NTNU Nano
2019/2020

NTNU
Norwegian University of
Science and Technology

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Front page: Atom Probe.
Photo: Geir Mogen/ NTNU

Introduction

Photo: IESE

Nanoscience lies at the heart of modern science and technology. NTNU is the largest single centre for nanoscience and nanotechnology in Norway, and nanoscale processes and phenomena underpin much of our research portfolio. Providing access to the right tools and facilities for studying and exploiting nanoscale phenomena is critical to the university's continuing growth and success and – alongside biotechnology and information technology – NTNU has designated nanotechnology as one of its three "enabling technologies". Together with my colleagues Peter Köllensperger and Hanna Gautun, I run the University's coordinating activity in nanoscience, "NTNU Nano". And it is our job to ensure researchers at NTNU have access to the support they need to carry out world-leading research in nanoscience, nanotechnology and functional materials.

The aim of this brochure is to provide a brief overview of nano-related activities at NTNU, and to point you in the direction of facilities and services that can assist with your research. In the following pages, you will read about some of the nano-related highlights of the past year, find short descriptions of the exceptional experimental facilities that are available for your use, and learn about the various initiatives that we have introduced to help raise the quality and visibility of nanoscience at NTNU. We are particularly excited to be launching our new Impact Fund, which provides small-scale funding for activities that will raise the impact of nanoscience at NTNU – be sure to check out the details on the next page. There's much more going on across the University that we couldn't squeeze into this brochure, so if you want to find out more, please also take a look at our website at https://www.ntnu.edu/nano. And, finally, our job at NTNU Nano is to help you to improve the quality and impact of your nano research. If you have any ideas about how we should be doing that, please do get in touch!

John de Mello,
Director of NTNU Nano

NTNU Nano Impact Fund

We are pleased to announce the launch of our new "Impact Fund", which will contribute funds of up to 20,000 NOK for activities to raise the visibility and impact of NTNU's work in the area of nanoscience and nanotechnology.

The scope of the Fund is not restricted, and we are prepared to consider any reasonable request for funding that is likely to improve the impact of nanoscience at NTNU. However, potential uses of the fund include production costs for cover articles in high-impact journals, photography or graphical artwork for publicity materials, public communication activities, the development of prototypes, and support for networking and workshops.

Applications should be made via a short online form at https://s.ntnu.no/impact, and will be considered on a competitive basis at the start of every month. In exceptional circumstances, it is possible to apply for more than 20,000 NOK, but priority will be given to requests below this level. Financial support from NTNU Nano should be acknowledged in any resulting publications or presentations.

Science Journalism

We are delighted to report the appointment of Kelly Oakes as the new science writer for NTNU Nano.

Kelly Oakes

Kelly is a freelance writer who specialises in science, health, environment, and technology. Her work has been published in New Scientist, BBC Future, Nature, BuzzFeed, and many other publications. She has a degree in physics and a master's in science communication from Imperial College London. You can find all of the articles that Kelly has written for us on our website, but we have reprinted a selection of her articles at the end of this brochure. Starting in 2020, all of Kelly's articles will be distributed through Norwegian SciTech News which distributes its articles widely throughout the world. This is a great way to communicate your research to the general public (and for RCN grantholders to deliver on some of their outreach obligations) so – if you have something interesting to report – please get in touch!

New Nanomaterials Infrastructure in Trondheim

2019 saw the establishment of the Norwegian national centre for minerals and materials characterisation, known as MiMaC for short.

MiMaC aims to look at every step of the process of turning minerals into materials. The centre is a joint project of NTNU, NGU (the Geological Survey of Norway) and SINTEF. When it's fully up and running in the coming months, it will be made up of five world-class instruments that allow researchers to look at materials in different ways, from the atomic scale up to the microscale. The crown jewel of the project is already in place: a state-of-the-art atom probe that can image materials in three dimensions. It works by using laser or high voltage pulses to evaporate away the tiny sample you put into the probe, pushing its way through a few atoms at a time, allowing you to reconstruct the location of each atom. As a national centre, MiMaC is open to scientists from other institutions who want to use its instruments, and it is hoped that researchers from inside and outside of NTNU will take advantage of the atom probe to see objects such as fossils and even meteorites in a new light. However, the main reasoning behind MiMaC is more down to earth. Using the centre's instruments, researchers will look at the whole lifecycle of minerals: from their extraction and processing, to their design and production, and eventually their re-use or recycling.
You can read more about the MiMaC's instruments here: https://www.ntnu.edu/nano/infrastructure

Rector's prize studentships in nanoscience, nanotechnology and functional materials

Each year the Rector sponsors a university-wide competition for two PhD positions in nanoscience, nanotechnology and functional materials, open to nano-active research groups in all faculties. In 2019 one position was awarded to *Jianying He* and *Helge Kristiansen* from the Department of Structural Engineering to develop high thermal conductivity interface materials for metal/polymer interfaces; while the other was awarded to Sverre Magnus Selbach, Mari-Ann Einarsrud and Sondre Kvalvåg Schnell from the Department of Materials Science and Engineering to develop high performance solid-state Li electrolytes for Li-ion batteries. We wish both research teams success with their projects, and look forward to reporting on their progress in future news items.

End of the Nano-Network

The Norwegian PhD Network on Nanotechnology for Microsystems was set up in 2009 to provide a strong national network focused on the improvement of microsystems through the introduction of nanotechnology.

Over the years, the scope and membership of the network has expanded to include many aspects of nanotechnology, with over 120 candidate members from UiO, USN, UiB, UiT, and NTNU. Amongst many activities, the Network has provided PhD courses, travel and research support, training in nanofabrication, and an opportunity for researchers across Norway to gather and share their research at its hugely popular annual workshop. Unfortunately, RCN funding for the NanoNetwork ends this year, and new funding for graduate level research schools will not become available until 2022 (next call 2021). In the meantime, we hope to continue running the Network in a slimmed-down form, with a small number of ongoing PhD courses and with the Norwegian NanoSymposium replacing the annual workshop as a yearly meeting place for Norwegian nanoresearchers (see below). We are tremendously grateful to Jostein Grepstad who – with the help of the NanoNetwork Board and management team – has led the Network tirelessly since its inception. Huge thanks also go to Berit Myhre, who has skilfully administered the Network for the past 8 years.

NanoNetwork
Norwegian PhD Network on Nanotechnology for Microsystems

Norwegian NanoSymposium

From left: Willem Mulder, Manish Tiwari, Erik Reimhult, Olena Zavorotynska, John de Mello, Vegar Ottesen, Olav Gaute Hellesø, Pawel Sikorski, Bodil Holst, Lasse Vines and Sofie Snipstad. Photo: Amin Zavieh/NTNU NanoLab

In November NTNU hosted the inaugural meeting of the Norwegian NanoSymposium – a general interest meeting on nanoscience and nanotechnology open to researchers across Norway and Europe.

The goal was to establish a fun, friendly and informal meeting covering all areas of nanoscience, where students and researchers from many disciplines could meet together, share ideas and make new contacts. The programme included talks from a wide range of internationally leading scientists and early-stage researchers, explaining the many ways in which nanoscale materials, devices and processes are helping to solve some of mankind's biggest challenges. Other activities included networking lunches, poster sessions, and a conference dinner.

With over 200 attendees from across Norway, this was one of the largest meetings NTNU Nano has hosted, and we hope next year's meeting will be even bigger!

Congratulations to Erik Dobloug Roede and Matthias Hartl for winning the best presentation and poster prizes, respectively. And special thanks to Hanna and Berit for their tremendous efforts in arranging the meeting. Be sure to check the NTNU Nano website for updates about the 2020 meeting.

Other workshops and meetings

In addition to the Norwegian NanoSymposium, NTNU sponsors and supports a number of smaller, more specialised workshops at NTNU. This year's events included: "Grey Goo" – a meeting organised by the student nanotechnology society, Timini (see below); a meeting on steep-slope transistors organised by Trond Ytterdal; and the first workshop on atomistic modeling, led by Astrid de Wijn, Sondre K. Schnell and Ida-Marie Høyvik..

If you would like to host a workshop in 2020 in a nano-related area, you may apply for financial support through the NTNU Nano Impact fund.

Photo: Inga G. Ringdalen

Organizers and invited speakers at the Atomistic Modeling Workshop. From the left: Astrid de Wijn, Sondre Schnell, Ida-Marie Høyvik, Nico van der Vegt and Trygve Helgaker.

Prizes and awards

From left Svein Flatebø, Senior Advisor at Yara, Rokas Sažinas, Winner of Yara's Birkeland Prize 2019, and Nathalie Skovholt, Corporate Marketing Manager at Yara. Photo: Madeleine Delp Bergsjø for Yara.

Many NTNU Nano members were recognised for their contributions to nanoscience in 2019.

It was an especially productive year for *Dennis Meier*, who received the Fridtjof Nansen award for young scientists from the Norwegian Academy of Science and Letters (DNVA), the I. K. Lykkes award from the Royal Norwegian Society of Sciences and Letters (DKNVS), and most recently secured a prestigious Consolidator Grant from the European Research Council (ERC).

Asle Sudbø was named a Fellow of the American Physical Society (APS) for "his pioneering contributions to the theory of vortex matter in strongly fluctuating superconductors, superfluids, and multicomponent condensates", while *Sverre Magnus Selbach*, *De Chen*, *John de Mello*, *Knut Aasmundtveit* and *Dennis Meier* (again!) were admitted as members of the Royal Norwegian Society of Sciences and Letters.

Amongst our current and former PhD students, *Rokas Sažinas* was awarded Yara's Birkeland Prize for his thesis on "Stability and cation diffusion in $BaZrO_3$-based proton conducting solid state electrolytes", while *Einar Sulheim* received the Chorafas prize for his thesis on "Nanomedicine and Sonopermeation in the Treatment of Cancer".

We offer our hearty congratulations to them all!

Timini 10^{-9}

is the association of students enrolled on NTNU's master program in nanotechnology. We aim to create a social arena for the students, and to help them build links with academia and industry. Lunch talks are arranged regularly in collaboration with NanoLab, where PhD-candidates in the field of nanotechnology present their research, followed by scientific discussions and servings of coffee and buns. One of the highlights in our calendar is the annual Grey Goo symposium, where companies get to meet students on the nanotechnology program. The aim of the symposium is to promote exchange of knowledge and ideas, and to encourage collaborative master projects with industry. Both students and industry representatives are given the opportunity to present their expertise, creating an atmosphere for further talks during the breaks. This year, around ninety students from NTNU participated, together with representatives from five Norwegian companies. The symposium was organised by Timini and kindly sponsored by NTNU Nano.

Starting next year (2020), we will be launching a new photography competition, where nano students and researchers will get to compete for a monthly prize. We are hoping to see some really striking images of nanoscience in action, and look forward to receiving your contributions! (More details will be posted on our website soon). We will also be hosting a twice-yearly international guest lecture on behalf of NTNU Nano. We have been given a free choice of the topics and speakers, but they have made one stipulation that it MUST BE FUN. We will definately rise to the challenge!

INFRASTRUCTURE

NTNU is fortunate to have many excellent infrastructures for micro- and nano-scale fabrication and characterisation. We have listed some of the most important facilities below with a brief description of what they do. If you want to learn more, you can find more details on the NTNU Nano website and at the websites of the individual infrastructures.

NTNU NanoLab

NTNU NanoLab is a 700 m^2 cleanroom, providing general purpose equipment for the fabrication and characterisation of complex systems on the micro- and nanoscale.

The cleanroom is an open-access user-operated facility, managed by a staff of nine full-time engineers. As part of the "Norwegian Infrastructure for Micro- and Nanofabrication" (NorFab), NanoLab is open to researchers from across Norway, independent of their academic, institutional or company affiliation. International researchers may also use the facility.

The lab offers a wide range of thin-film deposition methods (evaporation, sputtering, chemical vapour deposition and atomic layer deposition), covering metals, insulators, semiconductors and piezo-electrics. It also offers a broad range of etching methods, including wet and dry etching chemical techniques and ion-milling. NanoLab provides extensive optical and e-beam lithographic equipment, enabling patterning of features down to 1 μm and 6 nm, respectively. Two maskless aligners are available within the lab for rapid optical lithography.

"Bottom-up" preparation of nanomaterials is catered for in a chemical cleanroom equipped with fumehoods, laminar flow benches, a nitrogen glovebox, ovens, autoclaves, dip-coaters and a Langmuir Blodgett trough. A wide range of characterisation equipment is available, including a scanning electrochemical microscope, a particle size analyser, absorption spectrometer, Atomic Force Microscopes (AFMs), a 3D profilometer, a contact angle measurement system, and three Scanning Electron Microscopes (SEMs). Compositional analysis may be carried out using X-ray photoelectron spectroscopy (XPS), Auger electron spectroscopy (AES) or μ-Raman spectroscopy. Focused ion beam (FIB) enables deposition, sputtering, serial tomography, TEM preparation and subsurface investigations.

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Photo: Geir Mogen / NTNU NanoLab

Report from Peter Köllensperger, Director of NTNU NanoLab and NorFab

2019 HAS BEEN AN EVENTFUL YEAR for both NanoLab and NorFab – the Norway-wide consortium of micro and nanofabrication facilities. Following our submission of the NorFab III grant proposal to the Research Council of Norway in 2018, we received the welcome news this autumn that we had passed the review stage and were invited to negotiations. We are now finalising these negotiations for 100 MNOK in support over the next four years. In addition, as part of the Nordic Nano Network, NorFab has applied for NordForsk funding to support user and expert exchange between the cleanrooms in the Nordic region. NorFab also has a leading role in the EuroNanoLab consortium, and we are preparing an application to become part of the European Strategy Forum on Research Infrastructures (ESFRI) roadmap. This is an effort that includes over 40 cleanrooms in 14 countries, all working together to provide users with better access to infrastructure, training and processes. We also arranged a successful trip to the Nordic Nano Network User Meeting at the Technical University of Denmark (DTU) in Copenhagen, which was memorable not only for the quality of the presentations and posters, but also for the exceptional hospitality we received. Many thanks to Hanna Gautun for arranging everything. Without her help coordinating this and many other events throughout the year, it is doubtful any networking activities would have taken place at all.

Within the NanoLab we have been busy finishing the rebuild of the thin-film area to make space for a number of new investments, such as a Lesker e-beam evaporator, a Tepla Asher and an Oxford Instruments Plasma-enhanced chemical vapor deposition (PECVD) system. Our engineers Mark, Svenn Ove and Martijn have done an excellent job in planning, tender preparation and installation here, working within an extremely short timeframe. Meanwhile, Mathilde and Trine have reorganised the chemical area, which has included simplifying the glassware and installing a new Rapid Thermal Processor (RTP) system. Amin has taken over responsibility for the Auger electron spectroscopy/xray electron spectroscopy (AES/XPS) lab, as well as running numerous operator services to his clients' great satisfaction. Last but not least, Ken Roger has done an excellent job running the NanoLab. And, despite being two people short for the entire year, he still managed to prepare a tender for a new STEM in record time. None of this would have been possible without help from our committed duty workers and student assistants. Finally, our academic and commercial user community can also claim a major share in the successes of NorFab and NTNU NanoLab, providing us with valuable feedback and support, while at times granting us saintly patience as they waited for equipment repairs! We look forward to seeing many existing and new members at the NanoLab in 2020.

Peter Köllensperger, Director NorFab and NTNU NanoLab.

NTNU | Norwegian University of Science and Technology

NORWEGIAN MICRO- AND NANOFABRICATION FACILITY NorFab

Lithoarea, NTNU NanoLab. Photo: Geir Mogen.

INFRASTRUCTURE

Norwegian national centre for Minerals and Materials Characterisation (MiMaC)

MiMaC is a new collaboration between NTNU, SINTEF and the Geological Survey of Norway that aims to establish a world class facility for the structural characterisation and chemical analysis of minerals, metals and advanced nanomaterials. The Centre will provide structural characterisation facilities from the atomic scale through to the microscale, and will enable sensitive compositional analysis down to the parts-per-billion level. The instruments available within the centre include the following: (i) an Atom Probe Microscope, see below; (ii) an Electron Probe Microanalyser which provides compositional information by exciting a sample with an electron beam and using the spectral characteristics of the emitted x-ray photons to identify elemental species; (iii) a Field Emission Scanning Electron Microscope equipped with an electron backscatter diffraction (EBSD) detector for microstructural-crystallographic analysis and an energy dispersive x-ray (EDX) detector for high resolution compositional analysis; (iv) a split stream laser ablation instrument with parallel mass spectrometry (MS) and tandem MS detection channels for simultaneous analyses of elemental and isotopic compositions in minerals and materials; and (v) a laser ablation system with triple quadrupole Inductively Coupled Plasma mass spectrometer (Agilent 8900 ICP-QQQ-ICP-MS) for direct surface analysis of elements in solid samples.

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Atom Probe Laboratory

Recently installed in the department of materials technology, the Cameca LEAP 5000 Atom Probe Tomography setup enables 3D imaging and chemical composition measurements to be carried out at the atomic scale. The atom probe forms part of the newly established Norwegian national centre for Minerals and Materials Characterisation (MiMaC) – a collaboration between NTNU, SINTEF and the Geological Survey of Norway that aims to establish a world class facility for the structural characterisation and chemical analysis of minerals, metals and advanced nanomaterials.

In brief, Atom Probe Tomography works by taking a sample prepared in the form of a sharp needle shaped tip and subjecting it to a high DC bias to generate a large electric field at the sample tip, just below the threshold for atom evaporation. Further perturbation of the tip by a train of laser or voltage pulses is sufficient to trigger evaporation, causing individual ions to be emitted sequentially from the surface. By detecting their emission with a position-sensitive detector (PSD), it is possible to construct a three-dimensional image of the original sample, with the transit time from the sample to the PSD indicating the mass-to-charge ratio of each detected ion.

A wide range of materials may be analysed by Atom Probe Tomography, including metals, alloys, intermetallics, semiconductors, oxides and thin films. Key applications include: chemical analysis of nanoparticles; nanoscale compositional analysis and 3D imaging of grain boundaries in metals and alloys; investigation of interfaces in multilayer structures; analysis of phase separation in complex media; and spatial mapping of trace elements or dopants.

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The NTNU Nanomechanical Lab

specialises in techniques for investigating the deformation and degradation of materials, interfacial mechanics and adhesion, and interactions between materials on the nanoscale.

Detailed experimental investigations are supported by simulations involving ab-initio calculations, molecular dynamics and finite element methods. The lab is equipped with a variety of instruments for nanomechanical and nanotribological testing. Two Hysitron TriboIndenters allow Young's modulus, hardness and fracture toughness to be measured by nanoindentation and scratch resistance, critical delamination forces and friction coefficients to be quantified by scratch testing. A dynamic tensiometer allows for the weight-based measurement of contact angle, surface tension, interfacial tension, and critical micelle formation concentration. An environmental SEM equipped with an electron backscatter diffraction (EBSD) detector is available for microstructural-crystallographic analysis. The SEM also has an in-situ picoindenter for nanomechanical testing, and an in-situ tensile module for tensile and compression tests of specimens.

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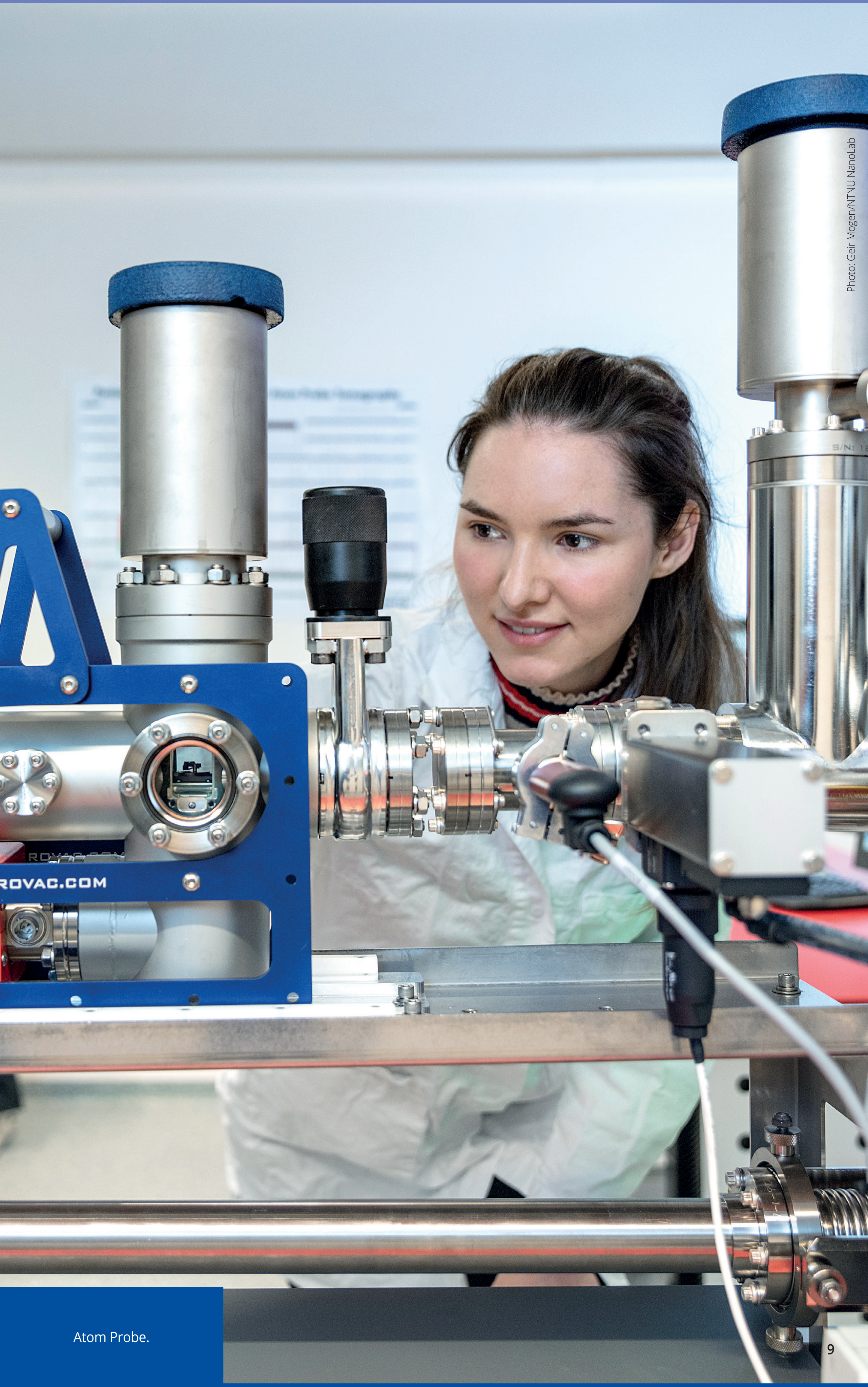

Photo: Geir Mogen/NTNU NanoLab

Atom Probe.

INFRASTRUCTURE

The Norwegian Centre for Transmission Electron Microscopy (NORTEM)

is a nationally coordinated initiative that makes state-of-the-art transmission electron microscopy (TEM) facilities available to Norwegian and international researchers.

The Centre has two nodes, in Oslo and Trondheim, and is a collaboration between NTNU, the University of Oslo and SINTEF. The Trondheim activity is run by theTEM Gemini Centre – a research team specialising in TEM from the Department of Physics, the Department of Materials Science and Engineering and SINTEF Industry. The Centre is part of the EU TEM network ESTEEM3.

The following TEMs are available within the Centre: a **Jeol JEM-2100 LaB6**, which is the workhorse for routine TEM studies, optimized for conventional TEM techniques such as bright-field (BF) and dark-field (DF) TEM and selected area electron diffraction (SAED); a **Jeol JEM-2100F** equipped with a field-emission gun (FEG), which is optimized for advanced materials studies, with a special focus on tomography and scanning precession electron diffraction (SPED); and a **Jeol JEM-ARM200F**, which is one of the best specified microscopes in Europe, capable of atom-by-atom imaging and chemical analysis. The system has aberration correction for the probe and image forming lenses. It has a large efficient Energy-Dispersive X-ray (EDX) detector and Electron Energy Loss Spectroscopy (EELS) for atomic scale spectroscopy.

The centre is equipped with extensive specimen preparation facilities and a computer room for data processing. Each TEM has its own set of single and double tilt holders. Other options include cold-stage holders, heating holders, environmental cell holders, transfer holders, tomography holders and two tilt-rotation holders. Specimen preparation facilities include different types of dimplers, saws, ultrasonic cutters and other tools for the preparation of cross sectional specimens. The Centre has three precision ion-polishing systems, while an ultramicrotome is available for thinly slicing soft specimens. For applications requiring sample preparation on the nanoscale, there are two focused ion beam systems available at NTNU NanoLab.

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Ugelstad Laboratory

The Ugelstad Laboratory was established in 2002 in memory of Professor John Ugelstad, and provides a wide range of experimental techniques for colloid, polymer and surface chemistry. The Lab has a strong focus on complex interfaces (especially in relation to dispersion stability and multiphase flow), and addresses application areas such as sustainable production and processing of oil and food, water treatment, and materials science. The Laboratory uses a wide range of techniques for investigating solid/liquid, liquid/liquid, gas/liquid and gas/solid interfaces. Listed below are some of the key methods available within the Lab that may be of interest to nano-researchers: (i) tensiometry for measuring dynamic and equilibrium surface tensions; (ii) methods for the characterisation of dispersions; (iii) Differential Scanning Calorimetry (DSC) and thermogravimetric analysis; (iv) methods for surface and particle characterisation; (v) a wide range of UV, visible, near infra-red (IR) and mid IR spectroscopies; (vi) instrumentation for high performance liquid chromatography, using UV- and RI-detection plus a combined GC-MS instrument. A full list of equipment is available on the laboratory web site.

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The Molecular Beam Expitaxy (MBE) lab

specialises in epitaxial growth (deposition) of III-V semiconductors in ultra high vacuum (UHV).

The UHV condition allows evaporated materials to behave like molecular beams that can be easily interrupted by the use of shutters, permitting the fabrication of multi-layer structures with atomically sharp interfaces. The use of elemental sources whose deposition rates can be individually adjusted (by changing the source temperature) allows alloys such as $Al_xGa_{1-x}As_ySb_{1-y}$ to be fabricated. Layers can be doped by co-deposition of a doping material, with a wide range of doping concentrations being possible. Growth of both thin-film structures and nanostructures, like nanowires and quantum dots, is possible. The lab usually stocks GaAs, GaSb, InAs, InP and Si as substrates.

The lab consists of 2 MBE systems, one of which is dedicated to full nitrides and the other of which is used for arsenides, antimonides and dilute nitrides. In addition, there is a CV-profiler in the lab that can be used to determine doping profiles in samples by destructive etching (while measuring the capacitive response of the semiconductor-electrolyte interface).

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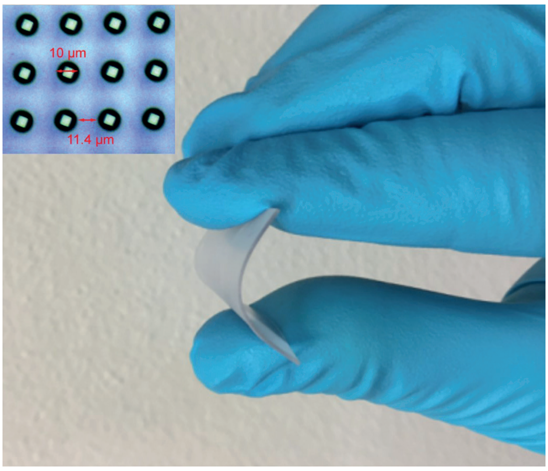
FEATURE ARTICLES

Cracking the problem of ice build-up

If you've ever set foot on an icy pavement you'll understand the importance of a good de-icer.



But ice doesn't just get in the way of people's daily lives. Infrastructure like aircraft, transmission cables, and offshore oil platforms can all be disrupted by ice, with potentially disastrous consequences. That's why Jianying He, a professor of nanomechanics at NTNU, and her colleagues are coming up with new ways to crack the problem of ice build-up.

"Nobody wants to go out in the winter to clean away ice, so we need to find a solution to avoid ice forming on the surface," says He. We used to think that the best way to tackle ice was to make surfaces repel water – the idea being that if water can't build up, it can't freeze – but it turns out that just slows down the formation of ice, and doesn't stop it entirely. So He and her colleagues decided to try another tactic: they'd let the ice form, but find a way to get rid of it afterwards. The most promising method works by creating lots of cracks that make the ice break off from the surface of its own accord. It's similar to how the perforations between postage stamps make it easier to tear them apart.

The method – called the macro-crack initiator, or MACI – involves applying a soft layer with inner holes on top of the surface you want to protect from ice. The soft layer fluctuates as ice forms on top of it, triggering lots of small cracks. This leads to whole layers of ice shearing off from the surface under their own weight. "Ice itself is rigid," says He. "Usually it moves like a whole piece." MACI is working remarkably well, she says, reducing the ice adhesion – a measure of how much the ice is stuck to the surface – even more than the team thought it would.

The next step is improving the durability of the material. Materials with lower ice adhesion are typically softer. To counter the loss in durability that comes from this softness, the group have designed a self-healing elastomer that works to fix any damage to the material. Their coatings are not in use outside of the lab yet, but He doesn't think it will be too long before they are. At the moment they could be used on something small, she says, say a webcam that's exposed to the environment. But after some more characterisation work – and some field tests – they could be coming to an oil platform or aircraft near you.

Kelly Oakes

DOI: 10.1039/C7SM01511A., 10.1039/C8SM00820E, 10.1039/C9SM00024K.

FEATURE ARTICLES

Creating a new kind of electronics

At the border between physics and material science, Dennis Meier and his colleagues are searching for a new kind of electronics.

They hope to make circuits that are smaller, faster, and better for the environment than today's electronics, by taking advantage of defects that already exist within materials. The electronic components the team have made so far are just a few atoms long, and could eventually be connected together to form circuits that measure mere nanometres across – far smaller than those we use today.

"We're working at the limit of what is doable in a solid-state system when you want to construct electronic components," says Meier, a professor in the Department of Materials Science and Engineering at NTNU. The defects used to create these components are made when two parts of the same material have different properties. For example, their electric dipole moments – a measure of the distribution of charge in a material – might point in different directions. When these contrasting sections meet at an interface, they create what is known as a domain wall. The domain wall doesn't behave like the rest of the material – for instance, it might be electrically conducting, even though the rest is an insulator.

So far, Meier's team has created two electrical components using domain walls: a digital switch and a half-wave rectifier. A rectifier turns alternating current that reverses direction regularly to direct current that just flows one way. The next step in his research is to connect components together. Once that's possible, the team can start thinking about creating logic gates and doing some basic computing with the circuits. Theoretically, circuits made with these materials could be tweaked when new technology demands it. "Once you have made your nanoscale circuit you can update it, you can upgrade it if needed, or even erase it and rewrite it – all within the same material," says Meier.

Because domain walls occur naturally in materials, the production process should – in theory – be simple. "The interfaces are always there and they are perfect, no additional work is needed," says Meier. These two features would mean that less material is needed to manufacture electronics, and we wouldn't need to throw things away as often. But making everyday electronics from these materials is not the end goal for Meier. "It's not necessarily about building a computer," he says. "It's more about opening up prospects and showing what we could do."

Kelly Oakes

The future work on this project, called "ATRONICS – Creating building blocks for atomic-scale electronics" is financed through an ERC Consolidator Grant 2019.

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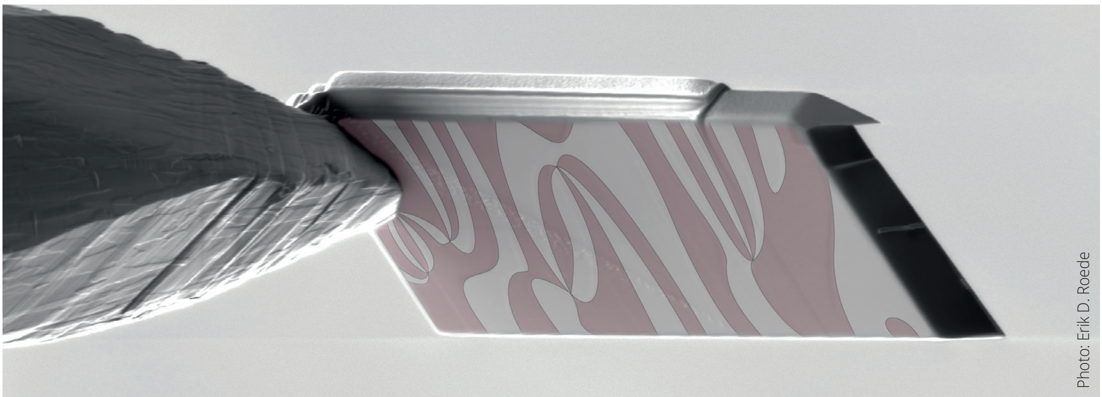

Photo: Erik D. Roede

Photo: Geir Mogen/NTNU NanoLab

FEATURE ARTICLES

Creating a miniature brain-on-a-chip

Growing a brain in the lab might still be a far-fetched idea, but perhaps it just got one step closer.

Øyvind Halaas, a professor of medicine at NTNU, in collaboration with neuroscientists Ioanna and Axel Sandvig and others, has created a mini-"brain-on-a-chip". The biological neural network is made of just three nodes, compared to billions in a real brain, but the structure is an improvement on previous designs. Their project was part of the Cyborg initiative which aims to merge robotics and biology.

Researchers have previously tried to connect single neurons in networks, but those systems don't always work because forming connections between individual neurons in patterns is inefficient. So Halaas and his colleagues decided to make each node a bundled group of brain cells instead.

The neurons grew from stem cells, and the three nodes were connected by micro-tunnels that the neurons themselves couldn't get through, but that did allow through their wire-like protrusions, called axons.

"The larger aim was to try to monitor the 'thinking' of this mini-brain-on-a-chip," says Halaas. They used an existing commercial system to monitor the neurons' electrical activity, and Halaas says they saw interconnection – and therefore communication – between the nodes.

The brain-on-a-chip could be used to study how brains develop and function and what exactly goes wrong when they stop working properly. "There's quite a bit of a gap from this system to trying to get neurons to form stable connections able to transmit signals, reminiscent of the thinking process in the brain," he says. "But still, it's kind of the beginning of a machine-learning/biology interface, which is truly fascinating."

Photo: Geir Mogen

Øyvind Halaas

Brains aren't the only organs researchers are replicating in the lab. Halaas' other research focuses on the immune system. Though your body's immune system isn't a separate organ like your brain or your heart, it's possible to recreate many of its workings using organ-on-a-chip models.

"The immune cells travel around the body, sensing their way forward towards infections or cancers, and initiating responses aimed at eliminating the threat," says Halaas. "I've been trying to make artificial cell systems to learn how these cells communicate, develop, interact and react to stimuli."

"The lymph node, where initiation of immune responses occurs, is particularly interesting when trying to create new solutions for vaccinations," he added.

Ultimately, he wants to use these systems to develop cancer treatments through immunotherapy, a type of therapy that works with someone's own body to fight off the disease. The idea would be to take cells from a cancer patient's body and put them into the artificial immune system, before extracting the immune cells created in the artificial system and putting them back into patients.

It's many years from being a reality, but Halaas believes it's a promising route. "The current solutions for cancer therapy are not good enough for many patients," he says.

Kelly Oakes

This work has been carried out by Rosanne Van de Wijdeven, who worked in NTNU NanoLab on making microsystem and microelectrodes in collaboration with Ola Huse Ramstad and Ioanna Sandvig (both at Dept of Neuromedicine and Movement Science, NTNU) who did the cell work.

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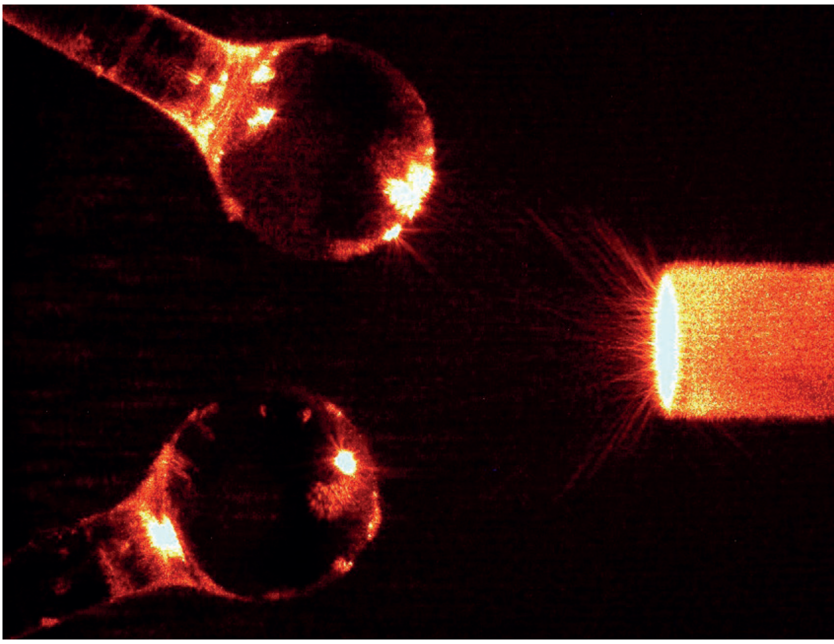
Moving towards an 'artificial pancreas' for people with diabetes

Living with diabetes often means having to prick your finger to test blood glucose levels several times a day.

That's why a group of researchers in Trondheim are working on creating an "artificial pancreas" to take over this responsibility. The work is still in its early stages, but the ultimate aim is for the device to automatically measure glucose levels, and administer insulin according to the results, doing away with regular manual testing.



"We would measure the glucose levels every few minutes, so almost continuously," says Karolina Milenko, a research fellow at NTNU's Department of Electronic Systems and a member of the Artificial Pancreas Trondheim research group, who is working on developing a tiny, implantable blood-glucose sensor for the device. "Then we would have an insulin pump that would be connected with the sensor, allowing the pump to administer insulin accordingly."

Some people with diabetes already have a pump that delivers a background level of insulin automatically, which they can top up manually when they need to. And some already use a device to measure blood glucose that sits just underneath their skin. These devices, which allow for either continuous or on-demand monitoring, measure the amount of glucose in the fluid that surrounds the body's cells, and still need calibrating with a finger prick test occasionally.

But an artificial pancreas – which won't resemble a real pancreas in appearance, but will mimic its role – could combine these two functions, measuring glucose levels continuously and releasing insulin as needed. This would help people with diabetes to keep their blood sugar levels stable, something which is important for both short and long-term health.

In a recent paper published in *Optics Letters*, Milenko and her colleagues detail a sensor that could one day measure blood glucose levels. It uses two optical fibres, each 220 microns in diameter: one to send light through the test liquid to an enhancement layer, which is made of a thin gold film over a layer of nano-spheres, and a second fibre to collect the signal. The sensor can identify a signature in the signal which is unique to the molecule it is designed to measure. A method called surface-enhanced Raman scattering amplifies the signal and makes it possible to see even small amounts of the molecule.

So far Milenko and her colleagues have tested the sensor by measuring the concentration of a dye, but the next step is to move on to measuring glucose itself. "Glucose is actually really difficult to measure at the levels it's found in the body, because of its very low concentration," says Milenko. Despite the challenges, she says preliminary experiments the group have yet to publish suggest that the sensor can in fact pick up glucose.

For the next step in their research, the team are using hollow fibres, created by researchers at the University of Bath, in the sensor. Because the hollow fibres have more favourable optical properties, the group hope they will provide better sensitivity to glucose.

Milenko hopes the eventual artificial pancreas will be able to respond to changes in blood-glucose levels quicker than existing devices that go under the skin, because it will be placed in a part of the abdomen called the peritoneal cavity. "There is some research showing that measuring glucose levels in the peritoneal cavity yields a faster response," she says.

Continuous monitoring would also be an advantage of the device, because the on-demand testing many people use now doesn't give them the complete picture of their blood sugar levels. "Even if you do it many times per day, you still might miss the times in a day where your glucose is too high or too low, for example, when you are sleeping, or when you're doing some activities, and you're not able to measure that specific moment," says Milenko.

It will still be a number of years before the team has a fully functioning device – but for many people with diabetes, it will hopefully be worth the wait.

Kelly Oakes

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