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Navigating the energy system transformation

How can policymakers better coordinate the energy system transformation and get citizens more effectively involved? An analysis and recommendation by Michèle Knodt,w Professor of Political Science at TU Darmstadt.

Professor Knodt, in your research you are analysing political challenges posed by the energy system transformation. You have been part of the Executive Committee of the Kopernikus ENavi Project that recently has been completed successfully. Why do we need a navigation system for the transformation?

We need a navigation system because many aspects of the transformation process are challenging. In Germany we are doing quite well when it comes to the expansion of renewable energies. What is not currently working well is cutting down on $C0_2$ emissions, especially in the energy, housing and transport sectors. We are also lagging behind in terms of energy efficiency.

What do you think is the reason for this?

The energy transformation cuts across many areas, from electricity to mobility to housing. To manage this, policymakers must take action in two dimensions: in a horizontal dimension, a large number of ministries need to be coordinated; in a vertical dimension, various governance levels from the EU to the federal states need to be integrated. Now, both dimensions are lacking effective coordination.

What is the situation in Germany?

Just to illustrate the challenges of horizontal coordination, in Germany, six federal ministries, including the Chancellery, are involved. For example, the Federal Ministry of Economic Affairs and Energy is responsible for energy policy and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety is responsible for climate policy. In the Ministry of Economic Affairs alone, 34 divisions in four directorates are dealing with the energy system transformation. If you extrapolate that, you can imagine how many people you need to bring together. The German government applies the principle of negative coordination, which means that one of the ministries takes the lead and submits a proposal, which then circulates through the other departments. All ministries have their own resources, seek to defend their various areas of competence and are led by different political parties in the coalition government. It was easy to see where this mixture of departmental particularism and party politics was leading during the struggle to agree on the climate plan proposed by the Ministry of the Environment in 2016 … namely to the lowest common denominator.

What would you suggest?

We recommend positive coordination, i.e. an interministerial working group should develop common perspectives and then draw up proposals with which decision-makers can identify across ministerial and party boundaries. This usually breeds better results. The more opportunities such bodies have to work together, the greater their esprit de corps. For example, this positive effect has been observable within the EU in the long-standing cooperation of core executives within the financial sector.

But there has been a climate cabinet in Germany established in 2019 in which all those responsible sit around one table. Isn't that a step in the right direction?

In principle, yes! But even the name shows that the set-up is inappropriate. The heads of the various fractions meet and negotiate about the proposals of a particular ministry, which are, first and foremost, about political issues that are currently highly controversial. This cannot work because it is mainly driven by party ideologies and competitive orientations. It is evident that people are dissatisfied with the results. The response to the CO_2 levy was devastating. We would advocate establishing policy formulation by continuous interministerial cooperation at a lower, rather specialist level. It's all about coming up with a joint plan.

Let's talk about the Energy Union, which is supposed to ensure that European energy and climate objectives are implemented at European level and within the Member States, but which seems to lack the proper instruments to do so.

The Energy Union is facing a dilemma: on the one hand, it is supposed to guarantee a secure, sustainable and competitive energy supply, whilst on the other it has to refrain from interfering in the energy policies of the Member States. It has no competences to intervene into national energy matters. The Energy Union was launched in 2014 under critical conditions: without the right to impose sanctions, with no voluntary commitments by the Member States, but burdened by conflicts between East and West. The 2018 Governance Regulation has changed little in this respect.

Why?

Because it still only allows for soft governance. Without hierarchies and competences, the EU can only

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Abbildung: Katrin Binner

Dr. Cornelia Fraune, Prof. Michèle Knodt and Dr. Jörg Kemmerzell are developing recommendations for the governance of the energy system transformation

propose guidelines, review their implementation by Member States, and recommend improvements. The Member States are expected to follow the recommendations, but the EU cannot oblige them to do so.

How could the Energy Union become more assertive?

Energy policy would have to be linked to a policy field with greater enforcement and sanction powers, i.e. the structural funds policy. Although the structural funds were originally initiated to support the weaker EU regions, all Member States now benefit from them. Energy transformation and climate change are already priorities and are being promoted in this context. This would need to be further developed and linked more closely to the provisions of the Energy Governance Regulation. This would not only allow for the inclusion and accentuation of more substantive specifications but would also make it possible to couple the award and payment of subsidies to the implementation of EU recommendations concerning Member State energy policies.

You also see a great need for action in terms of citizen participation. How could people be better integrated into the transformation?

Currently we are seeing a paradox in Germany: a majority of citizens supports the energy transition in general. But when it comes to implementation, many people suddenly take a different view, for example when a wind turbine is to be built on their own doorstep. One of the reasons for resistance is that citizens are generally involved at too late a stage in the decision-making process. Institutionalized participation opportunities are only implemented in the context of regional planning. Citizens are not involved in discussions at the federal level around values relating to the overriding objectives of the energy transition or on the definition of impositions, i.e. the development of the major criteria. We need participation right from the start at local, regional and national levels. Any consensus reached at these levels must be incorporated into the decision-making process of the representative system. In this way, the red lines will be revealed at an early stage, and ultimately it will be possible to increase acceptance of the energy transition.

Interview: Jutta Witte. She is a science writer and holds a doctorate in History.

Kopernikus-Project ENavi

ENavi (Energiewende-Navigationssystem) was funded by the Federal Ministry of Education and Research within the Kopernikus projects (15.10.2017 - 31.12.2019) and considers the energy system transformation as a change process for society as a whole. 84 partners participated in 13 work packages. Under the leadership of Prof. Dr. Michèle Knodt, Managing Director of the Institute of Political Science at TU Darmstadt and a member of the ENavi Executive Committee, several teams in the work package on „Structural and processual changes in the multi-level governance system“ analysed the coordination of the energy transition in Germany, Austria and Poland, multi-level coordination within the Energy Union, and the potential for improved multi-level citizen participation.

The ENavi Final Report:

https://www.politikwissenschaft.tu-darmstadt.de/media/politikwissenschaft/ifp_dokumente/arbeitsbereiche_dokumente/vergleich_integration_1/enavi/FREI4_191216_ENavi-Bericht_DE_Doppelseiten.pdf

Pause button for light particles

Researchers at TU Darmstadt halt individual photons and can release them at the push of a button. The tool could be used for bug-proof communications, for example, or for something that was previously impossible.

By Christian J. Meier

How do you stop something that is faster than anything else, intangible and always in motion by nature? A team led by physicists Dr. Thorsten Peters and Professor Thomas Halfmann is doing the seemingly impossible: stopping light for tiny fractions of a second. They then end the stopover at the push of a button letting the light pulse continue its journey. The researchers are even stopping individual light particles.

What sounds like a physical gimmick, could be of use for future applications. So-called quantum technology attempts to use bizarre effects of quantum physics for faster computers, more precise sensors and bug-proof communications. Photons, which are used in quantum technology as information carriers, play a decisive role in this. To this end, physicists, for example, require light sources that emit individual photons at the push of a button. To process the information stored on light particles, it would also be important for individual photons to interact, which they do not usually do. In future quantum computers, photons will for example have to transfer their information to atoms and vice versa. To this end too, the interaction between the two types of particles must be intensified, which the photons stopped by the group from the TU Darmstadt could make possible.

"Our objective was to make photons interact with atoms more strongly than they normally do."

How does this emergency stop for light work? For some time now it has been possible to freeze photons and re-emit them on command. However, whilst they are stopped, the photons do not exist as such. They are swallowed by an atomic cloud, which then assumes a so-called excited state and stores the photon as information. Only upon receipt of a signal does the excitation change back into a photon, which then continues on. The researchers in Darmstadt are doing it in a similar manner, but with one crucial difference: their photons are actually preserved.

The light literally stands still. The team uses a special glass fibre with a hollow channel in the centre with a diameter of less than ten thousandths of a millimetre. The fibre has a porous structure round the core that keeps light at bay. This causes a laser beam to concentrate in the centre of the hollow channel. Its cross-section narrows to around one thousandth of a millimetre. The researchers use the light beam as a kind of trap for atoms. They introduce atoms of rubidium into the hollow fibre, which concentrate in the centre of the laser beam due to electromagnetic forces. The researchers then send the photons they want to stop into the channel. Roughly speaking, the photon is brought to a complete stop by two additional laser beams that are guided into the hollow fibre on both sides. Metaphorically speaking, these hold the photons between them like two footballers kicking the ball back and forth.

„It is also similar to a chamber in which light is thrown back and forth between two mirrors," as Thorsten Peters explains. „Just without a mirror." The TU-team is the first to succeed in slowing down photons in such a narrow capillary in this way and it was not easy. It is made extremely complicated by an optical property known as birefringence. The team was able to refine their method through a laborious birefringence analysis to the point where stopping individual photons became possible.

But simply stopping light itself they did not satisfy themselves. „Our objective," says Peters, "was to make photons interact with atoms more strongly than they normally do." In particular, it should be possible for two light particles to interact with an atom at the same time, which would produce a useful phenomenon known in physics as nonlinear optics in which photons penetrate a medium, such as a special crystal. When two photons simultaneously strike one of the atoms in the crystal, they interact with one another, which changes the frequency, i.e., the colour, of the light. The new frequency could, for example, be the sum of the frequencies of the photons that are sent in.

Information

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There are many technical applications for such effects, for example in laser pointers. The method does have one disadvantage: high intensity lasers are needed to guarantee that enough pairs of photons strike an atom within the medium simultaneously. „With our method, on the other hand," says Peters, "a weak light intensity may be sufficient." This is possible because the atoms are confined to the same narrow area as the laser beam within the hollow fibre, thus maximising the contact between the light and the atomic cloud. Therefore the probability of two photons hitting an atom simultaneously is relatively high even when the light intensity is low. So the same technical trick that makes it possible to stop the photons should also create a new method for nonlinear optics.

The Darmstadt-based team has more ideas for how to apply his new process. One of these involves a switchable source for single photons. Another is to create a crystal made of photons. Crystals usually consist of atoms arranged in an absolutely regular grid, comparable to layered spheres. A large number of stopped photons could also form an ordered grid. „We could use this to simulate a solid," says Peters. The physics of solid materials is an active field of research. Theoretical models are used in research to gain a better understanding of them – often through computer simulations. But the models are so complex that they quickly overwhelm the computers. Researchers are therefore looking for other ways to imitate crystals. A simulated solid made of photons would be one way of doing this.

"We are continuing to work intensively on this," says Peters. According to the physicist, collaboration with other research groups is crucial for success. The team achieved the current work in collaboration with groups from Taiwan and Bulgaria within the framework of an EU-funded project. Industrial partners are also involved in the research project, whose objective is to develop innovative technologies for the interaction of light with matter. „The exchange is very active," Peters is pleased to say. The next successes will not be long in coming.

The author is a science writer and holds a doctorate in physics.

Further information

Thorsten Peters et al.: Single-photon-level narrowband memory in a hollow-core photonic bandgap fiber, Optics Express, Vol. 28, No. 4, 5340 (2020):
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EU-Projekt LIMQUET (Light-Matter Interfaces for Quantum Enhanced Technologies):
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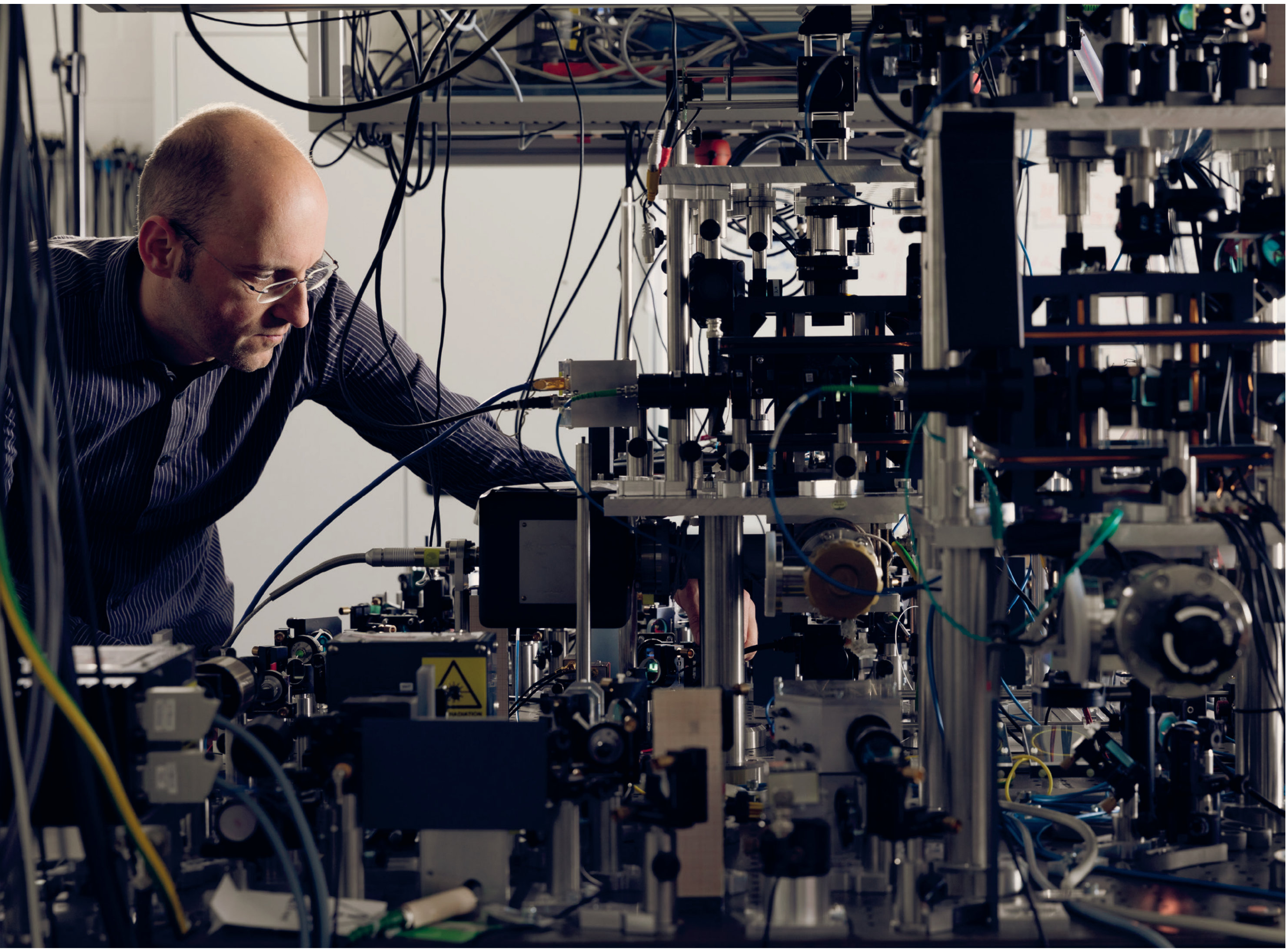

Experimental setup for decelerating single photons in an optical fibre filled with ultra-cold atoms.

Photo: Katrin Binner

Fewer stumbling blocks

Human movement when stumbling is manifold – and remarkably misunderstood. TU motion scientist have come to a well-founded conclusion that could even help robots to maintain balance.

By Boris Hänßler

The Angular Momentum Perturbator (AMP) looks like a backpack. It weighs 16 kilograms, and contains a fast-rotating tied gyro that is suspended from a motorised frame in such a way that torques are transmitted by an additional rotation to the person carrying the „backpack". The AMP has a simple function: it causes a perturbation of the subject's posture. The person then has to compensate for this disturbance with their body so as not to fall. For researcher Christian Schumacher and his colleagues at the Locomotion Laboratory at TU Darmstadt, this moment is an opportunity to take a closer look at the specific function of the leg muscles.

"One research hypothesis is that we create a certain overarching representation in the brain. The processed signals transform these decisions into a kind of exact road map for the individual muscles."

Schumacher conducted studies during a research stay at the Biorobotics Lab of the Delft University of Technology (Netherlands), where the AMP was developed. Both research groups were the first in the world to use a system of this kind to investigate the function of the so-called biarticular (two-joint) leg muscles. For the first time, the teams were able to demonstrate through experiments that these muscles responded most strongly when it came to realign the upper body, for instance after a push. An understanding of these processes not only helps to better understand the entire human motor control and to compensate for possible impairments with technology, but also encourages the development of robots that are able to walk more safely and more efficiently on two legs – which is still a tremendous challenge for science.

There are good reasons why the mechanisms of human motor control are not yet fully understood. „The biggest problem in our research is that the body is so diverse," explains Schumacher. When we are pushed, stumble or walk on an uneven terrain, our body coordinates a variety of muscles to compensate for the uncertain movements and restore balance. It has a tremendous number of levels of freedom at its disposal – and thus numerous possibilities for moving muscles and joints.

„Imagine you want to pick up a pen that's on the table in front of you," says Schumacher. „You can do it in an infinite number of ways." The mechanisms are understood. First, neural impulses are created in the brain, processed in the spinal cord and passed on to the muscles. These impulses create the contractions of the muscles, and with that the motion. At the same time, sensory signals arrive in the spinal cord e.g. from the skin receptors in the fingers as soon as we touch the pen and feel a counterforce. These signals support the control or, in turn, initiate new movements.

Although researchers can observe the movements closely and measure the neural signals from the muscles, they cannot (yet) be predicted. „This is because one has specific aims with every movement that influence the type of movement, for instance to do something efficiently or quickly," explains Schumacher. So the goals of a motion are as diverse as the movements themselves. So if researchers are unable to predict how a motion is actually performed based on body structures and hypotheses, it is difficult to explain the roles of individual muscles in the overall complex.

The same also applies to the leg muscles. One of the differences between leg and arm movements is that leg movements are often instinctive. If you reach out for something you plan the movement, but if you are running and then trip, you will have to rely heavily on your reflexes. The response is automatic. The spinal cord takes on a lot of the control by effectively responding directly to the incoming signals and controlling a whole range of muscles at the same time. „One research hypothesis is that we create a certain overarching representation in the brain, for instance: I want to go from A to B with these objectives or under these conditions," explains Schumacher. „The signals that are processed in

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Photo: Sandra Junker

Professor André Seyfarth, Dr. Maziar Sharbafi and Christian Schumacher (from left to right) adjusting the prototype of a soft-suit exoskeleton.

the spinal cord transform these decisions into a kind of precise road map for the individual muscles, which then know exactly what to do and when and how."

Although this, unlike the picking up of the pen, is an automatic sequence of events, there is the same motion diversity. „There is the same degree of variability between individuals as there is among the actual functions," says Schumacher. One may perhaps bend a knee a little more while another makes more use of individual muscles. This variability is an advantage because if an injury prevents a particular function from working, we might be able to use another one – often with almost identical results. This makes us more viable, you could say.

In order to investigate the role of the two-joint muscle, Schumacher and his colleagues divided movements into three basic functions: stance leg function, swing leg function, and upper-body balance. This division into clearly distinguishable functions has enabled researchers to identify the different functional contributions of the two-joint muscles. Among other things, this enabled the scientists to prove, as had been hypothesised, that these muscles were very active in stance leg control. They help us to save energy when pushing ourselves off the ground because they can transfer energy from one joint to the other. This means that we move more efficiently, but also that we have more strength, for instance when hopping.

Now it is a matter energy efficiency is relevant in the field of prosthetics. Most prostheses are still passive today, which is why prosthetic wearers consume up to 60 percent more energy when walking than people without prostheses. Actuated systems that actively support people when walking require a certain battery capacity – but wearers find the resulting greater weight unpleasant. The mechanisms of two-joint muscles can help to do more with less energy.

And finally exoskeletons benefit from these results. They have evolved tremendously in recent years. The cumbersome mechanical scaffolding has now been replaced by soft-suit exoskeletons – textile-based systems that transmit forces using cable pulls. They support people with impaired movement for instance during push-off or leg swing. The TU group has already shown that people with exoskeletons that include the mechanisms of two-joint muscles are able to walk more efficiently.

The author is a technology journalist.

Participating research groups:
Locomotion Laboratory of the Institute of Sports Sciences at TU Darmstadt **http://www.lauflabor.de**
Delft Biorobotics Lab at TU Delft **http://www.dbl.tudelft.nl**

Publications:

Review paper on simulation models, experimental studies and robotic systems with two-joint muscles: Schumacher, C., Sharbafi, M., Seyfarth, A., & Rode, C. (2020). Biarticular muscles in light of template models, experiments and robotics: a review. Journal of the Royal Society Interface, 17(163), 20180413, **http://doi.org/10.1098/rsif.2018.0413**

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Nanomembranes as virus filters

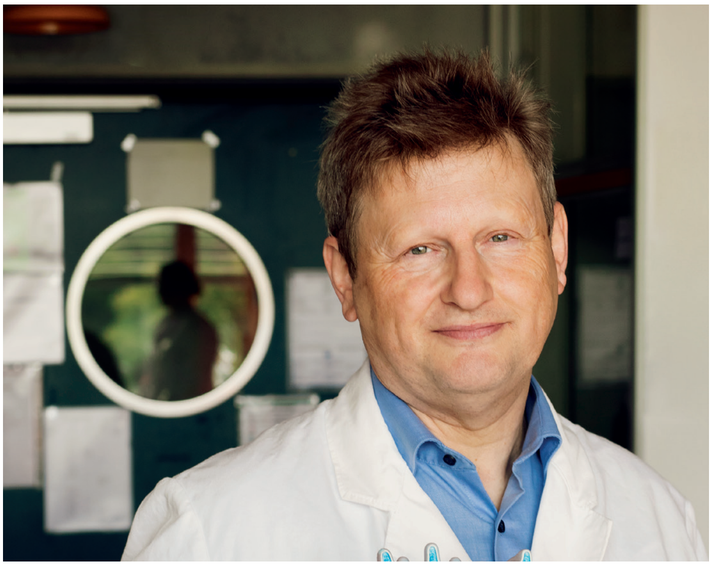

Photo: Katrin Binner

Professor Ensinger in the test laboratory for nanopore membranes for the simulation of virus filtration.

Researchers in materials science, led by Professor Wolfgang Ensinger, are developing plastic membranes with nanopores. Now they are experimenting to establish whether the thin films are suitable as air filters in the fight against coronaviruses.

By Uta Neubauer

The trigger for the current pandemic is tiny. With a diameter of about 120 nanometres, coronavirus Sars-CoV-2 is several hundred times smaller than the pores of cotton fabric. Home-made face masks therefore only offer partial protection against the pathogen. However, the membranes produced by a team led by TU Professor Wolfgang Ensinger are absolutely virus-proof. They consist of wafer-thin films with nanopores. Viruses do not fit through the small holes – but air, water and other tiny molecules do.

Can the material be used as a filter against coronaviruses? Scientists are now investigating this question. They have already tested the filter force with silicon dioxide nanoparticles. "The membrane is extremely reliable," says Ensinger. However, it is to be borne in mind that the model particles are very stiff whereas viruses have a certain flexibility. "In order to prevent the pathogens from slipping through, the diameter of the nanopores should be significantly lower than that of the viruses." Films with pore diameters of 60 nanometres were used in the model test.

In the development of the membranes, Ensinger's team worked closely with materials scientists from the GSI Helmholtz Centre for Heavy Ion Research in Darmstadt. There, the nanopore membranes are produced in a process called ion beam etching. The technology is only possible at the GSI in Germany because it requires an accelerating system that shoots ions onto a plastic film with extremely high energy. As they pass through the film, the ions destroy chemical bonds and leave straight traces into which fine channels can then be etched with caustic soda.

Ion beam etching may be expensive, but it is very well suited to industrial purposes. One commercial manufacturer of filter materials is already producing membranes for the preparation of blood samples. Polycarbonate films from a roll are first drawn through the accelerator, which fires them with argon ions, and then through the etching bath.

The team at TU Darmstadt uses the extremely stable and heat-resistant plastic polyimide. Heavier artillery is required to perforate this: the foils are irradiated with heavy gold ions rather than light argon ions. Ensinger stresses that this procedure could also be commercialised if a market were to arise. He has primarily air filtration systems in mind, perhaps for virus laboratories or quarantine stations in hospitals.

Protective masks cannot be made (yet) with these membranes as they consist of only ten percent nanopores and not enough air passes through to breathe. The film would have to have more perforations for this purpose – but then there would be the risk of the pores overlapping into bigger holes and no longer stopping viruses. "This is an issue of technical optimisation, a balance between air flow and the frequency of pore clusters," says Ensinger. It remains to be seen whether the project is a success. If it isn't, it certainly won't be because of a lack of demand for anti-virus membranes.

The author is a science writer and holds a doctorate in Chemistry.

iNAPO: Tiny sensors

At iNAPO at LOEWE, which is part of the Centre for Synthetic Biology at TU Darmstadt, Wolfgang Ensinger and his colleagues provide nanopore membranes with recognition elements to identify biomolecules. They now want to extend this concept to the detection of viruses or antibodies, and to this end are seeking a cooperation with virology experts.

Information

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