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Editorial

Over the past few years, months, and weeks, the new Feringa Building has been designed, constructed, and outfitted to provide a cutting-edge home for science in Groningen. Since the beginning of March, the relocation process for research groups focusing on Advanced Materials has commenced, with more teams joining in packing each day. The aim is for the majority of teams involved in Advanced Materials research, to be settled into this remarkable building by the end of June. This accomplishment stands as a testament to the incredible efforts, dedication, and meticulous planning of our technicians, whose hard work has facilitated the seamless transfer of equipment valued at millions of euros.

Before the first results emerge from our new premises, significant reassembling, rewiring, and calibration of our instrumentation are required. Nonetheless, we anticipate sharing new findings from our new home, soon. Meanwhile, with this edition, we bid farewell to the Physics & Chemistry Building at Nijenborgh 4. Enjoy reading!

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In this Issue

A self-powered sensor made from plants at the University Campus

FSE Science Newsroom | Charlotte Vlek

Macromolecular chemist Qi Chen from the University of Groningen used a problematic weed to build a tiny, self-powered sensor.

The story of Qi Chen's research is full of serendipity. In the first year of her PhD, she was hanging out with friends at the University's Zernike Campus, discussing the topics of their research. Chen told them she was going to study foam-like materials. A friend was casually peeling the stem of a grass-like plant, thereby revealing its insides that appeared to have an open and airy structure. He suggested jokingly that Chen might want to study it. She put it in her backpack and then forgot all about it.

Peeled soft rush stems in a jar | © Leoni von Ristok

Nearly two years later, Chen found the plant again in her backpack. She had been trying to induce electricity from bacteria, using foamy materials as an environment for them to live in. The results weren't promising, so she decided to have a closer look at this grass-like plant: a common wetland weed called soft rush (Juncus effusus L.).

Tiny snowflakes

'The structure of the soft rush stem consists of layers of interconnected stars, a bit like tiny snowflakes,' Chen explains. These layers are stacked on top of each other, creating a structure that allows a lot of air to flow through. Chen: 'My samples were ultra-lightweight. Once, I left the samples uncovered and as I opened the lab door, the samples were blown away. It looked like it had snowed in the hallway.'

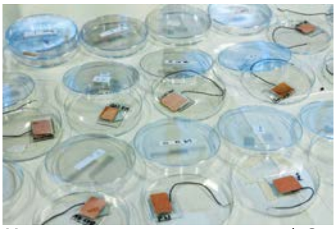
The insides of many aquatic or wetland plants consist of such an open structure, called aerenchyma. 'The plant needs this open structure to breathe,' Chen says, 'because with their roots in a wet environment, they need to take oxygen from the air and transport it through the stem.' As it turns out, this material is also a great alternative resource for natural plant-based foams.

A tiny device to put in your shoe

The unique shape of the little snowflakes in the soft rush stem were also perfect for building a nanogenerator: a tiny device that produces an electric charge, which can be used as a sensor or as an energy source. Such a nanogenerator can help make the current trend of ever smaller wearable devices more sustainable, replacing batteries that ultimately end up in electronic waste.

> You can put it in your show and when you walk, jump, or run, it releases a distinct signal we can recognize.

Together with colleagues Wenjian Li and Feng Yan, Chen built a nanogenerator the size of a postage stamp, about one millimetre thick. It works as a motion sensor, co-author Dina Maniar explains : 'You can put it in your shoe and when you walk, jump, or run, it releases a distinct signal that we can recognize.' This tiny device builds on the same phenomenon that gives you a shock when you touch a doorknob after walking on a carpet: the so-called triboelectric effect. It consists of two small layers with rough surfaces. The two layers are kept apart by a separator, but when pressed there is friction between the layers, which creates an electric charge – just like the electric charge that builds up when you shuffle your feet on a carpet. Maniar: 'This enables us to convert movement into electrical signals.'



Many nanogenerator prototypes | © Leoni von Ristok

The tiny snowflakes from the soft rush plant create a rough, foamy surface with many pores on the layers of the nanogenerator: perfect for optimal friction between the layers, while keeping it very lightweight. This was once again a serendipitous finding: Chen dropped some of her dissolved plant material on aluminium foil and failed to clean it up. The water evaporated, leaving a thin film with the rough surface of tiny snowflakes.

We can really call it sustainable

Researchers have been trying to produce foam-like materials based on cellulose from plants for years. 'Usually, a lot of resources go into extracting cellulose, breaking down the structure as it was,'

> Usually, a lot of resources go into extracting cellulose, breaking down the structure as it was. Then, a lot of resources go into producing the desired structure for new materials.

Professor of Applied Chemistry and co-author Katja Loos explains. 'Then, a lot of resources go into producing the desired structure for new materials.'

Chen was able to retain the building blocks – the little 'snowflakes' – of the soft rush insides, by peeling the stem and dissolving it in a simple mixture. 'So, we can really call it sustainable,' says Chen: little energy and no oil-based fossil materials went into this process. Chen is currently working on other applications: she wants to use the soft rush snowflakes as part of a battery, and for clearing up pollutants in water.

Unfortunately, the local municipality has recently removed a lot of the soft rush growth, Chen discovered. She shrugs. 'Now I just have to cycle a bit further to get it.' She smiles: 'In our lab, it's not a weed; it's a valuable resource.'

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The secrets of polydopamine coatings revealed

by René Fransen

Dopamine is best known as a neurotransmitter. What is rather unknown, however, the underwater glue used by mussels contains large amounts of L-Dopa molecules, an analog of dopamine. Inspired by this, polydopamine coatings have recently been described that could be used to activate otherwise inactive surfaces. One problem in the development of these coatings is that their exact structure is unknown. Several models of polydopamine coatings have been put forward, but University of Groningen scientists have now shown through direct measurements what these coatings really look like. Their results were published in Nature Communications on 7 February 2023.

Polydopamine coatings show great promise: they don't require any solvents other than water, and are biocompatible. They are versatile coatings that adhere to almost all surfaces and are useful as intermediate layers, for example on inactive surfaces like polyolefins. 'Yet until now, we did not understand their exact composition and the way in which they form,' explains Hamoon Hemmatpour, postdoc researcher at the Product Technology Group of the University of Groningen Engineering and Technology Institute.

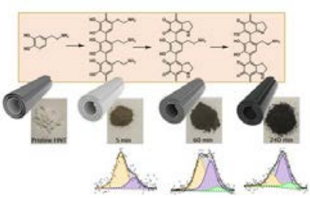
Building Blocks

To remedy this lacuna, Hemmatpour set out to study the formation of the coatings. 'On the macroscopic scale, this coating forms very quickly, too fast to study intermediates that might reveal what is happening,' he explains. He therefore used nanosized tubes from a clay mineral as substrate for the coating. A large surface area and negative charges in the mineral attract intermediates from the solution, thereby slowing down the polymerization process. 'This allowed us to take samples of the nanotubes during the polymerization process to identify the intermediates.' Previous attempts to characterize polydopamine coatings used techniques such as mass spectrometry, which reveal the composition but not the exact chemical structure of the polymer. By studying intermediates on the nanotubes with solid state NMR and X-ray photoelectron spectroscopy (XPS), Hemmatpour could reconstruct what happens during polymerization. 'These techniques show which chemical bonds are present.' Once all the information was there, Hemmatpour and his colleagues could uncover the structures of the building blocks in the coatings, and thus resolve their structure.

Buffering salt

The dopamine starts polymerizing when the buffered solution reaches a pH of 8.5 or higher. 'One thing we noticed is that the buffering salt TRIS became part of the structure, a sizeable part during the first phases of polymerization, and to a lesser degree as the reaction progressed.' The final analysis of the process reveals auto-oxidation of dopamine, followed by crosslinking, intramolecular cyclization, and isomerization.

This study reveals the formation and structure of polydopamine coatings, which allows scientists



Top to bottom: The molecular structure of intermediates in polydopamine-formation, the clay-mineral nanotubes change colour during the polymerisation process due to the absorbed intermediates, graphs showing different chemical bonds present in the intermediates during polymerisation. | Illustration Hamoon Hemmatpour, University of Groningen to adapt the process for different applications. 'We also believe that our use of clay nanotubes could be expanded to the study of other rapid processes,' says Hemmatpour. 'And adapting the nanotubes to increase surface area would allow us to slow down reactions even further.'

Neurons

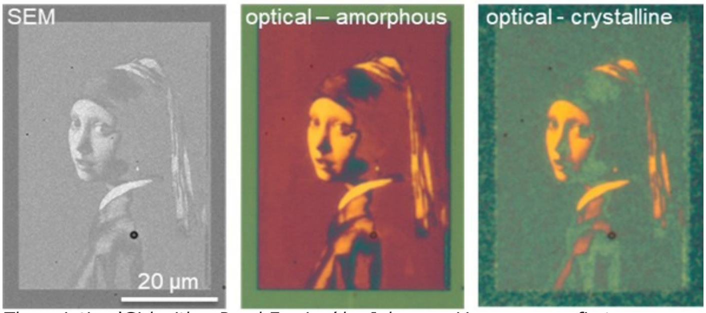
'There are other interesting observations from this study,' Hemmatpour adds. 'In neural cells, dopamine is stored in vesicles with a very low pH, but in neurodegenerative diseases, these vesicles somehow become leaky, and the dopamine accumulates in the cytosol where the pH is higher. There, the dopamine polymerizes into toxic clumps, which eventually kill neurons. Our study offers new insights into this mechanism and the intermediates of this process that can be used to find a way to treat neurodegenerative diseases.'

These paintings show the future of optoelectronics

FSE Science Newsroom René Fransen

Scientists at the Zernike Institute for Advanced Materials, University of Groningen, have just reproduced two famous paintings at the micrometre scale. This wasn't just a homage to Dutch masters Johannes Vermeer and Vincent van Gogh, but a proof of principle in manufacturing minute optical systems.

The canvas for these reproductions was formed by a layer of reflecting gold. On top of that, scientists led by professor of Nanostructured Materials and Interfaces Bart Kooi deposited a thin film of Sb_2Se_3 (antimony-selenium). Light-reflecting off the gold and passing through the film then takes on different colours, depending on the thickness of the film – just like a drop of oil on water will produce colourful reflections.



The painting 'Girl with a Pearl Earring' by Johannes Vermeer was first transformed into a grey scale image, which was then reproduced on a micrometre scale by a novel ion milling approach, creating nanometer-scale height differences. The left panel shows a scanning electron microscopy (SEM) image. The middle panel shows true structural colours due to height variations created in the amorphous top film. The right image shows true colours after the film was crystallized. | Images Bart Kooi lab, University of Groningen

Lithography

The pictures were first transformed into a greyscale image. An ion beam was then calibrated to mill the thin film to a depth that corresponded to the greyscale with nanometre precision. Light that is reflected through the thin film takes on a colour that depends on the local thickness of that film, resulting in a real colour image of the 'Girl with a Pearl Earring' by Vermeer (and also van Gogh's Starry Night, not shown here).

This miniature art was created as a proof of principle, to show that ion beam milling can create nanometre-scale pixels with continuous height differences, something that isn't possible when using traditional techniques like lithography. As the Sb_2Se_3 thin film is a phase-change material, it is also possible to change the properties of the pixels by switching their structure using electric pulses.

These tiny pixels could perhaps one day be used in displays, but will more likely be applied to create optical chips and other applications in optoelectronics.

The research was published in the journal Advanced Materials on 1 September.

The missing link to make easy protein sequencing possible?

Science Newsroom | Charlotte Vlek

There has been a real race among scientists to create a technology that enables easy protein sequencing. Professor of Chemical Biology Giovanni Maglia of the University of Groningen has now found the missing piece in the puzzle: a way to transport a protein through a nanopore, which allows sequencing of proteins in a simple, handheld device.

DNA sequencing has been a revolution in how we understand life, and sequencing proteins is the next holy grail. Maglia explains: 'DNA is mostly static. The processes in our cells are executed by proteins: they do the actual work. And by understanding proteins, we will understand even more about how our bodies work.'

Why would we want to sequence proteins ?

DNA is like a blue print for our bodies, but proteins are like the workers that do the actual construction. Based on DNA (the instructions), a range of proteins are formed, that execute various functions throughout our bodies.

Just to name a few, proteins are responsible for: taking up and releasing oxygen in our blood (hemoglobin), defense against pathogens (antibodies), and transmitting signals, for instance through the nervous system, but also through a cell wall (receptors).

Proteins can also be harmful. Some examples are venom from snakes or spiders, or some pathogens (such as viruses).

We know a lot about the human genome (our DNA). By also studying the proteins in our bodies, scientists hope to gain more insight into how cells operate and what can make them malfunction. Ultimately, this can contribute to new, better treatments against diseases.

The problem of pulling proteins through a hole

There are currently handheld devices on the market that can sequence DNA. These devices use nanopore technology: a single strand of DNA is pulled through a tiny hole (a nanopore) in a membrane, and as they pass through, the sequence of building blocks in the DNA strand can be 'read'.

There have been steps towards applying the same nanopore technology to proteins, but it was not yet possible to transport a long protein through the tiny hole in the same way as a DNA strand. 'It's like cooked spaghetti,' Maglia explains. 'These long strands want to be disorganized, they do not want to be pushed through this tiny hole.'
Single-stranded DNA is also a bit like cooked spaghetti, but it can be pulled through with an electric field because DNA itself is electrically charged. But proteins have a weaker charge, and can carry either positive or negative charge. 'Proteins and DNA are different,' Maglia explains, 'so the technology needs to be adapted.'

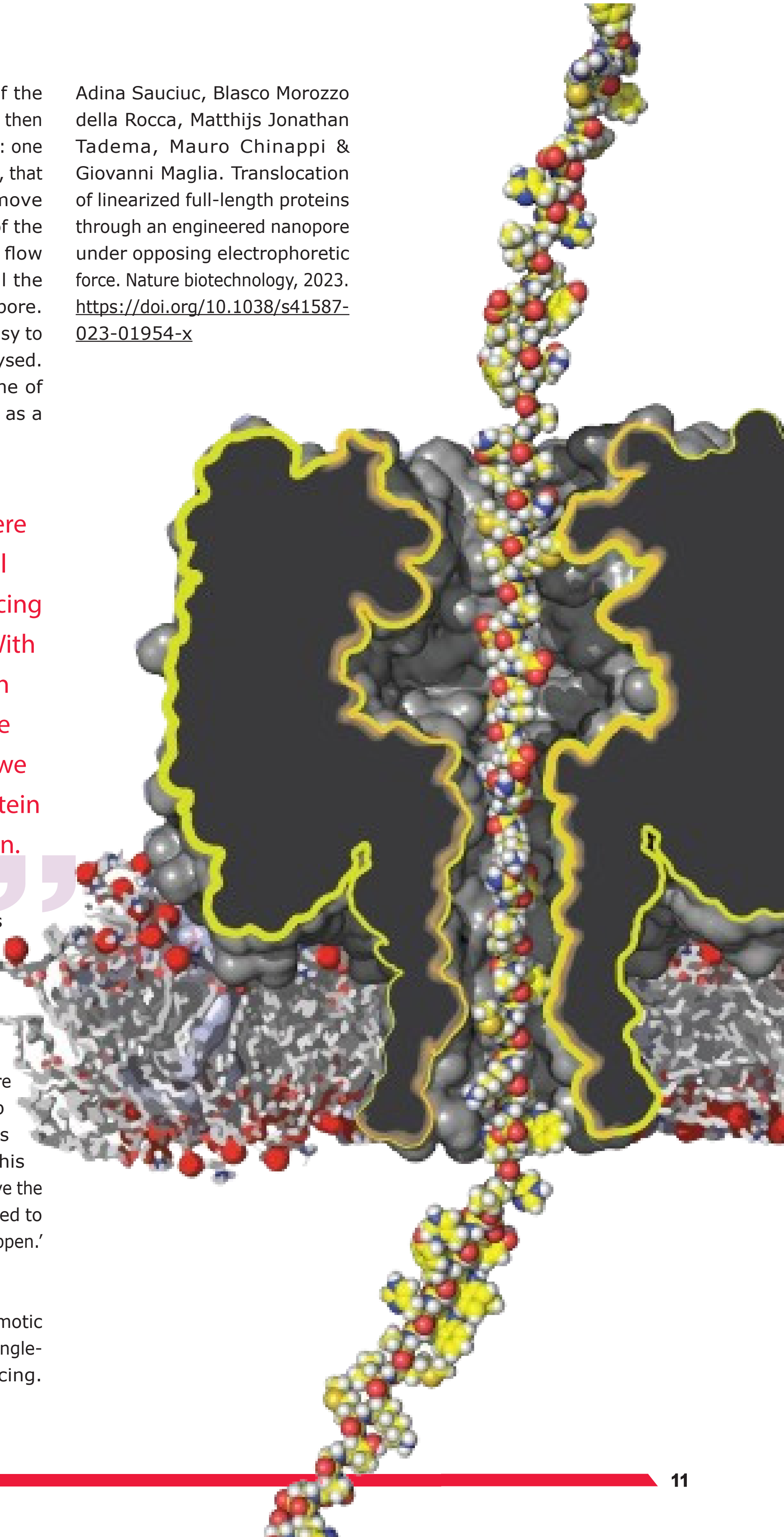
Going with the flow

To transport a protein through a nanopore, Maglia used a solution of electrically charged particles (ions), which can be pulled through the nanopore with an electric field. When this happens, they drag along the protein. It was not at all trivial to make this work, Maglia explains: 'we didn't know whether the flow would be strong enough. Furthermore, these ions want to move both ways, but by attaching a lot of charge on the nanopore itself, we were able to make it directional.'

Maglia engineered a system with the strongest possible flow without proteins. In a collaboration with researchers of the University of Rome Tor Vergata, computer simulations were performed, that revealed that the force of this flow on a protein was comparable to the force of the electric field on DNA. Maglia then tried it on a difficult protein: one with many negative charges, that would make it want to move in the opposite direction of the flow. But even then, the flow was strong enough to pull the protein through the nanopore. Maglia: 'Previously, only easy to thread proteins were analysed. But we gave ourselves one of the most difficult proteins as a test. And it worked!

> This proves that there is no fundamental limitation to sequencing proteins anymore, With this latest research result, we have the missing piece that we needed to make protein sequencing happen.

'This proves that there is no fundamental limitation to sequencing proteins anymore,' Maglia says. With his new startup called Portal Biotech, Maglia intends to make the nanopore technology from his lab available to users, such as labs and doctors. 'With this latest research result, we have the missing piece that we needed to make protein sequencing happen.'



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NWO Grant for Anastasiia Krushynska's MetaFlow project

Dr. Anastasiia Krushynska was awarded a grant from the Dutch Research Council (NWO) for her research project MetaFlow: Metamaterials and bio-inspired sensors to stabilize and monitor fluid flow and flow-induced vibrations. Anastasiia Krushynska is Assistant Professor on Dynamics and Vibrations at the Computational Mechanics and Materials Engineering (CMME) group at ENTEG. Co-applicant is Prof. Ajay Kottapalli of ENTEG.

NWO is awarding over 9.4 million euros to nine innovative PPP research projects on emerging key enabling technologies. The exploratory research has been awarded within the Emerging Key Enabling Technologies (KIC) call. This call provides space for pioneering PPP research around emerging key enabling technologies, focused on exploration and development of innovative ideas. These pioneering projects enable the public and private partners involved to take the next development step. Consortium partners are adding over 1.3 million euros in co-funding.

Metaflow

High-speed fluid flows in industrial pipelines are turbulent causing unwanted vibrations, noise, and threatening the safety of a system or device. MetaFlow proposes a unique approach to monitor and stabilize flows by combining extremely sensitive bio-inspired MEMS sensors and elastic metamaterials that can monitor and locally control flows actively in real-time through fine-tuned solid-fluid interactions. We will develop the setup demonstrating this technology and study practically relevant flow scenarios and pipeline dimensions. It will deliver ground-breaking results for understanding and stabilizing turbulent flows that will become new standards in flow control in industry and science, especially in high-precision applications.

Impactful technology

The aim of the Emerging Key Enabling Technologies call is to create a fertile seedbed for innovative, disruptive ideas. The technology is still so new that its disruptive nature has not yet been proven. This type of key technology is at a stage of broad potential application, where different sectors show interest in participating. An emerging key enabling technology has the opportunity to develop into a highly impactful technology that can contribute to industrial and/or societal impact in the longer term..

What is a key enabling technology?

A key enabling technology is characterised by a broad scope or reach in innovations and/or sectors. Key enabling technologies are essential in solving societal challenges and/or make a large potential contribution to the economy. They enable breakthrough process, product and/or service innovations. Key enabling technologies are relevant to science, society and industry. View the list of key enabling technologies.

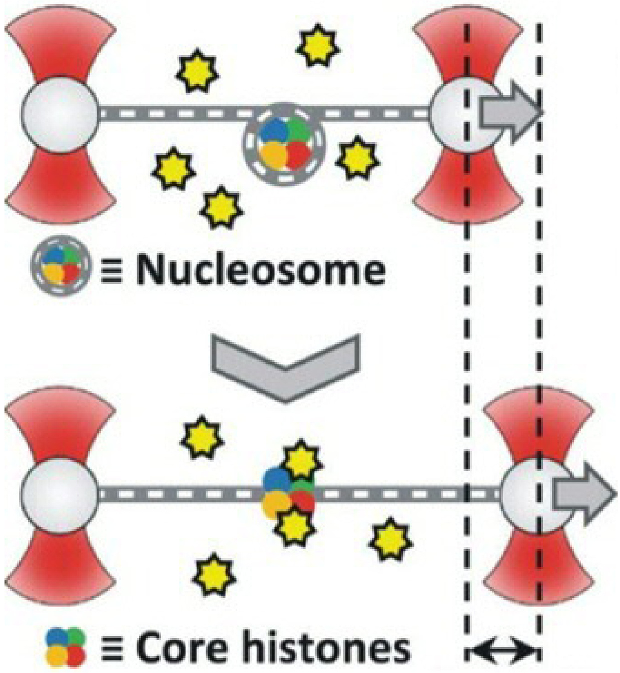
Collaborative projects

Other projects involving the UG or the UMCG have also received grants. These are awarded to Prof. Dr. S.M. Garcia Blanco of the University of Twente with the UMCG as co-applicant, and to Prof. Dr. H. Corporaal of the TU Eindhoven with the UG as collaboration partner.

Optical Tweezers show the dynamics of histone-DNA interactions

Together with researchers from Seville, Wouter Roos' group used advanced microscopy techniques to study chromatin function. Using optical tweezers, the researchers have shown how the interactions of histones with DNA - called chromatin - are influenced by other proteins. The results have been

The DNA with attached proteins is called chromatin. This is located in the cell nucleus. Chromatin is made by wrapping DNA around nucleosomes. These are protein complexes consisting of 8 histones. To read the DNA, the DNA must be unwound from the nucleosomes and later rolled up again so that it can be stored compactly in the cell nucleus. In this study, this coiling and uncoiling was investigated and in particular how the interaction with some histones and accessory proteins takes place.



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Roos' group used optical tweezers for this. This allows a single DNA molecule to be "suspended" in the liquid using light and you can see live how the DNA interacts with the histones, accessory proteins and how nucleosomes are formed. With this single-molecule technique, the researchers have shown that very different accessory proteins, the chaperones SET/TAF-1β and Nucleofosmin-1, still bind to the histones in the same way and apparently perform their function in a similar way. Furthermore, another protein has been studied, cytochrome c. This protein modulates the way in which the accessory proteins pick the histones from the DNA and thus regulate this process. The results provide a surprisingly detailed look at the activity of the proteins studied and provide new insights into the regulation of the process of DNA reading and coiling around histones.

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New target for antibiotics promises treatment for resistant superbugs

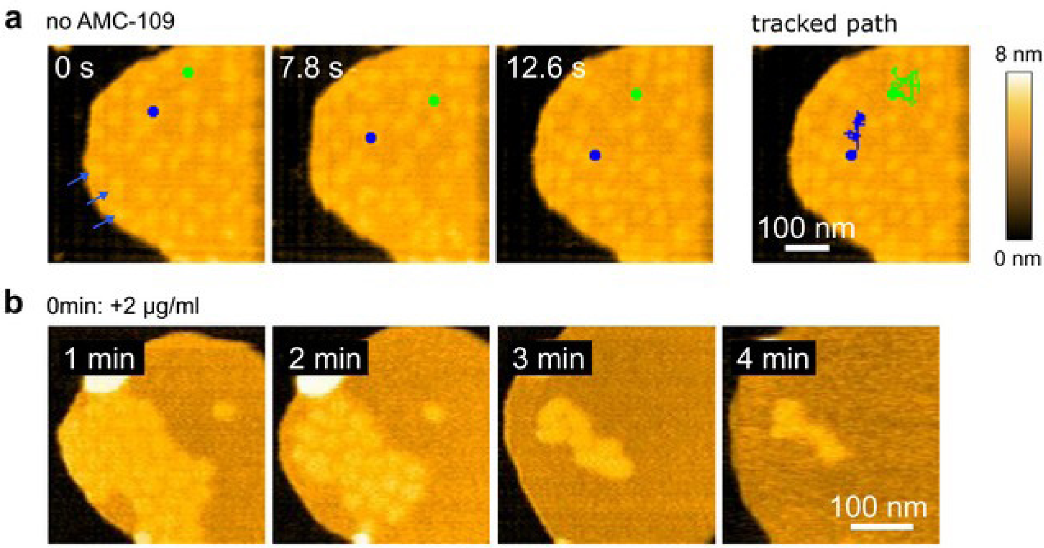
FSE Science Newsroom | Charlotte Vlek

The World Health Organization lists bacteria that are resistant to antibiotics as one of the top 10 global health threats. Therefore, researchers are looking for new antibiotics to counter this resistance. Adéla Melcrová, biophysicist at the University of Groningen, and her colleagues discovered that the relatively new antibiotic AMC-109 affects the cell membrane of bacteria by disordering its organization. This differs from most other antibiotics and could open up new directions for future treatment and drug development. The results were published in Nature Communications on 7 July.

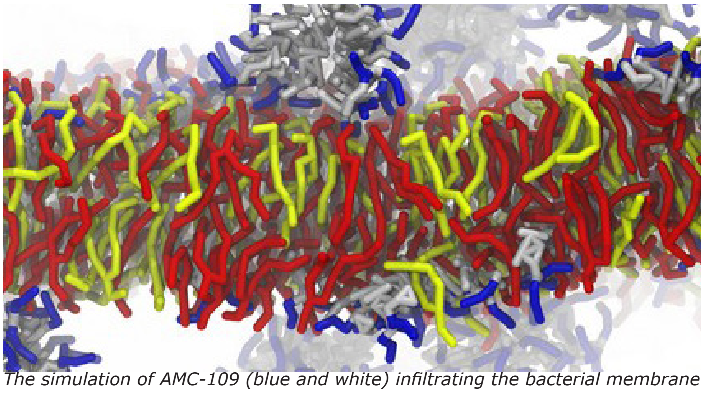
AMC-109, developed at the UiT Arctic University of Norway, has shown promising results in the lab as well as in clinical trials against the notoriously difficult-to-treat methicillin-resistant Staphylococcus aureus (MRSA). It will be tested on humans soon (phase 3 of clinical trials). However, it was not known exactly how AMC-109 works on bacteria.

'I found it surprising that no one knew exactly how it worked,' says Melcrová. 'So, I decided to have a look at it.'

Many antibiotics operate by punching holes in the membrane of the bacterium, which forms a boundary between the inside and the outside of the bacterium. This membrane is vital to regulating what comes in and what stays out, as well as to building the protective cell wall around the bacterium. 'The developers of the drug, who collaborated in this study, thought that AMC-109 makes holes in the membrane of the bacterium, just like other antibiotics,' says Melcrová. But this is not what she found.



HS-AFM imaging of the Staphylococcus aureus membrane (above), with thicker areas (light orange). After adding AMC-109, the thicker areas clump together and then dissolve (below). | Illustration Adéla Melcrová and Sourav Maity


The simulation of AMC-109 (blue and white) infiltrating the bacterial membrane (red and yellow). | Illustration Josef Melcr

Disorganization leads to death

Melcrová took the membrane of Staphylococcus aureus, extracted for her by the University of Groningen Molecular Microbiology group. Melcrová herself is based in the Biophysics group of Professor Wouter Roos, where, as she explains, 'we study biology with methods from physics.' Together with her colleague Sourav Maity, Melcrová studied the bacterial membrane with a High-Speed Atomic Force Microscope (HS-AFM), which speedily taps the material with a tiny tip, measuring thickness and stiffness of the material.

What Melcrová and Maity saw with the HS-AFM were small areas of a higher membrane thickness, indicating some sort of structural organization. Upon adding AMC-109 to the membrane, these thicker areas clustered together and then dissolved. 'A bit like an iceberg that melts: the material is still there, but the structure is gone,' Melcrová says. 'And apparently, the disruption of these areas is sufficient to lead to the death of the bacterium.'

Clumps: for once a good thing

In collaboration with the Molecular Dynamics group, Josef Melcr has built a simulation model of the interaction between the membrane and the antibiotic, using the Martini forcefield. Melcrová: 'While the experiments show us what happens, a simulation allows us to interpret what we see.' And what the simulation showed was that the AMC-109 forms small clumps. Subsequently, these clumps infiltrate the bacterial membrane.

'Any doctor would tell you that aggregation is a bad thing,' says Melcrová. 'Several diseases are caused by aggregating proteins: Alzheimer's disease, for instance. But in this case, it is a very good thing.' On its own, AMC-109 would also attack human cells. But by clumping together, some properties are 'hidden' on the inside of the bunched-up AMC-109, making it safe for the human body.

> This is still a hypothesis, but it could mean that a treatment with AMC-109 could potentially also boost the effect of a "classic" antibiotic.

Boosting other antibiotics

Now that the effect of AMC-109 on the membrane of bacteria is clearer, new possibilities for future drug development open up. 'For instance,' says Melcrová, 'drugs could be developed that explicitly aim to disorganize the membrane structure.' There is also evidence suggesting that the disorganization breaks down the resistance of the bacteria to old-fashioned antibiotics. 'This is still a hypothesis,' Melcrová explains, 'but it could mean that a treatment with AMC-109 could potentially also boost the effect of a "classic" antibiotic.'

'I am happy that this work is finally out,' says Melcrová. 'It took four long years of work. We went through a lot of stress, frustration, and arguments but we also enjoyed the great discoveries and putting the puzzle of this unique antibiotic action together. The fact that one of the collaborators, Josef Melcr, is also my husband meant that this project was always with me, even at home,' says Melcrová with a smile.

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Complex oxides could power the computers of the future

by René Fransen

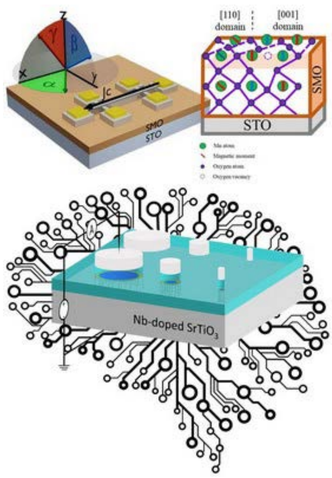
As the evolution standard microchips is coming to an end, scientists are looking for a revolution. The big challenges are to design chips that are more energy efficient and to design devices that combine memory and logic (memristors). Materials scientists from the University of Groningen, the Netherlands, describe in two papers how complex oxides can be used to create very energy-efficient magneto-electric spin-orbit (MESO) devices and memristive devices with reduced dimensions.

The development of classic silicon-based computers is approaching its limits. To achieve further miniaturization and to reduce energy consumption, different types of materials and architectures are required. Tamalika Banerjee, Professor of Spintronics of Functional Materials at the Zernike Institute for Advanced Materials, University of Groningen, is looking at a range of quantum materials to create these new devices. 'Our approach is to study these materials and their interfaces, but always with an eye on applications, such as memory or the combination of memory and logic.'

More efficient

The Banerjee group previously demonstrated how doped strontium titanate can be used to create memristors, which combine memory and logic. They have recently published two papers on devices 'beyond CMOS', the complementary metal oxide semiconductors which are the building blocks of present day computer chips.

One candidate to replace CMOS is the magneto-electric spin-orbit (MESO) device, which could be 10 to 30 times more efficient. Several materials have been investigated for their suitability in creating such a device. Job van Rijn, a PhD student in the Banerjee group, is first author of a paper in Physical Review B published in December 2022, describing how strontium manganate (SrMnO3 or SMO for short) might be a good candidate for MESO devices. 'It is a multiferroic material that couples spintronics and charge-based effects,' explains van Rijn. Spintronics is based on the spin (the magnetic moment) of electrons.



The devices 'beyond CMOS' created by Job van Rijn (top) and Anouk Goossens | Illustrations Banerjee group, University of Groningen

Banerjee: 'The magnetic and charge orderings are coupled in this material, so we can switch magnetism with an electric field and polarization with a magnetic field.' And, importantly, these effects are present at temperatures close to room temperature. Van Rijn is investigating the strong coupling between the two effects. 'We know that ferromagnetism and ferroelectricity are tuneable by straining a thin SMO film. This straining was done by growing the films on different substrates.'

Strain

Van Rijn studies how strain induces ferroelectricity in the material and how it impacts the magnetic order. He analysed the domains in the strained films and noticed that magnetic interactions are greatly dependent on the crystal structure and, in particular, on oxygen vacancies, which modify the preferred direction of the magnetic order. 'Spin transport experiments lead us to the conclusion that the magnetic domains play an active role in the devices that are made of this material. Therefore, this study is the first step in establishing the potential use of strontium manganate for novel computing architectures.'

> Therefore, this study is the first step in establishing the potential use of strontium manganate for novel computing architectures.

On 14 February, the Banerjee group published a second paper on devices 'beyond CMOS', in the journal Advanced Electronic Materials. PhD student Anouk Goossens is first author of this paper on the miniaturization of memristors based on niobium-doped strontium titanate (SrTiO3 or STO). 'The number of devices per unit surface area is important,' says Goossens. 'But some memristor types are difficult to downscale.'

Goossens previously showed that it was possible to create 'logic-in-memory' devices using STO. Her latest paper shows that it is possible to downscale these devices. A common problem with memristors is that their performance is negatively impacted by miniaturization. Surprisingly, making smaller memristors from STO increases the difference between the high and the low resistance ratio. 'We studied the material using scanning transmission electron microscopy and noticed the presence of a large number of oxygen vacancies at the interface between the substrate and the device's electrode', says Goossens. 'After we applied an electric voltage, we noticed oxygen vacancy movement, which is a key factor in controlling the resistance states.'

New design

The conclusion is that the enhanced performance results from edge effects, which can be bad for normal memory. But in STO, the increased electric field at the edges actually supports the function of the memristor. 'In our case, the edge is the device,' concludes Goossens. 'In addition, the exact properties depend on the amount of niobium doping, so the material is tuneable for different purposes.'

In conclusion, both papers published by the group show the way towards novel computing architectures. Indeed, the STO memristors have inspired colleagues of Goossens and Banerjee at the University of Groningen Bernoulli Institute for Mathematics, Computer Science and Artificial Intelligence and CogniGron (Groningen Cognitive Systems and Materials Center), who have already come up with a new design for memory architecture.

> This is exactly what we are working for. We want to understand the physics of materials and the way in which our devices work

'This is exactly what we are working for,' says Banerjee. 'We want to understand the physics of materials and the way in which our devices work and then develop applications.' Goosens: 'We envision several applications and the one we are looking at is a random number generator that works without an algorithm and is therefore impossible to predict.'

References: J. van Rijn, D. Wang, B. Sanyal, and T. Banerjee: Strain-driven antiferromagnetic exchange interactions in SrMnO3 probed by phase-shifted spin Hall magnetoresistance. Physical Review. B: Condensed Matter and Materials Physics, 15 December 2022. https://doi.org/10.1103/PhysRevB.106.214415

A. S. Goossens, M. Ahmadi, D. Gupta, I. Bhaduri, B.J. Kooi, and T. Banerjee (2023): Memristive memory enhancement by device miniaturization for neuromorphic computing. Advanced Electronic Materials, 14 February 2023. https://doi.org/10.1002/aelm.202201111

Scientists find first evidence for new superconducting state in Ising superconductor

by René Fransen (ScienceLinx)

In a ground-breaking experiment, scientists from the University of Groningen, together with colleagues from the Dutch universities of Nijmegen and Twente and the Harbin Institute of Technology (China), have discovered the existence of a superconductive state that was first predicted in 2017. They present evidence for a special variant of the FFLO superconductive state on 24 May in the journal Nature. This discovery could have significant applications, particularly in the field of superconducting electronics.

P. Wan

The lead author of the paper is Professor Justin Ye, who heads the Device Physics of Complex Materials group at the University of Groningen. Ye and his team have been working on the Ising superconducting state. This is a special state that can resist magnetic fields that generally destroy superconductivity, and that was described by the team in 2015. In 2019, they created a device comprising a double layer of molybdenum disulfide that could couple the Ising superconductivity states residing in the two layers. Interestingly, the device created by Ye and his team makes it possible to switch this protection on or off using an electric field, resulting in a superconducting transistor.

Tweaking

The coupled Ising superconductor device sheds light on a long-standing challenge in the field of superconductivity. In 1964, four scientists (Fulde, Ferrell, Larkin, and Ovchinnikov) predicted a special superconducting state that could exist under conditions of low temperature and strong magnetic field, referred to as the FFLO state. In standard superconductivity, electrons travel in opposite directions as Cooper pairs. Since they travel at the same speed, these electrons have a total kinetic momentum of zero. However, in the FFLO state,
there is a small speed difference between the electrons in the Cooper pairs, which means that there is a net kinetic momentum.

'This state is very elusive and there are only a handful of articles claiming its existence in normal superconductors,'
says Ye. 'However, none of these are conclusive.' To create the FFLO state in a conventional superconductor, a strong magnetic field is needed. But the role played by the magnetic field needs careful tweaking. Simply put, for two roles to be played by the magnetic field, we need to use the Zeeman effect. This separates electrons in Cooper pairs based on the direction of their spins (a magnetic moment), but not on the orbital effect—the other role that normally destroys superconductivity. 'It is a delicate negotiation between superconductivity and the external magnetic field,' explains Ye.

Ising superconductivity, which Ye and his collaborators introduced and published in the journal Science in 2015, suppresses the Zeeman effect. 'By filtering out the key ingredient that makes conventional FFLO possible, we provided ample space for the magnetic field to play its other role, namely the orbital effect,' says Ye.

Devices

'What we have demonstrated in our paper is a clear fingerprint of the orbital effect-driven FFLO state in our Ising superconductor,' explains Ye. 'This is an unconventional FFLO state, first described in theory in 2017.' The FFLO state in conventional superconductors requires extremely low temperatures and a very strong magnetic field, which makes it difficult to create. However, in Ye's Ising superconductor, the state is reached with a weaker magnetic field and at higher temperatures.

In fact, Ye first observed signs of an FFLO state in his molybdenum disulfide superconducting device in 2019. 'At that time, we could not prove this, because the samples were not good enough,' says Ye. However, his PhD student Puhua Wan has since succeeded in producing samples of the material that fulfilled all the requirements to show that there is indeed a finite momentum in the Cooper pairs. 'The actual experiments took half a year, but the analysis of the results added another year,' says Ye. Wan is the first author of the Nature paper.

> First author Puhua Wan produced samples of the material that fulfilled all the requirements to show that there is indeed a finite momentum in the Cooper pairs.

This new superconducting state needs further investigation. Ye: 'There is a lot to learn about it. For example, how does the kinetic momentum influence the physical parameters? Studying this state will provide new insights into superconductivity. And this may enable us to control this state in devices such as transistors. That is our next challenge.'

Reference: Puhua Wan, Oleksandr Zheliuk, Noah F.Q. Yuan, Xiaoli Peng, Le Zhang, Minpeng Liang, Uli Zeitler, Steffen Wiedmann, Nigel E. Hussey, Thomas T.M. Palstra & Jianting Ye: Orbital Fulde–Ferrell–Larkin–Ovchinnikov state in an Ising superconductor. Nature, 24 May 2023. https://doi.org/10.1038/s41586-023-05967-z

Materials scientist finds clue to treat deadly hereditary illness

FSE Science Newsroom | René Fransen

Patrick van der Wel is associate professor of Solid State NMR at the Zernike Institute for Advanced Materials, University of Groningen (the Netherlands). He can measure how the atoms in a material are connected, which provides information on its structure. This technique is used to study new materials for solar panels, but also biomaterials. In a study that was published in Nature Metabolism on 23 November, Van der Wel contributed to the measurements that helped discover the root cause of a deadly metabolic illness called Barth syndrome, which could be a step towards a cure.

In Barth syndrome, something is wrong with the energy factories of the cells, the mitochondria. This leads to the weakening of muscles, including the heart. As there is no known cure or treatment, patients — there are just a few hundred families worldwide in which this Barth syndrome is present — often die prematurely. The syndrome is caused by a mutation in a gene called tafazzin, which produces an enzyme that plays a role in the shaping of so-called cardiolipins, molecules that are unique to mitochondria. But so far, it hasn't been clear exactly what is going wrong.

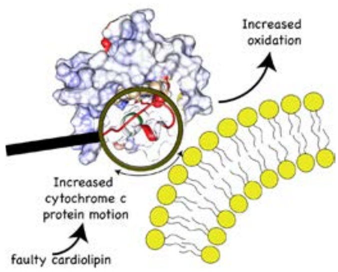
Energy factories

Van der Wel has a long-standing collaboration in studying mitochondrial lipids together with scientists at the University of Pittsburgh—led by professor Valerian Kagan— a place where Van der Wel once worked in the past. His co-workers came up with a hypothesis for the root cause of Barth syndrome: faulty cardiolipin molecules would bind to a protein called cytochrome c, and form a complex that oxidizes lipids in the mitochondria. This would then damage these energy factories, causing them to malfunction. Through genetics, computer simulations, biochemical experiments, and Van der Wel's solid-state NMR measurements, the international team set out to prove this scenario.

Fruit flies

'We used a number of different techniques to investigate this complex, one of which was solid-state NMR', says Van der Wel. This NMR technology is related to the more familiar MRI scans that are made in hospitals. In brief, this technology makes use of radio frequency signals that make atoms vibrate – a bit like striking a tuning fork. Every atom produces a unique 'sound', but this is modified when they connect to other atoms. Consequently, this technique shows Van der Wel which atoms in a material are connected, and also what the structure of a molecule is.

In this way, he was able to demonstrate how the faulty shape of the cardiolipin could facilitate the formation of an oxidizing complex. 'A great thing about solid state NMR is that it also allows you to see the dynamics of molecules', says Van der Wel. 'Normally, cytochrome c is a rigid molecule, but in this complex, it becomes floppy. This structural change causes the toxic oxidation of lipids in the mitochondrial membrane.' Moreover, Van der Wel was able to show how and where a molecule that improves



Cardiolipin with a faulty shape makes the cytochrome c protein less rigid. This results in the formation of an oxidizing complex. | Illustration Patrick van der Wel, University of Groningen the condition of fruit flies with Barth syndrome interacts with the cytochrome c protein, a result that was also supported by the other techniques used in the study.

Joint effort

As a result, the scientists have demonstrated both the probable root cause of Barth syndrome, and a potential way to treat the disease in an animal model. The road to a treatment for patients is still very long, but Van der Wel and his colleagues have made great progress. The next step is to analyze the faulty complex in more detail. This would help them to, for example, design a drug that could be used in humans.

Van der Wel points out that this study was a real joint effort. 'Our paper is the result of the combined expertise of scientists from all over the world.' Furthermore, the project shows how fundamental science can help shed light on a very practical problem, such as the mechanism for a disease. 'Solid state NMR is one of the few methods available to see what the complex of a cardiolipin with cytochrome c looks like. This means that our materials science lab can provide valuable insights into biomedical problems.'

Reference: Valerian E. Kagan et al: Anomalous peroxidase activity of cytochrome c is the primary pathogenic target in Barth syndrome. Nature Metabolism, 23 November 2023. https://doi.org/10.1038/s42255-023-00926-4

ENTEG start-up Sencilia secured SNN-valorization subsidy for 'SmartInfuus'-project

Sencilia, a startup company spun out of the Bioinspired MEMS and Biomedical Devices (BMBD) group within the Engineering and Technology Institute (ENTEG) at the University of Groningen, is pioneering IV infusion sensing technology.

This innovation enables continuous monitoring of the IV infusion's status, promptly notifying clinicians of any undesirable flow variations in the infusion line. In the SmartInfuus project, Sencilia will partner with the UMCG (University Medical Center Groningen) and the University of Groningen. This strategic alliance harnesses the expertise of these academic groups to expedite both technical and (pre)clinical development, ultimately bringing this technology closer to market availability.

To achieve the compact form factors required for clinical use, the BMBD group's MEMS fabrication expertise, led by Prof. dr. Ajay Kottapalli will be instrumental in miniaturizing the sensors. Subsequently, the sensor technology will undergo testing in a perfused pig kidney model developed by the Surgical Research Laboratory at the UMCG, under the guidance of Prof. dr. Henri Leuvenink.

We congratulate the team for successfully securing project funding and wish them every success with setting up the project.

In search of the coveted safer, better, longer-lasting battery: BatteryNL kicks off

On January 12th, a large number of parties involved in the development of batteries in the Netherlands – small companies, multinationals and knowledge institutes – attended the kick off of the BatteryNL consortium. Their goal is to develop the next generation of batteries within eight years that is safer, environmentally benign and has higher performances. Prof. Moniek Tromp, of the University of Groningen, is one of the partners in BatteryNL, a €9.3 million project funded by NWO-ORC.

Safer and higher density batteries

BatteryNL is aiming to develop the next generation of batteries based on a better understanding of material interfaces. These batteries will have higher energy densities and have a longer life-cycle – all of which are crucial for a society based on sustainable energy sources and necessary to stabilize the future power grid.

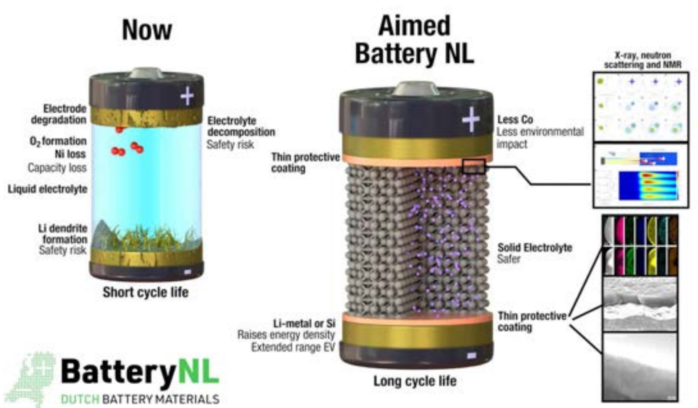
> Next to the novel materials and advanced (characterisation) methods we will develop, the project has already initiated the start of a Dutch Battery ecosystem, incl. the many diverse stakeholders, crucial for the energy transition and the position and role of the Netherlands within that.

The heart of the batteries

Drawing on unique Dutch expertise, the consortium will investigate and improve the heart of these highly coveted batteries – the electrode-electrolyte interface – using scalable technologies.

Pivotal role in the development of future battery technology

To facilitate the social integration of these technological breakthroughs, the social and economic impact will be evaluated in close collaboration with various



Comparison of current and aimed at battery technology. | Image obtained from batterynl.nl.

stakeholders. In doing so, this consortium of experts, small companies, multinationals and social organisations will pave the way for Dutch parties to play a pivotal role in the development of future battery technology.

All parties aligned: from academia up to start-ups

BatteryNL consists of experts within academics, high-tech startups, multinationals and societal partners. Next to the initiators, Delft University of Technology, University of Groningen, University of Twente, Eindhoven University of Technology, and Utrecht University, the consortium consists of University of Amsterdam, TNO, Holst Centre, Hogeschool Rotterdam, Hogeschool Utrecht, Hanze University of Applied Sciences, Saxion University of Applied Sciences, Fontys University of Applied Sciences, Delft IMP, E-magy, Euro Support, LeydenJar, Lionvolt, LithiumWerks, PTG/e, Shell, SALD, VSParticle, Air Liquide, Forschungszentrum Jülich, MEET Battery Research Centre, ANWB, DNV, Durapower, EnergyStorageNL, InnoEnergy, New Energy Coalition, RAI, Solvis, VDL.

BatteryNL represents the top academic universities and Universities of Applied Sciences active in battery research in the Netherlands. The academic partners are experts in battery and interface materials/chemistry and characterisation methodologies (especially during battery operation). Prof. M. (Marnix) Wagemaker (TU Delft - Faculty of Applied Sciences) is the project leader of the €9.3 million project funded by NWO-ORC (project number NWA.1389.20.089).

Research, education and valorisation

Furthermore the Universities of Applied Sciences developed Centres of Expertise on sustainability and energy transition, specifically targeting the role of batteries, where research and education meet and where results can be valorised and utilised.

The involvement of companies in the consortium will help generate a higher impact by enabling implementation of the successful technologies on a larger scale in battery systems, eventually contributing to a more sustainable society. The most relevant national stakeholders in mobility and electric cars, both civil society stakeholders and companies take part in Battery NL.

Contact

For more information, visit www.batterynl.nl or contact us if you would like to know more about the BatteryNL project at info@batterynl.nl or telephone +31 (0)15 278 54 07.

Modelling superfast processes in organic solar cell material

by René Fransen

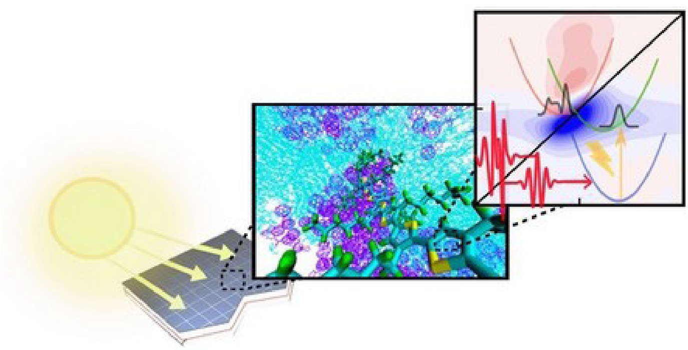
In organic solar cells, carbon-based polymers convert light into charges that are passed to an acceptor. This type of material has great potential, but to unlock this, a better understanding is needed of the way in which charges are produced and transported along the polymers. Scientists from the University of Groningen have now calculated how this happens by combining molecular dynamics simulations with quantum calculations and have provided theoretical insights to interpret experimental data. The results were published on 15 March in the Journal of Physical Chemistry C.

Organic solar cells are thinner than classic silicon-based cells and they are flexible and probably easier to manufacture. To improve their efficiency, it is important to understand how charges travel through the polymer film. 'These films are made up of an electron donor and an electron acceptor,' explains Elisa Palacino-González, a postdoctoral researcher in the Theory of Condensed Matter group at the Zernike Institute for Advanced Materials, University of Groningen (the Netherlands). 'The charges are delocalized along the entangled polymer chains and transferred from donor to acceptor on a sub-100 femtosecond timescale. So, we need theoretical studies and simulations to understand this process.'

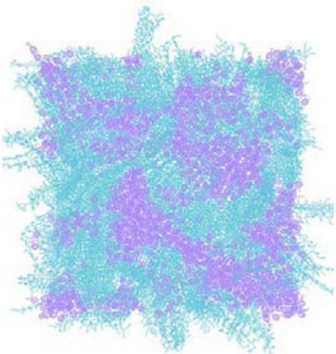
Charge transfer

The system that Palacino-González studied is made up of the plastic semiconductor P3HT as the donor and PCBM, a polymer with a C60 'buckyball', as the acceptor. 'We wanted to know how charges are conducted through the material to understand how this material captures and transports energy. For if we understand this, it may be possible to control it.' Experimental studies of the material provide some information, but only on bulk processes. 'Therefore, we combined molecular dynamics simulations to determine the motion of the molecules in the material with quantum chemistry calculations to atomistically model the donor polymer, using time-dependent density functional theory.'

These theoretical studies were carried out using a donor polymer that was made up of twelve monomers. 'We focused mainly on the donor to study how the excitations in the material occur.' The molecular dynamics simulations show the movement in the ground state due to thermal effects. Palacino-González calculated this for a period of 12.5 picoseconds, which sufficed to study the femtosecond charge transfer.



Simulations help scientists to understand charge transfer in organic solar cells. | Illustration Elisa Palacino-González, University of Groningen



Top view of the P3HT:PCBM thin-film blend morphology of simulation box size 40 x 40 x 5 nm3| Illustration Elisa Palacino-González, University of Groningen

Experiments

'And the next step was to superimpose the quantum world onto these molecules,' continues Palacino-González. To do this, she started with dimers. 'Two monomers next to each other in the polymer chain will interact, they 'talk' to each other. This causes a split in the energy levels of the duo,' Palacino-González explains. She created a 'fingerprint' of the dimer's energy in the shape of a Hamiltonian, a matrix that contains all the information about a molecular system. 'When two monomers are aligned in a parallel fashion, the two are coupled and talk to each other. But when they are at 90-degree angles, the interaction is minimal.'

Such an angle forms a kink in the molecule, which hampers energy transfer along the polymer chain. 'A statistical analysis of the simulated material, made up of 845 polymers, shows that around half of them are perfectly aligned, while the other half have mostly one or two kinks,' says Palacino-González. From dimers, she calculated the Hamiltonian of 12-mers (made up of 6 dimers). Her calculations included a varying number of kinks in the 12-mer donor polymers. 'These studies show the energy distribution along the polymers and provide us with a realistic model to characterize the effect of the environment created by the materials on the spectral signals of the acceptor polymer blends, which is directly comparable with current experiments on these materials.'

Realistic description

Although the model is limited, since it only allows monomers to interact with their direct neighbour, the results provide important insights into experimental results. 'Our calculations are from first principles and this is the first time that such an analysis, including the realistic description of the blend environment, was made for this material. This means that we can now help to explain the spectra generated from experimental studies with P3HT/PCBM mixtures. For example, we can show how size distribution changes the spectra that are generated by laser light excitation,' says Palacino-González. 'We are now able to look at the ultrafast charge transfer process, from donor to acceptor. This will inspire theoretical studies on organic photovoltaics and help experimentalists to understand their results.'

"We are now able to look at the ultrafast charge transfer process, from donor to acceptor. This will inspire theoretical studies on organic photovoltaics and help experimentalists to understand their results."

Reference: Elisa Palacino-González and Thomas L. C. Jansen: Modeling the Effect of Disorder in the Two-Dimensional Electronic Spectroscopy of Poly-3-hexyltiophene in an Organic Photovoltaic Blend: A Combined Quantum/Classical Approach. Journal of Physical Chemistry C, 15 March 2023. https://doi.org/10.1021/acs.jpcc.3c01080

The paper is published in a Special Issue of the Journal of Physical Chemistry C named "Early-Career and Emerging Researchers in Physical Chemistry". This issue is intended for scientists who have recently begun their independent research careers and are in charge of the development of the work presented in the paper.

Outstanding performance of organic solar cell using tin oxide

by René Fransen (ScienceLinX)

Organic solar cells have a photoactive layer that is made from polymers and small molecules. The cells are very thin, can be flexible, and are easy to make. However, the efficiency of these cells is still much below that of conventional silicon-based ones. Applied physicists from the University of Groningen have now fabricated an organic solar cell with an efficiency of over 17 percent, which is in the top range for this type of material. It has the advantage of using an unusual device structure that is produced using a scalable technique. The design involves a conductive layer of tin oxide that is grown by atomic layer deposition. The scientists also have several ideas to further improve the efficiency and stability of the cell. The results have been described in the journal Advanced Materials on 31 March.

D. Garcia Romero

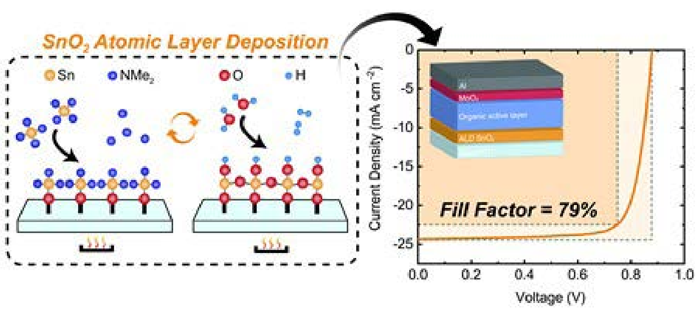
L. Di Mario

In organic solar cells, polymers and small molecules convert light into charges that are collected at the electrodes. These cells are made as thin films of different layers—each with its own properties—that are stacked onto a substrate. Most important is the photoactive layer, which converts light into charges and separates the electrons from the holes, and the transport and blocking layer, which selectively directs the electrons towards the electrode.

Stability

'In most organic solar cells, the electron transport layer is made of zinc oxide, a highly transparent and conductive material that lays below the active layer,' says David Garcia Romero, a PhD student in the Photophysics and Optoelectronics group at the Zernike Institute for Advanced Materials at the University of Groningen, led by Professor Maria Antonietta Loi. Garcia Romero and Lorenzo Di Mario, a postdoctoral researcher in the same group, worked on the idea of using tin oxide as the transport layer. 'Zinc oxide is more photoreactive than tin oxide and, therefore, the latter should lead to a higher device stability,' he explains.

Although tin oxide had shown promising results in previous studies, the best way to grow it into a suitable transport layer for an organic solar cell had not yet been found. 'We used atomic layer deposition, a technique that had not been used in the field of organic photovoltaics for a long time,' says Garcia Romero. However, it has some important advantages: 'This method can grow layers of exceptional quality and it is scalable to industrial processes, for example in roll-to-roll processing.



Production of the new plastic solar cells using Atomic Layer Deposition, which results in a highly efficient organic solar cell (as expressed by the fill factor). | Illustration Loi lab, University of Groningen

Scalable

The organic solar cells that were made with tin oxide deposited by atomic layer deposition on top show a very good performance. 'We achieved a champion efficiency of 17.26 percent,' says Garcia Romero. The fill factor, an important parameter of solar cell quality, showed values up to 79 percent, in agreement with the record values for this type of structure.

Furthermore, the optical and structural characteristics of the tin oxide layer could be tuned by varying the temperature at which the material is deposited. A maximum power conversion was reached in cells with a transport layer that was deposited at 140 degrees Celsius. This same result was demonstrated for two different active layers, meaning that the tin oxide improved efficiency in a generic way.

'Our aim was to make organic solar cells more efficient and to use methods that are scalable,' says Garcia Romero. The efficiency is close to the current record for organic solar cells, which stands around 19 percent. 'And we haven't optimized the other layers yet. So, we need to push our structure a bit further.'

"Our aim was to make organic solar cells more efficient and to use methods that are scalable."

Garcia Romero and his co-author Lorenzo di Mario are also keen to try making larger area cells. These are typically less efficient but are needed to step towards real-world applications and panels.

Improvement

The new solar cell with an impressively high fill factor is a good starting point for further development. Garcia Romero: 'It may be a bit early for industrial partners to take this on; we need to do some more research first. And we hope that our use of atomic layer deposition will inspire others in the field.'

"We always strive to understand what is happening in a material and in a device structure. Here, we think that there might be room for improvement. In that process, our tin oxide transport layer is a great initial step."

'We always strive to understand what is happening in a material and in a device structure,' adds Professor Loi. 'Here, we think that there might be room for improvement. In that process, our tin oxide transport layer is a great initial step.' This class of solar cells may make an important extra contribution to the energy transition because of their mechanical properties and their transparency. 'We expect that they will be used in a totally different way than silicon panels,' says Loi. 'We need to think broader and out of the box at the moment.'

Reference: Lorenzo Di Mario, David Garcia Romero, Han Wang, Eelco K. Tekelenburg, Sander Meems, Teodor Zaharia, Giuseppe Portale and Maria A. Loi: Outstanding Fill Factor in Inverted Organic Solar Cells with SnO2 by Atomic Layer Deposition. Avanced Materials, online 31 March 2023. https://doi.org/10.1002/adma.202301404

Zernike Institute involved in successful applications in the third round of the National Growth Fund

The Zernike Institute for Advanced Materials at the University of Groningen is well represented in proposals submitted in the third round of the National Growth Fund , for which national funding is available. In the third round, a total of four billion euros has been awarded to eighteen project proposals that will make a significant contribution to the economic growth and prosperity of the Netherlands. The Zernike Institute is involved in at least three of those eighteen proposals.

The Zernike Institute is collaborating with a wide range of partners on various groundbreaking projects that form the basis for the economy and society of the future. The Institute is involved in at least three proposals: Circular Integrated High-Efficiency Solar Panels (Loi et al.), M2i: Growing with Green Steel (Kooi), and Materials Independence Circular Battery Technology (Tromp).

Circular Integrated High-Efficiency Solar Panels

This project focuses on the development and industrialization of new solar PV technologies and ensures the development of the next generation of fully circular solar panels. Within the project, the UG will collaborate with the entire chain, from suppliers of raw materials to construction and automotive companies that will use integrated solar panels on a large scale. This initiative contributes to the energy transition and the energy independence of the Netherlands and the EU.

The National Growth Fund will invest up to €412 million in the project. This amount consists of a definitive award of €135 million and a conditional award of €277 million. Read more about the project here.

M2i: Growing with Green Steel

The goal of Growing with Green Steel is to accelerate the transformation to a sustainable steel sector and build a strong international competitive position by implementing circular chains and reducing emissions. The project focuses on innovations within manufacturing companies that contribute to reducing CO_2 emissions and other harmful emissions in the sector, as well as the reuse of raw materials.

The National Growth Fund will invest €124 million in the project.

Materials Independence Circular Battery Technology

Battery technology plays a crucial role in the energy transition as a storage system for green energy. This project aims to establish a strong position for the Dutch manufacturing industry in the global battery chain, with sustainability and circularity at its core. The project contributes to achieving climate goals and realizing sustainable economic success in the Netherlands.

The National Growth Fund will invest up to €296 million in the project. Of this amount, €118 million has been conditionally awarded, and €178 million is reserved. Read more about the project here

The Zernike Institute is delighted to contribute to these important projects and will leverage its knowledge and expertise to develop innovative solutions that contribute to the sustainable growth of the Netherlands.

Newsflash

Impact Award for Spin Memristor work of Tamalika Banerjee and her team

Vici grant for Marleen Kamperman

Professor Loi receives Hestia funding

Gosia Wlodarczyk-Biegun joins our team as assistant professor Biomaterials and Bioengineering

Poster awards for Monica Espinoza Cangahuala & David Picconi at KNCV CTC Spring

Prof. Shirin Faraji became the chair of the KNCV-CTC devision

Royal Decoration for Katja Loos

Open Competition Science-M grant for Jagoda Slawinska

ERC Synergy Grant for Prof. Dirk Slotboom and Prof. Wiktor Szymanski

PAR Foundation grant for Dr. Adela Melcrova

Best UG Engineering Thesis 2022 for Chongan Ye

KNAW appoints Marrink as members

Open Competition Science-M grant for Andrea Giuntoli

NWO XS grant for Onck

Veni grant for Samer Kurdi

Roberto Lo Conte joins our team as assistant professor Quantum Materials

Moniek Tromp appointed Captain of Science of the Top Sector Chemistry

ERC Synergy Grant for Elisabetta Chicca - SWIMS project: Transforming IoT Sensory Systems for Sustainable Future

Talieh Ghiasi wins Minerva Prize 2023

Sourav Maity receives NWO XS grant for research on membrane-active antibiotics

DFG grant for Elisabetta Chicca

Erika Covi joins our team as assistant professor Cognitive Devices

Remco Havenith receives an NWO M2 grant

university of groningen

faculty of science and engineering

zernike institute for advanced materials