

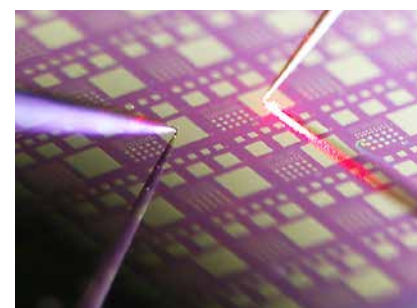
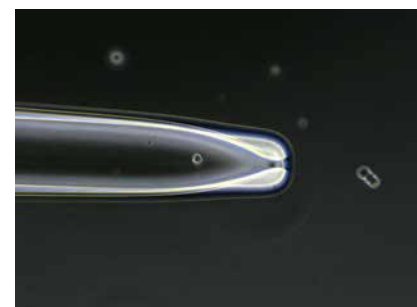


Corona and Its Impacts: Responding to the Virus | Research Funding: In the Service of Society | Mourning the Loss of Reinhard Grunwald | Geology: The Pompeii of the Permian | Geoscience: New Models for System Earth | Male Reproductive Health: Leave No Man Behind | German Basic Law: Logics of Freedom | Microelectronics: New Materials



Cover: Shutterstock/DOERS

*The coronavirus pandemic has many faces and enormous impacts worldwide – affecting research and research funding as well. This issue contains a special section (pages 2 to 6) devoted to this topic.*



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Katja Becker

# Responding to the Coronavirus

*How the coronavirus pandemic is affecting the work of the DFG and the researchers it funds – and how efforts to fight the pandemic emphasise the importance of curiosity-driven basic research, international research cooperation and dialogue between science and society*

This edition of *german research* is appearing at a time and under circumstances that none of us could have foreseen. For over two months, the coronavirus pandemic has defined our everyday lives, the way we interact and the way we work. This situation has also significantly impacted the academic research community and those employed at and involved with the DFG.

In recent weeks, many researchers at German universities and research institutions have had questions and concerns about the future of their current or planned research projects and have addressed these to the DFG. I would like to assure you that your questions and concerns are also our concerns. We are doing everything within our power to effectively support you and your work at this time.

The DFG acted early to take initial precautionary and protective measures against the coronavirus pandemic and its further spread. These measures will continue to be adapted to the latest developments. Along with the protection of all those involved, it has been our top priority to continue the funding activities of the DFG, and thus the funding of the best research, as seamlessly as possible.

We are united in our dedication to achieve this goal. DFG Head Office staff, most of whom have been working from home since mid-March, continue to process

Regular updates on the impacts of the coronavirus pandemic on the work of the DFG and all current and future measures are posted on [www.dfg.de](http://www.dfg.de) and on our Twitter account @dfg\_public.

proposals and manage financial flows, while reviewers, review board members and committee members decide on research funding proposals via telephone and video conference and written procedures. I would like to sincerely thank all those involved for this outstanding

cooperation. With respect to the decisions being made now and in the coming months, we will continue to take account of the fact that research projects could not be carried out in the scheduled manner and with the planned productivity owing to the current situation.

Furthermore, we have implemented a series of measures to alleviate the effects of the pandemic on the timelines and funding of research work and projects to the greatest extent possible. These measures include the cost-neutral extension of projects tied to fiscal years, as well as compensatory, bridge and completion funding or the extension of calls for proposals, fellowships and employment contracts of doctoral researchers. Additional cost-related measures will follow.

The DFG has also responded to the outbreak and spread of the coronavirus pandemic by creating funding opportunities for new research projects in this specific area. Like all infectious diseases, the current coronavirus pandemic can be tackled all the more effectively the better we understand the pathogen and its effects on humans. This requires comprehensive, long-term research into curiosity-driven questions – the kind of research that the DFG strongly believes in supporting.

In recent years, the DFG has funded a wide range of research projects on coronaviruses and the infectivity and genetic diversity of viruses in general, and much of what we currently know about coronavirus, diagnosis and therapeutic approaches is based on the results of such basic research.

At the end of March, we published a new call inviting proposals across a diverse range of disciplines and topics. Funding is available for research projects on the fundamental biological and medical aspects of a pathogen, preventive measures and therapeutic methods, and the psychological, social, cultural, legal and ethical implica-



Illustration: DFG/Ausserhofer

tions associated with the emergence, spread and treatment of epidemics and pandemics. Impacts on global and regional economic development, production and value creation chains, logistics, transport and communication will also be examined. Interdisciplinarity, transdisciplinarity and cooperation should play a key role.

Through this broad approach, we aim to contribute not only to the study of the current pandemic but also to generalizable scientific findings so that we can be better prepared for the multiple dimensions of future global infection waves.

We see our call for proposals, as well as our other funding activities in this area, as part of the worldwide scientific effort to fight the pandemic – because it can only succeed by considering the global situation and by pooling global knowledge. As in other areas of society, in research, it is no longer about competition: it is about cooperation, anticipatory action, solidarity and ensuring protection for those who need it most.

Finally, the pandemic has had considerable impacts on the DFG in a very different respect. This year we looked forward to celebrating the DFG's commitment to supporting independent, knowledge-driven research with a national campaign and a variety of opportunities for communication and exchange among and across communities. It was timed to coincide with the

100th anniversary of the founding of the DFG's predecessor organisation, the Notgemeinschaft der Deutschen Wissenschaft.

Due to the outbreak of the pandemic and the necessary restrictions on public life, many elements of the DFG2020 – Because Research Matters campaign, which was launched at the DFG's New Year reception in Berlin, cannot go ahead in quite the way we planned. It is especially unfortunate that our dialogue-based travelling research expedition has had to be cancelled, at least until the summer, as have our major award ceremonies and other public events.

This will make other activities and formats in our anniversary programme all the more important, particularly our online platform #researchmatters, which I would invite all readers of the DFG magazine to take part in. Amid the coronavirus pandemic our campaign motto is all the more relevant, because at the present time we can see just how important it is for our society – and indeed all of us individually – to recognise that research matters.

Professor Dr. Katja Becker  
is the President of the DFG.





## In the Focus of Research

*In response to the outbreak of SARS-CoV-2, the DFG is expanding its funding for epidemic and pandemic research with a new multidisciplinary call*

The outbreak and global spread of the coronavirus pandemic has turned the spotlight on research in this field. For scientists, as in everyday language, SARS-CoV-2 is in many ways a “novel” virus. But more generally, coronaviruses have been the subject of numerous research projects for some years.

Before the outbreak of the current pandemic, the DFG was already funding approximately 20 individual projects and larger-scale research groups on coronaviruses and the infectivity and genetic diversity of viruses, with a total of around €18 million per

year. Examples include CRC/Transregio 84 “Innate Immunity of the Lung: Mechanisms of Pathogen Attack and Host Defence in Pneumonia”, which is based in Berlin, Giessen and Marburg and has been funded since 2010, the Heidelberg-based CRC 1129 “Integrative Analysis of Pathogen Replication and Spread” and CRC 1021 “RNA Viruses: RNA Metabolism, Host Response and Pathogenesis” in Marburg, which have been funded since 2014 and 2013 respectively.

Other research groups concerned with questions relating to coronaviruses and novel viral dis-

eases include Priority Programme (SPP) 1596 “Ecology and Species Barriers in Emerging Viral Diseases”, led by Berlin-based virologist Professor Dr. Christian Drosten, which has been funded since 2013 and is about to be concluded; Clinical Research Unit (KFO) 309 “Virus-induced Lung Injury: Pathobiology and Novel Therapeutic Strategies” in Giessen, funded since 2016. And there are also individual projects, for instance within the framework of the DFG’s Africa Initiative for Infectiology.

At the end of March, in view of the current coronavirus pandemic, the DFG also launched a broad call

for multidisciplinary research into epidemics and pandemics.

Funding is to be offered for projects dealing with the prevention, early detection, containment and investigation of the causes, impacts and management of epidemics and pandemics, taking the example of SARS-CoV-2 and other micro-organisms and viruses which are pathogenic to humans.

This includes, for example, the investigation of

- the challenges and effects of an epidemic or pandemic and of measures taken for healthcare systems;

- psychological, social and cultural factors in the emergence, spread and treatment of epidemics and pandemics and the legal and ethical implications;
- the impacts on global and regional economic development, production and value creation chains, logistics, transport and communication;
- fundamental biological and medical aspects of a pathogen and the associated symptoms, as well as therapeutic methods or preventive measures in combination with one or more of the above topic areas.

The call is primarily aimed at multidisciplinary research projects. Proposals will also be considered for projects designed to gather and record basic data on the current epidemic and current countermeasures, which can serve as the basis for future retrospective analyses. Projects involving the simulation of the spread and consequences of pandemics and the effectiveness of interventions are also eligible for funding.

Suitable funding proposals can be submitted to the DFG until 1 September 2020. Researchers based at universities, universities



**Social Distancing:** The coronavirus pandemic has had a considerable impact on DFG public events and other major events. This is especially true of the campaign “DFG2020 – Because Research Matters”. Set to coincide with the 100th anniversary of the founding of the DFG’s predecessor organisation, the Notgemeinschaft der Deutschen Wissenschaft, this nationwide campaign was intended to demonstrate the value of free, independent research and its funding. In mid-January in Berlin, in par-

allel to the New Year reception, President Katja Becker and performing artists Kompanie Kopfstand presented an expedition bus that was to tour Germany starting in April. The rapid spread of the pandemic and the restrictions on public life have meant that all stops on the tour have had to be cancelled at least until the summer. This has lent added importance to the other formats included in the campaign, especially the online campaign #researchmatters. The award ceremony for this year’s Gottfried



Illustrations: DFG/Ausserhofer

Wilhelm Leibniz Prizes could not be held as planned at the beginning of March; unlike last year, the Leibniz Room at the Berlin-Brandenburg Academy of Sciences and Humanities remained empty. The presentation of the Heinz Maier-Leibnitz Prizes, scheduled for the start of May, has also had to be cancelled for the time being. Whether these and other events will take place in the usual format at a later date is still undecided, but the search for creative alternatives is already underway.





of applied sciences, non-university research institutions and healthcare facilities are equally eligible to submit proposals. Applicants should strive for international cooperation with researchers abroad.

For ongoing groups such as Research Units, Research Training Groups and Collaborative

Research Centres which thematically fit this call, it is possible to submit a supplemental or additional proposal. Planned long-term projects of an infrastructural nature at the interface of social and health sciences can use the funding programme Long-Term Projects in the Humanities and Social Sciences.

Researchers who are concerned exclusively with the biology of a pathogen, its manner of transmission and the development of drugs and other treatments are expressly requested to propose their projects within normal DFG programmes.

[www.dfg.de/en/research\\_funding/announcements\\_proposals/2020/info\\_wissenschaft\\_20\\_20](http://www.dfg.de/en/research_funding/announcements_proposals/2020/info_wissenschaft_20_20)

## Outstanding Science Communication Amid the Covid-19 Pandemic

*DFG and Stifterverband honour virologist Christian Drosten with a special award*

The coronavirus pandemic has demonstrated the necessity and importance of evidence-based information from the scientific community for politicians, the media and the general public. This year, the DFG and Stifterverband are therefore awarding a one-time prize for outstanding science communication during the Covid-19 pandemic. Worth €50,000, it will be presented by the executive committees of the two organisations.

The special prize is being awarded to virologist Professor Dr. Christian Drosten from Charité Berlin. The organisations noted that, more than any other scientist, he represents the special role of research during the Covid-19 pandemic. Drosten has succeeded in a very short space of time in making research, in the public perception, the most reliable source of orientation for managing the crisis. Through a clear, transparent, fact-based approach, he explains what

scientists know, how they work, what they are working on, and what uncertainties exist.



Illustration: dpa/POOL

But he also corrects scientifically unproven ideas, makes clear the limits of his own knowledge, and continually points out that science involves continuously pushing back these limits and revising what we thought we knew. Through this approach, he has achieved acceptance and trust among a large number of people

and among politicians, for whom he is currently one of the most important advisers.

In 2000, Christian Drosten joined the Bernhard Nocht Institute for Tropical Medicine in Hamburg. In 2007, he was appointed professor and head of the Institute of Virology in the Faculty of Medicine at the University of Bonn, before becoming director of the Institute of Virology at Charité Berlin in 2017. Since 2013, he has been the spokesperson for the soon-to-be-concluded DFG Priority Programme “Ecology and Species Barriers in Emerging Viral Diseases” as well as receiving funding for a variety of other research projects.

This one-time award is being presented separately from the Communicator Award, conferred by the DFG and Stifterverband, which this year goes to Berlin fisheries scientist Robert Arlinghaus.

[www.dfg.de/en/service/press/press\\_releases/2020/press\\_release\\_no\\_11](http://www.dfg.de/en/service/press/press_releases/2020/press_release_no_11)

Katja Becker



## In the Service of Society

*Science cannot solve global challenges on its own – but many of today's problems can only be tackled through a science-driven approach. This requires freedom, diversity and integrity in both research and its funding.*

*This article is the text of the speech given by DFG President Professor Dr. Katja Becker on 13 January 2020 at the DFG's New Year reception in Berlin. Some of the topics covered, particularly the anniversary campaign “DFG2020 – Because Research Matters”, have inevitably been affected by the coronavirus pandemic, but have by no means lost their importance. For this reason, the text is reproduced here in full.*

When you look at the world from a researcher's perspective, the DFG is among the greatest things you see. I always felt that way as a scientist myself. The sheer number of research projects funded by the DFG – over 30,000 per year – is no less breathtaking than the diverse range of research topics it supports and the variety of formats that often makes this research possible in the first place. As well as individual grants, the backbone of DFG funding, these

range from independent junior research groups, high-risk research and major research infrastructures to Collaborative Research Centres, Clusters of Excellence and a variety of research prizes – the most prominent being the Gottfried Wilhelm Leibniz Prize and the Heinz Maier-Leibnitz Prize.

And although all this is only the prominent tip of German research, these examples very clearly illustrate why the DFG's activities are of such vital importance to science and the humanities. That's why, for someone like me who has been dedicated to science for decades, there can be no more attractive and honourable role than that of President of the DFG.

This is especially true this year, as the organisation celebrates a very special anniversary. The DFG's predecessor organisation, the Notgemeinschaft der Deutschen Wissenschaft, was founded 100 years ago. Its re-establishment in 1949 was the beginning of the DFG as it is today.



But we are celebrating more than just the 100-year history of an institution. What we are celebrating is a principle: the principle of science-driven research funding.

But what this principle means today, what it can mean, and what it must never again mean – these are questions we should always be able to answer. Ultimately, the purpose and significance of the principle can no more be taken for granted today than in the past.

We must never forget how, in the 1930s and 1940s, so-called science-driven research funding included nationalistic and racially based thinking, outright racism and a pathos of radical objectivity. The result was a cold, inhuman kind of science which performed criminal human experiments in the service of fascist politics, but also of its own volition.

The dehumanising barbarism of the National Socialists was, in some ways, science-driven. So the term “science-driven” must never become an empty formulation: the extent to which science-driven research funding can be considered good is only ever the same as the extent to which science, and we ourselves as scientists, strive for integrity. Our task is to do this unflinchingly and communicate it with credibility.

So as we celebrate our anniversary this year, we do it with joy and enthusiasm, but also with self-criticism and humility.

**W**hen we look back, we see that the circumstances that led to the establishment of the Notgemeinschaft der Deutschen Wissenschaft in the still young Weimar Republic were striking.

The postwar era and inflation brought privations in many areas of life, and scientific productivity in Germany was especially affected. German science quickly lost its previous world-class status, soon there wasn't enough money to even print manuscripts, and finally the country's scientific activity began to grind to a halt.

To remedy this obvious emergency, industrialists, bank directors and businesspeople set up the Stifterverband der Notgemeinschaft der Deutschen Wissenschaft. In a dramatic appeal, they called on the business community to make generous donations to enable free research to continue. Support also came from abroad. In addition, the establishment of the Notgemeinschaft was aided by close, very constructive coordination between research organisations – a well-established characteristic of Germany's research system with roots that go back a long way. This year, Stifterverband and the DFG are jointly celebrating the anniversary of their establish-

ment. And they have good reason to celebrate, because together they have rendered an important and lasting service to research.

Over the course of the year, the DFG intends to run a nationwide campaign to raise awareness of the principles of free, independent research and its value to an open, informed society. With the motto “DFG2020 – Because Research Matters”, the campaign is designed to show how important knowledge and science are and what basic principles are associated with it, from equal opportunity to early career support and internationalisation. In this way, we want to show the public our commitment to independent science and invite them to stand up for it, too.

**B**ecause, unfortunately, academic freedom can no longer be taken for granted everywhere, despite the fact that it is becoming increasingly important in the face of challenges such as climate change, species loss, resource scarcity and population growth. What we need is science that is independent and that generates knowledge and value as a result of scientific curiosity, rather than this knowledge and value being predefined. In my opinion, this is the single most important thing the DFG has to offer.

Of course, some research priorities need to be aligned with certain key topics in order to address current challenges. But only the freedom to think, the freedom to develop new questions and concepts out of genuine interest, and diversity at all levels – in terms of researchers as individuals, funding formats, methods, topics and national and international cooperation – enable truly new combinations, ideas and innovation. The usefulness of these research processes often only emerges years, even decades, later, and sometimes in domains far removed from the original question that researchers set out to answer. Yet its scientific impact, and indeed its economic, social, political or cultural impact, may be significant.

So funding merit must not be reduced to a narrow concept of usefulness. And it certainly must not be subordinate to political aims or power ambitions. For example, when universities are purged of political dissidents, or even closed. Or when historical research is reduced to consensus on a single nationalistic perspective. Or when effective research on urgent issues such as climate change is prevented.

Of course, research still takes place even under such conditions. But its opportunities to make new discoveries are constrained ahead of time, its options prede-



finied. When the ability of modern science to add to our knowledge is limited in this way, it cannot make the wide-ranging contributions that it alone is capable of making, and which it must make in an era when governments and societies are facing ever-growing challenges.

Politicians and the public have a right to receive adequate advice from the scientific community. Herein lies our responsibility. So I'm delighted that in this anniversary year we have an opportunity to remember what makes our research system so special: outstanding researchers, excellent infrastructures, effective national and international networks, efficient division of labour between research organisations, and their outstanding cooperation in the Alliance and with the federal and state governments.

Thanks to the major science pacts agreed last year, we not only have the urgently needed planning security but also, through funding for new projects like the national high-performance computing programme and the national research data infrastructure, more opportunities for synergistic networking and cooperation than ever before. These must be used effectively to respond to current warning signs around the globe, to prevent irreversible damage to our living environment and thus the foundations of our way of living, and to tackle social inequalities and violent conflict around the world.

**O**bviously, science cannot solve the world's problems on its own, and nor can the DFG. But a large part of the world's problems can only be solved with a science-driven approach. Today more

than ever before, the sciences and humanities have a responsibility encompassing the whole of society. And the right decisions can only be made with their help. But so that these decisions can be made jointly by government, society and science, we, the people of our country, must convincingly demonstrate just how important science is. The people who don't trust in anything any more, who feel left behind, are the people that science must convince.

Berthold Brecht puts these words in the mouth of Galileo: “For I believe that the only goal of scholarship is to ease the toils of human existence.” Today, these words have almost staggering relevance. We have come to realise that this human existence depends on water, air and soil, animals and plants, and social community, and that in all probability we can only sustain our existence through true community and cooperation at all levels. In the years ahead we will learn what it really means to share.

I invite you all to join me in standing up for a science which is characterised by integrity and service to humanity, participates in defining its own tasks and contributes to a prosperous future for all of us. We can only do this together, and together we must agree what options we have, which steps are the most important and which steps should be taken next. Only with this approach can the DFG be to its member organisations and the research community that which we aim to celebrate this year: science-driven research funding. And this can only mean research funding led by the research community for the benefit of society.



# Mourning the Loss of Reinhard Grunwald

Former DFG Secretary General has died / "A moderniser with all his heart and mind"

The DFG is sad to announce the death of Professor Dr. Reinhard Grunwald. The former Secretary General of Germany's largest research funding organisation and the central self-governing organisation of the country's research community died on 21 March 2020 at the age of 77, after a long, serious illness.

"Many people at the DFG, in the science policy community and the research system as a whole, will remember Reinhard Grunwald as a remarkably dedicated Secretary General and human being, who knew how to use the gentle touch to implement his ideas for the benefit of scholarship. He will always be gratefully remembered for that," said current DFG President Professor Dr. Katja Becker.

Reinhard Grunwald led the DFG Head Office between June 1996 and September 2007. He was born on 21 August 1942 in Göttingen and studied law in his home city, in Munich and at Berkeley. He earned his doctorate from Göttingen in 1974 with a thesis on "Unconscionability, illegality and dolus malus: decision types and guidelines, developed on the basis of bank liability for credit measures". He subsequently held various management roles in research administration, for example as administrative director of the German Primate Center in Göttingen and finally, from 1984, as administrative director of the

German Cancer Research Centre (DKFZ) in Heidelberg.

During his 11 years at the DFG, Grunwald led the organisation alongside three presidents as Secretary General: until the end of 1997 with literary scholar Professor Dr. Wolfgang Frühwald, until



Illustration: DFG/Querbach

the end of 2006 with biochemist Professor Dr. Ernst-Ludwig Winnacker and finally, until his retirement, with engineer Professor Dr. Matthias Kleiner. During this time, the DFG budget doubled to almost €2 billion and the number of staff at Head Office increased from around 600 to nearly 800.

It was under Grunwald's leadership that in 1999, following the international system evaluation of the DFG and the Max Planck Society, the DFG Head Office was reorganised and modernised. In the years that followed, with his great

interest in procedural matters, Grunwald drove the transition to electronic proposal processing and the introduction of the review board system in the DFG's review, evaluation and decision-making process.

Other key issues during his time in office included the rapidly increasing internationalisation of research and research funding, and thus also the activities of the DFG, as well as the growing debate on the handling of scientific misconduct, which resulted in the standard-setting Recommendations for Safeguarding Good Scientific Practice.

When Grunwald retired from his role in early September 2007, a special event was organised in his honour at La Redoute in Bonn, attended by more than 150 guests representing academia, politics and society. Attendees paid tribute to him as one of the most influential and effective research managers both nationally and internationally, as a "soft-spoken general" and a "moderniser with all his heart and mind".

After his retirement, Grunwald maintained close links with the academic community and research administration, particularly as a director of the Centre for Research Management (ZWM) and honorary professor at the German University of Administrative Sciences (DHV), both in Speyer.

[www.dfg.de/en/service/press/press\\_releases/2020/press\\_release\\_no\\_9](http://www.dfg.de/en/service/press/press_releases/2020/press_release_no_9)

Ronny Rößler, Ludwig Luthardt and Thorid Zierold

# The Pompeii of the Permian

The "Petrified Forest of Chemnitz" is an approximately 291-million-year-old palaeobotanical fossil site, an ecosystem which has been exceptionally well preserved by volcanic activity. It provides geologists with insights into the development and disappearance of habitats and the dynamics of environmental and climate change.



Illustration: Eckehard Müller

Crowds of visitors – in the space of a few months, over 6,000 people visited the excavations in Chemnitz.



Many people know that the word “fossil”, which has entered everyday language, means something dug out of the ground. What is not widely known is that we owe it to a man called Georgius Agricola (1494–1555), the burgo-master of Chemnitz, who is regarded as the father of mineralogy. There has been a tradition in Saxony since the Middle Ages that the city of Chemnitz, which is nearly 900 years old, was founded on a stony or fossilised forest. But only in recent times have researchers working in interdisciplinary teams been able to open this archive of life and unravel some of its secrets. In the mid-18th century the coloured petrified tree ferns were popular decorative materials in the Saxon court and other European residences; by the begin-

ning of the 19th century the fossil plants of Chemnitz were playing a key role in the emerging science of palaeobotany. However, it would be a long time before the first animals of this fossilised forest were discovered beneath the city alongside the petrified trees. Chance finds have now become a complex fossil collection that represents the world’s best preserved Permian ecosystem. The Petrified Forest of Chemnitz, an exceptional fossil site of 291±2 million years old, was formed as the result of explosive volcanic eruptions which buried an entire habitat, preserving it in the process. Scientific excavations by the Museum of Natural History in Chemnitz have uncovered parts of this “Pompeii of the Permian”. The excavations, which have at-

tracted great public interest, shed light on the relationships between organisms and their environment in times of drastic environmental change. An international team of geologists, palaeontologists, evolutionary biologists, zoologists and geoecologists was formed for the task. The event documented in Chemnitz provides an opportunity to analyse, in these geological archives, the transition from an icehouse to a greenhouse climate. It turns the spotlight on the last extensive glaciation of entire continents before the most recent Ice Age, because this was the first ice age after plant life had spread over the Earth. This study of the many different ways in which organisms respond to climate fluctuations and

A spectacular find: *Opsieobuthus tungeri*, the first Permian scorpion in the world, found in its habitat – a hollow beneath a tree root.



Illustration: Volker Arnacker



Illustration: Ralph Kretschmar

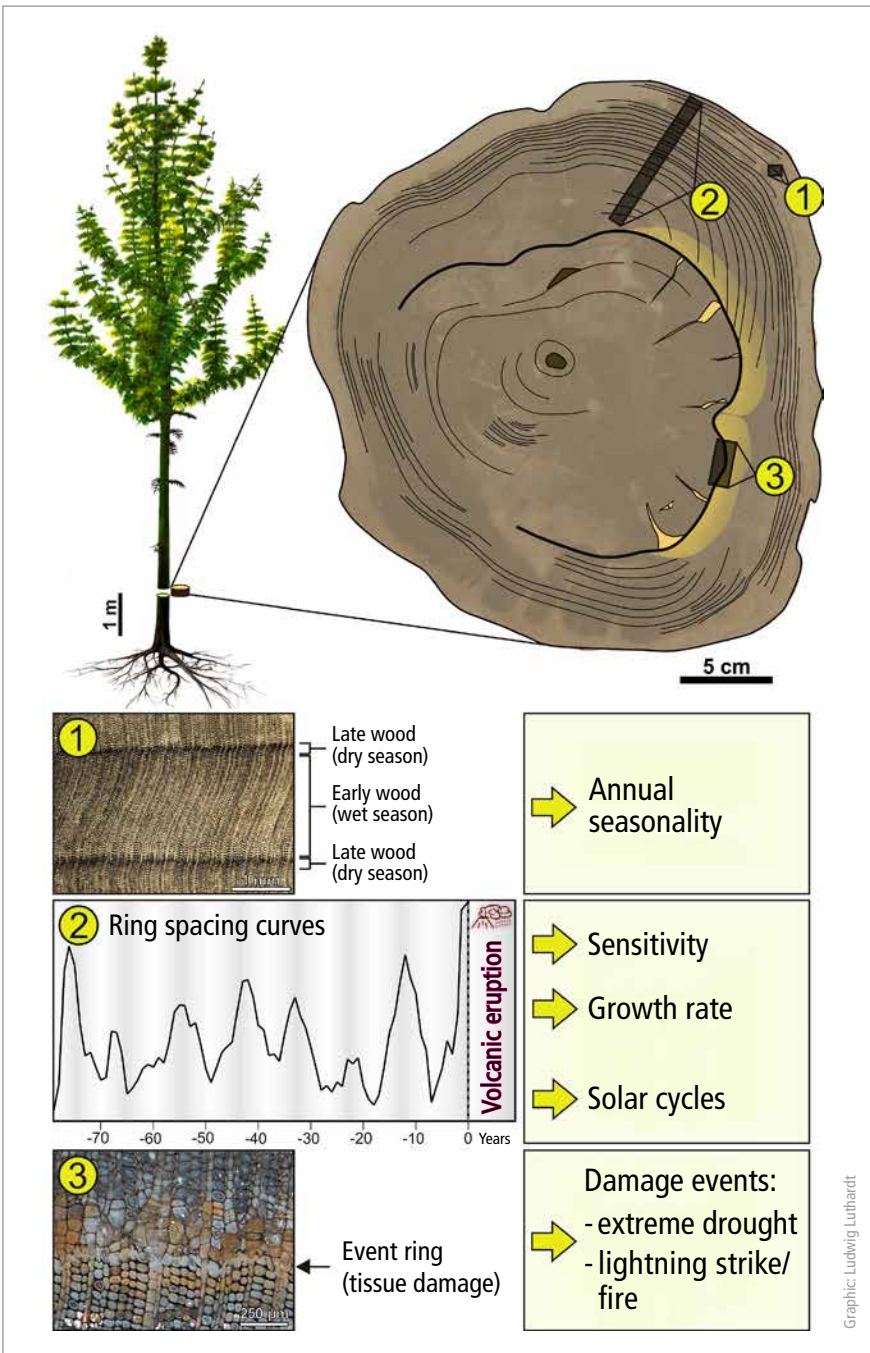
Rooted tree base of a petrified *Cordaites* tree, excavation at Hilbersdorf, 2011.

changes is of particular interest. Just as the biodiversity and biogeography of today, the result of millions of years of development, give clues to the mechanisms of evolution, fossil documents of the Earth’s history are enormously important to the forecasting of future climate and ecosystem changes. They provide a scientific insight into material cycles in the Earth’s history, the emergence and disappearance of habitats and their tolerance to disturbances or long-term changes, including their ability to regenerate after catastrophic impacts on the environment. Humans have already brought about far-reaching changes to the natural environment; fossil ecosystems give

us the opportunity to study and understand natural dynamics and control mechanisms. In Hilbersdorf, an area of Chemnitz, there are 53 trees still standing upright in the places where they grew, with roots extending down into the palaeo-soil. Here, in an excavation site of 18 x 24 metres, they are providing a glimpse of a unique habitat. It was home not only to dense, humidity-loving vegetation but also a rich fauna. In addition to the plants, the fossil record includes vertebrates, arthropods and snails. Five skeletons of highly specialised, tree-climbing mammalian ancestors have been found. At least three different groups of amphibians characterise

the habitat as seasonally dry. Faecal pellets of millipedes, animals just a few centimetres in size, have been found, which provide clues to the animals’ plant diet. We now know that *Arthropleura*, the largest terrestrial arthropod that ever lived at a length of up to 2.5 metres, existed for at least 40 million years, because now not only the world’s oldest, but also the youngest known specimens have been found in Chemnitz. Armoured arachnids measuring only around 10 millimetres, the last of an order which went extinct in the Permian, a whip scorpion, and finally the world’s first Permian scorpions – a pair and some moult remains – were preserved directly in their habitat.





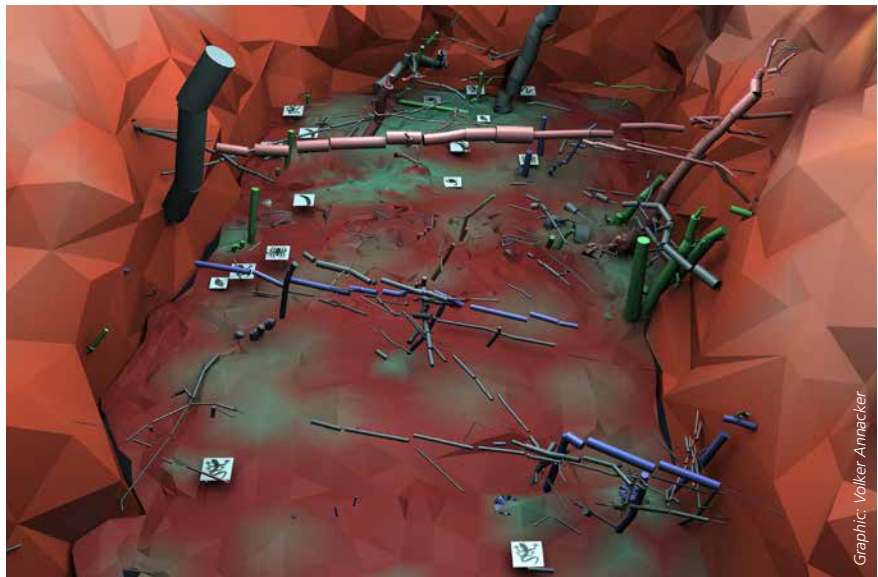
Above: Long-lived trees and their life cycles are valuable natural archives. The rings document environmental changes and allow us to form a picture of the Earth's history (reconstruction of tree-like horsetails: Frederik Spindler). Below: 291-million-year-old fossilised wood with growth zones.



For the first time, finds have been discovered in their exact original location, allowing researchers to create a 3D model simulation of the habitat – a sophisticated tool in palaeontology. The detailed study of the fossils will help us to answer unsolved questions about the development of Permian biotopes and habitats. But beyond that, the reconstruction of the volcanic event and the fossilisation processes also enable us to analyse the palaeoenvironment for the first time as a complete system, including soil, vegetation and fauna. This will give us a better picture of habitats prior to the mass extinction event at the Permian-Triassic boundary, as well as food relationships and the evolutionary stage of organisms.

The organic remains have petrified differently in the volcanic tuff; in ideal cases they are preserved together with their cell structure. Preserved down to cellular level like this, the fossil trees contain a treasure trove of information: the giants of the primeval forest, up to 30 metres tall and 5 metres in circumference, have annual rings. Have these unique natural archives recorded the environmental changes that occurred while the trees were alive before the volcanic eruption occurred?

The team of researchers set to work to answer this question, testing the methods of dendrochronology with surprising success in the Permian period. Being able for the first time to add a fourth dimension to the three-dimensional preserved ecosystem was fascinating. Suddenly, it seemed that the goal of recognising short-term palaeoclimatic events and processes far back in the Earth's history,



A 3D model of the excavation in Hilbersdorf documents the finds.

and interpreting their causes, was within reach.

After analysing the natural data archive preserved in the wood, the researchers realised that they could view approximately 80 years of the tree's lifetime. Amazingly, it was possible to identify up to 80 growth zones among the 43 best-preserved fossil trees selected. The diversity of the perennial plants, including conifers, relatives of the conifers, seed ferns and tree-like horsetails, is seen especially in their different responses to the same environmental influences in the same location. Rates of growth, sensitivities and adaptations varied significantly, but also allow the annual ring sequences to be correlated.

As an extra benefit of this comparison, it was confirmed that what was presumed to be dead wood in the forest was exactly that, as it had stopped growing years before the volcanic catastrophe. The most sensitive and fast-growing trees, the seed ferns, mainly show so-called event rings

– witness to dramatic short-term environmental influences on the plant, such as extremely dry seasons, to which the tree clearly responded by shedding its leaves and abruptly halting its growth.

An important question relating to the analysis of the growth zones is their annual character. This was verified by comparing morphological features and ring widths with modern trees in similar climates. The researchers concluded that the growth zones of the fossil trees probably had one growth season per year. This fits with the palaeoclimatological and palaeoecological results of geochemical and micromorphological investigations in the palaeo-soil.

The fossil substrate in which the trunks are still anchored by their roots is another data archive with a story to tell about the prevailing environmental conditions. Here the team found spherical mineral deposits that exhibit close intergrowth of carbonate and iron oxide and show that the climate

was highly seasonal. The cycle of alternating wet and dry phases was therefore confirmed by multiple independent lines of evidence. The relatively low level of weathering of mineral components in the palaeo-soil was unexpected, and allowed the research team to extrapolate an annual precipitation of around 800–1100 millimetres.

All in all, the studies carried out so far have reconstructed a complex and fascinating mosaic. The detailed reconstruction of this Lagerstätte will of course take a long time to complete. But the results so far from the excavation of the Petrified Forest of Chemnitz provide all the incentive we need for further concentrated efforts.



**Prof. Dr. Ronny Rößler** was the project leader and is the director of the Chemnitz Museum of Natural History and Honorary Professor of Palaeobotany at TU Bergakademie Freiberg.

**Dr. des. Ludwig Luthardt, M.Sc.** was a doctoral researcher on the DFG project.

**Dr. Thorid Zierold** is a scientific curator at the Chemnitz Museum of Natural History and co-initiator of the DFG project.

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[www.naturkundemuseum-chemnitz.de/en/projekte.html](http://www.naturkundemuseum-chemnitz.de/en/projekte.html)







Illustrations: private / websites of the universities

# Exceptional Potential

2020 Heinz Maier-Leibnitz Prizes: Ten researchers to receive Germany's most important early career award as recognition and encouragement

This year, ten researchers – including four women and six men – are to receive the Heinz Maier-Leibnitz Prize, the most important award for early career researchers in Germany. The recipients were chosen by a selection committee appointed by the DFG (German Research Foundation) and the Federal Ministry of Education and Research (BMBF).

The prizes, each worth €20,000, will go to:

- Dr. Dr. Daniel Kotlarz, Paediatric and Adolescent Medicine, LMU Munich
- Jun.-Prof. Dr. Ulrike Ingrid Kramm, Physical Chemistry of

- Solids, Technical University of Darmstadt
- Prof. Dr. Elvira Mass, Immunology, University of Bonn
- Dr. Frusina Molnár-Gábor, International Medical and Data Protection Law, Heidelberg Academy of Sciences and Humanities
- Dr. Timothy Nunan, Global History, Free University of Berlin
- Prof. Dr. Georg Oberdieck, Mathematics/Algebraic Geometry, University of Bonn
- Jun.-Prof. Dr. Michael Saliba, Materials Science, Technical University of Darmstadt
- PD Dr. Erik Schilling, Modern German Literature, LMU Munich

- Dr. Monika Undorf, Cognitive Psychology, University of Mannheim
- Dr. Wolfgang Zeier, Physical Chemistry of Solids, Justus Liebig University Giessen

The Heinz Maier-Leibnitz Prize has been awarded annually since 1977 to outstanding researchers at an early stage of their academic careers who do not yet have a permanent professorship. The prize serves as both recognition and encouragement to continue pursuing a path of academic excellence. Since 1980, it has been named after the atomic physicist and former DFG President Heinz

Maier-Leibnitz, during whose period in office (1973–1979) it was first awarded.

A total of 126 researchers representing all fields of research were

nominated for this year's prize. The winners were selected by the responsible committee chaired by DFG Vice President and mathematician Prof. Dr. Marlis Hochbruck.

[www.dfg.de/en/service/press/press\\_releases/2020/press\\_release\\_no\\_4](http://www.dfg.de/en/service/press/press_releases/2020/press_release_no_4)

[www.dfg.de/en/funded\\_projects/prizewinners/maier\\_leibnitz\\_prize](http://www.dfg.de/en/funded_projects/prizewinners/maier_leibnitz_prize)



## Communicator Award for Robert Arlinghaus

Berlin fisheries scientist honoured for varied and creative science communication

This year's Communicator Award, conferred by the DFG and Stifterverband, is to be presented to Professor Dr. Robert Arlinghaus, an expert in integrative fisheries management. The researcher, who works at the Humboldt University of Berlin (HU) and the Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB), is to receive the €50,000 award for his wide-ranging involvement in science communication.

The jury for the Communicator Award was impressed not only by the sheer variety of the communication formats that Robert Arlinghaus uses, but also their strategic and conceptual planning and implementation. He was able to link the seemingly specialised topic of angling with societally relevant issues of sustainability, conservation and the responsible management of natural resources. For Arlinghaus, it's important not only to communicate his research findings but also to encourage participation and informed decision-making on the part of his diverse audiences, which range from anglers and fisheries managers to conservationists, water users, policymakers and the general public.



Illustration: www.fishman.de

including the Cultura Prize of the Alfred Toepfer Trust and the Prize of the German Commission for UNESCO.

The Communicator Award – Science Award of the Donors' Association has been awarded every year since 2000 and is the most important prize for science communication awarded in Ger-

many. In the 20th anniversary year of the award, the DFG and Stifterverband refined the emphasis in recognising outstanding science communication. Researchers who are particularly creative in their communication, taking new, courageous paths and addressing their target groups in suitable and effective ways, now take centre stage. They must also recognise the societal dimension of their research and contribute their knowledge to public debate, opinion-forming and decision-making processes.

This year, the jury of science journalists as well as communication and PR experts chaired by DFG Vice-President Professor Dr. Julika Griem selected the prize-winner from 62 applications and nominations.

The DFG and Stifterverband are also awarding a one-time prize for outstanding science communication during the Covid-19 pandemic. This award, to be bestowed separately from the Communicator Award procedure, recognises Berlin-based virologist Professor Dr. Christian Drosten (see page 6).

[www.dfg.de/en/service/press/press\\_releases/2020/press\\_release\\_no\\_11](http://www.dfg.de/en/service/press/press_releases/2020/press_release_no_11)



Julia Pongratz, Julia Nabel and Kim Naudts



# New Models for System Earth

Three-quarters of Earth's ice-free land surface is used for agriculture or forestry. Geo-scientists are now seeking to better understand the direct and indirect impact of changing land use on climate and climate change.

It is widely understood that protecting forests not only helps to conserve plant and animal biodiversity, but also to reduce global warming. The Earth's forests remove carbon dioxide from the atmosphere through photosynthesis and store it as carbon in their trunks and roots and in the soil. When humans destroy areas of forest, sooner or later this carbon ends up back in the atmosphere. This extra carbon dioxide is a greenhouse gas that contributes to the much-discussed global warming.

The clearance of natural areas of land is an activity that stretches far

back into human history. 9,000 to 5,000 years ago, humans developed agriculture and animal husbandry independently in at least five different regions of the world: the Fertile Crescent in the Middle East, parts of China, and Central and South America. Over the millennia that followed, cultures that practised farming spread to almost all regions of the world. The expansion of agricultural land was constrained only by regional events, with epidemics or wars sometimes forcing populations to temporarily give up farming, and by a shift towards sustain-

able forestry at the beginning of the 18th century.

To estimate the impact on the global climate when humans modify vegetation cover, researchers use Earth system models. These models provide a simplified representation of the climate system, consisting of processes on the land surface, in the atmosphere and in the oceans. These three components are linked by the exchange of energy, momentum, water and important trace gases such as carbon dioxide. As far as possible, processes are represented by physical equa-

tions, for instance fluid dynamics in water and air.

Given the huge number of processes involved and the global coverage, the computing power required for such models is enormous – especially when it comes to the carbon cycle and land use. The carbon dioxide released into the air when land is cleared is mostly removed from the atmosphere again over slow time-scales, from decades to thousands of years. To map the carbon cycle, scientists use simulations that cover many centuries. Calculations such as these can only be performed by supercomputers like the one at the German Climate Computing Centre in Hamburg. Many Earth system models are now used all over the world. The results they generate are used, among other things, in the reports of the Intergovernmental Panel on Climate Change (IPCC).

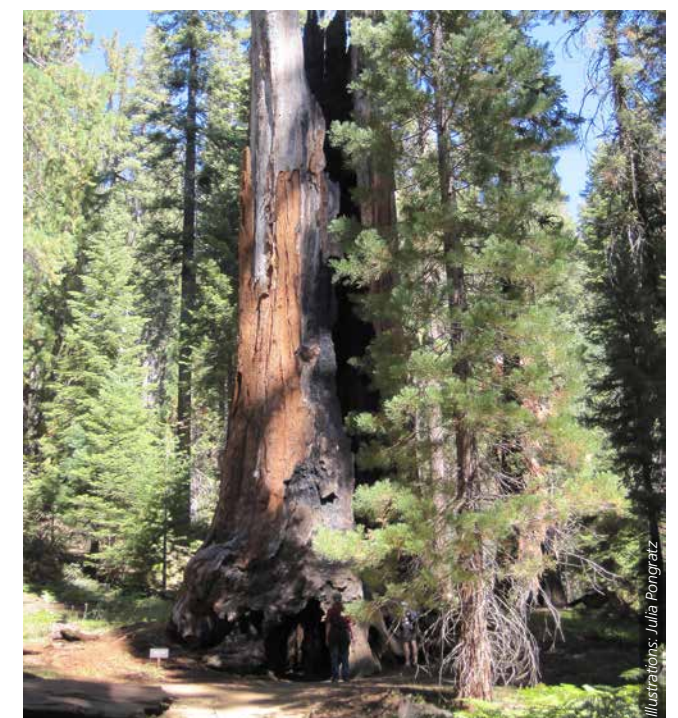
Model simulations for the past have yielded some interesting results. For example, historical deforestation seems to have increased carbon dioxide levels in the atmosphere back in the Middle Ages by amounts that cannot be explained by natural fluctuations. This was the conclusion reached by a study carried out at the Max Planck Institute for Meteorology in Hamburg (Julia Pongratz and colleagues). The researchers were able to show that humans were already influencing the climate long before the large-scale burning of coal, oil and gas that began with the Industrial Revolution.

The carbon cycle is not the only pathway by which vegetation changes affect the climate. Seen from the air, areas of cultivated and grazing land often appear much brighter than forested terrain. As a result,

they reflect more sunlight, which makes them cooler. On the other hand, farmland and grassland often evaporate less water than forests because they have less leaf area and shallower roots. Which effect predominates when forest is converted to agricultural use – cooling through the reflection of sunlight or warming through reduced evaporation – depends largely on the prevailing environmental conditions and plant type. Vegetation cover plays a crucial role in the local climate, and these processes are also integrated in complex Earth system models.

In most cases, Earth system models analyse only specific types of vegetation change. They are limited to representing land use activities that fundamentally change the type of vegetation, for example the conversion of forest to farmland (referred to as land cover change). However, in

*Left: The type of crop (wheat on the left and maize on the right, in a field near Zurich) largely determines the surface properties and thus the impact of vegetation on the climate. Below: The type of forestry also matters – on the left is a spruce monoculture in South Tyrol, on the right an uncultivated redwood forest in California.*



Illustrations: Julia Pongratz



reality large areas of land are used by humans without experiencing any change in vegetation type: a forest may remain a forest but be intensively exploited, farmland may be fertilised and irrigated, or the type of crop may change.

Observational studies have shown that these changes in land management have similarly significant effects on the climate to changes in land cover. And it's not only the effects that are significant; the area involved is enormous. Land cover change affects around one quarter of ice-free land surface, but around half of the ice-free land surface is subject to changes in land management. This is why climate researchers are working to repre-

sent the different types of land management in Earth system models.

One key type of land management is forestry. Only about 40 percent of the world's forests are classified as being in a pristine state (although these too are indirectly affected by humans through climate change). The remainder is managed by humans in one form or another. The impact of these activities on the climate may be substantial: detailed modelling carried out at the Laboratoire des Sciences du Climat et de l'Environnement (Kim Naudts and colleagues, published in 2016 in Science) reveals that in some parts of Central Europe, the conversion of deciduous forest to faster-growing,

more economically profitable evergreen coniferous forests has significantly increased summer temperatures. This is because the dark conifers reflect less sunlight.

Timber harvesting can also have a considerable impact on the carbon cycle and therefore the climate. Every year, approximately one gigaton of carbon is harvested globally, half of which is used as firewood and the other half for construction. This corresponds to around a tenth of the carbon released annually through the burning of fossil fuels. Sooner or later (sooner in the case of firewood, later in the case of wooden furniture or houses), this carbon enters the atmosphere. Unlike with fossil fuels, however, a large proportion of the carbon is reabsorbed by regrowing forests.

Nevertheless, the effects on forest structure and climate are clear to see: a study by an interdisciplinary research team led by social ecologist Karl-Heinz Erb at the University of Klagenfurt concluded that by harvesting timber, humans appropriate approximately 7 percent of forest net primary production (the carbon that is left over after taking both photosynthesis and plant respiration into account). In intensively cultivated regions like Europe, this figure may be twice as high.

Earth system models reveal that it isn't just timber harvesting per se, but also the way in which it takes place that affects the carbon cycle and the climate. Removing the same amount of timber from a forest may result in very different amounts of biomass – depending on whether young or old forests are harvested. The knowledge applied for many years by local forest economists is now being incorporated into Earth system models. The growth of dif-



The working group Forest Management in the Earth System at the MPI for Meteorology in Hamburg integrates observational data and models on the computer.

ferent types of forest – tropical and non-tropical, evergreen and deciduous – is represented in the model such as to allow observed growth curves to be reproduced.

Information about the age structure of a forest is based on data drawn from forest inventories and satellite images. Models like these now enable us to estimate globally the effects of various assumptions about the type of harvesting. This relates not only to biomass and carbon but also to surface properties such as reflectivity and evaporation.

On agricultural land, although the surface area is only half as large as that of forests, harvesting contributes significantly to changes in the Earth system. Compared to timber harvesting, crop harvests transfer around three times as much carbon from the natural carbon cycle to that used by humans, and this leaves behind a clear signal in the soil. Globally, soil stores three to four times as much carbon as vegetation. Scientists use observational studies to compare soil carbon in the context of different types of land use under

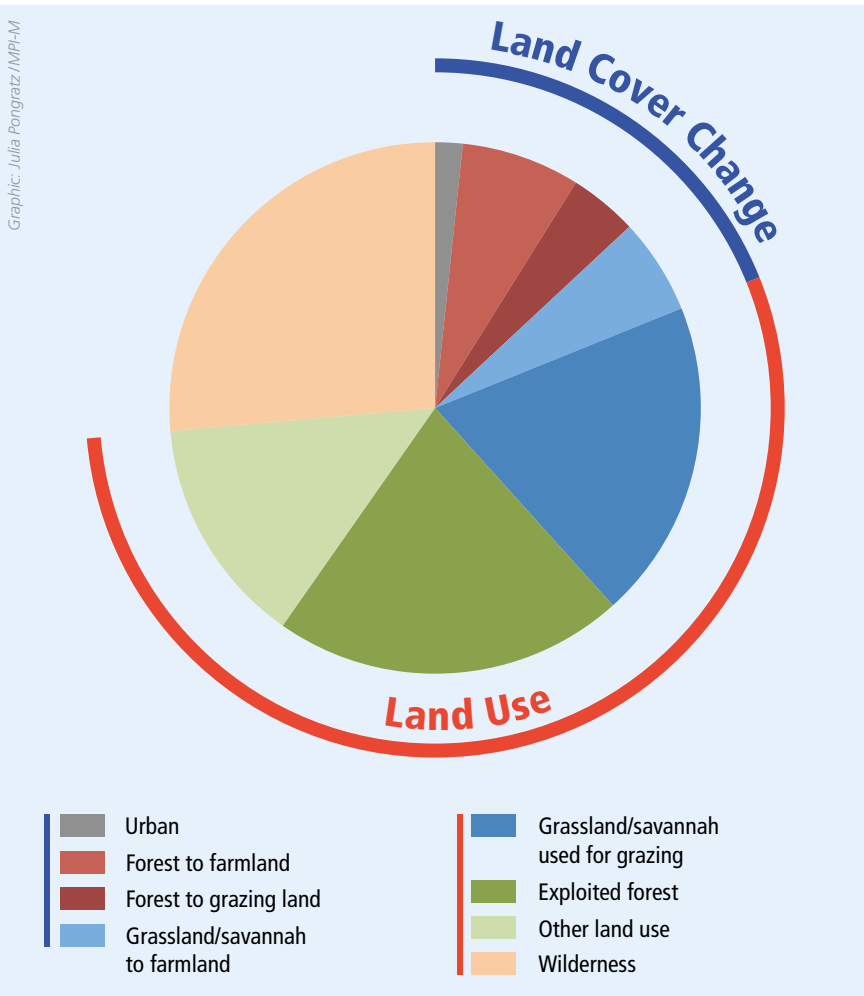
the same environmental conditions, for example in neighbouring fields used for different purposes. They also track the trend in soil carbon in a given location over a period of decades following a land use change.

Studies known as meta-analyses bring together all this observational data to form a cross-regional picture covering multiple land use types, presenting it on a scale that allows it to be compared with the results of global Earth system models. In 2016, a team led by Sylvia Nyawira at the Max Planck Institute for Meteorology demonstrated that this observational data cannot be reproduced by the models unless the harvesting of farmland is also simulated. Only then does the model capture the right order of magnitude of soil carbon loss over time. So Earth system models need to be expanded to represent land management to transform the models into useful tools – not only to understand the processes at work but also to deliver quantitative assessments of the actual strength of

the various land management effects on the Earth system.

After years of intensive research, it has been clearly demonstrated that expanding Earth system models to include land management is now more important than ever. Firstly, as natural land becomes scarcer and demand for food and fibre increases, we are seeing an intensification of forestry and agriculture. Secondly, the scientific community has reached a level of knowledge where we can begin to identify the type of land use and land management that may be able to counter global warming.

Changes to both land cover and the type of land management have direct and indirect consequences for climate change.



**Prof. Dr. Julia Pongratz** holds the Chair of Physical Geography and Land Use Systems at LMU Munich and leads the group Forest Management in the Earth System at the Max Planck Institute for Meteorology (MPI-M) in Hamburg.

**Dr. Julia Nabel** is a researcher at MPI-M in the group Forest Management in the Earth System.

**Dr. Kim Naudts** is a researcher at MPI-M; in April 2019 she accepted a junior professorship at Vrije Universiteit (VU) Amsterdam.

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[www.mpimet.mpg.de/en/science/the-land-in-the-earth-system/working-groups/forest-management-in-the-earth-system](http://www.mpimet.mpg.de/en/science/the-land-in-the-earth-system/working-groups/forest-management-in-the-earth-system)





Jörg Gromoll, Christian Schiffer and Frank Tüttelmann

# Leave No Man Behind

The burden of involuntary childlessness, carried by millions of couples worldwide, is caused by either male or female infertility. However, for traditional and social reasons research on male reproductive health was neglected for a long time. Now the “forgotten man” experiences his well-deserved renaissance.

*Micromanipulation of germ cells: Cultivated human stem cells, spermatogonia (the precursors of spermatozoa), are isolated with a pipette and then examined.*



Reproduction has driven our species' success since its origins as a staunch guard against evolutionary standstill. The complexity of genetic, endocrine, and cellular processes that the term "reproduction" summarises is amazing. Success depends on all of them to work as an entity: Only one weak link in a long chain of events – and a couple will not be able to conceive.

The likelihood that a couple remains involuntarily childless depends on various factors – above all, age. As people set aside longer periods of time for education and career development, the desire to have children is often delayed to a later phase of life. Yet the time

window for reproduction is narrow: Opening with puberty and closing again long before the onset of the female menopause, only twenty to twenty-five years remain to conceive.

Early adverse effects on fertility and the health of offspring begin to manifest already between 35 and 40 years. For example, already mild hormonal dysbalances frequently associated with age can disrupt the maturation of germ cells and, therefore, hamper fertilisation. In men, spermatogenesis becomes increasingly inefficient over lifetime, while for women the risk of genetic diseases like Down syndrome in offspring increases.

Physicians and researchers have been working for a long time to help couples fulfil their desire to have a child in spite of infertility. The breakthrough came in 1974 when British physiologist Robert Edwards succeeded in creating the first "test-tube baby" by fusing sperm and egg cells in vitro. His in-vitro fertilisation (IVF) technique won Edwards the Nobel Prize in medicine in 2010.

Technologies significantly evolved since then: While IVF still employs millions of sperm to fertilise one egg, intracytoplasmic sperm injection (ICSI) – at least in theory – requires only one single sperm to be injected into each oocyte. To

*Motility analysis of human sperm. A singular sperm, head-tethered to a microscope slide, is recorded with a fast camera to provide visual data for mathematical reconstruction and analysis of the flagellar beating pattern.*

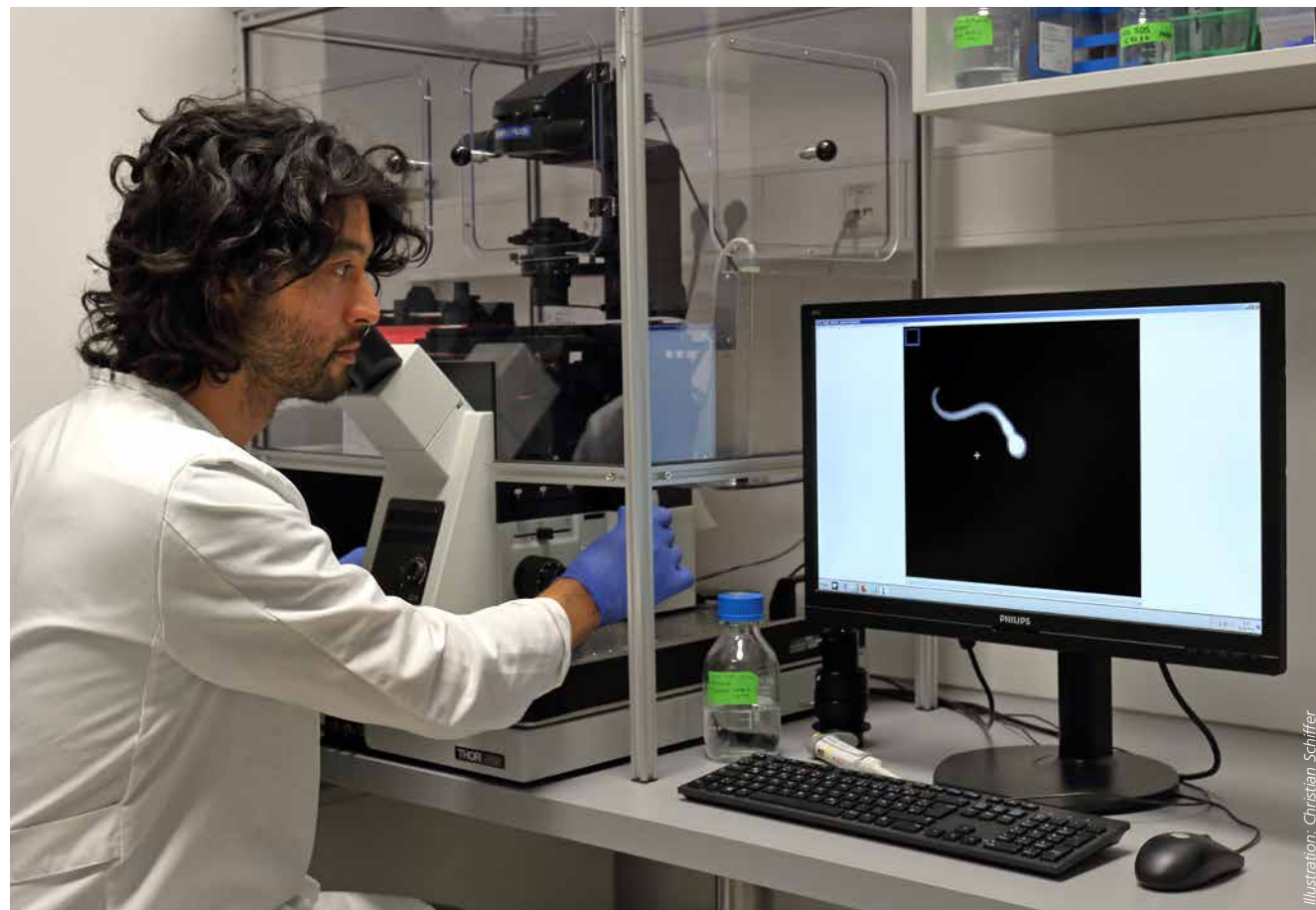


Illustration: Christian Schiffer

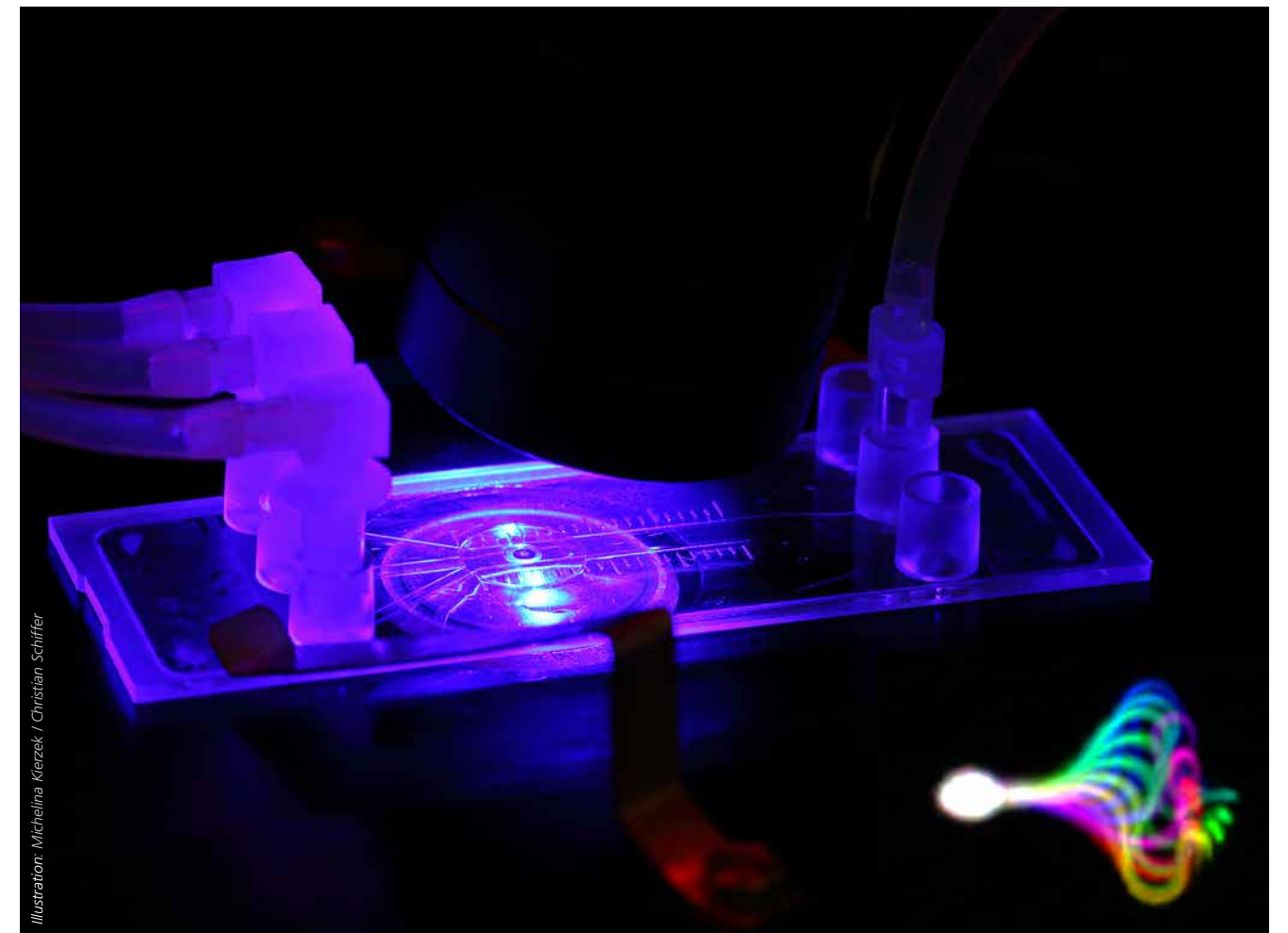


Illustration: Michalina Kierzek / Christian Schiffer

*To understand navigation of freely moving sperm, they are observed under the microscope inside shallow glass capillaries with a high-speed camera. A sequence of successive, aligned, superimposed, and color-coded images allows the flagellar beating pattern to be visualised (bottom right).*

many thousands of involuntarily childless couples every year, IVF and ICSI offer the alternative to resignation.

Indeed, reproductive medicine is in fact so successful that in some countries it is affecting demographic trends. In Denmark and Germany, 8 percent and 4 percent, respectively, of all newborns are conceived through assisted reproduction – with a marked upward trend in both countries. According to the most recent projections, by the end of the century around 300 million humans will owe their life

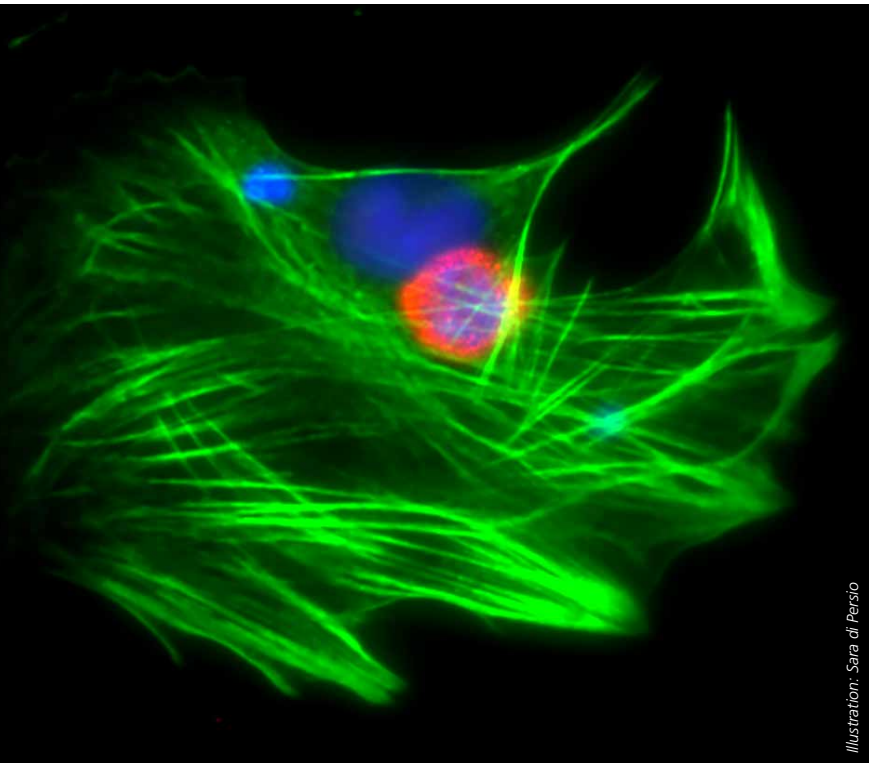
to assisted reproduction worldwide.

However, the insights into the underlying pathophysiology and attempts to cure infertility are not equally distributed between the sexes. Traditionally, mostly women were blamed for infertility in relationships – mainly because scarcely anything was known about the formation of male germ cells and the many stages at which spermatogenesis can fail. Basic science on male reproduction, crucial to understand male (in-)

fertility, was therefore seriously neglected.

Only in recent decades it has become clear that the causes of involuntary childlessness are in fact distributed equally between the sexes: in around 30 percent of cases, male infertility is to blame, and in another 30 percent, the origin lies with the woman. In 20 percent of cases both partners have a fertility problem, and for the remaining 20 percent of couples, current diagnostic tools fail to unravel the origin of infertility. But realising that the male contri-





Immunofluorescence staining for a germ cell (red) between somatic cells (green).

bution to the problem of infertility was massively underestimated did not lead to a greater research focus on men and their reproductive health: after all, why bother with research if even a single sperm cell does the job with ICSI? This rationale thwarted the development of diagnostic tools for male infertility, leaving them largely stuck in the 1960s.

Fortunately, international initiatives like “Man Up” are beginning to address these deficits in recent years. In Australia, for example, researchers and andrologists established an extensive five-year government programme focusing on the impact of male reproductive health on chronic dis-

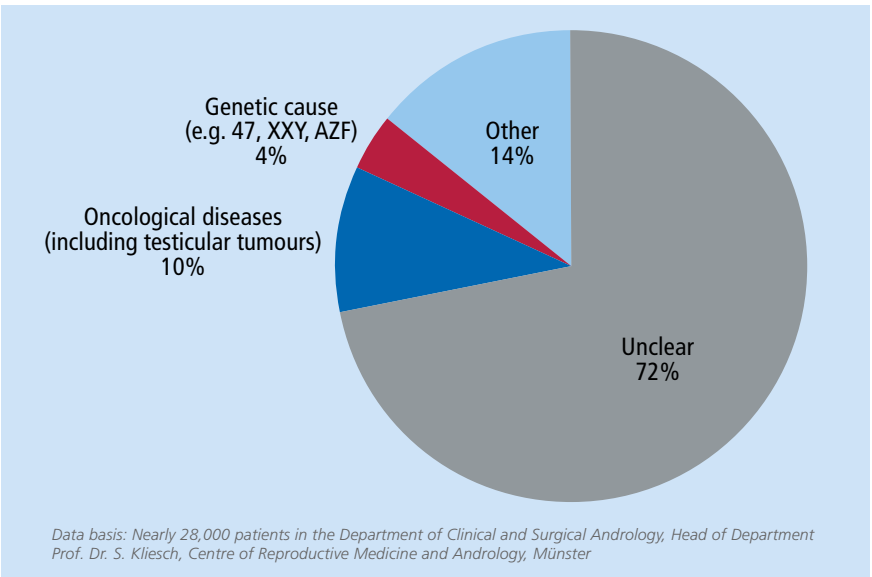
*The aim of reproductive medicine is to help couples fulfil their desire to have a child. But help is not yet available for everyone.*

eases and mental ability. A number of studies from Denmark have already shown that male infertility is associated with increased mortality and a higher likelihood of conditions such as diabetes.



What is the reason for this paradigm shift? A growing body of evidence suggests that male reproductive functions are not only relevant to fatherhood, but also affect overall health and wellbeing – both in the man himself and in his children. Male infertility has to be understood as only one symptom of a complex disease.

The situation with respect to children conceived through assisted reproduction is also complex. In-vitro fertilisation means to circumvent any natural selection in the female genital tract. It would appear that this is not without its consequences: a child conceived through assisted reproduction is at a higher risk of below-average birth weight and seemingly more prone to other comorbidities. A Belgian team led by Herman Tournaye recently dem-



*What causes male infertility? A clear reason can only be identified in about 30 percent of men only, with around 4 percent of cases being due to genetic factors; in over 70 percent of cases the causes are “unexplained”.*

egies to enable infertile patients to conceive even without in vitro fertilisation. “Assisted natural reproduction” – this is how we envisage the next generation of reproductive medicine. There may be many routes to achieve this goal, but one thing we know for certain: Men must not be left behind.

onstrated that, through IVF and ICSI, infertile men can transmit impaired spermatogenesis to their male offspring.

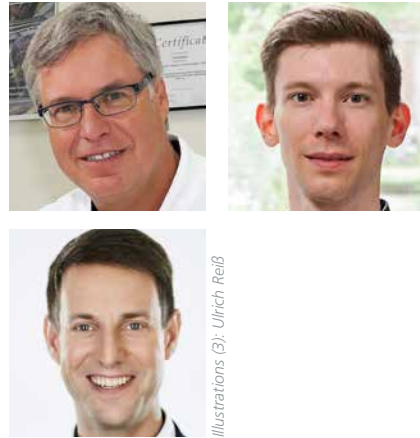
Understanding these unforeseen consequences of artificial intervention in human reproduction has just begun. The introduction of IVF and ICSI has launched a cross-generational long-term experiment whose results only future generations will be able to evaluate.

Research to overcome our lack in understanding male reproductive health is both a scientific and a medical imperative. To tackle this task, we have set up a DFG funded Clinical Research Unit in Münster. The interdisciplinary Unit provides the framework for clinicians and researchers in genetics, biology, and bioinformatics to work on the causes, diagnosis, and treatment of male infertility. Currently, around 70 percent of male patients leave the diagnostic process described as “unexplained infertility”. By using innovative methods such as whole genome and methylome

sequencing and novel sperm tests, we aim to slash this number over the coming years.

The Research Unit’s work programme also takes into account the complex disorders that can affect male reproductive biology beyond infertility. As a model, we collaborate with the Department of General Paediatrics of our University Hospital to study primary ciliary dyskinesia (PCD). This is a rare congenital disease involving defects in the action of the cilia lining the respiratory tract. The cilium is the link: The flagellum that propels a sperm cell shares its molecular architecture with the cilia in the respiratory tract. Genetic factors that cause PCD can therefore also result in poor sperm motility and cause male infertility.

Our Research Unit also pursues concepts that go far beyond the scientific study of male reproductive health and development of innovative diagnostic tools. For example, teams are working on hormonal intervention strategies to stimulate spermatogenesis in infertile men. We foresee such strat-



**Prof. Dr. rer. nat. Jörg Gromoll** is a biologist at the Centre of Reproductive Medicine and Andrology at the University of Münster and the spokesperson for the Clinical Research Unit “Male Germ Cells: From Genes to Function”.

**Dr. Christian Schiffer** is a biochemist at the Centre of Reproductive Medicine and Andrology at the University of Münster.

**Prof. Dr. med. Frank Tüttelmann** is the research coordinator of the Clinical Research Unit and holds a professorship in Reproductive Genetics, established for this purpose, at the Faculty of Medicine, University of Münster.

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[www.male-germ-cells.de](http://www.male-germ-cells.de)





## Christoph Möllers

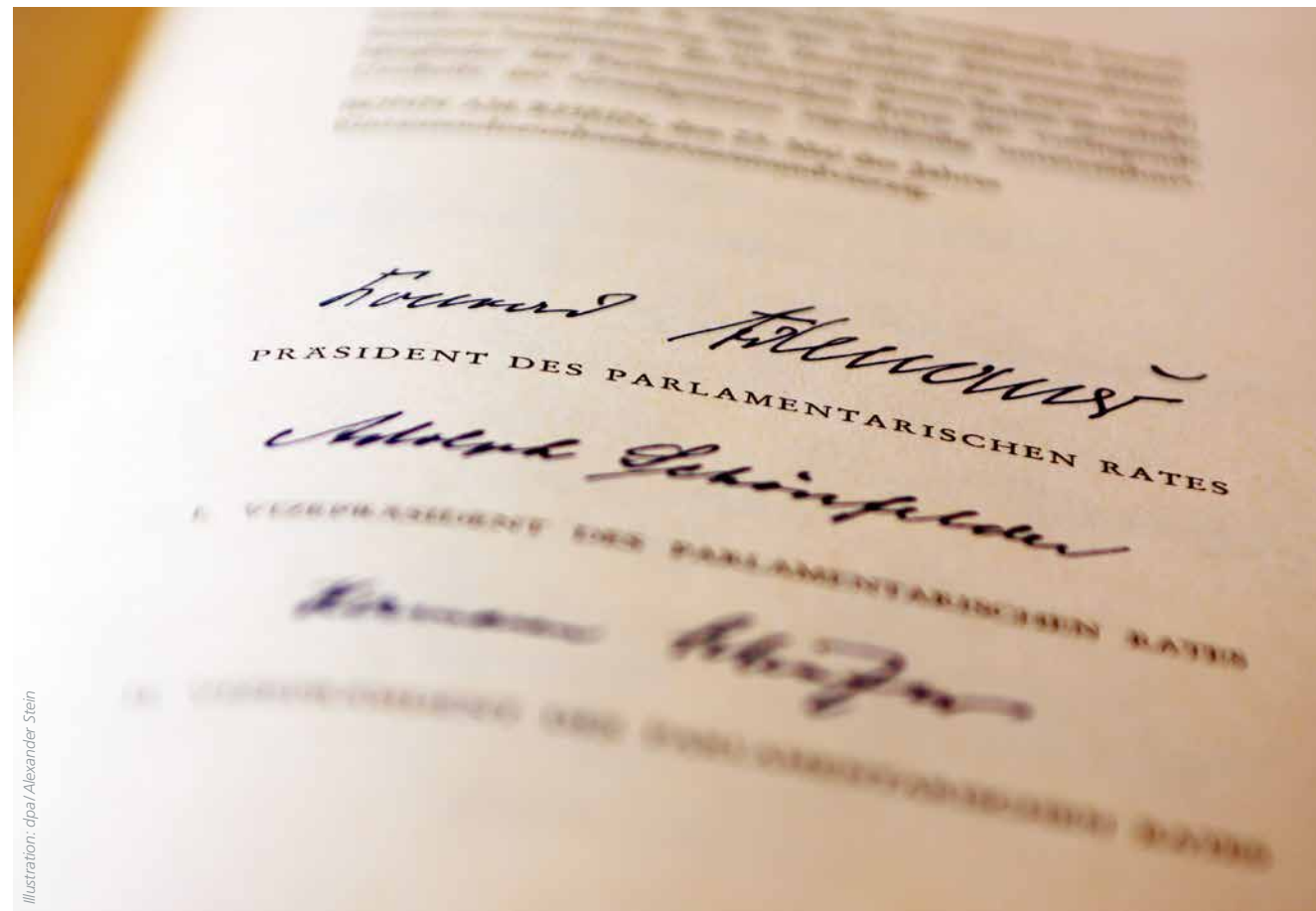


Illustration: dpa/Alexander Stein

# Logics of Freedom

For 70 years, the German Basic Law has protected both artistic and academic freedom as basic rights. Yet the latter is more complicated in its construction and may also be more difficult to defend. One key reason for this is the constitutive role of the state.

Arts and sciences, research and teaching shall be free." Such an explicitly formulated fundamental protection of two social practices, as found in Article 5 Paragraph 3 Clause 1 of the German Basic Law, should by no means be taken for granted, even in western-type constitutions. It is true that academic freedom featured in the draft of the Frankfurt Constitution of 1849 ("Scholarship and its teaching shall be free", Article 152). The Weimar

Constitution, which applied during the Weimar Republic, provided for the freedom of scholarship and artistic expression in a formulation very similar to that in the Basic Law ("Arts, sciences and their teaching shall be free." Article 142). But for a long time, provisions such as this remained the exception in European constitutions. Today, most traditional constitutions still only protect a broadly understood freedom of opinion and communication,

which may normally include artistic practices but does not expressly mention them.

*Above: Facsimile of the Basic Law of 1949, signed by Konrad Adenauer (CDU) as president and Adolph Schönfelder (SPD) and Hermann Schäfer (FDP) as vice-presidents of the Parliamentary Council. Right: On 23 May 1949, the Basic Law lies beneath a standard in the colours of the German flag at the promulgation ceremony in Bonn.*

The European Convention on Human Rights, which is still the most powerful list of basic rights in many European countries, from Turkey and Russia to France, the UK and the Netherlands, only recognises general protection for freedom of opinion, presumably including artistic expression. However, it would seem doubtful whether such guarantees also provide substantial protection for scholarship, academic freedom having so many more prerequisites – as we shall see. By contrast, the newer constitutions which came into force in Eastern Europe and other parts of the world after 1989 frequently contain special provisions that explicitly cover both scholarship and art.

The original intention of the provisions in the Weimar Constitution and the Basic Law focused on the traditional function of a basic right, that of protecting

private activity from interference by the state. In their consultations, the authors of the historic Frankfurt Constitution may have been thinking of the dismissal of the Göttingen Seven in 1837 by the King of Hannover; the members of the Weimar National Assembly in 1919/20 of police measures against scandalous plays or allegedly obscene objets d'art in the German Empire; and the Parliamentary Council in 1949/50 of the Gleichschaltung (enforced conformity) of scholarship under National Socialism. However, what is interesting about the now 70-year-old era of the Basic Law is that the two basic rights, identically formulated, throw up very different problems. Although the idea of artistic freedom has been further developed in various ways during this period, in essence it remains an individual basic right which is primarily deployed against the state or in certain cases between private persons.

A typical case involving artistic freedom would be an artist who has either been sanctioned by the state due to an instance of artistic expression or who claims the right to restrict the rights of others in the name of her own artistic freedom. Recently, a chamber of the Federal Constitutional Court heard a representative case in which the question at issue was whether a painter should be allowed to publicly exhibit a portrait of a child which had been painted with the parents' consent after the parents had withdrawn their consent to the picture being exhibited. An examination of past constitutional court rulings on artistic freedom reveals that most of them relate either to such a weighing-up of artistic freedom versus other freedoms or to the definition of the concept of art itself. This has consistently opened up case law in recent decades and removed the public perception of



Illustration: dpa/DENA



protection belonging only to high or legitimate art.

While such issues could theoretically also be relevant to academic freedom, disputes in constitutional courts have in fact moved in another direction. Here the problems are more complex, and indeed the legal situation relating to scholarship has given rise to an entire field of law and jurisprudence that does not exist in the realm of art. This trend may be attributed to two differences between art and scholarship in modern societies, specifically Germany. The first is the fact that research today is conducted as an organised project. Unlike art (or to be more accurate, unlike what is implied by the myth of the individual artistic genius, in contrast to which a division of labour is

increasingly evident in the visual arts), research can only be carried out in an organised way and with the expenditure of considerable financial and human resources. But this raises the question of whose academic freedom needs to be protected against whom in a different way. The second difference is that, in Germany at least, research is primarily supported by the state, which establishes and funds universities and other research institutions as well as specific research funding organisations such as the DFG.

This requires a different construction of the protection afforded by the basic right which, it would seem, not only protects private persons against the state or other private persons, but also

protects persons in a state-funded and state-established organisation against that same organisation. In other words, when it comes to academic freedom the state often features in three forms: as an organisation that threatens academic freedom, as an organisation or person that upholds academic freedom, and finally as the judicial instance that resolves this conflict on a case-by-case basis. In such inherent conflicts one may detect a problem relating to the theory of freedom and yearn for the private and independent corporate researchers that have never really existed in Germany. It would seem more appropriate to recognise in this construction a very ambitious attempt to legally rethink the protection of freedom in the frame-

*Lying down to rise up in dignity – citizens on Marktstraße in Bad Tölz symbolically mark the 70th anniversary of the Basic Law.*



work of modern, publicly organised research.

Admittedly, this is only the beginning of the problems, as numerous questions now arise. Who can invoke academic freedom – doctoral researchers, professors, faculties, universities? Answer: potentially all of them. Or: if the state provides the resources to carry out research, but thus also makes possible the invocation of academic freedom, do basic rights not also justify entitlement to such resources? Answer: generally, no; academic freedom does not give rise to any entitlement to resources, only an entitlement to decide how they should be used. If we were to try to reduce the varied and, in the details, very controversial principle that arises from this to a common denominator, it might look something like this: Academic freedom demands that decisions relating to scholarship be made in a manner that corresponds to the logic of the research system, that is to say in such a way that academic standards are independently applied.

This general phrasing leaves much open, but it does provide a starting point for many questions: when measured against this yardstick, appointment procedures for professors carried out without specific academic competence, a university organisation that used politicians and managers as supervisory staff, or accreditation requirements that could not make any scientific added value plausible would struggle to be constitutionally compliant.

How much protection do such guarantees provide against current challenges? In principle, these criteria are adequate to pre-



*What does the Basic Law stand for today? Participants in a flash mob in the centre of Braunschweig on 23 May 2019 provide a range of answers.*

vent the political appropriation of scholarship. Compared with other countries where research is also organised on a mostly state-supported basis, the protection of research in Germany is remarkably well developed. Direct interference by political entities in the practice of research is curbed and although the specification of research agendas can be encouraged by the provision of funds, it cannot be enforced by order. Even in systems based on the principle of freedom, all this is by no means automatic.

On the other hand, it is undeniable that a research system so dependent on state funding can only ever be protected from the state to a limited degree. Certainly, the state cannot simply point research in a new direction, but with the right political agenda it can leave it high and dry. Protection against this cannot be compared with the degree of resistance possessed by large, well-funded private universities – in spite of their dependence on private backers – which

in the United States can deal with the state as a societal force in their own right. Dependence on funding and reliance on organisation make academic freedom vulnerable. Seen from this perspective, the more simply constructed artistic freedom may be easier to defend in tough political times.



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Ulrich Böttger

# New Materials for Microelectronics

From microphones to inkjet print heads, ferroelectric components are found in numerous applications. Now, engineers have high hopes of novel and more eco-friendly layers based on hafnium oxide and zirconium oxide. So far, basic research in this field has delivered some surprising results.

Ferroelectric components are found in a host of applications, from mobile phones and cameras to audio technologies and surveillance systems. They can convert pressure into electrical current or, conversely, an electrical stimulus into tiny movements. This is due to the piezoelectric effect, a change in electrical polarisation and thus the

occurrence of an electrical voltage in solids when they are elastically deformed. This is what characterises ferroelectric components.

Their high, controllable “permeability” to electrical fields (the dielectric constant or relative permittivity) and its variation in response to tiny fluctuations in temperature are also exploited. Added material

properties enable applications integrated in microphones, inkjet print heads or pressure and rotation rate sensors, as well as high-resolution microscopes, motion detectors and energy harvesting systems. In short, it’s hard to overestimate the importance of ferroelectric materials.

To date, most products have been based on materials that con-

tain lead, such as lead zirconate titanate (PZT). If this heavy metal is not properly recycled, it can enter the water cycle and, through the food chain, humans. Even small doses of lead can cause nerve damage in the human body. Although the use of such toxic materials has been banned in the EU since 2006, exceptions are allowed where no suitable alternatives exist. Possible alternatives, such as potassium sodium niobate, did not meet the expectations of researchers and developers.

A new possibility is hafnium oxide, whose ferroelectric nature was discovered more or less by accident in thin films. Engineers at the former semiconductor company Qimonda noticed unusual electrical effects in silicon-doped hafnium oxide in a layer thickness of 10 nanometres. The typical reversal of polarisation provided an initial clue to ferroelectricity, but it was the butterfly shape of the electro-mechanical stress-strain curve and the discovery of a specific crystal phase, a prerequisite for the occurrence of ferroelectricity, that left no doubt as to the correctness of this interpretation.

The reason this effect was not observed sooner comes down to certain fundamental facts of physics. Positive and negative ions in a crystal lattice vibrate against each other. In conventional ferroelectric materials, if the temperature falls

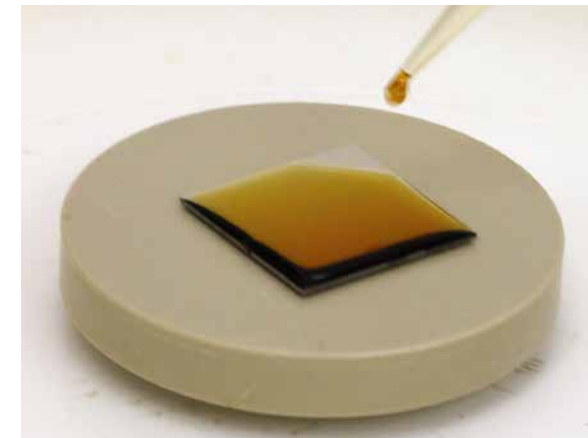
and this vibration comes to a halt (known as “freezing”), the ions locally form a stable electrical charge separation (“dipole moments”) whose average value is measured as the polarisation. When this effect occurs, the crystal is said to have transitioned into the ferroelectric phase. In some materials, such as strontium titanate, due to quantum fluctuations, vibration does not stop until close to absolute zero. The ferroelectric phase can be stabilised even at room temperature when the crystal lattice is disrupted by elastic stress, variation in composition, or defects. This is the case with hafnium oxide.

But this material offers even more, including the possibility of integrating ferroelectric properties in silicon semiconductor technology. Hafnium oxide is one of the few metal oxides that are thermodynamically stable with silicon at the temperatures required in microelectronics manufacturing. Because of its high permittivity, it has long been used as a capacitor material in integrated circuits. More recent applications exploit the polarisation state of the hafnium oxide layer as an innovative means of storing information.

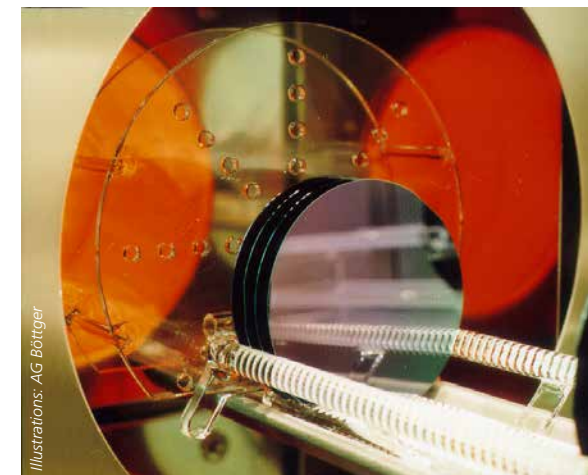
The ferroelectric property of hafnium oxide thin layers is not tied to a particular method of production: different techniques to deposit the material from the gas or liquid phase result in similar behaviour. One particularly interesting method is Chemical Solution Deposition or CSD, which is recognised as a suitable technique for manufacturing inorganic oxide films. A precursor solution is applied to a substrate by spin coating, immersion or spraying and, through a sequence of thermal



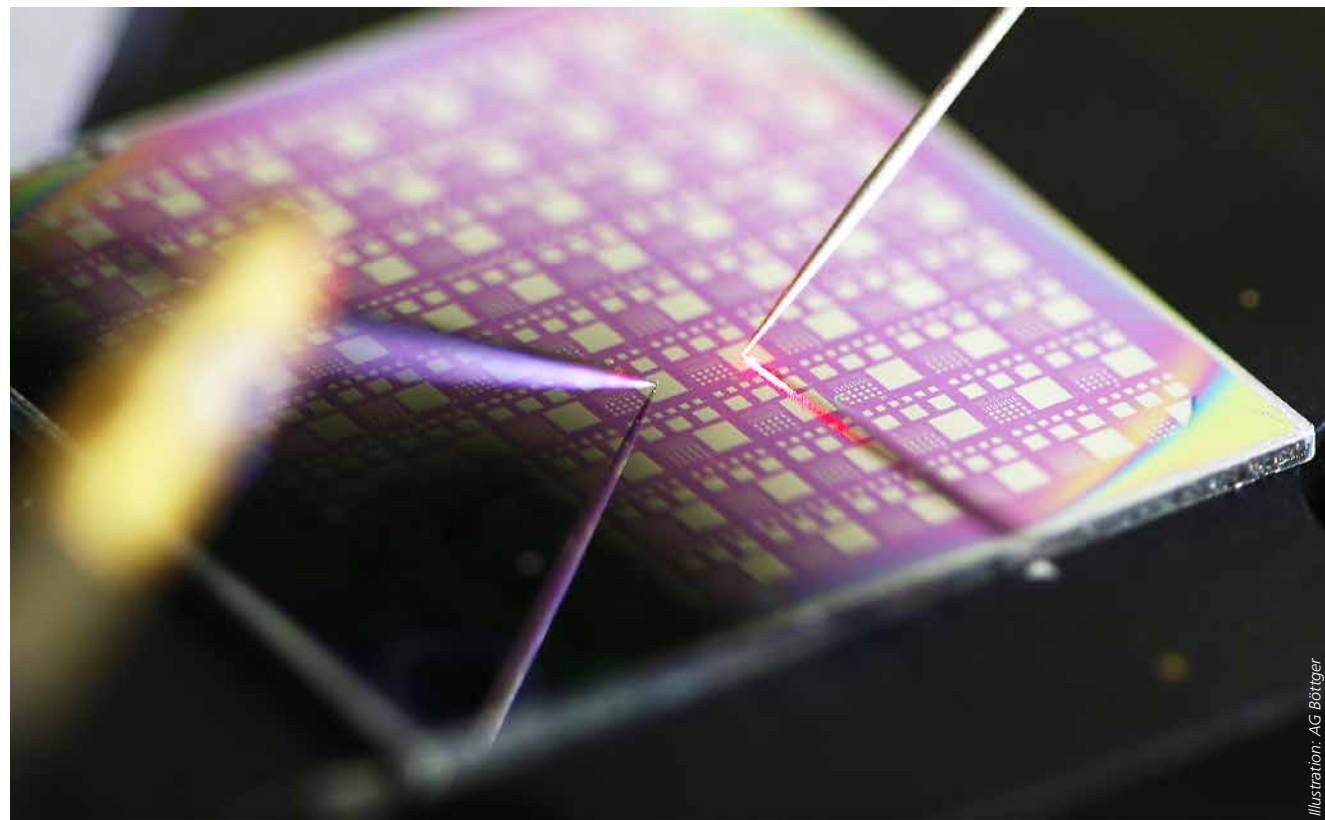
Solutions of yttrium-doped hafnium oxide (left) and undoped zirconium oxide (right) ...



... are applied to the wafer with a pipette prior to centrifugation.



The wafers then undergo crystallisation in the diffusion furnace.



Left: Characterisation of the piezoelectric activity of an yttrium-doped hafnium oxide thin layer. The electrical stimulus is applied via the needle and the resulting change in thickness is detected with a laser.

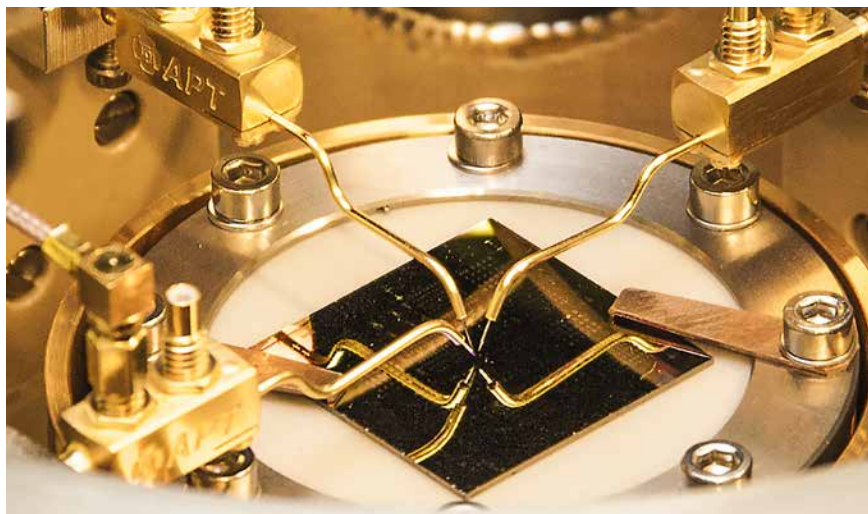
Illustration: AG Böttger

Illustrations: AG Böttger

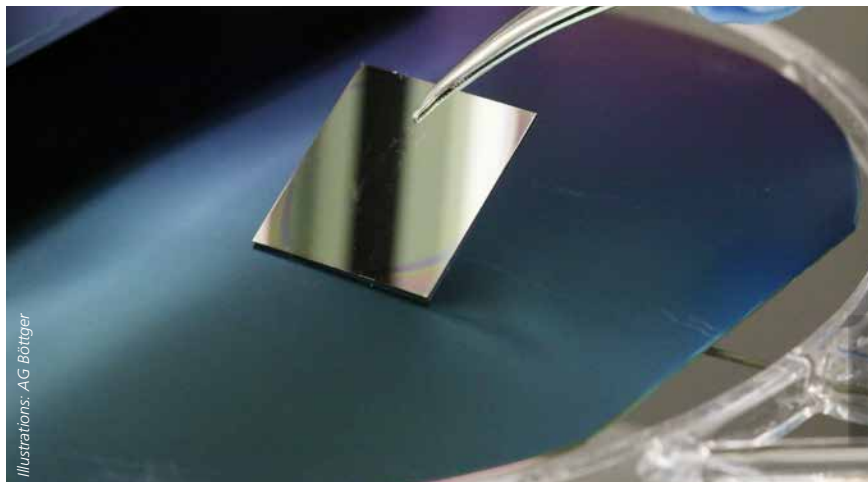




Structural transfer by means of optical lithography, under yellow light in the clean room.



Wafer testing: Automatic control by means of piezoelectric micropositioners.



Placing a coated wafer in a quick-heating furnace for crystallisation.

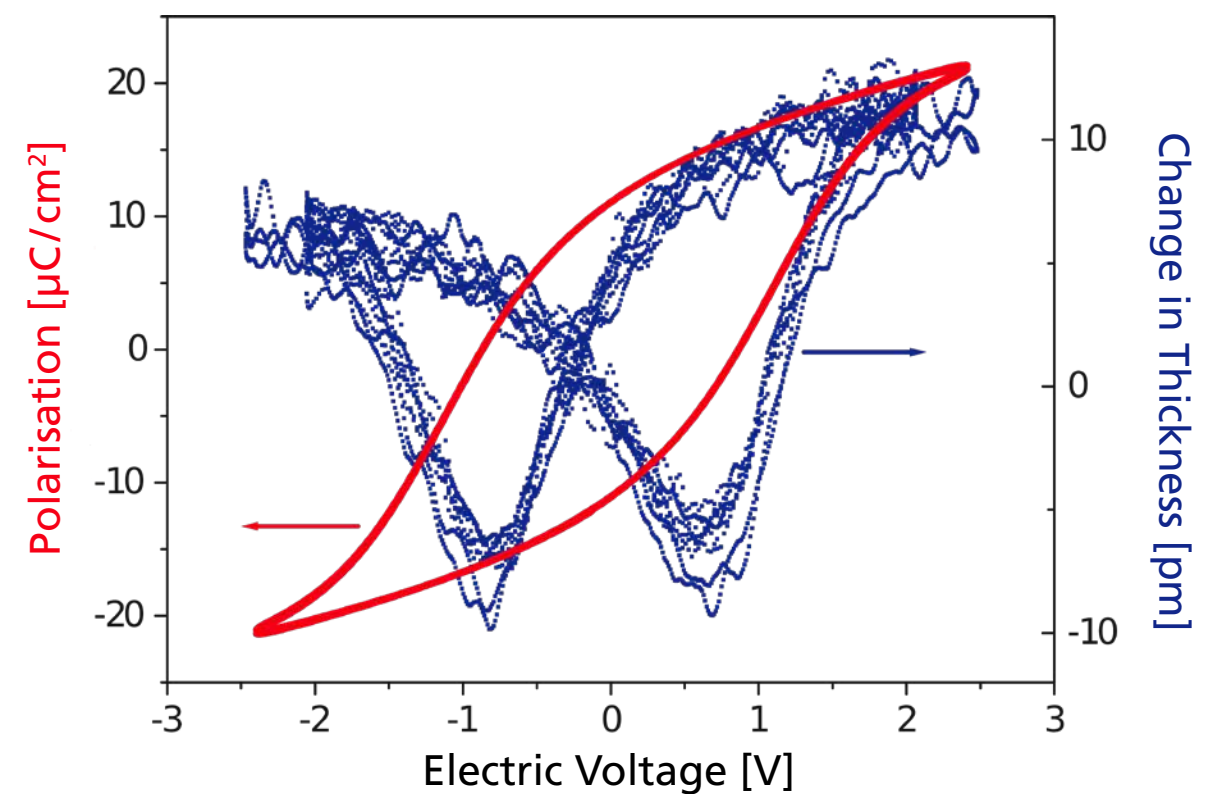
treatments, transferred to the desired crystalline phase.

The solution is based on precursor molecules. During synthesis, chemical stabilisers allow the properties to be precisely “adjusted” in the finished solutions. The advantages of this technique are its low cost compared to vacuum-based methods and its high flexibility. This deposition technique is therefore suitable for material screening and process optimisation. Another benefit of CSD is the fact that it allows economical production of layers just a few micrometres thick.

The addition of silicon isn’t the only way to achieve formation of the ferroelectric phase: the use of CSD has demonstrated that a range of doping agents (the atoms added during the process) result in the stabilisation of the ferroelectric phase. A dependent relationship was observed: ions with a radius significantly larger than hafnium exhibit more marked ferroelectric behaviour, while with smaller ions the effect is much weaker. Typically, all doping agents that cause a ferroelectric phase have a characteristic window of doping concentration, the origin of which is not yet understood.

Mixtures of hafnium zirconium oxide as well as pure zirconium oxide also exhibit ferroelectric properties. This is especially surprising in the case of zirconium oxide, which was also studied for years in connection with a wide range of applications without any indications of ferroelectricity being discovered.

The ferroelectric behaviour only develops after an alternating electrical field of approximately 1,000 cycles is applied (known as the “wake-up” process). If we look first at an yttrium-doped hafnium oxide



Graphic: AG Böttger

The striking butterfly shape of the electromechanical stress-strain curve for a silicon-doped hafnium oxide layer around 10 nm thick. By using a double-beam laser interferometer, it is possible to resolve changes in thickness of less than 1 picometre (1 billion picometres make 1 millimetre).

layer, it is known that the transition metal yttrium is incorporated as a trivalent ion into a crystal lattice of a tetravalent hafnium ion. The required charge neutrality in the crystal is ensured by the absence of oxygen ions with a double negative charge. It is currently assumed that the alternating electrical field causes the oxygen ions to be distributed homogeneously in the layer, and when they are present in the “correct” concentration, the ions produce stabilisation of the ferroelectric phase.

In mixtures of hafnium zirconium oxide, the microstructure has a decisive influence on phase stabilisation. Different grain sizes result in different surface energies. The ferroelectric phase is favoured

in the sense that hafnium-rich compositions require thinner layers, while zirconium oxide-rich mixtures demand thicker films. In the case of pure zirconium oxide, marked ferroelectric properties have been demonstrated at layer thicknesses of as little as around 0.5 of a micrometre.

Developments so far point to the future. Although the piezoelectric activity of the new ferroelectric layers is less than the conventional lead zirconate titanate by at least a factor of 4, the biocompatibility of the new materials offers significant market opportunities for components in medical applications. Another promising area of application is sensor technology, a field which

could also exploit the benefits of the new materials. The potential for practical applications would seem to be far from exhausted.



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## The Deutsche Forschungsgemeinschaft

The Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) is the largest research funding organisation and the central self-governing organisation for research in Germany. Its mission, as defined in its statutes, is to promote “all branches of science and the humanities”.

With an annual budget of around €3.4 billion, the DFG funds and coordinates approximately 33,000 research projects in its various programmes. These projects are carried out by both individual researchers and groups of researchers based at universities and non-university research institutions. The focus in all disciplines is on basic research.

Researchers at universities and research institutions in Germany are eligible to apply for DFG funding. Research proposals are evaluated by reviewers in line with the criteria of scientific quality and originality, and then assessed by review boards, which are elected for a four-year period by the German research community.

The DFG places special emphasis on early career support, gender equality and scientific relations with other countries. It also funds and initiates measures to develop and expand scientific library services, data centres and the use of major instrumentation in research. Another of the DFG’s core tasks is to advise parliaments and public interest institutions on scientific matters. Together with the German Council of Science and Humanities, the DFG is also responsible for implementing the Excellence Strategy to promote top-level research at German universities.

The DFG currently has 97 member organisations, primarily comprised of universities, non-university research organisations such as the Max Planck Society, the Leibniz Association and the Fraunhofer-Gesellschaft, the Helmholtz Association of German Research Centres, and academies of sciences and humanities. The majority of the DFG’s budget is provided by the federal and state governments, and it also receives funds from the Stifterverband.

For more information, visit [www.dfg.de/en](http://www.dfg.de/en)

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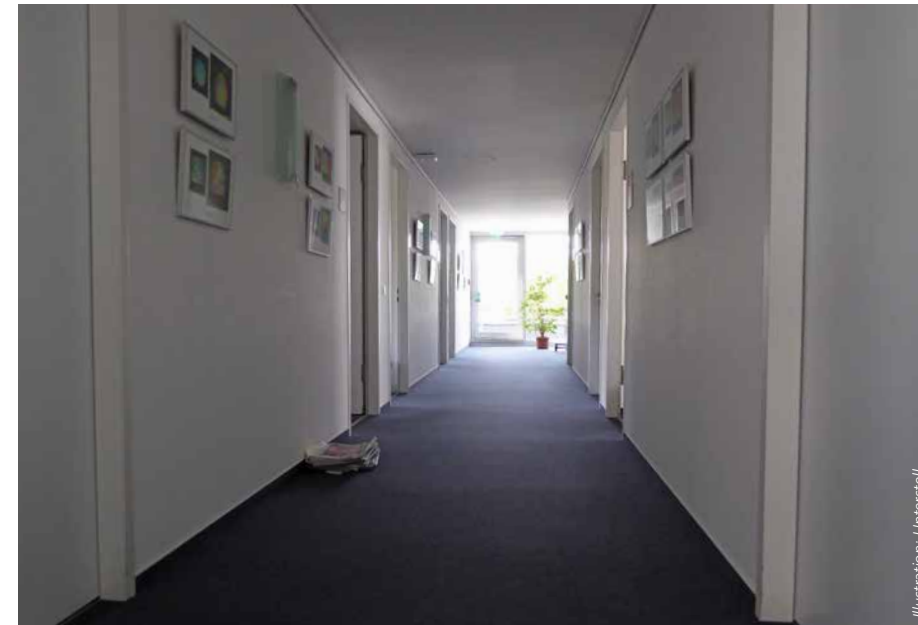


Illustration: Unterstell

Deserted corridor, empty offices – to keep everyone healthy and keep the pandemic under control. Since mid-March 2020, as with many businesses and organisations, the staff at the DFG Head Office in Bonn have been working from home. Like nearly all of the 800 staff of Germany’s largest research funding organisation, the editorial team of *german research* left their familiar working environment to produce the new edition of our magazine from their home offices. In addition to the usual feature articles from DFG-funded researchers, this issue takes a look at the DFG’s response to the outbreak and rapid spread of the coronavirus pandemic – including wide-ranging measures to ensure the almost seamless continuity of funding activities, relevant new funding opportunities, the cancellation, for the time being, of award ceremonies and anniversary events, and a special award for outstanding science communication during these unprecedented times. The fact that the magazine is appearing at almost exactly the same time as the first cautious easing of restrictions on public life perhaps represents, in its own way, a small light at the end of the corridor. As always, we hope that all our readers enjoy the magazine, but this time we would add that we hope you all stay well and healthy.