TUM Magazine
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MAGAZINE

MISSION: A HUMAN-MADE LEAF

In search of new materials for the energy transition

RETURN TO TUM

Interview with Nobel laureate and alumnus Johann Deisenhofer

BREEDING GROUND FOR START-UPS

A visit to the Venture Lab in Weihenstephan

Cover: Prof. Johanna Eichhorn (left) and Prof. Ian Sharp are researching fundamental processes in the conversion of renewable energies.

Groundbreaking research, innovative start-up ideas, inspiring alumni, exciting news from teaching, studying, and campus life. This is what our new TUM Magazine offers you every six months as a print edition, and online at any time at: tum.de/magazine

Dear Readers,

PROF. THOMAS F. HOFMANN
President of TUM

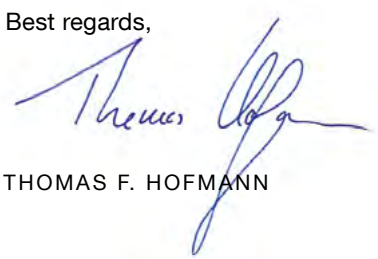
The TUM Sustainable Futures Strategy 2030 is our commitment as a university to becoming as environmentally friendly as possible. One of the key aspects of a more sustainable future is the efficient conversion of renewable energy. The pathways from sunlight or wind to electrical power or battery storage and the transformation into chemical energy resources such as hydrogen must be achieved with minimal energy losses. Our scientists are working on these demanding objectives in initiatives such as the e-conversion Cluster of Excellence. Our title story describes their research into new processes that seek to make artificial photosynthesis a reality. With the insights gained from this work, we aim to deliver crucial impetus to the energy transition and contribute to a drastic reduction in the use of fossil fuels.

In other Clusters of Excellence, our researchers are working on fundamental processes from the origin of the universe to the first building blocks of life, exploring complex quantum technologies, and seeking to gain a better understanding of neurological diseases and finding repair mechanisms for them. We are all confident that these challenging fields of research will continue to receive support in the next funding rounds of the federal and state Excellence Competition and that we will add further clusters in the future. Three new cluster proposals are addressing highly innovative research fields of great importance for the future of humanity. Starting in early 2025, TUM will present the proposals to international decision-making bodies. If successful, they will be submitted to the competition for the title of Excellence University in the summer. Meanwhile, we will continue our bold efforts to develop and improve our TUM, because in our rapidly changing world, the only constant is change itself.

We are also adapting and renewing our communication formats – such as this *TUM Magazine*. It may remind you of *TUM Campus*, our magazine that kept staff and students informed for many years. But this new title, like our former research-centered magazine *Faszination Forschung*, also covers scientific advances. And, similar to the *KontakTUM* alumni magazine, it features contributions from highly successful TUM alumni such as the Nobel laureate Johann Deisenhofer.

This is the first issue of our new *TUM Magazine*. It replaces our three previous titles and will keep you up to date with the most important developments at our university. Whether you are a TUM graduate or are studying, teaching, or working here, have a partnership with TUM, or are simply seeking inspiration from our faculty, researchers, and innovative talents, the reading experience will bring you closer to fascinating individuals and their stories, and yield insights into the continually expanding TUM universe. Happy reading!

Best regards,



THOMAS F. HOFMANN

Content

03 Editorial

06 News

Research

08 Mission: a human-made leaf

At the e-conversion Cluster of Excellence, researchers are exploring materials for the energy transition, drawing inspiration from the principle of photosynthesis.

18 Sustainability requires social equity

Anne Rademacher researches sustainable urban development at the TUM School of Social Sciences and Technology.

20 Humans at the heart of the mobility transformation

An inside look at MCube, Munich's research cluster for the future of mobility.

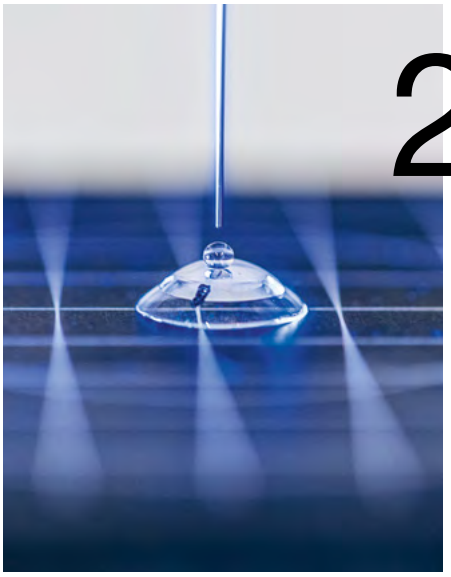
08

24 Versatile mucus

How natural mucus molecules are being used in medicine.

28 Controlling robots easily with ChatGPT

Researchers apply large language models to robotics.



24

In focus

32 The search for dark matter

In an experiment inside the Gran Sasso massif, researchers are striving to find out more about the universe.

Community

34 The dream of a sustainable sailboat
Light, fast, and sustainable: students have built their own sailing boat.

38 TUM in figures
Take a look at recent figures for our university and find out how you can support our development.

40 »We have the privilege of discovering new things every day«
Interview with alumnus and Nobel laureate in Chemistry Johann Deisenhofer.

44 The courage to start and fail
Alumna Sarah Fleischer is thriving with her start-up tozero – but starting a business isn't always easy.

Entrepreneurship

48 Entrepreneurship News

50 Breeding ground for biotech start-ups
A visit to the Venture Lab at the Weihenstephan campus.

International

56 Microalgae for the megacity
TUM's research and teaching contribute to a sustainable future in Singapore.

34

Public Engagement

60 Greater communication expertise
Participants in a new media training course for researchers share their experiences.

62 Learning better with artificial intelligence
At the TUM Center for Educational Technologies, children experience lessons with robots and AI tools.

66 A first-class address

66 Imprint

News

Prof. Alessandra Moretti is using organoids to research how damage to the human heart can be repaired. The ERC will be funding her project with an Advanced Grant.

Additional 19 projects receive European funding

Repair of the human heart and insights into exotic particles are just two of the new projects for which TUM researchers have recently successfully acquired funding from the European Research Council (ERC). These include two Synergy Grants, five Advanced Grants, and nine Starting Grants. In addition, three researchers whose projects are already being funded will receive Proof of Concept Grants to test their potential for marketable innovations. This brings the total number of ERC grants for TUM researchers to 230.

TUM opens commemorative space

TUM critically confronts its history during the National Socialist era. A new remembrance space at the main TUM campus on Munich's Arcisstrasse now commemorates 17 members of the then Technische Hochschule München, who were expelled and persecuted by the Nazi regime. The memorial space also provides information on the Technische Hochschule during the National Socialist era, documenting the personnel, ideological, and institutional changes of the time as well as the instrumentalization of the university in preparation for war. Topics covered include the expulsion of Jewish and "politically undesirable" scientists as well as the revocation of doctoral degrees and the complicity and self-mobilization of students, employees, and professors under the National Socialist regime.

The commemorative site is located on the first floor of the Arcisstrasse / Gabelsbergerstrasse section and is open on weekdays.

Top positions in international rankings

Our university has moved up to 28th place in the QS World University Rankings and to 26th place in the THE Rankings. According to the British magazine Times Higher Education (THE), TUM is once again the best university in the EU. In addition, higher education expert QS Quacquarelli Symonds has listed TUM as the best university in Germany for the last ten years. The evaluation is based among other things on the university's academic reputation, ratio of students to teachers, citation rate, international partnerships, and graduate success rate.

TUM regularly achieves top positions in renowned rankings.

Compressing and transmitting the sense of touch

MP3 and JPG are well known as popularly used audio and image file compression standards. A consortium led by TUM has now developed a similar new codec which can compress and transmit the sense of touch. Its potential uses include telesurgery, teledriving, and online gaming experiences.

Spectacular daycare center for Munich

The "Ingeborg Pohl Kinderoase an der TUM" will be built on Munich's Gabelsbergerstrasse.

Munich is to receive an unrivaled day-care center: a 22-meter timber-frame building designed by the Pritzker Prize winner and TUM professor Francis Kéré will be erected on Munich's Gabelsbergerstrasse, across from the TUM main campus, with the participation of emeritus Prof. Hermann Kaufmann. The five-story building will provide daycare space for as many as 60 children. The structure will feature a greened outdoor roof garden as a play and recreation space. The project has been made possible by the generous support of entrepreneur, sponsor, and TUM Honorary Senator Ingeborg Pohl.

Researchers at the e-conversion Cluster of Excellence are studying ways of improving the efficiency and sustainability of energy conversion. Their work is inspired by the principle of photosynthesis.

Mission: a human-made leaf

TEXT—— *Caroline Zörlein*
PHOTOS—— *Julian Baumann*

1 —— *Prof. Johanna Eichhorn, Prof. Ian Sharp and Prof. Ulrich Heiz (from left) are researching high-tech materials to harness sunlight for chemical reactions.*

It's 2040, and sparkling on the rooftops of apartment buildings, factories, and skyscrapers are the components of a revolutionary system that captures sunlight and extracts carbon dioxide (CO_2) from the atmosphere. The components contain high-tech materials that generate solar power while making the energy available for chemical reactions. Dispensing with battery storage or other intermediate stages, the system converts climate-damaging carbon dioxide into green fuels such as hydrogen and important basic chemicals for industry. The only "waste" byproduct of the process is oxygen.

To bring this future vision closer to reality, researchers at the e-conversion Cluster of Excellence are emulating the principle of photosynthesis. Their research focuses on developing materials known as photocatalysts that have the required characteristics, and systems that function like artificial leaves.

The Sun sends around 944 million terawatt hours of energy to the Earth every year. A small fraction of that amount would cover all of our planet's current energy needs. "At present, solar energy is used mainly to produce energy by heating water or to generate electricity in photovoltaic systems. Both of these forms of energy production can be used for industrial purposes in a second step," explains Prof. Ian Sharp, a materials scientist at TUM and coordinator of the e-conversion Cluster of Excellence. "But photocatalysts can do more than that: they can provide solar energy directly to generate chemical reactions."

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Understanding and improving catalysts

Although natural photosynthesis is a source of inspiration for the researchers, they do not intend to copy it. It is a highly complex process and, with a conversion factor of around 1 percent, it is not particularly efficient. Although sufficient to make plants grow, the process falls far short of what would be needed for technical applications and commercial use. Consequently, the researchers are looking for materials and processes for the efficient and sustainable production of basic chemicals and energy sources. This would make an important contribution to the energy transition and drastically reduce the fossil fuel requirements of industry.

"To efficiently implement artificial photosynthesis in molecular form, we still have major hurdles to overcome. Catalytic processes will play a decisive role," says Ian Sharp. In these processes, chemical reactions are accelerated by a substance – the catalyst – that is neither changed nor consumed. "The focus of e-conversion is on the boundary surfaces, because that is where the catalyst and the reacting modules come together." There are still many unknowns associated with these interfaces. The Cluster of Excellence researchers are seeking to close these knowledge gaps by developing suitable materials and trying to decode molecular and atomic catalytic processes. In this work, the e-conversion project teams are concentrating mainly on semiconducting materials because of their special optical and electronic characteristics: they can capture light efficiently and use the energy to produce negative and positive charges (electrons and holes) in the semiconductor. This makes the energy from the light available for chemical reactions (see infographic on pages 12/13).

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2——*To find suitable materials, the researchers are investigating new types of semiconductors and nanostructures that are ideal for photocatalysis.*

3——*Catalysis specialist Prof. Ian Sharp is developing tailor-made nanocoatings to control chemical processes.*

Inspiration from nature

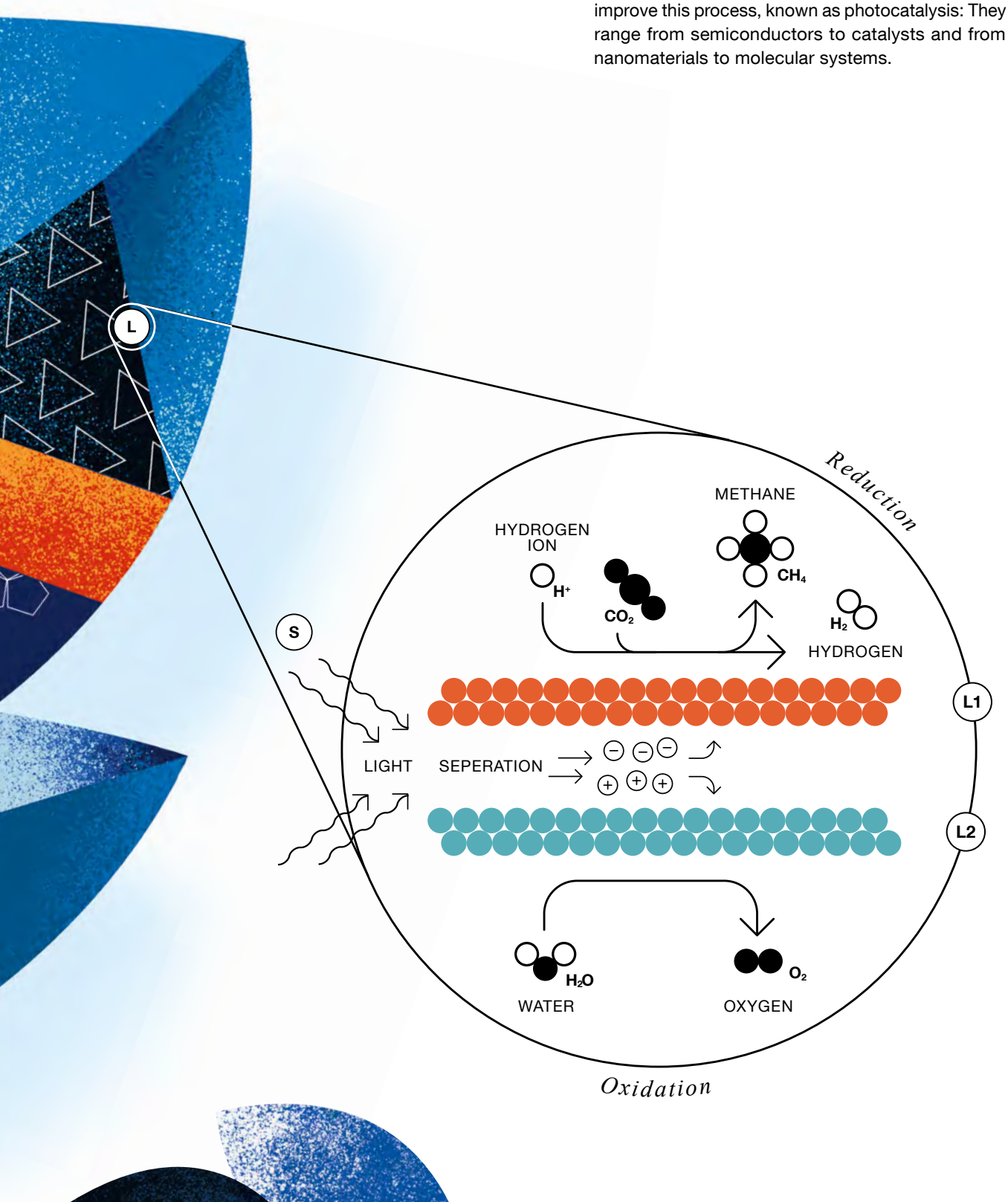
To obtain fuels from the energy carried in light, the researchers at the e-conversion Cluster of Excellence are applying the fundamental principles of photosynthesis in a simple form:

(S) Solar energy is captured and and transferred to negative and positive charge carriers. Light-induced charge separation (L) is essential here:

(L1) Through reduction, the initial materials of carbon dioxide (CO_2) and hydrogen ions (H^+) react directly to form methane (CH_4) and hydrogen (H_2) or other fuels.

(L2) In oxidation, water is split and oxygen (O_2) is released. Hydrogen ions (H^+) and electrons (e^-) are also produced and are available for reactions.

(M) Materials are being researched to further improve this process, known as photocatalysis: They range from semiconductors to catalysts and from nanomaterials to molecular systems.



Materials scientist Ian Sharp is working with his team to study various aspects of photocatalysis. A major part of their research relates to CO_2 reduction. If this is successful, sunlight could be used to convert carbon dioxide into industrially important molecules such as hydrocarbons or alcohols. However, the concentration of CO_2 in the air is low. "To make the conversion possible through catalysis, we have therefore developed a tailor-made nanocoating," explains Prof. Sharp. "With this trick, we increase the CO_2 concentration at the catalytic surface and make the gas more reactive." To convert the CO_2 efficiently into a desired product in the next step, the perfect material is needed. An examination of the list of criteria for the material shows that it must be a true jack of all trades: it has to be long-lasting and chemically stable, but also capable of absorbing most of the visible spectrum efficiently and converting the energy into electrical charges. In addition, it must be able to catalyze only the desired chemical reaction and must not contain any toxic elements.

Utilizing nanoeffects

The periodic table offers an endless list of combinations. To speed up the search for new materials, the researchers are using high-throughput screenings and applying artificial intelligence to evaluate potential materials. "In addition, theoretical calculations deliver key indications of whether certain combinations of elements will be stable and will exhibit the desired optical characteristics," says physicist Johanna Eichhorn. The professor at the TUM School of Natural Sciences uses various methods to create entirely new materials in the laboratory and characterize the physical principles underlying the energy conversion processes. One of her principal research interests is photoelectric performance. As she explains, "That's how we describe how efficiently a material converts light into electrical energy,and at the same time we can observe the stability of a material."

However, the catalytic characteristics of a material are also determined to a large extent by its structure and physical properties. "We look very closely at the crystal structures, and especially areas that deviate from the regular patterns," says Johanna Eichhorn. "These are often the docking points for molecules, and consequently the place where catalytic processes begin." In addition, these irregularities in the crystal lattice influence the paths taken by electrons or "holes" – and, as a result, the reactions as well. To obtain a material profile with the greatest possible precision, the researcher uses a special scanning microscope to zoom down into the nanostructures on the semiconductor surfaces and map the local differences. At the same time, the device gives her insights into the electronic characteristics – at the very same location. "In that way, we can correlate the structure and properties at a nanoscale level. That is extremely valuable because it gives us a macroscopic view of the effects," explains the physicist. "In case after case, we see that nanoeffects can have a positive impact on the perfor-

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4—— *The e-conversion teams are investigating how the structures of materials positively influence photocatalysis.*

5—— *Physicist Johanna Eichhorn has been appointed to the Rudolf Moessbauer Professorship for Nanoscale Microscopy and Spectroscopy of Energy Materials at TUM.*

5

»Nanoeffects often have a positive impact on the performance of a material.«

——*Johanna Eichhorn*

mance of a material. That is why basic research in this area is so important." Ideally, Johanna Eichhorn would like to use the insights gained to improve the stability and efficiency of semiconductors for photocatalytic water splitting and, as a result, to optimize hydrogen production.

Emiliano Cortés is also conducting research into the impressive impact of nanoeffects. The physicist at the Nano Institute at the Ludwig-Maximilians-Universität München, who is leading one of the 53 research groups in the e-conversion Cluster, is developing so-called supercrystals. These are gold particles around 100 nanometers (nm) in diameter which have self-organizing properties and form tightly spaced and regular patterns on a surface at a distance of just 5 nm between particles. Known as plasmonic structures, these arrangements have special capabilities: they can act like powerful lenses to focus sunlight and absorb far more energy from the incoming light than a surface completely coated with gold. "Strong electrical fields called hotspots arise between the gold particles," says Prof. Cortés. "When we place platinum nanoparticles at those precise locations, this generates a highly efficient conversion of formic acid into the energy source hydrogen." This system has gained the group the current world record for rapid production of H_2 using sunlight.

Decoding chemical reactions

The tiny platinum clusters are also at the center of the research conducted by Ulrich Heiz' team at TUM. The professor of physical chemistry wants to determine the ideal number of platinum atoms needed by a nanoparticle for the efficient production of hydrogen. "Along with making it possible to produce the catalytically active clusters to atomic-level accuracy, our high-tech equipment helps us to study how to optimize their position on a surface," explains the researcher. The systematic studies at the e-conversion Cluster of Excellence have also revealed that photochemical reactions follow different rules than previously assumed. "We have discovered that the long-familiar patterns that govern electrochemical processes, for example, do not apply to photocatalysis. Photochemistry opens up entirely new reaction pathways," says Prof. Heiz. Those who know and understand them will be able to discover, customize, or design suitable materials. "Every new piece of knowledge improves our understanding of photocatalysis and thus brings us incrementally closer to a real-world application," he says. "The e-conversion teams are applying multi-layered approaches, delving deep into the wealth of ideas in various specialized fields, and are extremely well networked. This is an excellent basis for innovation." And it is exactly what is needed to shape the energy transition and make a sustainable future a reality.

More about energy research at TUM can be found at tum.de/energy

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6—— *The researchers have shown that light-driven reactions follow different patterns.*

7—— *Interfaces and surfaces of materials are of particular importance in the research at the e-conversion Cluster.*

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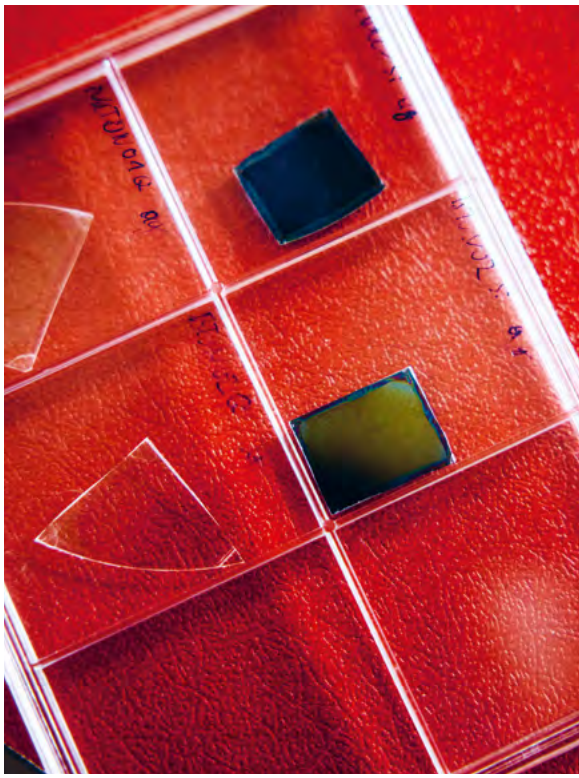

At the newly created Chair of Sustainable Urban Environments, Anne Rademacher researches the interactions between sociocultural dynamics and sustainable urban development.

Sustainability requires social equity

TEXT—*Andreas Schmidt*
PHOTO—*Andreas Heddergott*

Prof. Anne Rademacher's research focuses on the relationship between sustainability and social practice.

When we think of sustainable cities, we think of green spaces and vertical farming, e-mobility and solar systems. Anne Rademacher's starting point is different: "I'm not asking about green roofs, but about the quality of our social interaction," she says. "People can't take responsibility for the environment unless they can take care of each other."

After graduating in environmental studies, Anne Rademacher completed her PhD in cultural anthropology and environmental sciences at Yale University in 2005. She then worked in the field of international development for many years, including times of conflict, in locations such as Kathmandu in Nepal. In crisis situations like those, she says, the link between social justice and sustainable urban development becomes particularly clear: "For me, therefore, the key to more sustainable cities always lies in promoting solidarity and social equity." At TUM, she now aims to develop tools and methods to research the relationship between sustainability and social practices and make this connection clearer.

Developing independent questions

"As a professor and researcher, I have the freedom to ask my own questions," she says. "If I think a topic really makes a difference, it's my job to find out more about it. That's also how I see my role as a teacher: I want to empower students to develop their own questions and find creative answers to them."

Anne Rademacher's research topics range from migration and urban housing rights to the social and material practices of environmental architecture. She is also interested in urban rivers and waterways. "I grew up in Pittsburgh, a city between three rivers," she says. "Later, rivers also became an important part of my research. I worked for several years in Kathmandu, Nepal, trying to understand the connections between river restoration and social transformation. I found the two to be much more tightly linked than we usually assume." For Rademacher, rivers and waterways are important nerve centers of cities: In addition to supplying water and being used for transport, rivers like the renaturalized Isar contribute to the quality of life in cities.

However, that was not her main reason for accepting the appointment in Munich: "TUM is part of a vibrant community of environmental researchers in Munich, and an internationally renowned center for environmental research. In tandem with its unique range of subjects, it is the ideal place for me to conduct research and teach about sustainable urban spaces."

What attracts scientists to TUM? What applications do they see for their work, and how has their career progressed so far? In the NewIn video series, we introduce our newly appointed professors and reveal what they are passionate about – both in and outside of work: tum.de/newin/en

Mobility in Munich is to become intelligent, climate-friendly and affordable. In the MCube cluster, researchers are investigating the best way to achieve this objective, with the participation of those who are directly impacted: the people of the Munich metropolitan area.

Humans at the heart of the mobility transformation

TEXT —— *Moritz Müller*

When it's Oktoberfest time in Munich, even experienced motorists can be overwhelmed as tourist rickshaws, delivery vans, and large trucks join the rush-hour crush. The sidewalks overflow with pedestrians, who sometimes walk out into traffic on their way to the festival at the Theresienwiese.

Could an autonomous vehicle securely navigate through all this commotion? In a demanding empirical test, researchers at TUM have shown it's possible. For two days in September, test vehicle EDGAR hit the streets as a festival conveyance called the "Wiesn Shuttle." EDGAR made its way along a 1.8-kilometer route through the heavy traffic completely autonomously. The minibus had plenty of technology on board, with 14 different cameras and sensors are arrayed around the vehicle. The data they collect is processed and interpreted by a high-performance computer using sophisticated software with artificial intelligence.

EDGAR was developed by a team led by Markus Lienkamp. Lienkamp, TUM Professor of Automotive Technology, works with researchers from various disciplines at The Munich Cluster for the Future of Mobility in Metropolitan Regions, or MCube. MCube addresses topics ranging from autonomous driving and electromobility to political circumstances and to redesigning public spaces. "The mobility transformation can succeed if we get cars off the streets and viably expand local public transportation, as well as active forms of mobility like cycling and walking," says Prof. Lienkamp.

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1 —— *Fewer cars, more green spaces: in summer 2023, streets in Südliche Au and Walchenseeplatz in Munich were converted into temporary recreational areas.*

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»We imagine innovations that always start with humans, not technology.«

——*Oliver May-Beckmann*

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2——*The autonomous "Wiesn Shuttle" was in operation for two days at the Munich Oktoberfest.*

3——*The EDGAR test vehicle navigates safely through city traffic.*

4——*With the help of 14 different cameras and sensors as well as artificial intelligence, EDGAR has mastered the demanding test.*

The "Wiesn Shuttle" project was designed to point to the potential of autonomous driving in public transportation, especially in times of skilled labor shortages, but also to show the public how autonomous driving works. That's why instead of being assigned to an isolated, secret test route, EDGAR took the round trip around the Theresienwiese festival grounds. Two pop-up bus stops served as information stands for those who wanted to know more about the technology and the work done by the mobility cluster. Over 150 passengers and 600 visitors gained a first-hand impression of autonomous mobility.

Stimulating curiosity, breaking down prejudice

Placing the focus on humans, raising curiosity, and breaking down prejudice are also central elements of the other projects in the MCube Cluster. "We're taking a radical approach by imagining innovations that always start with humans, not technology. We work closely with society and the public, we involve small and medium-sized companies, and we communicate our solution strategies to municipal and regional authorities throughout Germany," says MCube Managing Director Oliver May-Beckmann.

The substantial importance of accompanying and communicating the Mobility Transformation is demonstrated by the project "Car-reduced quarters for a more livable city" (aqt). From June to October 2023, various measures for reducing traffic in the Südliche Au (Kolumbusstrasse) and at Walchenseeplatz (Landlstrasse) in Munich were implemented and scientifically evaluated. Not everyone was in favor of the idea: The concerns of people who depend on their cars every day or who appreciate the convenience of having a parking space right in front of their doors have to be heard as well. This is also reflected in the results of the online surveys held at the household level both before and after the implementation of the measures. While, for instance, a clear majority in both neighborhoods said they were in favor of permanently converting parking space into green spaces, approximately one third of the respondents voiced opposition to such a move. The surveys also highlight the importance of appropriate communication: around one-third of those surveyed said they did not feel adequately informed. The data and findings will now be integrated directly into further research projects and shared with, and processed by, the authorities involved.

The German Federal Ministry of Education and Research is also convinced that the general public must be included in the transportation transformation. The Ministry is financing a second funding round of approximately €15 million over three years, beginning in 2025. During this phase nine additional projects involving development of sustainable mobility solutions will be implemented, to include car sharing on private properties, autonomous mobility models for rural areas, and analysis and optimization of urban traffic measures.

Virtual testing of traffic measures

For example, the project "DatSim 2.0: Digital Mobility Twin Munich" aims to map the traffic conditions in the Munich metropolitan region using detailed simulations that will make it possible to test various traffic measures virtually. This facilitates precise analysis of changes in the flow of traffic, noise pollution, pollutant emissions, and the efficiency of the city's emergency response system. Municipal and transportation authorities will thus directly receive the information that helps them implement the right measures. The project is designed to generate a comprehensive data platform as well as expertise in simulation that will also benefit other projects.

Find out more about mobility research at TUM
tum.de/mobility

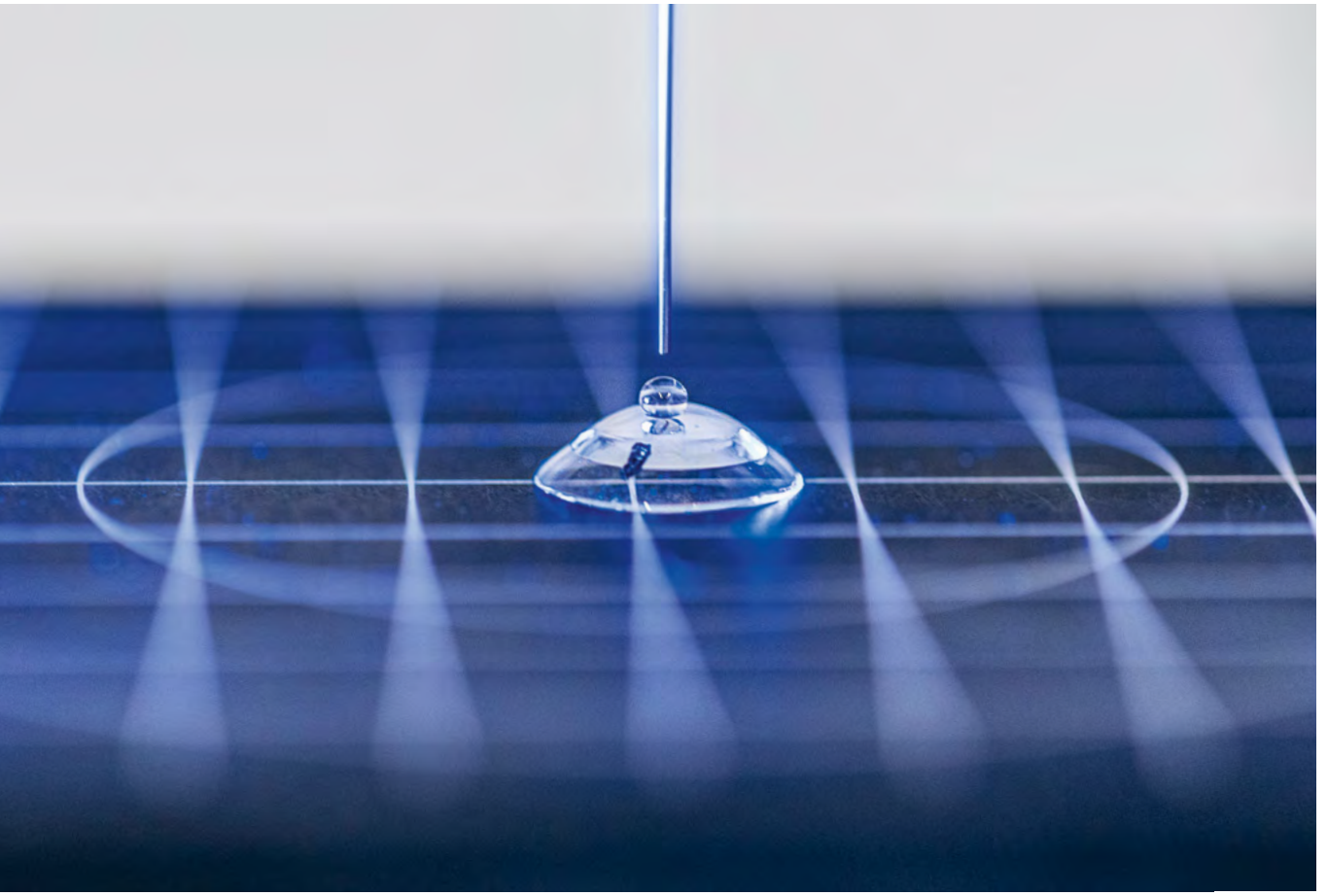
The Munich Cluster for the Future of Mobility in Metropolitan Regions is led by TUM and consolidates leading expertise in mobility from science, business, the public sector, and society under a single concept: "Together we can make possible." MCube investigates the broad field of future mobility, tests prototypes, and develops innovations for Germany and the world.

Blinking, swallowing, digesting – many of our bodily functions would be impossible without a protective mucus layer, consisting of hydrophilic molecules called mucins. Researchers at TUM are using these mucins to develop a variety of materials for medicinal applications.

Versatile mucus

TEXT —— *Carolin Lerch*

Prof. Oliver Lieleg conducts research at the Munich Institute of Biomedical Engineering (MIBE), an Integrative Research Institute at TUM. At MIBE, researchers specializing in medicine, the natural sciences, engineering, and computer science join forces to develop new methods for preventing, diagnosing, or treating diseases. The activities cover the entire development process from the study of basic scientific principles through to their application in new medical devices, medicines and software.



In laboratory tests, the mucin-based coating significantly improves the wetting of contact lenses and prevents damage to the cornea caused by friction.

Making contact lenses easier to wear

There are approximately four million contact lens wearers in Germany. However, for patients with dry eyes suffering from an insufficient natural protective lubricant film between the eye and the lens, wearing contact lenses can be uncomfortable and may even result in corneal damage. Oliver Lieleg, Professor of Biopolymer Materials at TUM, and his team have developed a mucin coating which is only a few micrometers thick and which protects the eye from corneal damage by reducing friction between the lens and the eye.

The team purified mucins to coat both hard and soft contact lenses. The researchers tested the coated lenses in the lab on dissected pig eyes. The coating improved the interaction of the lenses with water. The researchers were also able to show under the microscope that the cornea remained intact even after stress tests with rubbing. The lenses stayed transparent, and the mucin layer even made them resistant to the fat deposits that occur naturally in the tear fluid; otherwise, such deposits can result in clouding of the contact lenses after extended periods of use.

Targeted release of active ingredients

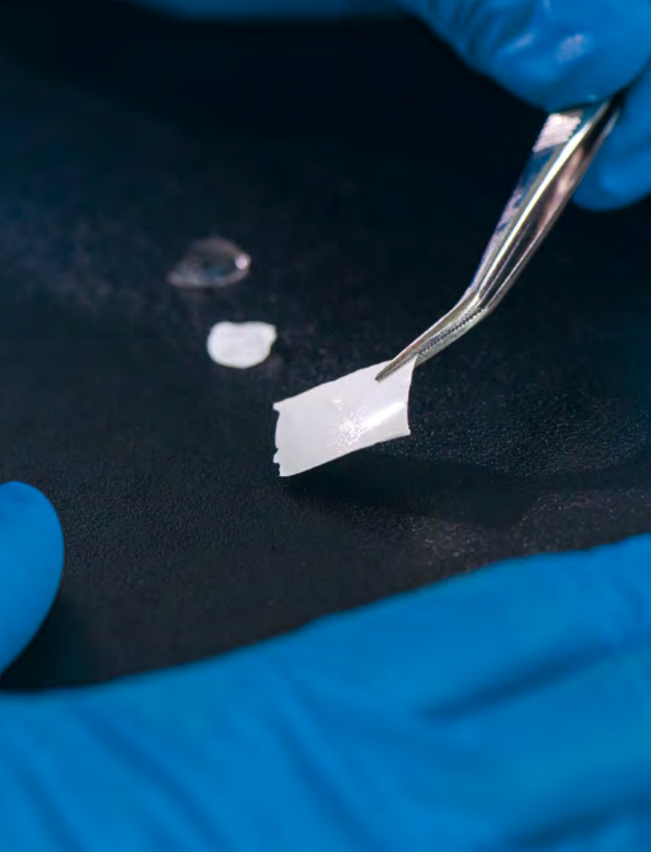
When we inhale tiny dust particles, pathogens, or pollutants, the mucus layer in our respiratory tracts captures some of them. For prevention, diagnosis, and medical applications, it is thus important to understand exactly how harmful particles interact with the mucus layer. Moreover, researchers are utilizing the moist properties of the mucus layer to package medications in such a way that they are released precisely at the mucus layer.

The researchers work with microfluidic chips, a model system in which they apply a gel made of mucins. This allows them to investigate the interfaces between the mucus layer and fluids, as in the intestines, and between the mucus layer and the air, as in the bronchia.

They used the model system to investigate what happens when the mucin layer is contaminated by respirable dust. The tiny particles occupy molecular binding sites in the mucin gel which are intended to capture other molecules, diminishing the barrier effect.

In a current project, the TUM researchers have been working together with scientists from Ludwig-Maximilians-Universität München to develop tiny packagings for active ingredients which can be inhaled. They have designed small spheres (microparticles) which they can use to encapsulate even smaller drug carriers (nanoparticles). The charge and the structure of the microparticles determines their docking and decomposition process on the moist mucus layer. Among the various materials tested, the most successful one was lysine packaging, since this positively charged amino acid performed best in binding to the negatively charged mucus.

The researchers are testing the coating for intubation tubes in the laboratory.



In the future, mucin-based dressings could be used for internal applications such as wound closure prior to suturing.

Closing and healing wounds

Conventional plasters are not suitable for treating injuries to soft tissue, such as the tongue, or surfaces such as the intestine. The alternative is a mucin-based healing dressing which adheres to moist soft tissue without damaging it, fights inflammation, can release active ingredients in a targeted manner, and then decomposes after use. Self-decomposition can be particularly useful in the context of post-operative use to protect internal wounds that are no longer accessible after surgery has been completed.

The dressing consists of two layers. The top side contains mucins which have an antibacterial effect; in addition, a biodegradable, synthetic polymer gives the dressing a certain amount of stability. The bottom layer contains substances including hyaluronic acid, known for its ability to bind water and promote wound healing, and dopamine, which ensures adhesion to moist tissue. The researchers can also integrate active ingredients such as antibiotics into the bottom layer, which are then released towards the wound.

A prototype of the dressing is currently being used for laboratory purposes. The team is now working on modifying the composition of the components to make the thin film more stable, so that the dressing can be adapted to additional application cases. The researchers are also considering the development of a wound-healing suture with a mucin coating for closing wounds.

Prof. Oliver Lieleg's team has been developing and optimizing the materials over the course of several years, and tests prototypes under laboratory conditions. The researchers use these prototypes to assess functionality in cell cultures and on animal tissue specimens. They are also investigating certain parameters, such as sterilizability, which go beyond basic research but are necessary for later application. Further steps and clinical studies will be necessary before clinical approval for future use of the applications on patients.

Preventing respiratory tract damage

Artificial respiration can save lives, but endotracheal tubes can also cause complications resulting from tissue damage or infection. The team developed a mucin coating for endotracheal tubes in order to reduce the risks involved in intubation.

The team applied four different coatings to endotracheal tubes. The respective coatings were based on mucin, hyaluronic acid, polyethylene glycol, and lysine-dextran. All four coatings reduced friction on tracheal tissue and prevented tissue damage. However, the mucin-based coating was significantly more effective in preventing deposits of cells, bacteria, and fats.

How can you get drones to fly in sync with music in a small space without colliding? A team led by TUM Prof. Angela Schoellig has used ChatGPT to prove that this type of large language model can make it possible for humans with no specialized knowledge to safely and securely control robots in the future.

Controlling robots easily with ChatGPT

TEXT —— *Andreas Schmitz*

It only takes a few minutes to prepare a small airshow with six drones. Doctoral student Martin Schuck calls up ChatGPT, enters a song title in the text field and asks the Artificial Intelligence tool to suggest a choreography. The screen now shows a simulated airfield with six drones flying to the music in circles. Then Martin Schuck uses another algorithm to check whether or not the suggested flight paths are feasible – and that's it. Soon afterwards, the palm-sized drones take off from the floor.

Martin Schuck is a doctoral candidate at the Chair of Angela Schoellig, TUM Professor of Safety, Performance and Reliability for Learning Systems. She and her team want the example of the drone choreography to demonstrate the potential of large language models such as ChatGPT in the context of robotics. Accordingly, they have developed SwarmGPT, which makes it possible for the layman to program swarms of robots.

The researchers use large language models to develop choreographies for several drones.

»Using large language models as an interface will keep getting better in other scenarios, too.«

——*Angela Schoellig*

Angela Schoellig is Humboldt Professor for Security, Performance and Reliability of Learning Systems at TUM.

In the Chair's laboratory, the research team has installed six ceiling-mounted cameras in a room measuring around 40 square meters and three meters high. Crosses are marked on the floor with electrical tape to indicate the starting positions of the drones. Once the computer has verified a possible choreography, they can take off. The cameras detect the position of the quadrocopters, which are equipped with four propellers and motors, 200 times a second, and the system compares them with the desired position. As many as nine drones can now fly simultaneously without colliding with one another thanks to the safety filter SwarmGPT, specially developed by the researchers. Without the special safety filter, only one in four demonstrations would be accident-free.

Prof. Angela Schoellig combined ChatGPT with the safety filter for the "Dance of the Flying Robots." "The ChatGPT AI tool was primarily created to generate texts, but it can also suggest choreographies," says the professor. "However, it starts off knowing nothing about the properties of drones and the physical limits for the flight paths, so of course it makes mistakes."

The additional safety algorithm SwarmGPT closes this gap and maps out flight paths for the proposed choreography so precisely that mid-air collisions are avoided. Drones can even fly towards one another diagonally. The tool generates the processes in the air while serving as an interface between robots and humans, who do not require any expert knowledge.

Programming without expert knowledge

When Prof. Schoellig began her drone research around 15 years ago, everything took longer than it does today. It took more than three years to develop the first six choreographies for six drones and get them up and running. "ChatGPT has brought about a quantum leap," says Prof. Schoellig. Today, it takes the researchers only around five minutes to develop a safe choreography for 30-second music clips with three drones. Over the past three months, the researchers have experimented with over 30 choreographies for up to nine drones. The more drones that are added, the more time ChatGPT needs for its calculations and the longer it takes to propose a choreography. But Prof. Schoellig is certain: "The concept is scalable."

This kind of interface using ChatGPT could also be useful in other application areas in the future: The success rate for robots that use voice control to grasp objects, lay cables, or open doors is currently only 63, 56, and 80 percent respectively. For Prof. Angela Schoellig, this is an incentive: "I assume that our approach will keep getting better in other scenarios, too." Soon, it may even be possible to easily reprogram suction-based and industrial robots by voice command with no need for programming skills at all.

Launch of the Robotics Institute Germany

Germany's leading robotics locations have joined forces to found the Robotics Institute Germany. The aim is to establish a central point of contact for AI-supported robotics in Germany, to pool available resources for collaborative research, to become internationally visible, and to promote young talent. Along with TUM, 13 other universities, research institutes with a focus on robotics, and associated partners are participating. The coordinator is Prof. Angela Schoellig. The project, which started on July 1, 2024, will be funded by the Federal Ministry of Education and Research with 20 million euros over the next four years.

The search for dark matter

PHOTO—— *Astrid Eckert*

Only a small portion of our Universe consists of “visible matter” such as atoms. The rest is dark matter. The nature of this dark matter is among the greatest enigmas of modern astrophysics. In the search for an answer to this question, researchers at the Collaborative Research Center SFB 1258 and the ORIGINS Cluster of Excellence are building better and better experiments. One of these is CRESST, located far beneath the Gran Sasso massif in Italy’s Apennine mountains, where it is well protected from possible background signals.

The photo shows Dr. Raimund Strauss, researcher at TUM, installing the detectors in the innermost part of the CRESST experiment. The detectors use ultra-pure crystals cooled to temperatures close to absolute zero. Dr. Strauss and his team are joining many other researchers around the world in the search for dark matter particles, which leave tiny measurable traces in the crystals. Successfully identifying such traces of dark matter would be a giant step towards a better understanding of the matter that makes up the universe.

Even during exam time, Tim Raible (l.) and Laura Drexler worked on their sailboat in the MakerSpace in Garching.

Lightweight, fast, and as sustainable as possible: That is the profile of a racing sailboat designed and built by a group of TUM students. Their objective is to win a university sailing cup in the Adriatic Sea off the Italian coast.

The dream of a sustainable sailboat

TEXT——*Undine Ziller*
PHOTOS——*Sebastian Kissel*

Benjamin Wittmann (r.) has long dreamed of building a sailing boat. He has realized this dream with Team Impetus.

A bang, a lurch, then both sailors are overboard. The rudder is cracked and bent in two. At right angles to the boat's course, the broken board catches the water and puts a sudden end to the race through the Mediterranean. The boat belonging to the student initiative Impetus has to be towed back to the harbor at Trieste before the race has even started.

Every September, student sailing teams from throughout Europe compete against one another in the 1001VELAcup in Italy. As the most important requirement to qualify for the Cup, the hulls of the small boats have to consist of at least 75 percent recyclable materials or natural fibers. TUM students took part in the race for the first time in 2024, when the Impetus team joined the contest for the fastest and most sustainable sailboat with a skiff named "Schickeria", which they had designed and built themselves.

Conventional sailboats are made of fiberglass-reinforced plastic with epoxy resin. "This ma-

Laura Drexler (l.), Benjamin Witmann, and the Impetus students rolled their sleeves and carried out most of the production steps themselves.

terial is extremely easy to shape and work with," says Tim Raible, one of the sailors and a student in the Master's program in Management and Technology at TUM. "However, there are no wide-scale recycling methods; the best you can do with it after its end of life is to shred it and use it as filler material."

When designing their boat, the students wanted to go one step further towards sustainability, and combined basalt fibers with a recyclable resin. This has the advantage that the components can be separated, and then reused. The students also made sure to look out for alternatives during construction; instead of milling a negative mold from a giant block of plastic, generating large amounts of waste in the process, the team decided in favor of a 3D-printed model for the hull of the boat. For the time being, the materials used are still more expensive than the alternatives, the design principle is more complicated, and there is no practical way to recycle the hull. "But we want our prototype to demonstrate the possibilities in boat building when it comes to closed-loop recycling," says Tim.

Working together at the MakerSpace

The idea of a sustainable sailboat originated with Benjamin Wittmann. While conducting a tour of the MakerSpace, a high-tech workshop of UnternehmerTUM in Garching where the Impetus sailboat is currently taking shape, Benjamin recalls traveling the coasts of Europe in his parents' sailboat as a child. Aged just seven, he took his first sailing course on Lake Starnberg near Munich. "I always wanted to build my own boat. I had no interest whatsoever in rockets or race cars," he recalls.

After gaining his Abitur (Baccalaureate), Benjamin decided to study Mechanical Engineering at TUM. Since then, he has been turning the dream of his own racing boat into a reality – albeit more as a hobby, as he admits. Realizing that he would not be able to make any more progress alone, he contacted the TUM Chair of Carbon Composites. Academics at the Chair provided Benjamin with specialized support, and also suggested to him that he launch a student initiative. He found interested colleagues via social media, and in the summer of 2023 the sustainable sailboat project was ready to leave port.

Today, around 50 students from a variety of disciplines are working on the Impetus project: The participants do everything themselves, from the design work, search for the best fibers, and 3D printing of individual components all the way to the woodwork for the hull. During the weeks before the start of the 1001VELAcup in Trieste, they worked at the MakerSpace almost every day despite the pressure of exams. Whenever the wind at Lake Starnberg was right, they practiced for the race.

One of the initiative's participants is Laura Drexler, currently in the Master's program for Aerospace at TUM. Working in an Impetus team, she generated a detailed CAD model for the boat's hull and investigated various load cases using finite element analysis. Based on the results, the students were then able to determine where bracing was necessary and where the mast and sail were to be anchored. "I think it's incredibly cool to work on a project like this and to learn so many new things," says Laura. "Now looking at the finished boat, it's fascinating to see what we've created together from scratch."

New design in no time

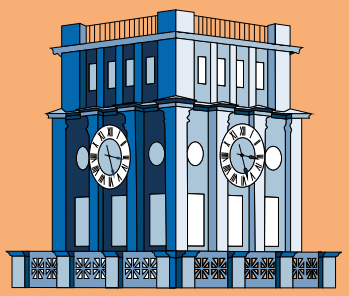
Experimenting, tinkering, and accepting failures were all part of the job when working on Impetus. Even when the rudder broke at the 1001VELAcup, the team wasn't discouraged: "We did more than just repair the parts; we started over and completely redesigned them to repair the defect. We laminated the 3D-printed parts with our composite material, making it possible to build even complex geometries quickly and accurately," Tim says after the competition.

Ultimately the Impetus students finished fifth among nine competitors. "The boat was very fast, especially when the wind was strong, and it felt good and solid," says Tim. He's satisfied, even if the team didn't manage to come in first: "We came to the starting line with a boat that was an entirely new construction. The teams that finished ahead of us have already been working on their boats for several years."

As a reward for all their efforts, after the competition the students will spend a week on Mallorca – sailing, of course. And after the well-earned break, the sustainable sailboat project will continue in the winter semester: "We aim to participate in another student sailing competition, this time for sustainable foiling boats," says Tim. "And of course, that means we'll be building another boat..."

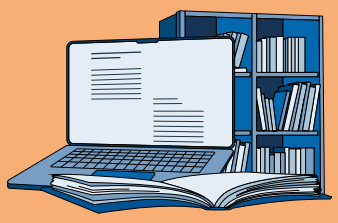
TUM in figures

tum.de/facts



53,000

students are enrolled at TUM according to preliminary figures. 36 percent of them are female, 45 percent come from abroad.



10,595

publications in 2023.

>670

professors research and teach at TUM.

>70

start-ups

are founded at TUM every year.

19

Nobel Prizes

have been awarded to TUM professors and alumni since 1927.

>12,000

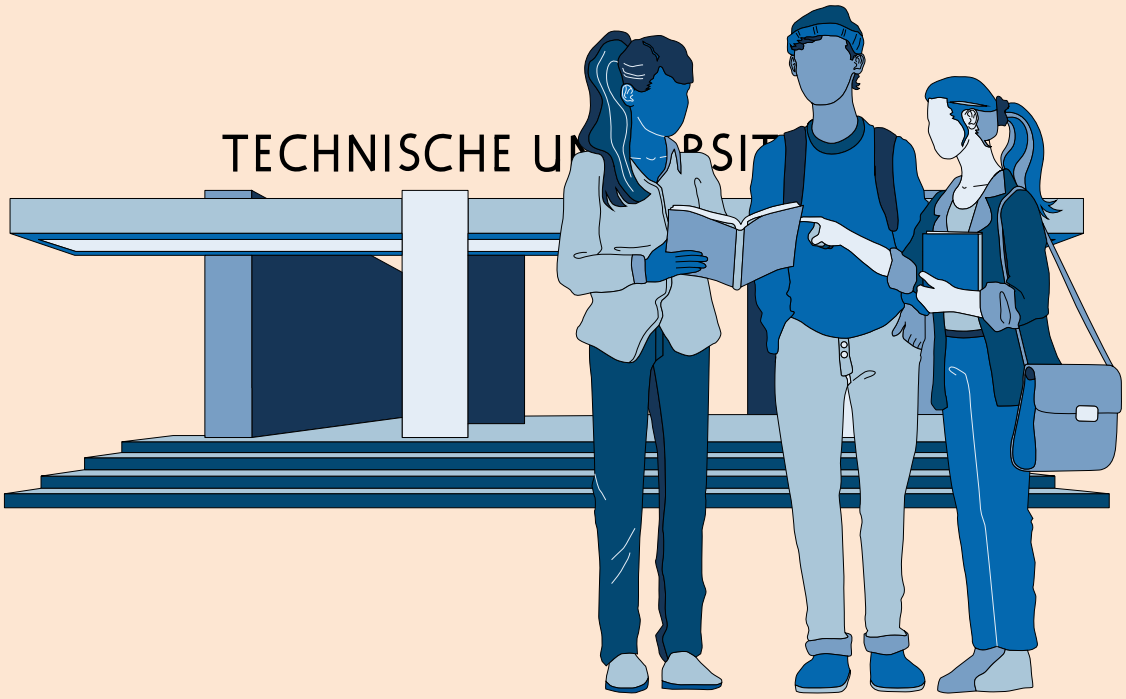
employees are working at TUM and its university hospital.

230

ERC Grants from the European Research Council (ERC) have been granted to our scientists.

>100,000

alumni make up our worldwide network.



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In 1988, Johann Deisenhofer was awarded the Nobel Prize in Chemistry together with his doctoral supervisor Robert Huber and Hartmut Michel. We spoke to him on the occasion of his golden PhD jubilee at TUM.

»We have the privilege of discovering new things every day«

INTERVIEW—*Sabrina Eisele*
PHOTO—*Astrid Eckert*

Professor Deisenhofer, you grew up in a small village in Bavaria on your parents' farm. What sparked your passion for science?

The expectation was, of course, that I would one day take over my parents' farm. But I never really found that appealing, even at a young age. At school, I found science relatively easy. I soon started reading on my own, and there was one book that has stayed with me to this day – "The Nature of the Universe," a popular science book on the basics of astronomy by Fred Hoyle. It contained the state of knowledge of astronomy in the 1950s and was incredibly well written. Reading it opened up a whole new world for me. That's when my dream of becoming an astronomer was born.

Yet after high school, you decided to study physics instead. Why was that?

Many people I spoke to convinced me that it would be better to start with a less specialized subject. Physics would give me a solid foundation to build on later. So it was a practical decision.

Growing up in Bavaria, Munich is an obvious place to study. So the options were TUM and LMU. What was the deciding factor?

Rudolf Mößbauer, the 1961 Nobel Prize winner, had been appointed professor of physics at TUM in 1964. This strengthened TUM's position as a center of physics research in Germany and attracted students from all over the country – and I was one of them. Half of Germany studied here! It was an incredibly exciting time.

Did you have the opportunity to experience Professor Mößbauer yourself?

I went to a few of his lectures, but to be honest I didn't understand much at the time (laughs). Overall, I remember my first days at TUM as very challenging, especially after 18 months of mili-

tary service, during which I had forgotten a lot of what I had learned at school. In any case, the first few semesters at TUM completely turned my view of science upside down.

In what way?

I realized that I had a romantically idealized view of science. I always thought that if I only kept learning and learning, I would eventually know everything, at least within a limited field. At TUM, however, we were taught that while we may know a little, there is so much more that we don't know. I came to understand that my youthful dream of becoming a scientist who knew everything was completely unrealistic.

What is your view of science today?

As scientists, we will never know everything. But we have the privilege of discovering and learning new things every day. This is actually far more beautiful than anything I imagined as a young person.

You then began your doctoral studies with Professor Robert Huber, also a TUM alumnus...

Yes, I happened to hear that there was a young professor at the Max Planck Institute for Protein and Leather Research who was putting together a new group to research into biophysics. I wanted to meet him, so I made an appointment.

How was your first meeting?

He was very different from what I had imagined. He was relaxed and down-to-earth, and he spoke Bavarian, not standard German. There was a rucksack and hiking boots in his office, so he obviously went to the mountains a lot. These were things that quickly won me over. He was also only six years older than me. In his group, people addressed each other informally, which was quite unusual at the time. In addition, his approach to research was very innovative and inspiring. He was a pioneer. You could count the number of protein structures known at that time on ten fingers, and he had contributed to one of them. It seemed like an environment where you could learn and experiment a lot. Fortunately, he accepted me as a PhD student.

After completing your PhD, you joined the Max Planck Institute as a postdoc and habilitated at TUM. Then you went to the University of Texas Southwestern Medical Center. Had you always wanted to work in the USA?

The offer came as a complete surprise to me. In the mid-1980s, Hartmut Michel, several

Johann Deisenhofer

Johann Deisenhofer was born on September 30, 1943, in Zusamaltheim in Bavaria. He studied physics at TUM, where he also obtained his doctorate in 1974 and habilitated in 1987. He then became a professor at the University of Texas Southwestern Medical Center in Dallas.

In collaboration with Robert Huber and Hartmut Michel, he succeeded in deciphering the three-dimensional structure of the photosynthetic reaction center of purple bacteria. The trio was awarded the Nobel Prize in Chemistry in 1988 for this groundbreaking work, which enabled a deeper understanding of photosynthetic processes. Johann Deisenhofer has also received numerous other awards, including the Order of Merit of the Federal Republic of Germany in 1990 and the Bavarian Order of Merit in 1992.

colleagues and I had achieved a great result with a photosynthetic reaction center. As a result, we were invited to give lectures all over the world. I felt that it was now time for me to look for my own research group or an independent position in science. I applied to several universities and institutions in Germany, was invited to give lectures, and then suddenly one day I received a letter in my mailbox from Dallas, Texas, offering me a professorship.

Did you know right away that you would accept the offer?

No. I also had an offer from a German university, but in the end it was a cultural difference that swayed my decision. The Texans told me, "We want you to come to us. Tell us what you need and you'll get it." In Germany, the response was much more hesitant, with phrases like, "Yeah, maybe, we'll see." So I went to Texas.

You had been a professor in Texas for eight months when you received the news that you had been awarded the Nobel Prize – together with Robert Huber and Hartmut Michel. Had you suspected anything?

Occasionally, colleagues would say, "You'll see, one day." But I always thought it would take at least another 20 years. The fact that it happened so quickly was completely unexpected. In the end it was very beneficial, as the Nobel Prize made my life significantly easier overall.

In what way?

This honor allows you to conduct exactly the research you want to pursue. It becomes easier to secure the necessary funding, and you no longer have to justify yourself as much. It's not as critical to constantly produce groundbreaking results. At the same time, there are naturally many distractions – invitations to conferences and lectures, interviews, and public appearances.

How did you find out you were a Nobel laureate?

The funny thing is that they first looked for me in Germany. I had only recently moved abroad. So the press initially descended on my family in Germany (laughs). It took about two hours for word to spread that I was in Texas. Fortunately, I had some time to come to terms with the news. The medical school where I was working had already had two Nobel laureates before and knew exactly what to expect. That was very helpful for me.

What is your most memorable moment from the days of the Nobel Prize ceremony in Stockholm?

My mother was a big fan of the Queen of Sweden, so it was very special for me to have my parents there and to see them together with the royal family. It also made me proud to show them that their trust in me and my education was justified. However, my wife says that I was rather grumpy during the time in Stockholm, mainly because the schedule was almost non-stop. I'm quite introverted and wasn't used to being in the public spotlight at that time (laughs).

Discover more stories of our alumnae and alumni on: community.tum.de/en/stories/


tozero

Lithium is scarce in Europe, but it is urgently needed for the transition to renewable energies. A problem that alumna Sarah Fleischer wants to address with her start-up.

The courage to start and fail

TEXT —— *Lena Bammert*

In a business park in Karlsfeld near Munich, a container that looks like a mason jar, complete with red-and-white checkered lid, sits on an office desk. But instead of homemade jam, it contains lithium. Revolutionary lithium. Recycled lithium. Sarah Fleischer calls it “white gold – made with love in Munich.”

The TUM alumna is one of the founders of tozero, one of the first start-ups in Europe for recycling lithium-ion batteries. Lithium is becoming one of the most crucial commodities in the world, more important than oil and gas, yet it is scarcely found in Europe. And without lithium the energy transition, with all its electric cars and solar panels, will be hard to achieve. There is a lack of mining areas and efficient technology to recover high-quality lithium from old batteries.

Start-up tozero is designed as an answer to this lithium problem. For founder Sarah Fleischer, however, the company is also the answer to the question: "Can I endure another failure?"

Starting a business right after graduation

Tozero is Sarah Fleischer's third venture. After completing her Bachelor's degree in Mechanical Engineering at TUM, she founded her first start-up: an online store for German baby products in China. A year later, she started a service company that facilitated the purchase of luxury goods for Chinese tourists in Europe. Both start-ups failed: the first due to diverging visions between Sarah Fleischer and her co-founder, and the second due to insufficient funding. "After that, I fell into a deep hole because failure is very challenging in German society," says Sarah Fleischer today.

For almost six years, she initially turned down new entrepreneurial offers. Next time, there had to be more purpose behind the project: "Starting a business is easy. Holding on, going through the ups and downs, that's the hard part," explains the TUM alumna.

Sarah Fleischer therefore concentrated on completing her Master's degree in Mechanical Engineering at TUM and starting a new career. In March 2019, she was a consultant for the Luxembourg Space Agency when she met Dr Ksenija Milicevic Neumann at a social networking dinner. That evening, the two women signed a contract on a napkin pledging to start a business together and reading: "We will conquer the universe together!"

Three years later, Sarah Fleischer received a phone call – from none other than Ksenija Milicevic Neumann, who was researching into the basis for tozero's later recycling technology at RWTH Aachen University. She said: "Hey, Sarah, you have to start a company with me! In case you've forgotten, a scan of the napkin is in your inbox." For six months, they tinkered with the idea for tozero alongside their full-time jobs, figuring out whether their visions aligned and planning the financing round.

It dawned on Sarah Fleischer that tozero might be something she could finally say yes to. Something that aligned with her roots as a mechanical engineer. Something for which she would be prepared to accept the risk of failure again because, as she points out, it could change the world for the better.

From Karlsfeld to the world

The two founders held their first job interviews in the free-to-use offices of the Munich Urban Colab at UnternehmerTUM in Munich's creative district. Today, 17 people from ten different countries work at tozero.

Thinking internationally and having different perspectives has always been important to Sarah Fleischer. She graduated from the German School Shanghai and completed her Bachelor's thesis at a university in Oman and her Master's thesis at Harvard Business School in the U.S. At TUM, she led the German-Chinese Alumni Club. "My group at TUM was already completely international and diverse, and I wanted the same for my team," she says.

Many of tozero's employees have moved to Munich, specifically to Sauerlach. The first prototype plant was built there in March 2023 after the founders raised €3.5 million in their initial funding round. The company outgrew the 100-square-meter production hall within two months. Today, tozero is located in Karlsfeld and operates in a larger facility, producing secondary lithium. Here, batteries are recycled and lithium, nickel, cobalt, manganese, and graphite are extracted.

Before visiting this hall, Sarah Fleischer sits in a white lab coat, safety goggles, helmet, and gloves in the changing room lined with green artificial turf and light wood. Pulling on shoe covers, she says: "To be able to create something out of nothing is just incredible."

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Battery recycling technologies can help to recover valuable resources and reduce waste.

Waste from lithium-ion batteries – possible scenario by 2030:

>30 % p.a.

annual increase in end-of-life lithium-ion batteries

~10 %

production scrap from lithium-ion battery manufacturing

>250,000 tons p.a.

of lithium-ion batteries reach their end of life in Europe per year

>1 M tons

of lithium-ion battery waste in total in Europe by 2030

Source: tozero

Entrepreneurship News

Think.Make.Start. is one of many teaching formats at TUM that prepare students for starting a business.

Start-ups off the assembly line

Following the model of the UnternehmerTUM start-up center, ten start-up “factories” are to be established throughout Germany as part of a competition organized by the German government. The five-year funding period will begin in 2025. UnternehmerTUM is supporting the competition with its network and expertise.

Start of serial production

With fresh capital, two TUM spin-offs will launch production. One is start-up company Reverion, which has developed highly efficient biogas power plants and can now start serial production. It will receive $62 million in investor and public funds. The fuel cell-based plants can be switched from power generation to power consumption when there is a surplus of electricity in the grid, for example from wind and solar energy. DeepDrive also successfully closed a €30 million financing round in 2024. The company develops modular platforms for electric vehicles with integrated batteries and high-efficiency wheel hub motors including the drive, steering, brakes, and chassis, enabling manufacturers to quickly build and bring new models to market. With this investment, DeepDrive is preparing for the launch of its first large-scale production projects from 2028.

Top for start-ups and innovation

Award for TUM's entrepreneurial ecosystem: The Financial Times named UnternehmerTUM the best start-up hub in Europe in 2024. It scored particularly highly for its strong network. TUM was also ranked first in the Times Higher Education THE Impact Ranking in the category "Industry, Innovation and Infrastructure," alongside seven other universities worldwide. The ranking shows how strongly universities contribute to sustainable innovation – through research, spin-offs and collaborations with companies.

The MakerSpace on the Garching campus offers high-quality machines, the latest CAD software, and support for building prototypes.

Entrepreneurs of Excellence

Many entrepreneurship events take place at TUM. One of the highlights is the TUM IdeAward.

Each year, President Thomas F. Hofmann awards the honorary title of Entrepreneur of Excellence to outstanding founders at TUM. The 2024 award was presented to Dr. Pedro Gómez, Dr. Maria Laparidou, and Dr. Miguel Molina Romero, founders of the start-up company Orbem. The technology developed by Orbem is based on artificial intelligence in combination with magnetic resonance imaging. Its uses in the food industry include looking inside eggs to prevent the killing of male chicks.

21st unicorn from TUM

Once again, a TUM spin-off has become a unicorn: The start-up company EGYM was valued at more than one billion euros in 2024. The company has become internationally successful with digital fitness equipment that offers personalized training programs and enables athletes to track their personal progress using an app. EGYM provides companies with a program that allows their employees to use thousands of sports facilities.

The TUM Venture Labs are an important element of our university's outstanding start-up ecosystem. We paid a visit to the Venture Lab Food / Agro / Biotech in Weihenstephan.

Breeding ground for biotech start-ups

TEXT—— *Tina Heun-Rattei*
PHOTOS—— *Astrid Eckert*

A source of ideas, a meeting place, a co-working space, a high-tech experimentation facility – the TUM Venture Lab Food / Agro / Biotech (FAB) does it all. Situated on the Weihenstephan Campus, it is part of the TUM Food & Agro Center for Innovation and Technology (FACIT). Venture Lab FAB was one of the first of eleven Venture Labs established to date and has a clear mission: to support students and researchers in refining their ideas, with the aim of developing and successfully launching a product or service.

Many have succeeded in doing just that. In fact, the Venture Lab FAB has supported 120 start-ups to date; the combined total for all Venture Labs is over 500. “We provide support throughout the entire start-up process, from generating ideas and acquiring funding or seed capital to the production of prototypes,” says Prof. Dr. Arne Skerra, Academic Director. “Together with TUM Entrepreneurship and TUM Start-up Consulting, we foster an exchange of ideas, help with developing business plans including market analyses, assist with patent-related issues, and facilitate contacts with industry and investors.” Many events at the Venture Lab provide opportunities to share insights and network, from the FAB Talks series to regular founder meet-ups and hackathons, while monthly open house days offer a low-threshold opportunity for people interested in Venture Lab FAB to find out more about its work.

The Venture Lab FAB features facilities that open many different doors. Situated at the heart of

1

2

1 —— *The huge machine hall provides a unique infrastructure for the teams.*

2 —— *Prof. Arne Skerra introduced entrepreneurship topics into biotechnology studies over 20 years ago.*

TUM's Weihenstephan Campus, it is a creative space with unparalleled infrastructure. On the ground floor, a string of laboratories sit shoulder to shoulder. Behind each door, start-up teams are hard at work, drawing on outstanding equipment and devices for use in every phase from research and development to prototype construction. The focus topics at FAB are biosciences and -technology, agritech, forest management, food and beverages, and production and processing technologies. It also gives fledgling companies in the food sector access to specialist laboratories in line with specific hygiene standards.

With BayWa AG and Dr. Oetker Nahrungsmittel KG, two well-known companies from the agricultural and food sectors are actively contributing their expertise and promoting the ecosystem on a non-profit basis. They advise start-up teams, establish contacts and are actively involved in events.

Vegan fish alternative makes a splash on the market

The father-daughter team behind Koralo developed a product that has since been successfully launched in South Korea: a vegan fish alternative made from microalgae and fungal mycelium, which are fermented together.

Dr. Guido Albanese studied chemistry at TUM and worked in industry for many years. During a stroll along the beach, he and his daughter Sina came up with the idea of using seaweed to create a delicious, healthy food product. "We worked through the entire process at the Venture Lab, from the idea to the finished product, and benefited from various services in every phase," says Albanese. To begin with, the team primarily drew on the lab facilities to test and refine their process. As the project progressed, they benefited from the extensive network within TUM. "We collaborated closely with three professorial chairs," says Albanese. "Not only did they significantly enhance our expertise, they also provided valuable insights into the potential benefits of our specific product." In total, over a dozen students supported the start-up team. Some wrote their bachelor's theses on the project, while others completed work placements. Everyone benefited from this arrangement; the students gained insight into the process of creating a deep-tech product, while the team sourced ideas and cutting-edge insights from the students.

In addition to scientific and technological input, business development was another key consideration for Koralo. Albanese connected with well-placed experts through the XPLORE and XPRENEURS incubator programs offered by UnternehmerTUM, TUM's center for innovation and business creation.

Following the product's successful launch in South Korea, the team refined the fish alternative, optimizing it for the demanding South Korean market. The first customers were restaurants, and major clients are now set to follow. The team also hopes to make inroads into the US market.

Until then, their work at the Venture Lab will continue, focusing on continuous product and process improvements along with scalability. A pilot system with a 100-liter fermenter has now been established in the TUM FACIT Machine Hall. Following its successful launch, the company is now using the infrastructure as a tenant.

3

Co-locating research and entrepreneurship

The close links with professorial chairs and scientific institutions of the TUM School of Life Sciences present an immense strategic advantage. These links help to generate ideas that can be developed in the Venture Lab FAB and also give entrepreneurial teams access to lab facilities and equipment. In the vast TUM FACIT Machine Hall, science and entrepreneurship are closely intertwined. Many of the systems are operated jointly with professorial chairs. In some cases, companies are also integrated.

An omnipresent spirit of optimism is visible and tangible in the Venture Lab. During our tour with

4

3——*Following their successful launch in Singapore, Sina Albanese and Dr. Guido Albanese aim to establish a presence in the US market.*

4——*Dr. Guido Albanese and Chukwuma Okereke (left to right) at the fermenter operated by the start-up in the machine hall.*

5

5—— *The TUM Venture Lab FAB creates extraordinary spaces as founts of ideas. The BayWa co-working space is always busy.*

6—— *Open dialogue: Managing Director Dr. Roman Werner advising the teams.*

Managing Director Dr. Roman Werner, not every laboratory is occupied. “Many teams only arrive late in the afternoon, after their lectures or after finishing work at the university,” he explains. Some people are sitting at their laptops, tinkering with software; others are configuring research equipment or preparing to conduct tests. Every one of them is personally acquainted with Werner. He asks one how their project is progressing and invites them for a coffee and a chat later on. He wishes another founder luck with their application for an EXIST Business Start-up Grant. TUM Start-up Consulting support teams with applications for state funding programs like EXIST.

Networking is also writ large at the Venture Lab – on campus, throughout TUM and beyond, including with state funding agencies, political stakeholders, foundations, and private enterprise. For example, the Hans Eisenmann Forum recently held a pitch event at TUM, shining a spotlight on start-ups. The winning team had developed a fully automatic process for identifying and sorting damaged potatoes, which small and medium-sized agricultural enterprises could retrofit into their existing facilities and systems.

EIT Food, Europe’s largest innovation network on the topics of food, nutrition, and agriculture, is a key institutional partner. The Food Entrepreneurship Made in Bavaria project is a joint endeavor. In this project, TUM Venture Labs and EIT Food are working with the Bavarian State Ministry of Economic Affairs to support innovative ideas and start-ups that aim to protect the environment and extract maximum value from available resources.

Innovations call for the courage to take risks

During our tour, we bump into Nathalie Stellwag, a management and technology graduate from TUM. She is working on a technique to turn brewer’s grains – a by-product of beer production – into a high-protein milk alternative. Dr. Mahmoud Masri, a biochemist, is developing an environmentally friendly alternative to palm oil. He processes yeasts to produce oil in (large-scale) bioreactors, which can help to reduce the damaging production of palm oil.

Nobody can say whether these entrepreneurs, and the many others like them, will make it to market. Even brimming with brilliant ideas and enthusiasm, entrepreneurs can sometimes run out of road in the start-up founding process. A common German perspective is to then consider such outcomes as “failures” – a view of which Roman Werner is critical. In the USA, he argues, things are very different; such outcomes are considered an opportunity to gain experience. And ultimately, most entrepreneurs are not dissuaded if an idea does not generate revenue. Instead, they focus their attention on a new topic and try again. “We need to adopt a more risk-friendly mindset,” says Roman Werner. Compared with the USA, Germany also attracts considerably less venture capital.

TUM, in conjunction with UnternehmerTUM, offers the best conditions for start-ups in Europe, as evidenced by its position at the top of the Financial Times’ ranking of Europe’s Leading Start-Up Hubs. Two contributing factors are the outstanding infrastructure and the fact that entrepreneurship courses are securely integrated into all study programs. Other international media outlets have also rated the ecosystem fostered by TUM and UnternehmerTUM as outstanding, even drawing parallels with Silicon Valley. “We weren’t even allowed to enter a nationwide competition currently underway for entrepreneurship centers – because we’re the role model,” grins Werner.

6

Directly anchored in the TUM Schools, the TUM Venture Labs are an evolution of the highly successful services offered by TUM and UnternehmerTUM. In the early 2000s, TUM became one of the first universities in Germany to actively support spin-offs and incorporate entrepreneurship content in its study programs.

tum.de/en/entrepreneurship

TUM's research and teaching is contributing to a sustainable future for the city state of Singapore.

Microalgae for the megacity

TEXT —— *Jeanne Rubner*

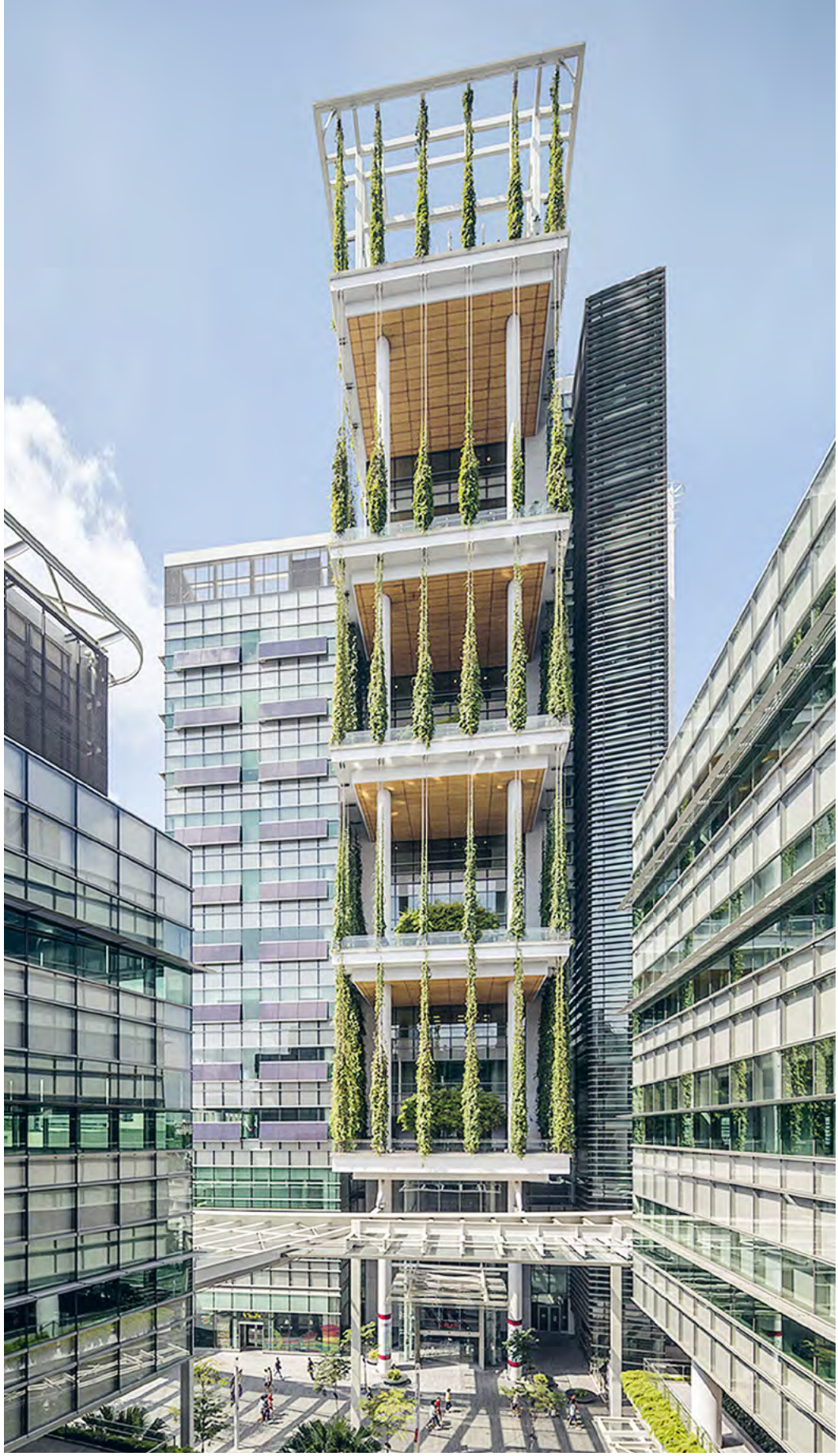
Two centimeters of research data: the tiny green plants sprouting behind glass are soybeans. They are growing in climate chambers on the ground floor of the CREATE Tower on the campus of the National University of Singapore. They are not destined to be eaten or fed to animals, but are part of an experiment: Their job is to grow under changing conditions. Light, temperature, humidity, soil composition, and distance between plants - all these factors affect growth, and the aim is to find the optimum conditions for the highest possible yield.

The experiment with the soybeans is a TUM research project and, at the same time, part of a big plan for the small country of Singapore. Because the city-state, with a population of almost six million, only has as much available space as the German city of Hamburg and because only one percent of its land can be farmed, most of the food has to be imported.

But Singapore is seeking to become more self-sufficient and has announced the "30-30" plan: By 2030, 30 percent of the country's food is to be produced domestically and sustainably. This can only be achieved with new methods and with high tech – like those fast-growing soybeans.

TUMCreate research platform

TUM researchers have been working in the CREATE Tower in Singapore since 2010. CREATE stands for "Campus for Research Excellence and Technological Enterprise." In addition to TUM, ETH Zurich and MIT are also located in the tower. Together with Singapore's universities and regional industrial partners, they are seeking solutions for Singa-



The CREATE Tower is home to scientists from top international universities.

pore's sustainable future. "This collaboration is unique," says Prof. Ulf Schlichtmann, TUMCreate CEO. "Everyone here is very open to unconventional and creative ideas."

"Controlled environment agriculture" is the branch of research of the soybean experiments. The hope is that edible crops can be grown and harvested in small areas, such as the roofs of high-rise buildings. Soybeans are one of the world's most important crops, but they can only be harvested once a year in the field, and a field yields only four tons per hectare. Trials have shown that rooftop-farmed soybean plants can be grown up to three times more densely than in the field and can be harvested three to four times a year. The optimum yield is 40 plants per square meter and four harvests. In theory, the yield can then be 30 percent higher than in the field – and with far less fertilizer.

The soybeans are part of a major research program called Protein4Singapore, which aims to show how the megacity can be adequately supplied with high-quality food in the future through innovative agriculture or 3D printing of proteins from soy or microalgae: Thomas Becker, professor of brewing and beverage technology at TUM, and the entire consortium are striving to optimize the production of vegan, meat-like textures. They seek to better understand how to vary the main ingredients – proteins, water, or substances called hydrocolloids – to produce products with the desired firmness. "This project not only allows us to completely rethink food, but also has a major impact on research work here in Germany towards future-oriented sustainable food safety," says Thomas Becker.

Close links between research and teaching

A few kilometers away from the CREATE Tower, Prof. Corinna Dawid is teaching a block course in Molecular Sensory Science in the TUM Asia lecture hall. At the start of the 2024/25 academic year, TUM launched a new Master's program: the Master Sustainable Food. "I teach what my team is researching on site," says Corinna Dawid, Professor of Functional Phytometabolomics at the TUM School of Life Sciences: For example, how do you select the raw materials for turning soybeans or microalgae into a tasty product? "Partially hydrolyzed microalgae, for example, do not taste good," Dawid says, and adds that in general, botanicals often have a bitter, grassy taste. There is still a lot of research to be done before Singapore can really move towards a plant-based diet.

Corinna Dawid therefore sees great potential in the Master's program: "The students come from the best universities and are very well educated," she enthuses. The course structure is demanding – eight hours of lectures and tutorials every day for two weeks – but she is convinced that it is worth it: "We're building an excellent international network here."

TUM Asia currently offers a total of seven Master's programs, and more are in the pipeline: "We are currently in talks with Nanyang Technological University about jointly offering another Master's program in electronics," says Dr. Markus Wächter, Managing Director of TUM Asia. According to Wächter, semiconductors are in high demand in Singapore at the moment as the politically tense relations between China and Taiwan have the whole world searching for new locations for chip production. Singapore, which sees itself as a bridge between the West and China, is an obvious choice.

In Singapore since 2002

It is a bridge that TUM has been using for a long time; TUM Asia has been on site since 2002. It is also a unique commitment; no other German university has a campus of this kind outside Europe. "German engineering excellence with Asian relevance" is TUM President Prof. Thomas F. Hofmann's description of the special character of TUM Asia, offering the best engineering education for the Asian market. Success is proving TUM right; TUM Asia now has around 3,000 graduates from 45 countries, most of them from China and India. Many work in leading research institutions and companies in the region and around the world.

One of them is Madan Jhanvi, who proudly received her Master's degree in Industrial Chemistry in July 2024. She now plans to join the family agrochemicals business that her grandfather founded in Delhi. "In my Master's degree, I found the perfect combination of chemistry and engineering that I need for our business," she says.

Ambitious climate goals

Singapore's net zero emissions goal is to stop releasing greenhouse gases into the atmosphere by 2050. TUM researchers are helping to achieve these ambitious goals. One of their projects is to harness geothermal energy for Singapore; another promising option is green hydrogen produced from geothermal energy, which could provide 170 tons per year.

Students at TUM Asia come from over 45 countries.

During the first funding phase of TUMCreate, numerous projects were developed that are now helping the city-state to electrify its transportation. The "Singapore Integrated Transport Energy Model" (SITEM), which aims to create the basis of a zero-emission transport system in Singapore, uses two TUMCreate simulation models: the "City Mobility Simulator," which accurately maps all traffic flows on the island, and the "Multi Energy System Modelling & Optimization," which simulates the effects of distributed energy resources such as solar photovoltaics on the grid. "This is a very exciting project with many stakeholders, and we are delighted to be involved," says CEO Ulf Schlichtmann. "Our simulation tools can provide valuable recommendations for Singapore's transportation planning."

This is why TUM President Thomas F. Hofmann is convinced: "With TUM Asia and TUMCreate, we are contributing to the sustainable transformation of cities – in Singapore, but also beyond. Thanks to the short geographical distances and the possibility of rapid implementation, the megacity is the ideal place to develop scalable solutions that can then be applied in other countries."

TUM Asia currently offers two undergraduate programs, Chemical Engineering and Electronics and Data Engineering, and Master's programs in Aerospace Engineering, Green Electronics, Industrial Chemistry, Integrated Circuit Design, Logistics Engineering and Management, and Rail and Urban Transport.

More information: tum.de/singapore

Emphasizing the role of research and strengthening trust in science is becoming increasingly important for universities. TUM supports its researchers in this with programs at the Institute for Lifelong Learning. After a media training first introduced in the fall of 2023, we asked three participants to sum up their experience.

Greater communication expertise

Prof. Stefania Centrone, who took part in the new media training at TUM, says: "Communication is an essential part of our work."

Prof. Stefania Centrone

The holistic approach is what appealed to me most. But I also appreciated that the training made me aware of how the media may take statements out of context and publish them with no further context and references.

The "Personal Branding in Social Media" course offered me valuable strategies for establishing an effective presence on social networks. Practicing firsthand how to summarize key points in my work in a simple form was genuinely helpful for me.

After attending the Public Engagement Academy, I received invitations to speak at numerous events: at the Leibniz Association in Hanover, a conference entitled "How AI Is Changing our Future" in Bad Homburg, the annual conference of the German Informatics Society, and acatech's annual assembly. All these conferences were broadcast via the usual media channels, and I felt well prepared and sure of myself.

I found these aspects especially important as professors are not normally coached in how to communicate the substance of their own research. Communication, however, is an essential part of our work. If those of us who practice science fail to take on this role, we will abandon the field to others who may be able to talk confidently, but may have no scientific expertise.

I would therefore recommend this training without reservation. There is no comparable course at any other university where I have worked.

Prof. Julia Steinhoff-Wagner

I particularly enjoyed the practical part. For example, there was one challenge where the professional interviewers tried to push us to make a statement that we, as the interviewees, had no desire to make. That's precisely the situation I think we're all afraid of when participating in a live interview. Seeing how such situations can be mastered in a gracious and unruffled manner, followed by an evaluation of possible alternatives, gave me an additional measure of personal confidence for the future.

Recently, for example, I received an email announcing "... we invite journalists to talk to the scientists afterwards. If anyone is not available for such an interview, I would ask for your brief feedback." In the past, an announcement of that kind would have left me feeling stressed, and I would have considered replying that I was not available, but after the training my response was more positive and in fact I was actually looking forward to putting what I had learned into practice.

The many exercises gave me greater composure when interacting with media representatives. And that composure comes across in the interviews. Intensive in-person training in small groups also promotes a relationship of trust with colleagues which would probably have never come about on a professional level – which is why the event was also enriching for me in interdisciplinary terms.

Prof. Markus Ploner

I benefited greatly from the training. It gave me the opportunity to hone my own communication technique with the help of professional trainers and highly engaged and motivated colleagues. In the process, I was able to network with others interested in the topic of communicating science, and I learned a lot from them.

Moreover, the training made us aware of the relevance of communicating science. It showed once again how important it is to look beyond disciplinary boundaries and communicate things simply, clearly, and in a motivational manner. This also helps me substantially in clearly defining the "big picture" behind my work. And last but not least, the training was a lot of fun. I therefore have no hesitation in strongly recommending the training to others.

The media training courses are part of the continuing education program at the TUM Institute for LifeLong Learning. This is where our university offers specialists and managers from TUM and companies scientifically sound, future-oriented and sustainable continuing education.

lll.tum.de/en

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Learning better with artificial intelligence

TEXT—— *Jeanne Rubner*
PHOTOS—— *Andreas Kusy*

TUM's EdTech Center hosts the "Münchner Kindl" program.

Elementary school students experience lessons with robots and AI tools at the TUM Center for Educational Technologies.

The pupils are supported by a scholarship from the Roland Berger Foundation.

Computer scientist Enkelejda Kasneci is the director of the EdTech Center.

Of course, Pepper is the center of attention. A few girls from the front row walk up to the meter-tall white robot and hug it. At the back of the lab, which is funded by the IT Foundation Esslingen and located at the TUM Center for Educational Technologies in Munich's Marsstrasse, 8-year-old Johan slides excitedly to and from on his chair. Alongside him, about three dozen second-graders are sitting in front of screens. Their task today is to write and illustrate a story with the help of artificial intelligence.

Prof. Enkelejda Kasneci explains the basics. The computer scientist and director of the EdTech Center asks the children if they know about ChatGPT. Of course, they've all heard of it. Then they talk about DALL-E, software that generates images from text descriptions. "The interaction between humans and AI plays a crucial role in modern education, especially for young students," says Kasneci. She points out that by using interactive learning programs and AI-based tools, children can be motivated to explore and learn independently. They can also understand complex concepts better when they are presented in a simple and interactive way. "This promotes engagement and motivation."

TUM opened the EdTech Center at the Institute for Lifelong Learning in 2023. Here, experts research, develop, and test educational technologies such as SAM, an AI-based learning environment for university teaching, and of course Pepper. The little robot currently only answers questions about anything and everything, but in the future children will be able to use it for specific learning projects. Future teachers will also be able to train in the use of AI in the classroom at the EdTech Center. "Experts from the fields of computer science, educational research, pedagogy, and natural sciences work together here on an interdisciplinary basis to research and test innovative educational technologies," explains Enkelejda Kasneci. "This is unique in Germany; it allows us to create solutions that are groundbreaking in terms of both technology and teaching."

A program of the Roland Berger Foundation

The children sitting in front of the monitors right now have a scholarship from the Roland Berger Foundation. Its "Münchner Kindl" program supports primary school children who are ready to learn and achieve and who do not receive the necessary support at home for various reasons. The program focuses on language skills, mathematics, creativity, and digital learning. "AI tools help to maximize the potential of each child," says Kasneci. "On the other hand, the scholarship holders bring a great deal of cultural diversity with them. This allows us to explore how AI topics can be taught in an inclusive way."

At the end of the afternoon, the second graders have written a short story using AI and illustrated it. Johan proudly shows his screen and says: "My story is about a robot."

The TUM Center for Educational Technologies is the university's center for innovation in digital education. Founded in 2023, the center develops, researches, and evaluates cutting-edge educational technologies.

edtech.tum.de

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A first-class address: Campus Garching

A new SAP research center for artificial intelligence opened on the TUM Campus Garching in the summer of 2024. At the SAP Labs Munich Campus, 700 SAP employees and 120 TUM researchers will work together on software solutions in areas such as the digital supply chain, the future of work, synthetic data, and quantum computing.

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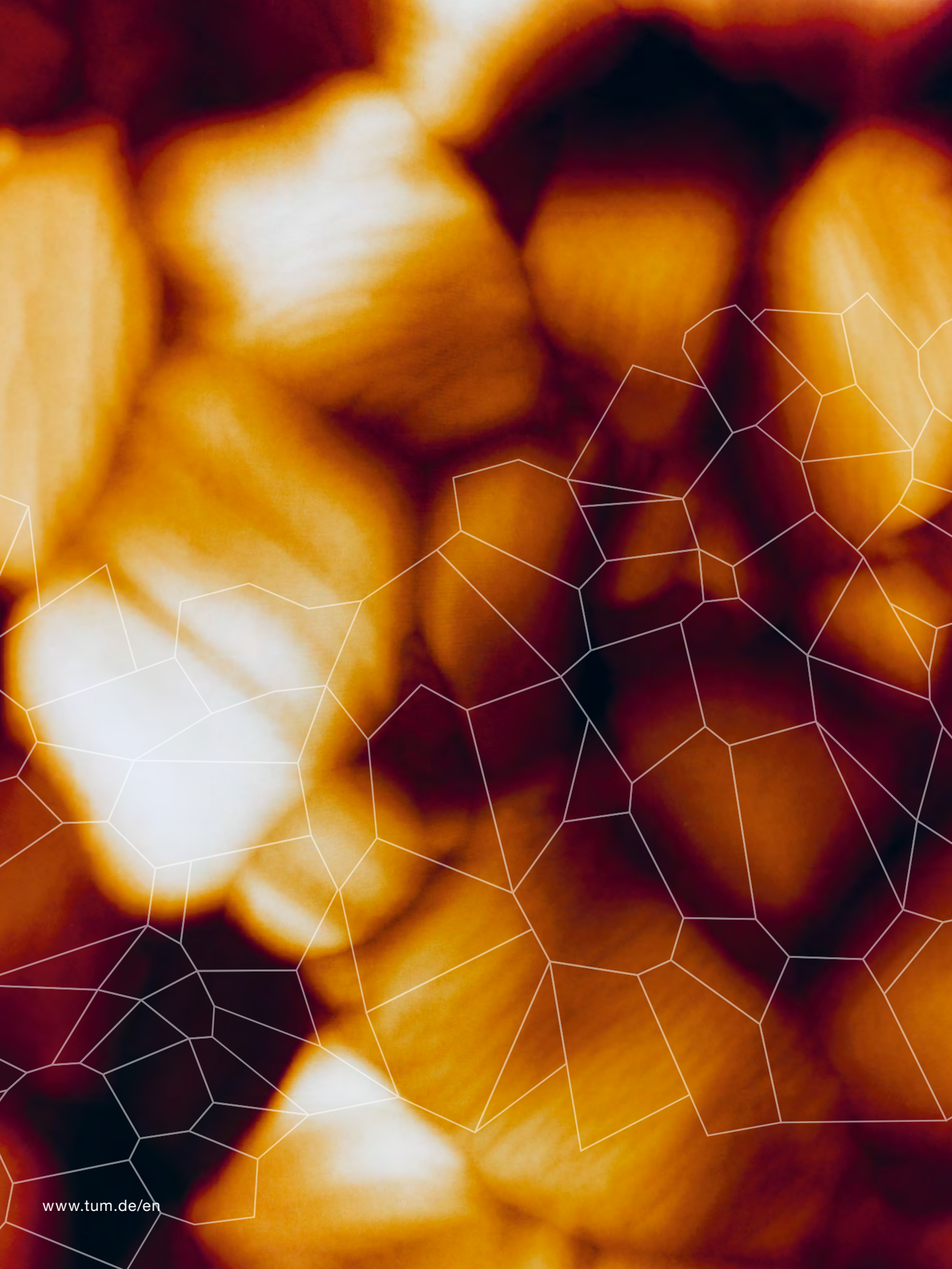

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