in2science

The Magazine About People with Ideas

#8

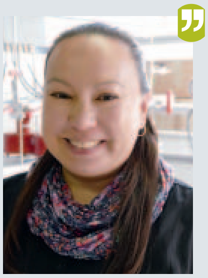
The Artificial Leaf • Network for Future Questions
The Benefits of AI in Materials Research
Reducing Space Junk • 10 Years GERICS

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Science in Transition

We live in the Digital Age. Our communication is changing rapidly, working procedures at companies are restructured, everything is going digital and is constantly interconnecting. This evolution effects all aspects of life – something that applies to research and development as well. This is why we asked scientists at the HZG:

What does digitalization mean for your research?



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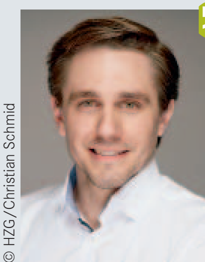
Dr Anna-Lisa Chaudhary

scientist in the Department of Nanotechnology, Institute of Materials Research

Digitalization has added extra dimensions to my research from both experimental and personal points of view. Together with my colleagues, we have built a fully automated high pressure hydrogen Sieverts apparatus (up to 2000 bar); full automation is something quite unique for these high pressure solid state hydrogen measurements. Simulation and modelling also compliments experimental work to better understand reaction kinetic and thermodynamic material behaviour. Delving deeper into this area has resulted in excellent current and future collaborations between myself and my simulation colleagues both at HZG and overseas.



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Frederic Bock

PhD student in the Department of Laser Processing and Structural Assessment, Institute of Materials Research

Via machine learning algorithms, I am processing empirical and synthetic data to gain new knowledge and discover previously hidden relationships for the development of innovative process technologies such as additive manufacturing. In this regard, I heavily depend on the availability and processability of digital data; thus, the digitalization is of crucial importance for my research. In the future, sharing digital infrastructures for computing, processing and storing comprehensive digital datasets of materials and their processes could empower all interested scientists to accelerate the generation of new knowledge and therefore promote scientific research and societal progress.

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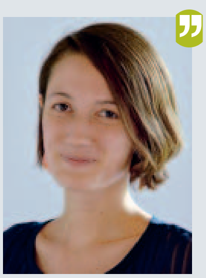
Dr Holger Brix

head of the Department for New Technologies, Institute of Coastal Research

In coastal research and for COSYNA (Coastal Observing System for Northern and Arctic Seas), digitization means that we increasingly rely on support through the analysis of existing data and models when planning and executing research projects. This is also done utilising concepts from the field of artificial intelligence. New possibilities in presenting data are researched in order to facilitate planning and decision making in the field. In addition, increased linking of measurement systems comes into play - known as “smart monitoring”, in which measurement devices communicate with each other and, in the long-term, independently make decisions on where and how to measure.



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Dr Marlene Klockmann

scientist in the Department for Coastal Impacts and Paleoclimate, Institute of Coastal Research

The exchange of knowledge between different disciplines has been greatly eased through digitalization. My work in the interdisciplinary project “Reduced Complexity Models” has profited immensely from it. There is, for example, so much freely available software that makes it easier to try new analysis methods. I test methods from the field of machine learning and artificial intelligence for climate reconstructions of the last two thousand years. The initial results are very promising. I also find it vital that it becomes increasingly easier to transparently document research results and to also reach new audiences through new methods of communication.

Dear Readers,

Approximately twenty thousand school students came out for the “Fridays for Future” demonstration at the end of May in Hamburg. They and many other thousands of students across Germany are to thank for making “climate change” a topic of discussion across large parts of the population again. Environmental and climate protection, as it seems, could once again gain higher status in policy making.

It has been the aim of the CliSAP Cluster of Excellence in Hamburg to inform and advise the political, commercial and societal sectors for the last twelve years: in collaboration, scientists from Hamburg and Geesthacht study climate change causes, links and adaptation measures. The CLICCS Cluster of Excellence (Climate, Climatic Change, and Society) has been confirmed as successor in September 2018. Several HZG scientists work on different projects within the cluster. We spoke with two lead scientists as well as the cluster spokesperson.

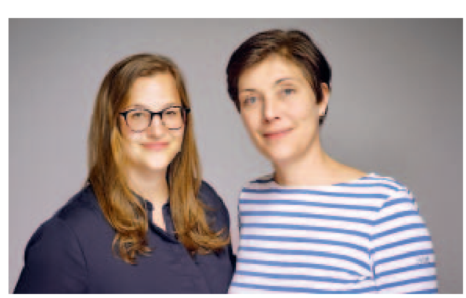
One possibility for reducing climate change is by using regenerative energies. Scientists in Geesthacht are therefore extensively researching hydrogen production using solar energy. The researchers at the HZG’s Hydrogen Technology Centre wish to harness the tricky technology by utilising new methods.

Science year 2019 kicked off in March. The topic this year: artificial intelligence. More and more scientists are utilising AI for data review, evaluation and for research. HZG materials researchers explain to us how they approach this field.

This time around, in the Portrait sections, readers will discover more about our scientific director and about a professor working in experimental materials mechanics.

As always, we would like to introduce our readers to as many topics from our centre as possible in this issue. We’ve also therefore prepared several short newsworthy items for you. Unfortunately, there isn’t enough room for everything. We have, however, compiled additional material for you on our webpages. Go have a look. It’s worth a visit.

We hope you
enjoy reading!
Your Editorial Staff



We are pleased to present the eighth issue of in2science

A call for submissions:
Employed at the HZG and have an exciting story or outstanding collaboration you'd like to share? Then please get in touch with our editors. We look forward to your ideas, praise and criticism. Simply write to us at in2science@hzg.de

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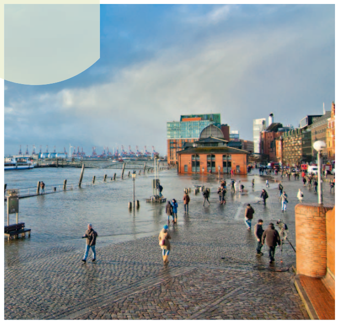

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The Artificial Leaf

When it comes to renewable energies, hydrogen as an energy carrier can't be ignored. HZG scientists are working on a climate-neutral method of producing hydrogen in which sunlight is directly utilised to split water: this is known as photoelectrochemical water splitting. The method breaks water down into its hydrogen and oxygen components. Similar to photosynthesis, solar energy is converted into chemical energy. Instead of a plant's leaf, however, the scientists use, for example, photoactive material layers. The best materials are still very expensive and complicated to produce. For this reason, employees in the Department for Sustainable Energy Technology at the Institute of Materials Research are developing surfaces that can be produced cost-efficiently.

Doctoral candidates Herman Kriegel, Ragle Raudsepp and Jiri Kollmann take us into their laboratories and show us how the photoelectrodes are produced and studied. The infographic in the middle of this issue shows readers how the principle of energy conversion works.

Tip:
You can explore this research in 360°: Ragle Raudsepp leads you through a 360-degree tour of the Hydrogen Technology Center laboratories.

www.hzg.de/artificial-leaf


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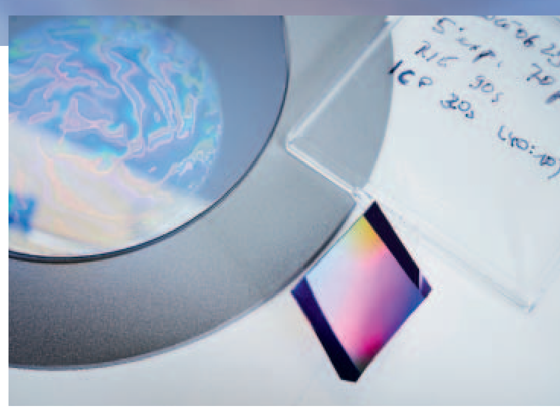


The Principle

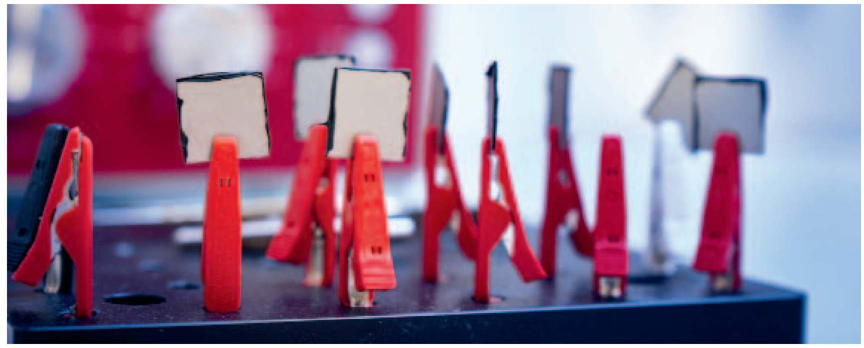
Semiconducting materials such as iron oxide or bismuth vanadate absorb light and thereby gain electron-hole pairs. In contrast to solar cells, they are submerged in electrolytes - in a salt solution, an acid or an alkaline solution. Using specialised methods, the scientists apply thin coatings measuring only a few micrometres. These coatings fulfil several functions in the process of water splitting - including light absorption, charge transport and catalysis.

Atomic Coating

The substrate (in this image a round silicon wafer) is carefully cleaned and structured to produce a rougher and larger surface. Individual layers are then applied to this surface with the help of several coating methods, such as atomic layer deposition (ALD). The image on the right shows the deposition of titanium oxide as the uppermost layer using ALD. In order to facilitate further study, several smaller samples are cut from the electrode (shimmering pink).

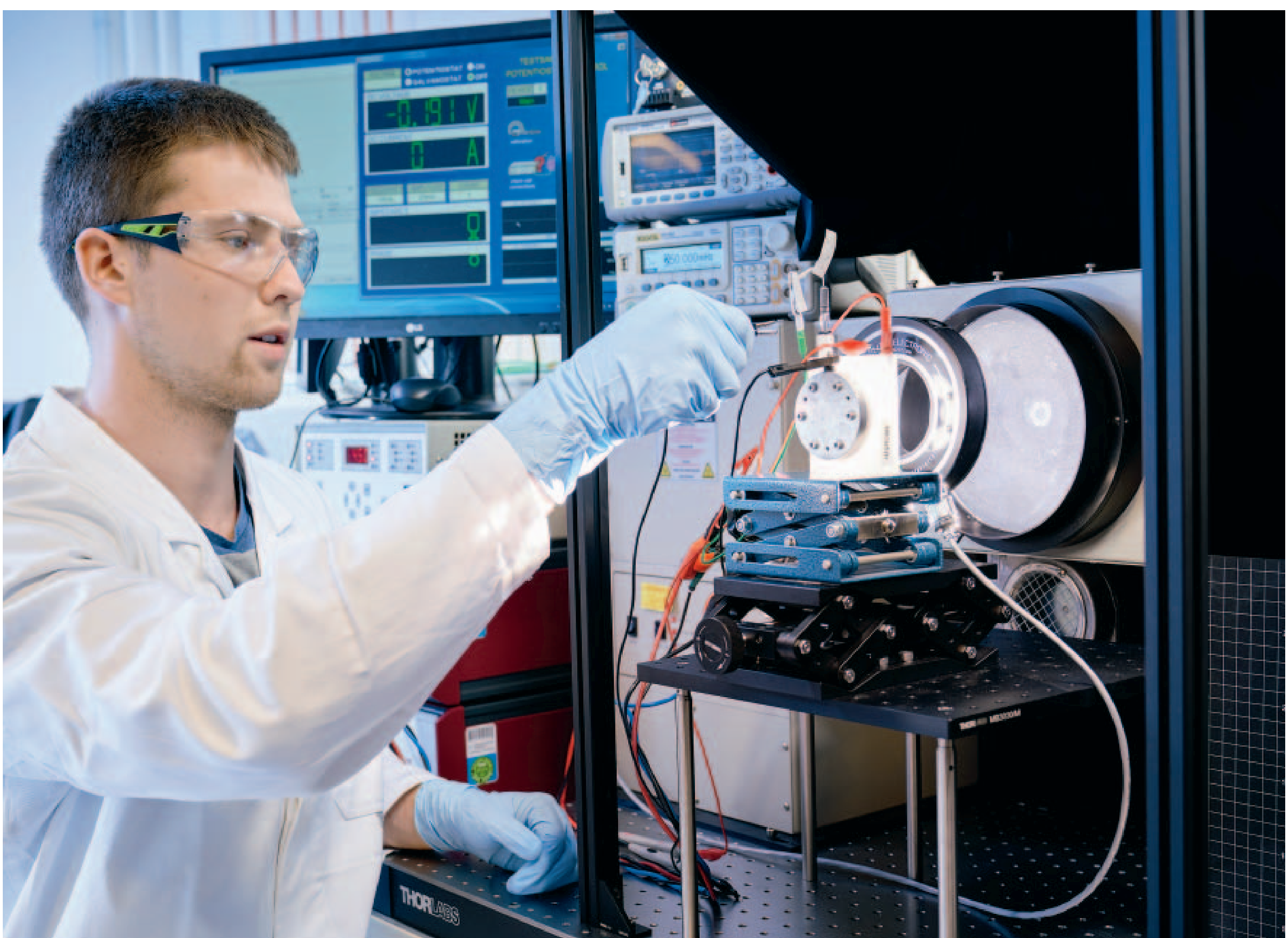
Directed Light

The next station is UV-Vis-NIR spectroscopy. This is where the optical properties of the photoelectrode are determined. Light is directed at the sample in a broad range of the electromagnetic spectrum, from ultraviolet and visible light to infrared; the reflection and transmission of the sample are measured. As a result, scientists know what fraction of the light spectrum can be absorbed by the photoelectrode.



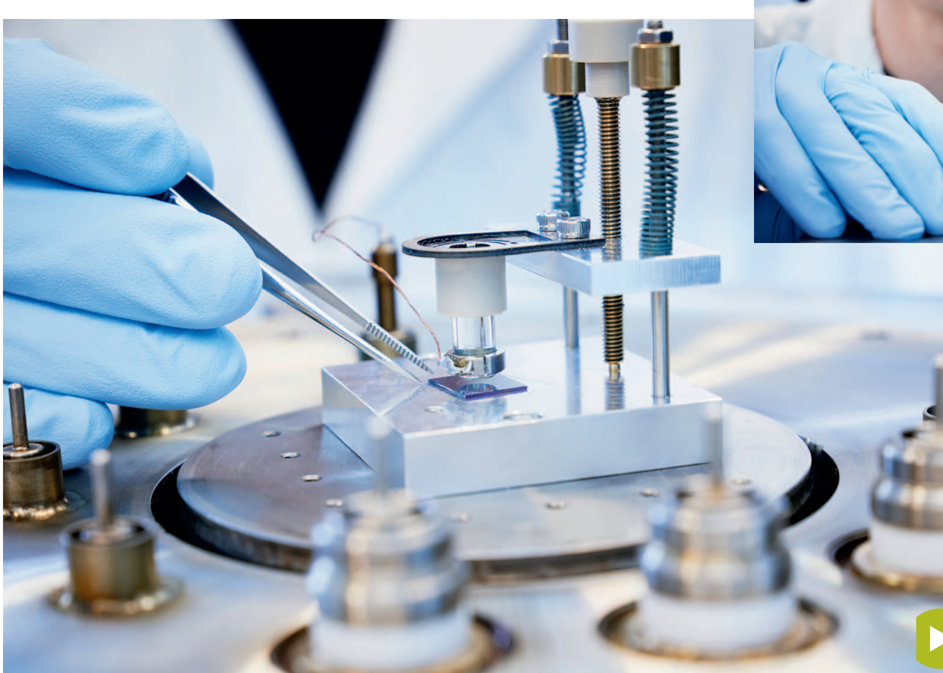
The Solar Simulator

The sample is now installed in a photoelectrochemical cell. After the electrolyte solution is poured, the cell can be clamped in front of the "solar simulator". Between the light source and the cell there is a shutter. When it is closed, the activity is zero; when it is open, electrons and electron holes are produced in the cell. They will split water into hydrogen and oxygen. We were allowed to lift the black curtains to take our pictures, but the curtains are normally down in order to block out light from any sources outside the experimental setup.



Moving Electrons

By measuring the surface photovoltage, the scientists can better understand the electron movement across the interfaces in the electrode structure. For this purpose, the sample is clamped in an SPV spectrometer.



In this publication, you can learn more about applying the SPV method to investigating photoelectrodes for water splitting.

"Characterization of BiVO4 powders and cold gas sprayed layers by surface photovoltage techniques"

The Publication:
doi.org/10.1016/j.cattod.2018.02.027

Nanometre Precision

The last station is the atomic force microscope. The probe is positioned precisely under the microscope. A tiny nanometre-sized tip moves over a grid pattern and scans the entire sample. What is special here is that the topography - for example, the roughness - and the electrical and electrochemical properties, such as photocurrent and photovoltage, are measured simultaneously. This is how the scientists can later determine precisely down to a few nanometres where the sample is more active.

Pictures © HZG/Christian Schmid

Toward a Hydrogen Future

For the scientists in the “Sustainable Energy Technology Department”, there’s still quite a lot to do. One thing is for certain though: research into the “artificial leaf” provides many new possibilities and perspectives.

You can find more photo features in our media library:

www.hzg.de/media_library

On the Trail of Pollutants

Emerging organic pollutants have been detected all the way into the Arctic

In *in2science #7*, we reported on the nearly four-week Arctic expedition undertaken by coastal researchers Hanna Joerss and Dr Zhiyong Xie on the research ship POLARSTERN. Almost a year later the evaluation is now partially complete.

On her journey from Bremerhaven to the Arctic, Hanna Joerss collected ninety-nine water samples in total for her research work on per- and polyfluoroalkyl substances (PFASs). The samples were mainly from surface water, taken at a depth of eleven metres. The doctoral candidate additionally studied the vertical distribution of the substances at six stations and collected samples at various depths down to 3,107 metres.

The chemist had then spent three months in the laboratory preparing and measuring the samples. She spent another three months evaluating and interpreting the results. The pollutant concentration is very low – less than a billionth gram per litre. This is why it's a huge challenge to detect the substances and determine their quantities in samples.

The scientist analysed thirty-two PFASs. The substance concentration generally decreased with increasing distance from the continent, but twelve PFASs could be detected all the way into the Arctic. This indicates that long-range transport of the substances occurs – they are what are known as long-lived organic pollutants. Joerss mainly concentrated on alternative substances replacing those already prohibited. What was especially noticeable was the HFPO-DA substance, an alternative used in industry since the 2000s for the restricted PFOA. This substance already makes up a quarter of all PFASs in the area close to the North Sea coast she investigated – that is three times more than the predecessor. HFPO-DA is, for example, used in manufacturing fluoropolymers such as polytetrafluoroethylene (PTFE). PTFE is also known as Teflon, used not only in pans but also in products such as outdoor clothing.

Studies of the vertical distribution serve to determine whether the substances are transported into deep waters. This is important for evaluating the extent to which the ocean functions as a pollutant sink. There had been no PFAS data as yet from the Arctic region that Joerss studied. She could actually detect individual substances in the deep water layers – the concentrations in the deep sea were, however, considerably lower than in the surface water. "In contrast, other organic substances have already been shown to accumulate in deep waters – possibly due to the fact that substances adhere to particles and sink along with them. This does not seem to apply to the PFASs due to their differing molecular properties."

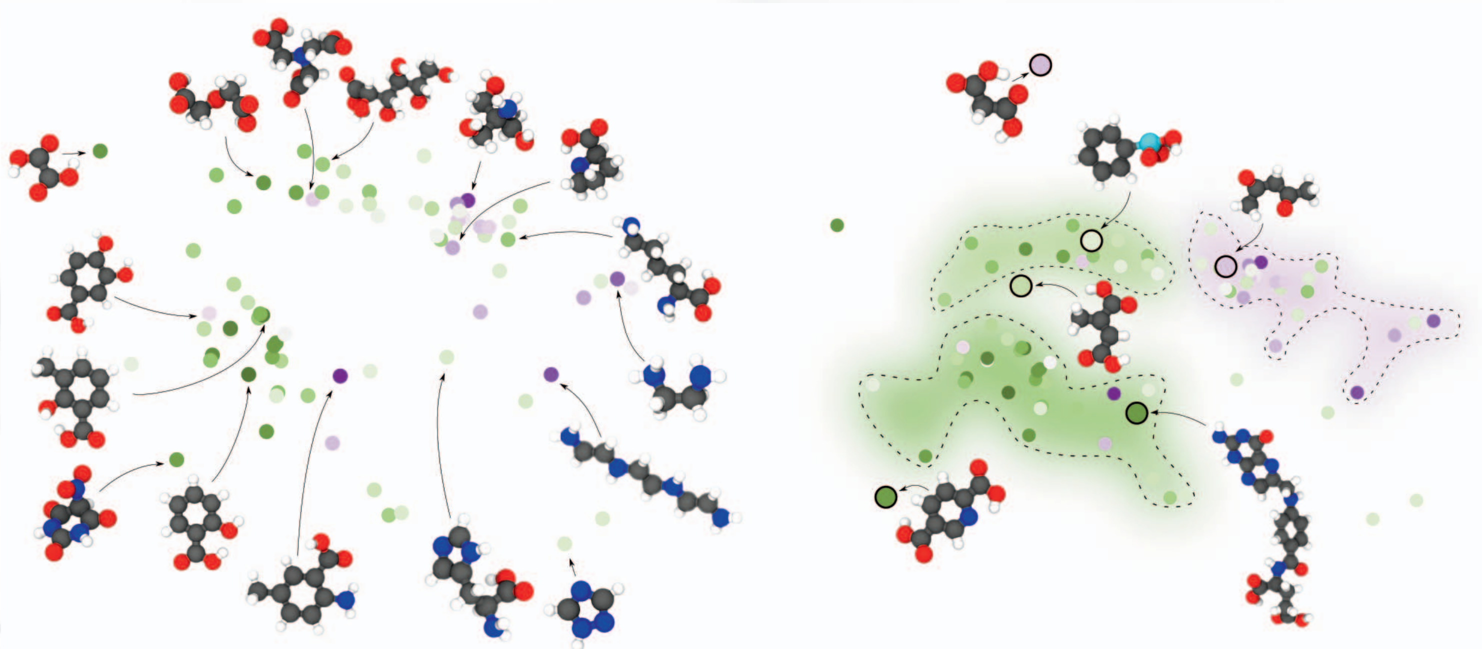
Hanna Joerss' findings can now be integrated into future assessments of long-lived organic pollutants.

The doctoral candidate's summary: "I find it alarming that the replacement substance HFPO-DA can be detected up into the Arctic. This indicates that it, like its predecessor substance, degrades slowly and is transported over long distances. Unfortunately, prohibited substances keep being replaced by those that are no less problematic. In order to find alternatives that are environmentally friendly while at the same time give products their desirable properties, scientists, legislators and industrial partners must work together."

Author: Gesa Seidel (HZG)

The Benefits of AI in Materials Research

Not only Google and Facebook use artificial intelligence methods. Neural networks and self-learning programs also increasingly come into play in materials research. At the Helmholtz-Zentrum Geesthacht, such methods assist in tailoring future hybrid materials and in developing new implants.

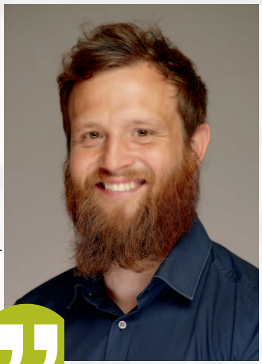


This simulation shows the scientists how well these molecules could serve as corrosion protection. © Robert Meißner

You could actually mistake it for an abstract piece of art – colourful surfaces and bright speckles that clump into small heaps in some areas. But take another look: "That is a type of map," says Prof Robert Meißner from the HZG's Institute of Materials Research. "Every speckle represents a different molecule and signals how well this molecule could assist in corrosion protection." The graphic is the result of an adaptive algorithm and represents a trend in materials science: artificial intelligence (AI) methods are increasingly finding applications here.

Computer simulations have already played a vital role in materials research for quite a long time now. If there is a desire, for example, to develop a new metal alloy, the computer can first simulate it. This is how experts can obtain initial clues about the alloy properties and can then tailor their experiments in a considerably more targeted manner. With artificial intelligence there is a new tool available to the professional community: on the one hand, it can help immensely in accelerating computer simulations and therefore make them more efficient. On the other, neural networks and deep learning programs can reveal connections that would otherwise remain hidden: how do the properties of a material depend on their microscopic structures – for example, on its crystal lattice?

Robert Meißner uses these new techniques to recreate materials virtually from scratch: he simulates on the computer how individual atoms, together with their electron sheaths, behave in a molecule – and by doing so, he deduces its properties. He, for instance, devotes his time to small organic molecules with an interesting property: they can inhibit corrosion in magnesium, a lightweight engineering material. "You could, for example, add them to a protective lacquer," explains Meißner. "If it gets scratched, these molecules could then be released and could render corrosive substances harmless."



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On the computer Robert Meißner simulates how individual atoms, together with their electron sheaths, behave in a molecule – and by doing so, he deduces its properties.

Artificial Intelligence for Corrosion Protection

There's a catch though: which molecules are particularly suitable here? In the laboratory, this question could only be cleared up through a great deal of effort and numerous series of measurements. This is why Meißner and his team developed a computer simulation based on artificial intelligence. On the one hand, the researchers fed into the software the molecular structures of approximately two hundred substances. On the other, they included data from experiments that describe the chemical behaviour of the respective molecules.

Based on this data, the adaptive algorithm created a molecular map with coloured areas and speckles. The map shows similar molecules in neighbouring regions. Some are anti-corrosive, while others accelerate corrosion. "In principle, the method works, but the errors are still pretty extensive," says Meißner. The method, however, is greatly promising for the future. This is because, in principle, the AI software can also sort molecules on the map for which there is no measurement data yet available. "This allows us to estimate which molecule is especially promising," says Meißner, hopefully. "This could be a vital clue for chemists to study this particular molecule more closely in the laboratory."

There is also another research field in regard to magnesium that benefits from artificial intelligence methods. The team led by Regine Willumeit-Römer develops implants made of this lightweight metal in the division for "Metallic Biomaterials". Screws, nails or plates made of magnesium could one day repair broken bones so that they fuse together again. Stainless steel or titanium implants have so far been used for this application. They, however, must be removed again after the bone heals, causing a strain on the patients. In contrast, implants made of magnesium would entirely dissolve in the body without the need for further surgery.

© HZG/Christian Schmid

This magnesium bone screw is biodegradable, rendering a second operation for removing the implant unnecessary. AI helps in understanding the different contexts.

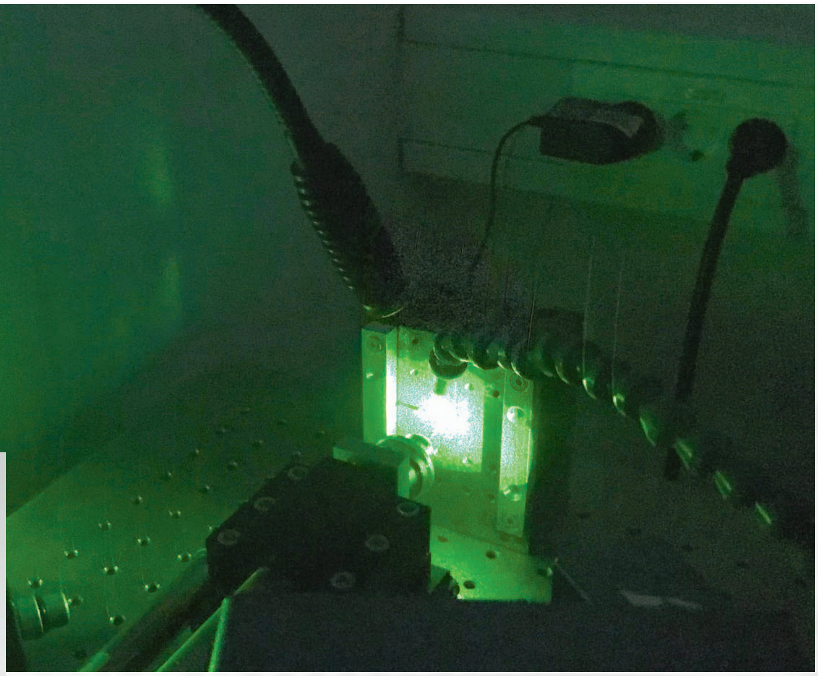
Support Using Self-Learning Software

The method is still in the research phase. The experts must, for example, determine how quickly and under what conditions magnesium dissolves in the body. The problem is that a living organism is a highly complex environment. It is teeming with so many different molecules, such as CO_2, oxygen, minerals and proteins – and they could all influence the magnesium's degradation. In order to determine what role each of the different molecules plays, researchers would need to set up numerous series of measurements – this is time consuming and very expensive in practice.

But then the team received support: Prof Norbert Huber, head of the Materials Mechanics Department, provided his assistance. Together with his team, he programmed a neural network and carefully trained it using selected measurement values. "Initially we determined that our software can quite accurately predict the rate at which the magnesium corrodes in the body," Huber explains. This laid the groundwork for an array of virtual experiments: the experts systematically removed certain parameters such as concentrations of CO_2 or sodium chloride – that is, common salt. The software then provided information on how a missing parameter affects the corrosion rate. In

What is Artificial intelligence?

Artificial intelligence programs exhibit one decisive feature: they are adaptive. What are known as neural networks, for example, are modelled on how the human brain works. They possess virtual neurons whose behaviour can be adapted over time to the input signals – to the data that are to be processed. In order for the AI to function, it must be "trained" – that is, with sufficient amounts of data. So that image recognition software can more reliably distinguish a dog from a cat, the more animal images it should be shown beforehand. Many of the AI methods have actually been around for several decades. It was only the quickly growing computing capacity of late that has helped in its breakthrough – meanwhile, experts are talking about a revolution in machine learning.



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Together with his team, Norbert Huber programmed a neural network and carefully trained it using selected measurement values.

addition, the researchers "fed" the neural network with just one parameter and observed what the program made of it.

The result was astounding: the calculations showed that the CO_2 content is much more important for corrosion than was expected," says Huber. "We earlier presumed that sodium chloride was the main cause of corrosion." Closer analysis showed that the interplay between the two parameters is the definitive factor: it is the combination of salt and CO_2 that decisively determines the corrosion rate – an insight with which further experiments can be much more effectively and selectively planned.

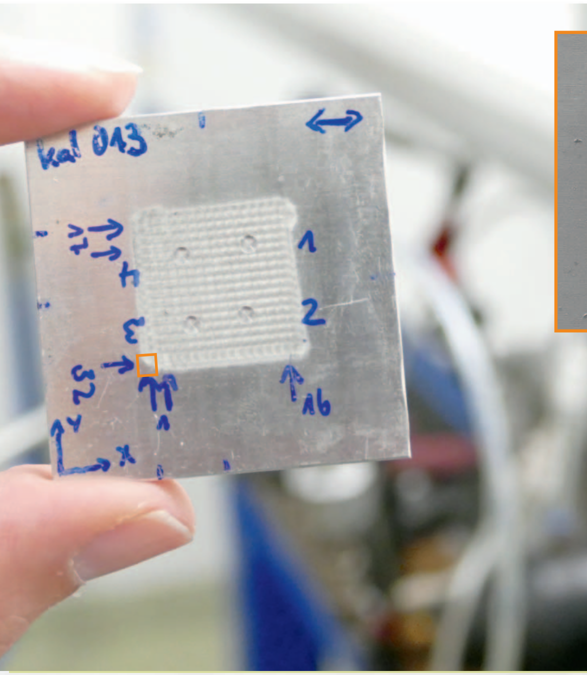
The special aspect of the project is that, in contrast to many other AI applications, it didn't require a great quantity of data to train the software. "In this case, a relatively small quantity of high quality data with little variance was sufficient," says Huber. "We provided the software with a lot of prior knowledge. This reduced the complexity of the problem so that we managed with less training data."

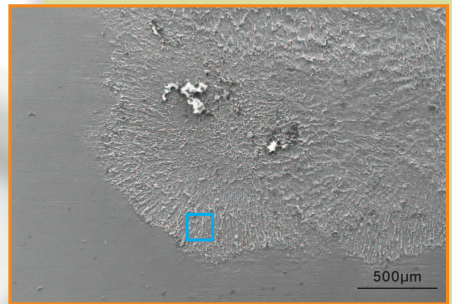
Corrections Through Learning Algorithms

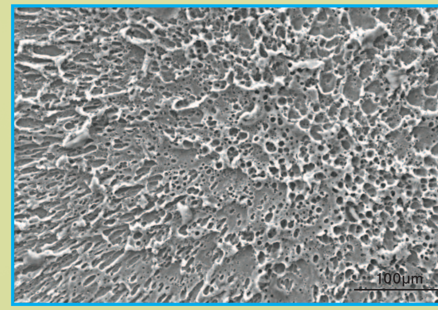
The departments for "Solid State Joining Processes" and "Laser Processing and Structural Assessment" also profit from AI methods – for example, when optimising a method that increases the lifespan of lightweight components. In "laser shock peening", a laser fires short light pulses at a metal, locally vaporising part of the surface. Starting from this vaporised surface, shock waves emanate through the material and change its properties. "We can thereby modify the residual stresses in the metal," explains Prof Benjamin Klusemann, head of the Solid State Joining Processes Department.

Residual stresses arise commonly when manufacturing and processing a component. If, for example, a sheet is bent during a rolling process, it then displays a certain "tensioning" even when it is no longer loaded. These residual stresses are not necessarily a disadvantage. Under certain circumstances, they can be used to retard the generation and propagation of short and long cracks and thereby increase a component's lifespan, such as on an aircraft wing. Laser shock peening can modify the material's residual stress in such a way that it can withstand higher loads. In an ideal situation, it increases the lifetime of a component up to fourfold.

To optimise the method, the HZG scientists use computer simulations. Here the computer virtually simulates the entire process – from the impact of the laser pulse and the propagating shockwaves, to a prediction of the crack growth in the laser-treated material. "These simulations







The material is initially treated using "laser shock peening". Short light pulses of the square laser convert the surface material into plasma. The spreading plasma produces shock waves that generate or modify residual stress. In order to measure the residual stress after treatment, small holes are bored into the "peened" material (left image). The middle image is a typical sample with four boreholes. The two images above were taken with a scanning electron microscope. The melted material surface can be seen on which the plasma is produced.

Benjamin Klusemann: If artificial intelligence is trained with inaccurate data, we get inaccurate results. It is extremely important that we evaluate how reliable the results are that we obtained through the assistance of artificial intelligence.

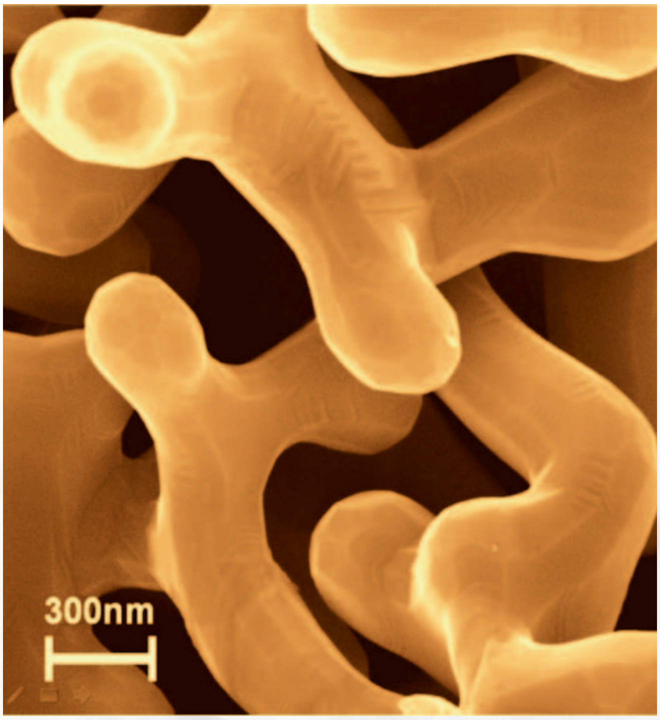
help us understand the influence of individual process parameters as well as the underlying mechanisms," says Klusemann. "We can, for example, use this to better adapt the method to a specific application."

In order to create as realistic simulations as possible, the experts must compare the simulations with data obtained from experiments: how large are the residual stresses after laser treatment in reality? In order to address this question, a drill is used to create small holes in the laser peened component. The researchers measure how the surface deforms as the residual stress decreases. From this measurement data, they can then calculate back to the size and direction of the residual stresses.

The problem is that this reconstruction leads to errors at high stresses. Normally time-consuming computer calculations are necessary to correct these errors later, which can take days. To speed up these corrections, adaptive software based on a neural network has been developed at HZG. "It can predict in a short period of time which corrections are necessary," says Klusemann. "In principle, it could be utilised in real time, so the result would already be available while drilling."

The necessary requirement is that for the AI to provide reliable results, it needs to be trained with appropriate data. "If artificial intelligence is trained with inaccurate data, we get inaccurate results," says the researcher. "It is extremely important that we evaluate how reliable the results are that we obtained through the assistance of artificial intelligence."

Christian Cyron: Artificial intelligence is really no magic bullet, but could serve as a vital tool in helping to solve fundamental problems in the field of materials research.



Nanoporous gold is an exciting material for applications in areas such as sensor technology.

Computation Acceleration with AI

The department for "Simulation of Solids and Structures" also places their hopes in artificial intelligence methods. Prof Christian Cyron and his team study, for example, how compound materials can be optimised. If, for instance, the rigidity of a soft, rubbery material increases when small hard particles are embedded, how then does this rigidity depend on the form and size of the embedded particles? "In order to simulate this on the computer, you would actually need to calculate all possible particle forms," Cyron says. "This would really take far too long."

So the experts use a different strategy: they run their simulations only for a limited number of particle sizes and forms. Using the results of these calculations, they then feed a deep learning algorithm. This algorithm can extrapolate the available data and is able to estimate the extent of rigidity that would result for other particle types that were not contained in the training data. "This is actually not as precise as an exact simulation," says Cyron. "But for our aims, we can live with an inaccuracy of a few per cent." These methods ultimately serve, above all, as a preliminary selection: which particle types are of further interest to research? Which ones can we disregard?

The experts have developed their adaptive algorithm with the help of fictitious example materials. They now wish to apply it to a real, promising class of materials: nanoporous (sponge-like) metals which combine low weight with high internal surface. This makes them interesting for applications such as in the field of catalysis or in sensor technology. The plan is the following: the researchers initially wish to carry out conventional computer simulations, which they will feed with data from high-resolution microscopes as well as from experiments that measure material properties. Using the results, they then wish to train the artificial intelligence. "By doing so, we want to predict the properties of the nanoporous metals more quickly than is possible through conventional simulations," Cyron says, hopefully. "Using machine learning, we can considerably accelerate computer simulations and process their results more quickly."

Lastly, AI could thereby provide clues as to how we can tailor a material, creating a kind of machine-intelligent material design. "We are still pushing forward, and no one can even say where this journey will lead or how useful these new methods will be in the end," says Cyron. "Artificial intelligence is really no magic bullet, but could serve as a vital tool in helping to solve fundamental problems in the field of materials research."

Author: Frank Grothelüschen

Reducing Space Junk

While satellites circle the Earth's orbit, so does a lot of junk. Approximately 20,000 larger objects and up to 900,000 centimetre-sized particles race at 30,000 kilometres per second or more through space. This becomes increasingly dangerous for satellites and space stations: the energy released by the impact of a particle is comparable to a car driving against a concrete wall.

Adding additional debris to outer space must be avoided. The European Space Agency (ESA) therefore stipulates that each new satellite is to be removed from space at the latest after twenty-five years. One method is through the controlled crash: the satellite is steered back into the atmosphere and burns up on re-entry. The problem is that satellite components, such as tanks, consist of the lightweight metal titanium. Titanium, however, burns up insufficiently in the atmosphere during re-entry and falls to Earth in larger pieces - creating a danger to both humans and infrastructure.

Jannik Entringer holds one of the tank prototypes in his hand. Behind him is the clamping device he developed.

Low melting materials like aluminium are more suitable as a structural material for the tanks, as they will certainly burn up in the atmosphere on re-entry. However, difficulties arise during manufacturing: the high process temperatures lead to critical changes in the material when using conventional welding for aluminium tanks. The enormous forces that occur during a rocket launch could lead to catastrophic defects at the weld seam of the satellite tank.

Special Welding Methods for Satellite Tanks

One solution is advanced welding methods such as friction stir welding. The HZG researchers are looking into this approach. "Our method joins the most dissimilar materials without any melting, sparking or vapours. The components are joined firmly together based on friction. The joint forms below the melting point of aluminium. Problematic stress levels in the material are considerably reduced with friction stir welding," explains Jannik Entringer, doctoral candidate at the Institute of Materials Research. This means that the friction stir-welded tank, made of a high strength aluminium-lithium alloy, will cope with the launch, but will burn up on re-entry.

Entringer carried out a comprehensive process optimization for his doctoral work with the aim of determining the ideal combination of process parameters. The scientist uses the bobbin tool, a two-shoulder variant of friction stir welding that welds the components from both sides of the metal. Parameters such as feed, pressure and rotation had to continuously be adjusted. Entringer studied the effects from the nanoscale to the macrolevel.

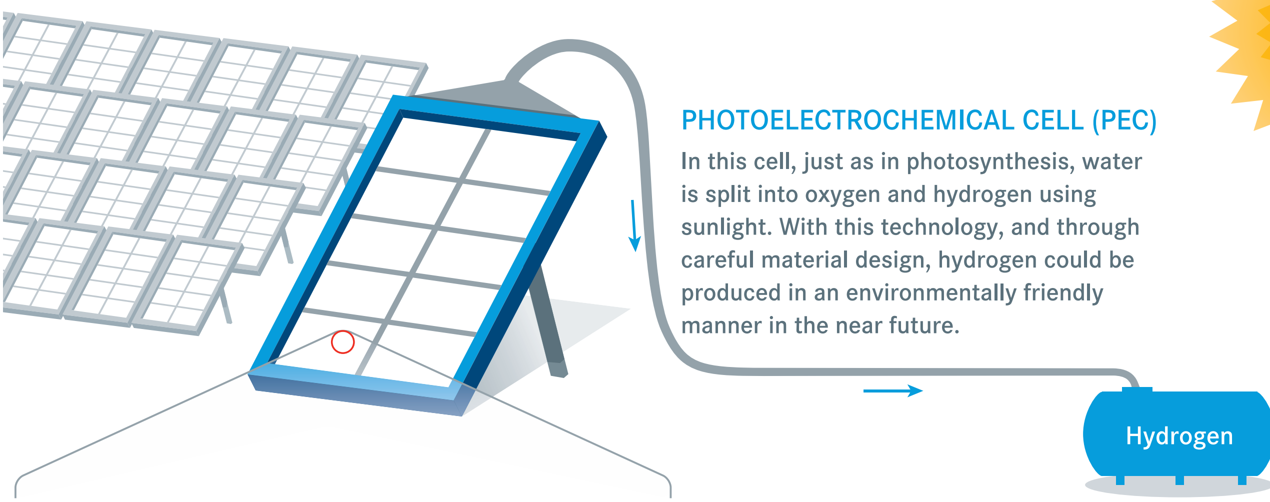
Prototype Development at the HZG

In addition to the welding process development, he also needed to control the clamping device and the deformation of the tank components. Due to the high forces during the joining process, he constructed a system that applies a torque of up to two thousand newton metres. Entringer points out: "I'm somewhat proud that our method works. In addition to the high torque, the round shape also needed to be taken into consideration, where the shape accuracy was particularly critical. Now I hope that my research one day helps keep the Earth's orbit cleaner." The welded tank prototype will head to the ESA as a start and there it will be exhibited.

Author: Heidrun Hillen (HZG)

Using Nature as a Model

Human technology has often been inspired by mechanisms found in nature. The leaves of plants absorb sunlight as well as CO_2 and water. This results in carbon compounds and oxygen. The department of “Sustainable Energy Technology” is developing an artificial method for converting light energy into an electrical charge. The electricity is directly used to generate hydrogen that can serve as an energy source. Hydrogen can considerably reduce the emission of harmful greenhouse gases in the future.

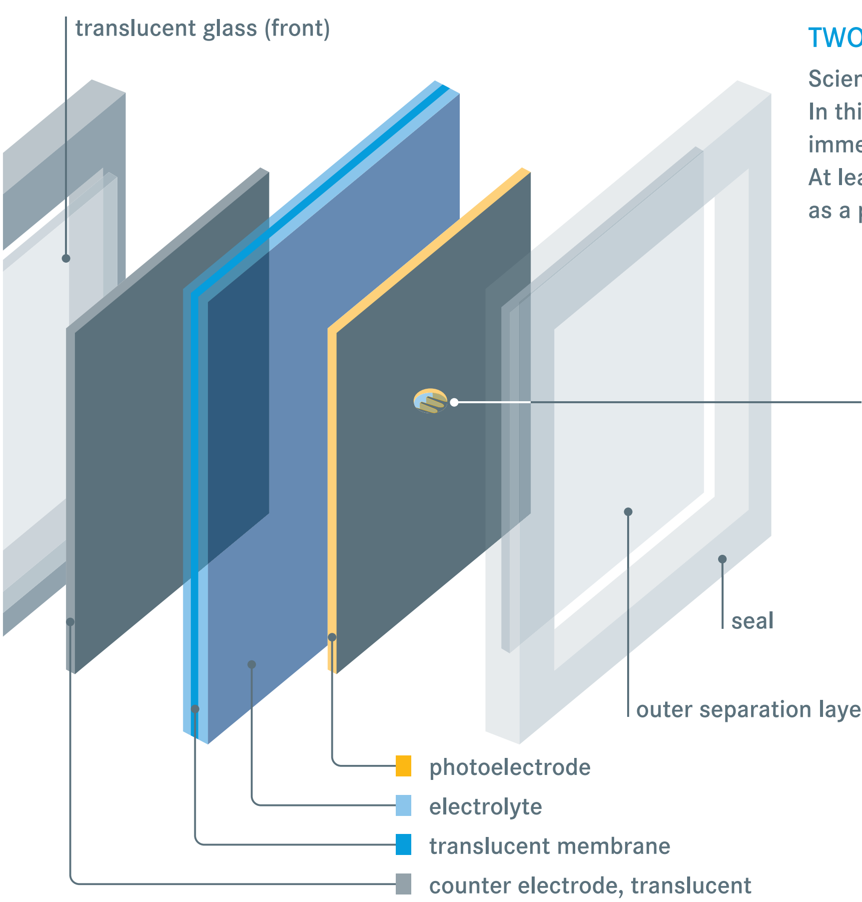


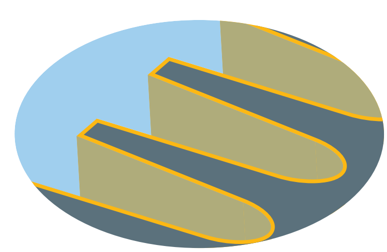
PHOTOELECTROCHEMICAL CELL (PEC)

In this cell, just as in photosynthesis, water is split into oxygen and hydrogen using sunlight. With this technology, and through careful material design, hydrogen could be produced in an environmentally friendly manner in the near future.

TWO-CHAMBER CELL

Scientists are studying different cell configurations. In this example, two plate-shaped electrodes are immersed in a thin electrolyte-filled chamber. At least one of the electrodes is what is known as a photoelectrode, which can absorb sunlight.



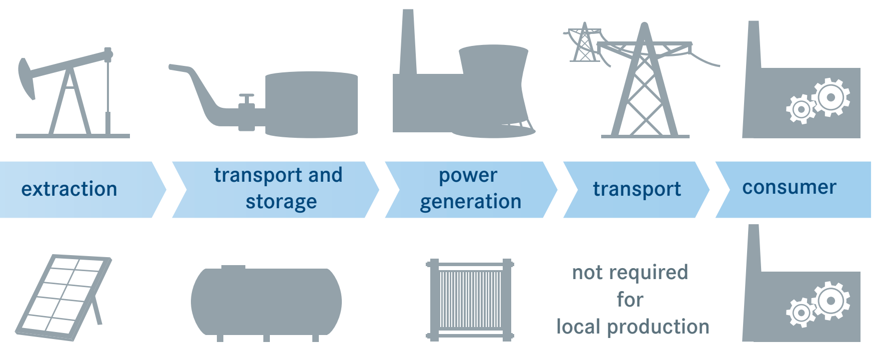


PHOTOELECTRODE

The water molecules are split on the surface of the photoelectrode. This electrode consists of several layers, including semiconductor materials that absorb light, such as titanium oxide (TiO_2). Etching produces a structured surface (a groove pattern in this example). This increases the contact with the electrolyte and optimises light absorption.

Current Status

Energy sources such as **crude oil, natural gas and coal** are extracted hundreds of kilometres away and transported to us via **pipelines** or other means. These fuels are burned to produce electricity in **power stations** for households and for the industrial and economic sectors.



A Future with Hydrogen

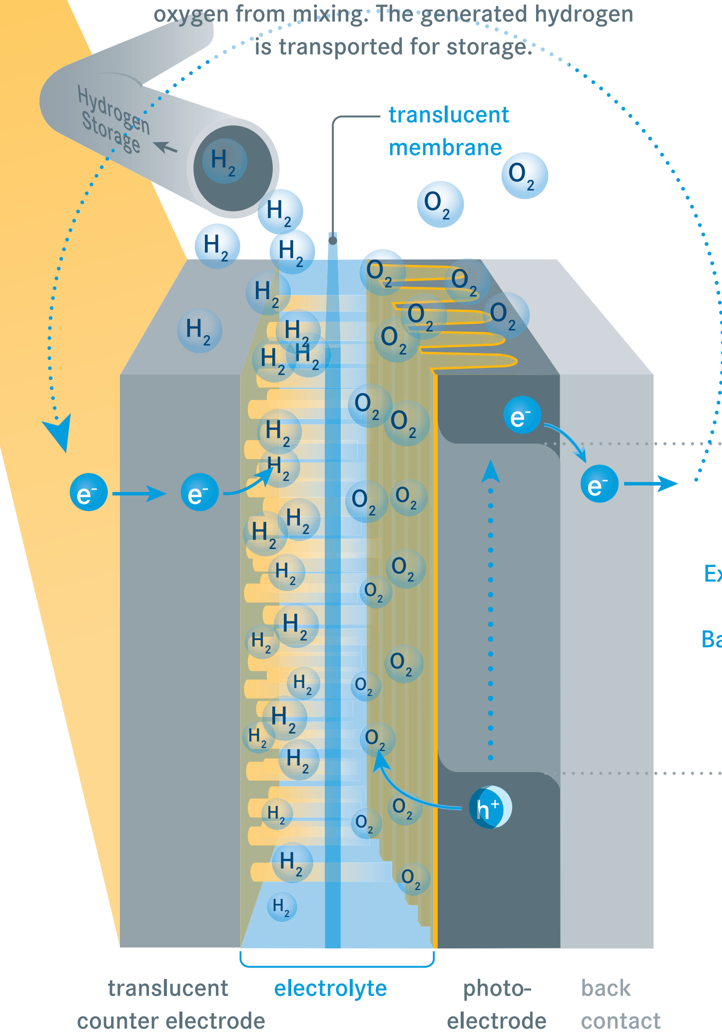
The **photoelectrochemical cell** converts water into hydrogen using sunlight. The **stored hydrogen** is converted into electricity as needed using a **fuel cell**. **Consumers** with extensive energy needs can generate this electricity directly on site.

THE SPLITTING PROCESS

Solar energy reaches the photoelectrode. Light absorption in the semiconductor produces a small electrical impulse that sets the water splitting reaction in motion:

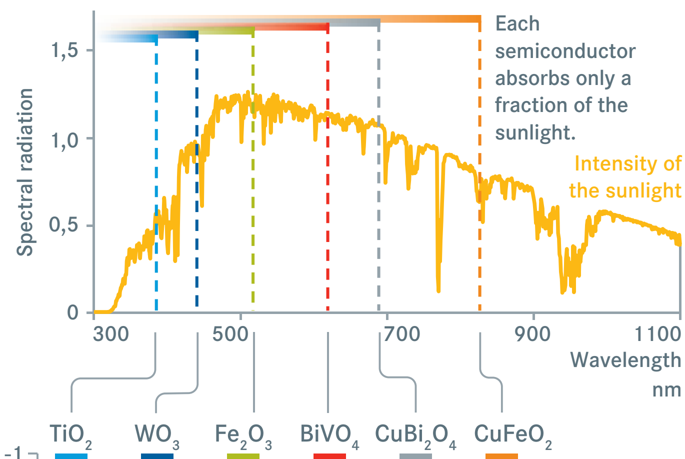
$$H_2O \rightarrow O_2 + H_2$$

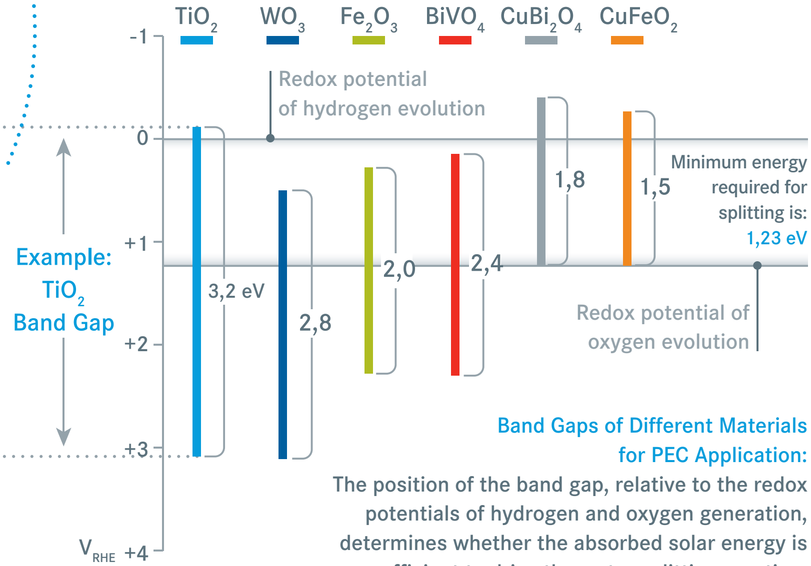
A membrane prevents the hydrogen and oxygen from mixing. The generated hydrogen is transported for storage.



SOLAR ENERGY

Solar radiation contains light with wavelengths between ultraviolet (UV) and infrared, with a maximum intensity at approximately 500 nm (green light).





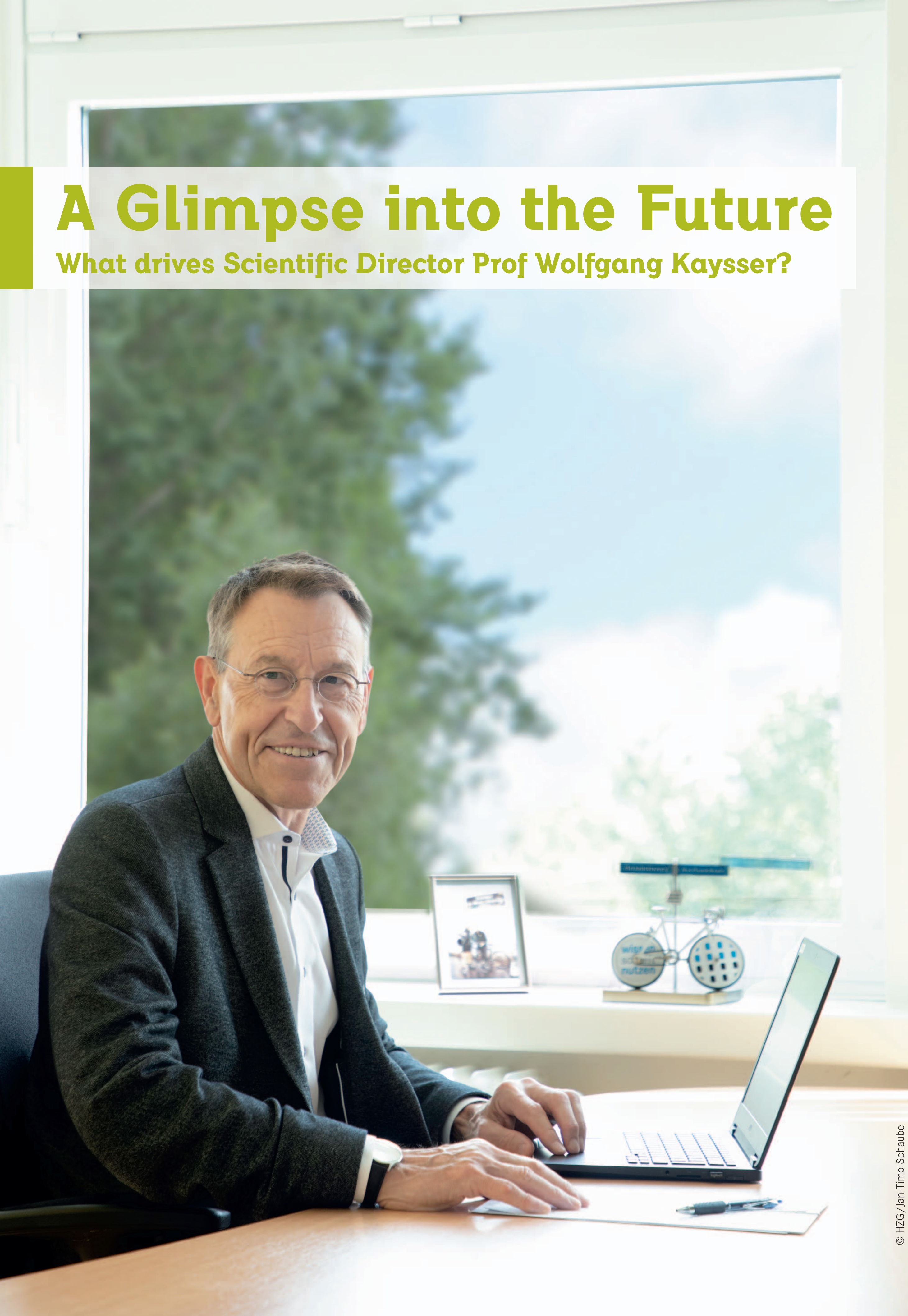
Band Gaps of Different Materials for PEC Application:
The position of the band gap, relative to the redox potentials of hydrogen and oxygen generation, determines whether the absorbed solar energy is sufficient to drive the water splitting reaction.

BAND GAP

In solids, the band gap refers to the energy gap between the valence band (electrons that contribute to chemical bonds) and the conduction band (electrons that can "move freely").

A Glimpse into the Future

What drives Scientific Director Prof Wolfgang Kaysser?



© HZG/Jan-Timo Schaube

Prof Wolfgang Kaysser

Scientific Director of the HZG

Prof Wolfgang Kaysser (68) is scientific director of the Helmholtz-Zentrum Geesthacht. This is an ideal job for a materials researcher who knows how structures, frameworks and ultimately large components arise from atoms; someone who has learned to make something whole from small building blocks.

The melody of his voice gives him away immediately: Wolfgang Kaysser hails from Swabia. He spent his childhood and teenage years in Winnenden near Stuttgart. He spent much of his time as a boy on his grandparents' farm; he trained in the judo club and skied, the latter with a special commitment - after he graduated from secondary school, he fulfilled his military service with the mountain troops. Kaysser then went on to study mechanical engineering for one semester in Stuttgart. But eight hundred people in one lecture hall? "I notice that I'm not going to really flourish there." This glimpse into his own future then brings about a switch to metallurgy. Here there are three professors for every six students for each year's class – one subject with a social structure where they expect students to perform well and enthusiasm for learning is fostered. That fits better. He soon begins a job as a student assistant at the nearby Max-Planck Institute. He leads an experiment that deals with the wetting behaviour of metals.

> **Suddenly I was really up close with research that I found incredibly fun.**

Kaysser developed his career at the institute quickly: he became group leader before he even turned thirty. Things didn't just remain that way, however; once again, he looked toward the future. "I wanted to make my own decisions and not find myself as an older researcher with a young institute director as my boss." So, Kaysser sent his job applications out into the world. There were two options open to him: an offer from the University of Saarland or serve as director of materials research at the German Aerospace Center in Cologne. "I was already familiar with the university and Max Planck environments - so I decided in favour of the large research institute." This alters his professional role: now Wolfgang Kaysser is primarily managing the research of others instead of undertaking research himself. It had been a "terrific time" in Cologne. He took horse riding lessons for the first time in his life, took part in Carnival and rode his racing bike through the Bergische Land. Shortly after the turn of the millennium, he then received a request from up north. His institute by this time had grown, as had his two children. In 2003, Wolfgang Kaysser took on the role as scientific director at what was then the GKSS.

What is the most vital component in such a position?

> **You need to determine what you want to represent as a centre. What contribution can your research make even in fifteen years time? That's what it's about!**

You therefore need to invent new fields of research at times. An example can be seen in membrane research, where Kaysser will soon lead a paradigm shift. Their work now concentrates on novel polymers. "That was a pioneering decision. Without it, we at the center really wouldn't be making membranes anymore today." As a director, you learn that often the future counts more than the present.

According to a saying, a Swabian has two obligations in life: working hard - and "building a house". Kaysser is no exception. At the HZG today, numerous buildings can be traced back to his initiative. "A centre lives from rejuvenation of its research and its infrastructural substance. Constructing buildings always has something to do with stabilisation."

Among the outstanding developments in HZG research of the past ten years are energy-saving functional lightweight engineering, clean mobility with hydrogen, and the body's own regeneration with the help of biomaterials. "Today we are already contemplating the systems of tomorrow - in coastal and climate research as well. How do the decisions we make today change the coastal seas of the future? Such questions must be addressed. That's why we engage in research." He feels especially proud today of the Climate Service Center GERICS, which arose from a simple project without a "blueprint". It had been a "march through the jungle," he says. "There was a lot of work and a great deal of tenacity involved." Magnesium research at the HZG has also been an enormous success story. Here we've meanwhile become one of the "three, four big players worldwide."

Wolfgang Kaysser will bid farewell in August as scientific director. How the story will continue afterward is something he keeps to himself. One thing is for certain, however: if he just rides his Italian carbon racing bike and waters his flowers on the balcony - well, that would "soon bore him." You can start placing your bets that Wolfgang Kaysser will undertake in the coming years something he has done during his sixteen years at the HZG. Looking toward the future. And then making good decisions.

Author: Jochen Metzger

Forging Plans Together

Part of an aircraft seat made from a magnesium alloy. This prototype came about through a collaborative project.

Heinz-Peter Reichel (left) has been working on different projects with the HZG's Magnesium Innovation Centre MagIC since 2005. During this time, various magnesium-based forgeable alloys have arisen for applications in the aerospace and automotive industries as well as in medical technology. Reichel met with Dr Norbert Hort (right), head of HZG's "Magnesium Processing Department", for a project meeting in the centre's Magnesium Casting Hall.

Mr Reichel, do you still remember the first project with the HZG?

Heinz-Peter Reichel: It started in 2005 with a forged magnesium component, which had to have a petrol and benzene resistant surface. It should be used, for example, for a car petrol tank neck or for the fuel filler flap. The alloy wasn't defined any further, so the scientists from Geesthacht developed a new alloy for us.

What became of it?

Reichel: We collaborated on the MagBone project from 2007 to 2009, in which magnesium implants were developed. The magnesium alloy had to be biodegradable and a bone screw was the target application. At the time we were dealing with blood interactions with the material. The alloy was invented and patented by Dr Norbert Hort. We took over the forging.

"Cast structures have completely different properties than those that are forged.

Heinz-Peter Reichel (right) has been working with his colleagues at MagIC for nearly twenty years.

More online:

www.hzg.de/magic

ABOUT

Heinz-Peter Reichel (image page 26 , left),
Partner at three companies: Weisensee Warmpressteile GmbH in Eichenzell, Hesse; MTW GmbH - Metalle und Technische Werkstoffe; and LMpv GmbH - Leichtmetall Produktion und Verarbeitung. MTW and LMpv are located in Dernbach, Thuringia. Reichel is also director of LMpv. All three firms employ approximately one hundred people in total. The 69-year-old precision mechanic and mechanical engineer was employed for a number of years in Canada at the start of his career. He then worked as a freelancer in the Frankfurt area producing machine tools. Reichel then acquired the Weisensee Warmpressteile company. This resulted in the subsidiaries MTW GmbH and LMpv GmbH.

Norbert Hort (image page 26, right),
Has headed the HZG's Magnesium Processing Technology Department since 2003. He completed his doctoral studies at the Technical University Clausthal in 2002. He began his employment at the HZG back in mid-2000. He is the expert in magnesium alloy development.

© HZG/Christian Schmid

Mr Hort, can you tell us more about the MgBone project?

Norbert Hort: Implants made of a mixture of hydroxyl-apatite and magnesium were to be produced in the project. Molten magnesium, however, reacts with hydroxyl-apatite and can produce toxic phosphine. Magnesium casting therefore was not an option. So we ground the magnesium alloy together with the hydroxyl-apatite, a bone-like material, in a ball mill. The alloy then needed to be compacted so that it produced a compact metal body. This massive body could be processed further by the LMpv firm. In the end, a biodegradable bone substitute was created.

How does a typical collaboration between the two of you look?

Reichel: For certain applications, we often need a new alloy for forging. This must initially be developed, and that is where the scientists come into play. The HZG then, for example, carries out a large part of the microstructure characterization, be it with the electron microscope or at the HZG synchrotron facilities. The alloy development and production is thus undertaken by Norbert Hort and his team. Our company, LMpv, casts a five-centimetre-thin plate, then the Weisensee cuts this plate into suitable pieces - for example, by forging. Finally, a component such as the seat structure for aircraft seats is produced (see image on page 27). This is normally the end of the project - that is, when such a demonstrator has been created.

What is special about the alloy for the seating structure?

Reichel: The component and / or the alloy is noticeably less prone to burning than conventional components. This alloy burns only at higher temperatures than one thousand degrees Celsius - that is, around three hundred degrees higher than aluminium. Our alloy, however, has the disadvantage that it can't be forged very well. It's a lovely material for casting, but not for forging. Unfortunately, cast structures have completely different properties than those that are forged. Expressed another way: the cast seat would collapse much faster than the forged seat because the latter can better bear the load. In a follow-up project, we therefore want to deal with elongating the metal. To do so, we use additives such as silicon in the alloy, which are finely ground to about fifty nanometres. But we encountered tremendous difficulties in coaxing this silicon dust into dissolving and sinking into the molten mass. This is comparable to milk powder in coffee; it sometimes just floats on top. And when you use a spoon to stir it, half of it sticks to the spoon. We still have a great deal of work ahead of us.

Hort: We do, however, have a very good idea of how it might go. We have ideas as to how we could stir in the particles on a laboratory scale. But it's only with larger quantities that we can see if and how this alloy is forgeable and what properties it will then have. This is where LMpv enters the picture, as a partner in larger scale applications. The LMpv material is then again studied using our scientific methods.

Thank you for the interview.

The interview was conducted by Heidrun Hillen (HZG).

EU-Funding at HZG: Millions for Science

Dr Hans-Jörg Isemer has been advising and overseeing the funding applications for EU research projects since 1999. He is to thank for HZG's current application success rate of 35 percent. During his tenure, HZG has already acted as the project coordinator forty-five times.

It is a competition for a pot of funds with billions of Euros: the European Union's Research Framework Programmes. One person who knows his way around the EU funding jungle is Dr Hans-Jörg Isemer, head of the HZG's division for "European and International Projects". The advisor who is well-connected across Europe supports scientists in various phases of the complex EU project application process.

According to Isemer, it is often easier to obtain funds for research projects in Germany than through the European Commission. The applications, for example, to the Federal Ministry of Education and Research or to the Federal Ministry for Economic Affairs and Energy are generally less complex and less laborious and often benefit from a higher statistical funding probability. The "Mr Europa" of the HZG is nevertheless deeply convinced that science can only be successful when it is internationally aligned.

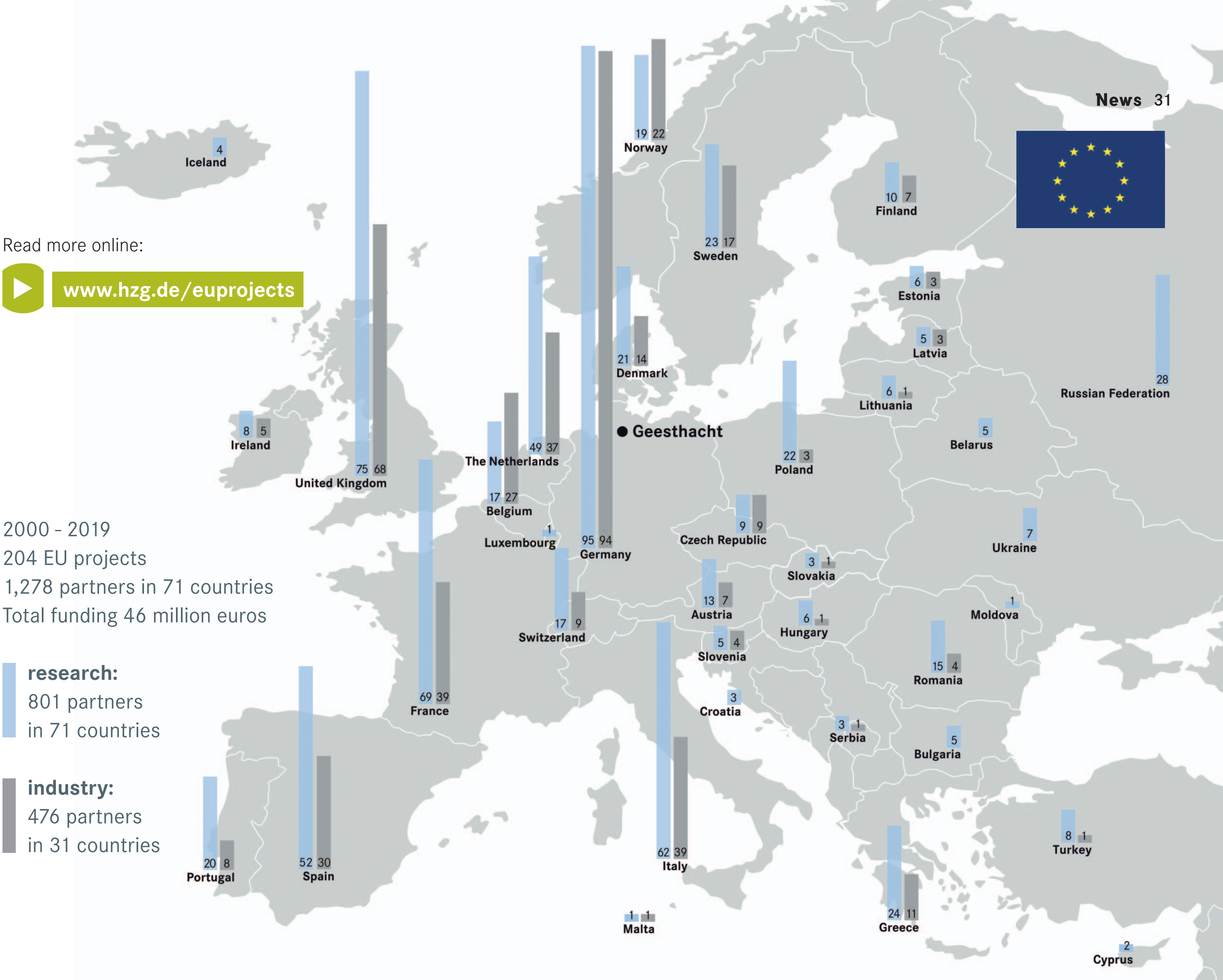
Hans-Jörg Isemer points out: "Global problems such as climate change, species protection or developing renewable energy sources must be dealt with internationally. Only then, in my opinion, does research make sense." Of particular significance is that in EU projects different people from various countries and cultures work jointly in research cooperations. The integration of research institutions from several EU Member States is one of the fundamental principles of the EU projects.

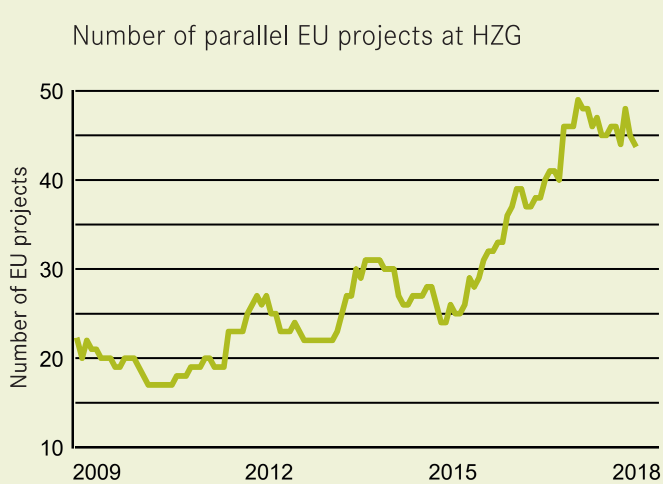
In the last ten years, the number of EU projects concurrently running at HZG increased from approximately twenty projects to forty-five today. This increase correlates with the billed subsidies, which reached over three million Euros per year since 2017 (see graphic: EU Billed Subsidies Since 2009). "We receive 300,000 to 500,000 Euros on average per project," says Isemer. "The highest individual grant was just over a million Euros."

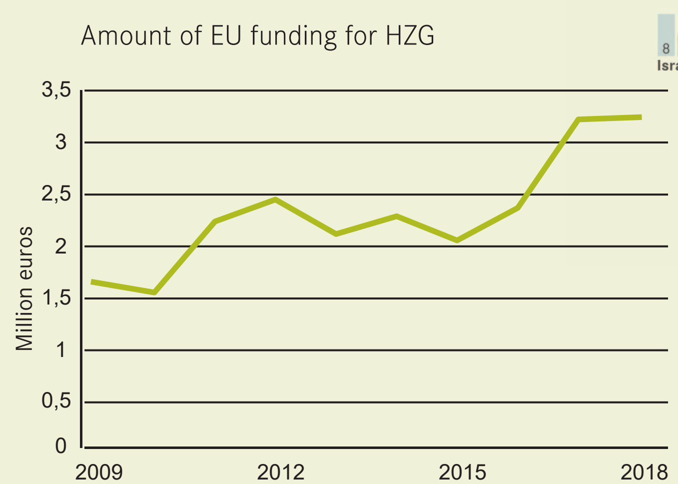
Speaking of Europe: what does Hans-Jörg Isemer think about Brexit? "The British have obviously gone crazy. I think it's terrible. Thousands of grants between the EU Commission on the one hand and research institutions and industry partners on the other would

Read more online:

www.hzg.de/euprojects







need to be newly negotiated and amended in case of a no-deal Brexit. Not only would the United Kingdom itself suffer, but also all of Europe."

Author: Heidrun Hillen (HZG)

The European Union funds research projects and programmes in all twenty-eight European Union Member States. "Horizon 2020", for example, offers a total sum of nearly eighty billion Euros.

News from the Centre

Pollutants in the Sea: A Comparison Between China and Europe

UV filters are not only utilised in sunscreens to protect people from the effects of sunlight, but they are also used in plastics for preventing what is known as photo-induced degradation. Many UV filters are suspected to mimic hormones and are classified as potential environmental pollutants.

© HZG/Christian Schmid

Christina Apel collected, evaluated and compared data from China and Europe.

Christina Apel, doctoral candidate in the Institute of Coastal Research's Environmental Chemistry Department, has developed an analysis method for twenty-two organic UV filters in coastal and marine sediments. The scientist collected sediment samples during different expeditions on research vessels and then used modern analysis methods to study them. Using this approach, sediment samples from the European North and Baltic Seas as well as from the Bohai and Yellow Seas in China were analysed, assessed and compared to each other for the first time in regard to the occurrence of UV filters. The aim of Apel's dissertation was to determine the environmental concentrations and distribution of UV filters and to identify potential sources.

The result was that the UV filters occurred in all of the areas studied. The concentrations of the respective substances in Europe and China were very similar. "That was surprising," says Apel. "In other studies, usually higher concentrations of other pollutants could be detected in China." What was particularly noticeable was the chemical substance octocrylene. In both research regions, this UV filter accounted for more than fifty per cent of the sediment contamination detected. Octocrylene has a high bioaccumulation potential, which means it can accumulate in organisms and therefore in the food chain.

Find out more about pollutants online:

https://coastmap.hzg.de/spotlights/pollutants/

Research in Open-Air Laboratories

Ten rural regions across the globe have been chosen as Open-Air Laboratories for the OPERANDUM project. Scientists are exploring nature-based measures in this scheme to reduce the impacts of droughts, coastal erosion, floods and other situations. The research aim is to obtain comprehensive knowledge on the effectiveness of "near-natural" approaches for reducing what are known as hydro-meteorological risks.

The Lower Saxonian Elbe Valley Biosphere Reserve serves as an Open-Air Laboratory in Germany. There, for example, the grazing livestock are used on the floodplain meadows as nature-based measures to keep the flood plains clear. The Climate Service Center Germany (GERICS) is one of the project partners in OPERANDUM and prepares, for example, tailored, regional climate information for the Open-Air laboratories.

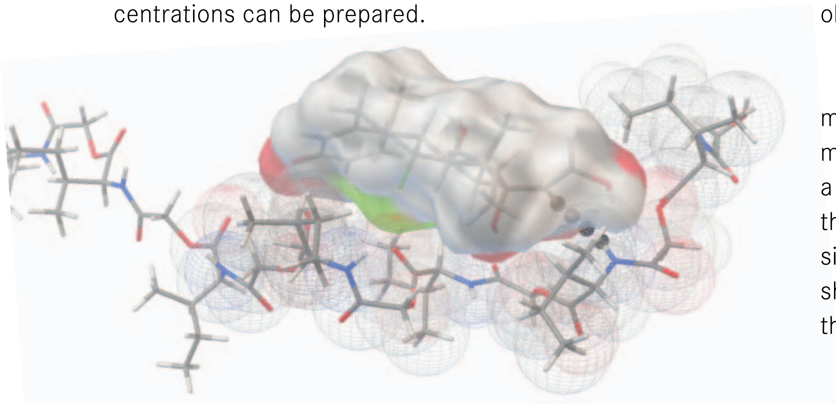
The work is undertaken within the framework of the OPERANDUM project. OPERANDUM stands for OPEn-air laboRAtories for Nature baseD solUtions to Manage hydro-meteo risks. The European Commission is investing 12.2 million Euros in the project with twenty-six partners.

www.operandum-project.eu

© istock/hsvrs

Tiny Drug Carriers

Nanocarriers come into play when substances are to be released locally into the body. Tiny particles made of polymers transport the medication to the target location. The substances are released at this location through diffusion or by the polymer's degradation. In order to be effective, they must be present in a therapeutically effective concentration. The problem with conventional polymers is that the carrier particles become unstable above a certain loading density. This is why scientists from the Institute of Biomaterial Science in Teltow are searching for a polymer from which stable carriers for high substance concentrations can be prepared.



The OMDB molecule created in the computer model. Carbon is grey, hydrogen white, oxygen red, nitrogen blue and fluorine green.

They forged new paths in this aspect: the researchers used computer-assisted models to preselect polymers with which they could subsequently conduct experiments in the laboratory. This is considerably more efficient than the conventional method, in which only experiments are involved.

In models as well as in experiments, researchers led by Prof Andreas Lendlein loaded two different degradable polymers with the commonly used anti-inflammatory medication Dexamethasone: PLGA, a clinically established copolymer, and OMBD, an oligodepsipeptide, which is still new to this application.

One result of the study is that the oligodepsipeptides are much more suitable as nanocarriers than the conventional polymer. “Depsipeptides are a very interesting substance group with a great deal of potential,” says Lendlein. The special aspect is that they provide great structural diversity due to their composition so that multiple physical interactions can be selectively shaped. This means that the substance adheres better here and the polymer can therefore absorb more of the substance.

There is still a long way to go before the substance carriers can be clinically used in a drug delivery system. The next step involves further development and optimisation of the synthesis in accordance with regulatory requirements for drugs.

Structure Formation in Hollow Fibre Membranes

For the first time, block copolymer self-assembly was studied during hollow fibre membrane fabrication using an x-ray beam. Hollow fibres are widely used in membrane technology, for example, to obtain drinking water.

Hollow fibres can be produced from polymer solutions through a spinning process. What are known as block copolymers (BCPs) are particularly interesting as starting material, as their self-assembly produces equally sized and uniformly distributed pores in a single step during spinning. At best, a regularly arranged, hexagonal structure of the pores results over the entire length of the fibre. A correct composition of the polymer solution and other spinning parameters are important in order to create the desired structures and allow the membranes to perform well.

In order to determine what affects the pore formation, HZG polymer researcher Kirti Sankhala forged new paths: using in situ small angle X-ray scattering (SAXS) at the HZG's own beamlines located at the Deutsches Elektronen Synchrotron (DESY) in Hamburg, she observed how the self-assembly of the BCPs is represented in the hollow fibre membrane. In the experiment, x-rays hit the nascent fibre. The beams thereby react with the electrons of the fibre and generate scattered waves that are measured by a detector. Conclusions can then be drawn about the structure of the investigated sample.

Sankhala used two different types of BCP solutions for her studies: one with magnesium acetate additive and one without. She explains: “Magnesium acetate stimulates the formation of ordered structures already in the solution. The so-called micelles are formed, which contribute to later pore formation.” Only the complex SAXS experiments and accompanying electron microscope images provided her with the systematic comparison of the factors influencing the spinning process. Her conclusion was that the addition of magnesium acetate promotes structure formation so that an optimal pore structure already occurs at generally more variable conditions and lower polymer concentrations. The latter is an important factor when using the relatively expensive BCPs.

You can find the publication online:

doi.org/10.1039/C8NR06892E

The Storyteller

Research to me means creativity

Find more portraits online:

www.hzg.de/portraits

Prof Erica Thea Lilleodden

head of “Experimental Materials Mechanics” at the Institute of Materials Research

Her office is full of books and scientific journals; her desk is strewn with notes; the windowsill is adorned with photos of her children and students; the whiteboard is full of equations; on the wall hang paintings from her kids; and on the shelf stand chemical structure models. Dr Erica Lilleodden looks around. “This is what you call multi-tasking,” she explains, laughing. The 46-year-old is the department head of “Experimental Materials Mechanics”.

“That’s also how my brain works: I think about a lot of things at the same time, often these things initially have nothing to do with each other, but they tend to link together at some point - for example, through discussions with other people.” She’s happy to hand over administrative matters when possible. This way she can concentrate more on science – for her, it’s a question of creativity.

It’s about finding the story in the research for me. In the beginning, there’s always a question from which something develops. We try out different approaches. It’s often a struggle and there are setbacks - but we ultimately find a solution in the best case scenario. Usually new questions arise in the end, prompting us to continue our research; then a new chapter begins.

The researcher grew up in the United States - in Saint Paul, Minnesota. She earned her doctorate in Materials Science at Stanford University. “The special thing about completing a doctorate in the United States is that PhD candidates still attend university lectures, which allow them to better bridge theory and practice. It’s precisely at this stage that young scientists should be able to experiment and be creative.” She attempts to transfer that approach to her doctoral students here: “We engage in lots of discussions - I don’t just define what should wind up in their dissertation. The PhD students should find their own path - of course by engaging with me and with other colleagues. This is how we all learn.”

Her path to Germany initially led to Karlsruhe in 2004. She worked at the research centre there as a Humboldt Research Fellow. Just when the scientist was toying with the idea of heading back to the US, she met the man who is now her husband. “He was what prompted me to stay.” She also knew Prof Norbert Huber in Karlsruhe, the current institute director of Materials Mechanics, who had just been planning a move to Geesthacht and to establish a new research focus on micromechanics. Lilleodden was excited by the prospect of her own lab and a permanent position. She began working at the HZG in 2006 and moved to Hamburg with her husband, who is originally from northern Germany. “My husband was happy that he could live closer to the HSV stadium again,” Lilleodden says, smiling. Today she lives with her two children in what is known as a Hamburg “Kaffeemuehle” (coffee mill) house.

Erica Lilleodden’s scientific story revolves around micromechanics, around nanostructures. How do mechanically stressed components - such as on aircraft - behave at the micro level? In order to find out, she excises samples measuring down to one hundred nanometres. This is approximately one-thousandth the size of a human hair. She studies these tiny samples in the lab with various instruments. “What interests me is: how is the material structured? How does it look at the atomic level? Those who study larger parts must make assumptions as to why a certain behaviour occurs. I look directly at the micro level and can therefore understand how the atomic level influences the big picture.”

She will be awarded the prestigious prize from the German Materials Society - the DGM Prize - in November 2019 for her outstanding fundamental research.

I’m incredibly happy! But the prize isn’t just for me. It’s an award for our work in its entirety, here in the group and from the influence of many colleagues worldwide.

She speaks German with an American accent. When she gets excited, she quickly slips into her native language and her eyes light up. In addition to her own research and duties as head of department, she mentors junior scientists, organises conferences, teaches at the university and participates on various committees. “That’s our responsibility as members of the scientific community, even if it's often time consuming. However, through such involvement you also obtain a great deal of insight and new perspectives along the way - everyone benefits.”

The Lilleodden family enjoys travelling - rarely to the same place twice. While a trip to Vietnam and Cambodia is planned for later this year, 2020 will be really exciting: from January to June, the family is moving to Saint Paul, back to Lilleodden’s roots. There she’ll work as a guest Professor in the Department of Chemical Engineering and Materials Science at the University of Minnesota while the children can spend a longer period of time with the American part of the family. Her 10-year-old daughter and her 8-year-old son are growing up bilingual. “We’re really looking forward to it and are curious what life will be like for us there.” They will return in July and her story will continue in Hamburg.

Author: Gesa Seidel (HZG)

Team Building Successful — Network for Future Questions

Hamburg's climate researchers join forces in a new Cluster of Excellence: nearly two hundred scientists are involved in the CLICCS interdisciplinary network, which analyses not only global climate development, but also advises cities and communities that wish to adapt to future scenarios. HZG experts are contributing to this large project.

It was just recently that traffic police needed to warn of heavy sand storms sweeping over some regions of northern Germany again – over the motorways and highways. Radio announcements asked drivers to reduce their speed, as visibility on the roads was limited. Gusts of wind had stirred up sand and carried it from the neighbouring fields to the asphalt: after weeks without rain, the fields were dried out - and this was in spring, normally a period with a great deal of precipitation. According to meteorologists at the time, some areas in northern Germany were comparable to deserts.

"Scenarios like this make it clear how much climate change could affect our everyday life in the future," says Detlef Stammer, climate researcher and director of the Center for Earth System Research and Sustainability (CEN) at the University of Hamburg. Studies show that extreme weather events, such as these droughts, could plague Germany more often in the future. According to Stammer, this makes it even more important for scientists not only to study global climate developments, but also to make regional assessments as well.

Hamburg climate researchers now want to undertake this balancing act in a new Cluster of Excellence research project: "Climate, Climatic Change and Society" (CLICCS). The project began in the Hanseatic city in January, with oceanographer Stammer as spokesperson. Nearly two hundred scientists are engaged in the network, such as meteorologists, geoscientists and experts in climate modelling, but also political scientists and conflict researchers, sociologists, ethnologists and legal experts. Experts from fifteen disciplines in total are networking in the initiative.

From CLISAP to CLICCS

This cooperation between scientists in the natural sciences, social sciences and the humanities has been a hallmark of Hamburg's climate research for many years. Together the experts initially developed the CliSAP research program, which became a Cluster of Excellence in 2007, for which funding ran out only last year. The German funding body "Deutsche Forschungsgemeinschaft" is now supporting the new CLICCS program until the year 2025 with thirty-eight million Euros. The program is to concentrate even more heavily on regional developments and strategies for local risk prevention.

Societal processes are always taken into account:

- what climate-relevant measures are put in place, for example, through politics?
- how do citizens react to climate protection initiatives?
- how quickly do industries change, particularly those that release a great deal of CO_2?

Though these factors heavily influence future climate, computer models have not yet been able to adequately take such developments into account. This is a gap that CLICCS wishes to fill.

"We not only want to know what climate scenarios are possible in purely physical terms, but also what would be especially probable when we take into account physical and social developments equally," says Stammer, explaining one of the aims of CLICCS. The range of research questions that the Cluster of Excellence wants to address is correspondingly large. Although the network continues to conduct important basic research, it also studies, for example, the social and political risks that climate change involves, and it analyses which protection measures would prove particularly useful in certain regions.

Hamburg Climate Futures Outlook

CLICCS wants to publish important interim results in an annual report, the Hamburg Climate Futures Outlook. It should also repeatedly illustrate to what extent the Paris Climate Agreement targets could be achieved. “There are already a lot of facts on the table; what matters now is developing effective strategies for action,” says Stammer.

Behind the research program, aside from CEN, are the Helmholtz-Zentrum Geesthacht’s (HZG’s) Institute of Coastal Research, as well as HZG’s Climate Service Center Germany (GERICS), the Max Planck Institute for Meteorology and the German Climate Computing Centre, with an additional eight partner institutions involved. The program content is divided into three main topics of focus with a total of fourteen projects: research area A conducts basic scientific research; segment B is dedicated to social science topics; and focus C concentrates on local climate scenarios and the accompanying necessary adaptation strategies.

The range of topics within these branches is large: the experts in area A study different regions, such as the Arctic and tropics or compare air circulation and atmospheric boundary layers in cities and forests. They want to illustrate climate events in more detail using measurements, experiments and satellite data as well as through the development of even more refined computer models. Take, for example, the carbon fluxes in coastal regions: the research teams know from their studies within the CliSAP initiative that coastal seas can absorb a great deal of CO_2. In this respect, the sea plays a vital role as a buffer. Without its absorption capacity, the effects of climate change would certainly be much more noticeable today.

CO_2 Uptake in the Coastal Sea

“How these processes function precisely, particularly in coastal waters, remains unstudied however,” explains Corinna Schrum, Director of the "System Analysis and Modelling” division at HZG’s Institute of Coastal Research. The oceanographer is leading the project "The Land-Ocean Transition Zone" in theme A. She is also a member of the coordination team for research area C and a member of the CLICCS Steering Committee.

Of particular interest is the perspective on these marine regions, as it is there that temporal, spatial and seasonal variations within the carbon cycles have been observed. A systematic analysis, however, is still missing. “This is something we want to

The Institute of Coastal Research is Heavily Involved in the CLICCS Cluster Of Excellence

Three additional HZG coastal researchers became project leaders in the Cluster of Excellence: Prof Beate Ratter, Prof Kay Christian Emeis and Dr Eduardo Zorita. In addition to the four HZG project leaders, numerous scientists at the HZG's Institute for Coastal Research are contributing to the cluster. The researchers are working on six CLICCS projects in total, particularly in the C1, C3 and A6 research areas.

Within the framework of the CLICCS Cluster of Excellence, geographer Prof Beate Ratter, for example, researches regional aspects of societal climate change adaptation. She is particularly interested in dealing with extreme events such as storm floods and storms on small islands and on the North Frisian coasts. In addition to leading the HZG's department of "Human Dimensions of Coastal Areas", Ratter is also a researcher at the University of Hamburg's section for "Integrative Geography".

Together with HZG institute director Prof Kay-Christian Emeis, they both lead the CLICCS project "Sustainable Adaptation Scenarios for Coastal Systems." Coastal systems are interacting human-environmental systems. They are impacted by local as well as large-scale feedback between climate and society. Integrated coastal system numerical models are developed in the project, which represent the effects of climate change and take into account major human impact. Future scenarios are thus developed, such as linking data for marine food webs with geophysical, biophysical and socioeconomic components that are socially plausible.

The CLICCS researchers thereby use an iterative and participatory modelling approach and thus develop sustainable strategies for adapting to climate change. HZG scientist Dr Eduardo Zorita is a leader of the CLICCS project "Earth System Variability and Predictability in a Changing Climate". The project is to clarify what role the small-scale processes play in the climate system; how they influence variability, trends and predictability of the global climate; and how important they are in creating climate extremes. These are questions that still strongly influence the uncertainties of the current climate projections and are addressed in CLICCS through novel climate models.

address now," says Schrum. Her research group also wants to determine whether the coastal seas are absorbing more CO_2 today than in recent decades.

To this end, the scientists will be combining new and existing data in the coming years. Together with her colleagues at the University of Hamburg and the Max Planck Institute for Meteorology, Schrum's aim is to create a new ocean model, depicting the global coasts in higher resolution – ICON-Coast, which is later to become a component of a new climate model. With ICON's help, Schrum's working group will study the not yet understood exchange processes between the open sea and the coastal regions – and in doing so, contribute to the understanding of global climate development.

Collaboration Between Science and Society

These interactions between local and global climate, between physical and societal impact factors should, however, not only be studied theoretically. What is also particularly important to the CLICCS teams is the close link to practical application: the insights generated should help decision makers ascertain what measures are useful in climate protection and ensure that cities and communities also have ways to adapt to climate change.

The Climate Service Center Germany (GERICS) at the HZG plays one role here. "We want to bring the scientific and societal sectors together in a dialogue," explains GERICS Director Daniela Jacob. GERICS scientists therefore are actively exchanging knowledge with different establishments – for example, with agricultural bodies, water authorities, farming and tourism associations, energy companies and shipping experts.

Scientists wish to learn the following from representatives of these bodies: what questions concerning climate change are particularly pressing for them in terms of their future work? Transportation planners, for example, perhaps need to know how often street tunnels will need to be closed in the future, as the tunnels are no longer navigable after severe rain events, Jacob explains. She also points out, "Our job will be to see if today's knowledge is already sufficient for providing answers to such concrete questions or if we need to mediate a dialogue with an expert from the CLICCS research network." If the necessary information or a suitable expert is lacking, the scientists can determine whether the question is relevant enough to warrant inclusion as a new aspect in their research work.

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Climate research within the cluster, therefore, will not become a one-way street. "We provide our expertise, but we also want to hear from users what knowledge gaps we have perhaps so far overlooked," explains Jacob.

GERICS is directly involved in two research projects: the scientists, for example, study what types of water management cities within the Hamburg Metropolitan Region need for the future when dealing with varying stress factors, such as floods, heavy rains, storm surges and increasing groundwater levels. According to Jacob, urban planners here are sometimes forced to develop completely new ideas, as existing drainage systems can't always be easily expanded further. "Hamburg's sewage system, for example, cannot be randomly expanded at any location for structural reasons," she says. Instead, large amounts of water could in future, perhaps, be channelled to areas that are suitable as catch basins in the short term.

In another project, GERICS scientific research provides support in how rural areas can arm themselves against the effects of climate change. These communities primarily require local information that is spatially well-resolved. How will the climate develop in the future, particularly in their region? It's not easy to provide answers - after all, global climate change does not have the same impact everywhere. In some regions, precipitation will increase, while in others it will decrease. The warming itself can also be very different. This is where refined computer models can provide vital answers on climate change. It is crucial that these systems are easy to use. "We want to simplify access to the model results and make them user friendly," says Jacob. "To this end, we develop customised products for users, providing data and information on possible regional climate change tailored to users in specific regions."

Furthermore, a system model is under development in a supporting CLICCS project financed by the Helmholtz Association. This model is to provide users with the opportunity to link the effects of socio-economic factors with the local impacts of climate change by incorporating their own information. In particular, complex relationships and feedbacks are to be identified and effective adaptation measures are to be developed.

Addressing Ethical Climate Questions

For Detlef Stammer, collaboration between the most varying scientific disciplines is indispensible in finding answers to such complex questions. A philosopher, for example, is also contributing to the recently begun project, the CLICCS spokesperson explains. After all, it deals with crucial ethical questions: how will societal conflicts, which climate change will inevitably bring, be resolved as equitably as possible?

In this respect, the mammoth CLICCS project does not only rely on the content of the predecessor CliSAP project. It also benefits organizationally from the experience of the long-practised, interdisciplinary collaboration. "Natural scientists and social scientists generally work very differently, so it requires a certain curiosity and openness," says Stammer. Over the years, however, the Hamburg climate researchers have grown together as a team. This has paid off today, with the confirmation as a Cluster Of Excellence: "We have a ten-year head start, so our collaboration works outstandingly well today."

Author: Jenny Niederstadt

www.cliccs.uni-hamburg.de

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10 Years GERICS

On the 1st of July, 2019, the Climate Service Center Germany GERICS celebrates its tenth anniversary. A small selection from the success story:

February 2009
The first employee, Irene Fischer-Bruns, begins working at the Climate Service Center (then the CSC)

July 2009
Director Guy Brasseur takes up his position; official founding of CSC marked by a scientific symposium

July 2011
The www.klimanavigator.eu portal goes online as a guide for climate knowledge in Germany

October 2011
Launch of the CSC-coordinated EU project IMPACT2C, with seventeen European partners

November 2012
Prototype of “Country Climate Fact Sheets” launched, marking the start of the “Fact Sheet” product line

December 2012
Co-published book: *Klimawandel und Biodiversität – Status für Deutschland*

August 2013
Creation of the “toolkits” product line: first public appearance of the “Adaptation Toolkits for Cities” in Kiel

June 2014
Incorporated into the Helmholtz Association; Daniela Jacob takes over directorship of the center, which has meanwhile grown to thirty-four employees

February 2015
“European Roadmap for Climate Services” published in collaboration with Daniela Jacob

June 2015
New scientific journal *Climate Services* launched with the Elsevier publishing house; Daniela Jacob as founding editor

December 2015
IMPACT2C Web Atlas goes online

June 2016
Founding of the Helmholtz Institute for Climate Service Science (HICSS) in conjunction with the University of Hamburg

November 2016
Publication of the scientific book *Klimawandel in Deutschland (Climate Change in Germany)*

July 2018
New project: “Bundesländer Check” on climate change. A new publication series: “City Series”

October 2018
IPCC Special Report on Global Warming of 1.5°C is published; Daniela Jacob is coordinating lead author

May 2019
Today sixty-two staff members from many different disciplines work at GERICS

GERICS
Climate Service Center Germany

More information in the interactive graphic:

www.gerics.de/10-years

Science in Transition

We live in the Digital Age. Our communication is changing rapidly, working procedures at companies are restructured, everything is going digital and is constantly interconnecting. This evolution effects all aspects of life – something that applies to research and development as well. This is why we asked scientists at the HZG:

What does digitalization mean for your research?

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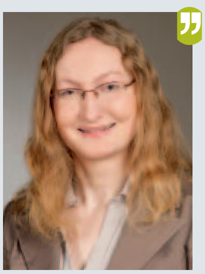
Dr Volkan Filiz

head of the Department for Polymer Synthesis, Institute of Polymer Research

What digitalization means for both me and for my colleagues in the Department of Polymer Synthesis is that we can synthesise our monomers and polymers in a more targeted manner in the future. The later membrane properties can possibly be predicted through modelling of material properties. Digitalization will allow us to generate more data in the future and use it, for example, for further polymer syntheses. I, however, also see a great danger, particularly in predicting material properties; simulation and modelling should be done with great care.



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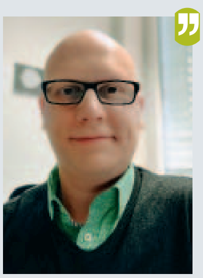
Linda Baldewein

scientist in the Department for Modelling and the Assessment of Coastal Systems, Institute of Coastal Research

My colleagues and I are creating a digital infrastructure for the Institute of Coastal Research: the Helmholtz Coastal Data Center (HCDC). This center will facilitate open and long-term access to research data and results. The quantity of data in coastal research has become increasingly immense in recent decades, and we wish to make this data available for science using innovative methods. Due to digitalization, cloud solutions are likely to increase in the future for data access and computations. The HCDC's Coastal Cloud, most likely to emerge within a few years, will contribute to the further digitalization of the Institute of Coastal Research.



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Dr Sarkis Serge Gavras

scientist in the Department of Magnesium Processing, Institute of Materials Research

Digitalization of research can assist with the production of artificial neural networks, which can be used to model or predict outcomes. This means the greater the amount of data that can be digitized the more accurate the model will be. This can and has helped to cast specific alloys which have properties that improve upon those that already exist. In the future, with the help of digitalization, it may be possible to accurately predict properties of materials provided the models used are accurate and can support real life results. This in turn will save time and money by narrowing down the selection of alloy compositions before we produce them.