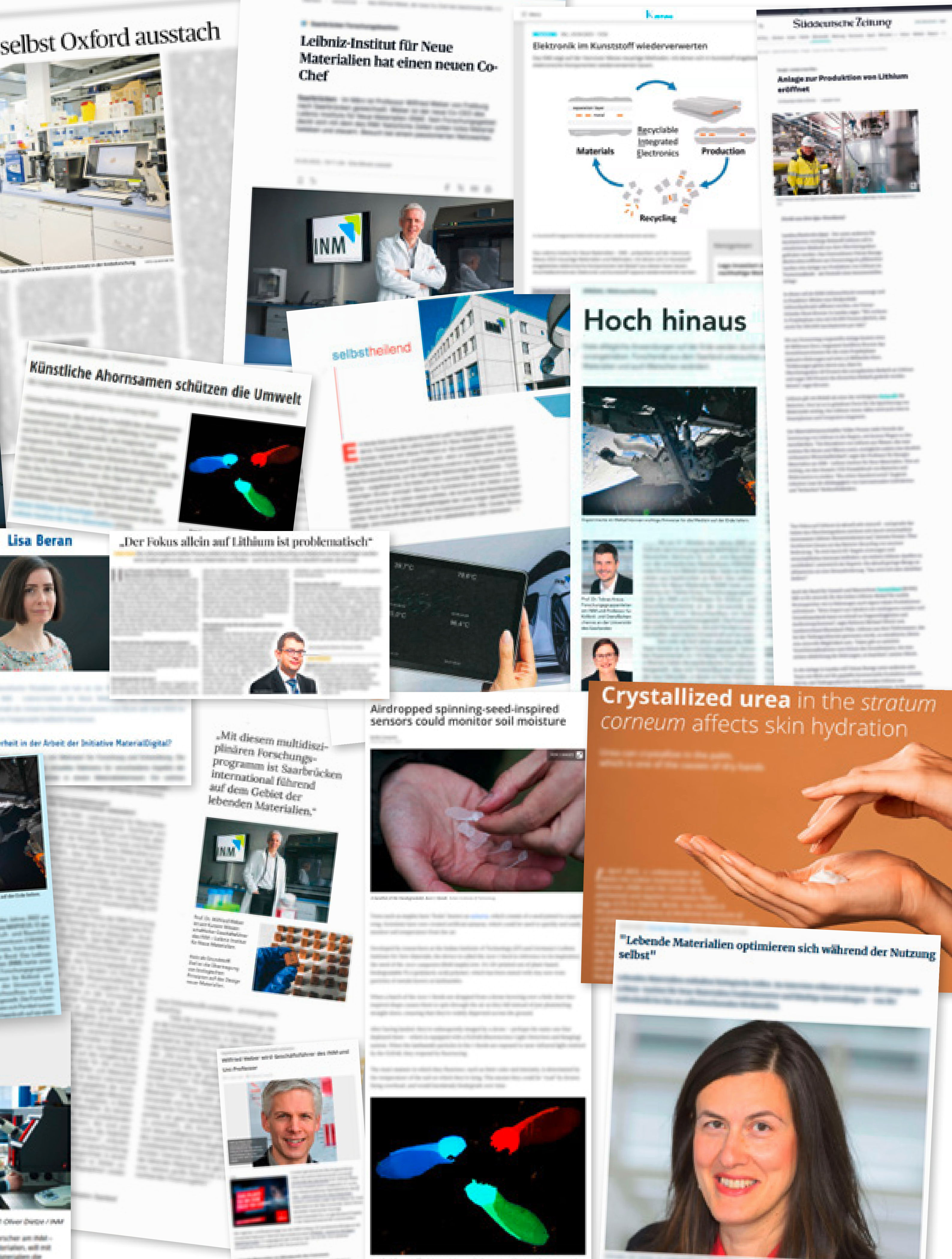
Foto: Istituto Italiano di Tecnologia (IIT)

Die programmierte Unsterblichkeit der Lithium-Ionen-Batterie

Neue Märkte & Technologien

"Das Projekt bringt Daten zu Rohstoffen, Prozessschritten und Zellanalysen zusammen"

Emmy-Noether-Programm: Oskar Staufer will Tarnstrategien von Krebszellen entschlüsseln


selbst Oxford ausstach
Leibniz-Institut für Neue Materialien hat einen neuen Co-Chef
Elektronik im Kunststoff wiederverwerten
Recyclable Integrated Electronics
Materials
Production
Recycling
Süddeutsche Zeitung
Anlage zur Produktion von Lithium eröffnet
INM
selbstheilend
Hoch hinaus
Künstliche Ahornsamen schützen die Umwelt
Lisa Beran
„Der Fokus allein auf Lithium ist problematisch"
„Mit diesem multidisziplinären Forschungsprogramm ist Saarbrücken international führend auf dem Gebiet der lebenden Materialien."
Airdropped spinning-seed-inspired sensors could monitor soil moisture
Crystallized urea in the stratum corneum affects skin hydration
"Lebende Materialien optimieren sich während der Nutzung selbst"

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Iris Maurer (S. / p. 10, 12, 14, 18, 24, 26, 28, 30)

Titelseite / *Front page:*

oben / *top:* Außenansicht des INM / *Exterior view of INM (Henrik Ollmann).*

unten links / *bottom left:* Fluoreszenzgefärbte Bakterienkolonien, die in einem zweischichtigen Hydrogel wachsen. / *Fluorescently stained bacterial colonies growing inside a bilayer hydrogel.*
(Forschungsgruppe Bioprogrammierbare Materialien / *Research Group Bioprogrammable Materials)*

unten rechts / *bottom right:* Spinnfackel von e-gesponnenen Polymerfasern für die Herstellung elektrisch leitender Beschichtungen. / *Spinning flare of e-spun polymer fibers for the fabrication of electrically conductive coatings.*
(Forschungsabteilung Optische Materialien / *Research Department Optical Materials)*

SAARLAND
Großes entsteht immer im Kleinen.

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Geschäftsführer: Prof. Dr. Aránzazu del Campo (Vorsitz),
Prof. Dr. Wilfried Weber, Michael Marx

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