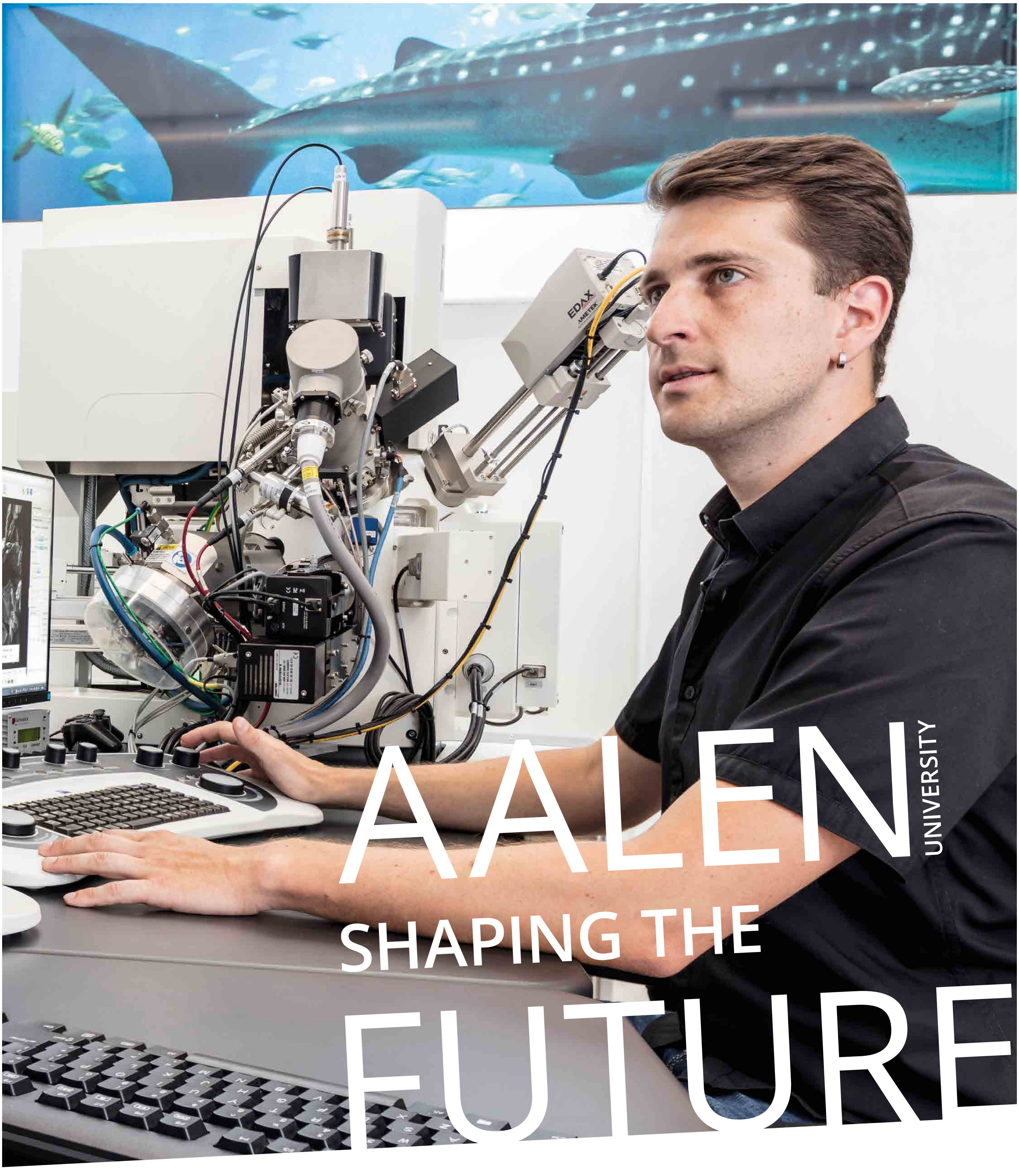


AALEN UNIVERSITY

SHAPING THE FUTURE

Aalen University

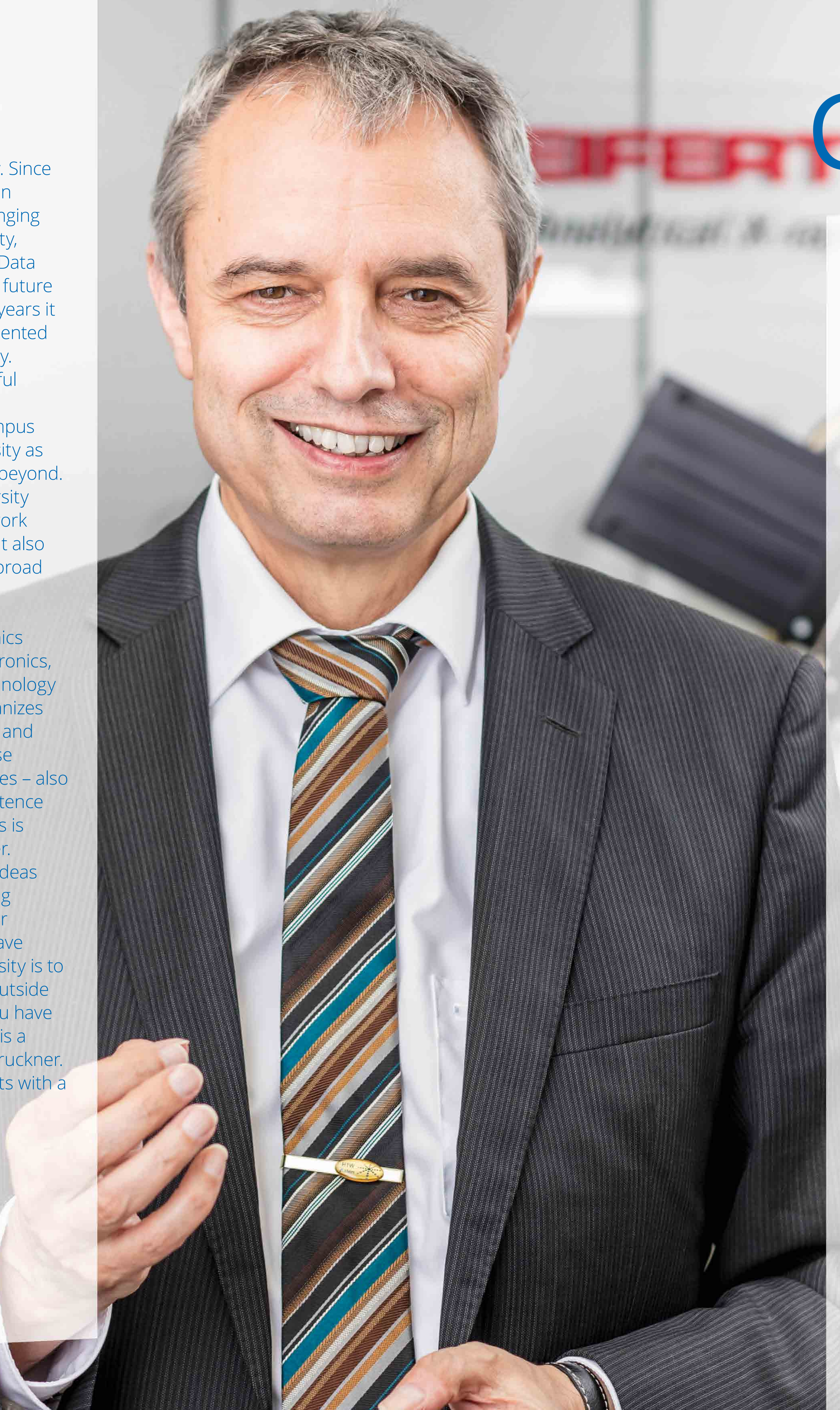
Dear reader,

A pioneering spirit, endurance and vision characterize the history of Aalen University. Since its founding in 1962, our university has been constantly renewed and responsive to changing needs and demands. Whether Virtual Reality, Artificial Intelligence, Autonomous Driving, Data Science or Photonics: the challenges of the future are pursued at Aalen University. For many years it has been one of the strongest research-oriented universities for applied sciences in Germany. Increasing numbers of students, a successful transfer of expertise to industry and other institutions and a steady growth of the campus show the rapid development of the university as well as its significance for the region – and beyond. The international character of Aalen University is underlined not only by a worldwide network of more than 130 cooperation partners, but also by the approximately 600 students from abroad studying in Aalen.

With its five faculties of Chemistry, Electronics and Computer Science, Optics and Mechatronics, Mechanical Engineering and Materials Technology as well as Economics, Aalen University organizes its curriculum around topics of great social and economic relevance. In doing so, it is in close contact with global market-leader companies – also through research collaboration. The coexistence of research, teaching, practice and business is particularly evident in the Innovation Center. Here students can develop their business ideas and build their start-ups. Under the heading "Entrepreneurship University", programs for students, entrepreneurs and companies have been established. The goal of Aalen University is to educate creative people who like to think outside the box. "If you want to build tall towers, you have to work on the foundation for a long time," is a quote from the famous composer Anton Bruckner. We do our very best to provide our students with a solid foundation for their future.

Sincerely,

Prof. Dr. Gerhard Schneider
(President)



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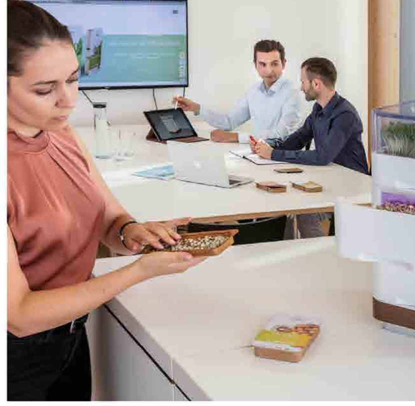

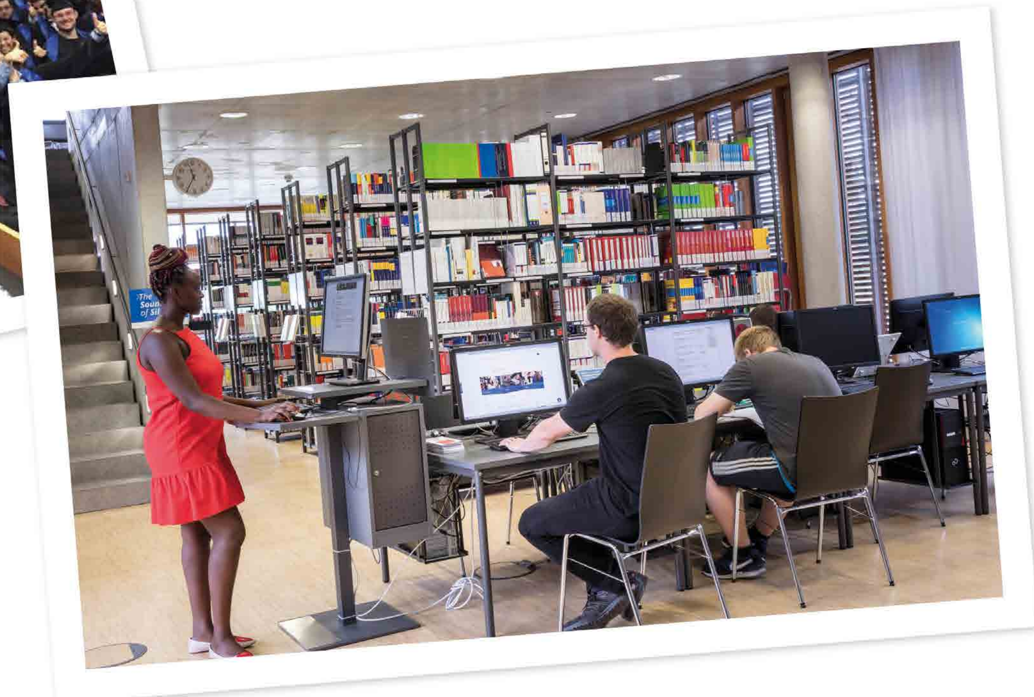

Aalen Rocks

A Passion for Research at Aalen University

Aalen, a city with a population of about 70,000 in the Eastern part of Baden-Württemberg, boasts one of Germany's most dynamic Universities of Applied Sciences. One reason for this: professors, students and companies from the region are working towards a common goal

by Wolfgang Hess and Saskia Stüven-Kazi

"The most emotional moment is when the racecar is up on its wheels and driving on its own. Then you suddenly forget all the long nights that your team spent working on it," Carolin Reichelt reports enthusiastically. The 26-year-old student of the research master program Advanced Systems Design has been the General Project Manager of Aalen University's E-Motion Racing Team for three years and continues to support it, even after leaving the team to focus on her studies. 60 students are active members of the team. "Every year we build a new electric racecar, right now even two. In addition to our standard electric racecar, we also want to get our first self-driving electric racecar to the starting line," says Reichelt. The students race at Hockenheimring or at the Red Bull Ring near Salzburg. The name of this competition is Formula Student, and is supported by the German Engineering Society VDI.

Many young people are excited about this international design competition. In 2018, nearly 30 teams from Germany competed in the Formula Student Electric. Some of them especially enjoy studying in Aalen because they can help develop electric racecars in their free time and alongside their studies. One example is Alexander Topp, who successfully completed his degree in International Business Administration and was the Head of Marketing for Aalen's Formula Student team. Carolin Reichelt moved from the Stuttgart region to East Württemberg for the same reason. "I only applied at universities that had a Formula Student team, and I chose Aalen because of its high-quality teaching staff," she says. Dominik Walk, Bachelor student in Electrical Engineering, also has his reasons for coming to Aalen University. "At the big universities, you're just a number. Here, there is much more direct contact with the lecturers – and it's easy to get out into nature."

Plans for the future

Christoph Scheff also appreciates the personal contact with lecturers. He is studying Business Administration for small and medium-sized enterprises – a program not found at very many universities in Germany. He hopes it will help him with his own business one day. The 20-year-old student already has plans for the future: he wants to become self-employed and counsel craft producers for professional Web sites together with his buddy. Mark Auwärter, a fourth year Mechanical Engineering student, is studying here for practical reasons. "The university is easy to get to from where I live," he says.

From China to the Ostalb Region

That argument does not apply to Hongfei Chen at all. She is from Hangzhou, China, and is studying for a Master's degree in Chemistry. She found her way to the Ostalb region through an exchange program at her university in China, Jiliang University – one of Aalen University's more than 128 partner universities worldwide. As one of 600 foreign students at the university, Hongfei now speaks excellent German. Aalen University has worked tirelessly on expanding its network of bilateral partner universities over the last years. Moreover, Aalen's researchers maintain countless research-contacts with their colleagues in foreign countries. And the numerous and various language-, culture- and leisure time facilities boost the networking between German and international students. "As a University of Applied Sciences, we are a place of international meeting", says Pascal Cromm, Head of the International Office. "We do live an international mindset here." The international orientation is an integral part of the university's strategy. "Ultimately, speaking a foreign tongue or a sensible and well-informed interaction with people from other cultures is an important requirement for a successful working life", says Cromm. The possibilities at or with Aalen University are diverse: Language courses and internationally acknowledged language tests, semesters abroad, double graduation, theses, international modules in compulsory subject choices, summer school and many more.

The educational institution, which now has nearly 6,000 students, started in April of 1962 as a state engineering school with just 32 students. For 13 years now, Aalen University is continuously at the top of the ranking as a strong research university for applied sciences in Baden-Württemberg, a region that already has a strong reputation in the research field. It is divided into five faculties: Chemistry, Electronics and Computer Science, Mechanical and Materials Engineering, Optics and Mechatronics, and Economics. The more than 150 professors are able to generate about 12 million euros of research funding every year.

Since 2008, the president is Prof. Gerhard Schneider, whose experience as a Max Planck researcher and holder of various positions at Robert Bosch GmbH make him a skilled advocate for education in the region of East Württemberg. For instance, he is a member of the Executive Board of HAW BW e.V., an association that includes the 24 universities of applied sciences in Baden-Württemberg and represents the interests of 3,000 professors and more than 100,000 students.

Off to an enthusiastic start: For many years, students from Aalen have successfully been designing electric racecars for the Formula Student competition.

A Pillar of the Region

"The familial, concentrated atmosphere at Aalen University is a great advantage when it comes to educating talented young people," says Prof. Michael Kaschke, the CEO of Carl Zeiss AG and Chairman of the University Council at Aalen University. Zeiss (sales volume: just under five billion euros per year) is one of the largest industrial employers in the region, and has nearly 8,000 employees at its site in East Württemberg (more than 30,000 worldwide). Other entrepreneurs also see Aalen University as a pillar of the region. "The university trains qualified young workers and provides them with corresponding practical knowledge, which is an enormous benefit for us as well," says Dr. Jochen Kress, a member of the Executive Board of Mapal Dr. Kress KG, an Aalen-based tool-building company with 5,500 employees worldwide.

The region of East Württemberg comprises the districts of Heidenheim and the Ostalbkreis. Nearly half of all its workers are in the manufacturing industry – an amazingly high number compared to the national average. The main employers are mechanical engineering companies and automotive suppliers. One in two East Württemberg residents works in a research and development-intensive company. The East Württemberg Chamber of Industry and Commerce (IHK) supports the university during every phase of its expansion, and has participated in university committees for many years. The Ostalbkreis district also identifies strongly with the university. "For decades now, the university and our district have participated in a location-oriented collaboration as part of the initiative Future ETW. That builds trust and adds value", says Head of District Klaus Pavel.

Currently, more than 900 committed players from the local government, businesses, and associations are participating in a dynamic district development process that particularly involves universities with their expertise, clever ideas and groundbreaking research measures. The Ostalbkreis was recognized as an innovative "WINregion" by the state of Baden-Württemberg for this work, and launched innovation projects with a volume of more than 30 million euros for a funding corridor through to 2020. That includes building a new "Technik für Nachhaltigkeit" (Technology for Sustainability) center at Aalen University, which will be used to continue the successful cooperation and is expected to be an important step towards the sustainable development goals of 2030.

Growth at the Edge of the Forest

The city of Aalen is also committed ensuring a strong university. After all, it increases the attractiveness of Aalen and the entire region – for instance in the competition for young talents. "The Waldcampus is one of the most important goals in our city policies", says Mayor Thilo Rentschler. A total of 60 million euros from the State, the city and the university will be invested as part of the 2020 Master Plan. The Waldcampus will connect the two existing parts of the campus. "New centralized services such as childcare and a cafeteria, along with the Economics faculty building, will help merge the two sections of the university," says Rentschler.

Over the last thirteen years, Aalen University has become significantly more dynamic. In 2006, a second location was opened just a few meters away from the first one. 2008 saw the opening of explorhino, a workshop for young researchers (see info box, "Sparking curiosity" opposite page). The INNO-Z innovation center opened in 2015 (see info box, "Welcoming smart people and makers", p. 18). There, students can try their ideas for a business and train entrepreneurial working in a playful way. This way, the founding of start-ups out of the university is promoted and the innovative force of the regional economy is improved. Special attention is placed on the transfer between university and industry. "It is important for us to foster a lively start-up-spirit at Aalen University and to kindle entrepreneurial spirit in our students at an early stage", stresses president Prof. Dr. Gerhard Schneider.

Under the heading "Entrepreneurship University", many offers were started so that students interested in founding their own business can choose from a diverse palette of faculty-spanning education and support offers. As early as 2002, Aalen University implemented the topic "start-up founding and management succession" in the program "business management for small and medium sized companies". For three years now, the master's program "Business Development/ product management & start-up management" has been teaching methods for strategic business development. "This way, students can try being a founder without any risks during their studies", says Schneider. The earlier students are faced with the topic of founding, the easier it is to reduce fears or wrong expectations. "We want to place entrepreneurial culture, spirit and thinking in the heads of our students. For short: the taste for founding", says president Schneider. That Aalen University offers their students the best foundation for this, has been confirmed by the so called "Gründerradar 2018", a foundation that compares universities of applied sciences with regard to their start-up support. In the national ranking of the Donors' association for the promotion of humanities and sciences in Germany, Aalen University scored a leading place – 10,6 of 12 points. In the group of medium sized universities of applied sciences, Aalen was awarded with the national eighth place.

One of the student-founders is for example Philip Frenzel. When his new smartphone broke, he declared war on the so called "spider app". Through his clever invention – the innovative smartphone case "ADcase" – crash-landings of smartphones remain without consequences. Sensors in the case register the fall and cause protection-metal-springs to unfold which dampen the fall. That is where the name "ADcase" comes from: active damping. During the last couple of months, the student and his partner Peter Mayer caused an international furor and countless media inquiries. "The support of the university and the INNO-Z was super", says 26 year old Frenzel. "We are currently looking for investors and have already established several promising contacts."

Aalen University is coming up aces in other fields, too. Currently, on the campus two new research centers are being built. "We are the first university of applied sciences in Baden-Württemberg and only the third one in Germany to be chosen for the federal and regional program for constructing research buildings," says Dr. Ralf Schreck, contact partner for Research and Transfer at Aalen University. The Center for innovative Materials and Technologies for efficient electric energy converting Machines (ZiMATE) and the Sustainable Technology Center (ZTN) will combine various research activities for Aalen University.

The two centers are being built as a single complex. That is possible because both funding measures were approved at almost the same time – 50 percent of the ZiMATE project is being funded by the German government and 50 percent of the ZTN funding comes from EU grants. The facilities will be handed over to the university in the fall of 2019. Overall, they will then have received 26 million euros to help solidify Aalen's status as a research hub.

Of course, all of that only works if students participate alongside the academic staff. The relationship between the scientists and young researchers is clearly healthy.

Info
www.aalen-university.de

Sparking Curiosity

"explorhino is a great advertisement for Aalen University," writes president Prof. Gerhard Schneider in his editorial for an issue of the university's magazine "limes." The workshop for young researchers opened its doors in 2009, though under a different name. In the beginning of 2018, the Science Center has been opened that offers children and teens huge opportunities for playing and experimenting on more than 1500 square meters.

What does electricity taste like? What is a bluescreen? Why don't polar bears get cold? Those are just a few of the questions that children will be able to explore on their own. "We want to spark the curiosity that lies inside every young person," says Dr. Susanne Garreis, the director of explorhino. There is a serious reason for taking an exploratory safari with the center's colorful rhinoceros (hence the name explorhino). Germany's economic and social development depends on encouraging more people to study science, technology, engineering and math (STEM) in the future. Schools provide plenty of information – but there is little time to cogitate, puzzle, tinker and learn through play. explorhino wants to provide support for this, and strengthen children's interest in STEM fields with their own experiments.

The new Science Center features about 120 inviting, interactive exhibits. There are other impressive facts, too: In 2016, Susanne Garreis counted 150 daycare centers and 50 schools as supporters, more than 100 school field trips, around 100 children's birthdays and a fan club made up of 300 families. explorhino is active during school breaks, too – its employees offer exciting vacation programs, with classes and events that include science camp, an animation workshop and a visit to the German Aerospace Center.

All this grew out of the personal initiative of a family of entrepreneurs, the Grimmingers. The family owns Kessler & Co. GmbH, a leading manufacturer of drive components for heavy vehicles (sales volume: about 300 million euros a year). The student lab is now also permanently funded by Zeiss and LMT Group, along with numerous other supporters. "explorhino is part of our society, and its impact is felt beyond the region," says Dr. Susanne Garreis.

www.explorhino.de

Puzzling, tinkering, doing independent experiments:

explorhino inspires children and teenagers to learn through play. It is fun, and it encourages them to get involved in technology and the natural sciences.

explorhino

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Teaching and Learning at Aalen University

You Can‘t Start a Fire without a Spark

Award winning teaching, excellently equipped laboratories and strong ties to working life - Aalen University remains up to date

by Saskia Stüven-Kazi

Aalen University shows profile: In the teaching section, it focuses its attention on quality and innovative education models and offers students a sound, theoretical, principles oriented education that helps them form their personality. Strong practical orientation as well as the orientation towards current research findings mark the university's courses and lectures. Especially in the natural science programs, the emphasis lies on practical seminars held in highly modern laboratories. Through cooperation with and field trips to regional companies and a mandatory semester of internship, students also get to know the praxis of working life and can apply their acquired knowledge. Extra offers like the Studium Generale, interdisciplinary projects like the E-Motion Racing Team or the business plan-competition complete the teaching section. These promote the motivation and development of students. The university's Study Support Center supports students for example with preparation courses, tutorials and open consultation hours.

A special focus for Aalen University lies on international exchange – after all, it is more than ever the requirement for modern education, research and innovation. A semester abroad during one's studies strengthens global thinking and knowledge of foreign languages. Nearly ten percent of the student body at Aalen University comes from a foreign country and makes their contribution to an international mindset. Aalen University also develops its internationalization by an increase in English-taught study programs. A very special program is for example the Research Master's Program, which is only offered by very few German universities. Students are closely integrated into the working groups of professors strong in research and receive intensive training in performing careful scientific work.

As an educational establishment keeping up with current affairs, Aalen University orientates its offers based on topics with high social relevance or at the demands of the industry. The progressing digitalization causes not only a change in technology, but also in other areas of life. That is why digitalization is also a considerable force for the development of the study programs at Aalen University. That is for example why the university introduced the innovative program "Internet of Things" in the fall term of 2015/2016. Aalen University also reacted to current developments in technology and economy by creating new study programs "User Experience", "Data Management / Industry 4.0" and "Business Development / Product Management & Start-up-Management".

Moreover, the diverse study programs offer courses that are unique and rare throughout Germany: Optical Engineering, Technical Content Creation and Optics and Audiology. The E-Learning and Didactics Center opened in 2018 and since then has been supporting the digitalization in foundation lectures, especially in the sections mathematics and computer science. Due to different learning and teaching preferences, the team of the E-Learning Center is developing an online platform that offers lecture content, scripts, practice exercises and much more. The platform will for example offer the chance to watch a lecture again if students need the revision. By doing so, students can learn, revise and practice in an individual, digital way.

Lifelong learning is also held in high regards at Aalen University. It wants to offer to those in employment the chance of further academic education at a later point in life. With the foundation of the Aalen University Academy of Further Education as well as the Graduate School Ostwürttemberg, extra-occupational study programs have become an integral part of the study programs at Aalen University. At the center of all of this are always the students: They profit from the familiar atmosphere, the small groups and the project-oriented learning as well as from the personal counseling and support.
The extraordinary good positions in national and international rankings are indicators of the high quality and the long lasting, continuous development of the study program. Two years ago for example, Aalen University among four other German universities reached the highest number of A-positions in the subject area of business studies in the U-Multirank, which is the biggest, international university ranking. Moreover, in the CHE-Ranking, which is attracting a great deal of attention, Aalen University has reached top positions. For the second time, Aalen University has received the teaching award from the state of Baden-Württemberg in 2017 for excellent and innovative teaching methods as well as the ZEISS MINT Award in 2018. "These distinguished honors also mark the high standards of teaching at Aalen University", says President Prof. Dr. Gerhard Schneider. "The teaching staff are the ones to kindle enthusiasm among our students. They also pass on the fascination of a subject. To awaken the intrinsic motivation is the most important thing in teaching." After all, the Greek philosopher Heraclitus already knew: "Education is the kindling of a flame, not the filling of a vessel." To this day, this sentence has not lost any of its validity – and the professors of Aalen University kindle this flame every day anew.

Contact
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Study at Aalen University

Mechanical Engineering and Materials Science

- Mechanical Engineering | B.Eng.
- Product Development and Simulation | M.Eng.
- Plastics Engineering | B.Eng.
- Polymer Technology | M.Sc.
- Mechanical Engineering/Production and Management | M.Eng.
- Mechanical Engineering /Development: Design and Simulation | B.Eng.
- Datenmanagement in Produktentwicklung und Produktion | M.Sc.
- Surface Technology/New Materials | B.Sc.
- Advanced Materials and Manufacturing | M.Sc. | Research Master
- Applied Surface and Material Sciences | M.Sc.
- Leadership in Industrial Sales and Technology | M.Eng.
- Technology Management | M.Eng.
- Light Weight Engineering | M.Sc

Chemistry

- Chemistry | B.Sc.
- Analytics and Bioanalytics Chemistry| M.Sc.

Electrical Engineering & Computer Science

- Electrical Engineering | B.Eng.
- Internet of Things | B.Eng.
- Data Science | B.Sc.
- Data Science and Business Analytics | M.Sc.
- Computer Science | B.Sc. + M.Sc.
- Advanced Systems Design | M.Sc.
- Machine Learning and Data Analytics | M.Sc.

Optics and Mechatronics

- Optical Engineering | B.Sc.
- Optometry | B.Sc.
- Ophthalmic Optics and Psychophysics | M.Sc.
- Audiology | B.Sc.
- Mechatronics | B.Eng.
- Technical Content Creation | B.Eng.
- User Experience | B.Eng.
- Mechatronics/Systems Engineering | M.Eng.
- Technical Teacher Education | B.Eng.+ M.Sc.
- Applied Photonics | M.Sc.
- Business Development/Product & Start-up Mangagement | M. A.
- Digital Health Management | B. Sc.

Management and Business Science

- Business Studies SME | B.A.
- Small and medium sized Enterprises Management | M.A.
- Health Management | B. A. + M.A.
- Business Psychology | B.Sc.
- International Business Studies | B.A.
- International Marketing and Sales | M.A.
- Auditing, Finance and Governance | M.A.
- Business Informatics | B.Sc. + M.Sc.
- Industrial Engineering | B.Eng.
- Industrial Management | M.Eng.

Committed to Scientific Excellence

A Leader in Applied Research

Over the years, Aalen University has established itself as a stronghold of applied research in Baden-Württemberg and beyond. The activities tackle major challenges including climate change, energy and resource efficiency, mobility as well as digitalization. In 2020 two newly constructed, state-of-the-art resarch centers will be completed – and host close to 100 research staff

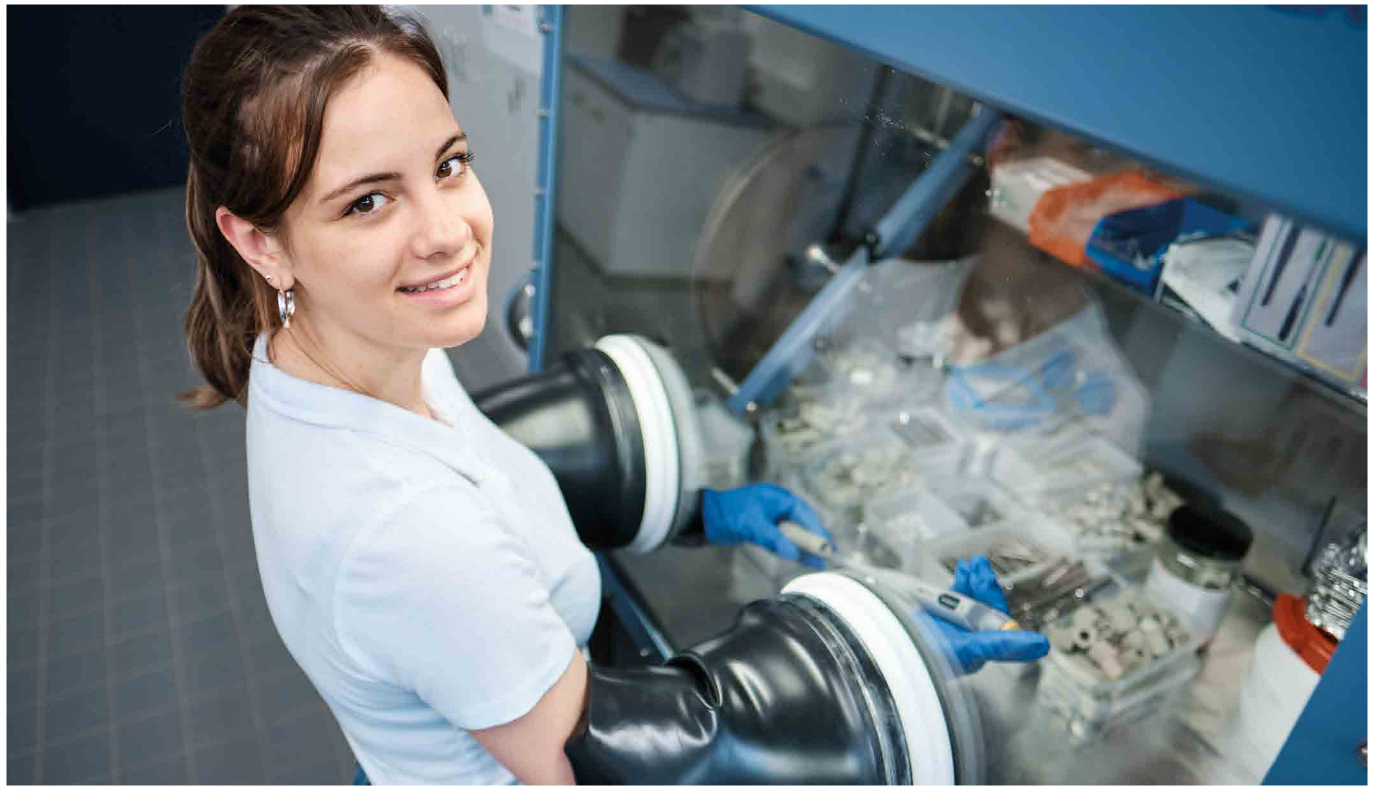
by Dr. Ralf Scheck

Mission

Research has become an important profile element of Aalen University contributing significantly to its increasing attractiveness and visibility. Over the years, Aalen University has established itself as a stronghold of applied research in Baden-Wurttemberg and beyond. For example, with respect to financial volume of ongoing research projects, it is the foremost University of Applied Sciences (UAS) nationwide in the main Federal Research Program for UAS. In Baden-Württemberg it is the leading research UAS for the 13th year in a row. It was also the first UAS to be successful in the annual competition for large scale research facilities since implementation of the Federal-State Program in 2006. With an annual average increase of more than 10% in third party research funds and publication numbers there are favorable prospects for further dynamic growth and fruitful development of research activities.

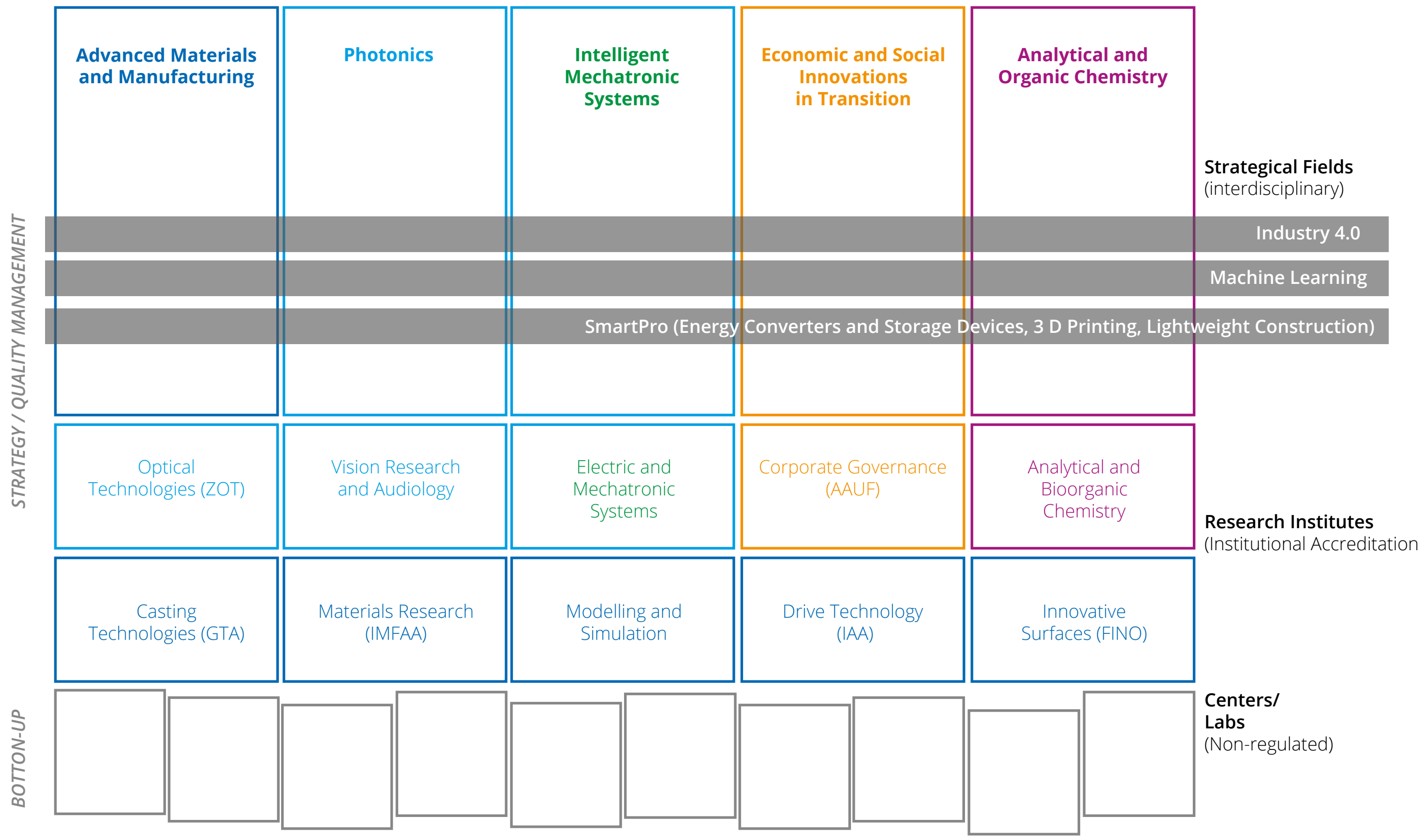
Excellent Infrastructure

In 2020 two newly constructed, state-of-the-art research centers with a total invest of 26 Million Euro will be completed: The Center of Innovative Materials and Technologies for Efficient Electric Energy Converters and the Center Techniques for



Overview Research Institutes

Research Core Areas (disciplinary)



Sustainability – Resource Conservation, Renewable Energies and C02-Reduction.They will host close to 100 research staff and provide ample opportunities to pursue new avenues in applied research. Over the last five years, Aalen University has also been particularly successful in securing large scale research equipment from national competitions. More than 12 devices and systems with a total volume of more than 13 Million euros have been attracted and will be moved for the most part to the new facilities.

Nudging Innovative Research

Aalen University is committed to scientific excellence in applied research. Our activities tackle major challenges including climate change, energy and resource efficiency, mobility as well as digitalization. For this, research is structured in 5 major priority areas with a disciplinary focus. The two main research topics are “Advanced Materials and Manufacturing” and “Photonics”, which encompass about three quarters of third party research funding. Smaller research activities run under the topics “Intelligent Mechatronic Systems”, “Economic and Social Innovations in Transition” and “Analytical and Organic Chemistry”. In addition, 3 cross-sectional topics are currently developed and supported by Aalen University as key strategic, interdisciplinary fields: Industry 4.0, Applied Machine Learning/Data Science and research activities embedded in the SmartPro project. Research is performed in 2 levels of institutions: Research Institutes with a regular institutional quality check and bottom-up Research Labs and Competence Centers.

Collaborative Research at its Best

Aalen University is actively participating in national and international research projects. At the same time, strong emphasis is placed on technology transfer and common research activities with regional players. These do not only include global leaders such as Zeiss, Voith, Paul Hartmann, Mapal and Leitz, but also many small and medium enterprises benefitting from the rich experience and expertise of more than 140 research staff including 60 PhD students. Outreach activities with community partners address topics such as Smart Cities and sustainability issues.

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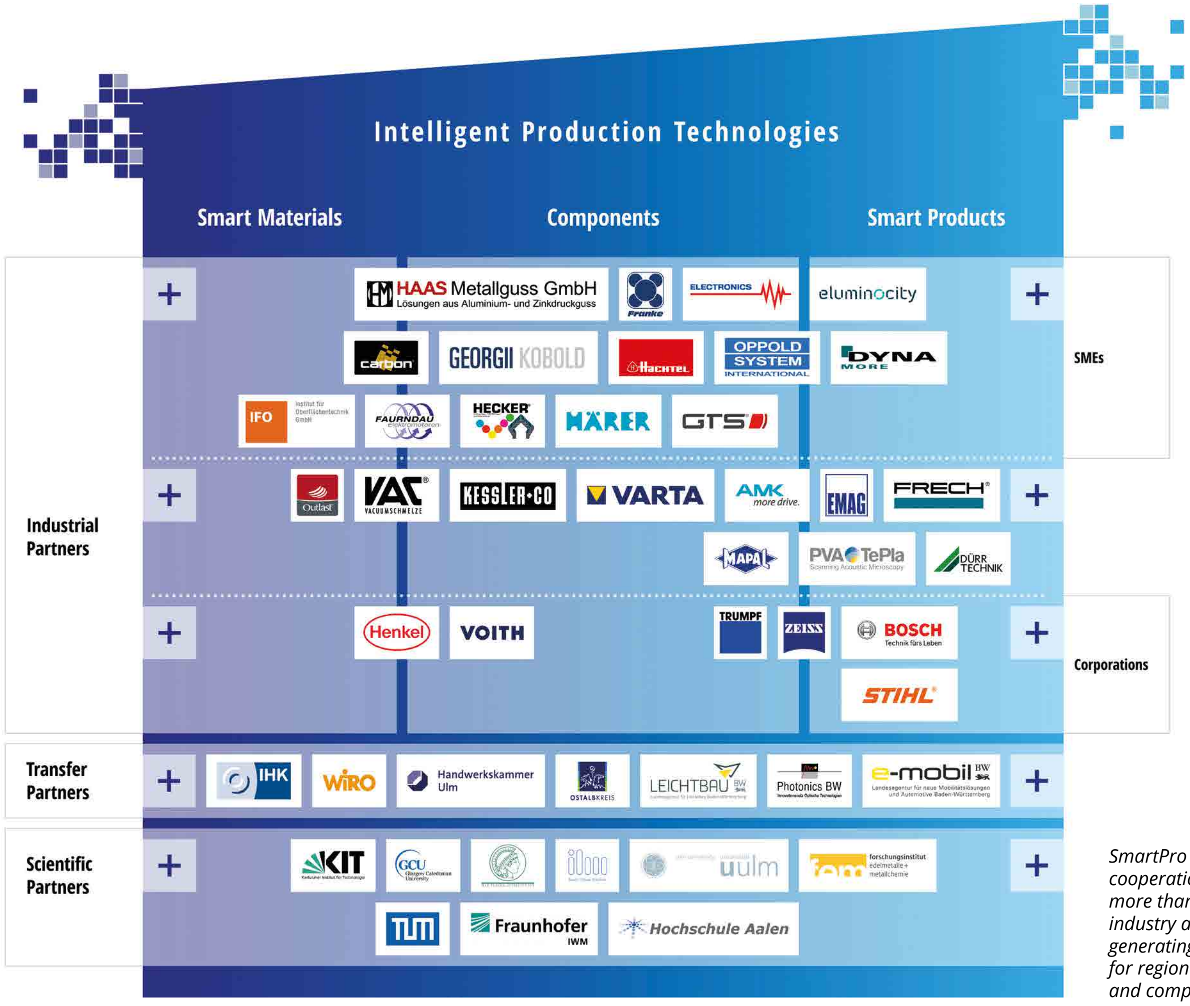

SmartPro is a strong cooperation network with more than 50 partners from industry and academia generating a strong impulse for regional innovation and competitiveness.

SmartPro: Key to Smart Products!

SmartPro is a key project for Aalen University. SmartPro stands for Smart Materials and Intelligent Technologies for Future Products with High Energy Efficiency. It is a research-based innovation network with more than 50 primarily regional partners from industry and academia. With a total volume of 5,8 million Euro it is funded by the German Federal Ministry of Education and Research as well as by financial contributions of industrial partners for an initial funding period between 2017 and 2020

Fierce Competition

For the first time in the history of the German Federal Ministry of Education and Research a special funding initiative worth 100 Million Euro was installed in early 2016 to support universities of applied sciences. More than 80 universities of applied sciences submitted funding proposals. In the end just 10 proposals were selected for funding by an international jury. Aalen University was amongst them, thereby demonstrating again its presence among the top national institutions when it comes to applied research.

Regional Impact

One of the aims of the project SmartPro is to set up a sustainable partnership with primarily regional companies by cooperative R&D projects. Up to now close to 40 companies ranging from small and medium enterprises to global innovation leaders covering a wide range of industrial sectors are actively involved. President Gerhard Schneider is enthusiastic: "By contributing to the immediate R&D needs of our regional partners we hope to become even more attractive for future research collaborations thereby stimulating technological innovation and economic competitiveness in the region."

Tackling Global Challenges

The responsible use of resources is a key factor in sustainable development. SmartPro is addressing this challenge by research activities focusing on new and improved materials and technologies that contribute to an efficient utilization of energy and materials including critical metals and rare earth elements in four major areas:

(1) Efficient Energy Converting Machines
Research activities focus on improved materials and technologies for energy-efficient converters, thereby generating strong impulses for light, compact and efficient electric motors and thus for sustainable mobility, power tools and industrial automation. "Smart magnetic materials are a key to resource-efficient products attractive to the market", explains project leader Dagmar Goll.

(2) Innovative Battery Technologies
Cost-effective Lithium-based energy storage systems and rechargeable batteries are in high demand. The focus here is on increased energy density, lifetime and safety for applications in electromobility and portable electronics "We explore smart battery material systems and intelligent production technologies for lithium-ion batteries up to market readiness", illustrates project leader Timo Sörgel.

SmartPro establishes a basis for future smart products — for e-mobility, mobile and autonomous systems.

(3) Hybrid Lightweight Construction
Lightweight construction is a key technology for transport, energy supply and industrial automation. Multi-material composites are of great interest, in particular for the automotive and aerospace industry. "We focus here on intelligent joining technologies such as die casting, thermal joining or adhesive bonding taking into consideration also novel design and quality assurance methods", highlights project leader Lothar Kallien.

(4) Additive Manufacturing
Additive Manufacturing is a key enabling technology for the economic as well as the energy- and resource-efficient production of individualized products. "We address industry demands by developing and adapting technologies and materials for 3D-printed components with novel properties and functionalities such as intelligent sensors", reports project leader Rainer Börret.

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An incentive to dive into self-employment: The INNO-Z Innovation Center provides young founders with 1,400 square meters of space and a modern infrastructure.

Welcoming Smart People and Makers

"We want to create a culture of experimentation," says Dr. Andreas Ehrhardt, Managing Director of the innovation center at Aalen University (INNO-Z), which officially opened in June of 2015. The center now houses more than 50 startups. "We are very pleased about that," says Ehrhardt.

***Walking through the offices,** labs and machine shop, you meet young men and women who are working on exciting and innovative business ideas. For example: How can we improve the lifespan of cell phones? Is it possible to turn a profit with healthy fast food? How can fitness equipment be controlled using intelligent apps?*

***Sven Jooss, the co-founder** of Fitfood, gave up a good job with the world market leader Zeiss; now he is working full-time with Alexander Abele to produce nutritious food. "We offer fresh, delicious and high-quality fast food at a fair price. We developed a concept for a restaurant chain in the system catering sector – with an interactive ordering system for creating customized menus," he reports.*

*Johannes Lutz and his sister Maria started **with 3D printing.** Their company "Mark3D" fulfills every engineer's dream of holding a finished component in their hands as quickly as possible. "We print fiber-reinforced components in just a few hours. Our printers can fit on every desk in your design office," says Lutz. The undergraduate's company now has nine employees and a sales volume in the millions. What does Johannes Lutz have to say about Aalen? "There is no shortage of opportunity here for us. You should see the university and the innovation center as a springboard for your career – a network for your further development."*

*Company founders have a total of **1,400 square meters** available for their use. "The standard office is 17 square meters, and the labs are 26 or 60 square meters. All of the offices are connected by doors. The modular structure makes it very easy for startups to grow," says Ehrhardt. Once a month, founders and potential founders from the university and the East Württemberg region meet for a "founders' evening" at the INNO-Z. "Experts come and talk to us about protecting intellectual property, about company financing and internationalization," Ehrhardt explains. "And I report on new developments and interesting things from the startup scene."*

***In 2017,** the university joined together with universities in Reutlingen and Stuttgart to create the founding initiative "Spinnovation." Supported by state funding, the goal is to promote a startup culture at the universities. In Aalen, the result was the "stAArt-UP!de" project. "We hope it will inspire students to think harder about starting their own company as an attractive career option," says the INNO-Z managing director.*

innovationszentrum-aalen.de
staartup.de

stAArt-UP!de powered by Spinnovation

INNO›Z DAS INNOVATIONSZENTRUM AN DER HOCHSCHULE AALEN

Nickel-based cathodes provide hope for better batteries. Here, Sandra Meinhard and Timo Sörgel prepare an experiment on manufacturing them.

Creating Energy Storage for the Future

Investigative Work between Electrodes

Researchers are looking for a battery that can do it all. One goal is creating high-performance electric cars with a long range

by Eva Wolfangel

Safety goggles, an electrolyte bath, and a homemade frame holding a bare polished, gleaming sheet of stainless steel: Andreas Waibel is ready to shape the future. In this case, the path to the future leads to a lab at Aalen University, where countless basins are filled with different colored liquids. All different kinds of metal ions are dissolved in the liquids.

Waibel is focusing on the nickel electrolyte. It is a special electrolyte that also contains the active material in a battery, as small suspended particles. The undergraduate student is waiting for it to reach the right temperature for his experiment. Then he will dip the bare, polished and carefully degreased stainless-steel sheet into the liquid, leaving it with a coating of nickel. The new feature of this experiment is that the active material particles will be integrated into the layer. How exactly that works is a secret.

"This setup allows us to pull the separated composite layer of the stainless-steel sheet at the end, as a composite film – and there we have our battery electrode," says Waibel. He can then test various ways of adding a structure to the electrode film. That further improves the film's characteristics for later use in batteries. For the young man, this job as a research assistant is an opportunity to use the knowledge he has gained in his Surface Technology studies – and maybe make a small contribution to the energy supply revolution.

Prof. Timo Sörgel, who is coordinating the battery research as part of the SmartPro project, explains the specific approach they are taking. He is also excited about seeing the results, because this small experiment in composite electroforming could advance an idea that he originally came up with. Timo Sörgel studies future-oriented battery structures. The head of the Research Institute for Innovative Surfaces (Forschungsinstitut für Innovative Oberflächen, FINO) at Aalen University does not just want to test new materials – he wants to change the manufacturing process, too. Until now, the active electrochemical materials were applied onto current-collecting films together with inert auxiliary materials as a "slurry mass." This also involved using poisonous solvents. The new process is a simpler way to create electrodes, and it is environmentally friendly.

The researchers are currently working to make the manufacturing process so reliable that there are only minimal fluctuations in the electrode characteristics. Experts often only realize later on that a battery is not working the way it should. When they take the time to open it up and use precise processes to investigate the cause of the failure, the problem is often due to fluctuations in the manufacturing process.

Looking for Abnormalities

In order to understand this better, we need to leave the lab for a moment and talk to a researcher who has inspected many batteries. Dr. Ute Golla-Schindler, who works at the Materials Research Institute (Institut für Materialforschung) at Aalen University is surrounded by modern electron microscopes that allow her to precisely identify details in the battery materials, down to the nanometer range. The researcher uses them to show the anode and cathode particle structures that are applied on copper or aluminum films, and she looks for abnormalities in the active materials – such as cracks, newly created layers, and chemical changes. She tries to link these abnormalities to the battery's history, for instance its manufacturing process or its charging and discharging. "It would be wonderful to develop a perpetual battery that contains a great deal of energy," says Golla-Schindler, as though it were the most natural thing in the world. And if you think about all the plans the world has for energy innovations in the next few years – from electric cars to renewable energy – you have to admit she is right. In the end, all those things involve storing and using energy.

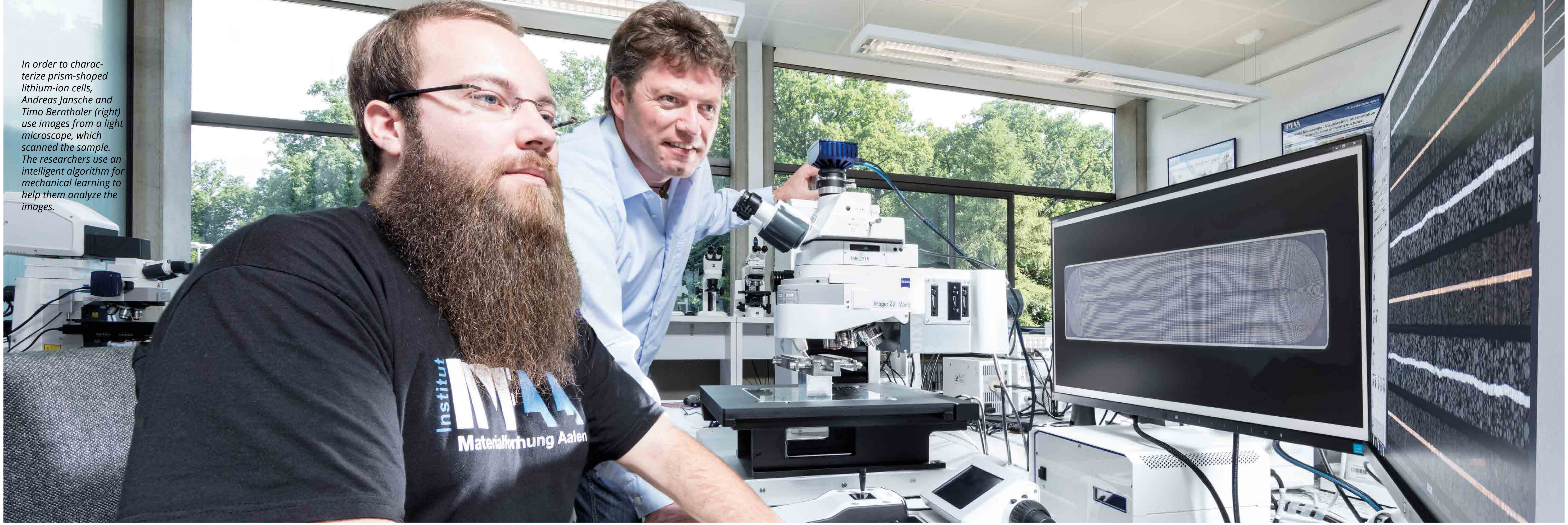
Battery Corpses on the Autopsy Table

Battery technology could use improvement in many areas. "There is plenty of room for growth," one often hears at Aalen University. Ute Golla-Schindler is at the end of the chain: where the "battery corpses" land. "I would love to perform non-destructive tests," she says, "but we still have to open the batteries up to find their weaknesses." The expert hopes to move away from that by going back to the beginning.

"We are working on analytical methods that can be used while developing new battery materials in order to identify initial production errors or aging effects early on" – and not just to find out what went wrong retroactively. The Material Analytics team cooperates closely with the other two groups, which are working on new materials and processes for battery manufacturing.

That includes Timo Sörgel's team, whose laboratory we will now return to. Sörgel has declared war on the layers of active materials, additives and binders, which until now were applied to a metal film as a thick, honey-like mass and later form anodes and cathodes. There has to be an easier way, he said to himself when he left the industry and came to the university in 2011. One of the issues he brought with him was composite plating – a process that had never been used in battery manufacturing before. This process integrates functional particles into an electroplated metal layer. "This type of dispersion layer could also be used as an electrode," was the researcher's hypothesis. Timo Sörgel published it jointly with his colleagues – and also went ahead and applied for a patent.
In the future, electrodes could be created using the approach that Andreas Waibel is taking in the lab: with a stainless-steel sheet and a nickel electrolyte solution. That might be a way to produce the batteries of the future. At the same time, the structure of the layers could also be influenced, says Sörgel. "Batteries with identical active materials always have the same voltage under open circuit conditions, but as soon as current flows, structure comes into play (influencing batteries performance)." The right structure can increase their efficiency, for example.

We're all familiar with this everyday phenomenon: Smartphones get hot when they are intensely used, and while charging. This heat is lost energy. "The amount of heat lost depends heavily on the structure of the electrodes," explains Sörgel. And the less energy lost in this way, the more efficient the battery.



In order to characterize prism-shaped lithium-ion cells, Andreas Jansche and Timo Bernthaler (right) use images from a light microscope, which scanned the sample. The researchers use an intelligent algorithm for mechanical learning to help them analyze the images.

Weight is Decisive

Another goal is to optimize batteries for their intended purpose, says Sörgel. "Depending on the application, different characteristics are needed." Conventional cars, for instance, still use lead accumulators as a starter battery, even though they are very heavy. But they would be unsuitable for electric cars. While for electronic devices such as smartphones we mainly focus on the size of the battery, in cars and airplanes it is the weight that is most important. Sörgel and his colleagues have also experimented with foams to which they applied the electrode material, using composite coating. "It preserves the pores in the foam, and the active material can be used more efficiently," says Sörgel.

Another adjustment that can be made in developing the battery of the future is the microstructure of the electrodes. The research on this is being done by Prof. Volker Knoblauch from the Materials Research Insitute, a few doors down the hall. "We need new material systems in order to develop high-performance batteries," he says. Here it is important to know which characteristics of the electrode structure create which characteristics in the batteries.

Knoblauch's path too, often takes him back to Ute Golla-Schindler and her modern microscopes. A battery's weaknesses become apparent especially as they age, and this has not previously been well understood. Suddenly, a smartphone's battery only has two hours left – but no one can explain what happened to it. All we know is that it is old. "We have to understand which mechanisms cause a cell to age," says Volker Knoblauch.

His laboratory features several life-sized climate-controlled cabinets. One of them bears a label: "Long-term experiment." Here, battery cells are charged and discharged over and over again under defined conditions. A clever safety technique ensures that nothing can go wrong even under extreme testing conditions. In this experiment, doctoral candidate Christian Weisenberger is testing how batteries that use the next generation of active materials change after a certain number of charging and discharging cycles.

"Batteries need better energy density and power density in order to provide large ranges with short charging times," says Weisenberger, explaining his wishes for energy storage systems. "In addition, they need to be safe and long-lasting – and as cost-effective as possible." It is not yet possible to integrate all of those features into a single package, but Weisenberger is highly motivated to resolve the contradictions.

Hardly Investigated Relationships

How thick is the ideal electrode? How well does it need to be sealed? The relationships between these characteristics and their effects have hardly been researched. "We are looking for the ideal microstructure for the material systems of tomorrow and beyond," says the young researcher. For instance, a porous electrode has a high power density: It can be charged or drained quickly. At the same time, its energy density is lower – the battery soon needs to be recharged. "But everyone wants to drive long distances with electric cars and spend as little time as possible charging them. For now, that is still a contradiction."

The solution to this paradox lies slumbering in the laboratory's numerous "glove boxes": air-tight work cabinets that require workers to put on tight-fitting gloves before reaching into them. Weisenberger and his colleagues have combined numerous different electrode materials with various structures here to create battery cells, and are subjecting them to a series of experiments. "We want to manipulate the microstructure of the electrodes so that both things are possible: rapid charging and driving long distances," says Volker Knoblauch.

The researchers on his team are laying completely new paths, for instance by using lasers to modify the electrodes and focusing on the next generation of batteries: solid-state batteries. In the process, Weisenberger, the doctoral student, is constantly pushing battery cells to their limits – like in the long-term experiment. "In order to understand the impact of changes in the microstructure, we perform a 'post-mortem' analysis," he says. It is like a murder mystery. "First we identify the cause of death, then we define the sequence of events."

Andreas Jansche takes a different approach: The Master's student has cut open a large prismatic cell, the kind used in hybrid vehicles, and prepared it so he can inspect it using a light optical microscope. The many tightly wrapped layers, with insulation in between them, act like densely rolled-up pouches. Jansche is interested in the manufacturing quality of the battery. Thus the student is looking for fault sources such as foreign particles and fluctuations in layer thickness.

The microscope, with its scanning table and computer, creates a gridded image of the battery cell at one-millimeter intervals, which produces high-resolution photos. The result is up to 35,000 images per cell. "No one can possibly look at all of them," says Jansche. As a result, the young computer scientist is working to automate the process using artificial intelligence. After all, fault sources need to be discovered as quickly as

The significance of batteries for energy storage is growing, for instance in electronic devices. In this photo: a cut-open lithium-ion battery.

possible – not just once the battery factory has already been producing scrap for days.

"How can we evaluate manufacturing quality?" asks Dr. Timo Bernthaler, Jansche's thesis advisor and the Head of the Institute for Material Research. The goal is not just to develop an automatic process that identifies errors, but also to integrate it into production.

Perfect Batteries for Electric Vehicles

The research partner here is a company in the auto industry that plans to start manufacturing batteries for electric vehicles in grand style. Those batteries need to be as close to perfect as possible. Until now, it was common to X-ray cells during production. "But that doesn't show you everything. And what you do see, you see very late," says Bernthaler. When batteries are installed in electric cars, it is important to avoid incidents like Samsung's cell phones catching fire in 2016. "The manufacturer's investigation report says that it involved exactly the same issues we are working on now," says Bernthaler. Some of the layers were distorted by packaging too tightly so that they cracked, causing a short circuit.

Some improvements are still needed. No one wants to replace modern batteries for electric vehicles, which cost thousands of euros, as often as they do cell-phone batteries. There is plenty of room for growth. And Aalen is filling that gap.

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Dagmar Goll is doing research on novel magnetic materials. The metal band in her hands has been fabricated by melt-spinning (equipment shown on the picture).

New Materials for the Magnets of the Future

Gold Rush at the Kocher River

Aalen University already has six patents on materials that could be important for future electric vehicles. Researchers in this city along the Kocher River are doing their best detective work to find more

by Eva Wolfangel

They tell us that this small container holds the future of electric motors. To be more specific: the future of energy conversion. It looks almost like a tiny ashtray, with a thick black rim and a recess in the middle that holds a shiny metallic substance. But the way Prof. Dagmar Goll handles this tiny thing – no bigger than a single-serving package of jam – indicates that it is something special.
“We are looking for magnetic gold,” confirms the professor of Physics of Magnetic Materials, who is also the spokesperson for the SmartPro project. The small, valuable object is called a crucible – and it packs a punch. It could even contain a revolution. Dagmar Goll can’t reveal any more than that. The researcher tracked it down through intricate work, following all clues.
The crucible is the result of a process that first came into being at the Institute for Material Research at Aalen University – at least in the form used for this application. Here’s how it works: New magnetic materials are in higher demand than ever before. That is in part because electrification requires increasingly efficient, lightweight and compact energy converters – electric motors for cars, generators for wind and solar power and actors for autonomous systems. They all rely on the effect of magnets, and are taking the previous materials to their limits. On the other hand, the best magnetic material available today contains rare earth metals. “One electric motor contains about 500 grams of neodymium and dysprosium,” says Goll.

As the name implies, rare earth metals are quite uncommon; more importantly, they are a finite raw material. Most of them come from China and are subject to strong price fluctuations. That poses a dilemma for engineers; neodymium iron boron magnets are considered to be the most efficient, but they are expensive. On the other hand, cost-effective hard ferrites are available as an alternative material, but they are inefficient. “There is a huge gap between them,” says Goll.

Trying to Fill the Gap

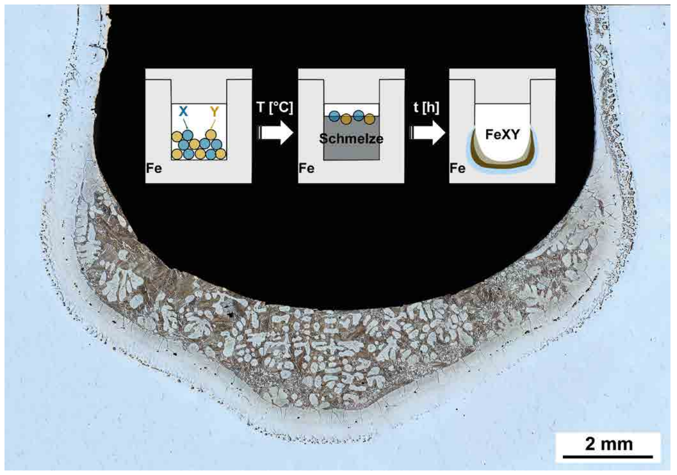
So why not just search for a new magnetic material that is not made from rare earth metals, or one of that uses very little of them? Or one based on relatively cheap rare earth metals such as cerium? The goal is to find a material that fills the gap or even extends the upper range of magnetic materials. The periodic table of elements may be limited, but there are many possible combinations of elements – and only a fraction of them have been studied in experiments up until now. Neodymium iron boron has been known as a magnetic material since 1984. “From a magnetic perspective, it is about time to discover a promising new material,” says Goll.
At Aalen University, a team led by Dagmar Goll and Rector Prof. Gerhard Schneider has been working on this for more than ten years. It does not mean testing every possible combination in the periodic table. “From the field of material research, we know there are four transition metals that are fundamentally suitable for magnets,” says Schneider. These are cobalt, nickel, iron and manganese. In addition, around 50 other elements are potentially interesting.
Still, even with these limitations, there are millions of possible combinations of chemical elements and only about 1.500 have been studied so far. Most of them are systems consisting of two or three substances. “Then there are the many possible combinations of four or more elements, which can in turn be combined in a variety of ways,” says Goll. “That opens up an enormous potential.” But finding the best combination is like looking for a needle in a haystack.

In order to tackle this daunting task, the researchers in Aalen developed a prioritization process. The process shows which combinations of elements are technically, economically and ecologically promising. After running this check, around 1.000 combinations of three or four elements remain. But no one has performed experiments on them, let alone checked all of the possible combination variants. “Testing even just one of the combinations would be an entire doctoral project,” says Schneider.

A Creative Concept

Since it is not feasible to hire 1.000 doctoral students to take on this immense job, Goll and Schneider are counting on a creative concept. They developed the high throughput approach which produced the contents of the small crucible that Dagmar Goll now holds in her hand like a jewel. The elements of each combination to be tested are placed in there. The vessel itself is made from the main element in the substances being tested, for instance iron. Together with the other two or three elements, the whole thing is then heated. “Thermodynamics takes care of the rest,” says Schneider briefly, as though it were the simplest process in the world.

In fact, when heat is applied, the elements in the crucible react with each other and form new phases. If the temperature is high enough, the components in the reaction vessel melt. A chemical reaction occurs between the melted mass and the still-solid vessel. In the process, atoms at the interface are diffused into the material of the container. That creates a



A single step to narrow down numerous possible materials – the high throughput process was developed by researchers in Aalen. In this process, substances are placed in a crucible and heated. After a while, chemical reactions produce many different alloys in the vessel.

concentration gradient, a diffusion couple. “Ideally, you end up with every type of alloy that is possible for each system, represented in a single crucible,” says Schneider, “at least as far as kinetics allow and in terms of what we are interested in. And all that in just a few days!”

After that, an efficient analysis process is used to determine whether the resulting alloys contain any promising magnetic materials. The researchers take advantage of a special feature of the materials that occurs through magnetism: Under a microscope and in polarized light, their surfaces reveal typical patterns that are reminiscent of crosswalk lines or rose windows in a church. Physicists call this bizarre light and dark formation a domain pattern. It is the magnetic material’s fingerprint.

Domain patterns with very wide stripes or rosettes, as well as with strong light/dark contrast, indicate especially promising materials. “That allows us to draw initial conclusions about the properties of magnets that are made from them, and about the characteristic features of machines that are built with them,” says Goll. “The coarser the pattern, the more resistant the magnet is to disruptive fields in the machine. And the larger the contrast, the stronger the magnet’s effect.”

The research group in Aalen has found promising magnetic materials using this approach, and already holds six patents on them. The new materials are cost efficient and contain only a small percentage of rare-earth metals.

But the crucible that Dagmar Goll holds in her hand is not the end of her detective work. The path to a new material is longer than that – in the next step, a larger amount of the new material must be synthesized. That way it can be studied more closely in terms of its physical and chemical properties. This is followed by developing suitable process technology in order to manufacture “real” magnets out of the material. That can take several years. Only then large-volume production can begin. Still, “the course has already been determind thanks to our targeted search for ‘magnetic gold’,” says Gerhard Schneider.

Power Units for Electric Bikes

If you want to know how this magnetic gold will be used in the future, you can visit Prof. Heinrich Steinhart, a professor of Power Electronics – and a practical expert. Many of his experiments demonstrate one thing above all: Efficient magnets with special properties are needed more urgently than ever. Most recently, Steinhart developed the motor for an electric motocross bike. “That was an enormous challenge,” he says. Racers do many laps at high speed, and the extreme torques and sand exposure put a huge strain on the motors. Many magnets just give up, run too hot or do not provide enough power.

But high-efficiency magnets are not only used in motors for electric vehicles; in miniature form, they are also found in robots for digitally networked production plants. Daniel Lebsanft, a doctoral student in the Industry 4.0 field, is currently working on the perfect drive mechanism for the joint of a robot‘s arm. Working on a computer, he simulates friction, force, mobility, energy flows, magnetism – and the resulting heat. “There is not much space in the joint, but the robot still needs to be strong and to work precisely,” explains Lebsanft. Then he shows us one of his motors. “Try to turn the shaft.” It can be done, but only with great effort. The reason is the cogging torque – another stumbling block on the path to precise technology. “A powerful robot cannot get by without efficient, tailor-made magnets,” says team leader Heinrich Steinhart. Fortunately, the experts on that are located just next door.

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Magnets for Motors

Many electric motors are so called permanent-magnet synchronous machines. They consist of an unmoving stator and a moving rotor that contains both permanent and soft magnets. Once permanent magnets have been magnetized, they produce a constant magnetic field on their own. They are normally found in the rotor. Soft magnets reinforce the magnetic field of electrified coils that wrap around them. Only then they do exhibit their magnetic properties. Usually, they are found in the stator.

High-performance electronics control the poles of the soft magnets, so that they are pushed away by the permanent magnets. That causes the drive mechanism to rotate. These permanent-magnet synchronous machines have an energy conversion efficiency rate of up to 95 percent, which makes them much more efficient than other drive concepts. Only about five percent of the electrical energy put into them is lost when it is converted to heat.

The more efficient the magnets, the more lightweight and compact the motors that can be built. Efficient magnets also increase the range of electric vehicles. Rare earth magnetic materials make especially efficient permanent magnets, and electrical steel strips are efficient soft magnets. However, each drive mechanism requires up to 1.5 kilograms of rare earth metals and 40 to 100 kilograms of electrical steel material.

The major challenge with permanent magnets is reducing the rare earth metal content. In addition, when the motors operate, they run up against their maximum possible working temperature of about 200 degrees Celsius. The problem with electrical steels? They reach their limits as the machines run faster and faster. For these magnets, the important thing is to minimize any losses that occur. In addition, on the technical side, it is becoming increasingly important to tailor the material's properties to the demands of the machine.

The expert on electric motors: Heinrich Steinhart directs the lab for electric drive mechanisms and power electronics. Among other things, he and his team developed a motor for electrically powered motocross bikes – just one of the areas where high-efficiency magnets are extremely valuable.

“A Unique Opportunity to Further Develop our Research Profile”

Gerhard Schneider is the President of one of the most successful universities of applied sciences in the field of research. This interview highlights the dynamic activities at Aalen University

Interview by Wolfgang Hess

Aalen University considers itself a strong research university. Can you give us some examples, Prof. Schneider?

The first indicator is our high level of third-party funding. Research at our applied sciences university is not part of the general budget, so we have to obtain third-party funding through national and federal calls for projects, competing against other research institutions. We maintain a good network with companies and public institutions. Our research often focuses on issues that these partners bring to us. That produces most of our annual research budget of approximately 12 million euros. A second indicator of our research strength is our great number of scientific publications. Anyone who looks at the trend in our third-party funding and publication figures can see how dynamically research is developing at our university. In the State of Baden-Württemberg, which is known for strong research, we have been the number one university of applied sciences for thirteen years now in terms of third-party funding and publications per professor.

What are some other features?

For one thing, there is our excellent research infrastructure. In addition to the modern equipment, that includes two research buildings that were funded by the Science Council and the State of Baden-Württemberg in a competition with other German universities – an investment of about 26 million euros. Construction started in the summer of 2017. Another indicator is the funding of our “SmartPro” concept by the Federal Ministry of Research. Only 10 of the 81 technical colleges and universities of applied sciences that took part in the national “FH-Impuls” competition were chosen, and will now receive about five million euros apiece for at least four years. By the way, many university professors who apply for positions with us say things like, “I’ve heard that Aalen is a strong research university, and I’m very interested in working there.”

What distinguishes researchers at Aalen University, an applied sciences university, from those at other universities?

Our researchers often use their own ideas to tackle current technological challenges. This motivation makes them very similar to researchers at research universities. Since we do not have money in the general budget for research, though, our scientists can only do research if they convince experts and company partners to invest in their work. That’s why it is essential for us to have good contacts in the business sector, especially in this region.

Professors are expected to spend most of their time teaching. How do your colleagues respond to additional research responsibilities?

Our professors do a great job of teaching. I value that very highly. We don’t want to convince every one of those good teachers, with their extremely high teaching load, to start spending a lot of time on research, too. But we do want to support those who have a talent for research – with good framework conditions that let them do their research as well. That means reducing their teaching load, for example. No one can teach 18 semester hours a week and also do successful research. They also need well-equipped labs and sometimes even start-up financing to try out new things.

For 13 years in the top position within Baden-Württemberg

Gerhard Schneider
has been the president of Aalen University since 2008. Schneider (born in 1958) earned his doctorate at the Max Planck Institute for Metals Research in Stuttgart and was a Professor Visitante at the University of Sao Paulo from 1988 to 1989. In 1989 he continued his research career at Robert Bosch GmbH. From 1996 to 2001, the metallurgist was a professor for Material Sciences at Aalen University. Then he went back to Bosch, where he was the executive vice president of the Robert Bosch Corporation in Palo Alto, California, from 2005 to 2007. Schneider is a member of numerous committees and commissions that focus on research and transfer.

A look into the future: This is what the new research building will look like. Construction works began in the summer of 2017.

How do you transfer research findings to the business sector?

Since 2015, we have been running the INNO-Z innovation center, which was planned about ten years earlier. The idea is to professionalize the interface between businesses and the university and to appoint a transfer manager. That person's job is to pay attention to what companies are looking for. Then they make connections between the right people in the business sector and the university. One service for our professors is that they do not need to worry about organizational aspects. That is handled by the transfer manager. Our researchers should be able to focus on contributing their technical expertise so they can help bring about specific solutions.

The public sees universities somewhat differently than applied sciences universities. Some even refer to it as a two-tier society...

... which annoys me. Of course we have different profiles. But we are in favor of performance-oriented support for both types of institutions. If someone at our school has an outstanding research idea, he or she should be supported, not hindered by the institution's status. Class-based thinking suppresses innovative potential. In the context of research projects, I always hear that this is just a university of applied sciences – not a real university! But applied sciences universities are specifically designed to implement their research towards practice.

Can you tell us why potential students should choose Aalen University in particular?

Aalen is right in the middle of prosperous southern Germany – between Munich and Stuttgart. Our region is one of the most innovative areas in all of Germany – with world-class companies such as Zeiss, Bosch and BMW. Another consideration is that our teaching and research are top-quality in our focus areas of technology and business.

What is the percentage of women at Aalen University?

It is disappointing that we have not been able to draw more women to highly attractive, promising technical fields. The numbers are much better in the Healthcare Management and Business Administration programs.

What distinguishes your students?

We see ourselves as a regional player in the fields of mechanical engineering, electrical engineering, mechatronics, computer science, economics and chemistry. Most of our students have roots in the region. Our regional industry is counting on them and hoping that they will stay and work here after their studies. In addition to the regional aspect, we are also very attractive nationally in several areas – such as optometry, surface technology and materialography. Students in these fields have often already completed an apprenticeship. They come to Aalen because they are interested in our specific course content.

How are the salary prospects?

Our graduates study fields that are in high demand in the employment system, and as a rule they find well-paid work right after they graduate. Salaries are in the top range and according to the studies I have seen, they are no different from the income ranges for comparable university graduates.

What is your overall strategy?

As an important regional player, we look at the topic areas of education and innovation – from childhood up to the transfer of our research findings to the business sector. explorhino, our workshop for young researchers, encourages boys and girls to engage with technology and natural science through play. Our curriculum provides a solid educational foundation, which is the basis for our Bachelor's and Master's programs. Our research fields have an excellent infrastructure, and our application-based research is successful and publicly visible. Our strategic focus is rounded out by our innovation and transfer center INNO-Z, which strengthens our impact in the business sector and in society. The quality of our teaching and research is extremely important in all this.

What is the situation with small and medium-sized enterprises (SMEs) and their partnerships with universities?

When it comes to strategically important long-term issues, it is worthwhile to turn them into research projects. That can take a year or two, but it is often too time-consuming for SMEs. They lose interest in further communication. That is why we want to establish the transfer manager position, to build bridges between a fast-moving SME and our academic structures. Our "SmartPro" project also plays an important role in our interactions with companies.

What is Aalen University hoping to achieve with the SmartPro project?

With SmartPro, our winning concept in the Federal Ministry of Research's "FH-Impuls" competition, we hope to make important contributions to the sustainable development of the region's innovative strength. SmartPro stands for smart materials and intelligent production technologies for the energy-efficient products of the future. One goal is to bring together material research and manufacturing technologies in a future-oriented way. In addition, SmartPro is a unique opportunity to further develop the university's profile in collaboration with the business sector. With SmartPro, we want to optimize structures, make further quality improvements, and fuel the research transfer. It involves 14 of our most active professors as well as more than 30 companies from various industrial sectors. They are looking at electromobility, Industry 4.0, battery technology, lightweight construction and autonomous systems.

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Young researcher Dominic Hohs

Studying in the Research Lab

Dominic Hohs is one of more than 50 students working towards a research-based Master's degree. He appreciates the combination of science and practical relevance

Magnets have a magical attraction for Dominic Hohs. The ones he is studying are used in the coils of electric motors. In order to make these motors even better, it is important to understand the magnets' behavior as clearly as possible. Hohs is investigating how the structure of the magnetic material influences later properties of the electric motor. The 27-year-old student is completing his Master's by Research in Advanced Materials and Manufacturing at the Materials Research Institute (IMFAA) in Aalen.

The program was established in 2013. It is different from a traditional Master's degree because of its focus on applied research. There are lectures just as in any degree program, but most of the time is spent on experimental projects in the lab. "Physics, chemistry and engineering play an important role in this interdisciplinary program, but everything has a very practical focus," says Hohs. "Half of my research activities take place in the lab, where I synthesize and characterize samples and half of them involve data analysis at my desk." Above all, the student appreciates being able to work independently on a project. "I'm not just studying for exams; I'm also learning through research." Hohs has already presented some of his own research findings at specialist conferences.

The Solingen native started with the ideal conditions for a Master's degree. After school, he completed his training as a technical assistant for metallography. Then he worked at the Cologne University of Applied Sciences for two years. "My goal was to choose and optimize a suitable material for manufacturing an innovative spring," says Dominic Hohs.

In 2012, he enrolled in the seven-semester Bachelor's program in Materialographie / New Materials at Aalen University. Thanks to his previous knowledge, Hohs was able to work as a research assistant at the IMFAA at the same time, preparing samples and conducting analyses. In the process, he found out about the Master by Research from other students. The result was inevitable – Hohs wrote his Bachelor's thesis about the area where he had worked as an assistant and continued his Master's there as well.

At the same time, Hohs founded the local "jung-DGM" (Young-DGM) group in Aalen as part of the German Materials Society. "Our regular meetings have participants from various academic fields, from first-year students to doctoral candidates," he says. The main focus is on transferring knowledge, for instance with field trips and presentations of final thesis projects. Training, Bachelor's, Master's – Hohs is not done researching yet. He plans to earn his doctorate at the IMFAA, too. The magnets have him in their grip. MV

Further information on the program: hs-aalen.de/AMM

An Unusual Program of Study

Very few German universities offer a Master by Research. Students are closely integrated into the working groups of strong research professors and receive intensive training in performing careful scientific work. "They learn to ask the right questions and to develop and implement approaches for solving them. And, most importantly, they learn to critically question and discuss the results in order to turn them into knowledge," explains Aalen's academic dean, Prof. Volker Knoblauch. "We set the bar very high, and we expect our students to publish an academic article about their topic at the end of their studies." Response from the industry has been very positive, and graduates are usually able to find their dream job – unless, of course, they have gotten hooked on research and decide to stay on at the institute as doctoral students.

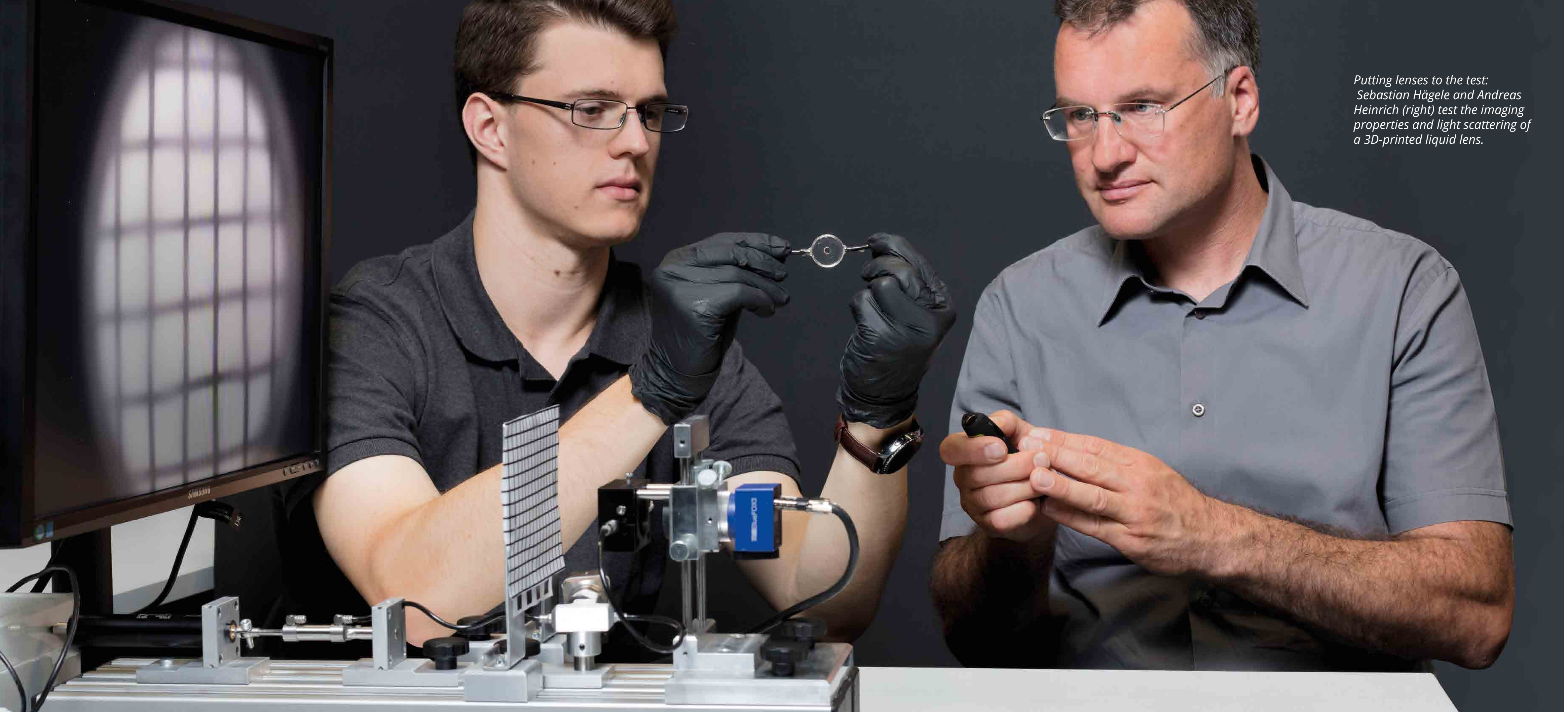
The Fast Lane to Perfect Lenses

Lenses Made to Order

More and more companies are now relying on 3D printing. Researchers in Aalen are laying the groundwork so this process can be used for making complex molded optical components

by Michael Vogel

Brilliant results from a printer: Rainer Börret leads the Optical Manufacturing Technology division at Aalen University. 3D printing offers completely new possibilities in this area. For instance, optical elements can be manufactured with unusual shapes and delicate internal structures.



Putting lenses to the test: Sebastian Hägele and Andreas Heinrich (right) test the imaging properties and light scattering of a 3D-printed liquid lens.

There was a time when plastic lenses were only used in children's toys and cheap imported goods. High-performance lenses, on the other hand, were made of glass. That time is long gone. Today there are many complex devices that need to concentrate or direct light in one way or another, and they use lenses made from transparent plastics. Eyeglasses and contact lenses are well-known examples, but even smartphone cameras and motion sensors now rely on plastic. The major advantage over glass: Plastic lenses are cheaper to manufacture, and their surface shapes can be more complex. In addition, plastic is more lightweight than glass. Unlike a glass lens, a plastic lens does not need to be ground, but can be injection molded.

In this field, too, there is constant development. When Prof. Andreas Heinrich from Aalen University thinks about plastic lenses, he is mainly considering ways to eliminate their weaknesses. "When you manufacture a lens combination using injection molding, you always develop the lens and its mechanical support separately. That takes time and construction space. In addition, lenses manufactured that way cannot have structures inserted into them." 3D printing removes those limitations on the lens. The potential is well known, although there are not yet many people researching it. Heinrich's working group and the team led by his colleague Prof. Rainer Börret are among those few.

Threads or Liquid

The plastics used for printing are available either as thin threads, which are melted and applied in layers, or as a liquid starting product that is cured one layer at a time using UV light or a laser. That is how Heinrich's 3D printers created a transparent cube with a sphere in the center as an integrated scattering center. "We use a tiny projector to beam a video of the rotating Earth into this sphere from underneath, through an optical head, so it looks like the sphere itself is rotating," explains the researcher. The video's planar image information is thus presented on a physical body. The cube, optical head and mounting were all created at the same time using 3D printing.

A complex 3D lens used as the output for a light guide has more practical applications. It can be used in manufacturing to check the quality of a pump component. "The component looks like a tower with a spiral staircase on its inner wall. We want to measure the shape of that spiral staircase," says Heinrich. "The incline of the coil can vary from one component to another. In other words, the surface to be measured during quality control has a different angle and curve every time." That is hard to check with traditional measurement technology – and is not cheap. "With 3D printing, on the other hand, we can make a cost-effective lens that is based on the complex shape of the coil," says Heinrich. The necessary lens is reminiscent of the coil, and it cannot be manufactured using conventional processes. 3D printing is what makes it possible.

The physicist and his team are taking an additional approach with liquid lenses: two thin membranes that define a cylindrical volume. When optical immersion oil is pumped into this space, the membranes bulge outward, creating a lens. The oil pressure can be used to adjust the focal length. "With 3D printing, we can add mechanical structures that are connected to the membranes – such as rings, or a three-pointed star – in order to give the lens multiple focal lengths," says Heinrich.

Lenses With a Ring and a Star

A ring inside the structure produces two ring-shaped lens areas with different focal lengths. The three-pointed star creates three "pie pieces" with different focal lengths. "Printed liquid lenses are interesting for measurement technology and for visual quality assurance inspections, for example in mass production," says Heinrich.

However, when the lens comes out of the 3D printer, it is not as nice and transparent as one would like. The optically effective surfaces first need to be polished, like a glass lens. That is where Rainer Börret's team comes in; they are developing processes to polish complex plastic surfaces using industrial robots. "Nowadays that is mostly still done by hand," reports Börret. "It is not very appealing from an economical standpoint and it's hard to find properly trained personnel."

But for Börret's team, the automation process doesn't just start with polishing. "We are investigating whether a modern industrial robot that can move in every direction could optimize the printing process." The print head could then be angled in any direction, and the surface where the lens is being created one layer at a time could move along all three spatial axes.

This is illustrated by the example of a curved light guide constructed in layers. At the transition between each layer, there are unavoidable irregularities – differences in material characteristics where light is scattered. That is undesirable. Aalen's researchers believe that if the printed layers could be placed parallel to the light guide wherever possible, there would be less scattering.

"It can be done with a print head that can swivel in any direction and a matching printing trajectory, as we have already been able to demonstrate," reveals Börret, "but our goal is to achieve a surface precision of one micrometer so we can compete with the precision of injection molding." Rainer Börret and his team are well on their way there.

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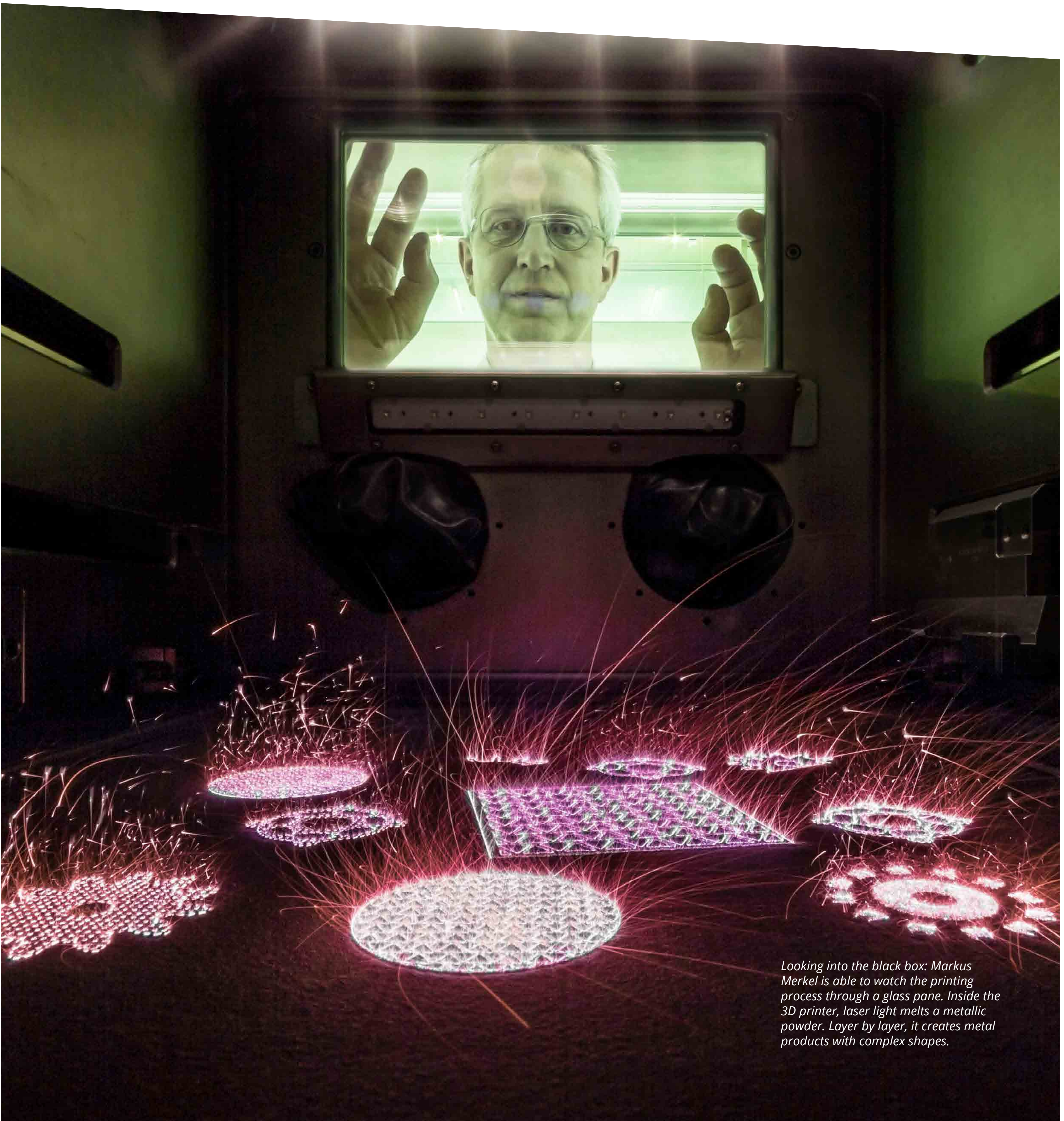
A Look at the Entire Process Chain

A Gearwheel with Gumption

3D printing of metal components allows the creation of all-new functions for smart products

by Michael Vogel



Looking into the black box: Markus Merkel is able to watch the printing process through a glass pane. Inside the 3D printer, laser light melts a metallic powder. Layer by layer, it creates metal products with complex shapes.

In many drive systems, gearwheels are essential components. That means they are fairly commonplace objects. The one lying on the table in front of Prof. Markus Merkel, though, stands out from the crowd of conventional gearwheels – it features hollow spaces. "In a sense, the holes add value," Merkel explains. The engineer and professor at Aalen University, together with his working group, prints these gearwheels using metal powders. A laser melts selected areas of each powder layer, which then bond with the previously melted areas in the layer below. Layer by layer, that creates a three-dimensional product – in this case, the gearwheel.

Putting an End to Waste

One advantage of this "additive" manufacturing process is its sparing use of resources. When a gearwheel is milled out of a solid metal block, for example, the cutout material becomes waste; 3D printing, on the other hand, uses only the amount of material that is needed for the product. Some applications for the procedure that Merkel and his team have in mind during their research include electric drives and transmissions that are subjected to extreme changes in speed. 3D printing allows them to create hollow spaces in the component in a single process step. "That's not possible with the existing manufacturing processes," says Merkel.

The hollow spaces make the gearwheel lighter and give it a lower mass moment of inertia, which means less energy is needed for accelerating and braking. In addition, coolant can be fed into the hollow spaces so that external cooling is no longer necessary. That reduces the amount of space required.

"The spaces could also be used to house sensors or actuators," says Markus Merkel, continuing the thought process. "Then the gearwheel could communicate with the overarching assemblies and report a problematic increase in temperature, for example, in real time. That way the overall system could respond before the gearwheel or transmission is damaged."

Additive manufacturing processes are a hot topic at many research institutions as well as in companies. Merkel explains what is interesting about the approach they are taking in Aalen. "At the university, we look at the entire cycle of the process – from the starting material and the printing technology to surface processing of the components." There is a general rule behind this: "Anyone who studies and does research with us needs to understand complex processes and be capable of networked thinking," emphasizes Merkel.

Construction of the component is computer-aided and digital, as is the analysis of its mechanical properties. The actual 3D print is based exclusively on digital data. No tools or molds are needed. Even the quality analysis of the resulting component provides comprehensive digital 3D data, which can then be used to improve the material and the technology. "Our approach makes our research completely Industry 4.0-compatible and future-oriented," says Merkel.

There is one issue: The surface of a printed gearwheel feels much rougher than if it had been milled. That is where Simon Ruck comes in. He is a research assistant and doctoral candidate on Prof. Harald Riegel's team. Ruck and his colleagues are studying laser processes that can be used to smoothen a rough surface. "We have to be very careful with this type of post-processing, or else the printed component becomes unusable," he explains.

Finishing Touches with Laser Pulses

After 3D printing, there are still many residual powder particles on the surface of the gearwheel that are left behind after manufacturing. In order to get rid of them, the surface is heated with laser pulses, each lasting less than a microsecond. "That blasts off the undesirable particles and oxide layers," says Simon Ruck. "If we added more energy, though, the blast would be so strong that the particles would tear tiny craters in the surface. Naturally we don't want that."

After cleaning comes laser polishing, which the researchers use to reduce surface roughness to one-fortieth of the original level: to an "arithmetical mean roughness value" of less than 0.2 micrometers. Like 3D printing, the laser polishing – which re-melts a hair-thin edge layer of the surface – requires ultrapure material. As a result, conventionally manufactured metal components often cause problems.

Until now, the industry has only been able to post-process 3D contours by hand. "To do it mechanically, we have to use a laser polishing robot that can follow the contour precisely enough, in other words not just by moving along three spatial axes," explains Ruck. He says the researchers in Aalen will keep working to improve this method in the future, as part of the SmartPro project.

The raw material for printing the gearwheel is an aluminum alloy that is commercially available as powder. However, it needs to be adapted to the chosen 3D printer's process to ensure the appropriate quality. This task is performed by Tim Schubert, a material scientist and doctoral candidate at Materials Research Institute Aalen, together with Dr. Timo Bernthaler and Rector Prof. Gerhard Schneider. “The printing process had unsatisfactory results at first, but for banal reasons – for instance because of varying residual moisture in various batches of the powder,” explains Schubert. He and his colleagues use various devices to analyze the properties of the powder and the printed products, so they can then be optimized for 3D printing using the selected process parameters. That lets them find the ideal print settings – through research teamwork.

Tim Schubert from the Materials Research Institute Aalen develops customized powdered metals for use in 3D printing.

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Material Analyses Are a Central Priority

A Team with Deep Insights

The team of Timo Bernthaler can build their work on a unique combination of measurement instru-ments, experimental methods and speicalist competence in their field.

Without data correlation, automation and neural networks, it would be impossible to develop the technologies of the future. Researchers in Aalen have mastered these approaches

by Michael Vogel

In the future, many people will be driving electric cars that run on power from a battery. Ideally, the body would be made from lightweight components while remaining sturdy and safe. From the perspective of a material researcher, that can only be done if the properties of the materials, such as the characteristics of the battery electrodes, are known and can be influenced at a microscopic scale.

"In order to approach this scientifically, we have to be analytically involved in material development early on," says Dr. Timo Bernthaler from the Materials Research Institute (IMFAA) at Aalen University. That is because you need to know which microstructural properties in the component determine its function in order to understand why it is generally behaving as intended – or why not.

The IMFAA has many modern devices – light microscopes, X-ray microscopes and electron microscopes as well as computer tomographs. Researchers use them to determine the structure of materials: What is the material made of? How granular is it? Are there any defects or undesirable manufacturing influences? It is interesting to look at how the processes interact, since each one contributes to the overall image. The computer tomograph shines non-destructive X-ray light through the material and creates a three-dimensional representation. Microscopes use light or electrons to provide information down to the atomic dimension. 3D printing with hard metals demonstrates the growing importance of analytics for material research. A hard metal uses a metal matrix as a carrier structure. Hard metals are embedded in the structure as small particles. Compared to conventional steel, the metal is harder and more rigid. When it comes to manufacturing a workpiece, that means a drill or cutting tool made from hard metal can work at a higher speed. And in manufacturing, as we know, time is money.

Fewer Defects in Hard Metals

High-quality components made from conventional metal or alloy powders can be manufactured using the 3D printing process. However, that does not work for hard metals yet – the powder particles are sensitive to the high heat from the laser used for printing. In response, IMFAA scientist Tim Schubert has developed a new process for preparing the powder. "We extract the particles from a suspension," he reveals. That makes it easier to control the quality and composition. As a result, there are fewer errors in the printing process.

This development involved repeated sample manufacturing and analytics. "We studied the samples mechanically and using microscopes, and then varied the material process based on the results," reports Schubert. Aalen's researchers are now on a promising path. High-quality 3D printed products made from hard metals are on the horizon.

Still, that does not mean the end of the material analysis, explains Timo Bernthaler. "There is rapid development going on, and we are playing a significant part in it." The development involves three areas where Aalen's scientists are performing research: correlative, automated and sensory microscopy. The process can be illustrated using the example of electrodes in batteries for electric cars. Seen through a microscope, these electrodes do not have a homogenous structure. They contain a variety of particles, including foreign particles. "We can see them tomographically – but we only see roughly how big they are," says Bernthaler.

A light microscope would allow scientists to look at the electrode structure more precisely. But in order to get at a foreign particle, the electrode would need to be ground and polished for the microscope without removing it from its current location. "Finding the exact spot is time-consuming, and usually cannot be automated," says Bernthaler. An electron microscope is more targeted. The data from the tomograph serves as a "map" to find the position of the particle. The researchers use an ion ray to dig down to it, then use the electron microscope and associated analytics to study its chemical properties. Finally, correlation delivers the desired information.

Electrodes can also be used to illustrate the process of automated microscopy. "We are now able to map stacked electrodes, such as the ones used in electric-car batteries, with a light microscope in order to identify irregularities," says Bernthaler. The electrodes could be as big as 50 square centimeters – "an enormous area under the microscope." Because the microscope only shows a tiny section at a time, it would be too much work for one person to check each section. "It can quickly add up to 100.000 individual images." The solution lies in machine learning. With algorithms they have developed themselves, the team can identify deviations in the electrodes and evaluate them – the analysis then takes place automatically.

"If you use extensive image data to train an artificial neural network with the help of a computer, you arrive at sensory microscopy," says Bernthaler. "Then we can link structural data from the images, based on artificial intelligence and models, with real-life characteristics."

Knowledge on materials microstructure leads to advances in 3D printing of metals.

In the long term, the researcher hopes this will allow aging and storage capacity to be predicted as well. "This concentrated competence in all three areas is hard to find in Germany," says Bernthaler, "Especially in connection with the material and process technology expertise that we also have in Aalen." That makes it easier for new technologies to find their way into industrial applications, and makes the IMFAA an attractive research partner well beyond the region of East Wurttemberg.

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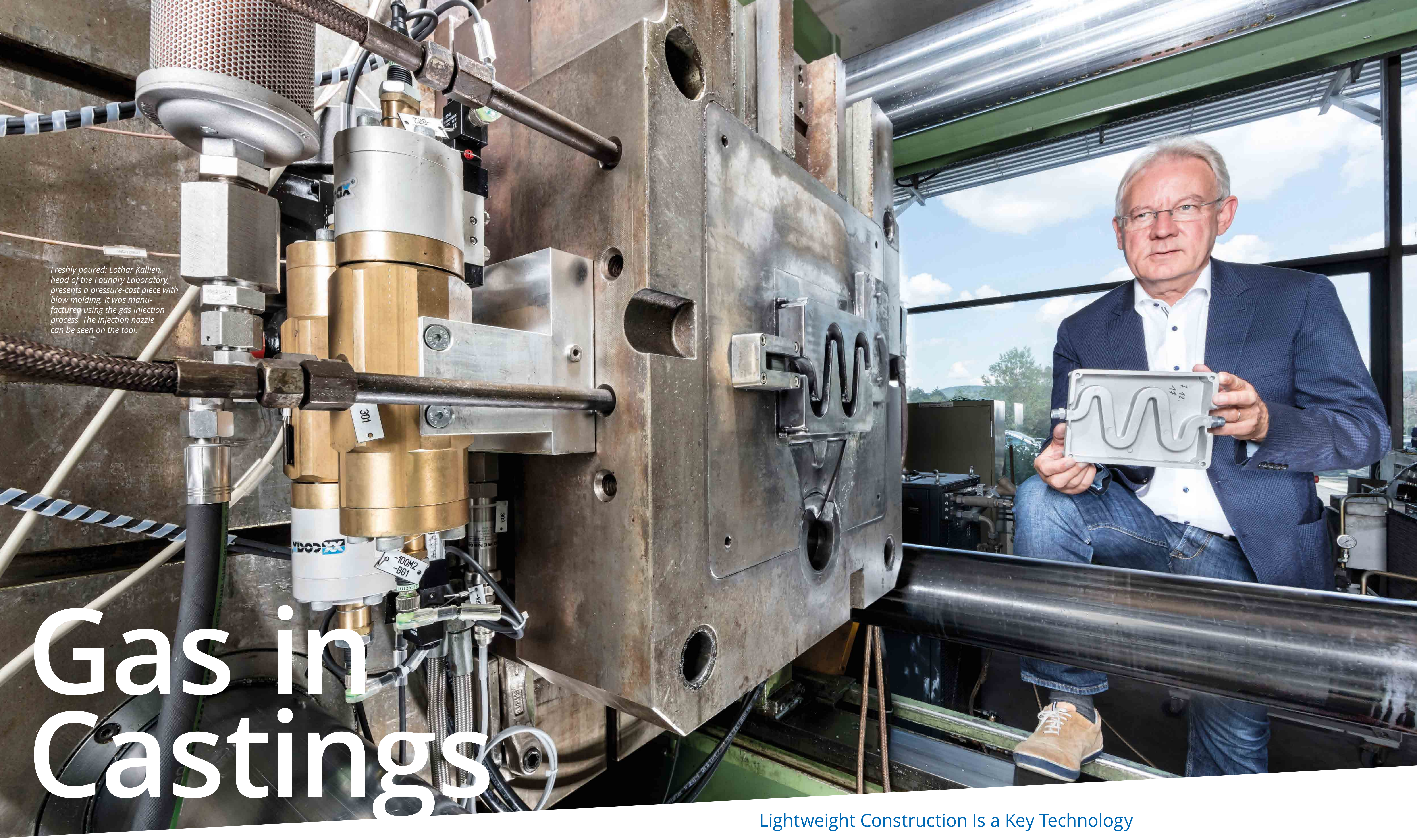


Freshly poured: Lothar Kallien, head of the Foundry Laboratory, presents a pressure-cast piece with blow molding. It was manufactured using the gas injection process. The injection nozzle can be seen on the tool.

Gas in Castings

Lightweight Construction Is a Key Technology

Researchers in Aalen are taking a variety of approaches to make components for cars, airplanes and machines more lightweight and thus more climate-friendly. A tour through the labs

by Bernd Eberhart

Lower weight with the same or better performance: Lightweight construction is one of those principles whose simple genius touches many industrial sectors. The incentives for lightweight construction-solutions are, and have always been, the same: saving material and therefore money, and achieving better energy efficiency. Now there is another red-hot issue joining the mix: reducing emissions such as carbon dioxide that are damaging to the climate and harmful to health.

Researchers at Aalen University recognized the potential of lightweight engineering early on and it is a significant focus of their work. They see the university as a central research platform and an important technology developer in this field – working hand in hand with highly specialized small and medium-sized enterprises in the East Württemberg region.

Rethinking Products

It would be selling lightweight construction short to say that it is just about replacing materials. Rather, it involves a complete rethinking and reconstructing of products and individual components to make them more efficient. This only works if researchers from different fields collaborate closely and network their ideas to create a unifying philosophy based on various lightweight construction techniques.

As a strong research institution, Aalen University combines its expertise and many years of experience with short paths. The first path leads to Prof. Lothar Kallien in the Foundry Laboratory, one of the university's largest labs – and one of the largest academic foundries in all of southern Germany.

Subtle Ridges in the Aluminum

The lab uses a broad range of casting techniques. "But the main emphasis of our research activity is pressure-casting using lightweight materials such as aluminum and magnesium," says Kallien, who leads the casting technology department in Aalen. As an illustration, he fishes a component off the shelf. The aluminum part has subtle structures and ridges running across its surface, and the walls are of different thicknesses. And the workpiece feels light – surprisingly light. "This kind of suspension strut used to be made out of ten sheet-steel pieces," explains Kallien. "Now it is simply pressure-cast from aluminum. That lightens each car by more than ten kilograms."

The researcher pauses again in front of the first of four pressure-casting machines in his lab, which is equipped with two robot arms. Here the melted aluminum mass, heated to about 680 degrees Celsius, is shot into a steel mold at speeds of up to 200 kilometers an hour. It takes just 50 milliseconds to fill the mold. After seeing this, it is clear that the process is much more than traditional casting – pressure-casting belongs to the realm of modern manufacturing technology.

"The local casting industry has to be sure to stay on the ball when it comes to technology," warns Lothar Kallien. "There might be fewer cast iron parts in an electric vehicle, for example. But even in the future, you won't be able to make a car without casting some parts. Pressure-casting in particular is future-proof." What is needed are innovative processes for casting thin-walled, stable, lightweight cast metal parts – such as the gas-injection and salt-core processes, both of which were significantly advanced by research in Aalen.

"Germany is by far the world leader for casting technology," says Kallien. Through his work, he is doing everything in his power to make sure it stays that way – among other things with the EU-funded "MUSIC" project, an international cooperation that has developed quality standards for pressure-casting and plastic injection molding.

Lothar Kallien takes a curved rod, measuring about two centimeters thick, out of a glass cabinet. It lies heavy in the hand, and the surface feels floury and dry – a salt core. The principle according to which it is used is similar to the grains of sand used in iron casting: After casting, the salt is rinsed out of the metal component. What remains is a precisely measured hollow space. The salt version of these casting cores can withstand even the enormous pressure needed for casting aluminum or magnesium. In Aalen, researchers are mainly working to find the ideal composition of the molten salt that is used to form the cores.

The gas-injection process is still in the experimental stages, but will soon move into series production. It is familiar from plastic processing: Hot plastic is filled into a mold, and later on certain areas are opened up again by blowing in up to 400 bar of nitrogen. This creates hollows and channels in the component. "It takes a couple of seconds because plastics cool slowly," explains Lothar Kallien. "But in pressure-casting, the gas injection needs to take place within milliseconds." Many foundry workers doubted that it was possible, but Kallien tried it. Now he is holding one of the first products in his hand: a water-cooled electronic control housing made from aluminum, cast in a single piece. Across the back of the housing is a channel that was opened up using gas injection.

Spin-off Company Offers Service

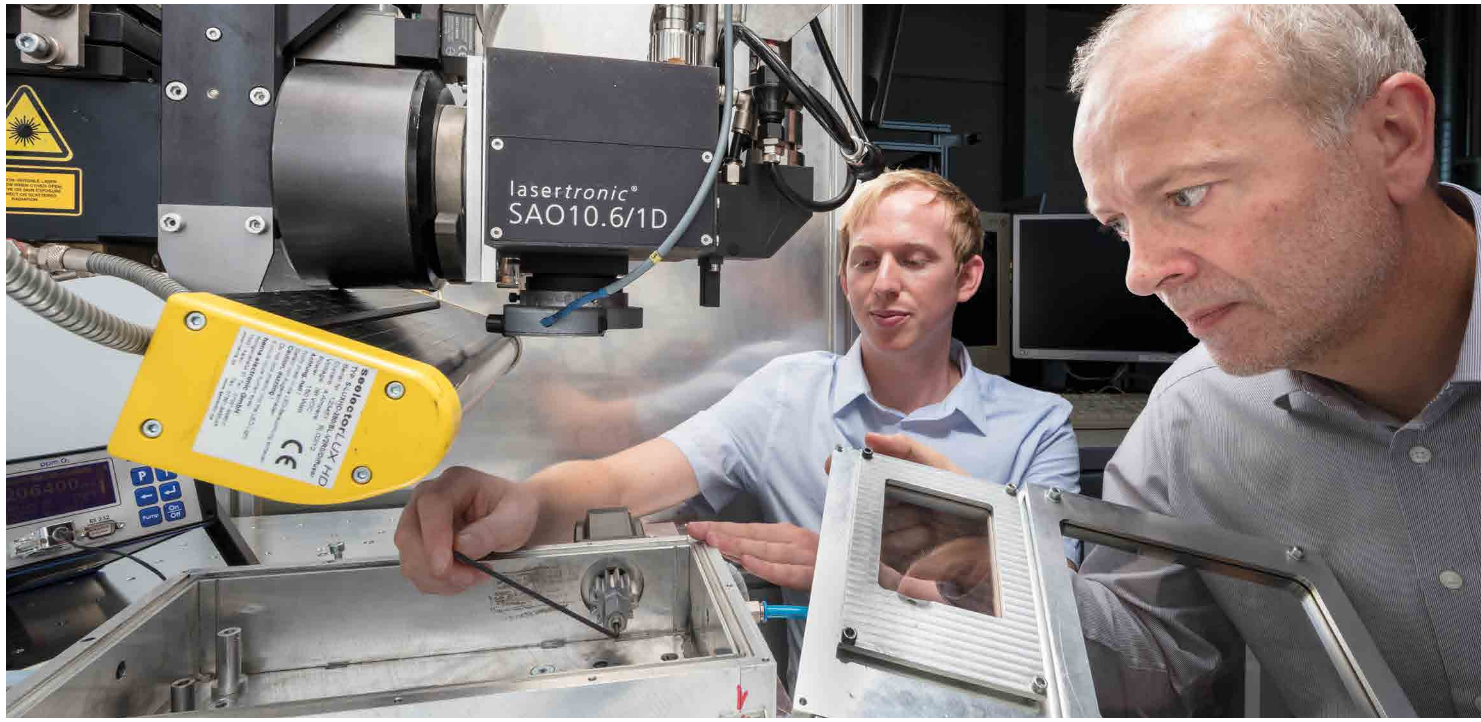
Aalen's casting experts are researching technologies, materials and processes with a clear focus on their practical applications. Gießerei Technologie Aalen (GTA) GmbH, a spinoff that offers regional companies extensive development and service support for everything having to do with cast parts, is affiliated with the university. That means the research, and transferring the corresponding results to practice, are directly connected to one another in Aalen.

By the lab's exit, Lothar Kallien has one more unique thing to show us. His latest project has to do with joining, or permanently connecting different materials. He proudly points to a narrow sheet of carbon fiber-reinforced plastic (CFRP), which is firmly attached to an aluminum part at the top. The CFRP is neither glued nor welded on. Instead, it is surrounded by pressure-cast aluminum using a newly developed recasting process.

The metal is cast very thinly so that it can cool quickly enough to avoid damaging the synthetic resin matrix of the CFRP. An iron weight dangles from the sheet, and reads "2.5 tons." "We actually hung an entire car from it in a virtual test," reports Kallien, "and it held." The researcher is convinced that pressure-recasting is the next big innovation for foundry technology.

Casting technology is one thing, and the ideal design of the parts is another. That is where Dr. Wolfgang Rimkus comes in. He is the Director of the Technology Center Lightweight Construction – a joint institution that includes Aalen University, the city of Schwäbisch Gmünd, the local design college Hochschule für Gestaltung, and the Research Institute for Precious Metals and Metal Chemistry (FEM).

Among other things, Rimkus works on designing lightweight molds: "How do I find the ideal design for a mold and thus for a component?" That is how the researcher describes the important question in this field. His contribution to lightweight construction is entirely digital, using special software tools and powerful computer processing. A central issue for Rimkus is what is known as topology optimization.



Lasers instead of rags: Harald Riegel (right), head of the Laser Application Center, and doctoral student Simon Ruck clean the surfaces of printed components in the lab using light from a laser.

The starting question: How can a part be optimized for its specific loads so that it weighs as little as possible but retains at least the same rigidity?

Cutting Material Consumption in Half

With precisely defined specifications, calculations can reduce the material so that only structures that contribute to the part's rigidity and functionality remain. This can save anywhere from a third to a half of the material. On his monitor, Wolfgang Rimkus points to a three-dimensional model of the side impact protection in a car door. He clicks through various versions of the component, which undergoes a process similar to evolution as it moves through the stages calculated by the computer. There is

Drilling Down

The universities of Aalen, Mannheim and Ulm are participating in the joint SPANTEC light project **in order to look at an innovative research topic** from as many different angles as possible. The goal is to better understand the machining of lightweight construction materials such as carbon fiber reinforced plastic (CFRP). Dr. Dieter Meinhard, a research associate at the Institute for Material Research (IMFAA) and project manager for the research project, holds a CFRP sheet in his hand. A good 200 holes have been drilled into it as part of a test series. It is striking how the drilled holes begin to become fibrous and frayed – over time, the drill starts to wear out. "Now we have to ask ourselves how disruptive these delaminations are. Do they make a CFRP component less stable? Or are they negligible?" Some other questions: "Does a clean drilled hole last longer than a frayed one? What is the ideal drill? And how long can I use it until it needs to be replaced?"

In a basement facility at Aalen University, Andreas Häger, a doctoral student at the university, studies the samples very rigorously, performing endurance tests until they fail. Professors Schneider, Schuhmacher and Knoblauch can then track down the cause of the damage using various detection methods – microscope, ultrasound, and computer tomography. "A commercial aircraft has several hundred thousand drilled rivet holes," explains Dieter Meinhard. Many of them are in CFRP parts, which make up a large portion of the outer wall in a modern airplane.

"Our research activities aim to evaluate the quality of the drilled holes and the effects of any damage," says Meinhard. The findings are then used to help develop more efficient drills for participating companies.

Dieter Meinhard inspects holes drilled in CFRP using drill bits with varying degrees of sharpness.

still a resemblance to the original version, but the part begins to seem sleeker, more dynamic, almost bionic – inspired by structures found in nature.

"Topology optimization can be compared to natural growth processes," explains Rimkus. "Take a tree that is always exposed to wind blowing from the same direction. It will reinforce its trunk on just one side to fight the wind." Later on, the simulations go hand in hand with prototype testing – the results of which in turn will influence the simulation. "Topologically optimized structures lend themselves very well to casting, since the engineer has a lot of freedom in designing the geometry for manufacturing cast parts," says Lothar Kallien.

Simulations Get Up to Speed

The Technology Center Lightweight Construction led by Wolfgang Rimkus is housed in the Forum Gold und Silber, located about 30 kilometers from Aalen in Schwäbisch Gmünd. There are many companies here that can benefit from the center's research activities and services involving topology optimization. "Our simulations accelerate and improve the development process enormously, so we can help people save time and money," says Rimkus. He is especially thinking of medium-sized enterprises, which often lack expertise in this area.

Prof. Volker Knoblauch and Dr. Dieter Meinhard greet us with knowing smiles in the labs at the Institute of Material Research (IMFAA). "Professor Kallien probably raved about pressure-recasting," speculate the two material researchers, who mainly work on adhesive joining processes – the gluing of different components. They are taking part in SmartPro's "InDiMat" lightweight construction project, and they are unified by their love of healthy competition. They are studying various joining techniques. Each one has its strengths and weaknesses, along with very specific application areas. Compared to the foundry lab, the material scientists' lab feels like a completely different world. It has a controlled, almost sterile atmosphere. Various analysis devices and light microscopes are lined up in a row, and a computer tomograph and two electron microscopes are kept in separate rooms from one another.

"Modern lightweight construction means hybrid lightweight construction – a broad mix of materials," says Volker Knoblauch. "That's why there is a huge need to study joining technologies." Every aluminum part, magnesium piece and CFRP laminate touches another material at some point – and needs to be firmly attached to it. Vehicle manufacturing in particular often uses adhesives, because that is often the easiest and sturdiest solution. And it stands up to a cost comparison, too.

Hundreds of Meters of Adhesive Joints

"Modern cars have several hundred meters of adhesive joints running through them," reports Knoblauch. But which adhesive is best for gluing which combinations of materials? What is the ideal way to apply the glue, and how long should it be clamped and cured? How do temperature fluctuations affect the bond? And how does an adhesive joint behave during an accident? Those are the kinds of questions that Volker Knoblauch and his team ask themselves – so they can find answers using adhesive tests, stress tests and high-tech analysis devices.

The right surface treatment for the materials to be adhered also makes a huge difference. For CFRP components in particular, it is important for the adhesive to stick not just to the plastic matrix in which the carbon fibers are embedded – it also needs to adhere to the fibers themselves, which give the material its extreme stability. Every hobbyist is familiar with this principle. Before two wood pieces are glued together, they need to be roughened with sandpaper. That increases the surface area and creates a better purchase.

CFRP can also be roughened, but laser pretreatment creates better results. That is the specialty of Prof. Harald Riegel, a professor of Laser Technology at Aalen University. Among other things, his team focuses on ways to functionalize and clean surfaces. "We make sure adhesions are as strong as possible," explains Riegel, "sometimes even between surfaces that couldn't normally be glued together."

The lab's industrial lasers come in many different sizes – some as compact as a microwave, others as big as a garage. Doctoral student Simon Ruck shows off two processed pieces. One is a steel plate a centimeter thick, roughened in the middle like a Velcro fastener. A plastic block has been melted onto the rough area, very solidly – a rough example of laser surface pretreatment. Next to it, the doctoral student holds out a cast aluminum gearwheel. It is dark gray, but the center shines bright silver – the result of thorough surface cleaning using a laser. This kind of pretreatment, for example on adhered surfaces, is effective and functional, and it reduces the need for chemical cleaning agents. That also makes the method environmentally friendly.

Symbolic: Wolfgang Rimkus, head of the Technology Center Lightweight Construction, carries out research at facilities in the Forum Gold und Silber in Schwäbisch Gmünd (in the background). Lightweight construction is entering a golden age, too.

"We don't care what we laser," says Harald Riegel. „We can do anything: aluminum, steel, CFRP – in any pattern and with every possible depth and degree of roughness." Researchers look for the perfect surface depending on the application, component, and material mix. "Ultimately, we get into all kinds of places where no one will ever see us," jokes Riegel. His team is an important link – between metal and CFRP, cast pieces and plastic, and between Lothar Kallien, Wolfgang Rimkus and Volker Knoblauch. The invisible details show how complex lightweight construction is – and how much high-level expertise and research are needed to stay at the forefront of this future-oriented area.

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Young Researcher Martina Winkler

From Accident to Vocation

Martina Winkler brings new casting techniques from the research lab to the industry

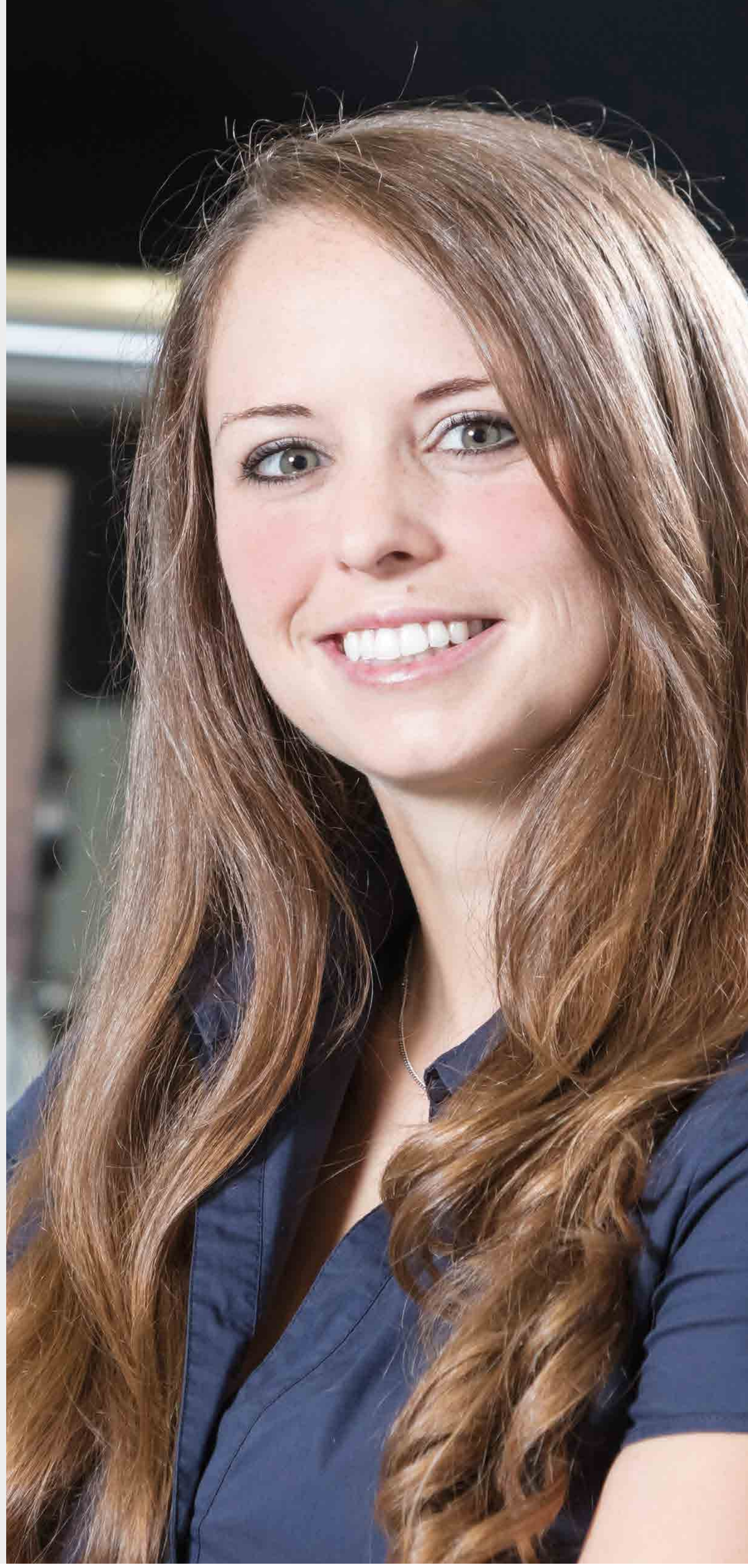
"In the foundry industry, I discovered exactly where I belong," says Martina Winkler. Since the spring of 2017, she has had a job with Frech in Schorndorf – a company that specializes in pressure-casting. Even after a few years in the field of casting, the young woman is still fascinated by the various processes. "Even the liquid metal is incredible. And I think it's amazing that pressure-casting can create a finished component in just a few seconds."

And yet Martina Winkler found her way to the industry more or less by accident. She was enrolled in a Bachelor's program in Mechanical Engineering/Manufacturing Technology at Aalen University. During a company field trip to Schwäbische Hüttenwerken SHW AG, a leading automotive supplier in nearby Wasseralfingen, she saw a giant engine block being cast.

Impressed, she chose Prof. Lothar Kallien's Foundry Laboratory for her sixth-semester thesis project – and then simply stayed on: for her Bachelor's thesis, in a position as a research assistant during her Master's program in Industrial Management, and then for her doctoral thesis, which was jointly supervised by researchers at Aalen University and the Clausthal University of Technology in Lower Saxony.

Her research focused on self-optimizing systems for pressure-casting. And now she can apply her acquired expertise directly to her career – at Frech, she is continuing to work on future-oriented interfaces between pressure-casting and Industry 4.0 – the production of the future.

Martina Winkler never had a problem with the heavily male-dominated foundry industry. "Sure, I was almost always the only woman around," she reports, "but I can deal with that. When you work just as hard and don't make any distinctions yourself, you are simply accepted as a colleague." She definitely wasn't handled with kid's gloves, laughs Winkler. But the Foundry Laboratory is no place for kid's gloves, anyway. BE



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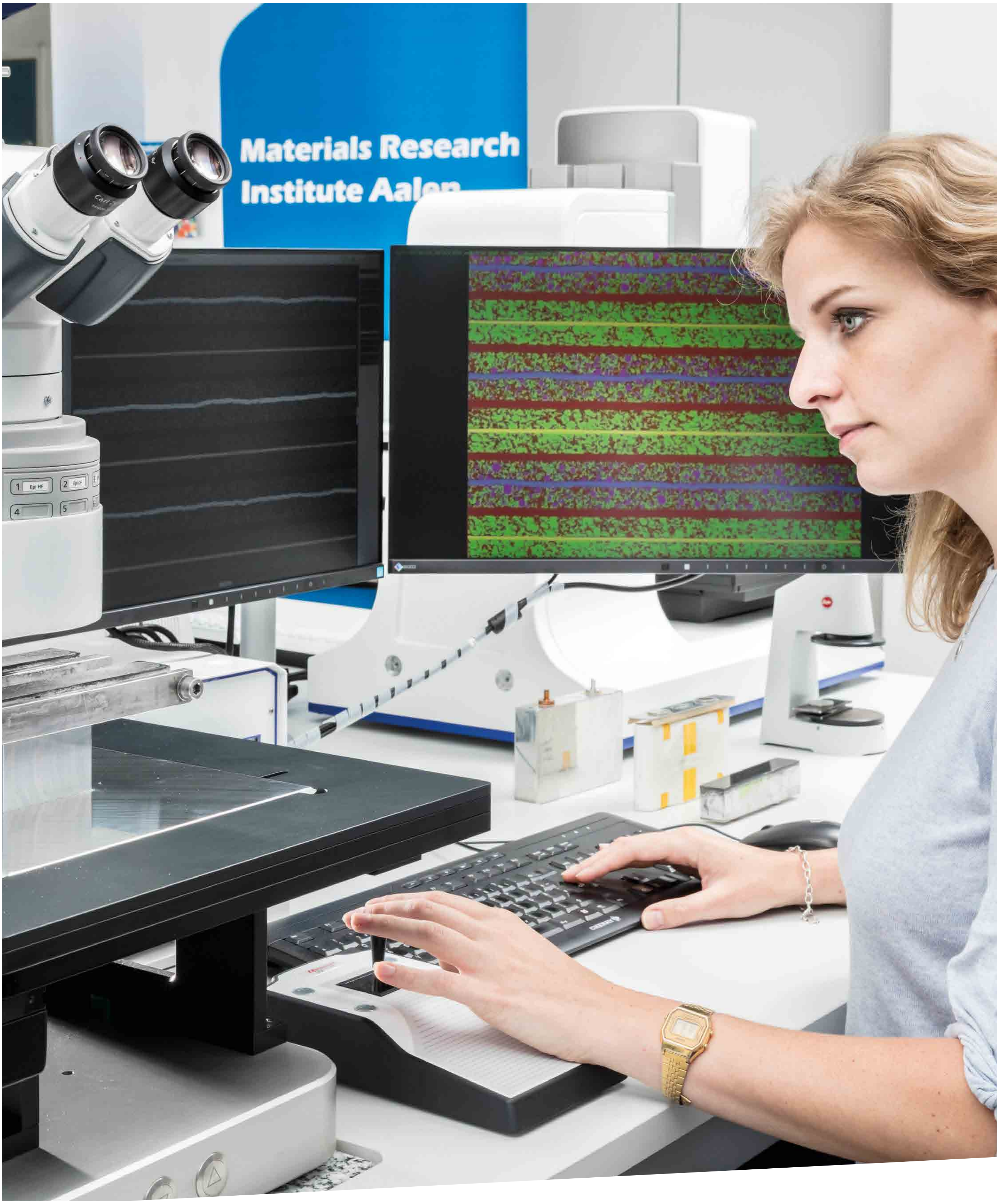

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