in2science

The Magazine about People with Ideas

#6

Test the storm • The godfather of magnesium
Re-thinking robotics • Sleepless at the microscope
How scientists unravel the behaviour of materials

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Relevant future questions! Answers from science?

**We asked scientists at the HZG the following questions:
Which relevant issues are you focusing on?
What is the objective of your work?**

Elisabeth Viktor
(Climate Service Center Germany)

Climate Services is a relatively young scientific discipline. Our aim is to effectively integrate climate research results in decision-making processes of business and administration and to find suitable formats to achieve this. A wind power company, for instance, needs to know where to place its turbines for optimal energy production, both today and in the future. To solve such issues, we develop and use scientific models and collaborate closely with industry partners. Relevant knowledge about climate change is important for society in order to better assess the risks and hazards related to climate change and to provide solutions for adaptation.

Dr Jörg Hammel
(Materials Physics)

I am a beamline scientist. That means that, on the one hand, I support external groups in their experiments and, on the other hand, I advance our research projects in computed topography. We use the largest X-ray source in the world, which provides a very special X-ray light in order to get a glimpse inside objects, which is not possible using any other method. Using this process, we see into the micro- and nano-world of materials or objects. And not just in two dimensions, but truly three dimensionally. That means we can depict objects virtually on the computer and examine them non-destructively. This plays a role in many scientific disciplines, not just materials science, but also the life sciences, such as medicine, biology, archaeology and geosciences.

Dr Maria Balk
(Active Polymers)

In my research, I focus on the design of hydrogels which show a shape-memory effect. In this phenomenon, a material with a certain original shape can be temporarily turned into another shape through deformation. Subsequently, this temporary shape of the hydrogels can be fixed. By application of an external stimulus, I can reproduce the original shape. These materials are particularly important for biomedical applications, for example, as intelligent implant materials. On the one hand, they are able to imitate the mechanical properties of soft, physiological tissues, and on the other, they can be inserted in the body via minimally invasive surgery by using the shape-memory effect. Here, a small incision can be made in the human body and the material can be inserted in a compressed shape. Then, once it's in the body, it can return to the required original shape after application of an external stimulus.

Dr Jan Bohlen
(Magnesium Innovation Centre MagIC)

I work with wrought magnesium alloys and I try to use the toolbox given to us by nature to develop alloys and improve properties for application as lightweight construction material or as a degradable biomaterial. With magnesium, our cars will be lighter, use less fuel and exhaust emissions will be reduced – a highly topical advantage for society. On the other hand, magnesium corrodes at high rates and is therefore interesting as material for biodegradable implants. This means an implant can be inserted into the body during a surgery, but no further operation is required for its removal as it will vanish naturally after fulfilling its function.

Ina Teutsch
(Systems Analysis and Modelling)

The aim of my work is to discover why extreme waves form. After all, only when you know the causes is it possible to predict the likelihood of such rogue waves. With this kind of prediction, you could protect a great many people from being affected by these extreme waves. The exciting thing about rogue waves is that there have actually been sightings for centuries, but the opportunity to prove them is relatively new.

Dear Readers,

Relevant future questions! Answers from science?

– this is the motto of the annual Helmholtz-Zentrum Geesthacht conference of 2018.

The scientists at our centre take on major challenges every day: They are working on finding solutions to problems that concern us as a society. Because only if we ask ourselves these questions can we find sustainable ways to attain a future worth living. Knowledge is growing rapidly in the field of research – but the complexity of the numerous issues is increasing at least as quickly. To find out what researchers at the HZG are currently working on, have a look at the statements on the inside covers of this issue of in2science.

This issue particularly focuses on the biomaterials research conducted at our site in Teltow near Berlin. The Institute of Biomaterial Science focuses on multifunctional, polymer-based biomaterials, for example, for regenerative medicine. In our photo story you can see how so-called actuators are produced – and in the infographic we explain how they work. Barbara Mazzolai from the Italian Institute of Technology explains in an interview what soft robots are and how they are connected to biomaterials.

In coastal research, many researchers are dedicating themselves to the topic of offshore wind turbines. Three of them present their projects in *in2science*. These include, for example, a huge dataset that allows plant operators, shipping companies and shipyards to better plan.

Christina Krywka from HZG and Jozef Keckes from Montanuniversität Leoben met at a beamline at the German Electron Synchrotron and discussed about their joint projects. The two physicists study the behaviour of materials with a method not used anywhere else in the world: a combination of X-ray diffraction and nanoindentation.

The Portrait section presents Karl Ulrich Kainer, Institute Director in the field of materials research, and Johannes Bieser in coastal research. And of course, you can read about exciting news on current research findings in the “News from the Centre” section.

We hope you find the research presented in this issue fascinating and insightful.

Editorial Staff

We are pleased to present the sixth 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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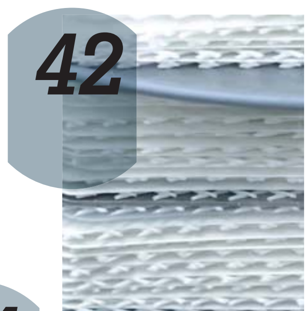
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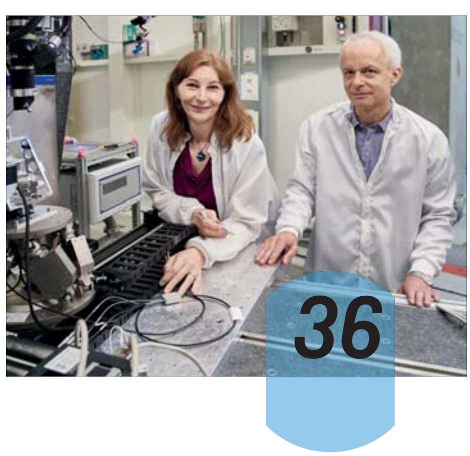
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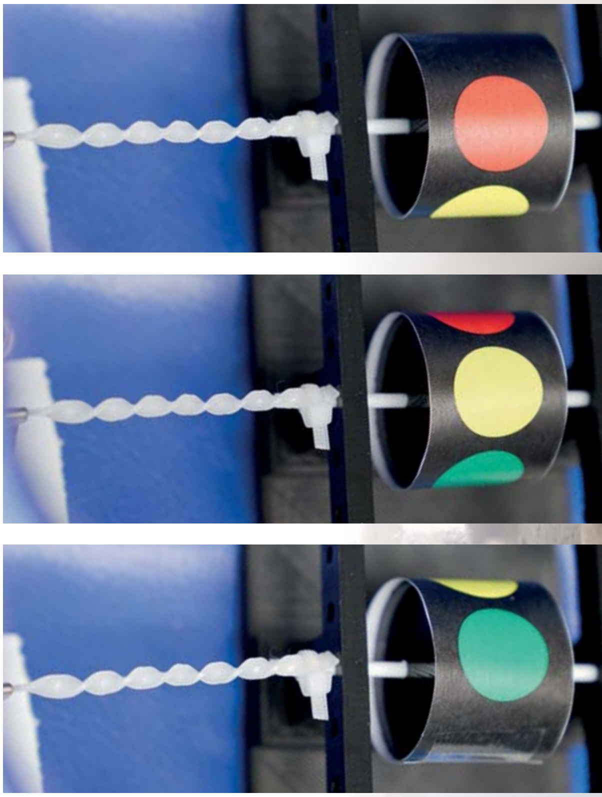
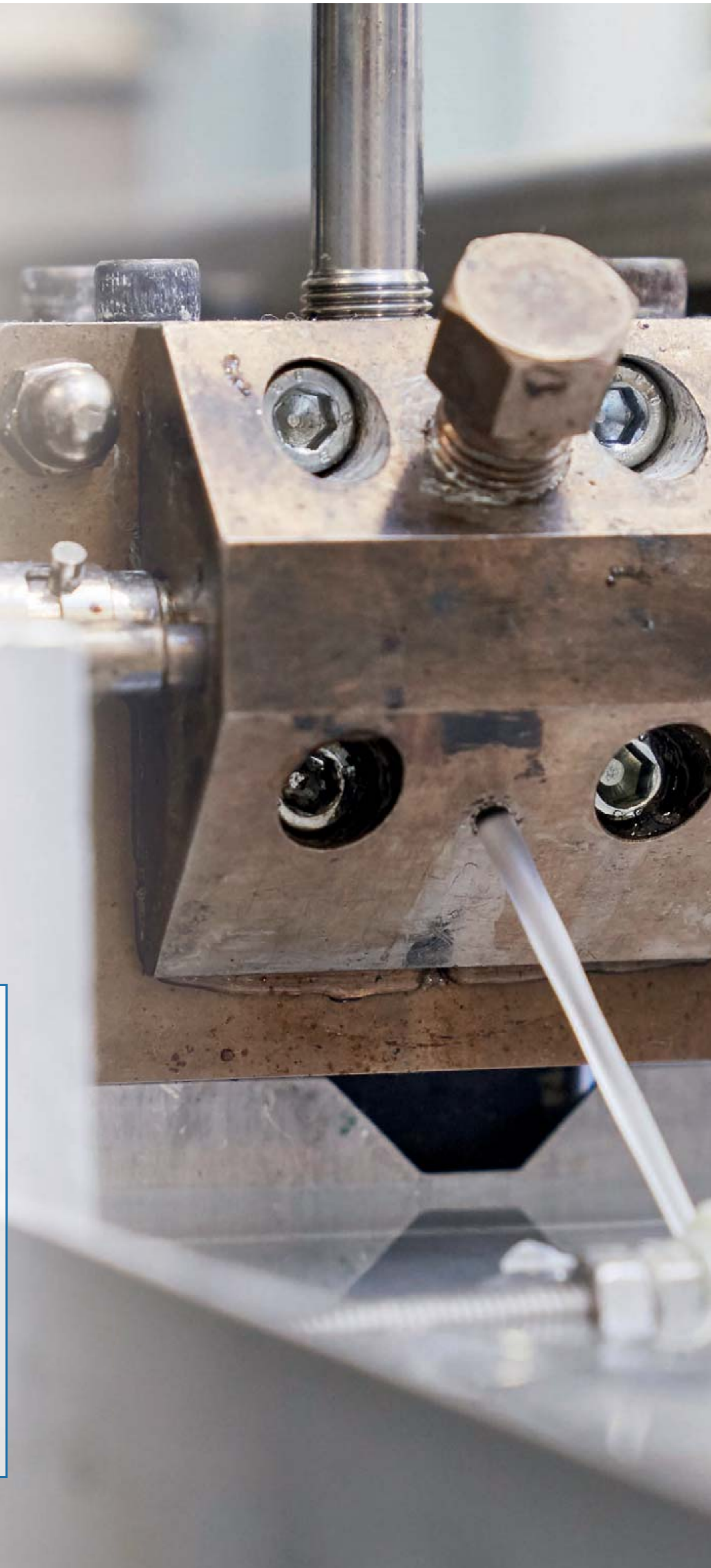


A stepwise back-and-forth motion between different stages, as, for example, in the operation of traffic lights, is of high significance in numerous technical applications. In this demonstrator the polymer actuator drives the traffic light, which can switch between red, yellow and green in a stepwise manner. The work is based on the publication of Muhammad Farhan et al. (see info box below).



Soft, stepwise responding actuators

A thermo-sensitive polymer actuator able to perform reversible shape change sequences step by step while heating and cooling is applied, has been realized recently. Accordingly, the shape switching occurs in separated stages, allowing the movement to temporarily pause, even though the temperature changes continuously. This is achieved by crosslinking a mixture of two industrially used polymers with well separated melting and crystallization temperatures. The ability to stop the motion without applying an additional external trigger or antagonist represents a new level of complexity in movement options for soft actuators.

Noncontinously Responding Polymeric Actuators, ACS Appl. Mater. & Interf., 2017, 9, 33559-33564.

Actuators: Shape-memory polymers with the ability to switch back and forth

Scientists at the Institute of Biomaterial Science in Teltow teach specific polymers, so-called shape-memory polymers, to move. In order to, for example, turn or bend a lifeless plastic strip or filament, researchers use various signals, such as temperature or magnetic field, as triggers for the movement.

This effect is based on the programmability of such polymers, which at the molecular level consist of netpoints and switching domains. By utilizing specific material properties, the polymers are instructed when to change their shape. So far, only a one-way-effect was feasible, as it is known from heat shrinkable polymer foils or tubes.

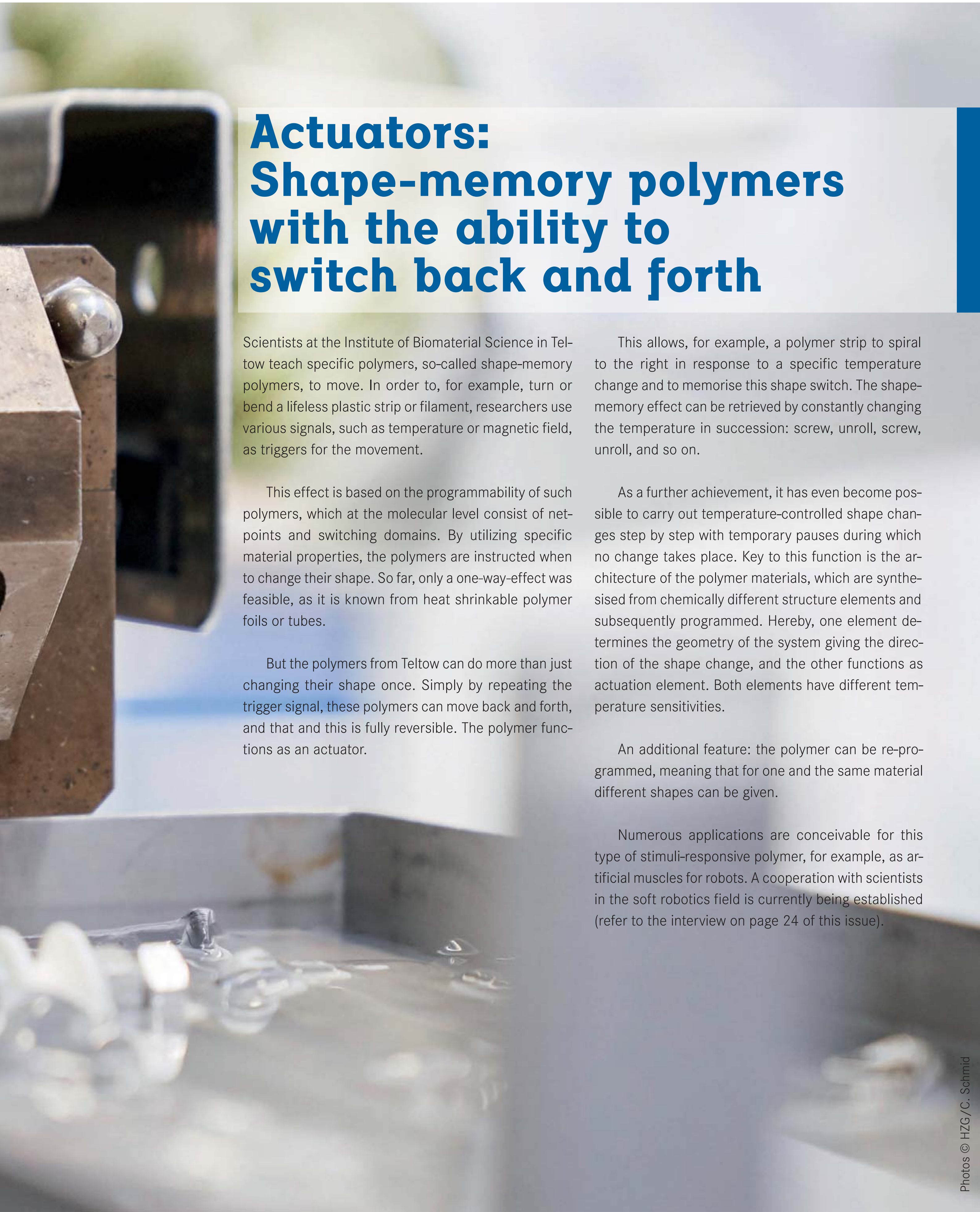
But the polymers from Teltow can do more than just changing their shape once. Simply by repeating the trigger signal, these polymers can move back and forth, and that and this is fully reversible. The polymer functions as an actuator.

This allows, for example, a polymer strip to spiral to the right in response to a specific temperature change and to memorise this shape switch. The shape-memory effect can be retrieved by constantly changing the temperature in succession: screw, unroll, screw, unroll, and so on.

As a further achievement, it has even become possible to carry out temperature-controlled shape changes step by step with temporary pauses during which no change takes place. Key to this function is the architecture of the polymer materials, which are synthesised from chemically different structure elements and subsequently programmed. Hereby, one element determines the geometry of the system giving the direction of the shape change, and the other functions as actuation element. Both elements have different temperature sensitivities.

An additional feature: the polymer can be re-programmed, meaning that for one and the same material different shapes can be given.

Numerous applications are conceivable for this type of stimuli-responsive polymer, for example, as artificial muscles for robots. A cooperation with scientists in the soft robotics field is currently being established (refer to the interview on page 24 of this issue).



Fabrication of actuator material

First, the polymers, which are the building blocks of the actuators, are synthesised. The so-called ring opening polymerisation is conducted in stirrer reactors at the Teltow Up-Scaling Laboratory. The synthesised polymers are then dried and crushed into powder.

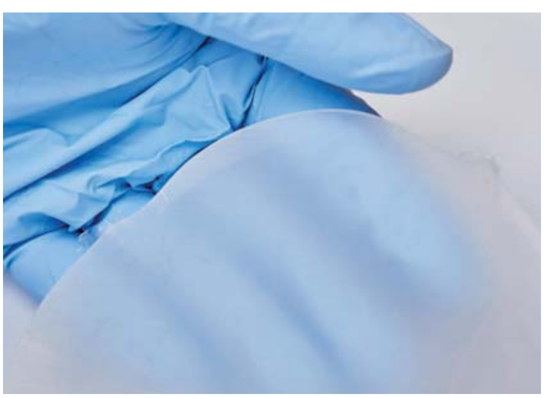
Standing, from left to right:
Dr Karl Kratz, Dr Ulrich Nöchel, Dr Maria Balk,
Prof Dr Andreas Lendlein, Dr Tobias Rudolph;
seated, from left to right: Dr Marc Behl, Dr Oliver Gould

Photos © HZG/C. Schmid

Blending starting materials

To obtain the actuator material, two polymers are mixed and molten together to form a blend, which is then extruded as a strand. This strand is subsequently crushed into granulate so that any actuator shape can be created.

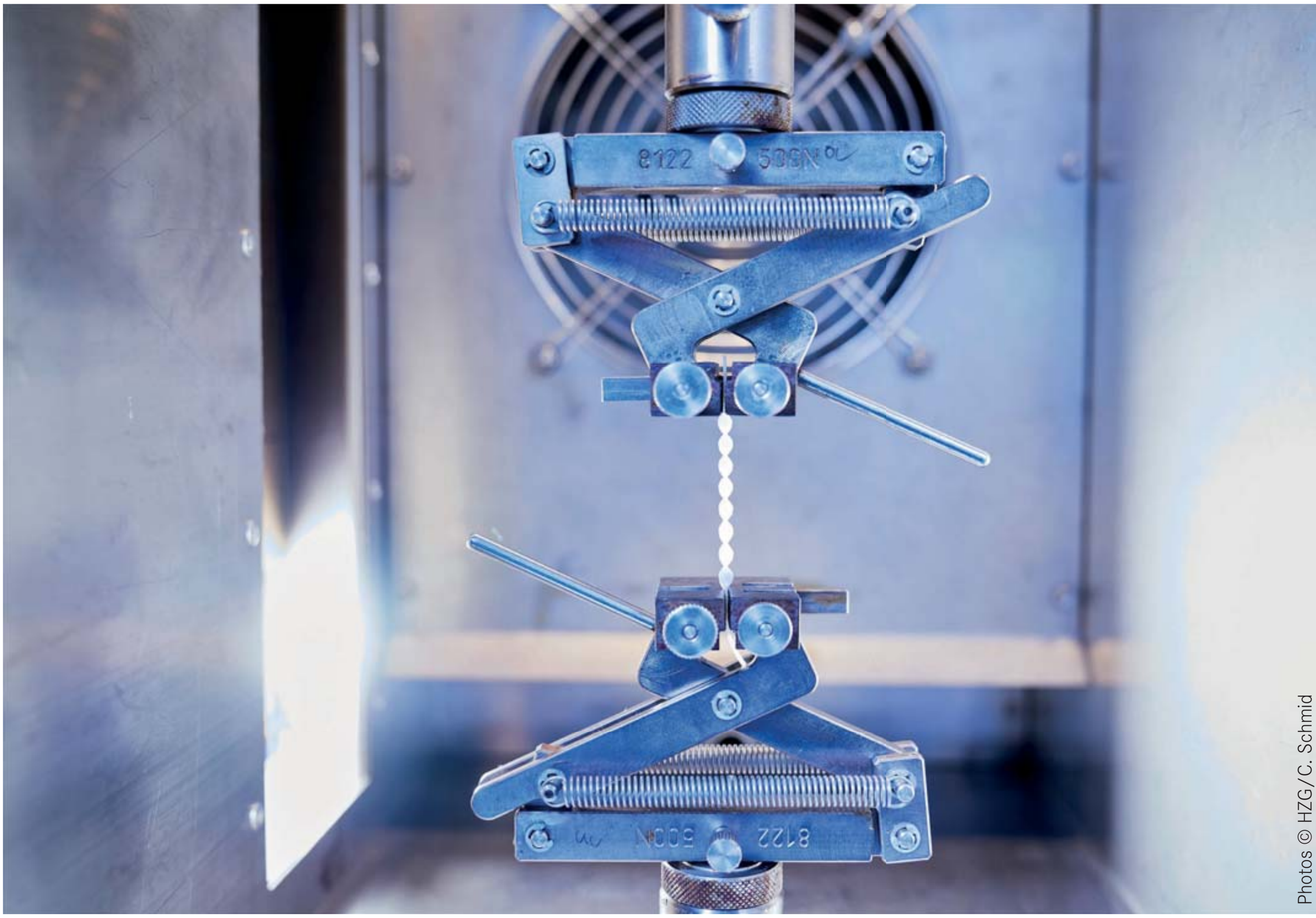
Photos © HZG/C. Schmid



Shaping

Materials researchers use the press to produce a thin film from the granulate. In order to obtain a uniform actuator material, several parameters in this shaping step must be carefully considered i.e., temperature, quantity of polymer granulate and process duration.

The quality of the resulting material is then checked by Teltow scientists, for example, by measuring the thickness of the foil (see picture on the left).



Photos © HZG/C. Schmid

Various shapes are punched out of the polymer film in which the required shape change can be programmed. Here, for example, a strip was clamped into a tensile tester, heated above its melting temperature and twisted unidirectionally by applying a defined rotation. On cooling, the strip is now programmed and can readily switch from its straight to its twisted form.

Actuation performance is measured using an extensive number of switching cycles. Teltow scientists could show that these cycles are repeatable many hundreds of times. (For more information on the concept of actuator programming, refer to the graphic on page 22).

Look at the detail

Polymer actuators are further characterised at the nanoscale level with small and wide-angle X-ray scattering techniques. This determines the location and orientation of crystal structures within the polymer. A small sample of the material is displayed in the specimen holder (picture on the right).

You can find more photo features in our media library:

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Test the storm

Wind farms in the North Sea should lie at the centre of the energy revolution. How this may be accomplished is the focus of the coastal researchers at the HZG.

Autumn came to Germany with Elmar: the storm's low pressure system ended up dropping yearly temperatures ten degrees below average, rain came down hard on the land and stormy gusts roared on the North Sea. Not a good day for excursions. But a perfect day for maximum performance: because on this 22nd of October, the Elmar storm front allowed wind farms in the German Bight to produce 4,350 megawatt hours in just one day, the highest output for 2017. This represents as much power as can be produced on land by four to five very large coal-fired or nuclear power plants.

Over the past year German wind farms delivered a total of 18 terawatt hours of power from the open sea – that is more than the city of Berlin consumes in a year. Offshore wind power plants show more and more clearly what they can provide: The first German wind farm is only eight years old and today more than 1,000 wind turbines are turning in the North Sea. According to federal government plans, the capacity of offshore parks is to be increased to 6.5 gigawatt by the year 2020.

Scientists at the Helmholtz-Zentrum Geesthacht have been working on the subject for a number of years now to reach this target.

- Where, for example, can we expect constant strong winds and where should such facilities be built?
- How do the huge turbine rotors affect local airflows?
- And what environmental risks can we expect from above and under water structures?

Experts from various fields are collaborating on these questions to build the main research focus “offshore wind farms” at the Institute of Coastal Research.

Many surprising results have already been found: for example, environmental scientists could prove that the North Sea is noticeably less turbid around wind power plants because mussels attach to turbine pillars and filter the sea water. Oceanographers have developed a wind forecasting system which relies on marine radar images and allows extremely quick predictions (30 to 60 seconds). In the future, this will be very useful to offshore park operators to manage facilities. Social scientists also investigated how the pylons could gain more acceptance on land, where they are often perceived as visually unpleasant - their studies even involved acceptance among such diverse groups as surfers, fishermen and staff at local tourism offices.

Many research projects focusing on offshore windfarms are completely independent but take inspiration from each other. Today, their colleagues‘ current analyses are used to determine, for example, where environmental technologists take their water samples.

Three experts at the Helmholtz-Zentrums Geesthacht present their perspectives on the power stations of the high seas for *in2science*. They discuss about their sense of achievement and setbacks in the research towards the energy revolution.

Author: Jenny Niederstadt

You can find more information online:

www.hzg.de/windparks

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Dr Beate Geyer:
Our data provide the ideal timeframe for construction of the facilities

It takes many months for the super computer to create our simulations. After all, it includes the climate data of the past 70 years. Once they are calculated, simulations provide definite data that is crucial for the building of wind farms. For example: which locations provide enough wind, but not too much and not too often? How strong are the waves in the worst-case scenario? When are there reliably calm phases, for example, for maintenance?

Answers to these questions are provided by the data set coastDat, which enables precise wind, temperature and sea condition analyses of a twelve-kilometre North Sea grid. That way, we can estimate the climate conditions for locations for which we do not have original measurement data.

This information is extremely important for the operators of offshore facilities. Our data does not quite determine the location of the wind farms, but rather the extent of the calm construction window because the constructors need calm seas to build. The facilities are huge, some of the rotors have a diameter of 170 meters. Loading in the harbour or building at open sea is much too dangerous during strong waves.

This is why coastDat predicts the ideal time corridors within a year, which have previously coincided with preferably low wave heights. This is not only about the crew's safety, as long waiting periods of the usually chartered transport ships in the harbour are also very expensive. Nearly all wind farm operators in the German North Sea therefore use our data for the building and planning of their facilities.

Today, nearly every other coastDat user is in industry, and yet the data set was originally developed for climate research. Such regional simulation results are much more exact than the usual global climate data. This is not only important for scientists, authorities, and offshore facility operators. For example, our data also helps with ship construction. With it, the shipyards can more precisely estimate which stresses a hull will have to endure.

And the development also continues for wind farms. Our data can determine when wind turbines on the high seas and on land collect a certain amount of energy and what energy solar panels collect during the same time period. This way, the electricity grid's supply on land can better be planned.

Tidal current and water level: The coastDat data set is based on numerical models. The portal has been providing scientific data for more than 15 years. It is used, for example, in the planning of offshore wind farms. ©DKRZ/HZG

© HZG/A. Reese

© HZG/J. Lippels

Dr Jeffrey Carpenter:

The sea also has its seasons

I have always been interested in water; this might be because I grew up in Canada, in an area full of lakes. I have also loved maths since my studies. In my area of expertise, fluid mechanics, I can connect these two passions. I am going out to sea for my projects, especially to collect data using robots. The robot glider's probes register the water's movements and measure its density and temperature completely automatically.

Back on land, I use that data to perform various simulations which document – and predict – the water's flow behaviour. This is important if we want to gauge how sea water will react, for example, to the wind power plant's foundation structures. Mechanically, they create barriers, around which the currents must flow.

I am especially interested in the water's stratification: almost all lakes and seas form certain layers, which differ in temperature and density, some of them very strongly. In summer, the sun heats up the North Sea surface layer while the bottom waters remain cool. However, in winter, cooling and storms produce heavier waters that will mix with the cooler bottom waters left over from summer.

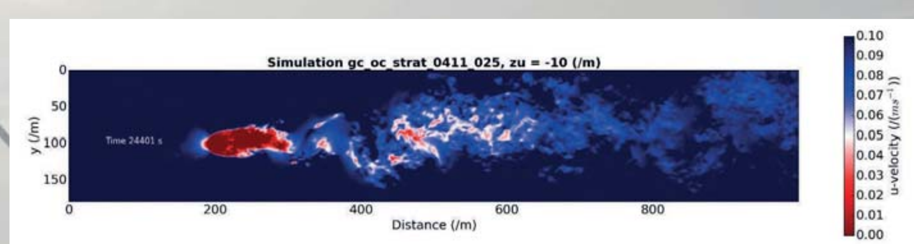
So, the sea also has its seasons. And its seasonal layering is extremely important for the animals living there because it enables them to, for example, deliberately seek zones with especially large amounts of nutrients, light, or oxygen.

Furthermore, there is usually a dividing zone between the layers called the thermocline. It is relatively quiet and stable, by contrast, at the sea surface, there is often turbulence due to winds and at the bottom due to friction. The thermocline is like a buffer between these turbulent zones.

This finely balanced system could be disrupted close to wind power plants, because their foundation structures cause the normally quiet intermediate zones to whirl up and mix.

For the past four years, I have been researching what effect turbulence has. Positive effects are conceivable, say, because nutrients from the lower levels are lifted and fish will find more to eat in the higher zones. But we must also be aware of the negative consequences because our research shows that the layers react sensitively; one storm is enough to mix the North Sea down to the seabed.

Wind farms do not transfer this enormous force and yet, in the future, the presence of wind farms could be vast. With many more structures built in the sea, effects relating to the water column could have much larger consequences.



The image shows a single moment of a large eddy simulation (LES). The view is from above at the water surface; the momentary movement is from left to right. Blue indicates a strong current and red a weak current. ©Jeff Carpenter/HZG

© HZG/C. Schmid

Dr Daniel Pröfrock:
Good ideas can also be harmful

I like working in the field out at sea. I enjoy these moments away from the desk and the laboratory, even though our journeys and campaigns are often exhausting. Most recently, we went out to the North Sea in mid-April, to sample water and sediments near offshore wind farms. Together with my team and in cooperation with our partners at the Federal Maritime and Hydrographic Agency BSH, we are investigating how the corrosion protection systems of the wind farms releases chemicals and if these have a negative impact on the marine environment – a topic on which there is currently barely any available information.

Wind turbines are usually protected from sea water, above and under water, in two ways: their surfaces are protected with coatings consisting of a wild cocktail of chemicals, including many substances that could be harmful for the environment while their foundations are equipped with so-called galvanic anodes. Multiple tons of anode materials, which mostly consist of an aluminium alloy, protect the actual structure from corrosion. This maintains the stability of the structure over the entire projected lifetime. Effectively, the anode sacrifices itself, but therein it releases problematic alloying elements, for example highly toxic cadmium and lead.

Ships also use such anodes. But it is completely unclear what the consequence to the surrounding marine environment might be when such protective systems are applied to a much larger extent in North Sea wind farms. Therefore, we examine the sea water and the sea floor around the foundations. We want to know which pollution and risks to expect around the pillars in the long term.

We will take the HZG research ship *Ludwig Prandtl* out there again this year to deploy and to recover so-called passive sampling devices. These will have been deployed for one to two months at multiple locations on the wind farm and will provide data about the water's average chemical composition during the deployment period.

We also want to collect mussels, which will be deployed in parallel with the passive sampling devices using a specific cage system. This system was developed at our institute to test for possible accumulation of certain harmful substances in their tissues. Our findings will help our project partners to develop suitable guidelines for the wind farm operator or the future approval process of new offshore parks:

- Which coating system should be permitted for use?
- Where and how often should the water quality be tested?
- How dangerous are current galvanic protection approaches?

After all, there are alternatives: the wind turbine foundations could be protected by so-called impressed current corrosion protection systems. In this case, facilities are slightly charged with an electrical current, which interrupts the corrosion processes. Such systems are used to protect pipelines and bridges and some wind farms also use this approach. This method has proved reliable, but it is expensive.

If we want to ensure that offshore facilities actually provide clean power in the future, we must make sure that wind farms do not create other environmental problems. After all, good ideas can also be harmful.

Photos © HZG/A. Reese

Images above: Sediment is lifted from the seabed with a box grabber.
Right-hand image: The water sampler is lowered into the water. It automatically collects seawater at different depths.
Back on land, the samples are examined in the laboratories in Geesthacht.


www.hzg.de/magic
The Godfather
Karl Ulrich Kainer

Prof Karl Ulrich Kainer
Head of the Magnesium Innovation Centre MagIC at HZG.
He is currently the most influential magnesium researcher in the world.
He plans to enter retirement on February 1st, 2019.

The godfather of magnesium

What motivates magnesium researcher Prof Karl Ulrich Kainer?

Karl Ulrich Kainer has little time to spare. He's just returned from China, where the world's largest magnesium factory has recently opened; he was invited to say a few words at the opening. Now he's sitting at booth E46 in Hall 5 at the Hannover Messe and waiting: the minister-president of Schleswig-Holstein has announced he'll be visiting at two o'clock this afternoon.

At HZG, Karl Ulrich Kainer is head of "MagIC", the Magnesium Innovation Centre. But out in the world, he's been given other titles: In German-speaking countries, he's known as the "Magnesium Pope", while in China and the USA, he is the "Godfather of Magnesium". In 2018, a research conference held a complete symposium in his honour. How does one accomplish such a thing?

When Karl Ulrich Kainer speaks, he does so in the melodic accent of North Rhine-Westphalia: "My mother actually wanted me to become a tax official," he says. And so, after completing his secondary education, he attended business college. "But I quickly realised that I just wasn't cut out for it." Instead, he completed a one-year electrical engineering internship, and after completing his vocational diploma, attended the Osnabrück University of Applied Sciences. "Having learned a trade is something I've always benefitted from. Between semesters I'd work as an industrial electrician: laying cables, creating circuits, fixing machines – it was always fun for me." Such affinity for a technical trade goes hand in hand with scientific curiosity. After his undergraduated studies in electrical engineering, he first encountered metallurgy and materials technology, which he pursued in his studies. During his degree studies, instead of seeking a job in industry, Karl Ulrich Kainer went to the Claustal University of Technology, where he studied Materials Science. He worked with steel, copper, aluminium – metals became his bread and butter, one might say.

The element magnesium came to his attention more or less by chance. "Back then, it was a topic that the automotive industry was very interested in," says Karl Ulrich Kainer. Of course it was: magnesium is extremely light, but also sturdy; it doesn't cost much to recycle, and as a natural resource, it is available in almost unlimited quantities. This is why by the 1990s at the latest, the automotive industry saw great promise in magnesium – less weight, lower fuel consumption, fewer CO_2 emissions. In one of his first projects, Karl Ulrich Kainer worked with BMW to develop a fibre-reinforced magnesium component for a Formula 1 motor. "It wasn't until years later that I found out the part I developed was used in at least one race." His complete specialisation in magnesium would come with his postdoctoral qualification in 1996 and his appointment to Geesthacht in 1999, when he was 46. On January 1st, 2000, Karl Ulrich Kainer became head of his institute in Geesthacht. "Back then, I was my only employee." Bit by bit, he would be joined by doctoral candidates, full-time employees and division heads; his institute even got its own building.

When it comes to the development of sheet magnesium, Karl Ulrich Kainer sees MagIC as "number one in the world" today. This makes it all the more tragic that the necessary casting and rolling facility was destroyed in a fire in the summer of 2017. "Once it's rebuilt, it's going to be an 'Industry 4.0' facility, equipped with sensors and will be capable of digital operation. So perhaps there's a silver lining to the whole affair after all." Another topic currently undergoing research at MagIC that he finds especially exciting is magnesium surface coating. Magnesium is "highly reactive", so how is it possible to use it to coat surfaces without corroding? Karl Ulrich Kainer believes this matter will have "extreme implications for the future", given that whoever finds out how to protect magnesium from corrosion will certainly be able to do so for other materials. So how was he himself able to become the elder statesman of magnesium research?

> **A lot of it had to do with luck, he says. You make decisions without knowing if they're ever going to bear fruit; you just make them because you think it's a brilliant topic.**

Aside from a fascination with the subject matter and a certain perseverance, there may have been a third key factor: Karl Ulrich Kainer is a networker by nature. He organised a magnesium conference for the first time back in 1998, and today, members of the scientific community meet every three years: "That would be around 600 people from all over the world." Listening to colleagues, speaking openly with them, and about issues that currently have no solution at that – Karl Ulrich Kainer's guidelines sound like they've been taken straight from the handbook of a Silicon Valley start-up. Evidently, they worked just as well 20 years ago as they do today.

On February 1st, 2019, the Godfather of Magnesium plans to enter retirement. "I've got two options," he says, "either the gradual phase-out – or going cold turkey." Once, at the send-off for one of his colleagues at HZG, another colleague showed a picture of the steam locomotive that, in 1895 at Gare Montparnasse in Paris, ran through the buffer stop, across the platform, and through the wall of the station, where it landed on the street, looking like a beached whale. The warning, Karl Ulrich Kainer says, got through to him: "That's definitely not how I want to feel on my first day of retirement." He intends to stay on at HZG as a consultant, which may well help him bring the wild ride that has been his career to a somewhat gentler stop.

Author: Jochen Metzger

Soft actuators

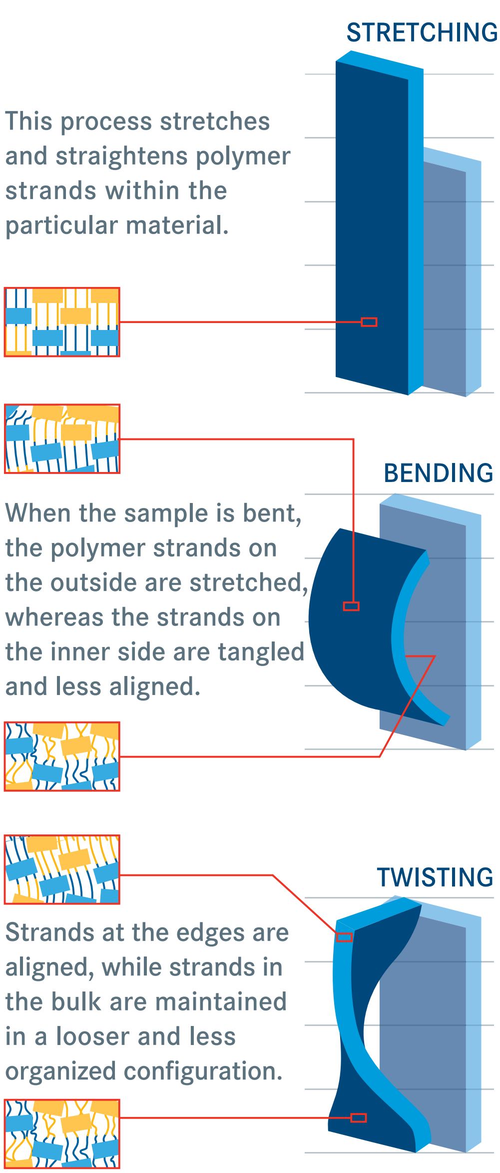
Storing shape information in a polymer and recalling this shape once has already been achieved in the form of classical shape-memory effect. But scientists at the HZG in Teltow have developed a completely novel way to repeat such movements hundreds of times. Even entire sequences of movements can be repeated. What exactly happens in the polymer and why it moves in a particular manner is explained on this double-page spread.

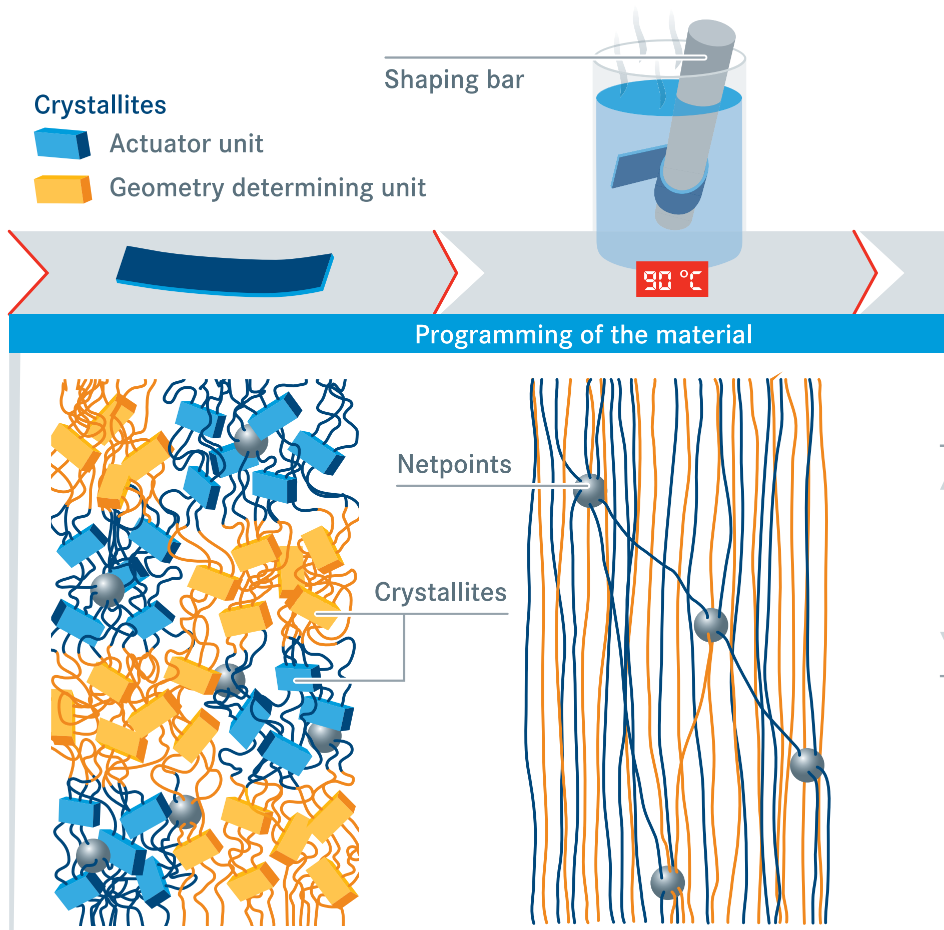
Actuation

By appropriate programming of the polymer, any type of movement can be performed. Elongation, bending and twisting can all be combined, to create complex motion sequences.

Shape-memory

Here we show how a polymer is programmed and set in motion by means of twisting action. The same principle applies to every type of movement.



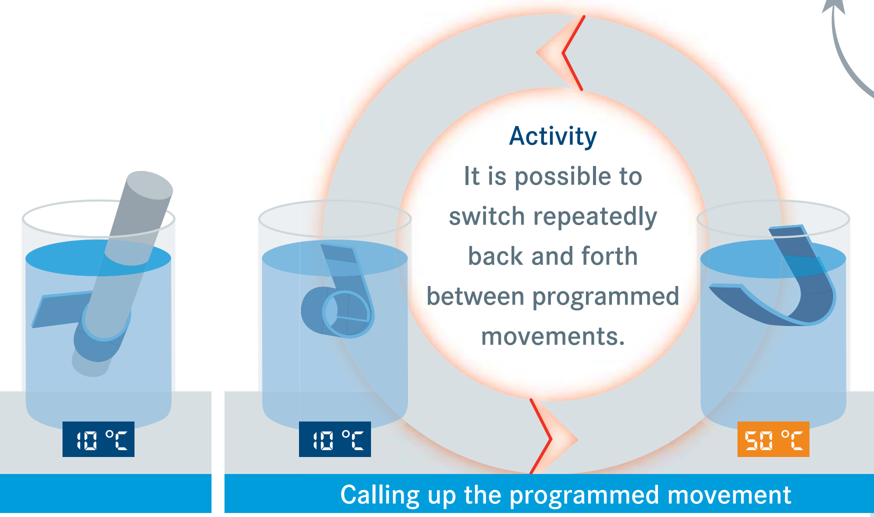


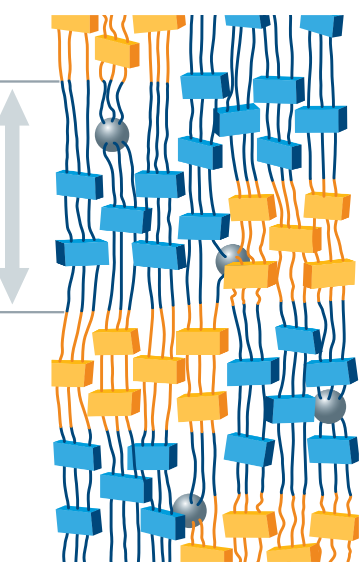
Starting material

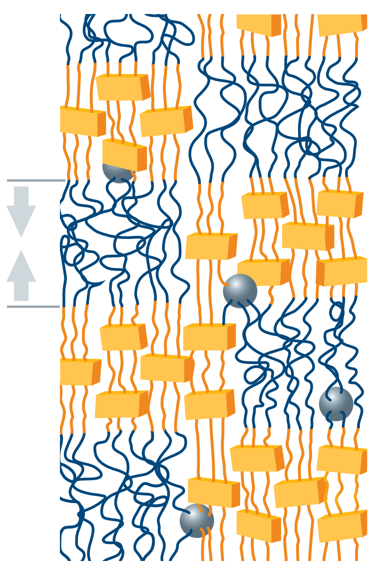
In the starting material polymer chains are not ordered. Only netpoints provide a structure.

Programming

When immersed in hot water at 90 °C, crystallites melt and polymer chains can be reoriented by deformation.







Shape A

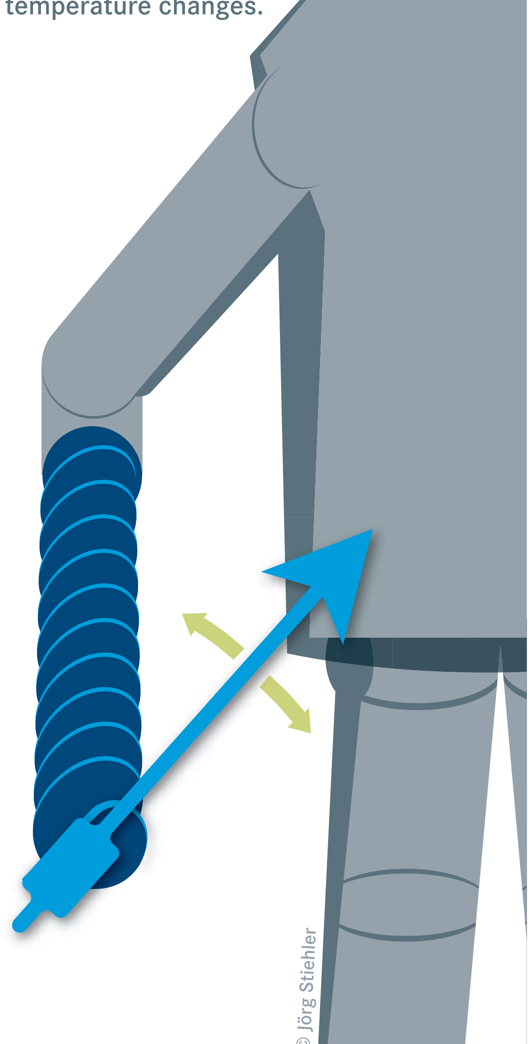
Crystallites are formed through cooling. This defines the specific shape.

Shape B

Water at medium temperature partially melts some of the crystalline blocks. This changes the shape. The sample can now switch back and forth between shape A and B.

Twisting arm

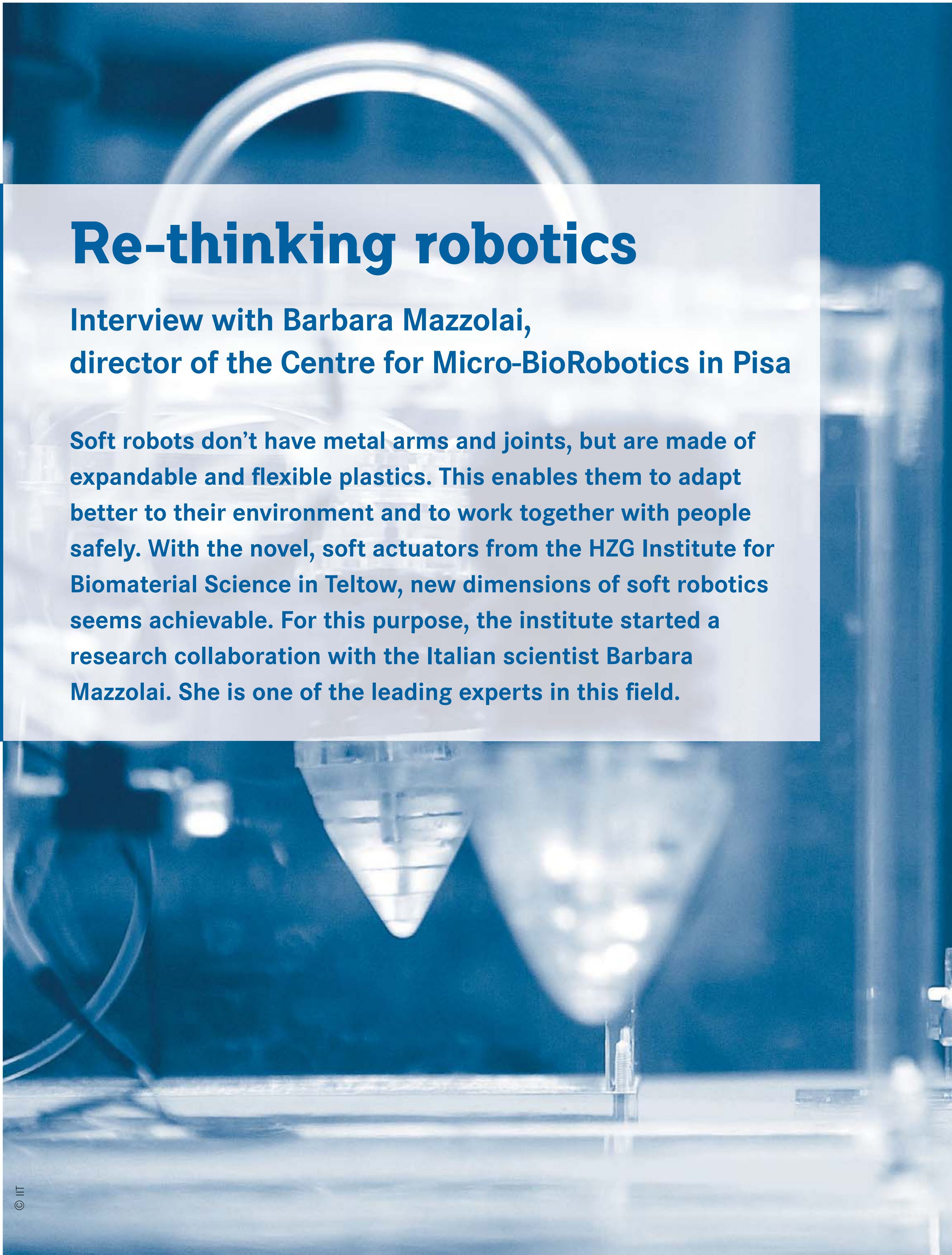
Meanwhile, even actuators, which move in a stepwise manner have been created. This means that movement can be temporarily paused despite continuous temperature changes.

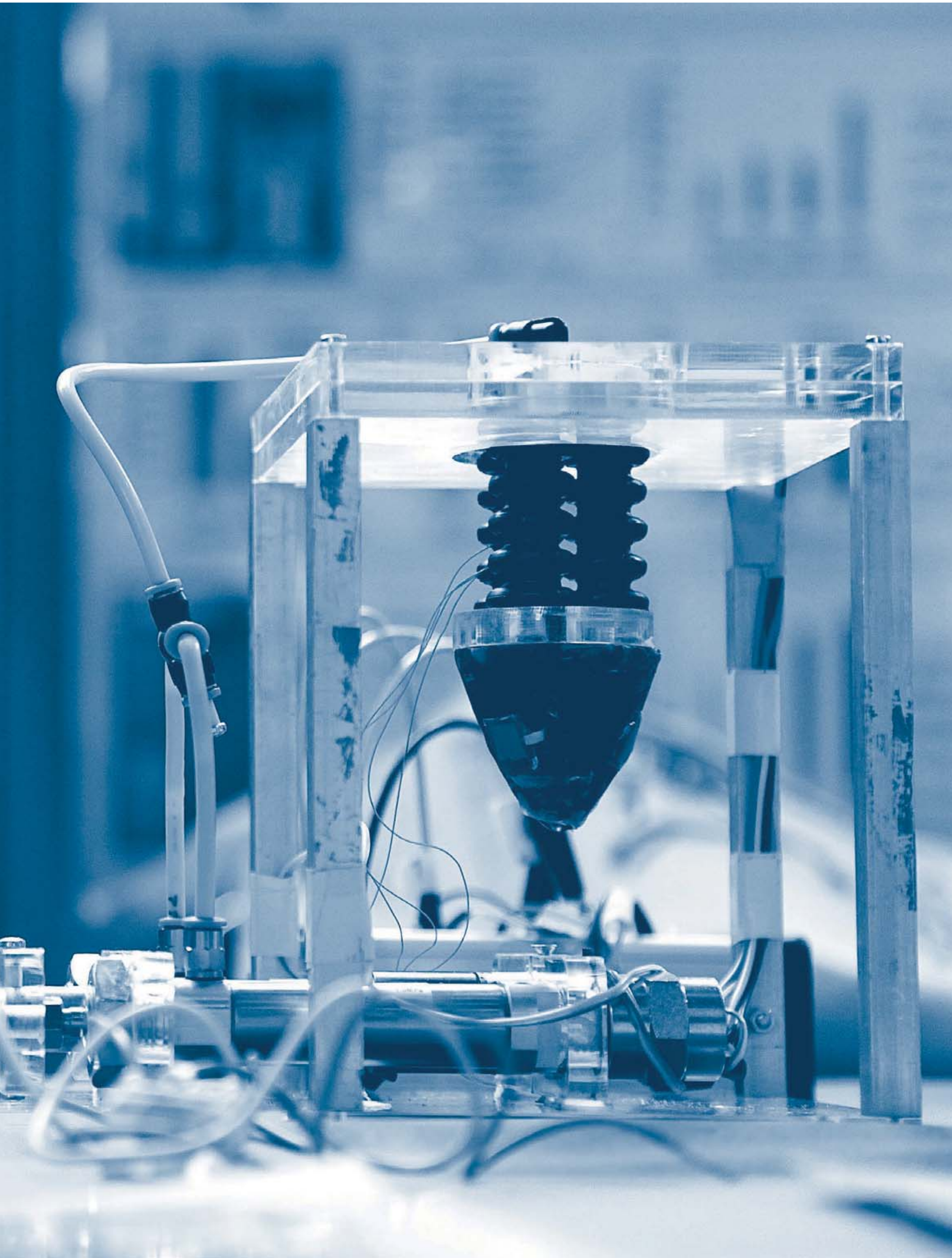


Re-thinking robotics

Interview with Barbara Mazzolai, director of the Centre for Micro-BioRobotics in Pisa

Soft robots don't have metal arms and joints, but are made of expandable and flexible plastics. This enables them to adapt better to their environment and to work together with people safely. With the novel, soft actuators from the HZG Institute for Biomaterial Science in Teltow, new dimensions of soft robotics seems achievable. For this purpose, the institute started a research collaboration with the Italian scientist Barbara Mazzolai. She is one of the leading experts in this field.





The scientists at IIT have developed a plantoid, a robot that behaves and grows like a plant. It serves the investigation of biological and technological questions.

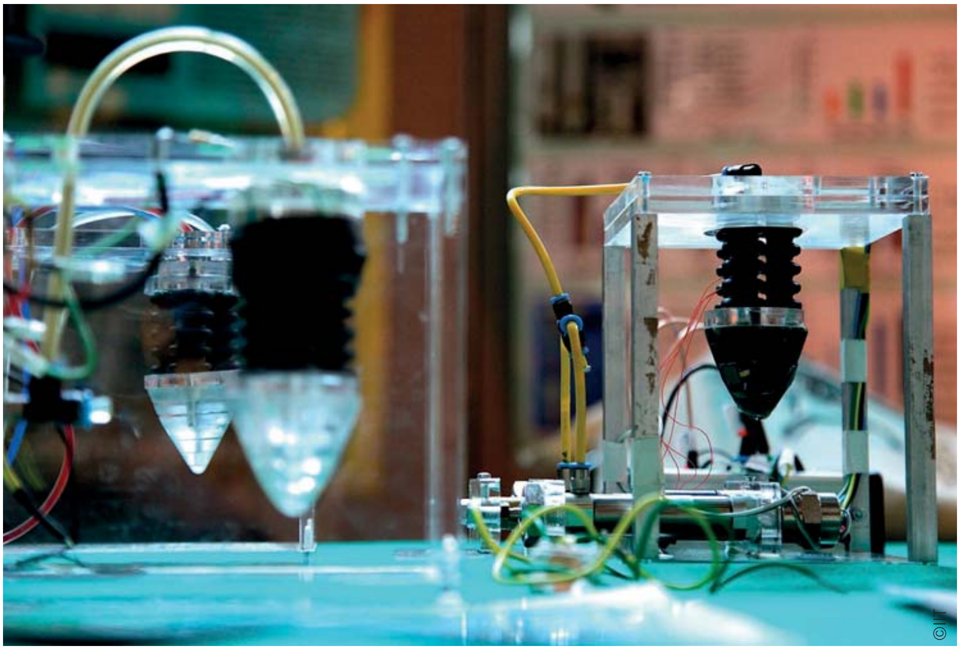
Ms Mazzolai, you and your team are working in the field called soft robotics. What does that mean – how are they different from normal robots?

Conventional robots have solid bodies and limbs and are made predominantly of hard materials, such as metals. As a rule, they are designed to operate in a structured, fixed environment, such as in an industrial factory. This means that for safety reasons, cooperation with humans is limited because the hard, fast-moving arms of the robot can definitely lead to injuries. Soft robots, on the other hand, are made of resilient, flexible plastics such as silicone - materials which recreate natural organic materials. Such robots have the ability to react more flexibly to their environment and their soft limbs allow them to work safely with humans. They cause no damage and could even be used inside the human body for medical purposes. Search and rescue robots are conceivable as further applications, as are small mobile machines for environmental monitoring.

What are the challenges in developing small robots? Which difficulties must be overcome?

The research field is still in its infancy and we still have some basic problems to solve. Control is a major challenge. We have to develop completely new mechanisms so that robots can move in a targeted manner. How can we combine different materials into one system and control them purposefully and reliably? And how can this system be combined with the right sensors? For this we need new materials that fulfil different functions and at the same time act as sensors and actuators. We take inspiration from nature to build robots which can cope with complex environments and adapt to new environmental conditions. Our aim is to fuse technology with biology. We have already achieved some initial successes: in 2012, for example, we presented a robot whose flexible arms were conceived based on octopus tentacles. Although we're still in the midst of the pioneering phase, industry is slowly becoming aware of the field and is starting to provide some funding support.

> **We take inspiration from nature to build robots which can cope with complex environments and adapt to new environmental conditions. Our aim is to fuse technology with biology.**



This is a close-up of a plantoid's roots. Each root extremity is movable, equipped with chemical sensors, sensitive to gravity and touch.

ABOUT:

Dr Barbara Mazzolai has headed the Centre for Micro-Biorobotics (CMBR) at the Italian Institute of Technology (IIT) in Pisa since 2011. After studying biology, she studied the influence of toxins on the environment and humans. In her PhD, she turned to microsystems technology for constructing tiny sensors, which can efficiently detect air and water pollutants. In order to develop mobile carrier platforms for these sensors, she became increasingly involved in what is now her current field, robotics. Barbara Mazzolai has since established herself as a leading expert in the field of soft robotics. These "soft robots" are inspired by octopuses, caterpillars and plants and are built using expandable, flexible materials.

You've recently started collaborating with the Helmholtz-Zentrum Geesthacht, with the group led by Andreas Lendlein from the Institute for Biomaterials Science in Teltow near Berlin. What is the goal of this collaboration?

Both partners have different, complementary skills. In Pisa, we have the know-how to build a soft robot prototype. The Institute of Biomaterials Research, on the other hand, has expertise to develop the adaptive materials for this robot. In order to be as effective as possible in the field as engineers, we have to work as closely as possible with materials research - we absolutely need to be exposed to the different visions and perspectives provided by other disciplines. As engineers we can't design robots all alone in our corner. We need input from other disciplines, such as biology, materials research and chemistry. This interdisciplinary collaboration is something new for us robotics experts. I find that very exciting because there are very few examples of such cooperation in our field.

Why did you decide to cooperate with the Helmholtz-Zentrum Geesthacht? What exactly do you seek from this new collaboration?

The challenge is to teach the new robots targeted and directed movements. To date, artificial tendons, for example, have been recreated by inserting wires or fine tubing controlled by air pressure into a silicone matrix. The shape-memory polymer actuators from Teltow promise significant improvements here. The polymer itself can function as an actuator which can be moved extremely accurately – and specifically responds to changing external conditions, such as temperature. The behaviour of the polymer is programmed into its design structure such that its movement range is predetermined to changing environmental conditions, be they increasing temperature or increasing humidity. Incidentally, plants that react to certain environmental stimuli with movement, for example, the Venus flytrap, work in a very similar way. By creating novel components with the new polymer actuators from Teltow and integrating them into our prototypes, we can significantly reduce the complexity of the systems.

https://mbr.iit.it/

In the future, new components for soft robotics will be researched together with the ITT and the Institute of Biomaterial Science.

Which projects will you work on together first? Which milestones are you aiming for?

Together with the Helmholtz-Zentrum Geesthacht, we want to introduce novel adaptive materials to robotics and use them to build our first prototypes. We are thinking of a robot with features from plants or a prototype that can hop and swim like a frog. Our long-term vision is that of robots, which can themselves reprogramme their actuators - much like a type of transformer, which independently changes its shape. Prototypes with self-healing properties and machines which can collect and store energy and are therefore largely self-sufficient are also feasible. To consolidate the fundamental research underlying such systems, we have recently applied, for example, for a Helmholtz International Lab with the Teltow Institute, where we want to build such components for soft robots which can actuate autonomously. We are ready for action.

What could the most important applications be?

We can conceive robots, which move skilfully and flexibly through unknown terrain and explore impassable areas. They could then use their sensors to search for toxins and pollutants and play important roles in environmental monitoring. Or they could search for survivors in disaster areas, such as where earthquakes or floods have occured. There are promising perspectives in medicine too. We are thinking along the lines of novel endoscopes for colonoscopy. Today's colonoscopy endoscopes can cause pain when their relatively hard tip hits the intestinal wall. With soft robotics, soft, flexible tips are totally feasible. In this way, the examination could be done much more gently and delicately.

Thank you very much for the interview.

The interview was conducted by science journalist and physicist Frank Grotelüschen.

New publication in Science Robotics

Prof Andreas Lendlein, who is conducting research on shape-memory polymer actuators in the context of soft robotics at his Institute of Biomaterial Science in Teltow, reports on their potential application in the scientific journal *Science Robotics*. Classic shape-memory polymers are able to selectively modify their shape when subjected to suitable external stimuli. These include heat, but also magnetic fields or light. The main limitation of the first-generation shape-memory polymers is their one way–one time switching character.

Some years ago, the breakthrough was achieved: The reversible switching of a shape-memory polymer be-tween two shapes could be realized – with several hundred repeats. These materials were named shape-memory actuators. These materials contain two sets of nanostructured units. One unit serves as an internal skeleton, which directs the movement, meaning it controls the geometry of the motion, whilst the other unit is responsible for actuation in two directions, i.e., bidirectionally. The desired shape of the polymer actuator can be programmed as well as reprogrammed. This enables a targeted expansion and contraction of shape-memory polymer actuators. Alternatively, once they have been reprogrammed, the actuators can bend themselves out of shape and then straighten themselves again. Or they can twist akin to an elastic band, only to return to their original state later. There are no limits to the variations.

To date, the institute has been focusing its research on medical applications, such as implants or healthcare technologies for age-appropriate medicine. In future, the new polymer actuator technology will also find application in the field of soft robotics.

"Fabrication of reprogrammable shape-memory polymer actuators for robotics", A. Lendlein, Sci. Robot. 2018, 3, eaat9090, DOI: 10.1126/scirobotics.aat9090

Watch a shape-memory actuator in action and listen to a podcast about the biomaterial science (podcast only available in German)

www.hzg.de/aktuatoren

ABOUT:
Prof Andreas Lendlein has been Director of the Institute of Biomaterial Science at the Helmholtz-Zentrum Geesthacht in Teltow since 2002, and is Professor of Materials in Life Sciences at University Potsdam.

His research interests in macromolecular chemistry and materials science are the creation of material functions by selective design and implementation of multifunctionality in polymer-based materials. His work gives special emphasis to stimuli-responsive polymers, especially shape-memory polymer actuators, biopolymer-based material systems and structured biomaterials. In his scientific work, Andreas Lendlein follows an interdisciplinary approach comprising chemical, physical, biological, pharmaceutical, and engineering principles to understand and precisely control, for example, processes occurring at the interfaces between materials and biological environments. The results obtained are forming the basis for the translational research on biomaterial-based regenerative therapies, controlled drug release systems, health technologies, and robotics.

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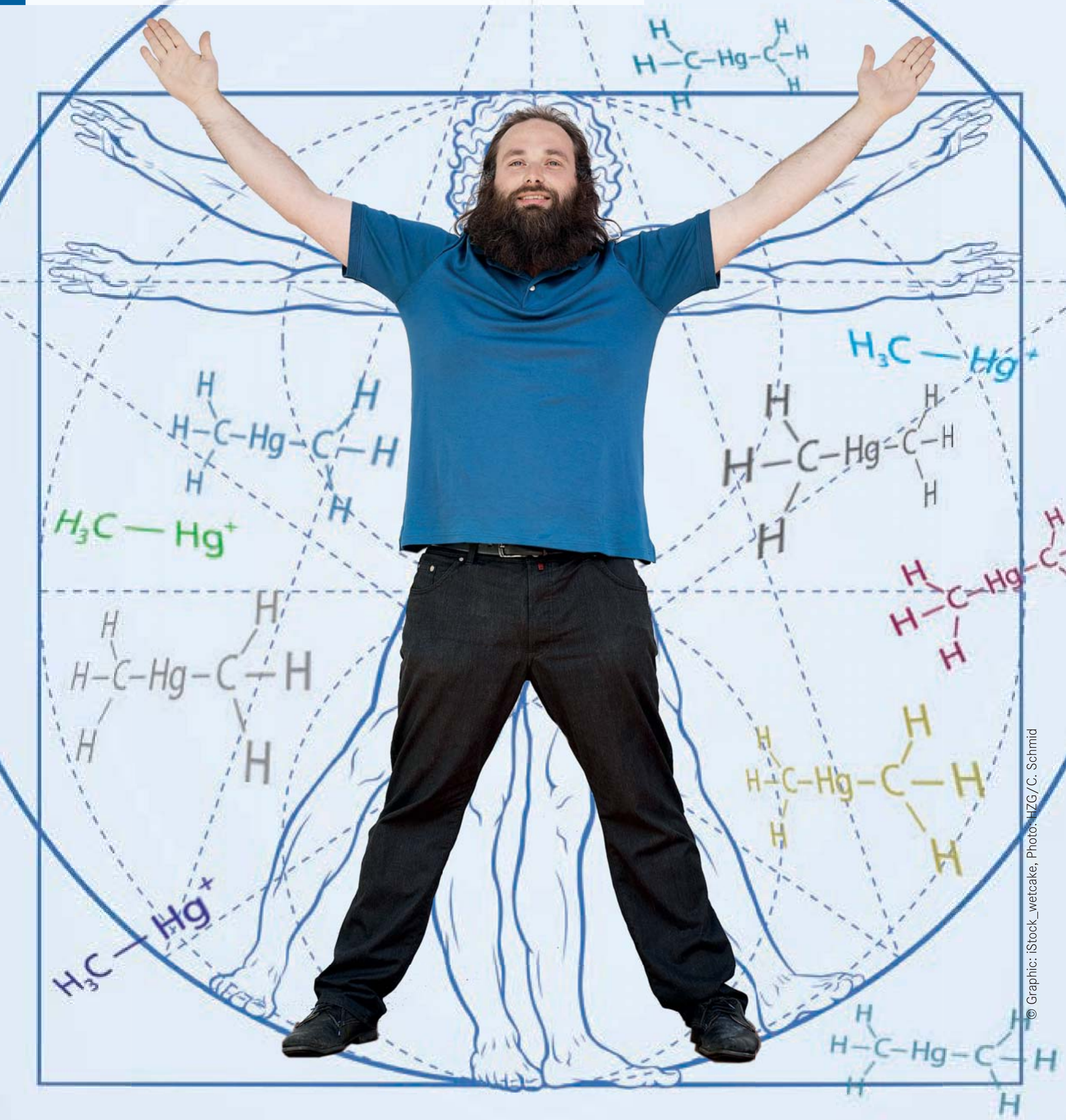
Andreas Lendlein studied chemistry at the Johannes Gutenberg University Mainz and received his doctoral degree in Materials Science from the Swiss Federal Institute of Technology (ETH) in Zürich. After research activity at the department of Chemical Engineering at the Massachusetts Institute of Technology, Cambridge, USA, he completed his habilitation in macromolecular chemistry at the RWTH Aachen University.

Exploring the vast expanse of science



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Dr Johannes Bieser –

works on matter transport and ecosystem dynamics at the Institute of Coastal Research

Johannes Bieser has a passion for science. That much is immediately obvious: “Aristotle, Gottfried Wilhelm Leibniz, Leonardo da Vinci – I’ve always been fascinated by the great polymaths, even as a child,” he explains; they knew so much, were well versed in many different fields. “That’s just not possible today; as a society, we’ve accumulated far too much knowledge and information for this.” Nevertheless, Bieser tries to connect as many different fields of research as possible in his work.

Johannes Bieser is originally from a small town in the Black Forest. After earning his Abitur (the German equivalent of A-levels), he really wanted to see what life was like in the big city – so he moved to Hamburg to complete his compulsory civilian service. “To me, it was just the coolest big city in Germany,” he says with a laugh. That he would be permanently living there with his family many years later is something he would not have guessed at the time.

Deciding what he would study at university was a huge challenge for him: from molecular biology to philosophy, to music – he considered it all. Eventually this young man from the Black Forest with many interests decided to go to Leuphana University of Lüneburg and study environmental science, a field that combines several disciplines:

> **To me, studying environmental science promised a chance to explore the natural sciences in a way that applied to society and policy.**

The 35-year-old first came into contact with HZG while still a university student. In 2005, Ralf Ebinghaus, head of the environmental chemistry department at HZG and professor at the university in Lüneburg, suggested he undertake an internship in Geesthacht. It was during this internship that Bieser discovered his love of computer models. “I did some programming as a kid, when my brother and I built networks together – but I forgot just how much fun I had doing that sort of thing.” He went on to complete his diploma thesis and to earn his doctorate at HZG.

His dissertation was primarily concerned with establishing an emissions model for Europe. In order to determine where certain pollutants come from, scientists model them in temporally and spatially high resolution, making use of a wide variety of datasets. They then piece it all together like a puzzle, superimposing a grid over a map and collecting data for each cell in the grid. “For instance, if we know how much fuel a country consumes, where agriculture is undertaken, and how big certain forests are, we’re able to merge all this data and much more.”

The model programmed by Bieser enables him to change individual parameters. He can calculate what would happen if we were to drive less or what the effects are when forests are cleared or the meat consumption declines. For him, the model itself is just a tool that allows him to make predictions. His actual research interests, however, lie in the transport and transformation of pollutants in the environment. In his doctoral dissertation, the researcher applied his model to one very specific pollutant: benzo[a]pyrene, a carcinogenic pollutant that is primarily formed by wood combustion.

Today, the environmental scientist mostly occupies himself with studying his favourite element: mercury. Mercury is a unique element – a heavy metal that is four times heavier than iron, yet it naturally occurs in gaseous form in the atmosphere. It’s also highly toxic and tends to accumulate in the food chain as methylmercury. “Its chemical properties make it unique – the way I see it, it should get its own category in the periodic table. Also, there isn’t a thing on Earth that doesn’t have mercury in it, at least in extremely small quantities,” gushes Bieser. According to him, this is precisely why it’s so exciting to study how it’s distributed. Since the element cannot be broken down and forms very few stable bonds, anthropogenic mercury emissions remain in the system for up to ten thousand years. In the last 150 years, the quantity of mercury in the air and water has increased fivefold. The way this works, in the oceans in particular, remains largely unexplored. “New measuring techniques have allowed us to obtain data, without which we could only speculate until now. Research into the distribution of methylmercury has only just begun,” says Bieser.

Even while at his home in Sülldorf, on the outskirts of Hamburg, where he lives with his wife and their two daughters, he often continues to engage in his research.

> **If science isn’t one of your hobbies, then you’re no real scientist.**

At times, he immerses himself completely in his work while he’s there. “Sometimes I just can’t help it,” he says with a smirk. “But at our farmhouse with our cats, two dogs, two horses, and chickens, there are enough things to distract me – plenty of physical labour in the outdoors.” His fondness for the environment is apparent in more than just his work – as a family, the Biesers are enthusiastically involved in food sharing. With all of this buzzing activity going on, Johannes Bieser likes to play the piano whenever he finds time for himself: “It’s the one activity where I can really let everything else fade away.”

Author: Gesa Seidel (HZG)

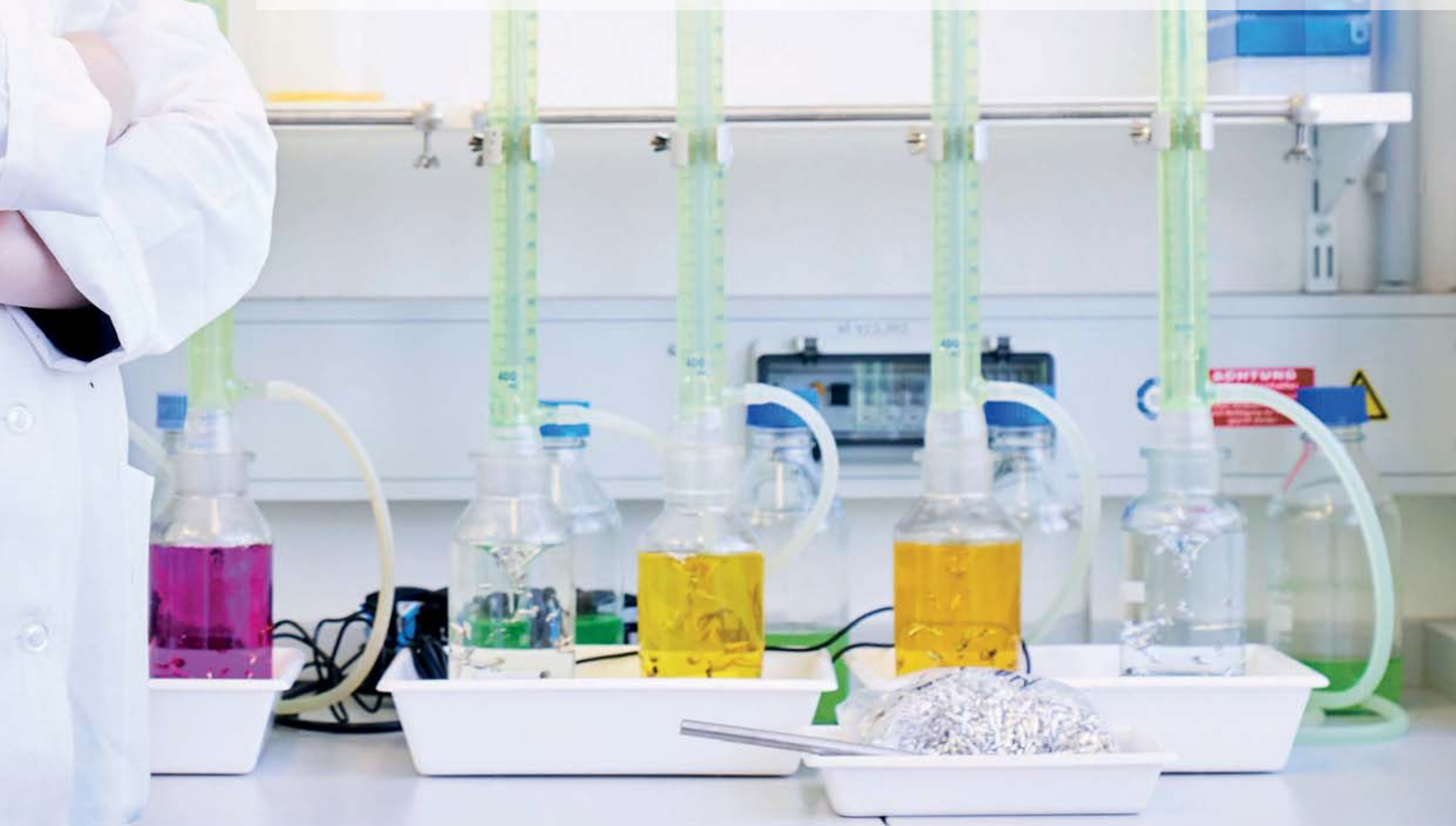
Sleepless at the microscope: The exhaustive search for chromate replacements

For Dr Sviatlana Lamaka, a scientist at the Magnesium Innovation Centre at HZG, coatings are her passion. As a corrosion expert, she researches new coating additives as part of the ALMAGIC project ("Aluminium and Magnesium Alloys Green Innovative Coatings"). The Clean Sky initiative is funding her work with 280 thousand Euros until 2019.

"We are working closely with our partners at the Complutense University of Madrid, Delft University of Technology, with the project coordinator at the Spanish company CIDAUT, with AkzoNobel, Henkel and MTU Aero Engines," explains Dr Lamaka, leader of the HZG team. "Our task in Geesthacht is to find non-toxic coating additives that effectively prevent magnesium and mag-nesium alloys from corroding."

It is precisely this aspect, that often restricts the use of magnesium in automotive and aerospace engineering. If untreated, the light metal easily reacts in salty and humid atmospheres, i.e., it corrodes. Chromates are the corrosion inhibitors currently widely used as additives for protective coatings. The problem is that chromates are extremely toxic, highly carcinogenic and harmful for aquatic life, flora and fauna. New European Union legislation has therefore banned the use of chromates beginning in January 2019. Only in exceptional cases will an authorized extension be granted.

Chromate replacement would therefore be enormously important in many realms of industry. It is, however, a Herculean task: Sviatlana Lamaka, with HZG doctoral candidates Bahram Vaghefinazari and



Clean Sky

Be it greenhouse gas emissions or noise pollution, the aviation industry's environmental reputation isn't always positive. The overarching Clean Sky 2 aviation project is therefore researching new technologies for cleaner and quieter aircraft. A joint, broad spectrum initiative between the European Commission and the aviation industry to improve all realms of technology and service, ranging from aircraft concept development to new propulsion methods and environmentally friendly operations.

One inconspicuous but vital aspect is developing new, chromate-free coatings for magnesium components used in aerospace engineering to provide corrosion protection.

Photos © HZG/C. Schmid

The small magnesium chips were produced from the six alloys and three pure magnesium varieties. Due to their shape, they have a particularly large surface area. Bahram Vaghefinazari measures hydrogen production due to magnesium dissolution in saline solution with or without the inhibitors.

Samples of coated magnesium plates are exposed to salty moist air for several days or weeks. Sviatlana Lamaka and Bahram Vaghefinazari check the samples.

Photos © HZG/C. Schmid

Di Mei have tested more than 150 chemical compounds as preparatory work for the ALMAGIC project. The inhibiting effect was tested against six different alloys and three types of pure magnesium.

The most promising candidates, after several thousand tests, proved to be compounds binding trivalent and divalent iron (Fe^{3+}/Fe^{2+}). Iron, always present as a minor impurity in magnesium, tends to initiate an expanding cathodic reaction. Blocking its dissolved species results in magnesium corrosion inhibition. This concept has been previously introduced by the HZG team at the Department of Corrosion and Surface Technology.

The search for these magnesium corrosion inhibitors took approximately two years. This work resulted in several scientific publications, but also, as Lamaka points out, “It is very satisfying for me that countless sleepless nights in front of an electron microscope contribute to solving the pressing problem of replacing carcinogenic, highly toxic chromates with environmentally friendly materials. The quest for replacement of carcinogenic chromates continues because it is one thing to find an effective inhibitor, but it is much more difficult to ensure that the inhibitor keeps performing once it is incorporated into the protective coating”.

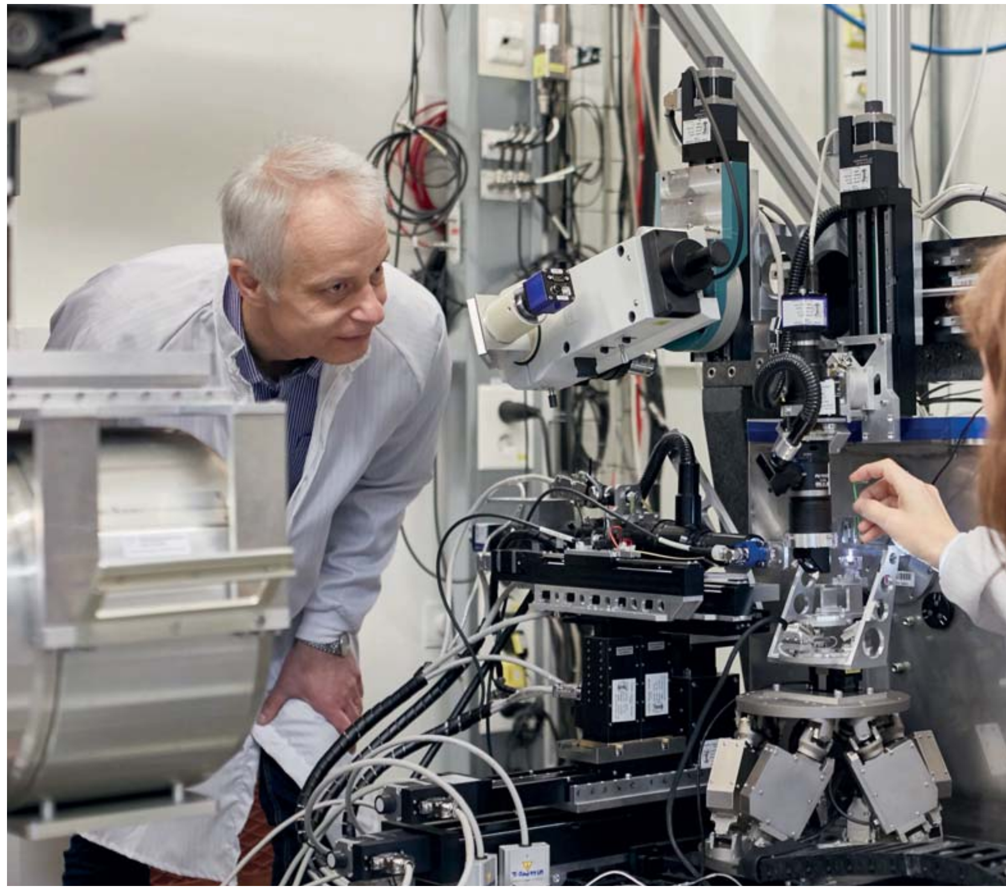
Author: Heidrun Hillen (HZG)

Lamaka: It is very satisfying for me that countless sleepless nights in front of an electron microscope contribute to solving the pressing problem of replacing carcinogenic, highly toxic chromates with environmentally friendly materials.

Stronger, tougher, harder: How scientists unravel the behaviour of materials

Dr Christina Krywka has headed the HZG department "X-ray Imaging with Synchrotron Radiation" since 2016. She was previously responsible for the Nanofocus Endstation at the P03 X-ray Scattering Beamline. At the time, she was still a physicist at Christian Albrechts University in Kiel. She studied physics and obtained her doctorate at the University of Dortmund.

Prof Jozef Keckes has been an associate professor at the Montanuniversität Leoben (Austria) since 2000. Born in Slovakia, he studied solid state physics and is a group leader in the Materials Physics Department at the Montanuniversität Leoben.



Two successive hexapod positioners were used on the beamline.
Six drive elements each move the platform with the sample into the beam.

Scrrmp – the heavy doors close with a rich sound a bit like a kiss. The small experimental chamber, crammed full of instruments, can now no longer be entered. A concrete and lead wall protects the outside world from the X-rays inside Helmholtz-Zentrum Geesthacht's (HZG) Nanofocus Endstation at Beamline P03 of the Deutsches Elektronen-Synchrotron (DESY) in Hamburg.

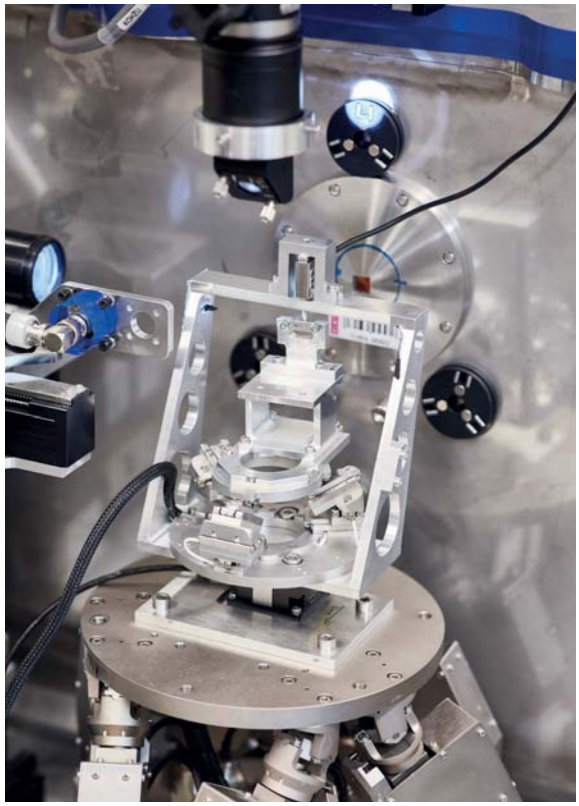
Keckes: We study the mechanical properties of the layers using a nanoindenter.

While the deflected X-ray beam shines through the sample inside, physicists Dr Christina Krywka and Prof Jozef Keckes excitedly watch the monitors in the next room. Now the head of HZG's X-ray Imaging with Synchrotron Radiation Department and the group leader of the Department of Materials Physics at Montanuniversität Leoben (Austria) can only hope that the sample has safely survived all of the preparations as there's nothing they can do to change the sample now.

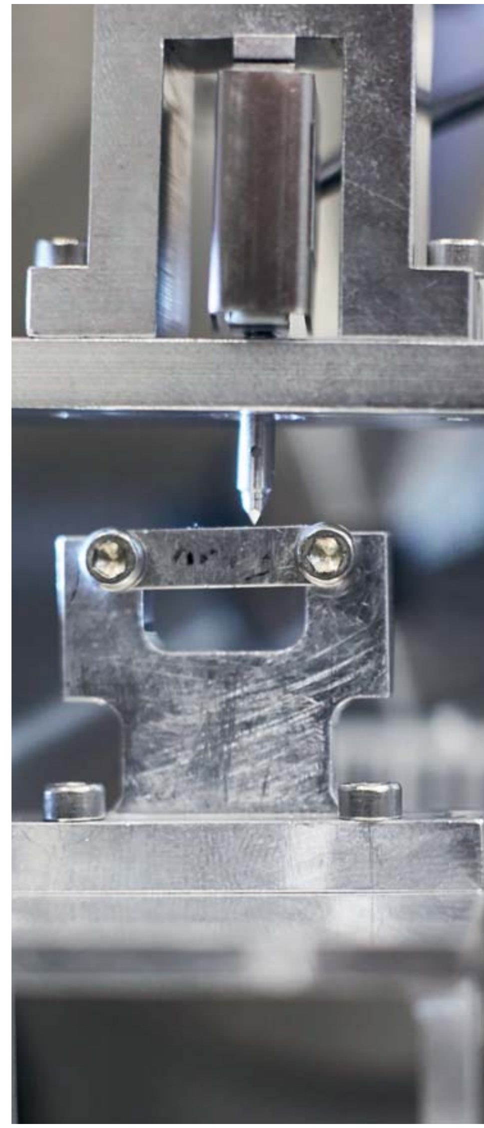
There! It shows the characteristic circle-shaped scattering pattern of a diffraction experiment. Relieved, the two look at each other: the sample is intact, so these data can be used and analysed. Now they can attack their materials science questions in a systematic way.

The scientists are investigating novel coating processes for special tools, such as those used by industrial partners, including manufacturers of engines and turbines. These extremely hard tools are used to mill or cut individual components

Photos © HZG/R. Otzipka



The positioners push the sample into the tip of the indenter with a defined force (right hand image).

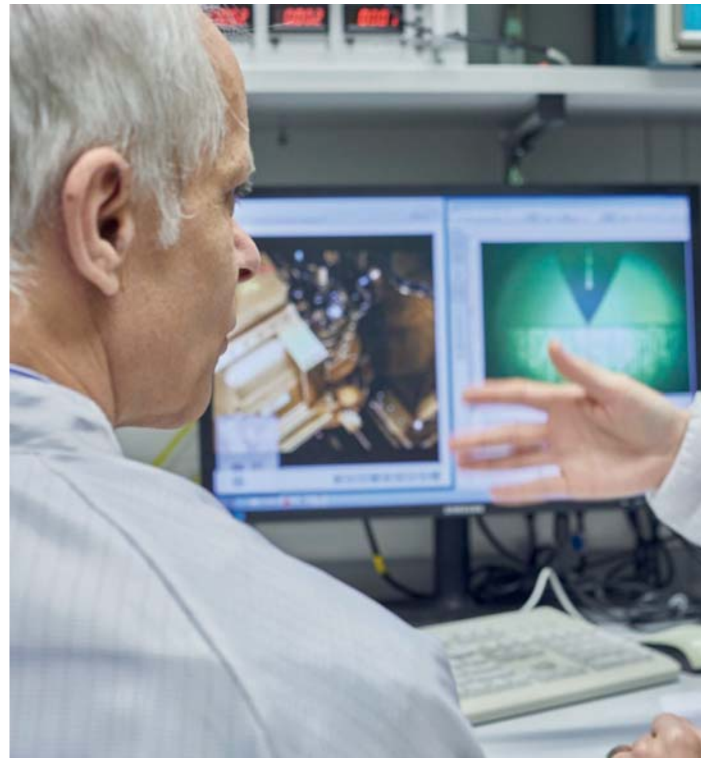


out of raw materials. Tungsten carbide is often used as the material for the tools themselves, and there is virtually no harder material. Even so, these tools wear down over time, and so each can be used to produce only a limited number of components. In order to extend the lifetime of these tools, they are treated with special coatings. The wafer-thin layers are approximately two microns (two one-millionths of a metre) thin and made of, for example, titanium nitride.

Jozef Keckes and his group study and develop these coatings. Why not just make the hard layers on the tools twice, or three times, as thick? Jozef Keckes explains: “Due to the deliberately introduced residual stress, the layers can't be any thicker, as they would spall off. Also, the layers are grown on the substrate by a process called sputtering. That means they are built up atom by atom in a plasma. That can take hours, sometimes even days.”

Materials researcher Jozef Keckes has been coming with his group to Hamburg regularly since 2011 to carry out research into the coatings at the Nanofocus Endstation. Often at his side is Christina Krywka who, on behalf of HZG, constructed and now maintains this equipment at Beamline P03. Jozef Keckes explains: “We study the mechanical properties of the layers using a nanoindenter. Our question was, ‘how does the material respond on the nanoscale to external influences, such as high pressure?’”

An indenter is an extremely sharp, very small diamond tip, which, with a defined force, creates a tiny notch into the layer of the sample. For example, it is pressed with a force of 10 millinewtons, which corresponds to a weight of 1 gram.



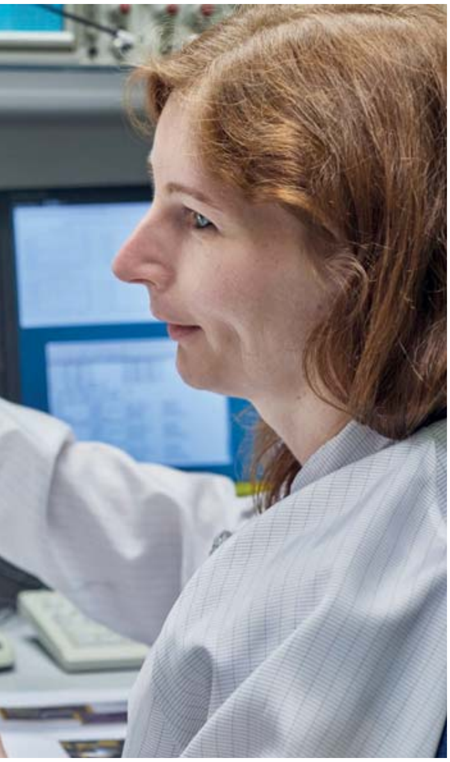
There is time to discuss upcoming experiments while the measurements are carried out and also later in the office. Among other things, the measurements are compared with images taken under the electron microscope.

Christina Krywka and HZG Institute Director Prof Martin Müller had the idea to build a device which would make it possible to observe the deformation process in real time, fulfilling a long-held desire of Jozef Keckes. While the indenter presses into the layer, scattering patterns can be recorded at the beamline. The great advantage of such in situ (real-time) experiments is that they can be used to observe the elastic deformations, which only occur while the pressure is actually applied. These are no longer present after the tip is removed. Correspondingly, during ex situ measurements (i.e., after the indent is made), only the plastic deformation of the material remains.

The response is also measured for several samples under different, changing forces. This way, the immediate elastic response of the material, the residual stress, can be determined as a function of the force and penetration depth, as well as a function of the environmental conditions.

“We want to understand how the material at this length scale deals with an external force. Until we developed our experiment, stress fields could not be recorded in situ. Here, modellers used to have to make assumptions, and the understanding of the model needed to be extremely precise. The smallest errors in the assumptions lead to large variations in the material,” Jozef Keckes explains.

The challenge for the real-time measurement was to design the geometry of the apparatus so that it would be compatible with the geometry of the X-ray beam and the instrumentation at the beamline. For this purpose, two connected hexapod positioners were used. These special devices align samples in all directions, both horizontally and vertically. The frame around the indenter, and the hexapod positioner, also had to be designed in such a way that they did not deform under the relatively high forces because this would distort the measurements.



Krywka: We are planning what you might call the Swiss army knife of in situ nanoindentation.

The solution: one of the hexapods uses a defined force to press the sample from underneath onto the fixed indenter, whose diamond tip is stationary in the X-ray beam. The other hexapod aligns the entire instrument with relation to the beam, and finally the precise scanning-motion is performed using a piezo positioner sitting in between the two hexapods.

A further difficulty was to make the system light enough that the delicate hexapods and all the other built-in positioners could withstand the load, as these extremely precise devices do not tolerate overloading. “We dived right into the electronics and customised the controllers of some of these positioners”, explained Krywka.

From 2011 to 2013, samples were first measured ex situ; the first measurements with the indenter in the beam began at the end of 2013. “We had to reinvent the technology for ourselves, and the sample preparation also gave us headaches. Then everything had to be formulated mathematically and, for example, the residual stress in the material predicted. We needed around two years to take all components into account and to be able to correctly analyse and then publish the data,” Jozef Keckes tells us.

With success: now they can measure with the nanoindenter on the beamline in real time, using any loads or forces that cause the layers to fail. In their first findings, they were able to confirm in real experiments a number of modellers' assumptions.

So far, Keckes and Krywka were the first in the world to put this combination of X-ray nanodiffraction and nanoindentation into practice. Soon they will push their endeavours even further. Christina Krywka explains, “We are planning what you might call the Swiss army knife of in situ nanoindentation. We are currently developing a new nanoindenter which will be capable of covering the entire range of forces, from a few millinewtons to several newtons. When we achieve that, even more classes of materials could be studied.” In addition, the force sensor will include a digital interface to the beamline hardware.

This will ensure that Christina Krywka and Jozef Keckes will be sitting in front of the beamline monitors for many more days to come. The pair won't be letting go of their materials science questions.

Author: Heidrun Hillen (HZG)

On the way to HyScore

They form a barrier between two areas, regulating which molecules are allowed to pass through – we're talking about membranes. Whether in chemistry, biology, or in our everyday life, membranes are everywhere.

Membranes made of polymers have long been used, for example, to separate gaseous mixtures. Among the advantages provided by polymers is that they can be processed in various ways to form mechanically stable membranes.

In producing these membranes, however, other components such as nano-scale filler materials and additives can also be included along with the polymers. What are known as "mixed-matrix membranes" combine polymer membrane properties with those of the additives to produce results that would be impossible using the different materials on their own.

A team of scientists from HZG's Institute of Polymer Research has recently produced a membrane free of defects using polymers and activated carbon. Dr Prokopios Georgopanos, scientist at HZG, explains: "Normally, selectivity would become worse whenever permeability would increase. This means that the faster the gases pass through the membrane, the sharper the decline in the quality of the membrane's separation efficiency." What is special about these newly developed membranes is that their permeability can be increased without sacrificing selectivity. Georgopanos adds, "Compared to pure polymer membranes, this mixed-matrix membrane is more efficient at separating gas mixtures, as not as much membrane area is required."

With this new combination of polymer and activated carbon, the scientists have now been able to demonstrate, using a variety of analyses and measurements, that the activated carbon in the mixed-matrix membrane exerts influence on permeation behaviour. The polymer researchers produced membranes with different proportions of activated carbon, from 0 to 50 volume per cent. Georgopanos says, "We observed that by increasing the amount of activated carbon in the membrane, the selectivity remains stable even though the permeability increases." The scientists speculate that the transport mechanisms of the gases in the polymer membrane are altered by the activated carbon embedded within it. Doctoral student Fynn Weigelt has additionally compared the practical experiments with theoretical models, demonstrating that theory and practice are well in agreement.

Fynn Weigelt

Dr Prokopios Georgopanos

The next step will be to check to what extent these new membranes might be used in the field of hydrogen technologies. The idea is that similar polymer composites might eventually be utilised in hydrogen storage tanks. This is where colleagues from materials technology come into play, as their research includes developing materials used in storing hydrogen.

In early 2018, Georgopanos and Weigelt, together with other scientists from the Institute of Polymer Research, published the initial results of their study in the open-access journal Polymers. These studies are conducted as part of the HyScore project ("Efficient H_2 storage using new hierarchically porous core-shell structures with embedded light metal hybrids"), a HZG collaboration between the Institute of Polymer Research and the Materials Technology division within the Institute of Materials Research. This joint project is funded by Germany's Federal Ministry of Education and Research (BMBF) in the amount of two million Euros.

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Relevant future questions! Answers from science?

Dr Domonkos Tolnai
(Magnesium Innovation Centre MagIC)

Most magnesium alloys are made using casting methods. It is therefore crucial to understand the solidification processes in different magnesium alloys. That is why we're carrying out in situ X-ray experiments that will give us an insight into the development of the microstructure during solidification.

Dr Natalia Konchakova
(Magnesium Innovation Centre MagIC)

I focus on the modelling, simulation and characterization of magnesium and magnesium alloys in order to understand in detail corrosion mechanisms and damage behaviour as well as to provide the modelling tools for computational analysis and service life prediction of magnesium based materials.

Martin Bönewitz
(Systems analysis and modelling)

The objective of my work is to gain a societal perspective on natural processes and hazards in East Frisia. Due to climate change and rising sea levels, this is fundamentally important for our future encounters with natural risks in coastal regions.

Dr Tobias Rudolph
(Micro-/Nanotechnology)

The objective of my work is the exploration of polymer-based materials that exhibit a shape-memory effect. Such shape-memory materials are capable of storing information about another, second, shape and actively take the stored shape upon application of a suitable stimulus (e.g. heating). In particular, my research is about materials that possess the ability to reversibly switch back and forth. The technology of multifunctional polymer actuators is required to produce soft and autonomous robots that will perform complex functions in the future.

Bettina Steuri
(Climate Service Center Germany)

Our task is to make the scientific findings of climate research comprehensible and usable for actors from practice, such as the private sector and public authorities. This is particularly important because the effects of climate change can already be felt today. In this context, cities play a central role because they are highly vulnerable to the impacts of climate change.

Dr Florian Wieland
(Metallic Bio-materials)

I hope to understand how biodegradable implants made from magnesium are broken down in the body, and what sort of influence that has on the bones. This is important because permanent implants sometimes require a second operation for removal. For example, in children who are still growing, the implant will no longer fit in some way anymore. With biodegradable implants, a second operation is unnecessary, which means a significant increase in comfort for the patient. What's more, this would also lead to reduced costs and lower risk of infection as well.

Dr Fabian Wilde
(Materials Physics)

The aim of my research is to enable the best possible performance for our experiment on the beamline. That means we want the highest possible resolution, the highest possible speed at the limits of what is currently possible. This is important so that researchers all over the world, and we too, can take the best measurements using this instrument.

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