#28
< DE | 2022-2 | EN

TU Graz research

Research Journal of Graz University of Technology

SCIENCE
PASSION
TECHNOLOGY

SMART PRODUCTION

Page 4

STARTING SIGNAL FOR GRAZ CENTER FOR MACHINE LEARNING
Page 9

ERC STARTING GRANTS FOR TU GRAZ
Page 10

CONSEQUENCES OF TECHNOLOGICAL DEVELOPMENT: TU GRAZ RESEARCHER CHRISTIAN DAYÉ IN PORTRAIT
Page 14

Dear colleagues, research partners and those interested in research at TU Graz,

Horst Bischof
Vice Rector for Research
Lunghammer – TU Graz

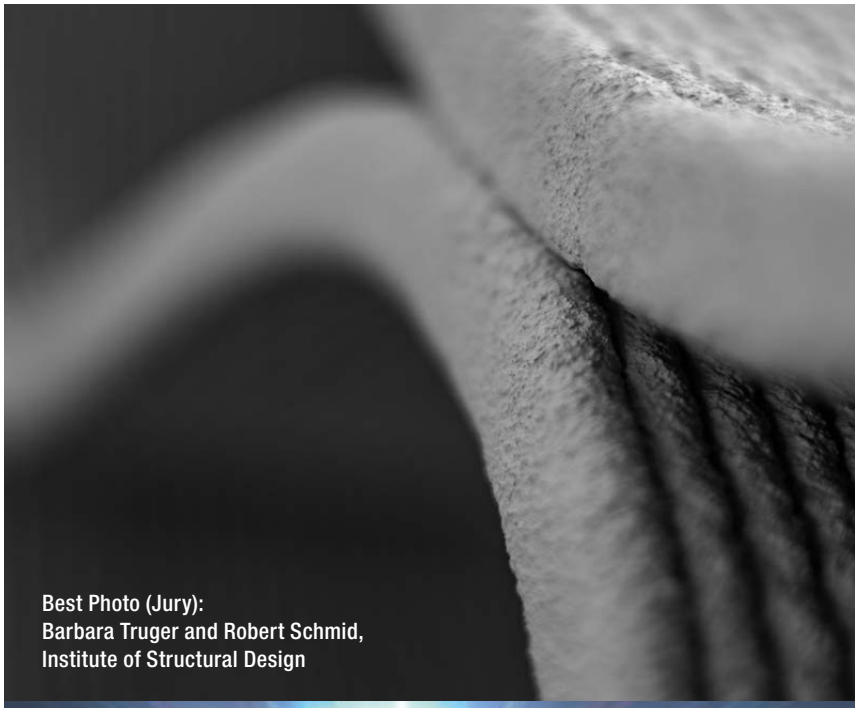
We are in times of great change. We haven't quite left COVID behind yet, but we seem to have found a way to live with the virus. The pandemic has shown us how important science is, but it has also accelerated digitalization. Graz University of Technology (TU Graz) has always been a leader in this field, and was able to make another big leap.

Russia's war of aggression in Ukraine has plunged us into the next crises. On the one hand, inflation is hitting us hard. From the present perspective, TU Graz will assume an additional requirement of 50 million euros for this performance agreement period. I hope that by the time you read this issue of TU Graz research, we can already give the all-clear and that the finance minister will largely cover these additional needs of the universities. The universities cannot possibly meet this additional burden on their own.

This war has dramatically shown us once again our dependence on fossil energy sources, which we already know in the context of the climate crisis. TU Graz was a pioneer here with its plan for CO_2 neutrality by 2030. Nevertheless, much remains to be done. TU Graz has excellent research to offer, especially in the field of renewable energies (for example our Center for Sustainable Construction or the Hydrogen Research Center, to mention two of our research centres).

Numerous changes are on the horizon at TU Graz for the new year. The University Senate was reconstituted in October 2022. The new University Council will begin its work in spring 2023. And there will also be changes in the Rectorate of TU Graz: I will have the great honour of leading TU Graz as Rector from October 2023. But more on this in the last issue of TU Graz research on my watch as Vice Rector for Research in spring 2023.

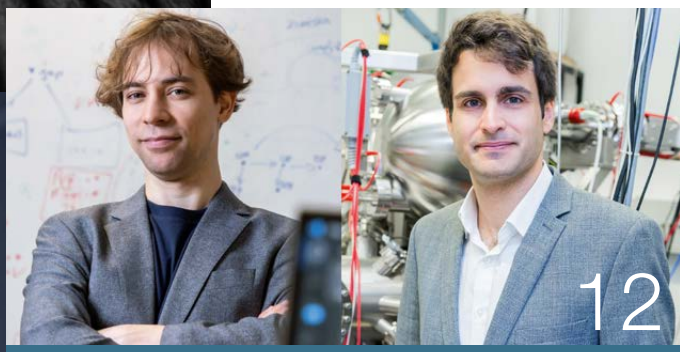
Regardless of the current situation, I wish you and your loved ones a peaceful and reflective Christmas season. Hopefully you'll find some time on your hands to browse through our magazine during the holidays. With this in mind, I hope you enjoy reading this issue of TU Graz research and wish you and your families a good and somewhat calmer 2023.



Best Photo (Jury):
Barbara Truger and Robert Schmid,
Institute of Structural Design

TU Graz SciPix: The colourful world of science
2022, researchers at TU Graz have once again dug deep into their box of ideas and captured the beauty of their work in pictures and videos. A jury of experts and the online audience chose their winners at the TU Graz SciPix competition.

Images sources from left and downwards: Barbara Truger, Stefanie Eichinger, Michaela Roschger, Karin Wewerka, Peter Bauer, Rafaela Greil, Robert Winkler, Georg Rudelstorfer, Harald Plank, Viktoria Haberl und Maximilian Fuchs, Jana Lasser, Jan Egger, Background: RealCG – AdobeStock



Best photo (Audience): Jan Egger, Institute of Computer Graphics and Vision

SciPix Videos and more Information

Contents

Publication details: Owner: TU Graz. Publisher: Vice Rector for Research. Editor-in-Chief: Birgit Baustädter, Communications and Marketing, Rechbauerstraße 12/I, 8010 Graz. E-Mail: TU-research@tugraz.at Design/layout: Christina Fraueneder, TU Graz; Petra Temmel, manege frei!. Translation: Andrew Peaston. Printing: Druckhaus Thalerhof. Print run: 2,000 copies. Our thanks to the authors for providing the texts and photos. The editors reserve the right to make minor changes. Cover picture: Lunghammer - TU Graz. TU Graz research is published twice a year. ISSN 2664-1712. www.tugraz.at/research-journal

The joining of metallic and composite materials is an important topic.

Bilder: Lunghammer – TU Graz

Smart Products from Smart Factories

Research is conducted on materials in the laboratories of the Institute of Materials Science, Joining and Forming.

If we think today about the factory of the future, robots, artificial intelligence, resource-efficient production methods and new materials have a firm place in it. At TU Graz, research is being carried out to turn this vision into reality.

Birgit Baustädter

Already today, not only people but also countless collaborative tools work in factories. The goal is to create higher flexibility and customer orientation (down to batch size one production), more efficiency and faster production speed. These targets are mainly due to the increased demand for environmentally friendly production of green products, the circular economy and the high speed of innovation in new products. The factory of the future must be agile, in other words, it should be able to adapt very quickly and flexibly to changing production tasks and must remain competitive despite rising costs for personnel, raw materials and energy.

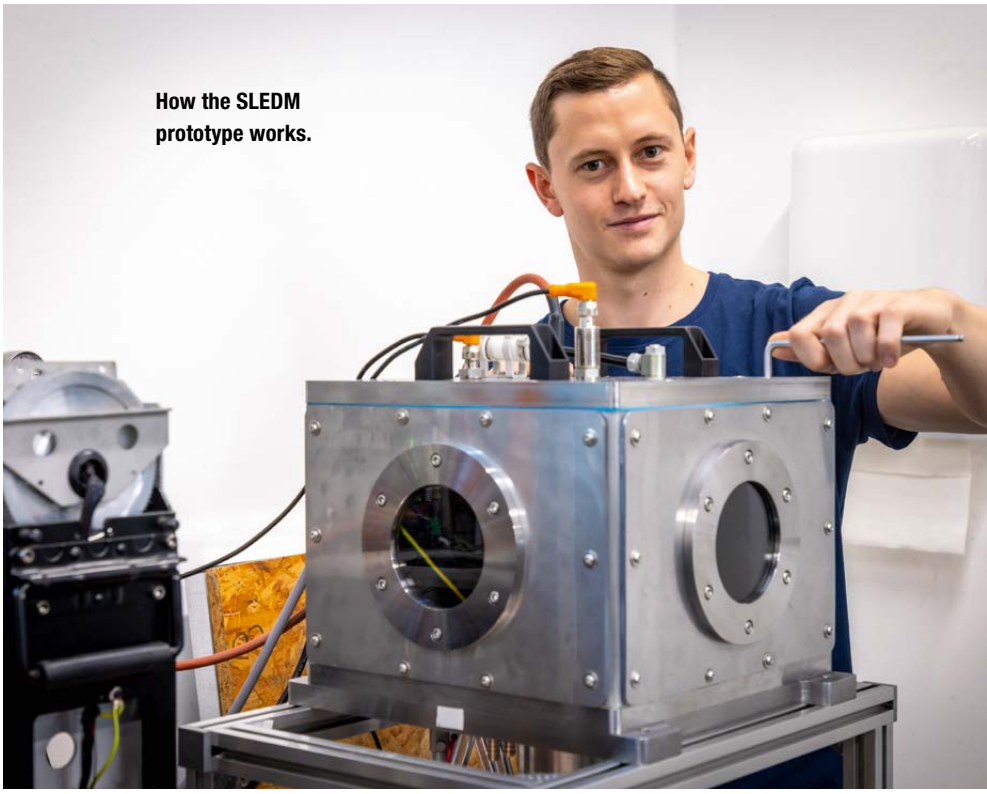
At TU Graz, research is being carried out on several fronts, but above all together on the production of the future. The researchers working on this topic already linked up several years ago in the Research Center Smart Production Graz. Research Center head Christof Sommitsch: “We’re concerned with the close networking of available forces, joint projects and the best possible proposals for the business community, which is urgently looking for solutions.”

LIGHTWEIGHT CONSTRUCTION

Christof Sommitsch himself works in materials science and, together with his team at the Institute of Materials Science, Joining and Forming, is investigating how different materials can be effectively additively manufactured, joined together and formed. This is especially important also for environmental protection. Sergio Amancio holds the BMK Endowed Professorship for Aviation at the Institute and works on lightweight materials for aviation. “Of course, our technologies can also be used in any other transport sector,” explains the professor. He is mainly involved with the joining of composite materials, i. e. fibre-reinforced plastics, and metals. Two materials that traditionally cannot be mixed, but which can make aircraft components considerably lighter when combined. Lighter components mean less weight to transport, >

Sergio Amancio on new joining techniques.

Christof Sommitsch on smart production.



How the SLEDM prototype works.

which means less fuel is needed, thus causing less impact on the environment. But: “Metal and plastic behave like water and oil. They don’t mix. The liquid metal forms small beads in the plastic but does not bond with it.” Amancio and his team are therefore, among other things, changing the surface structure of metal components in a newly developed process in order to be able to produce stable connections. The metal component is produced with a 3D printer. Its surface structure is designed in such a way that the liquid plastic can be deposited in it and “get a grip”. “We were inspired by geckos’ feet. They look like microscopic mushrooms that can insert themselves into the surface structure of walls, for example, and thus get a secure hold,” explains Amancio. These surface-structured, 3D-printed, metal components are joined in an energy-efficient way using ultrasonic joining with the composite materials or hybridized with other novel additive manufacturing processes to form a lightweight macro-composite structure.

This is how joining is done by means of ultrasound.

3D PRINTING

3D printing is an important topic in the factory of the future. It allows the production of precisely planned individual pieces that are stable, light and precisely built. For example, at the Institute for Chemistry and Technology of Biobased Systems, where a bio-printer is doing its job. The GeSiM BioScaffolder BS 3.2 is capable of 3D printing organic materials and is unique in this form in the Alps-Adriatic region. Forward-looking research projects on this device are already being planned – from the production of functional materials for an artificial aorta to alginate hollow fibre membranes or printed polysaccharides for tissue cultivation. Or with plastics in the Schumpeter Laboratory for Innovation, where above all product innovations can be developed and prototypes built.

But metallic 3D printing is also a central topic. Franz Haas from the Institute of Production Engineering has delved into this topic with his team. Metallic 3D printing traditionally uses a powerful laser light source to build up the material in a box full of metal powder layer by layer with extreme precision. Of course, such a powerful light source cannot be used in every environment in terms of safety. For example, in an operating theatre, where individually printed metal parts could be useful during operations, its use is not possible. That is why Haas and his colleagues developed the SLEDM method, as he explains: “Instead of a laser, we use a very powerful LED array whose individual LEDs can be specifically controlled and thus the energy density in the melting zone can be optimised. This can decisively improve material properties and energy efficiency. We have been granted a patent for this process and have built a prototype for LED melting tests. This lays the foundation for basic experiments and modern process monitoring through the use of numerous sensors in the demonstrator.”

BATTERIES

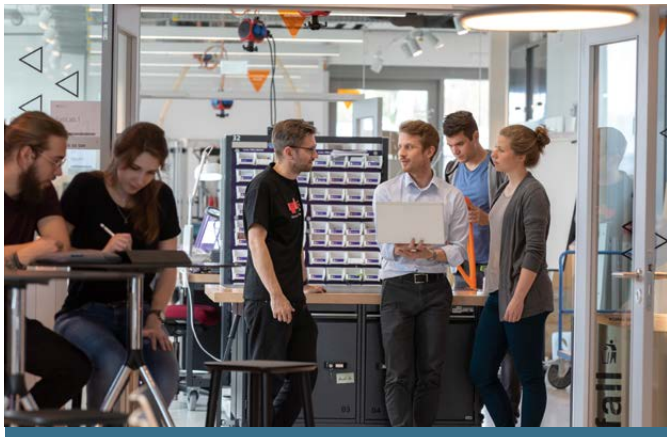
However, Franz Haas is also working on other areas to make the factory vision of the future a reality. His institute also works with the AVL company at the Battery Innovation Center – a battery research infrastructure on the AVL premises. For a few months now, there has also been a smaller assembly line for the robotic

The Battery Innovation Center is researching the automatic testing and stacking of battery cells.
Lunghammer – TU Graz

Talk Science To Me
TU Graz-Poscast

Franz Haas on future production.

construction of battery modules at TU Graz. In the future, batteries will play an increasingly important role in mobility, which is why the demand for factories and automation solutions in this area is already very high now. “For me, the battery cell in all its diversity of types and geometries is the screw of the future,” is how Franz Haas describes it. “It is already in high demand now and will be more and more so in the future. Be it a button cell in electronics or as a pouch cell installed in modern battery packs in the floor plates of current e-vehicles.” Due to the increasing demand for electrical storage media, their production must also be raised to a new level. And that is exactly what is happening at the Battery Innovation Center. The production line located at Campus Neue Technik automatically recognizes which battery cell is to be processed. The right gripper which was previously produced next door using 3D printing is automatically selected. The gripper guides the battery cell to the test station, where it is first checked visually and then mechanically. An important factor in smart production is the automated quality check of all products. “Metrology is a big issue. In this way, we guarantee the service life, energy efficiency and create the data basis for the return of the value stream at the end of the service life,” reveals Haas. >



SCHUMPETER LABORATORY FOR INNOVATION

Equipped with the latest digital manufacturing technologies and appliances for the production of prototypes and innovative product designs, the Laboratory for Innovation offers everything a maker’s heart desires: from cutting-edge 3D printers for FDM, STL and CFF methods, CNC 4-axis and 3-axis milling machines and appliances for laser cutting and laser engraving, to water-jet cutting, sand-blasting, circuit-board printing and vinyl cutting. Here, students and researchers engage in multidisciplinary cooperation, as do start-ups, SMEs and established industrial companies involved in joint innovation work.

To Schumpeter Labor for Innovation


Lunghammer – TU Graz

DIGITAL & SUSTAINABLE PRODUCTION

TU Graz offers the focus Digital & Sustainable Production in the university course Leadership in Digital Transformation as a continuing education programme of Life Long Learning. All information can be found on the course website.

Rudolf Pichler on the smartfactory@tugraz.

Talk Science To Me
TU Graz-Poscast

"If a single cell in a battery pack is defective, only that single cell needs to be replaced. But we have to create the conditions for this," says Haas. "Today a battery has several lives. The first, for example, in an e-vehicle. And when the required storage capacity can no longer be provided or meet the safety standards of mobility, then it can take on another life as a storage unit in the home or in industry to store solar energy for example." In future, it will also be possible to test and assemble fuel cells in the lab and in the adjacent mini clean room.

Pro²Future

The COMET competence centre Pro²Future, which is located between Graz, Linz and Steyr, also has a strong connection to industry – with a central focus on cognitive products and production systems. Pro²Future is shaping such cognitive systems and implements them both in products and in production systems as well.

The core topics of cognitive products and cognitive production systems are supported by the foundational areas around machine perception and awareness, cognitive robotics and shop floors, and cognitive decision support systems.

SMART FACTORY

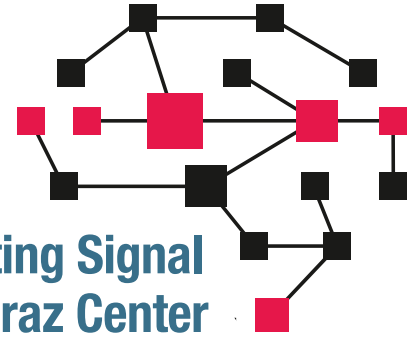
The Institute's second location, at Campus Inffeldgasse, is home to the smartfactory@tugraz, a learning factory managed by Rudolf Pichler and equipped with state-of-the-art production and communication facilities. In the smartfactory@tugraz, disruptive technologies, the networking of IT and OT levels and the safe interaction of often highly heterogeneous aggregates are tested and demonstrated on the basis of show cases. Several production robots are ready for this, communication can run quickly and securely via the campus's own 5G network, and Rudolf Pichler's constant message applies: "We are happy to invite companies to implement and test out their ideas in the smartfactory. Smart production systems are not only useful in large industrial companies, but also offer small and medium-sized enterprises in particular valuable opportunities to improve performance."

DIGITALIZATION

Easily recognizable, the topic of smart production is closely linked to advancing digitalization. This is why, in addition to the production-focused institutes, several other institutes at TU Graz also address the topics of cybersecurity, safety and the Internet of Things (IoT). For example, the Institute of Technical Informatics, the Know Center and the Institute of Engineering and Business Informatics. The topic will also be central to the GraML Research Centre – Graz Center for Machine Learning.

SPACE FOR PEOPLE

There is one very big prejudice that Franz Haas would like to decisively counter: the deserted (i.e. humanless) smart Factory. "Production without people can never be smart. On the contrary, we are faced with a shortage of skilled workers in this field despite the many developments around Industry 4.0." ■



Starting Signal for Graz Center for Machine Learning

The Graz Center for Machine Learning (GraML) research network was launched at TU Graz. The focus is on machine learning, which, according to the head of GraML Robert Legenstein, will change the world in a similar way to the internet and computers.

Susanne Filzwieser

Artificial intelligence and machine learning are becoming one of the most important tools of the future. “Machine learning will change our world just as the internet and computers have done,” says a convinced Robert Legenstein. He heads the Institute of Theoretical Computer Science at Graz University of Technology (TU Graz) and recently also the new Graz Center for Machine Learning.

TU Graz has established this research network, known as GraML for short, in order to significantly advance the further development of machine learning. Interdisciplinary work is being done on the further development of machine learning – whether to draw efficient and meaningful conclusions from big data, to find the most optimal material combinations or to make the systems themselves one step smarter.

All GraML participants will introduce the unique scientific angles of their daily research. The scientific work is divided into six core research areas, which are primarily dedicated to the foundations of machine learning, and several flexible modules. The six GraML core research areas are: Visual Intelligence, Optimization in Machine Learning, Ressource-efficient and brain-inspired Machine Learning, Probabilistic Methods and Causal Models, Recommender Systems and Behavioural Analytics as well as Domain Specialized Machine Learning and Trust. In addition to the core research areas, research will be conducted on the application of machine learning methods to a wide range of domains, with experts from the field of machine learning working closely with representatives from other faculties. ■

Lunghammer – TU Graz

Science shapes the future – TU Graz Science for Future

Digital Visions was the topic at the TU Graz science day 2022. The keynotes “From data to knowledge – a journey to the extreme” by Lothar Thiele and “Dependability in the internet of things” by Kay Römer are available to watch online.

Birgit Baustädter

At the science day of TU Graz, researchers show how they are meeting societal challenges across all disciplines with innovative technologies and shaping our future.

FROM DATA TO KNOWLEDGE

ETH Zurich professor and renowned digital expert Lothar Thiele spoke at the beginning of the event about how knowledge can ultimately be gained from the vast amounts of data collected. A road paved with enormous scientific challenges. Thiele also touched on the possibilities of using big data to observe and analyse environmental processes and ultimately make predictions that can be used to ensure an environment worth living in.

DEPENDABLE INTERNET OF THINGS (IOT)

TU Graz professor and head of the first lead project at TU Graz Kay Römer presented the results of his eponymous project, which was completed after six years of research, in his lecture “Dependability in the internet of things”. He spoke about safety-critical applications in the IoT, the foundations of dependability and security and the industrial application of the results achieved.

2023

The next science day “TU Graz – Science for Future” will take place in September 2023. Everything will revolve around the topic of smart production and smart factories. Make a note of the date in your calendar. ■

Highly Endowed ERC Starting Grants for Daniel Gruss and Marcus Ossiander

Computer scientist Gruss receives the prestigious EU funding award for research into energy-efficient IT security, and physicist Ossiander for work on nano-optics for ultra-fast microscopes.

Susanne Filzwieser

Daniel Gruss (left) and Marcus Ossiander.
Lunghammer – TU Graz, right: Sabine Hoffmann

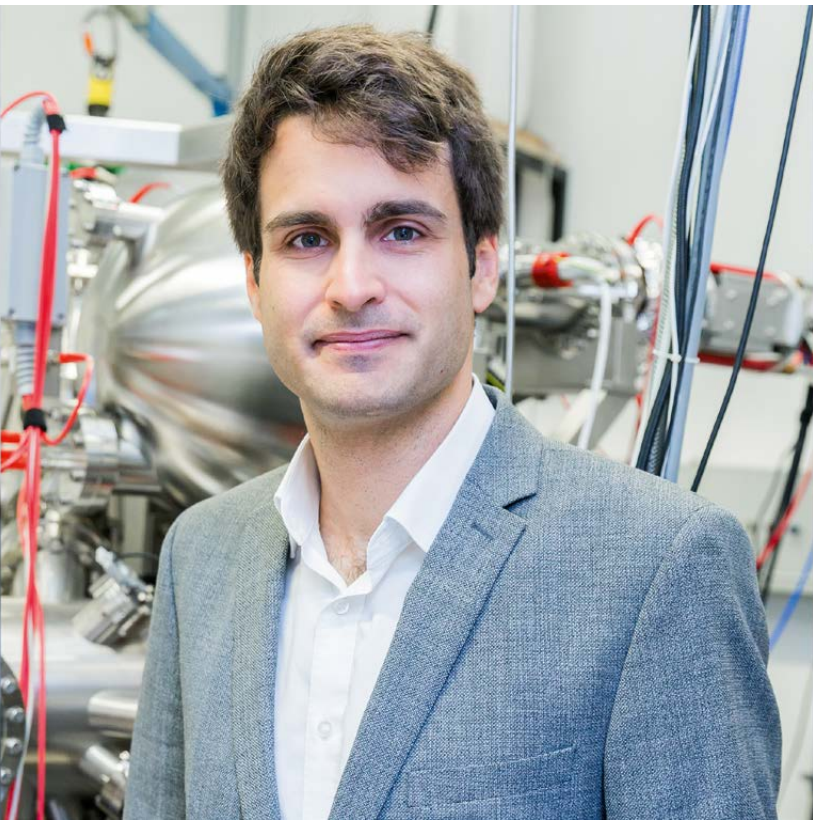
Two top researchers from Graz University of Technology (TU Graz) will receive highly endowed Starting Grants from the European Research Council in 2022. The research of computer scientist and cybersecurity expert Daniel Gruss and experimental physicist and START Prize winner Marcus Ossiander will receive funding totalling 3.3 million euros over the next five years, the European Research Council announced today. Of the 408 Starting Grants awarded across the EU, a total of 17 went to researchers from Austrian institutions. Austria is thus in 8th place, ahead of Sweden, Spain and Denmark, for example. Horst Bischof, Vice Rector for Research and future Rector of TU Graz from autumn 2023: "With Daniel Gruss and Marcus Ossiander, the ERC Starting Grants are not going to strangers, quite the contrary. Both are top researchers in their fields who have already made impressive achievements despite their young age. Daniel Gruss regularly causes a stir in the world of cybersecurity; Marcus Ossiander is in the process of transferring from Harvard to TU Graz and in this interim phase alone has already acquired an Austrian Science Fund (FWF) START Prize and now the ERC Starting Grant. I extend my warmest congratulations to both of them. TU Graz is particularly proud of such top minds in research."

DANIEL GRUSS: FOUNDATIONS FOR SUSTAINABLE SECURITY

Daniel Gruss (born in Brühl, Germany, in 1986) studied computer science at TU Graz from 2008 and dealt early on with the unauthorized tapping of data in his dissertation. In 2018, he was a key member of an international team of scientists who uncovered the serious hardware security vulnerabilities Meltdown and Spectre in Intel processors (link). Since then, he has explored even more IT security vulnerabilities. Gruss holds a tenure track professorship at TU Graz and is a regular speaker at international IT security conferences. He specializes in side-channel attacks in which physical effects allow conclusions to be drawn about protected data. He will now receive the ERC Starting Grant of 1.5 million euros for the project "FSSec – Foundations for Sustainable Security". "IT already consumes 11 per cent of the world's electricity, with a strong upward trend. The question now is how to increase efficiency without causing security gaps at the same time," explains Daniel Gruss. So far, energy efficiency has not played a role in safety. But Daniel Gruss wants to change that. For example, the use of cryptography instead of established error correction methods should help systems achieve a significant gain in efficiency compared to current systems due to the increased security. In November Daniel Gruss was awarded the Promotion Prize of the Austrian State of Styria.

MARCUS OSSIANDER: EXTREME ULTRAVIOLET META-OPTICS FOR ATTOSECOND MICROSCOPY

Marcus Ossiander (born in Munich, Germany, in 1989) wrote his doctoral thesis at the Max Planck Institute of Quantum Optics and received his PhD in ultra-fast physics from the Technical University of Munich. Since 2020, he has been conducting research at Harvard University in the field of meta-optics, and from January 2023 he will be working at the Institute of Experimental Physics at TU Graz. He has the Austrian Science Fund (FWF) START Prize (link), which was acquired in June 2022, and now also the ERC Starting Grant project EUVORAM – Extreme-Ultraviolet Meta-Optics for Attosecond Microscopy with a budget of 1.8 million euros. Both projects pursue the same goal: the research and development of new nano-optics for ultra-fast microscopes. According to Ossiander, ultra-fast physics opens up many possibilities. "We can use it to study solar cells, improve catalysis and other chemical reactions, or even analyse how fast digital communication can be in the first place." Flat nanostructures, similar in function to a photo lens, are designed to focus particularly



The **European Research Council** (ERC) supports outstanding researchers with highly remunerated grants. Starting Grants are awarded to young researchers who are conducting groundreaking research and wish to establish their own independent research group. Further categories are the Consolidator Grant for scientists already established in the research community, the Advanced Grant for established scientific leaders and the ERC Proof of Concept Grant for researchers who have already received a grant.

high-energy ultraviolet light. The short wavelength in turn then makes it possible to observe the smallest electronic movements with time resolutions in the range of attoseconds. “An attosecond is a quintillionth of a second and is to a second what a second is to the age of the universe”, explains Ossiander.

WINNERS OF ERC GRANTS AT TU GRAZ

Birgitta Schultze-Bernhardt and Gustav Oberndorfer are currently conducting research at TU Graz with ERC Starting Grants and Paolo Falcaro with an ERC Consolidator Grant. Two Consolidator Grant projects (Stefan Mangard and Gernot Müller-Putz), as well as three completed Starting Grant projects (Anna Coclite, Thomas Pock and Stefan Freunberger) complete TU Graz’s ERC record to date. ■

Mind_the Gap: Prizes for Equal Opportunities

What emotions women’s football arouses in men and women, how multimedia recommendation systems neglect unpopular content or how the topic of artificial intelligence could be widely communicated – these topics and more are the projects that TU Graz recently awarded Mind_the Gap prizes to.

Ute Wiedner

When human beings in all their diversity in technology and the natural sciences take centre stage, exciting questions arise. Once again, this is impressively demonstrated by the total of five publications and projects from research and teaching that were recently awarded the Mind_the Gap prizes of TU Graz. They all include different aspects of diversity such as age, gender, origin, language or culture.

WOMEN’S FOOTBALL

Jana Lasser and Max Pellert (Institute of Interactive Systems and Data Science) analysed 2.8 million tweets from the 2021 Men’s European Championship and the 2022 Women’s European Championship to find out what emotions they aroused in fans.

LACK OF DIVERSITY

Emanuel Lacic and Dominik Kowald (Institute of Interactive Systems and Data Science) illustrate in their scientific publication that artificial intelligence-based multimedia recommendation systems such as Spotify or Netflix over-represent popular content.

ARTIFICIAL INTELLIGENCE (AI)

In the project ENARIS – Education and Awareness for Intelligent Systems, a team at the Institute of Software Technology developed workshop formats and teaching content that convey a basic understanding of AI in a low-threshold manner.

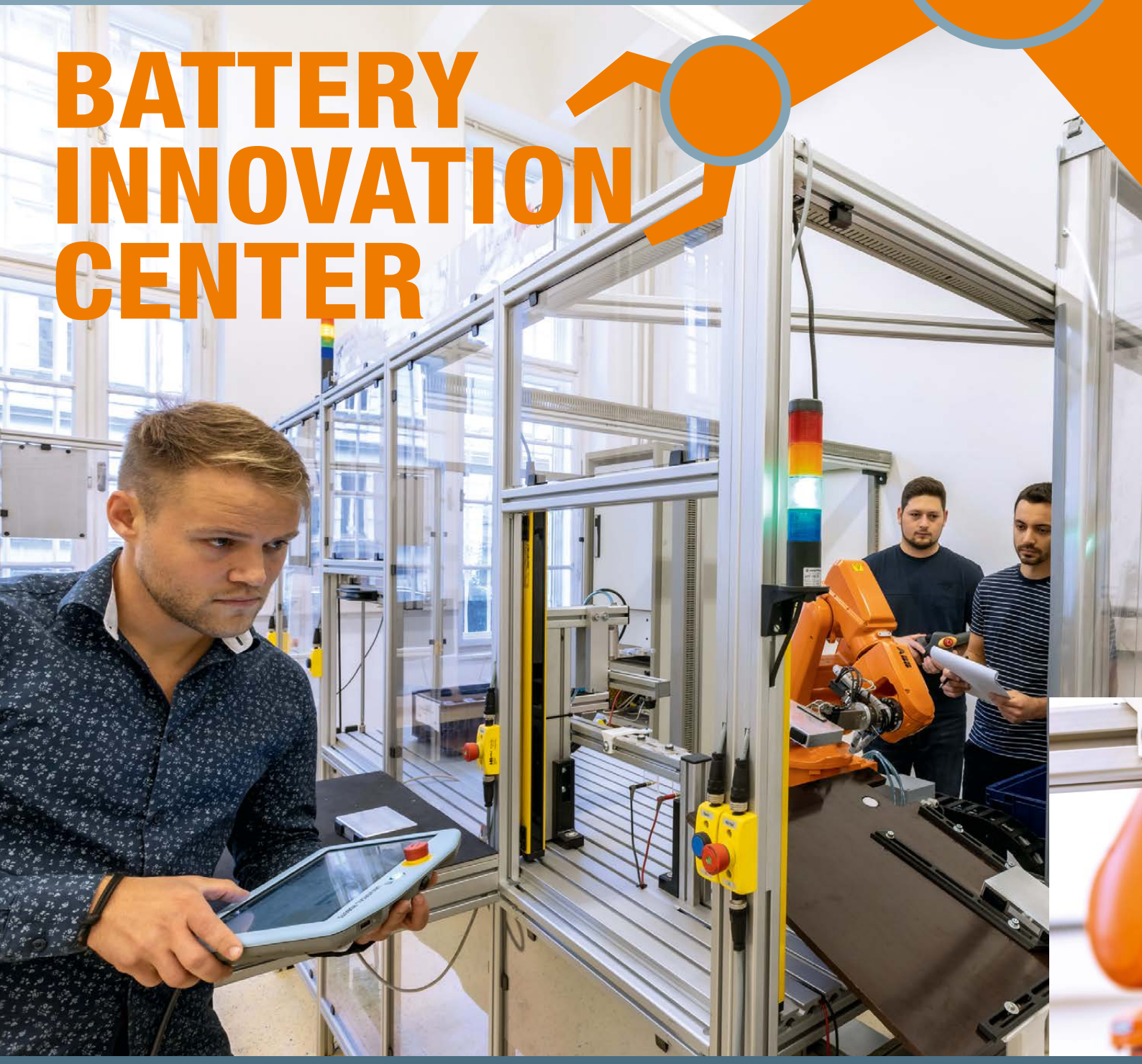
ELECTRONICS BASICS

A team at the Institute of Electronics designed the interactive online course ElectrONIX – Amplifiers to teach the basics of electronics to students, upper school students and people in further education.

STEM SUBJECTS

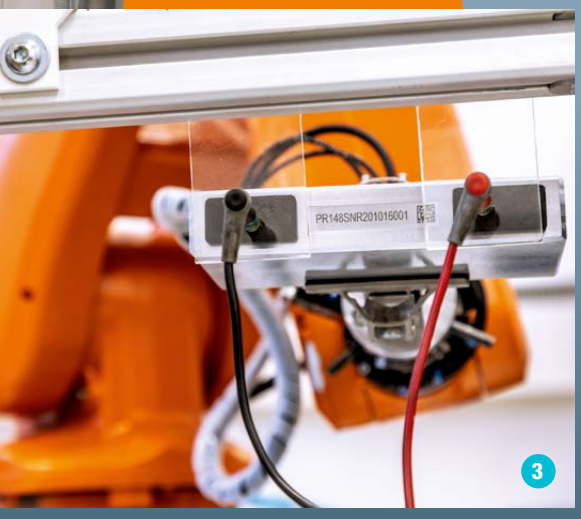
During the core time of the RADEC specialist conference in the field of radiation, which is aimed at professionals in electrical engineering and physics, Alicja Michalowska-Forsyth (Institute of Electronics) organized a lecture and discussion panel with three renowned former women researchers. ■

BATTERY INNOVATION CENTER



Bilder: Lunghammer – TU Graz

"Battery cells are the mechanical elements of the future," says TU Graz researcher Franz Haas, meaning that batteries will be as widespread in industrial applications and mobility of the future as for example screws are today. Accordingly, the construction of large quantities of battery modules and different cell types must be efficient and automatic. And this is exactly what TU Graz is researching together with the AVL company at the Battery Innovation Center. The large test factory is located on the AVL site, but there is also a collaborative production line on a smaller scale at TU Graz. Here, batteries of different types are tested and arranged into stacks – in the future, the researchers will also test the processing of fuel cells in a recently built dedicated clean room integrated into the robotic cell.



1. The first step in the production line is to select the appropriate gripper for the battery type. All common battery types can be picked up by means of vacuum. The robot picks up the battery cell ...
2. ... and transports it independently to the test stand.
3. At the test stand, the battery cell is first checked visually and then electronically for functionality and faults.
4. The robotic arm then places the battery on a ramp which transports it to the next production step – stacking.
5. Finally, the individual battery cells are integrated into a module housing and are now ready for final contacting and installation in battery packs.

“The Future is being Shaped at Universities of Technology”

Christian Dayé explores what role the future plays for societies. For several years, he has been focusing on how technological advances impact on society. His book on this topic has now won an award.

Birgit Baustädter

Christian Dayé is a sociologist at the Science, Technology and Society (STS) Unit.
Baustädter – TU Graz

“This award for my book from the History of Sociology & Social Thought Section of the American Sociological Association is a huge recognition of my work,” explains Christian Dayé, beaming. He is sitting comfortably in his office at the Campus Neue Technik of Graz University of Technology (TU Graz) – an office he is about to leave soon in order to move into the newly built Data House in Campus Inffeldgasse. But for now, there are three floors of old stairs to climb to his office. After that, a paradise of high bookshelves and bright old windows opens up. In the middle of all this sits Dayé and talks about his passion for the future.

TECHNOLOGY FOR THE DAY AFTER TOMORROW

“If you express it in a rather grand way, you could say the future is being shaped at universities of technology – here at TU Graz,” he says with admiration. “Technologies are being developed here that will shape our everyday lives the day after tomorrow.” Curiosity about things to come has led him into his current field of research. In his early years as a student, the sociologist studied how knowledge about the future is generated and how technical innovations affect society, how societies imagine the future and in which areas they invest resources, and how new technical developments can affect society and the environment of the future. “An interdisciplinary division of labour is important and right in these issues. Innovations can only succeed if researchers have as much time as possible to develop their ideas. Sociologists of technology like myself are here to sound out with them the possible consequences of their innovations on culture and society.”

DELPHI AND POLITICAL GAMING

Today, Dayé uses various scientific methods to investigate the future at the Institute of Interactive Systems and Data Science at TU Graz. In particular, the Delphi method and political gaming are popular methods of futurology. It was on precisely these two methods that Dayé wrote his book Experts, Social Scientists, and Techniques of Prognosis in Cold War America in 2020, which has now received the aforementioned Distinguished Scholarly Publication Award 2022. Specifically, the researcher looked at how research methods that are still in use today were developed in the Cold War era to assess possible developments, simulate courses of conflict and make decisions for the future.

ASTONISHED OBSERVER

Whether his own vision of the future was connected to the bright office at TU Graz is not an easy question for Christian Dayé. An enthusiastic musician, he started studying electrical engineering with a focus on sound engineering after graduating from a humanistic secondary school in Graz. But: “I lacked the background there and the studies were rather unsuccessful.” A blessing in disguise, as he recognizes today. After completing his doctorate in sociology at the University of Graz and occupying a university assistant position at the University of Klagenfurt, his career path led him back to TU Graz: “And today, as an amazed layman, I can experience technological innovations from the front row and reflect together with my colleagues from the natural and engineering sciences on what all this means for the society of the future.” Here he also found the opportunity to use the two methods interactively in teaching and to give students a sense of the interplay between innovation and society.

But there is one more thing... The award from the American Sociological Association is missing from both the desk and the bookshelves. Christian Dayé walks around his desk with a grin and fishes it out of a black cardboard package. “My son has forbidden me to hang it up here. He is afraid of it being stolen and would rather keep it at our appartment.” Perhaps as an incentive to make sure that the next generation doesn’t run out of ideas for the society of the future. ■

Science Slam 2022

Manuel Galler from the Institute of Electrical Systems and Networks is the Austrian Science Slam State Champion 2022. With his performance “Netzfehler – wir müssen draußen bleiben” the researcher not only won over the audience in Graz at the Styrian Science Slam, but also in Vienna at the Austria-wide final event. Now it’s off to the European finals for Galler.

Sponsorship prize

TU Graz researcher Daniel Gruss has been awarded the Förderpreis of the province of Styria.

Phoenix founder award

TU Graz researcher Viktor Hacker and his team have won the Phoenix Founder Award in the prototype category for their durable, sustainable catalyst for fuel cells.

edX

Several TU Graz courses are online on the plattform edX: Electromagnetic Compatibility Essentials, Side-Channel Security: Developing a Side-Channel Mindset, Cache Side-Channel Attacks and Mitigations, Physical and Advanced Side-Channel Attacks und Introduction to Software Side Channels and Mitigations.

THE Ranking

In THE World University Ranking 2023, Graz University of Technology is ranked 601-800, as it was last year. Graz University of Technology performs best in the area of International Outlook.

Award of Excellence

TU Graz graduates Daniel Kales (Computer Science), Gernot Pongratz (Mechanical Engineering) and Johanna Rock (Computer Science) received the Award of Excellence for their doctoral theses.

GI Dissertation Award

TU Graz cybersecurity expert Moritz Lipp was awarded the GI Dissertation Prize for his dissertation Exploiting microarchitectural optimizations for software.

Young Researcher Award

Two TU Graz researchers were awarded the Young Investigator Award at the Austrian Energy Congress 2022. Florian Ainhirn for his dissertation “Development of an extended calculation method for the thermal design of a 400-kv cable system based on empirical data” and Mathias Maurer for his Master’s thesis “Effects of transient stresses in the Austrian high-voltage grid”.

Publication Award

Christian Dayé, Institute of Interactive Systems and Data Science, received the 2022 Distinguished Scholarly Publication Award from the American Sociological Association for his book “Experts, Social Scientists, and Techniques of Prognosis in Cold War America.”

DGM Award

Sergio Amancio, Institute of Materials Science, Joining and Forming, was awarded the DGM Prize 2022 of the German Society for Materials Science for his many years of research work. Ricardo Buzolin, also at the Institute of Materials Science, Joining and Forming, received the Young Investigator Award of the German Society for Materials Science.

Young Researcher Group

Daniel Kracher (Institute of Molecular Biotechnology, “Infection-related redox systems in pathogenic bacteria”) and Horst Lechner (Institute of Biochemistry, “Active site transfer to generate new enzymes”) have each received funding from the inter-university research network BioTechMed-Graz to establish a Young Researcher Group.

TU Graz research: The variety of research topics at TU Graz

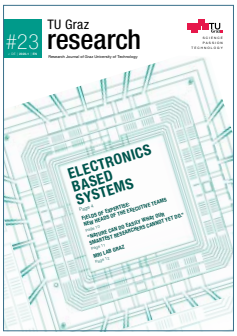
In each new issue, the research magazine TU Graz research focuses on a socially and scientifically relevant topic. The QR code next to the respective issue will take you directly to the e-paper.

Printed copies of the magazine can be ordered free of charge from the TU Graz Purchasing Service at the e-mail address **einkaufsservice@tugraz.at.**

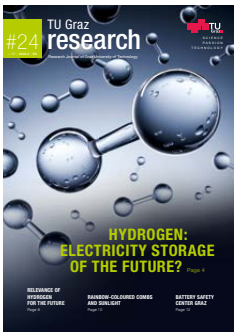
Would you like to receive the magazine regularly in the future? Click here for a free print or e-paper subscription: **https://www.tugraz.at/go/research-journal**

#21: CYBERSECURITY

#22: ADDITIVE MANUFACTURING

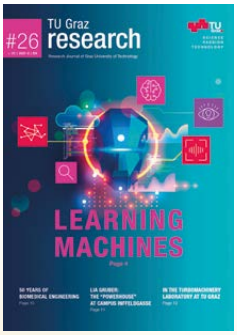


#23: ELECTRONICS BASED SYSTEMS



#24: HYDROGEN

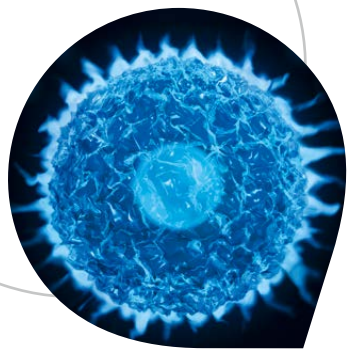
#25: BIOTECHNOLOGY

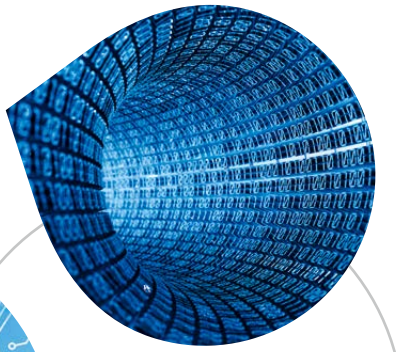


#26: LEARNING MACHINES

#27: SUSTAINABLE CONSTRUCTION

MiaStendal – AdobeStock




Fields of Expertise

TU Graz's research activities are grouped into five strategic, forward-looking Fields of Expertise. Researchers engage in interdisciplinary cooperation and benefit from different approaches and methods, shared resources and international exchange.

Advanced Materials Science

Editorial: Christof Sommitsch

The Potential of Polysaccharides in Biomaterial Science

Rupert Kargl

Human & Biotechnology

Editorial: Gernot Müller-Putz

Protein from Carbon Dioxide: A Sustainable Perspective

Helmut Schwab

Information, Communication & Computing

Editorial: Kay Uwe Römer

Identification and Monitoring of Aortic Diseases by Electrical Impedance Measurements

Alice Reinbacher-Köstinger

Mobility & Production

Editorial: Rudolf Pichler

Smart Production: The Jump-Off Base for Industry 5.0

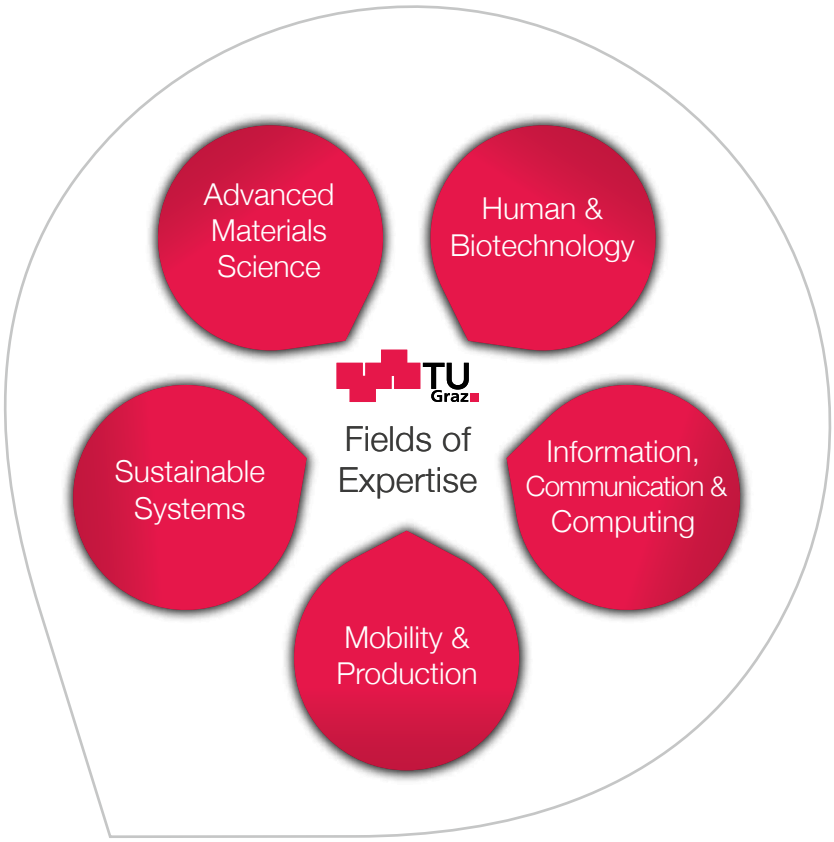
Matthias Wolf, Rudolf Pichler

Sustainable Systems

Editorial:
Urs Leonhard Hirschberg

Fundamental Fluid Mechanics for Sustainable Applications

Carole Planchette



TU Graz has divided its research into five innovative areas: the Fields of Expertise. Researchers in the Fields of Expertise break new ground in basic research. They take part in interdisciplinary cooperation, gain support for outstanding projects and are based in the region as well as part of international networks. They also develop key technologies for industry and commerce, and perform research in the framework of company shareholdings and partnerships.

Source: TU Graz

ADVANCED MATERIALS SCIENCE
Researchers aim to understand the smallest components in the structure and function of new materials, and develop and assemble them in special processes.

HUMAN & BIOTECHNOLOGY
Researchers develop devices and methods for medical applications and therapies, and focus on using enzymes and living microorganisms such as bacteria, fungi and yeast in technical applications.

INFORMATION, COMMUNICATION & COMPUTING
Researchers face challenges prompted by the information age, for example data security and efficient use of the ever-increasing volume of data.

MOBILITY & PRODUCTION
Researchers investigate novel vehicle technologies, new drive systems and more economical product manufacturing processes.

SUSTAINABLE SYSTEMS
Scientists focus on the complex challenges presented by a growing population and increasingly scarce natural resources.

ADVANCED MATERIALS SCIENCE

Fields of Expertise TU Graz

Source: istockphoto.com

Christof Sommitsch,
Advanced Materials Science

Source: Lunghammer – TU Graz

Smart production of smart materials is a hot topic in the FoE Advanced Materials Science as well as at the Smart Production Graz research center. Many activities are being pursued in materials science, physics, and chemistry.

Powder-based additive manufacturing, e.g. by laser powder bed fusion or plasma direct metal deposition, of functional materials, such as magnetic materials, high-entropy alloys or shape-memory alloys is one example of ongoing research. The process can be advanced for building smart parts, e.g. integrating temperature, pressure, and humidity sensors, realizing porous structures for NH_3 and biofuel synthesis and joining metallic and fiber reinforced polymers in-situ and ex-situ. However, also wire-based additive manufacturing by electron beam, plasma, and arc, as well as hybrid methods are applied for different tasks.

Another example is the technology of biobased systems, dealing with the development of conjugates based on biomolecules of living organism origin and analogues. This implements the manufacturing, analysis and application of organic structures and inorganic/organic hybrid systems. The focus here is set on the development of biomaterials with emphasis on surface specific processes (surface functionalization) and manufacturing of 3D structured materials and using modern technology as 3D printing or laser lithography, development of bio-inks formulations, cross linking – and self-assembly structures, for example tissue engineering.

A third research area is in in-situ atomic force microscopy enabled by an emerging 3D nano-printing technology. The research program is centered around Focused Electron Beam Induced Deposition which is an increasingly relevant direct-write technology for flexible, bottom-up synthesis of high-resolution nanostructures, applicable on virtually any substrate material and morphology. The research activities are focused on two main aspects, i.e. controlled 3D nanofabrication and defined material properties.

More and more important is the consideration of increasing the efficiency of processes (e.g. by reducing scrap), the reduction of critical raw materials (e.g. rare earth elements), the realization of lightweight structures (e.g. by topology optimization) and taking into account usage of circular materials (e.g. by using recycled materials). Machine learning methods are a means that are used to meet those targets.

Source: Lunghammer – TU Graz

Rupert Kargl

The Potential of Polysaccharides in Biomaterial Science

Natural polymers form the basis of life and understanding and modifying their properties can lead to new applications. From hyaluronic acid in connective tissue to cellulose in plants and peptidoglycans in bacteria, polysaccharides are one of the most important structural components of living things.

The use of naturally occurring or chemically modified polysaccharides in material science, or in contact with living tissue is therefore our main research interest at the Institute of Biobased Systems (institute head Karin Stana Kleinschek). This requires a highly interdisciplinary expertise, which we are trying to create together with collaborators within and outside TU Graz. >

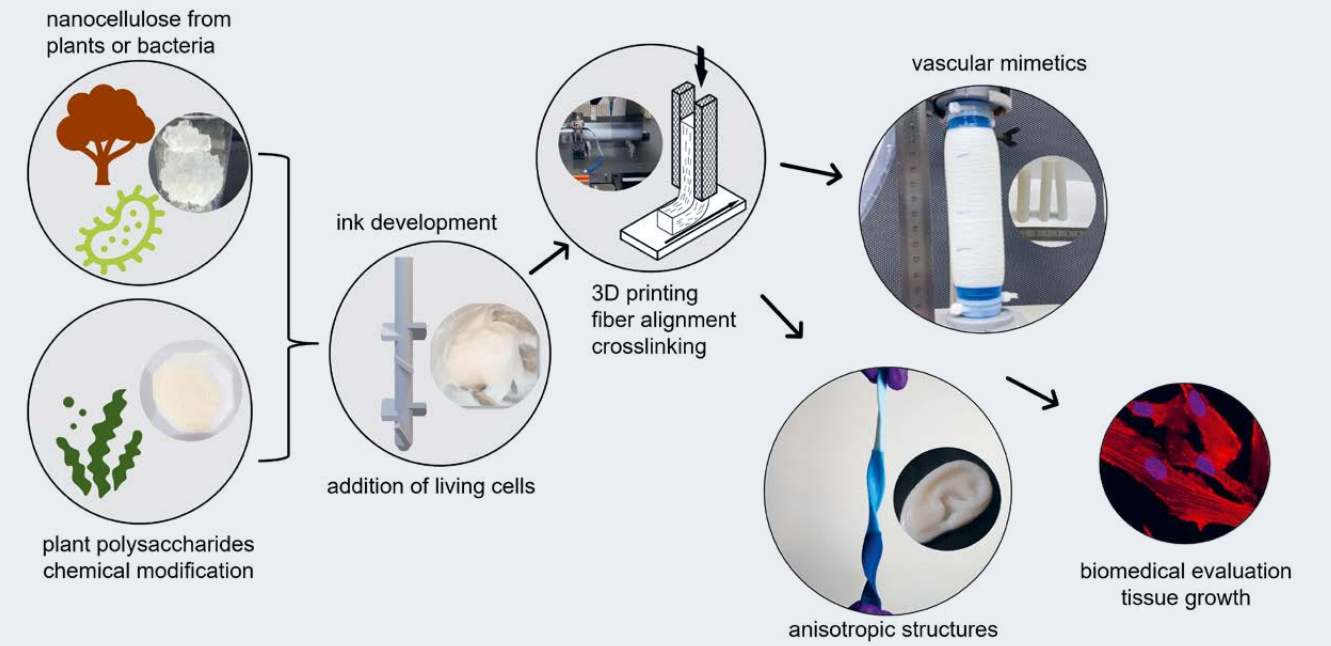


Figure 1:
Workflow of exemplary biomaterial research at IBIOSYS. Nanofibers are formulated into 3D printable inks with chemically modified polysaccharides optionally containing living cells. Extrusion is used to align nanofibers into desired directions. Various shapes are produced and evaluated for mechanical and biological properties. Parts of the work are funded by FoE Advanced Material Science (initial funding programme) and performed within the doctoral studies of Florian Lackner. Our colleague Tamilselvan Mohan is highly acknowledged for his contributions.
Source: Rupert Kargl

Two examples are given of how IBIOSYS attempts to utilize polysaccharides in advanced (bio-)material science. Figure 1 shows a general concept of how polysaccharide nanofibers with a diameter of 10 - 500 nm and a length of several hundred micrometers are used in the manufacturing of extrudable inks that can be 3D printed [1] into macroscopic shapes of advanced materials. The basis for our nanofibers form plants, but more interestingly also bacteria, that might be capable of delivering well defined polymeric sequences and supramolecular structures. Chemical modification of the components and the addition of living cells to our inks can be used to create tissue mimetics that could find application in regenerative medicine for skin or in the vascular system. The chemical modification is driven by our endeavor to find new ways to construct defined and complex polysaccharide peptide co-polymers that can be cross-linked into stable gels through enzymatic or non-covalent means. [2, 3]

We are also interested in the biomechanical properties of these materials in collaboration with Gerhard Holzapfel and team, Institute of Biomechanics, TU Graz. We could show in preliminary studies that water- and pressure-resistant tubes comprising hydrophilic components can be manufactured (Figure 1 right top) and that these tubes have similar tensile strength and elongation when compared to porcine tissue. The aim is to imitate the fibrous structure of native vascular or connective tissue which is comprised of collagen and elastin fibrils surrounded by proteoglycans. Cell tests and growth studies are planned in collaboration with Petra Kotzbeck and team, at the COREMED facilities of Joanneum Research, Graz.

(Poly)saccharide interfaces are decisive when biological molecules and living cells interact with solids. To elucidate basic mechanisms of semi-synthetic carbohydrate interactions, another interest is in the manufacture and study of defined and novel carbohydrate solid-liquid interfaces on a range of substrates [4] (Figure 2). These can be gold, silicon, polystyrene, and polyester, among others. Chemical methods are devised to synthesize and couple unusual carbohydrates to surfaces in collaboration with the Glycogroup of Tanja Wrodnigg at IBIOSYS. These surfaces are evaluated with respect to their interaction with proteins and living cells and conclusions are drawn from irreversible binding, cell layer formation, enzymatic activity, or antimicrobial action. Layers and coating methods can find use in biosensors, for drug screening, for enzyme immobilization or again in tissue growth. Integration into fluidic systems and cell culture plates are parts of the planned work.

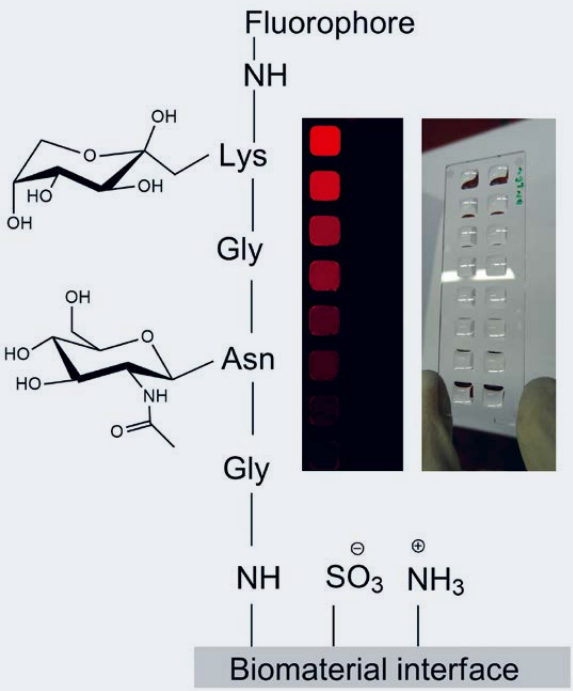


Figure 2:
Glycosylated peptides on amino group containing biomaterial surfaces. The glycosides can be naturally occurring or chosen from a very large library of saccharides including (pseudo-) C-glycosides. The aim is to investigate surface interactions with biomolecules or cells. The inset shows microscope glass arrays of fluorescently labelled biomolecular surfaces. Ongoing work in collaboration with DI Tobias Dorn, currently performing his doctoral studies at IBIOSYS.

Source: Rupert Kargl

Overall, we are convinced that biopolymers and carbohydrates have a significant potential to be used as biomaterials due to their very large structural variability and biological origin to which living cells respond. New chemical and physical methods are still needed to better understand and to finally utilize the beneficial properties of such materials. In any case a network of strong collaborators and an openness to disruptive ideas are necessary to reach the aims described.

Rupert Kargl
is assistant professor (2020) at IBIOSYS, TU Graz. His main expertise is in the chemical and physical properties of biologically produced renewable resources, especially polysacccharides. He aims at the characterization, chemical modification and application of these materials in the life- and biomedical sciences. He obtained a habilitation in the field of materials at the University of Maribor, Slovenia (2016), where he also completed a two year Marie Curie fellowship. Before that he spent six months at the German Federal Research Center for Forestry and Forest Products in Hamburg. His basic education is a doctorate in physical chemistry (2011), and an individual diploma of environmental system sciences with emphasis on chemistry (2006), both with distinction from the University of Graz, Austria..

Source: Privat

REFERENCES

[1] Mohan, T.; Dobaj Štiglic, A.; Beaumont, M.; Konnerth, J.; Gürer, F.; Makuc, D.; Maver, U.; Gradišnik, L.; Plavec, J.; Kargl, R.; Stana Kleinschek, K., Generic Method for Designing Self-Standing and Dual Porous 3D Bioscaffolds from Cellulosic Nanomaterials for Tissue Engineering Applications. ACS Applied Bio Materials 2020, 3, (2), 1197-1209.

[2] Mohan, T.; Kleinschek, K. S.; Kargl, R., Polysaccharide peptide conjugates: Chemistry, properties and applications. Carbohydr. Polym. 2022, 280, 118875.

[3] Bratuša, A.; Elschner, T.; Heinze, T.; Fröhlich, E.; Hribernik, S.; Božič, M.; Žagar, E.; Kleinschek, K. S.; Thonhofer, M.; Kargl, R., Functional dextran amino acid ester particles derived from N-protected S-trityl-L-cysteine. Colloids Surf., B 2019, 181, 561-566.

[4] Katan, T.; Kargl, R.; Mohan, T.; Steindorfer, T.; Mozetič, M.; Kovač, J.; Stana Kleinschek, K., Solid Phase Peptide Synthesis on Chitosan Thin Films. Biomacromolecules 2022, 23, (3), 731-742.

HUMAN & BIOTECHNOLOGY

Fields of Expertise TU Graz

Source: fotolia.com

Gernot Müller-Putz, Human & Biotechnology
Source: Lunghammer – TU Graz

After a "hot autumn" with the deadlines for FWF START, ERC Starting, ERC Consolidator and ERC Synergy Grants, we would like to point out that there is an ERC Club at TU Graz that aims to provide applicants with the best possible support for their applications and interviews. In a relaxed atmosphere, ERC grantees talk about their experiences and applicants can ask questions on all topics related to the ERC, such as When should you start? What does high risk/high gain mean? How does the review process work? How should one write the different parts of the proposal? What are the panels? These and many more questions will be addressed at the next ERC Club meeting in spring 2023. Interested parties can contact Gerald Pichler at the Research & Technology House.

However, it is also again possible to get a large grant at TU Graz. Currently, the LEAD projects are being advertised again and there is the possibility to apply with a consortium. We call on our FoE members to participate in this TU Graz-internal funding opportunity.

We have good news to report from our FoE. The Stefan Schuy Prize of the ÖGBMT (Austrian Society for Biomedical Engineering) has been awarded to Sonja Langthaler (Institute of Health Care Engineering). The prize was presented at the three-country meeting of the German, Swiss and Austrian societies in Innsbruck at the end of September.

Helmut Schwab has written an interesting article on a highly topical subject of industrial biotechnology for this issue. It is about the use of carbon dioxide and hydrogen for the microbial production of valuable substances, in his case protein as animal feed.

Helmut Schwab

Protein from Carbon Dioxide: A Sustainable Perspective

The extreme release of CO_2 into the atmosphere by using fossil carbon resources is drastically influencing the climate of our planet. Technology to recycle CO_2 and turning it into valuable compounds not only provides important solutions to reduce negative impacts on the climate, but also opens up a sustainable raw material source.

With our research for developing a bioprocess for producing protein based on CO_2, novel routes for food and feed production are enabled. The company Econutri GmbH, a spin-off from research work performed at TU Graz and the Austrian Centre of Industrial Biotechnology (acib GmbH), is now transferring basic research into industrial application by research at pilot scale.

WHY PROTEIN?

The supply of protein in sufficient quantities for human nutrition is increasingly becoming a challenge due to the rising population growth. In particular people in developing countries are already severely suffering from lack of protein, thus generating hunger and problems in the development of body and brain in children.

Helmut Schwab researches at the Institute for Molecular Biotechnology.

Source: Foto Fischer

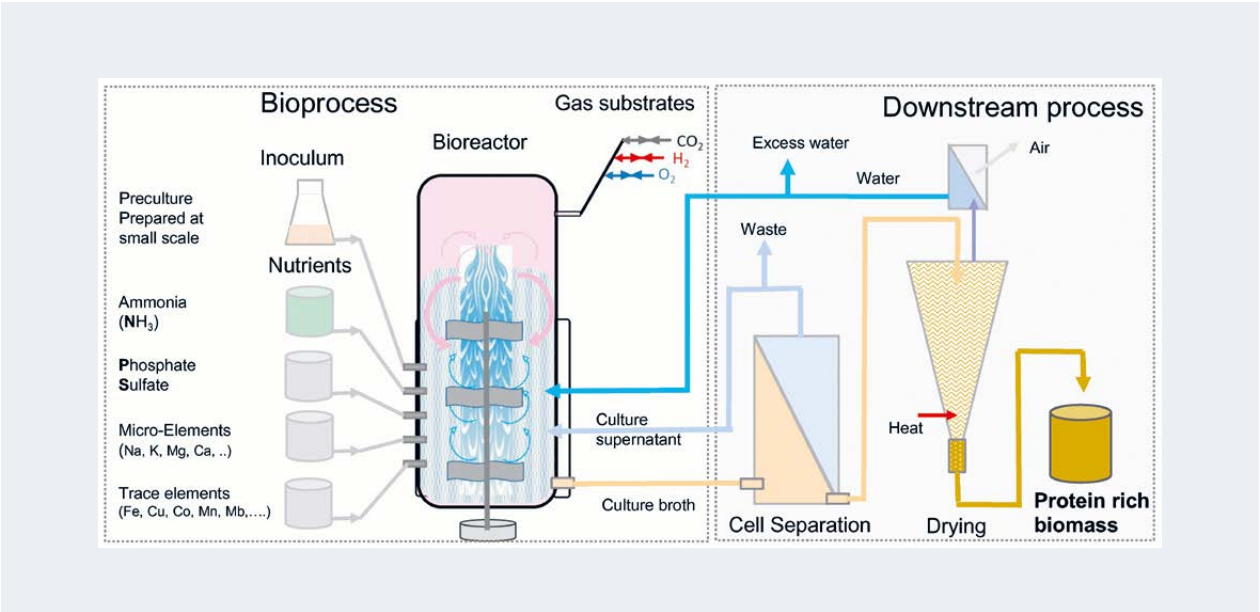


Figure 1: Scheme of the bioprocess for SCP from CO_2.
Source: H.Schwab / Econutri

The current sources of protein for human nutrition, plants and animals have already come up against strong barriers. The cultivation of protein-rich plants, such as for example soy bean, needs large areas of cultivable land, high amounts of water and the application of herbicides and pesticides. As the available cultivable land is already totally limited, large areas of virgin forest are being burned down thus triggering additional CO_2 release into the atmosphere. Fisheries are a major source of protein from animals. Extreme overfishing of our oceans is already strongly endangering fish populations, and fish farming again needs other protein sources. As a consequence, novel solutions for protein supply not needing large land or fish resources are indispensable in order to guarantee sufficient protein.

ALTERNATIVE PROTEIN BY PRODUCTION IN INDUSTRIAL PLANTS

Several concepts for producing protein in industrial plants have been established. One line is cultivation of insects, mainly as protein-rich larvae. Such processes can be performed in rather simple production facilities and usually use waste products from agriculture or food production. A more sophisticated strategy is cultivation of animal cells in tissue culture systems. This strategy is expected to directly serve as a substitute for meat. However, very complex and extremely expensive cultivation media are needed which again are dependent on agricultural resources. The most promising route is the cultivation of microbial cells in bioreactors (Single Cell Protein, SCP). Many microbes can efficiently synthesize protein and their biomass can contain up to 80% protein (SCP). Processes employing – for example – yeast have been run for many decades and are mostly based on sugar-containing substrates such as molasses, thus also creating a dependence on materials from agriculture.

CARBON DIOXIDE IS A CARBON SOURCE FOR BIOPROCESSES INDEPENDENT FROM AGRICULTURE

In living nature, carbon dioxide serves as the central carbon compound and is constantly consumed and produced in an equilibrated cycle system. Fixation of carbon dioxide in order to build organic compounds and biomolecules takes place in the domain of plants. Organisms which gain their nutrition directly or indirectly from plant products produce CO_2 acting as a sink in energy production. Besides plants, a variety of microbes also can utilize CO_2. Algae and microalgae (cyanobacteria), like plants, use solar energy via photosynthesis as an energy source. However, the establishment of industrial photobioprocesses is restricted by the demand of large surface areas for transmission of light to the cells. Alternatively, chemolithoautotrophic bacteria use chemical energy for CO_2 fixation. The most interesting group of such organisms are bacteria which can utilize molecular hydrogen as an energy source.

THE BACTERIUM CUPRIAVIDUS NECATOR – A WORK HORSE FOR CO_2-BASED BIOPROCESSES

The bacterium C. necator is a facultative chemolithoautotrophic bacterium which can either grow heterotrophically on organic compounds or autotrophically using CO_2 and hydrogen as sole sources of energy and carbon. It has been well-studied over decades and has a long history of safe use. Large bioprocesses based on heterotrophic nutrient supply are already well established, e.g. for the production of the biopolymer polyhydroxybutyrate (PHB). Autotrophic growth is well established at small scale and several companies are already considering this organism as a platform for the production of various compounds based on CO_2. >

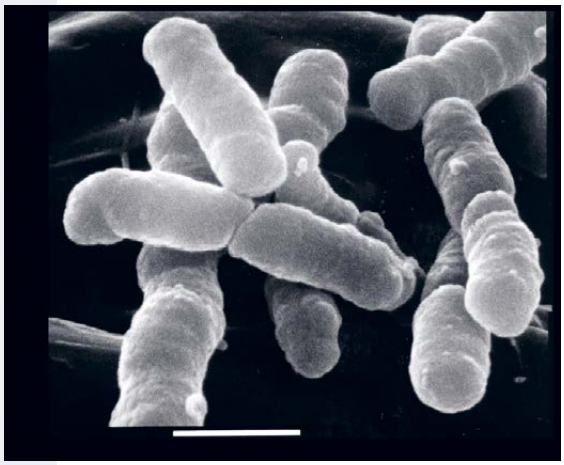


Figure 2:
Electron micrograph of cells of Cupriavidus necator.
The white bar represents 1 µm.
Source: H.Schwab / FELMI-ZFE

Figure 3:
Pilot gas bioreactor at 300 L volume capacity.
Source: H.Schwab / Econutri

GAS FERMENTATION AT LARGE SCALE IS A CHALLENGE

The bioprocess for protein production from CO_2 needs a bioreactor which provides a highly efficient gas-to-liquid transfer capacity. This is especially driven by the fact that molecular hydrogen is poorly soluble in aqueous systems and it represents the major molecule and cost-driving factor of the entire process. This becomes quite evident from the summarizing mass balance of the autotrophic protein production process.

$$\mathbf{21.36\ H_2} + 6.21\ O_2 + 4.09\ CO_2 + 0.76\ NH_3 \rightarrow ([\ C_{4.09}\ H_{7.13}O_{1.89}N_{0.76}\ ] = \text{biomass}) + 18.7\ H_2O$$

Most of the hydrogen is used for energy production by an electron transfer process from hydrogen to oxygen, thus creating water as an end product (biological "burning" of hydrogen). We have developed a novel reactor design for efficient gas fermentation to meet the demand for efficient gas-to-liquid transfer. The reactor operates under pressure up to 6 bar in order to raise the partial pressure of the gases and it has a specifically designed mixing system for creating high-contact surfaces between gas and liquid phases. In addition, the reactor design also includes a safety management system in order to prevent explosion. It is installed at the Institute of Thermal Engineering, where the proper infrastructure for operating processes using hydrogen has been established.

UPSCALING TO INDUSTRIAL LARGE SCALE

In our current research work performed in collaboration with acib GmbH, the operation parameters for the bioprocess are optimized and suitable fermentation protocols for high biomass production, high protein content and rapid growth are worked out. In the next year, the downstream process will also be included in the pilot plant. It is also planned to extend the research work by including the needed supply elements, such as hydrogen and oxygen production by electrolysis, and using real off-gas from CO_2 emitting industries. The first product of our process will be dried protein-rich biomass, which is intended to be used as an ingredient for animal feed. In the context of developing the downstream process, we will also perform research on extraction of pure protein fractions out of the biomass. Such a pure protein product could then also go directly into human nutrition.

INFORMATION, COMMUNICATION & COMPUTING

Fields of Expertise TU Graz

Source: istockphoto.com

Kay Uwe Römer,
Information, Communication & Computing
Source: Lunghammer – TU Graz

After more than one and a half years of online and hybrid conferences (often with very limited in-person attendance) I just returned from my first presence-only conference just like they used to be in good old pre-COVID times. Many senior persons and close colleagues attended and were actually around in the lecture hall most of the time – as if they had missed the possibility to mingle. During the joint lunch I learned informally about the latest research topics they are currently investigating. We exchanged experience about online teaching during the coffee breaks. We went out in the evening for a glass of wine over which we shared the latest rumors about who had accepted a faculty position at which university. They told me during the social event – in a beautiful collegiate church with an organ whose low notes could literally be felt in the belly – how their families are doing. The welcome reception was held in a smart factory, so we could see and touch the latest equipment they have installed there. During the demo session there were many good hands-on demonstrators where one could touch and play with the prototypes. All this never happened during the online conferences and only to a very limited degree during hybrid conferences, because the "interesting" colleagues joined only online. This reminded me that all these informal side activities during an in-presence conference are at least as important as the paper presentations. Fortunately, there are things in life that cannot be digitalized.

In this edition of TU Graz research, Alice Reinbacher-Köstinger, assistant professor at the Institute of Fundamentals and Theory in Electrical Engineering, gives us some insights into her research. Enjoy reading!

Alice Reinbacher-Köstinger

Identification and Monitoring of Aortic Diseases by Electrical Impedance Measurements

Aortic diseases such as aortic aneurysm or dissection can be life-threatening and are not always detected in time. Therefore, an easy-to-use, non-invasive method to detect such a disease would be of great benefit. A suitable method that is already in clinical use but for a different purpose, is impedance cardiography. With numerical simulations of an adapted measurement system, including patient-specific geometries, the feasibility of such a method to be able to identify and monitor pathologies of the aorta is being investigated.

Electrical bio-impedance measurements are performed by placing adhesive electrodes on the body surface and injecting a low-amplitude alternating current. As shown in Fig. 1, additional sensor electrodes measure the voltage drop in the region of interest, which is proportional to the impedance and varies during a cardiac pulse wave. Since blood has a higher electrical conductivity compared to the surrounding tissue types, the impedance changes are mainly due to the pulsatile blood flow in the aorta. The blood pulsation causes volumetric changes of the aorta and also flow-induced conductivity changes. >

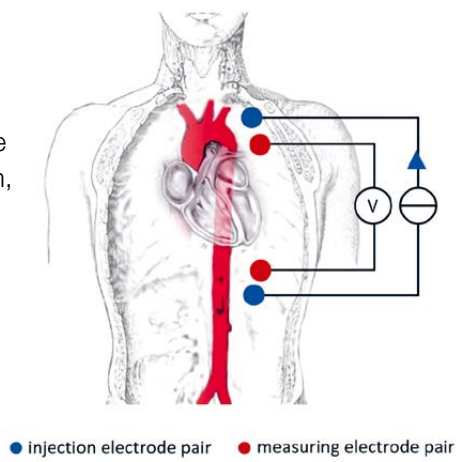


Figure 1: Principle of thoracic bio-impedance measurements.
Source: J. Heuser, Wikimedia, with modifications

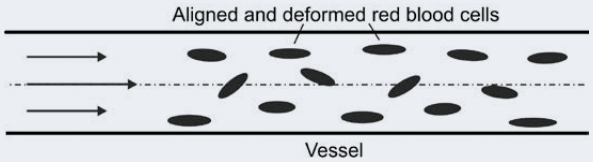


Figure 2:
Sketch of the alignment and deformation of red blood cells in a vessel.
Source: Alice Reinbacher-Köstinger

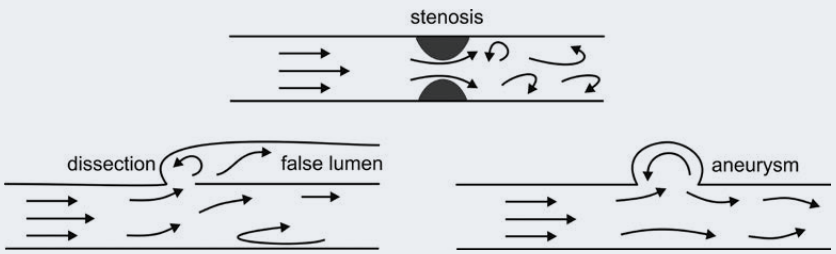


Figure 3:
Sketch of flow disturbances for different aortic pathologies.
Source: Alice Reinbacher-Köstinger

Both are altered in case of an aortic pathology and these changes should provide the opportunity to identify the disease.

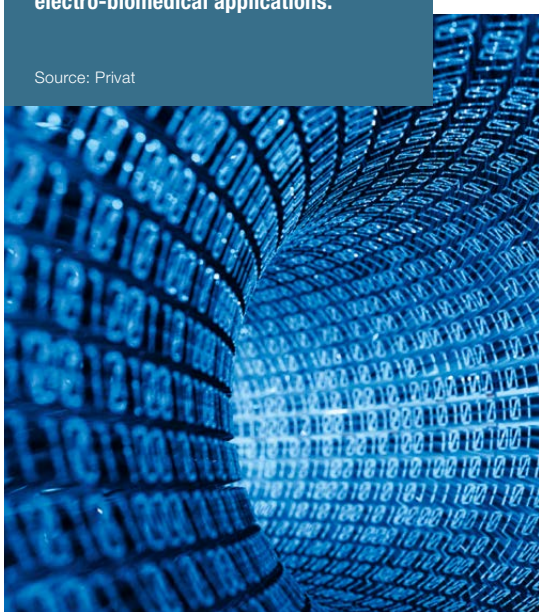
A numerical model of the thorax is used to simulate the electrical behavior of the measurement setup mentioned above. By simulating and assessing many different models the most influential factors can be identified. While the geometry of the different tissue types and also the temporal volumetric changes of the blood-filled aorta can be extracted from imaging data, the material parameters have to be taken from the literature and are subject to a very high uncertainty. Special attention must be paid to the flow-induced and therefore time-dependent behavior of the conductivity of blood.

Blood is a physically highly complex fluid that consists of cells (red and white blood cells and platelets) suspended in blood plasma. From experiments over the last 100 years, it turned out that the electrical conductivity and the viscosity are mainly determined by the properties of the red blood cells (RBCs) and the surrounding plasma. Furthermore, it has been observed that the alignment and deformation of the electrically isolating RBCs suspended in the well-conducting blood plasma causes the blood conductivity to become anisotropic in the case of flowing blood, i.e. it is higher in the direction of flow and lower in orthogonal direction. Furthermore, it is spatially distributed since the shear stresses are higher close to the vessel wall, as can be seen in Fig. 2. This anisotropic, flow-dependent conductivity is calculated based on CFD simulation results performed by our partners within the TU Graz lead project “Mechanics, modeling and simulation of aortic dissection”, the groups of Thomas Hochrainer, head of the Institute of Strength of Materials and Günter Brenn, head of the Institute of Fluid Mechanics and Heat Transfer. In order to model the non-Newtonian behavior of blood used in the CFD simulations, rheological data is needed. Ursula Windberger, head of the rheology lab of the Center for Biomedical Research (Medical University of Vienna), conducts research in the field of material characterization of suspensions and, in particular, of human and animal blood and measured the viscosity of various blood samples at different shear rates. With the resulting flow field quantities, the spatial, anisotropic electrical conductivity is calculated using a sophisticated conductivity model for suspensions of ellipsoidal particles.

While the numerically obtained conductivity changes in laminar flow in a rigid vessel have already been validated by measurements, there are no data available for the case of flow disturbances in the vessel,

Alice Reinbacher-Köstinger has been an assistant professor at the Institute of Fundamentals and Theory in Electrical Engineering since 2020. Her work is focused on the numerical optimization of technical systems and on inverse problems, especially in electro-biomedical applications.

Source: Privat



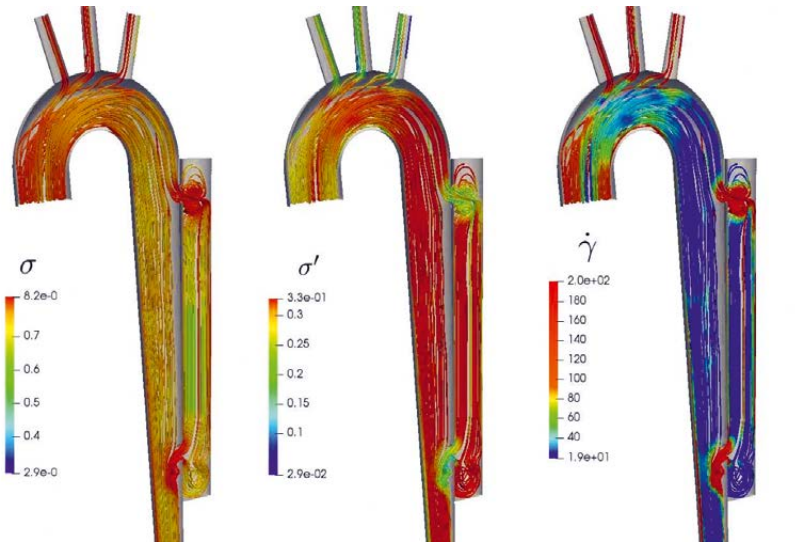


Figure 4: Shear rate ($\dot{\gamma}$) and el. conductivity in flow direction (σ) and orthogonal to the flow (σ') in case of an aortic dissection.
Source: Alireza Jafarinia

as is the case with aortic diseases. Therefore, experimental investigations for different types of disturbances (see Fig. 3). are performed in our laboratory. Before using human blood for the experiments, a suspension made of fibers in the µm range, which have been provided by the Institute of Chemistry and Technology of Biobased Systems, is used. Due to the shape of the fibers (non-spherical isolators in a well conducting liquid) a similar behavior of the alignment at higher flow rates is observable.

For the case of an aortic dissection, where the innermost layer of the aorta ruptures and blood starts to flow between the intima and the media layer, the blood conductivity has been computed using openFoam and the result is shown in Fig. 4. As a result of the dissection, a new, so called false lumen develops besides the original aorta. The local hemodynamic conditions such as flow disturbances and recirculations may cause thrombus formation and growth there and the status of this thrombosis is of great importance in the medical management of respective patients. By 3D FEM electric field simulations using openCFS, as shown in Fig. 5, significant impedance changes due to physiological changes during a thrombosis are determined, confirming that the modified impedance cardiography can be a valuable method in the medical management of aortic dissections.

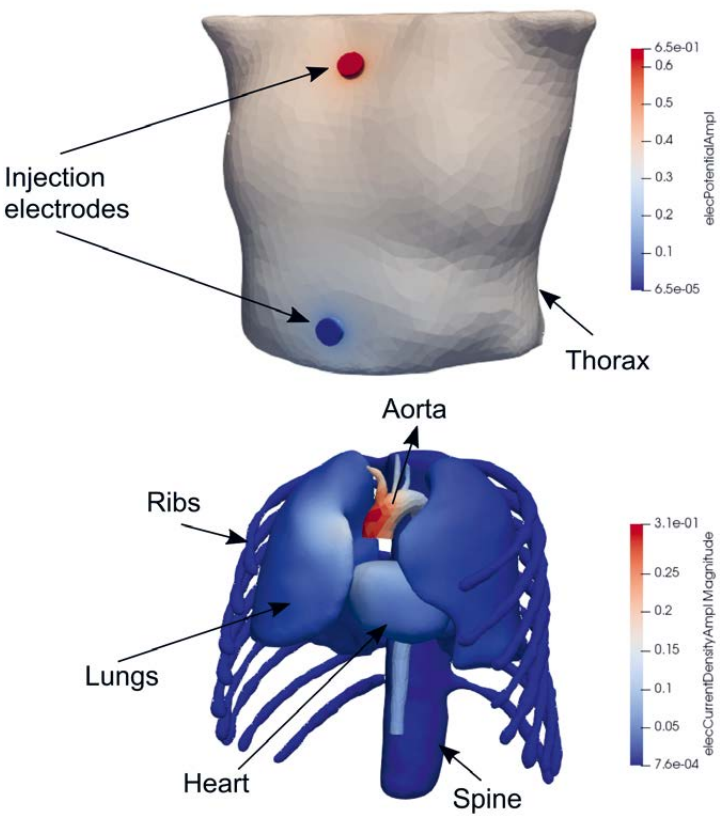


Figure 5: Patient-specific 3D FEM model.
Source: Vahid Badeli

ACKNOWLEDGEMENTS

This work is part of the TU Graz lead project “Mechanics, modeling and simulation of aortic dissection”. The main contributors to this subproject are Vahid Badeli from the Institute of Fundamentals and Theory in Electrical Engineering, Alireza Jafarinia from the Institute of Strength of Materials and Gian Marco Melito from the Institute of Mechanics.

MOBILITY & PRODUCTION

Fields of Expertise TU Graz

Source: istockphoto.com/fotolia.com

Rudolf Pichler,
Mobility & Production
Source: Lunghammer – TU Graz

The most wonderful thing this summer was being able to meet people again and to work without masks for a longer period.

There were two events worth mentioning in the FoE Mobility & Production where we had the opportunity for an intensive exchange of knowledge.

In the middle of July the Institutes of Automative Engineering and of Thermodynamics and Sustainable Drive Systems organised a symposium with more than 40 PhD students presenting and discussing their results on vehicle and drive technology. In September, our university once again hosted a conference and showed the latest research results in the area of Mobility and Production. Our FoE participated with six speeches and three posters.

There is also good news in the area of funding. The Institute of Production Engineering, which also the runs the smartfactory @tugraz together with Vienna University of Technology and the JKU University in Linz, was able win a five-year funding programme to network their pilot factories in order to generate sustainable innovation on basis of the new European Platform Gaia-X. This funding programme goes hand in hand with the article that follows, which gives deeper insights into the new era of industry 5.0. It shows that TU Graz is again proactive in this new dimension of using highly up-to-date technology in order to create competitive worlds of production.

Source: Shutterstock/asharkyu

Matthias Wolf, Rudolf Pichler

Smart Production: The Jump-Off Base for Industry 5.0

One could discuss whether the latest industrial revolution (Industry 5.0) launched by the EU commission already deserves a full digit rise, but one thing is evident: It is the smart world of digitalization (Industry 4.0) which is the powerful enabler of these new 5.0 topics, comprising resilience, human-centric work and sustainability. What TU Graz is doing exemplarily in these new fields of research will be introduced here in the following.

SMART PRODUCTION ON ITS WAY TOWARDS INDUSTRY 5.0

More and more companies have arrived in the world of smart production with its borderless benefits of communication and interaction. There seems to be no limit when leaving the former strict hierarchy of the automation pyramid and using the new forms of collaboration and ICT based interconnection of facilities either within an independent company or even better across the value chain of a series of companies.

All the advantages of this networked operations (global CPPS) aside, there has been a missing something that is at least of the same importance and necessity for

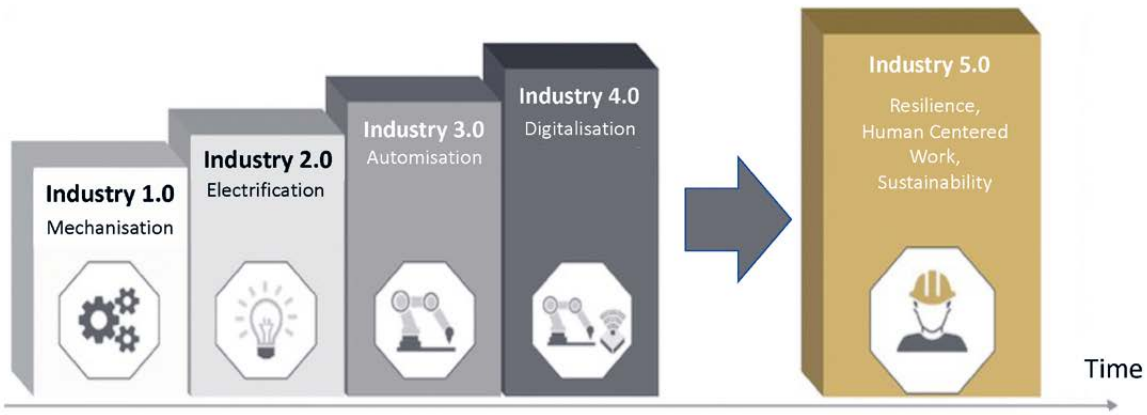


Figure 1:
The step forward to industry 5.0.
Source: Own representation.

sustainable smart operation in the actual situation of companies. The European Commission found out that there is a strong need to focus the aspects of Resilience, human-centric Work and Sustainability in order to reinforce the Smart Production Initiative and the economy of European production as a whole. Thus, Industry 5.0 [1] was launched. What TU Graz is contributing in these matters and which research fields it has put onto its agenda will be introduced here.

THE MAKERS OF RESILIENCE

It is the new way of engineering (simulation, virtual reality, etc.), the use of disruptive technologies (IoT, Artificial Intelligence, CPPS) and the design of top competitive working environments (collaborative robotics, wearables, agile infrastructure) which enable the future of human work to be mastered. All these new means build the important tool kit for achieving the status of resilience and the condition of remaining robust and successful in always faster and furiously volatile markets.

In order to demonstrate how such resilient or agile concepts could look like in the field of production there are two specific laboratories established at TU Graz. On the one hand there is the “LEAD-Factory” and on the other the “smartfactory@tugraz” where Virtual Plant Design, Virtual Commissioning, Mobile Working Stations for Agility, Process Simulation, Digital Twin and similar tools are installed and researched. These environments build an attractive offer for joint research and introduce many living solutions to students and industrial companies.

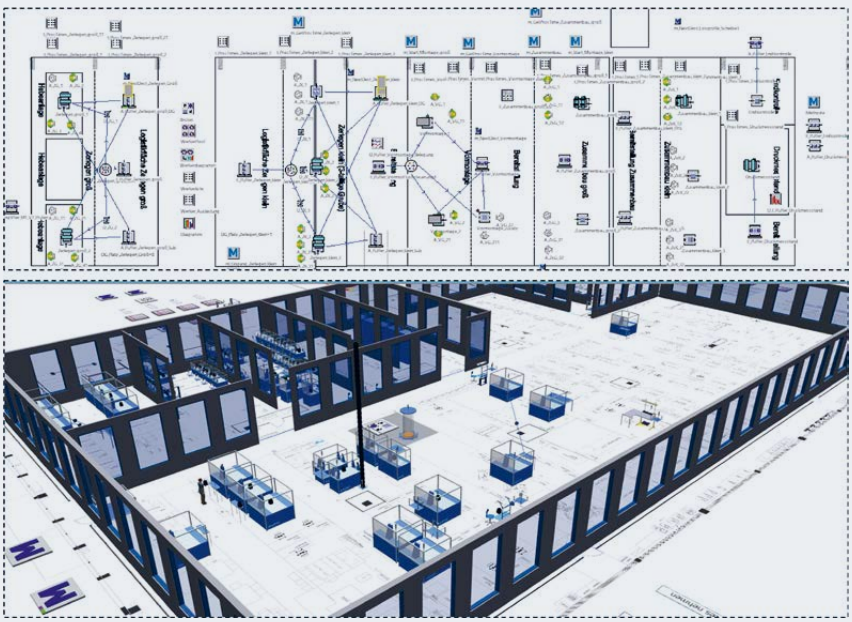


Figure 2:
Simulation-based factory planning as a tool for resilience.
Source: Own representation.

PEOPLE AT THE CENTER OF VALUE CREATION

Increasing competition and growing efficiency requirements lead to a higher intensity of work. Going into a higher degree of automation can only counteract this to a limited extent because of technical >

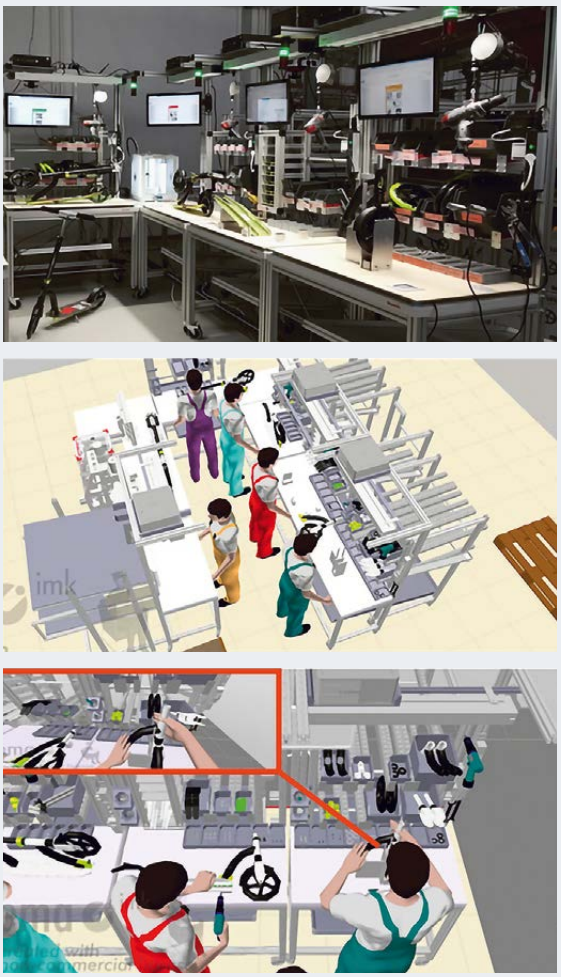


Figure 3:
LEAD Factory and digital workplace design.
Source: Own representation.

and economic limits. Even more so, the goal of a "smart factory" has never been to create a factory without people. Rather, it is about flexible automation and collaborative working environments in which humans and machines complement each other's capabilities. So, the focus remains or has to be reinforced again on the working people.

Regarding this, researchers at TU Graz are actually working on the simulation-based ergonomic design of workplaces (Fig. 3) or RTLS systems for linking humans and technical systems. For example, research is being conducted on how and when systems for physical support (e.g. CoBots, exoskeletons) are useful in order to avoid overload and absenteeism (e.g. research project ExoFitStyria).

As for the growing amount of information to be processed, worker-guidance systems and "extended reality" applications are becoming more and more important. To put working people at the center of production processes, the task of research is to offer efficiently designed devices.

Last but not least, the necessary raising and transfer of skill levels is also part of the research at TU Graz (actually conducted in the research projects LeNuWas and VolaDigital).

MINIMIZING THE ECOLOGICAL FOOTPRINT

Due to the EU's goal of ensuring CO_2-neutral production in Europe by 2050 [2], the reduction of environmental footprints will be a central target especially for manufacturing companies. Regarding this, smart production concepts are predestined to provide the relevant data as a "by-product".

The relevant emission data, the product footprint (CPF) and other sustainability targets can be computed and monitored quite easily even with high temporal and spatial resolution via smart data acquisition directly at the machines and with the use of networked libraries. This is the basis for controlling the actual situation and finding new potentials of reduction.

At TU Graz research is being done on transparent procedures for determining the relevant emissions (the Transform. Industry project) as well as knowledge transfer for their targeted reduction (energy efficiency LEAD factory training). Additionally, this is part of two generously funded projects (PilotLin-X and ResearchLin-X) for sustainable innovation networks (Fig. 4). Together with the corresponding universities in Vienna and Linz and 20 companies, a modern network architecture (Gaia-X) and its Data Spaces are going to be designed for complex and sustainable innovations. As a basis and for a better understanding, this process is being carried out using the example of sustainable co-design and co-production of an industrial product.

SUMMARY AND OUTLOOK

The digital possibilities of an existing smart production concept offer the appropriate mindset and the right tools for creating a successful world of industry 5.0. So, the new topics of Resilience, HumanCentric Work and Sustainability find their ground to develop properly. TU Graz has already started to step into these new dimensions of the future working style in production environments. It has been running various related projects and wants to be one of the industry 5.0 frontrunners.

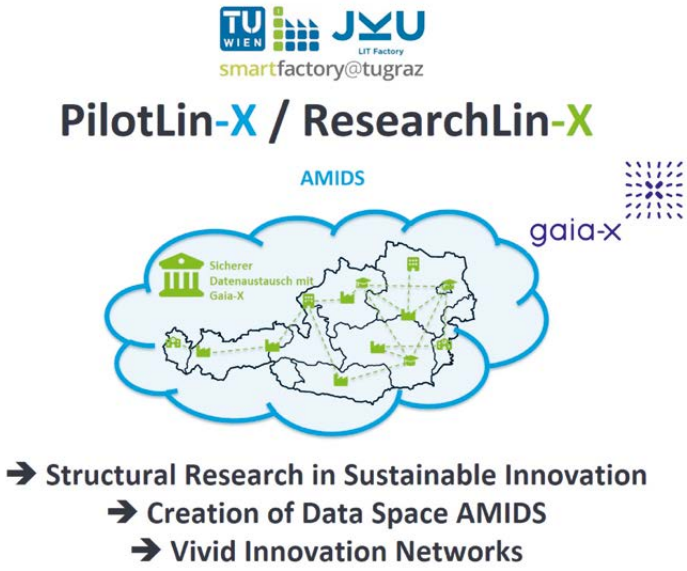


Figure 4: Funded research projects on sustainability.

Source: Source: Own representation.

REFERENCES

[1] European Commission, Directorate-General for Research and Innovation, Renda, A., Schwaag Serger, S., Tataj, D., et al, Industry 5.0, a transformative vision for Europe: governing systemic transformations towards a sustainable industry, Publications Office of the European Union, 2022, https://data.europa.eu/doi/10.2777/17322.

[2] European Commission, A European Green Deal - Striving to be the first climate-neutral continent; https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en, 2022.

Matthias Wolf

Is assistant professor at the Institute of Innovation and Industrial Management. His research focuses on the topics of industrial management, human-centred work system design, green production and engineering education with a focus on learning factories.

Source: Privat

Rudolf Pichler

is senior researcher at the Institute of Production Engineering and leads the research and learning factory smartfactory@tugraz: His major research field is the digitalization of manufacturing environments with emphasis on sustainable systems.

Source: Privat

SUSTAINABLE SYSTEMS

Fields of Expertise TU Graz

Source: ymgerman – fotolia.com

Urs Leonhard Hirschberg, Sustainable Systems

Source: Lunghammer – TU Graz

In the 17th round of the initial funding program, a total eight proposals were submitted in the Sustainable Systems category, and the following five projects received funding.

Tajda Potrc Obrecht from the Institute of Structural Design proposes A Roadmap for the Decarbonization of Austria's Building Stock, an ambitious undertaking that aims to create a comprehensive dynamic building model, including all inflows and outflows of material, using data mining, statistical and probabilistic models as well as Life Cycle Assessment (LCA) methods in an interdisciplinary endeavor. Such a model, her proposal argues, will be necessary to test potential decarbonization strategies.

Milena Stavric, associate professor at the Institute of Architecture and Media, wants to further explore Alginate as a Matrix in Biocomposite Architectural Acoustic Materials. Alginate, which is found in brown algae cell walls, is a material that can be produced sustainably in large quantities and which, while used in a growing number of applications, is still largely unexplored for use in construction. The interdisciplinary team will build on a range of promising experiments with Alginate that were done as part of the FWF SFB project Advanced Computational Design, where Stavric is a sub-project PI.

Sonja Wogrin, newly appointed head of the Institute of Electricity Economics and Energy Innovation, was successful with her proposal BASIS, which stands for Basis-oriented time series Aggregation for decarbonized power System optImization modelS. Her project aims to address one of the fundamental problems of power system optimization models: the tradeoff between model accuracy and computational tractability. Her interdisciplinary approach will include aggregated optimization models and Machine Learning (ML) methods to approximate full model results as closely as possible with a reduced amount of data.

Gerald Krebs from the Institute of Hydraulic Engineering and Water Resources Management wants to address the problems posed by flooding, which have increased as heavy rain events have become more frequent due to climate change. In his proposed project KARLA, which stands for "KlimawandelAnpassung durch hochwasserReduzierende LAndwirtschaft" (climate change adjustments through flood reducing agriculture), Krebs and his interdisciplinary team want to study the relationship between agricultural practices and water runoff and thereby lay the groundwork for improved numerical modeling methods for flood prevention schemes.

Fridges and freezers are typically the biggest consumers of electrical energy in a household and account for about 12% of annual electrical energy use worldwide. Even small increases in efficiency in these consumer products can thus have a large impact. Michael Lang and his group from the Institute of Thermodynamics and Sustainable Propulsion Systems think they have a new approach to optimizing these appliances, which they want to develop with the household appliance company Liebherr in an FFG project.

We wish all successful applicants the best of luck with their proposals and hope that the resulting projects can one day be presented on these pages, just like the work of Carole Planchette on the next few pages.

Carole Planchette

Fundamental Fluid Mechanics for Sustainable Applications

The controlled manipulation of small liquid quantities offers, among others, possibilities to reduce material consumption, gain efficiency, and reduce unwanted pollution, … . Such attributes make it an essential step on the path to more sustainability. Yet, as simple as a droplet may look, it is subject to complex phenomena which need to be better understood in order to be rationally optimized.

As dimensions of liquid bodies come in the range of millimeters or below, the role of their interface becomes predominant. It is responsible for the shape of drops, for the instability of liquid jets, for the coalescence or rupture of bubbles, for the difficulties in producing sprays or applying a regular coating. As the interface becomes curved, it leads to a pressure jump, which, for instance, drives the ascension of coffee in a porous sugar cube, a well-known principle used in paper-based microfluidics. Depending on the systems at stake and the targeted purposes, the interfacial effects, also called capillarity, must be either minimized or enhanced. Yet, despite its apparent simplicity, the dynamics of capillary systems, i.e. drops, bubbles, jets, thin films … often remains very challenging to predict. This is partly due to the complexity of the momentum equation used in fluid mechanics. The difficulty, however, is enhanced by the presence of a liquid interface whose local curvature contributes to the pressure field which, in turn, influences the bulk flow, possibly leading to liquid fragmentation. This aspect makes the problem costly for numeric approaches: the interface must be well resolved, tracked and reconstructed, while questionable thresholds, often related to the mesh size, must be set to induce fragmentation. Thus, combining experiments and analytical modeling remains a method of choice for the study of these fascinating systems, a task which my group and I work on at the Institute of Fluid Mechanics and Heat Transfer. >

Carole Planchette has been working on the physics of droplets for more than 10 years. After her graduation in Paris, she worked for the Research Center for Pharmaceutical Engineering (RCPE, Graz) where she applied her knowledge to industrial processes. Since 2019, she has had a tenure-track position at the Institute of Fluid Mechanics and Heat Transfer of Graz University of Technology (TU Graz). With over 20 peer-reviewed publications in top-ranking journals, she is a recognized expert in capillary hydrodynamics.

Source: Privat

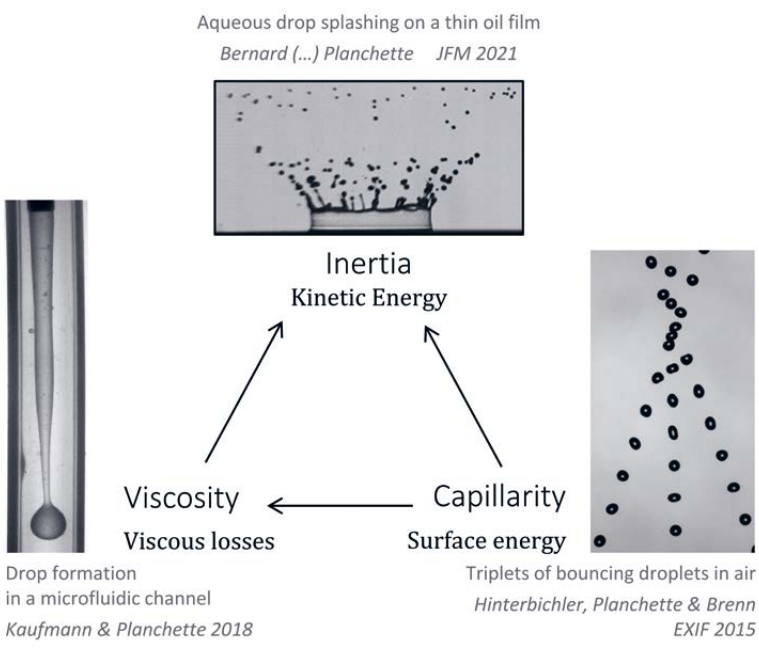


Figure 1:
Interplay between inertia, viscosity and capillarity and diversity in the phenomena in question.

Source: Carole Planchette

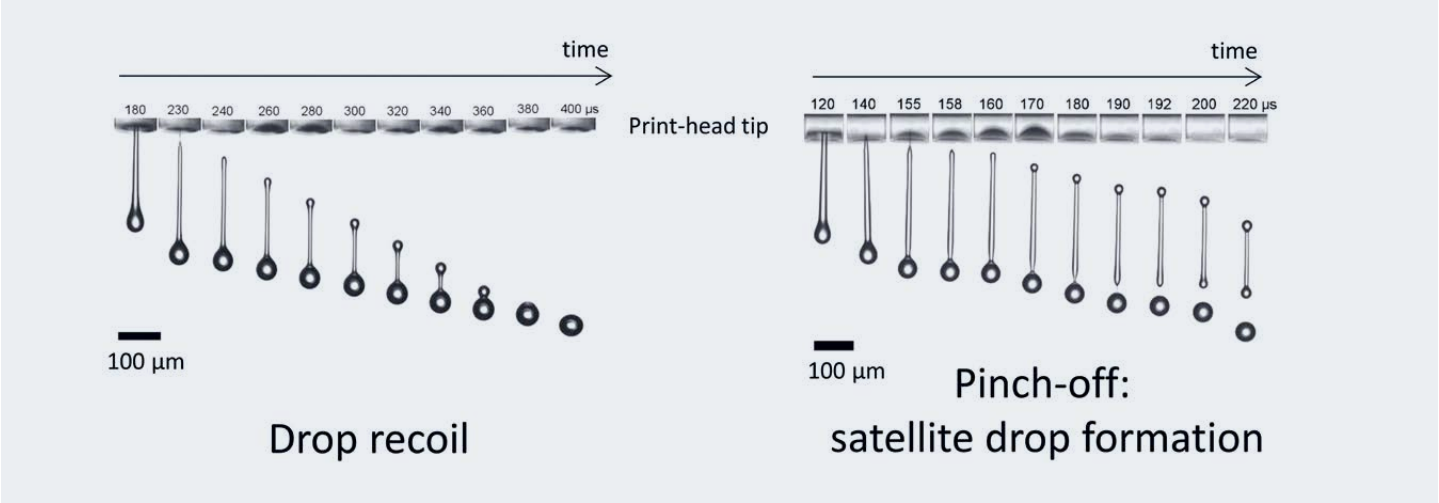


Figure 2: Droplets ejected from a piezo-based print-head. Left: recoil and right: pinch-off.

Source: Adapted from Phys. Rev. Fluids 4, 124004 (2019)

PRINCIPLE OF CAPILLARY HYDRODYNAMICS

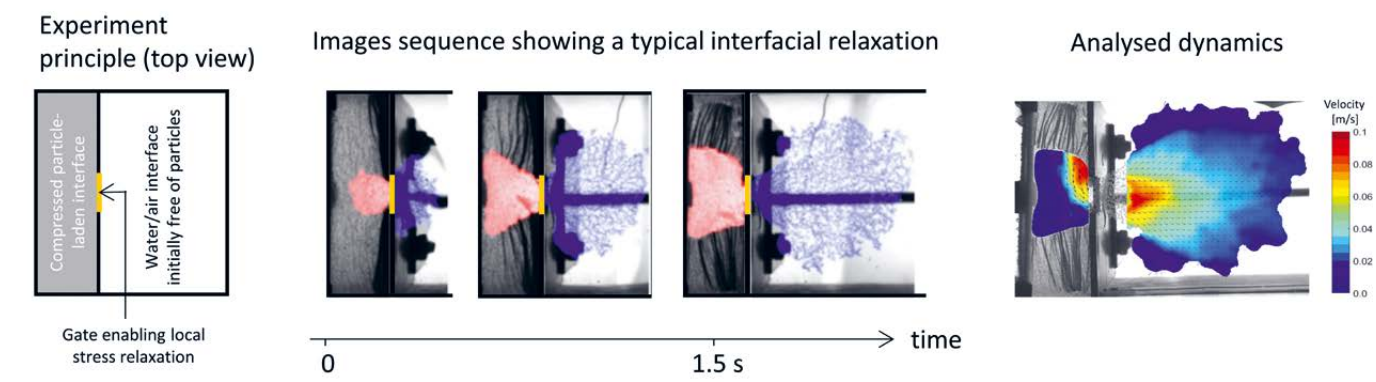
In practice, our research deals with a variety of systems whose common point is the significant contribution of the liquid interface to their dynamics. Depending on the relative importance of inertia, viscous losses and capillarity, very different phenomena can be obtained, see Figure 1. When inertia dominates, as during drop impact on a liquid film, a splash gives rise to many small secondary droplets, a potential issue for coating applications. In some cases, drop formation is desired and may be driven by viscous shear, a principle exploited in some microfluidic chips. Finally, the systems can also be dominated by capillarity. This is the case in bouncing droplets, which can be observed during collisions in air or impacts on hot surfaces. Also known as the Leidenfrost effect, the latter makes spray cooling a poorly efficient process. Indeed, the sustainability of numerous industrial processes depends on the dynamics of capillary systems. Let me briefly present some concrete problems my group "capillary hydrodynamics and milli- micro- fluid mechanics" is currently working on.

APPLICATION TO INKJET PRINTING

In the last decades, printing has become one of the most popular additive manufacturing methods. Droplets of a few nanoliters can be accurately placed on various substrates for applications going beyond graphic arts, such as printing medicines and electronics. The possibility to print in three dimensions has raised further interest. Yet, as versatile as it seems, it remains challenging to formulate a functional ink whose properties are adapted to a print-head. The latter must be designed to overcome excessive viscous losses. Further, empirical tuning is required to find the appropriate printing parameters (pulse voltage, duration, shape). Empirically conducted, these adjustments cost much time and materials. Our expertise

Figure 3: Left: experiment principle dedicated to the study of the self-healing properties of particle-laden interfaces. Center: images showing the relaxation of compressed interfaces upon local stress release triggered by the opening of a gate (yellow, 1 cm wide). The particles initially jammed (grey) are unjamming (red) and cover (blue) the interface area intially free of particle. Right: analysed dynamics.

Source: Adapted from Phys. Rev. E, 106. 034903 (2022).



in the dynamics of deformed drops has contributed to the rationalization of this crucial step. The emergence (or not) of unwanted satellite droplets, results from the competition of the capillary recoil of the droplet tail and its viscous pinch-off, see Figure 2. By modeling these processes, we have opened the route to a rational tuning of inkjet printing.

APPLICATION TO INTERFACE STABILIZATION

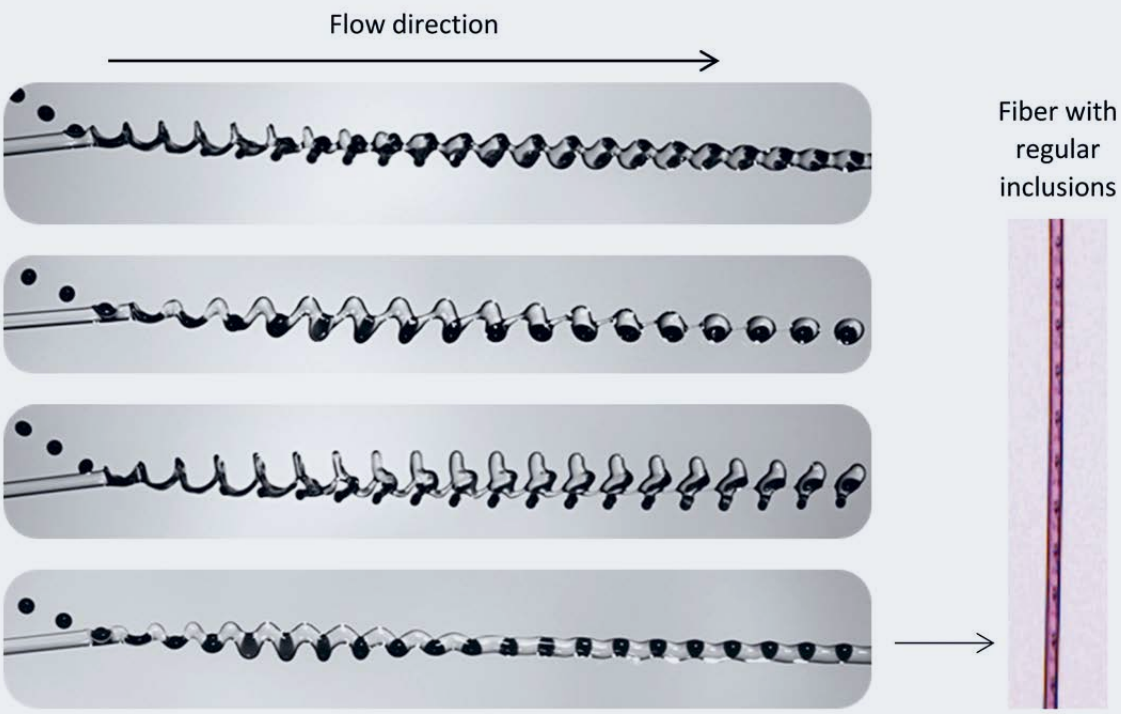
Whenever foams or emulsions come into play, it is essential to stabilize the interface of their individual bubbles or drops. These intrinsically unstable systems age and eventually reach phase separation, losing their applicability. This stabilization can be obtained using surfactants. These molecules, however, are rarely environmentally friendly, and recovering them from waste is difficult. Thus, in my group, we propose using microparticles which capillary adsorb at the interface, providing stabilization. The particles can be easily filtered, and the encapsulation of drops or bubbles is reversible. The mechanical properties of these interfaces remain poorly understood and constitute a bottleneck for their industrial usage. Our key expertise is to design dedicated experiments to fill this gap. Figure 3 shows the relaxation of a compressed particle-laden interface and illustrates its self-healing capacity.

APPLICATION FOR LIQUID ENCAPSULATION

Another important field of expertise of my group is in-air microfluidics for liquid encapsulation. In-air microfluidics consists in combining drop streams and jets in air to form regular liquid structures. The latter may then be hardened to produce capsules or fibers. This presents several advantages over classical chip-based technology. Thanks to the absence of a chip, there is no need for a continuous carrying phase, there is no risk of clogging, the throughput is increased (factor 10 to 100) and the energy needs are decreased (no viscous losses at the wall). Following this approach, we have obtained various types of liquid structures, see Figure 4. Successful on-the-fly solidification of the “drops-in-jet” structure produces remarkable fibers.

Figure 4: Four types of liquid structures produced with dyed glycerol solution (drops) and a silicon oil (jet, transparent). From top to bottom: fragmented-drops-in-jet, capsules, mixed fragmentation, and drops-in-jet with corresponding fiber (right). Drop diameter: 200µm; 0.1 ms between two consecutive drops.

Source: David Baumgartner



PLANET RESEARCH

See what our researchers are doing in the Fields of Expertise and other areas, and learn about how their results will affect our lives. Get to know young research talent and keep informed about research infrastructure at TU Graz.

TU GRAZ RESEARCH

Subscribe now and register for the next issue of TU Graz research, which you can receive either digitally or as a print edition.

TU GRAZ RESEARCH MONTHLY

The monthly research newsletter provides you with selected news, stories, interviews and blog posts from the world of research.
We will also be informing you about upcoming events in science and research at TU Graz.

Research @ www.tugraz.at: Keep up to date!

Forschung @ www.tugraz.at: Bleiben Sie auf dem Laufenden!

TU GRAZ RESEARCH MONTHLY

Mit dem Forschungsnewsletter erhalten Sie jeden Monat ausgewählte Beiträge rund um aktuelle Forschungsthemen. Zudem informieren wir Sie über die nächsten Event-Highlights in den Bereichen Wissenschaft und Forschung an der TU Graz.

TU GRAZ RESEARCH

Holen Sie sich Ihr digitales oder gedrucktes Forschungs-Abo und melden Sie sich gleich für die nächste Ausgabe von TU Graz research an.

PLANET RESEARCH

Erfahren Sie, woran die Wissenschafterinnen und Wissenschafter in den Fields of Expertise und darüber hinaus forschen und wie sich ihre Ergebnisse auf unser Leben auswirken. Lernen Sie junge Forschungstalente kennen und informieren Sie sich über die Forschungsinfrastruktur der TU Graz.