University of Basel

Swiss Nanoscience Institute

SNI SWISS NANOSCIENCE INSTITUTE

EINE INITIATIVE DER UNIVERSITÄT BASEL UND DES KANTONS AARGAU

Annual Report 2020

Swiss Nanoscience Institute
University of Basel

The Swiss Nanoscience Institute (SNI) is a research initiative of the Canton of Aargau and the University of Basel.

Swiss Nanoscience Institute
Klingelbergstrasse 82
4056 Basel
Switzerland
www.nanoscience.ch

Cover image: Scanning electron microscope image of parts of a spin qubit device which was fabricated by means of electron beam lithography. It is colored in rainbow colors, because the structures arrange themselves at a distance a little smaller than the wavelength of visible light and show different colors depending on the viewing angle. (Jann Hinnerk Ungerer, SNI PhD Student, Department of Physics, University of Basel)

Contents

Foreword

Dear ladies and gentlemen,
dear colleagues,

2020 – what a year!

Not one that we'll forget in a hurry, as it showed us how quickly our lives can be turned upside down.

For many, it was a hugely challenging year that brought risks in terms of both health and income. And even if everyone managed to stay healthy and work was able to go ahead almost as normal, many of us nonetheless experienced drastic changes as schools and kindergartens abruptly closed and we were forced to give up our familiar routines and leisure activities.

But 2020 was also a year that highlighted the central role played by science in our modern world. At an unprecedented pace, scientists from research institutions and companies around the world worked together to sequence the virus genome and then develop and produce tests and vaccines.

With these vaccines comes the promise of a return to normality and a world in which we can once again meet in the same room and talk to each other face to face. That is something I am especially looking forward to!

But I also believe there are valuable lessons to be learned from the pandemic. Although a Zoom call is no substitute for meeting face to face, it is often a valuable addition. Over the last year, we have come to realize that the process of inviting colleagues from around the world to a lecture can be greatly simplified by holding it online. And it seems that our students also often benefit from having video recordings of their lectures available to rewatch at any time.

In this annual report you will read about the activities and projects that defined 2020 for the SNI, and how we tackled the various obstacles posed by the coronavirus pandemic.

As in previous years, the annual report is divided into two parts. In the scientific supplement, which you can access by scanning the QR code on the final page, project managers and doctoral researchers report on the progress of their Nano Argovia and PhD projects.

In the general section you are reading now, alongside figures and facts, we write about various SNI projects in language comprehensible to a general readership and tell you a little about some of our students, doctoral researchers and other members of the network.

Particularly at a time when personal connections can no longer be taken for granted and are more difficult to maintain, we are again and again reminded of just how important the

members of our network are to the SNI. They are the SNI, filling the framework we provide with life and exciting research!

I wish you an enjoyable read, and look forward to meeting you all again in person in the course of 2021.

Kind regards,

Christian Schönenberger

Professor Christian Schönenberger, SNI Director

Swiss Nanoscience Institute
The interdisciplinary center of excellence for nanosciences in Northwestern Switzerland

The Swiss Nanoscience Institute (SNI) at the University of Basel is a center of excellence for nanosciences and nanotechnology, founded in 2006 on the initiative of the Canton of Aargau and the University of Basel. In the SNI network, interdisciplinary teams of scientists conduct basic and applied research. The SNI actively supports knowledge and technology transfer to industrial companies from Northwestern Switzerland through the Nano Argovia program, and is a founding member of the ANAXAM technology transfer center. The SNI's Nano Imaging Lab offers a comprehensive range of imaging and analysis services for samples of all kinds aimed at companies and research institutions. A bachelor's and master's program and a PhD school provide interdisciplinary training for young nanoscientists. Finally, the SNI is also involved in public relations, specifically supporting initiatives aimed at generating interest for the natural sciences among various target groups and promoting collaboration between academia and industry.

Commitment from the Canton of Aargau
The SNI was founded in 2006 by the Canton of Aargau and the University of Basel to promote research and training in the nanosciences and nanotechnology in Northwestern Switzerland. Nanotechnologies are highly relevant to research and industry in the heavily industrialized Aargau region. The numerous successful SNI research projects, in which scientists from various disciplines and institutions work together, support the Canton of Aargau's hightech strategy and offer companies from Aargau and the two Basel half cantons access to new scientific findings and technologies. In 2020, the SNI spent over 8 million Swiss francs, of which around 5.4 million were provided by the Canton of Aargau and 2.7 million by the University of Basel.

A diverse, active network
The success of the SNI is based on the interdisciplinary network that has been built up over the years while retaining its dynamic nature and constantly attracting new members. This network includes the Departments of Chemistry, Physics, Pharmaceutical Sciences and Biomedicine and the Biozentrum at the University of Basel, as well as research groups from the Schools of Life Sciences and Engineering at the University of Applied Sciences and Arts Northwestern Switzerland (FHNW) in Muttenz and Windisch, the Paul Scherrer Institute (PSI), the Department of Biosystems Science and Engineering at the Federal Institute of Technology (ETH) Zurich in Basel (D-BSSE), the CSEM (Centre Suisse d'Electronique et de Microtechnique) in Muttenz and the newly founded ANAXAM technology transfer center. The wider network also includes the Hightech Zentrum Aargau in Brugg and BaselArea.swiss, which promotes knowledge and technology transfer.

Excellent education for students
The University of Basel has offered bachelor's and master's programs in nanosciences since 2002. At the end of 2020, a total of 47 students were enrolled on the bachelor's program and a total of 32 on the master's program. The students on the bachelor's program receive a solid basic education in biology, chemistry, physics, and mathematics. Over the course of this demanding program, they can choose from a wide range of practical and theoretical courses that allow them to focus on specific topics. Early on in their education, they have the opportunity to participate in various research groups and gain insights into research projects within industry.

A variety of topics at the PhD School
To promote the further training of young scientists and a wide spectrum of basic scientific research, the SNI initiated a PhD School in 2012. Within the SNI PhD School, each doctoral student is supervised by two members of the SNI network.

The doctoral students' interdisciplinary education is further enhanced by participation in internal scientific events such as the Winter School "Nanoscience in the Snow", the Annual Meeting and various courses developed specifically for the PhD School. In 2020, a total of 39 doctoral students were enrolled, six of whom have completed their doctoral theses. Eight new projects were approved that will start in 2021.

The interdisciplinary SNI network comprises leading research institutions in Northwestern Switzerland, ensuring diverse and exceptional nanoscience research. (Background image: Shutterstock)

Leaders in their field
Basic sciences form the foundation of research work at the SNI. In addition to the various projects funded as part of the PhD School, the SNI also supports the basic scientific research performed by Argovia Professors Rodrick Lim and Martino Poggio. Their work contributes to the SNI's outstanding international reputation.

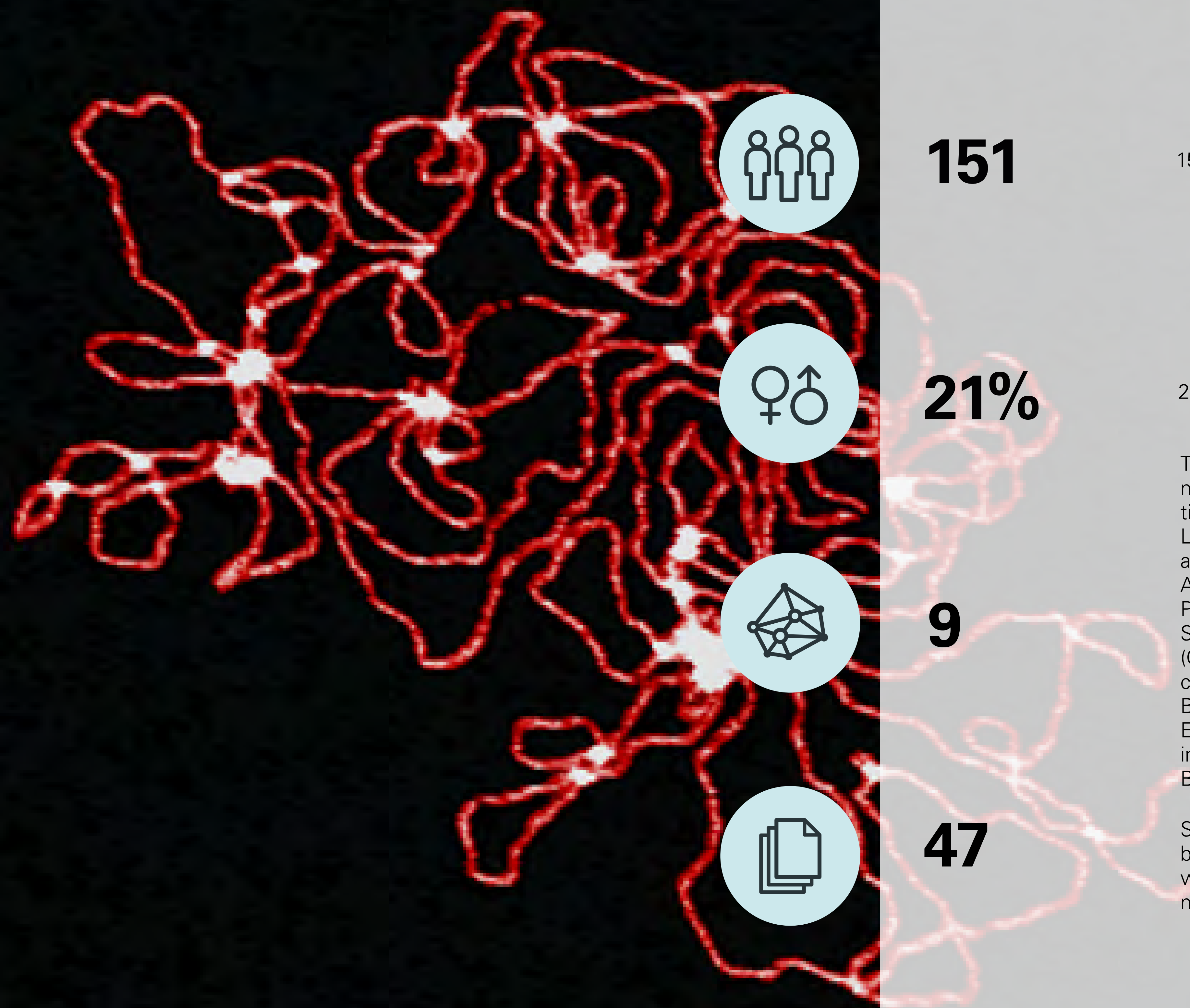
In addition to the Argovia Professors, the SNI supports three titular professors: Professor Thomas Jung teaches and researches in the Department of Physics at the University of Basel and leads a team at the PSI. Professors Frithjof Nolting and Michel Kenzelmann also lecture at the Department of Physics and are active with their research groups at the PSI.

Strong connections to practical application
The transfer of academic findings to industry plays an important role at the SNI and is supported by the Nano Argovia program. In 2020, five new projects were approved and six projects from 2019 were extended for an additional year. Seven of the partner companies came from the Canton of Aargau, and four were from the two Basel half cantons. Collaboration with industry is also promoted through the new ANAXAM technology transfer center. ANAXAM provides companies throughout Switzerland with access to state-of-the-art analysis methods.

Services in demand
The SNI is also on hand as a provider of various services for partners in academia and industry. At the heart of these services is the Nano Imaging Lab (NI Lab), which has been part of the SNI since 2016. The NI Lab's five members of staff have a wealth of experience in electron and scanning probe microscopy and can provide comprehensive imaging services thanks to the lab's outstanding equipment and their expertise. The SNI also supports the excellently equipped workshops for technology, electronics and mechanics in the Department of Physics. Research institutions and industrial companies can access both the expert knowledge of the staff and the outstanding technical resources of the SNI and affiliated departments.

Sharing the fascination with others
For the SNI, it is important to keep the public informed of its activities and to involve them in its fascination with the natural sciences. For example, the SNI team participates in science festivals and exhibitions and provides schools and groups of interested visitors with an insight into everyday laboratory life. In 2020, the year of Covid-19, the team focused on electronic formats such as an extensive collection of short videos describing and explaining experiments for kids. These activities were supplemented by an electronic magazine, press releases, the website, social media channels and various brochures, all of which provided ample opportunity to report on the outstanding research results and activities of the SNI.

SNI network



151

151 members belong to the SNI network.

21%

21% of the SNI members are women.

9

There are nine partner institutions in the SNI network. These include the research institutions the University of Basel, the School of Life Sciences and the School of Engineering at the University of Applied Sciences and Arts Northwestern Switzerland (FHNW), the Paul Scherrer Institute (PSI), the Centre Suisse d'Electronique et de Microtechnique (CSEM) in Muttenz, the technology transfer center ANAXAM, and the Department of Biosystems Science and Engineering at the ETH Zurich in Basel. The network also includes the Hightech Zentrum Aargau and BaselArea.swiss.

47

SNI members published 47 scientific papers based on SNI projects and presented their work as part of 58 talks at national and international conferences.

Atomic force microscopy (AFM) topograhy image of a double-stranded DNA.
(Image: S. Manioglu, ETH Zurich in Basel/D-BSSE, Biophysics Lab)

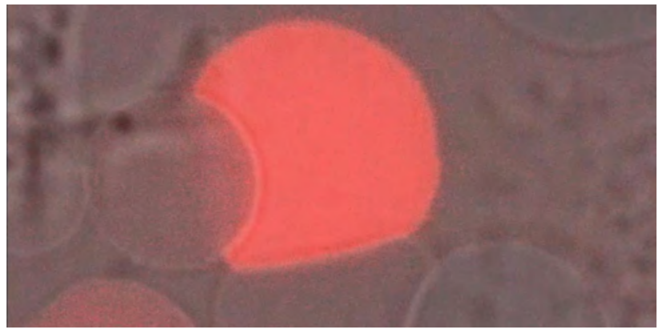
News from the network
Reports on a range of topics

In 2020, researchers from the SNI network published 47 papers in prestigious scientific journals. Some examples shown here reflect the diversity of research in the SNI network. In addition, quotes from SNI members demonstrate the added value generated by the SNI for nanoscience research in Northwestern Switzerland.

Molecular factories: The combination between nature and chemistry is functional

Researchers at the University of Basel have succeeded in developing molecular factories that mimic nature. To achieve this they loaded artificial organelles inside micrometer-sized natural vesicles produced by cells. These molecular factories remain intact even after injection into an animal model and demonstrate no toxicity, as the team report in the scientific journal *Advanced Science*.

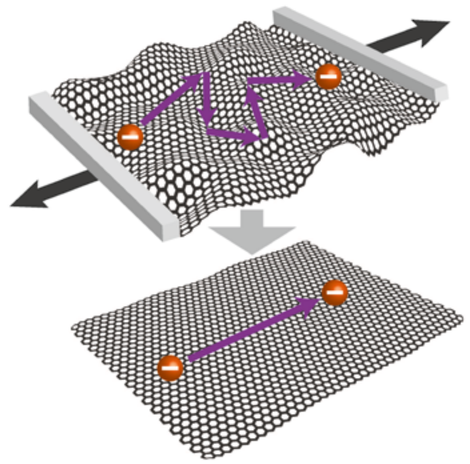
Original source: doi.org/10.1002/advs.201901923



In molecular factories injected into zebrafish embryos, a color reaction occurs when the trapped enzyme (peroxidase) is working. The researchers thus prove that the combination of synthetic organelles and natural vesicles also works in the living organism. (Image: Department of Chemistry, University of Basel)

"SNI provides an excellent support for collaborative projects between academic groups and industry from which all partners can benefit."

Professor Cornelia Palivan, Department of Chemistry, University of Basel

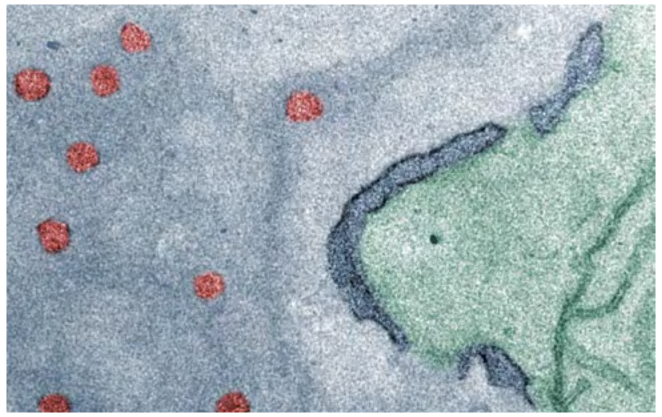


Corrugations in graphene slow down the pace of traveling electrons. By pulling on the graphene sheet on two opposite sides, it is flattened and smoothed, improving electron transport. (Image: Swiss Nanoscience Institute, University of Basel)

Flatter graphene, faster electrons

Scientists from the Swiss Nanoscience Institute and the Department of Physics at the University of Basel developed a technique to flatten corrugations in graphene layers. This leads to an improved sample quality and can be applied to other two-dimensional materials. The results were recently published in *Physical Review Letters*.

Original source: doi.org/10.1103/PhysRevLett.124.157701



To enter into the cell nucleus (gray), the polymersomes (red) must selectively translocate across the nuclear membrane (dark blue) via the nuclear pore complexes (gaps in the membrane). (Image: C. Zelmer, Biozentrum and E. Bieler, Nano Imaging Lab, Swiss Nanoscience Institute, University of Basel)

Nanocontainers introduced into the nucleus of living cells

An interdisciplinary team from the University of Basel has succeeded in creating a direct path for artificial nanocontainers to enter into the nucleus of living cells. To this end, they produced biocompatible polymer vesicles that can pass through the pores that decorate the membrane of the cell nucleus. In this way, it might be possible to transport drugs directly into the cell's control center. The researchers have published their latest findings in the *Proceedings of the National Academy of Sciences*.

Original source:
doi.org/10.1073/pnas.1916395117

"We have built a network of universities, research institutes and companies that share one common vision – that is to leverage our excellence in nanoscience teaching and research to cultivate nanotechnology scientist and entrepreneurs of the future!"

Argovia Professor Roderick Lim, Biozentrum, University of Basel

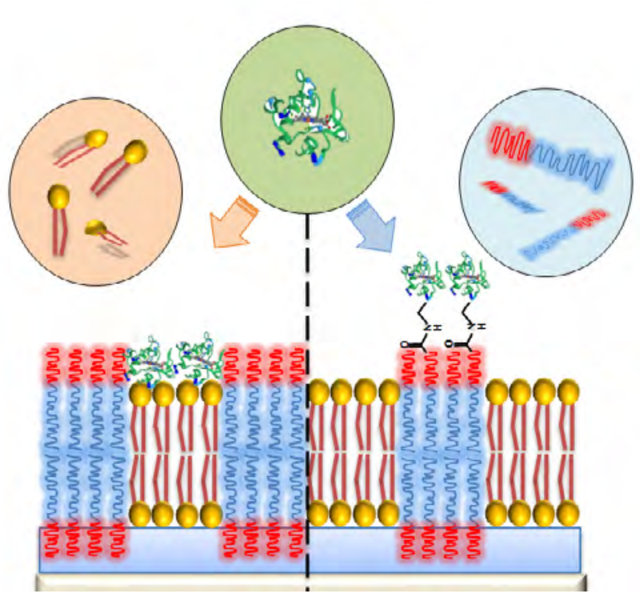
"The SNI enabled me to embark on new interdisciplinary research projects which otherwise would not have been possible."

Professor Stefan Willitsch, Department of Chemistry, University of Basel

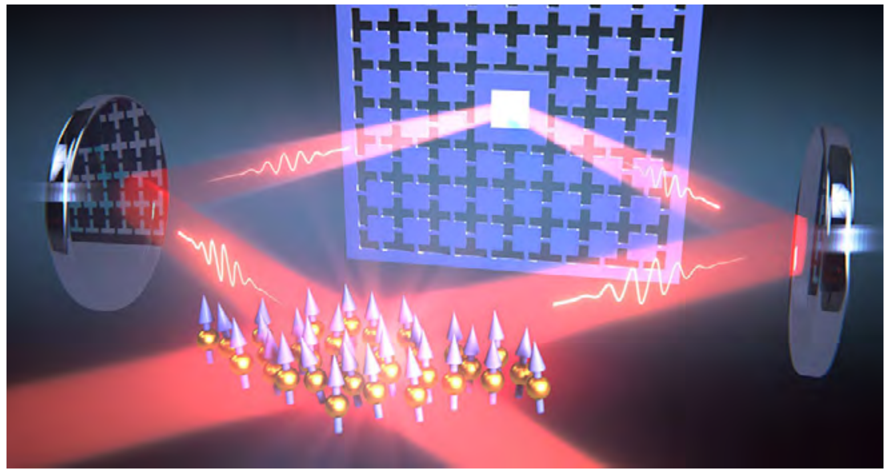
Attachment to membranes

Chemists at the University of Basel have shown that various artificial membranes provide a favorable environment for the attachment of redox proteins. Proteins could be used to develop novel biosensors, but their attachment to solid substrates often leads to their denaturation. The researchers report in the *Journal of Physical Chemistry B* that hybrid membranes composed of lipids and polymers allow attachment of a model protein by covalent bonding to the polymer domain and by insertion to the lipid domain of the membrane. In doing so, the chemists were able to optimize the accessibility of the protein and its resulting functionality.

Original source: https://doi.org/10.1021/acs.jpcb.0c02727



The model protein cytochrome c can either be integrated into the lipid domain of the hybrid membrane by insertion (left) or covalently bind to the polymer domain (right). (Image: S. Di Leone, Department of Chemistry, University of Basel)



A loop of laser light connects the oscillations of a nanomechanical membrane (back) and the spin of a cloud of atoms (front). (Illustration: Department of Physics, University of Basel)

Laser loop couples quantum systems over a distance

For the first time, researchers have succeeded in creating strong coupling between quantum systems over a greater distance. They accomplished this with a novel method in which a laser loop connects the systems, enabling nearly lossless exchange of information and strong interaction between them. In the journal *Science*, the physicists from the University of Basel and the University of Hanover reported that the new method opens up new possibilities in quantum networks and quantum sensor technology.

Original source:
doi: 10.1126/science.abb0328

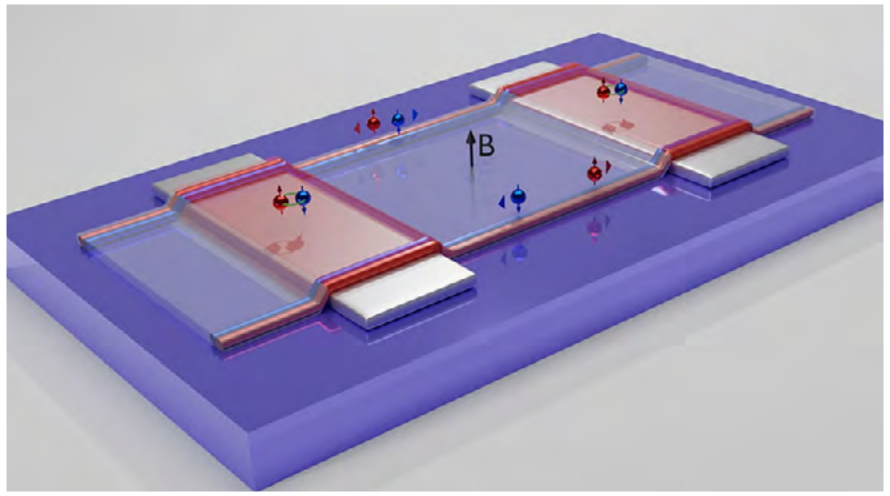
"The Swiss Nanoscience Institute represents a great networking platform where partners from Northwestern Switzerland (from both academia and industry) can meet and initiate new collaborations. The funding opportunities are for both fundamental and applied research. They are managed in a very pragmatic and efficient way."

Professor Patrick Shahgaldian, School of Life Sciences, FHNW Muttenz

Lossless conduction at the edges

Atomically thin layers of the semimetal tungsten ditelluride conduct electricity losslessly along narrow, one-dimensional channels at the crystal edges. The material is therefore a second-order topological insulator. By obtaining experimental evidence of this behavior, physicists from the University of Basel have expanded the pool of candidate materials for topological superconductivity. The findings have been published in the journal *Nano Letters*.

Original source: https://pubs.acs.org/doi/10.1021/acs.nanolett.0c00658

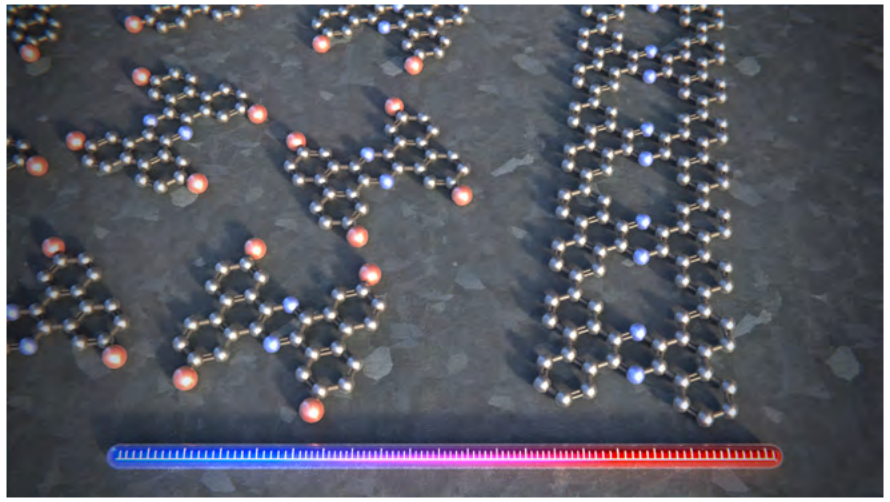


An atomically thin layer of tungsten ditelluride is located between two contacts (in silver). Current only flows through the material in very narrow channels at the outer edges. (Image: Department of Physics, University of Basel)

Porous nitrogen-doped graphene ribbons for future electronics

A team of physicists and chemists has produced the first porous graphene ribbons in which specific carbon atoms in the crystal lattice are replaced with nitrogen atoms. These ribbons have semiconducting properties that make them attractive for applications in electronics and quantum computing, as reported by researchers from the Universities of Basel, Bern, Lancaster and Warwick in the *Journal of the American Chemical Society*.

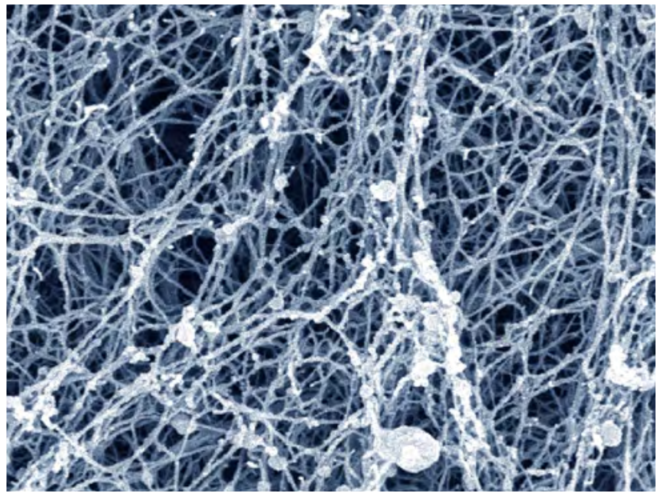
Original source:
doi.org/10.1021/jacs.0c03946



The individual building blocks are heated on a silver surface in order to synthesize a porous graphene ribbon that exhibits semiconducting properties and a ladder-like structure. In each rung of the ladder, two carbon atoms have been replaced with nitrogen atoms (blue). (Image: Department of Physics, University of Basel)

"SNI is a great and valuable resource to the University of Basel. A huge thanks is due to all the organizers for the hard work to make this happen!"

Professor Michael Nash, Department of Chemistry, University of Basel and D-BSSE, ETHZ in Basel



Elastin-like polypeptide aggregates bind to fibrin networks and change their mechanical properties. (Image: I. Urosev, Department of Chemistry, University of Basel)

More stable wound closure

A team of molecular engineers from the University of Basel and ETH Zurich has described a protein that specifically binds to fibrin and changes its mechanical properties. Fibrin is the "glue" in our blood that plays a crucial role in blood clotting and wound closure. The protein under investigation belongs to the group of elastin-like polypeptides (ELP). It reinforces the blood clot that forms during an injury by incorporating itself into the network of fibrin fibers. The study, published in the scientific journal *Advanced Functional Materials*, shows a new approach with potential to treat bleeding disorders in clinical situations.

Original source: https://doi.org/10.1002/adfm.202005245

Efficient valves for electron spins

Researchers at the University of Basel in collaboration with colleagues from Pisa have developed a new concept that uses the electron spin to switch an electrical current. In addition to fundamental research, such spin valves are also the key elements in spintronics – a type of electronics that exploits the spin instead of the charge of electrons. The results were published in the scientific journal *Communications Physics*.

Original source:
doi.org/10.1038/s42005-020-00405-2

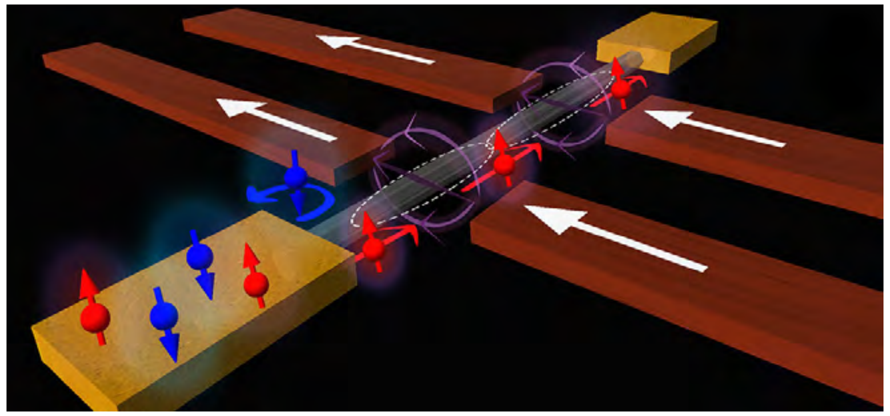
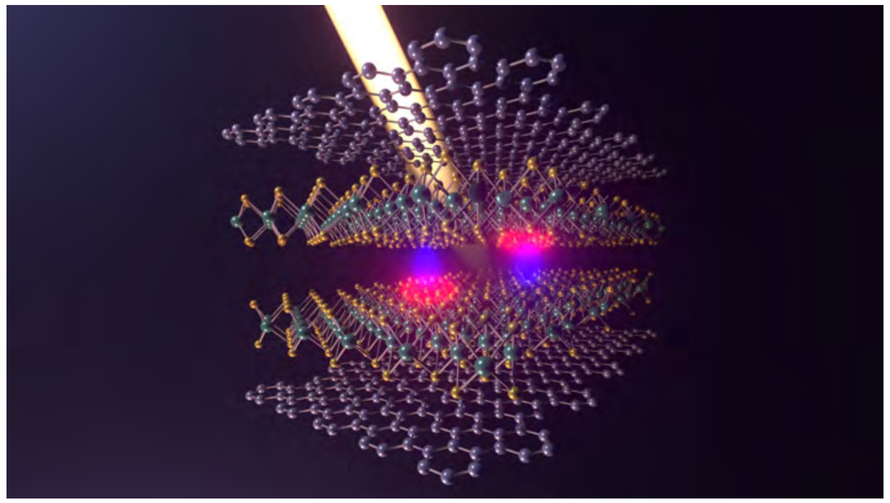


Illustration of the spin valve: Both quantum dots (dashed ellipses) on the nanowire are tuned by nanomagnets (brown bars) such that they only allow electrons with an “up” spin to pass. If the orientation of one of the magnets is changed, the current flow is suppressed. (Illustration: Department of Physics, University of Basel)

"SNI is a great and unique institution allowing stronger collaboration between the University of Basel, FHNW and the Paul Scherrer Institute. It puts this region at the forefront of nanoscience in Switzerland."

Professor Christian Ludwig, Paul Scherrer Institute

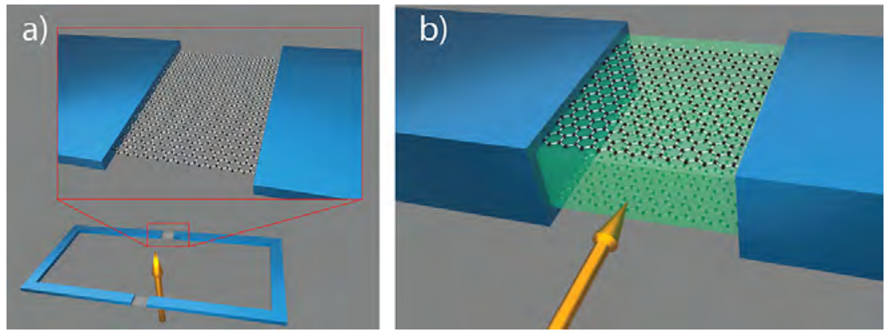


Schematic illustration of the electron-hole pairs (electron: pink, hole: blue), which are formed by the absorption of light in the two-layer molybdenum disulfide layer. (Image: N. Leisgang and L. Ceccarelli, Department of Physics, University of Basel)

A highly light-absorbent and tunable material

By layering different two-dimensional materials, physicists at the University of Basel have created a novel structure with the ability to absorb almost all light of a selected wavelength. The achievement relies on a double layer of molybdenum disulfide. The new structure’s particular properties make it a candidate for applications in optical components or as a source of individual photons, which play a key role in quantum research. The results were published in the scientific journal *Nature Nanotechnology*.

Original source:
doi.org/10.1038/s41565-020-0750-1



a) A conventional superconducting quantum interference device (SQUID) consists of a superconducting ring interrupted at two points by weak links (in this case a graphene layer). b) The new SQUID is made up of a stack of two-dimensional materials, including two graphene layers separated by a thin film of boron nitride. (Department of Physics, University of Basel)

A tiny instrument to measure the faintest magnetic fields

Physicists at the University of Basel have developed a minuscule instrument able to detect extremely faint magnetic fields. At the heart of the superconducting quantum interference device are two atomically thin layers of graphene, which the researchers combined with boron nitride. Instruments like this one have applications in areas such as medicine, besides being used to research new materials.

Original source: doi.org/10.1021/acs.nanolett.0c02412
Video: https://youtu.be/pGuQHxf2jdw

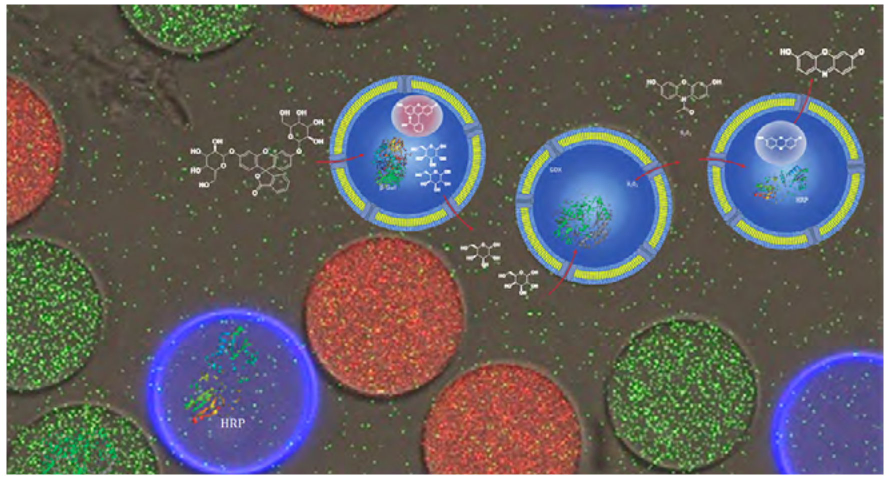
"Being a member of the SNI gives me access to a unique network in nanoscience and technology covering fundamental science as well as applied projects. It is this interaction with excellent experts in different fields and concrete applied questions from a variety of fields that pushes me forward."

Professor Frithjof Nolting, Paul Scherrer Institute

An artificial cell on a chip

Researchers at the University of Basel have developed a precisely controllable system for mimicking biochemical reaction cascades in cells. Using microfluidic technology, they produce miniature polymeric reaction containers equipped with the desired properties. This "cell on a chip" is useful not only for studying processes in cells, but also for the development of new synthetic pathways for chemical applications or for biological active substances in medicine.

Original source: https://doi.org/10.1002/adma.202004804



The researchers used the newly developed microfluidic platform to produce three different types of vesicles with a uniform size but different cargoes: β-galactosidase (red vesicle), glucose oxidase (green vesicle) or horseradish peroxidase (blue). The water-soluble enzymes gradually convert the starting product into the final colored product Resorufin, which — like all of the intermediates — enters the surrounding solution via selective channels in the vesicle membranes (Department of Chemistry, University of Basel).

"I have just started as a junior research group leader in the Chemistry Department at the University of Basel and would be very interested in joining the interdisciplinary network of SNI for exciting research collaborations and stimulating information exchange at SNI events."

Professor Murielle Delley, Department of Chemistry, University of Basel

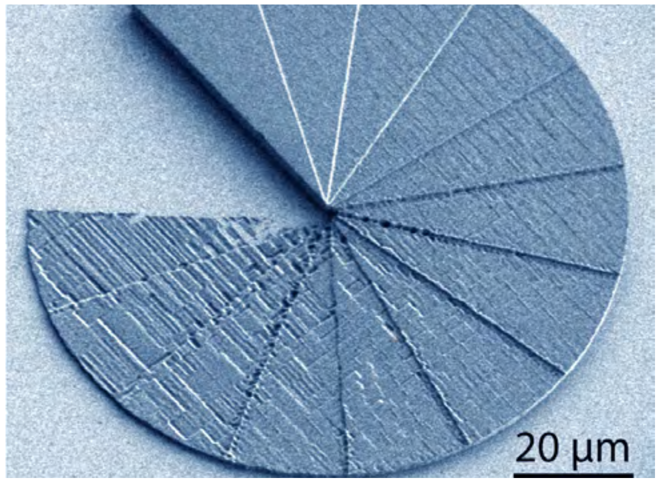
"Being a member of the SNI increases the inspiration to think out of the box and to be interdisciplinary. The possibility to meet and network with excellent scientists from different fields adds value to my research. I am also grateful that the SNI has supported me in exposing my research to the public."

Professor Ilaria Zardo, Department of Physics, University of Basel

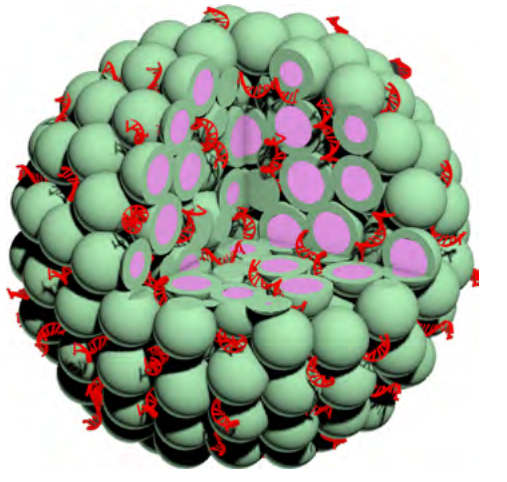
Tiny, micrometer-high three-dimensional structures

An interdisciplinary team of scientists from the Paul Scherrer Institute and the University of Basel has characterized an electron beam lithography technique that can be used to produce three-dimensional structures several micrometers high. Using the so-called grayscale electron beam lithography, the development depth of the structures, especially at higher exposure doses, depends on the time between exposure to the electron beam and the subsequent development of the resist material used. Thermal post-treatment also affects the resulting three-dimensional structure, the researchers report in the scientific journal *Microelectronic Engineering.*

Original source: https://doi.org/10.1016/j.mee.2020.111272



Using grayscale electron beam lithography, tiny three-dimensional structures can be produced. (Image: T. Mortelmans, PSI and University of Basel)

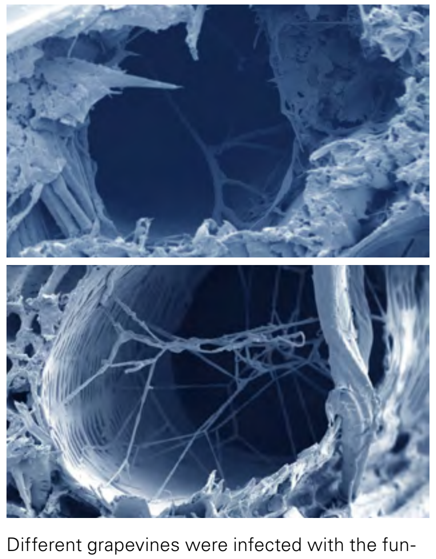


DNA consisting of up to 100 nucleotides can be transported with the help of the new transport system made of peptides. (Image: S. Tarvirdipour, Department of Chemistry, University of Basel and Department of Biosystems Science and Engineering, ETH Zurich)

Peptide-based gene delivery system

A team of researchers from the University of Basel and the ETH Zurich has developed a purely peptidic nanovector for DNA delivery. The self-assembling peptide nanoparticles are able to entrap DNA up to 100 nucleotides long. Multicompartment micellar nanoparticles maintained a stable size and structure over five months at 4°C while they dissociate into individual micelles and release the DNA at 37°C (body temperature). This peptide-based delivery system has the potential to fulfill critical prerequisites for gene therapy. The scientific report of this work is published in the journal *Soft Matters.*

Original source: https://doi.org/10.1039/C9SM01990A



Different grapevines were infected with the fungus *Neofusicoccum parvum*. Two months after infection, researchers found less fungal hyphae growing in the pathways of a resistant grapevine (top picture) than in a susceptible grapevine (bottom picture). The reason for this is not the architecture of the pathways, but chemical processes.
(Image: E. Bieler, Nano Imaging Lab, Swiss Nanoscience Institute, University of Basel).

Towards resistance

Diseases of the wood of grapevines are spreading as a result of climate change, leading to major losses worldwide. As part of the Interreg Upper Rhine project Vitifutur, an international team of scientists has studied the wild ancestors of our grapevines that are resistant to the fungus *Neofusicoccum parvum*, which is involved in wood diseases.

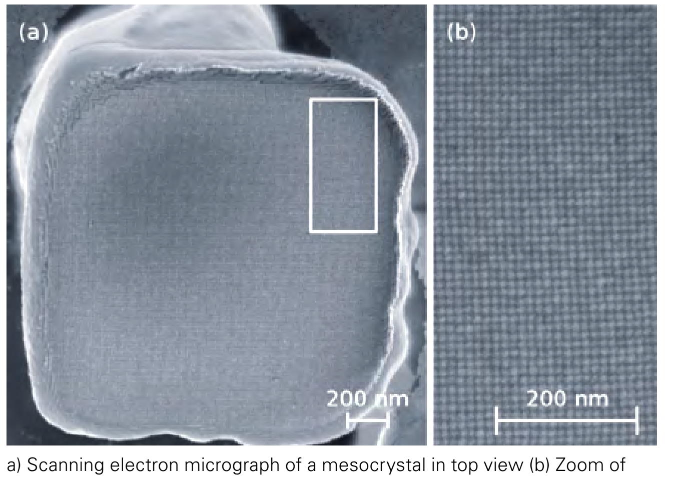
Using cryo scanning electron microscopy, the SNI's Nano Imaging Lab found that there is no correlation between vessel diameter and infections. Resistant vines, on the other hand, accumulated more stilbenes. The researchers from Germany, Egypt, France and Switzerland specified a resistant chemotype, paving the way for breeding vines resistant to the destructive fungus. The results of the study were published in the journal *New Phytologist*.

Original source: https://doi.org/10.1111/nph.16919

Magnetic forces in mesocrystals

Researchers from the University of Basel, Germany, Belgium and Sweden have succeeded in precisely determining the properties of magnetic mesocrystals. In a paper published in the scientific journal *Physical Review B*, they describe the use of highly sensitive, dynamic cantilever magnetometry to analyze the magnetic forces in mesocrystals.

Original source: https://doi.org/10.1103/PhysRevB.103.014402



a) Scanning electron micrograph of a mesocrystal in top view (b) Zoom of the area shown in (a). (Image: Department of Physics, University of Basel)

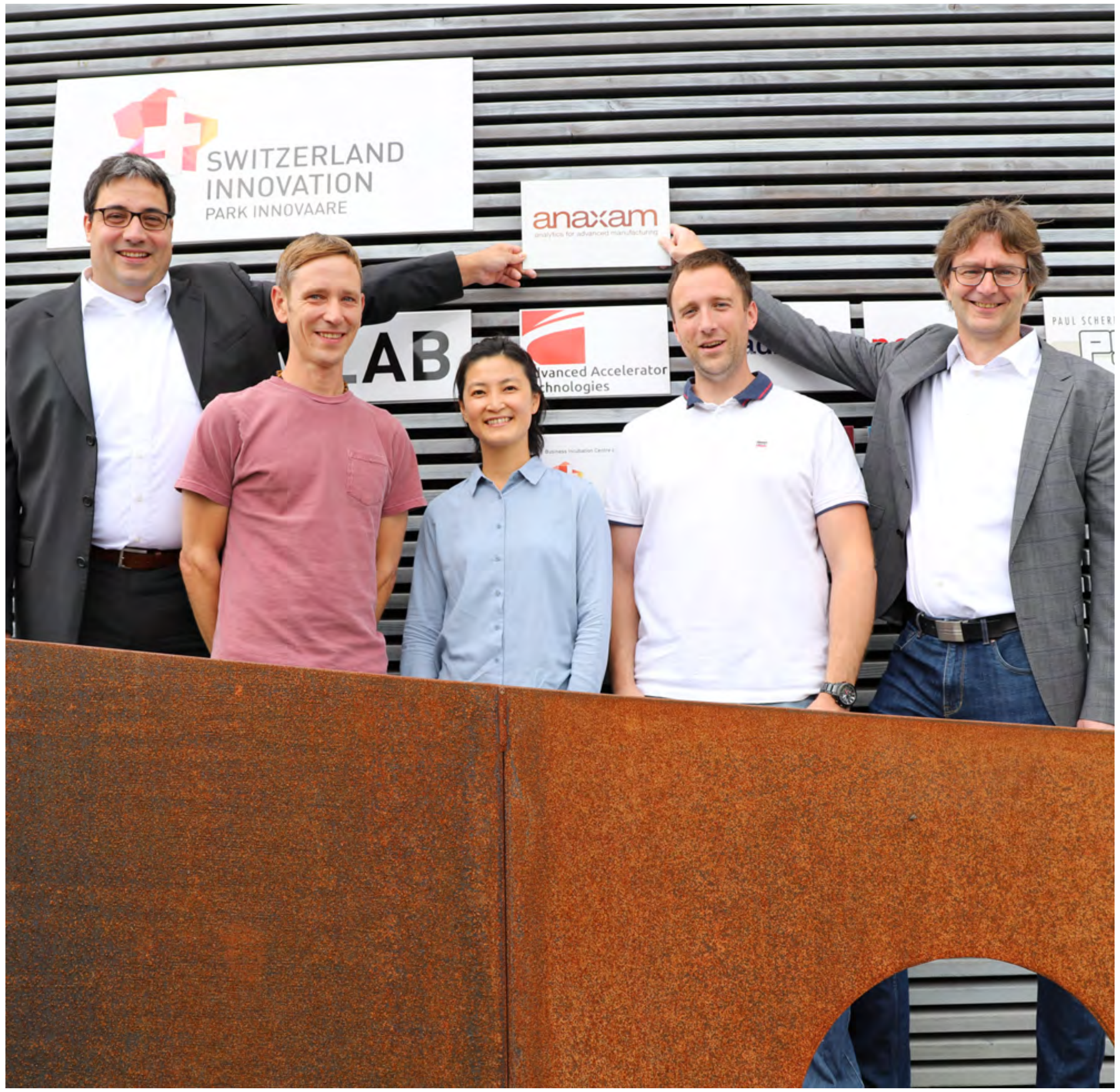
"The SNI is an engine for academic and technological innovation. Within the University, the SNI PhD Program is crucial for supporting projects between physics, chemistry and biology that would otherwise not happen."

Argovia Professor Martino Poggio, Department of Physics, University of Basel

Financing secured for the next few years

ANAXAM on track to establish itself as a center for state-of-the-art materials analysis

The ANAXAM technology transfer center, established in 2019, achieved several key milestones in 2020. The service provider, founded as a collaboration involving the Paul Scherrer Institute (PSI), the University of Applied Sciences Northwestern Switzerland (FHNW), the Canton of Aargau, and the Swiss Nanoscience Institute (SNI), supports industrial companies with state-of-the-art materials analysis.



The ANAXAM team, comprising Christian Grünzweig, Philippe Würsch, Cynthia Chang, Matthias Wagner and Frithjof Nolting, achieved several key milestones in 2020, and is well equipped to tackle challenging problems in collaboration with companies throughout Switzerland. (Image: ANAXAM)

"In 2020, we took some crucial steps toward establishing ANAXAM as the preeminent center for state-of-the-art materials analysis in Switzerland. We look forward to collaborating with the SNI on further projects in the future."

Dr. Christian Grünzweig, director of ANAXAM

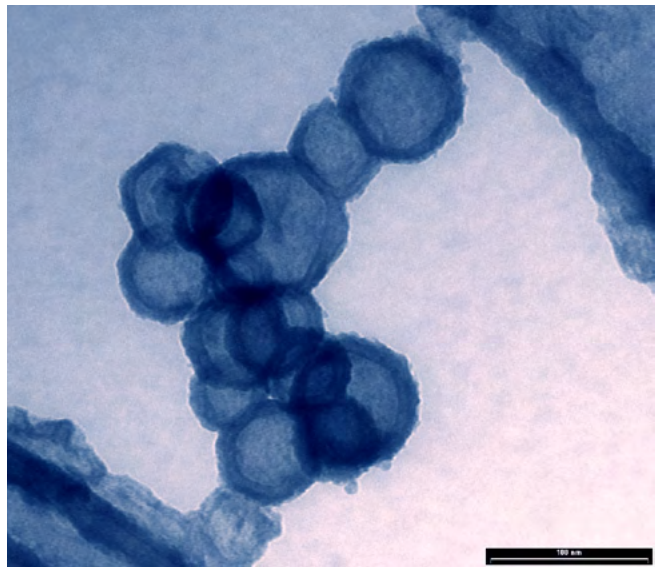
Financing for next few years

In 2020, ANAXAM secured the funding it needs to establish the center as a distinguished provider of cutting-edge materials analysis to customers throughout Switzerland during the coming four years. In June 2020, the Grand Council of Aargau approved 2.4 million Swiss francs in funding for the next four years. Then at the end of the year, the Department of Economic Affairs, Education and Research approved federal funding for the center totaling 3.2 million francs over four years.

New headquarters

In summer 2020, the ANAXAM team moved to PARK INNOVAARE's deliveryLAB, where it handles enquiries from a diverse range of industrial companies.

A collaboration with the company springFix, for instance, examined the micro and nanostructure of key blanks made of nickel silver. The SNI's Nano Imaging Lab was involved as a partner, delivering scanning electron microscope images. In conjunction with Synchrotron computed tomography analyses, these images gave the company the information it needed to optimize its product and implement a quality control system.



Scanning electron microscope image of the mechanosensitive liposomes under study in the Nano Argovia project ForMel. (Image: FHNW and Nano Imaging Lab, SNI)

Active role for SNI members

Several SNI members occupy positions on the ANAXAM board. Titular professor Frithjof Nolting is chairman of the ANAXAM association, while Argovia professor Martino Poggio and titular professor Michel Kenzelmann are members of the association's board. For the practical execution of orders placed with ANAXAM besides neutron and synchrotron analysis, the main partner is the Nano Imaging Lab (NI Lab). In particular, the NI Lab team provides detailed imaging and analysis of surfaces.

Another highlight of 2020 was the execution of two Nano Argovia projects in collaboration with ANAXAM. In the project ForMeL, ANAXAM is collaborating with the company Acthera Therapeutics AG (Basel-Stadt) and the FHNW School of Life Sciences to develop a stable formulation for liposomes that are loaded with active agents and react to changes in blood pressure. The team has begun the process of extrapolating the entire production and storage process to the pilot scale in order to produce material for pre-clinical trials.

In the second Nano Argovia project in collaboration with ANAXAM, the project team worked with the FHNW School of Life Sciences and the company Orchid Orthopedics Switzerland GmbH (Baden-Dättwil) to explore treatments for joint implants.

The researchers examined a process for improving titanium implants with a plasma-sprayed aluminium/titanium oxide coating, as well as optimized post-treatment methods. Their goal is to develop joint implants that can sustain heavy loads with minimal abrasion due to movement and strain, and do not trigger immunological reactions.

Network creates added value

Survey shows high satisfaction among members

One of the reasons for founding the Swiss Nanoscience Institute (SNI) was to intensify the collaboration of academic institutions with one another and with industrial companies in Northwestern Switzerland. At the same time, the SNI has always aimed not only to act as a source of funding, but also to generate added value by promoting and supporting interdisciplinary collaboration in the nanosciences and nanotechnology. A survey of SNI members in November 2020 shows that the majority of project leaders at the SNI appreciate this added value.

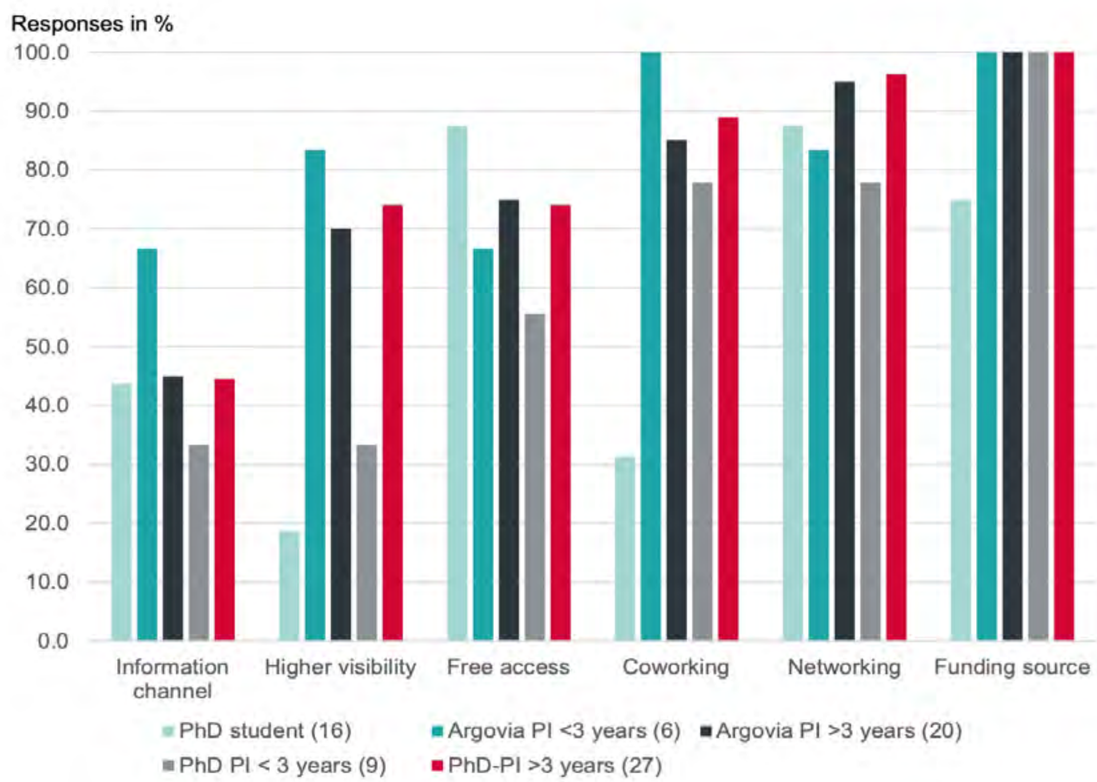
For this survey, we asked all project leaders, titular professors supported by the SNI, honorary members and doctoral students at the SNI PhD School to complete a short, anonymous questionnaire. Of the 149 SNI members we wrote to, a total of 47% responded, including 16 doctoral students, 36 project leaders at the PhD School and 26 project leaders in the Nano Argovia program. Twelve of the scientists are active both in the applied Nano Argovia program and at the PhD School.

Differences between groupings

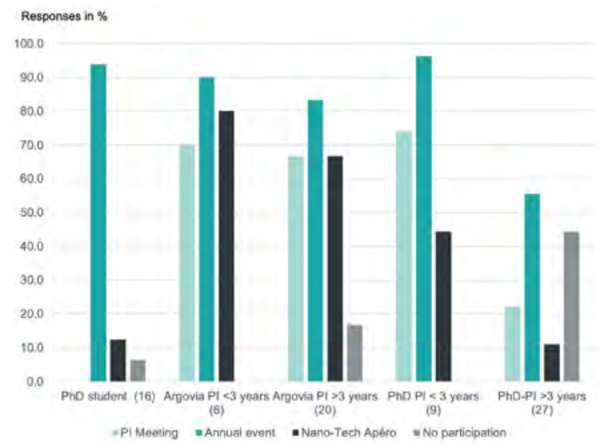
In the analyses, we identified a number of differences between the various groupings. Accordingly, we considered doctoral students and project leaders from Nano Argovia projects and the PhD School separately, as well as distinguishing between project leaders based on whether they became active within the network in the last three years or at an earlier stage.

All project leaders consider the SNI to be a valuable source of funding for research projects. For long-standing members of the network, the opportunity to exchange ideas with colleagues from other disciplines and institutions and to build up a network of contacts is almost as important as the monetary aspect. The chance to work with these colleagues is also seen as a bonus by a majority of project leaders.

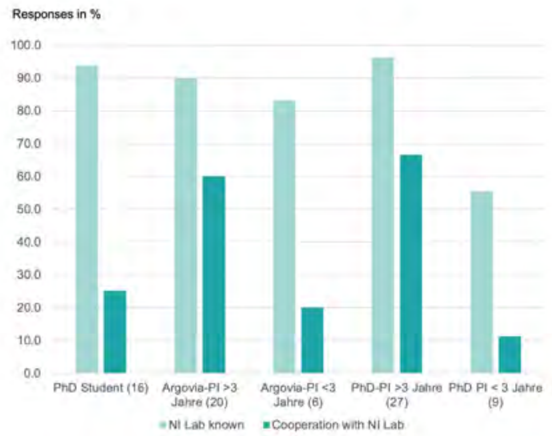
Free entry to events such as the Swiss NanoConvention, the Nano-Tech Apéro and the SNI Annual Event not only provides doctoral students with networking opportunities, but also offers them tangible added value. For project leaders, this plays a less important role than other aspects.



The various groups (project leaders in the Nano Argovia program, project leaders at the PhD School, and doctoral students) sometimes give different assessments of the added value generated by the SNI. For project leaders, the opportunities to exchange ideas and collaborate with colleagues from other areas of research and institutions are considered a particular benefit of the SNI, in addition to its role as a source of research funding.



The various internal SNI events are aimed at different target groups. As a result of the coronavirus pandemic, the annual conference and Nano-Tech Apéro were canceled in 2020, meaning that some project leaders (PIs) who have only recently become active within the network have not yet had a chance to attend.



The Nano Imaging Lab is well known among long-time project leaders (PIs) and PhD students. More than 60 percent of PIs who have been in the network for a long time have already worked with the Nano Imaging Lab.

Numerous project leaders have already found that SNI communication activities help improve the image and overall visibility of research activities. In particular, project leaders who have not been on board for long might not be aware that the SNI can also support them in this way. Slightly less than half of respondents use the SNI as an information channel.

Events are important components

To support all of these activities, the SNI team organizes a variety of events for its members. For example, all members are invited to the regular Annual Event, which is usually attended by 80-90 people but was canceled this year due to the coronavirus pandemic. The Nano-Tech Apéro is aimed not only at everyone working in applied research, but also at companies from Northwestern Switzerland. Moreover, project leaders regularly attend a PI meeting in order to clarify internal matters and exchange information.

All SNI members are invited to the Annual Event, which is therefore attended by the majority of members. The cancellation of this conference in 2020 meant that some of those in the group of project leaders who have not been part of the network for long have not yet had a chance to attend. Given that the Nano-Tech Apéro is primarily aimed at PIs in applied projects and industry representatives, it's no surprise that the event is attended above all by project leaders from the Nano Argovia program. Again, the cancellation of the event in 2020 meant that new project leaders have not yet had a chance to attend.

These events play a key role not only in building links between SNI members, but also in raising awareness of the various service areas within the SNI network. Since the Nano Imaging Lab joined the SNI network, its staff have taken part in the Annual Event and the Nano-Tech Apéro in order to present their services. As a result, the NI Lab is now well known within the network – even among members who have not yet worked with its staff, who are experts on all types of imaging.

Good networking

Overall, the analysis of the survey results shows that the SNI has succeeded in building up a functioning network that is characterized by a valued and effective exchange of ideas and collaboration between different disciplines, areas of research and institutions. Regular events are a vital part of ensuring that new contacts can be developed on an ongoing basis and that the network retains its dynamism.

Nano Study Program

79

In 2020, 47 students were enrolled on the bachelor's program and 32 on the master's program.

25%

25% of the students are women.

8+20

Eight students successfully completed the bachelor's program and 20 completed the master's program in 2020.

35

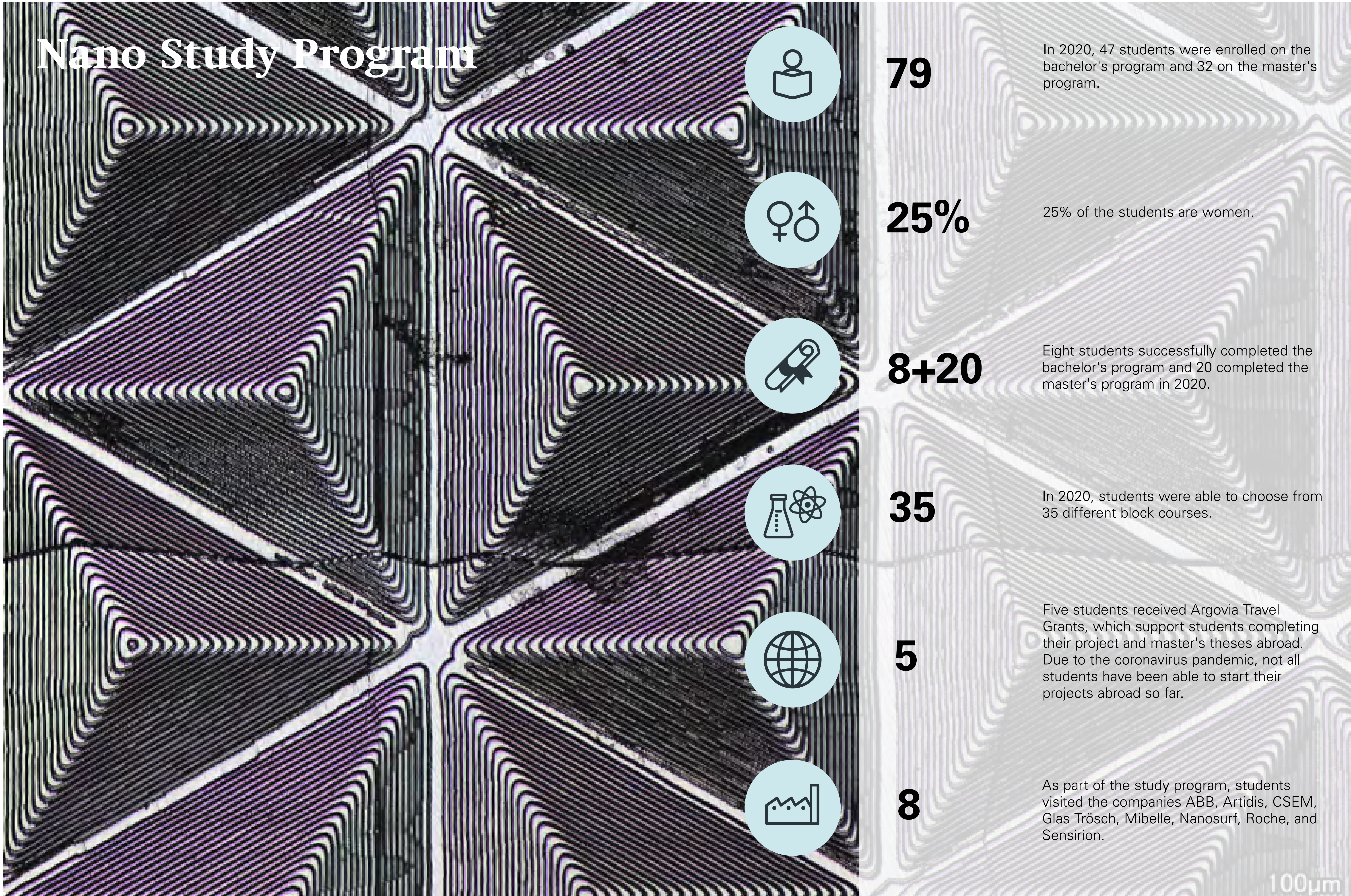
In 2020, students were able to choose from 35 different block courses.

5

Five students received Argovia Travel Grants, which support students completing their project and master's theses abroad. Due to the coronavirus pandemic, not all students have been able to start their projects abroad so far.

8

As part of the study program, students visited the companies ABB, Artidis, CSEM, Glas Trösch, Mibelle, Nanosurf, Roche, and Sensirion.



Surface topology of a de-glaring foil, used for lighting solutions and characterized with a confocal laser scanning microscope. (Image: T. Aderneuer, SNI PhD Student, CSEM Muttenz, results of a collaboration between CSEM Muttenz and INKA, FHNW)

Understanding aging processes
Daniel Stähli wins the award for the best master's thesis

The prize for the best nanoscience master's thesis has been awarded to Daniel Stähli in recognition of his excellent project on aging processes in the blood-brain barrier. For this research, the young nanoscientist worked at Stanford University (USA) in the laboratory of one of the world's leading researchers on the subject of aging, where he came to appreciate his colleagues' optimism, enthusiasm and openness. Spending time in California was the perfect way to conclude his studies in nanoscience – a subject he would definitely choose again.

Success on his own initiative
From an early stage, Daniel Stähli knew that he wanted to complete his master's thesis abroad. Searching the internet for research groups that study aging processes, he stumbled across Professor Tony Wyss-Coray of Stanford University (Palo Alto, California, USA). Wyss-Coray is a world-leading expert in this field and is known in particular for studies in which he showed that transfusing plasma from young mice had a rejuvenating effect on older mice.

Daniel wrote to him and was quickly accepted. After dealing with some administrative hurdles, he traveled to California in October 2019 to embark on nine exciting and intensive months of research.

Role of the blood-brain barrier in the aging process
During this period, Daniel concentrated on the blood-brain barrier and its protein permeability. The blood-brain barrier is a selective barrier that shields the brain from the rest of the body and regulates and restricts the absorption of plasma proteins. It is formed by endothelial cells with the aid of pericytes and astrocytes. As a person grows older, and in cases of neurodegenerative diseases such as Alzheimer's, the barrier's extreme selectivity decreases. This allows various substances to penetrate into the brain that are not detected in young, healthy brains. It is important to understand precisely how the blood-brain barrier works when treating neurodegenerative diseases – if the blood-brain barrier is intact, it also prevents therapeutic antibodies from entering the brain.

Daniel investigated how the blood-brain barrier changes with age. Together with his supervisor, Andrew Yang, he developed a new method to test the permeability of the blood-brain barrier and examine the normal aging process of the barrier in mice. First, the researchers marked all proteins in the blood plasma. Then they studied which of these proteins were detected in the brain cells and in the endothelial cells that make up the blood-brain barrier. They identified certain genes that support the absorption of plasma in the endothelial cells.

The results showed that numerous proteins were able to pass through the blood-brain barrier. In young mice, these proteins are absorbed via specific receptors; in older mice, they do not have a specific route. On the whole, however, the absorption of plasma proteins does not increase, but actually tends to decrease. Daniel was also able to show that the number of pericytes – one of the cell types that make up the blood-brain barrier – decreases with age.

His work not only proved which processes are triggered by aging, but also which proteins can break through the blood-brain barrier. In the future, these proteins could potentially be used as shuttles for therapeutic agents.

The perfect end to an exciting course of studies
Daniel's nine months in Palo Alto were the perfect end to what had been a hugely exciting and varied course of studies overall. He is glad that he opted for nanoscience seven years ago. "I've been able to gain a wide range of experience – not only in various subject areas, but also in different countries thanks to support and funding from the SNI, the University of Basel, the Voluntary Academic Society of Basel and my parents," says Daniel Stähli.

"We have been thoroughly impressed by Daniel's passion and dedication to science and his aptitude for experimental research. We would have loved to keep him longer."

Professor Tony Wyss-Coray, Stanford University (Palo Alto, California, USA)

"The degree program didn't just enrich my subject knowledge. Over the years, I have made many good friends."

Daniel Stähli, former nanoscience student and winner of the award for the best master's thesis

Daniel Stähli carried out the work for his award-winning master's thesis at Stanford University. His data has contributed to a paper in the journal *Nature*.
https://www.nature.com/articles/s41586-020-2453-z

Rafael Eggli has been a nanoscience student at the University of Basel since 2016. In 2020, he has received a scholarship from the Werner Siemens Foundation.

A wide range of commitments

Rafael Eggli receives a fellowship from the Werner Siemens Foundation

In 2020, the Werner Siemens Foundation awarded a fellowship to Rafael Eggli, who has been studying nanosciences at the University of Basel since 2016. Hailing from Switzerland, the 22-year-old has also held a scholarship from the Swiss Study Foundation since 2017. With these grants, he is able to establish a wealth of new contacts and gain access to completely new subject areas. Rafael sees the sheer variety of topics available as a highlight of his studies.

A new world thanks to the scholarship

In 2016, Rafael Eggli completed his Matura (high-school diploma) at the Gymnasium Kirschgarten secondary school and immediately embarked upon a nanosciences degree at the University of Basel. The Swiss Study Foundation accepted him for a scholarship in 2017 based on his good grades, wide range of interests and broad community engagement.

Since then, whenever his studies have allowed, the young Swiss student from Allschwil has taken advantage of the broad range of educational opportunities that the Study Foundation has to offer. Scholars can choose from over 75 courses across a wide range of subject areas, including seminars from the Werner Siemens Foundation – some of which Rafael has already attended.

As of September 2020, he is now also receiving financial support for a period of one year in the form of a Werner Siemens Fellowship from the foundation of the same name. He was selected in 2020 as one of 10 fellows who stood out due to their academic excellence and were prepared to commit themselves to the support and promotion of STEM subjects in wider society.

This is something that Rafael is already doing in numerous ways, including by teaching math and physics as a supply teacher at Gymnasium Kirschgarten. He is also involved in a project that aims to prevent the extinction of Parosphromenus, a genus of labyrinth fish from the peat swamps of Southeast Asia. In addition, he helps out as a scout leader as needed and when time allows.

A good choice

Rafael is still very pleased with his choice of degree program. "So many times, I've come out of a lecture and thought to myself: Now I understand just a little bit better how nature works."

The diversity of the block courses in the bachelor's program was a particular highlight for him, and he is also delighted at the opportunity to dig deeper into different subject areas as part of his master's studies. "Since I joined the Study Foundation, I've met many students on different degree programs, including at other universities in Switzerland. None of them have the opportunity to acquaint themselves with as many different subjects, topics and methods in their course of studies as I do on the nanosciences degree here in Basel," he says.

Rafael completed his first project in Professor Richard Warburton's group, where he examined various geometries of a fin field-effect transistor (FinFET) for the realization of spin qubits. His second project, at Cornell University in New York, was actually supposed to follow on from this work – but, with his plans up in the air as a result of the coronavirus pandemic, it will now be 2021 before he travels to New York. Once there, he will use high-speed atomic force microscopy to study the conformational changes of an ion channel that occurs in human synapses and plays a hugely important role in medicine. In the meantime, he is working on his master's thesis at the Department of Physics in the group led by Professor Dominik Zumbühl, in research that follows on from his first project on the FinFET.

Once he has completed his studies in the nanosciences, Rafael plans to do a doctorate – although he doesn't yet know whether this will lean more toward nanophysics or nanobiology. In any case, his aim is to learn how technology can contribute to progress in our society. In the long term, he would like to be part of that progress.

"I haven't heard of any other degree program that offers the opportunity to learn about so many different subjects, topics, and methods."

Rafael Eggli, student on the Master's Program in Nanosciences, University of Basel

Challenges successfully overcome
A very different year for students

Studying always involves times of stress and intensive learning – as well as numerous examinations. In normal circumstances, however, these phases are balanced out by leisure activities, new friendships and, in some cases, the chance to explore and get to know a new city or country. That was not the case in 2020. In both the spring and fall semesters, the university was forced to switch classroom courses over to online formats as far as possible, and students faced massive restrictions in their private lives. We asked a number of nanoscience students how they fared in these unusual times.

An American and a German in Basel

Tania Beringer and Mina-Lou Schleith both started the Bachelor's Program in Nanosciences at the University of Basel this year – with Tania having traveled from California (USA) and Mina-Lou from Germany. For both students, a keen interest in the natural sciences since their school days led them to choose this interdisciplinary degree course.

At the start of the fall semester, they were still attending classroom courses every day and could enjoy events organized by the nano student association. These were vital opportunities for both of them to meet other first-year students, as well as students from higher semesters.

Then, from the start of November onward, stricter coronavirus measures saw teaching delivered exclusively online. Even for practical courses, the students found themselves sat in front of their computers at home rather than meeting at the university. Nevertheless, they formed virtual groups so that they could learn together and support one another. Both Tania and Mina-Lou feel that they have received excellent support from the tutors. "The tutors are great, and we have plenty of opportunities to ask questions," they said.

The two young women haven't let the restrictions get them down – indeed, they are enjoying their studies and keeping up with the material well. Although they found it a bit harder to motivate themselves from time to time, and practical courses in particular would be easier in the classroom, the two students are largely pleased with the way their course has started.

This is certainly helped by the fact that they managed to make some good connections right at the start of their studies. Moreover, they are both involved in the nano student association, where Mina-Lou is the board representative for first-year students and Tania has been elected vice-president.

Studying for a master's in Basel

Andreas Ruh and Dimitrios Tripkis were also new arrivals in Basel this fall semester. Both of them had already completed their bachelor's programs and moved to Basel to do a master's in nanosciences. Dimitrios had previously studied materials science in Greece, while Andreas studied nanosciences in Tübingen.

Before they can start the master's degree program, however, both Andreas and Dimitrios still have several courses to catch up on from the bachelor's program – which they set about doing this fall semester.

In 2020, Tania Beringer, Mina-Lou Schleith, Dimitrios Tripkis, and Andreas Ruh have started to study nanosciences at the University of Basel.

Dominik Lüthi and Timon Baltisberger received their prizes for the best poster and the best presentation at "Smalltalk" in person a couple of weeks after the online event.

Dimitrios has already completed a block course on atomic force microscopy (AFM), and it was a real highlight for him to be able to work on such high-tech equipment himself. "In Greece, the professors showed us how the devices worked, and we just watched," he says.

It hasn't been easy for Dimitrios and Andreas to start their studies in Basel, as they are the only students who came from abroad and enrolled on the master's program this semester. Their fellow students already know each other well, and the lack of classroom courses makes it harder to form personal connections. Nevertheless, they also benefited from events organized by the nano student association at the start of the fall semester, and the nano study coordination team is always on hand to provide advice and assistance.

Although the circumstances haven't always been ideal, and despite the lack of contact with fellow students, both Andreas and Dimitrios say they made the right choice in coming to Basel, and neither of them has any regrets about their decision. Indeed, they are happy here and looking forward to embarking on their master's studies in earnest once they've obtained the remaining credit points.

Clear advantages

In spring, the students who've been studying nanosciences for some time also found themselves forced to adapt to a completely new set of circumstances. Several block courses and projects were canceled, and other activities were held exclusively online – including, for example, the annual mini conference known as *SmallTalk*, which is organized by students on the bachelor's program. As part of the conference, students give talks and present posters on the block courses they have completed.

In 2020, SmallTalk was the first SNI conference to be held entirely online. The seven participating students were joined by seven evaluating scientists, as well as several audience members, for a Zoom meeting and subsequent poster session.

Despite holding the event online, the students gave interesting talks and presented very professional posters. Some even managed to turn the virtual format of the talks to their advantage. Timon Baltisberger, for example, gave a vivid demonstration of something that is possible in quantum systems but not in our macro world, appearing in two places at the same time as part of his presentation.

The students generally gave a very positive assessment of the online courses and even saw some benefits. "The advantage with video and audio recordings is that I can rewind them if I'm unsure of something and can run through the lecture at my own pace," says Nicolas Brunner, for example.

At the same time, all of the respondents said they missed the personal contact with other students and tutors. Some also said they found it difficult to learn from home and ignore the plethora of potential distractions. Likewise, they then struggled to switch off at some point and enjoy their leisure time. Many looked to sport for relaxation, although this too was subject to restrictions – especially in the case of team sports.

Flexibility needed

In any case, the last few months have taught us how to remain flexible and keep adapting to changing circumstances. For several students on the master's program, this has meant postponing their plans to study abroad or abandoning them altogether.

For example, Fabian Wyss had been promised an Argovia Travel Grant in order to do his project work in Singapore, but this sadly did not come to fruition. A similar situation faced Meret Amrein, who had started her master's thesis in Copenhagen in March but had to return to Basel in April.

Rafael Eggli, on the other hand, has only had to postpone his plans for project work in New York for the time being and has taken the opportunity to start his master's thesis in Basel beforehand. Likewise, Nicolai Jung, who wants to do his master's thesis in Australia, is hoping – like so many others – for low infection numbers so that he can make his plans a reality in 2021.

SNI PhD School

39 In 2020, 39 PhD students were enrolled in the SNI PhD School.

30% 30% of the PhD students are women.

15 PhD students from 15 different countries are enrolled in the SNI PhD School.

6 In 2020, six doctoral students successfully defended their theses.

12 12 of the 33 PhD students who had completed their PhDs by the end of 2020 work at a federal or research institution.

18 18 of the 33 former PhD students work in industry.

Surface pattern of a diffuser, used to homogenize light, characterized using a confocal laser scanning microscope. (Image: T. Aderneuer, SNI PhD Student, CSEM Muttenz, results of a collaboration between CSEM Muttenz and INKA, FHNW)

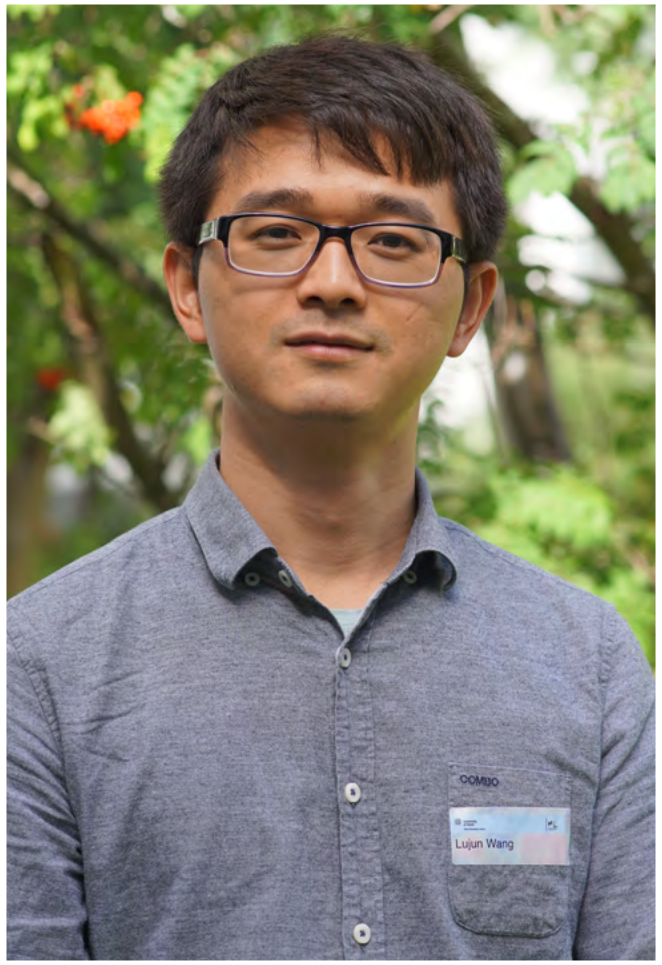
SNI PhD School
An ideal starting point for a career in an interdisciplinary environment

In 2020, six young nanoscientists successfully completed their theses at the SNI PhD School. The theoretical and practical work for their dissertation, they carried out in the Departments of Physics, Chemistry or Biozentrum at the University of Basel, at the Paul Scherrer Institute or at the School of Engineering at the University of Applied Sciences Northwestern Switzerland. In the past few years, these young scientists have not only acquired a great deal of knowledge in their specific field, but they have also gained a good insight into other natural science topics thanks to their participation in numerous interdisciplinary SNI events. Courses specially developed for SNI doctoral students on rhetoric, innovation, and their own strengths and talents have complemented the interdisciplinary training.

Engineered electronic properties
In his doctoral thesis, Dr. Lujun Wang has developed various routes to engineer the electronic properties of graphene. This can be achieved by controlled strain of the material or by combining atomically thin graphene layers at a slightly rotated angle which leads to superstructures with modified properties.

He has developed a new platform that allows such investigations. He built a kind of "stretching board" for monoatomic layers. In various transport experiments at very low temperatures, he investigated effects arising from controlled deformation. By selectively pulling with the stretching board, Lujun changed the atomic structure, which can lead to interesting electronic effects.

He also discovered a new generation of moiré superlattices in a three-layer sandwich of boron nitride-graphene-boron nitride layers. With the different moiré patterns, the electrical properties of the material also change. This enlarges the catalogue of synthetic materials available for various applications.



Lujun Wang worked on the modification of electronic properties of graphene. He is now a postdoctoral researcher at ETH Zurich.

"The SNI PhD school offers a good platform for students to learn about research from other fields. The events organized by the SNI such as the winter school, rhetoric seminar or excursions not only help us to improve our scientific presentation techniques and communication skills, but also support us to make connections to industry and make friends outside of work."

Dr. Lujun Wang, former SNI PhD student, currently postdoctoral researcher at ETH Zurich

Improved properties thanks to carbon nanotubes
In his doctoral thesis, Dr. Wojciech Szmyt investigated hierarchical composites of polymers reinforced with carbon fiber and carbon nanotubes (CNT).

For various applications where low mass is to be combined with high stiffness and strength, carbon fiber reinforced polymer composites (CFRP) are clearly surpassing other materials such as steel. However, the CFRP strength is not ideal under compressive or shear stress, with the properties of the polymer matrix and the fiber-matrix interface dominating. Carbon nanotubes (CNT) could compensate for these deficits.

In his thesis, Wojciech Szmyt has applied CNTs to carbon fibers by chemical vapor deposition to achieve additional reinforcement of the interface between carbon fibers and the embedding matrix on the nanoscale. However, the CNT growth on the carbon fibers poses a challenge because carbon fibers degrade during the chemical vapor deposition process. He therefore used an alumina barrier layer to protect the carbon fibers and to effectively support CNT growth.

The method he developed ensures homogeneous, dense and aligned growth of carbon nanotubes on carbon fiber fabrics. In addition, he and his team developed a novel analytical model of gas transport in fibrous media, and validated it experimentally.

Wojciech Szmyt has worked at the University of Applied Sciences and Arts as well as at the University of Basel and the Paul Scherrer Institute. He is now working as a postdoctoral researcher at Empa.

"The PhD project at the SNI gave me a wonderful opportunity to meet, discuss, and collaborate with researchers from different disciplines, which has helped me broaden my horizon."

Dr. Wojciech Szmyt, former SNI PhD student, currently postdoctoral researcher at Empa

Magnetic orientation in nanostructures
In his doctoral thesis, Dr. David Bracher investigated antiferromagnetic nanoparticles that are being discussed as potential building blocks for future applications in spintronics.

Linear antiferromagnetic materials are characterized by the fact that the spins of the magnetic atoms align themselves antiparallel to one another and therefore cancel each other out. The absence of effective magnetic moments makes it difficult to manipulate materials of this kind using external magnetic fields.

David Bracher has investigated individual crystalline goethite and cobalt oxide nanoparticles with respect to their magnetic properties and morphology. For this, he combined X-ray microscopic analyses with high-resolution scanning electron microscopy and correlated the morphology of the nanoparticles with their magnetic orientation.

His results indicate that interactions with the substrate have a significant influence on the orientation of the magnetic spin axis of goethite nanoparticles. The magnetic ordering of single-crystalline cobalt oxide nanoparticles often correlates with specific crystal axes.

The experimental data also show that the magnetic moments of the nanoparticles depend on the size of the particles and are subject to thermal fluctuations.

David Bracher conducted his research both at the Paul Scherrer Institute and at the Department of Physics of the University of Basel.

Panagiotis Fountas now works at Baloise Insurance.

New device for ion-nanowire hybrid system
In his doctoral thesis, Dr. Panagiotis Fountas has fabricated and implemented a new quantum device with the goal to realize a hybrid ion-nanowire system that could be suitable for quantum information experiments, spectroscopy, and mass spectrometry.

In such a hybrid ion-nanowire system, an ultracold trapped ion will be coupled with a much larger nanomechanical oscillator out of a conductive nanowire. The nanowire can then be used to control the motion of the ion and vice versa.

In this interdisciplinary work at the interface of quantum science, quantum optics, and nanoscience, Panagiotis first showed in theoretical simulations that the coupling of the tiny ions with the comparatively large nanowires is theoretically possible.

He then fabricated, developed and implemented a new quantum device for the interface of the trapped ion and the nanowire. Initial measurements of the nanowire provided promising results for the realization of the ion-nanowire hybrid system, which could be used as a new device for quantum technology.

Altered vibrations provide information
In his PhD thesis, Dr. Paolo Oliva has developed a new imaging platform that can be used to analyze the mass, stiffness and viscosity of liquid biological samples precisely, fast and requiring only small sample volumes. Using the platform, biological samples can be examined quantitatively and, for example, how proteins are built up or degraded can be monitored in real time.

First, 1 microliter of the sample is applied to a silicon nitride membrane located in a small chamber for measurement. In a closed temperature- and humidity-controlled system, the membrane is excited to vibrate at various points. Depending on mass, viscosity and stiffness, the amplitude and phase spectrum of these vibrations changes. These changes are precisely recorded and allow the mass, viscosity and stiffness of the sample to be determined.

Using the new measurement principle, Paolo Oliva was able to follow the polymerization of the protein G-actin in real time and without prior labeling or functionalization. He has also started to analyze amyloid proteins, which play an important role in neurodegenerative diseases.

Paolo Oliva started working for SBB as a RAM (Reliability, Availability, Maintainability) engineer right after finishing his PhD.

In his PhD thesis, Thomas Karg coupled two quantum systems via a loop of light. He is now a postdoctoral researcher at IBM in Zurich.

Coupling quantum systems with light
In his doctoral dissertation, Dr. Thomas Karg worked on connecting quantum systems over a long distance. He succeeded in coupling an oscillating micromechanical membrane with the spin of an ultracold cloud of atoms over a distance of one meter and across a room-temperature environment. Every movement of the membrane, which was just 100 nanometers thick, therefore exerted a force on the spin of the atoms and vice versa.

He achieved this using a loop of light in which a laser beam is sent back and forth between the two systems. This beam behaves like a mechanical spring stretched between the atoms and the membrane, and transmits forces between the two. The properties of the light can be configured so that information about the motion of the two systems is not lost to the environment and therefore the quantum mechanical interaction is not disturbed.

Thomas Karg not only performed the theoretical calculations, but was also able to demonstrate experimentally that the two quantum systems can be coupled via the loop of light. This new technique for light-mediated coupling opens up a whole host of possibilities for the development of quantum networks and new types of quantum sensors.

Graduating in uncertain times

Some SNI PhD School leavers affected more than others

We spent most of 2020 firmly in the grip of the Covid-19 pandemic. Doctoral researchers at the SNI's PhD School were no exception, and had to adapt to the new circumstances. Some of those who completed their dissertations in 2020 had to rethink their plans, while others were fortunate enough to embark on an exciting career just as they had planned at the start of the year.

Change of plan

Dr. Lujun Wang was the first SNI PhD student to successfully defend his dissertation in 2020. His time at the SNI PhD School came to an end on 7 January. On completing his doctorate, he had originally intended to apply for a PostDoc.Mobility fellowship from the Swiss National Science Foundation; enquiries to several research groups in the US had already met with positive feedback. Then came the US entry ban and extensive travel restrictions, prompting Lujun to look for an exciting alternative in Switzerland instead. Accordingly, after completing his dissertation, he stayed on the University of Basel for few months, writing a paper for publication and sending out applications. Since July, he has been working as a postdoc at ETH Zurich. "Ultimately, the development turned out to be positive for me. This way, I get to keep on doing exciting research and spend another 2 or 3 years in beautiful Switzerland," Lujun reflects.

Still searching

Dr. David Bracher also completed his dissertation in January 2020, and was therefore unaffected by the impacts of the Covid-19 pandemic. His greatest difficulty lay in finally calling it a day, and not becoming caught up in making endless improvements. His position at the Paul Scherrer Institute continued until the end of April, at which point widespread uncertainty in the job market made it very difficult for him to find a suitable job. He is nevertheless optimistic that employer confidence will return soon, leading to a wider range of opportunities in his chosen fields of data science and research & development.

Lujun Wang had his defense at the Department of Physics at the University of Basel in January 2020.

David Bracher was not yet affected by the Covid-19 pandemic when he completed his work.

Thomas Karg did not feel that the Covid-19 pandemic has significantly changed his plans. (Image: T. Karg)

Staying in Basel as a postdoc

Like Lujun and David, Dr. Thomas Karg – who completed his dissertation in mid-Febrary – was also able to finish his doctorate according to plan. All three had the opportunity to defend their dissertations in a lecture hall with a live audience, before celebrating their achievement in the company of colleagues. As Thomas could continue working for the University of Basel, he doesn't feel that the Covid-19 pandemic has affected his plans. In fact, he is happy that lectures are now held mainly online: "This has made it easier to invite international guests and participate in lecture series at other universities," he remarks.

Contract signed in spring

The picture was a very different one for all of the other doctoral candidates who defended their theses at the SNI PhD School in 2020. Virtual defenses became the norm, and the subsequent drinks receptions with colleagues were restricted to a very small number of attendees.

In June, Dr. Paolo Oliva became the SNI's first doctoral candidate to defend his thesis from his computer at home before an audience that was also attending remotely. Although he had no problems with this arrangement, he reports that while writing up his thesis at home he sometimes struggled not to put work first all the time, and to develop a balanced new routine in spite of the lack of physical separation between work and leisure.

Paolo realized well before finishing his doctorate that academic research was not for him, so by mid-January he already had his eye on several positions in the region. His interviews were all held at the start of the year, and Paolo was able to spend some time in person at his new place of employment, Swiss Federal Railways (SBB). By the time social distancing rules came into force in spring, Paolo had already signed his contract. And so, a week after defending his dissertation he took up his new post as a RAM (Reliability, Availability, Maintainability) engineer at SBB at the start of July.

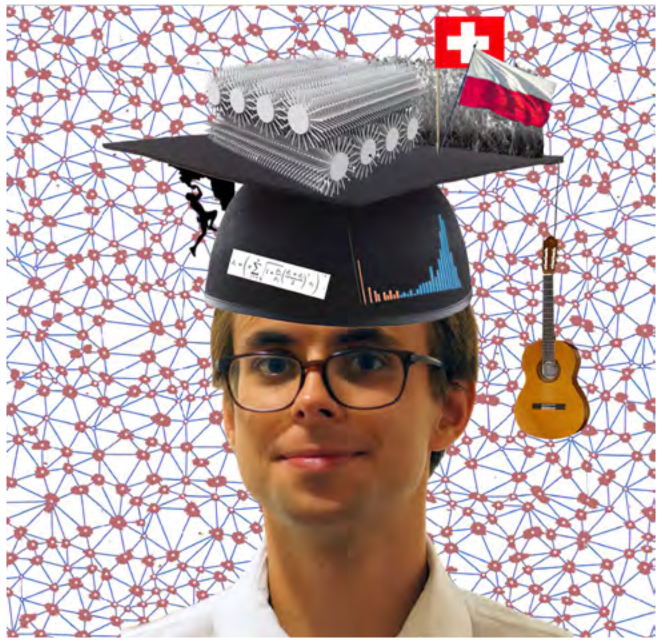
In June, Paolo Oliva became the first SNI doctoral student to defend his thesis virtually (Image: P. Oliva)

Juggling work and school

For Dr. Panagiotis Fountas, the process of finding a job went just as smoothly: in February 2020, he had already taken up a position as a quantitative developer / actuary with Bâloise Insurance. The result was a stressful few months until his defense in June, writing up his dissertation in parallel to his demanding new job. This meant that the lockdown actually worked in his favor, as it allowed him to work from home instead of commuting. "The time and energy I saved meant that in the evenings I was still in a fit state to write up my dissertation after my day's work," Panagiotis recounts. Under normal circumstances he would have preferred to defend his dissertation in person, but given the time constraints he found the virtual format, in which he only had to worry about the presentation, quite relaxing.

Time saved by online meetings

Dr. Wojciech Szmyt was the last doctoral candidate to finish in 2020. He too had already completed the practical side of his work when the lockdown began in spring, before writing up his dissertation at home. His virtual defense took place in November. In October 2019 he had already begun working as a research associate at Empa, which he will now continue as a postdoc. As Wojciech was collaborating with various research groups all over Switzerland, he also saved a huge amount of time by communicating primarily online over the last few months rather than commuting.



Wojciech Szmyt not only had a virtual defense, he even got a virtual doctor's hat. (Image: W. Szmyt)

A seamless transition

Paolo Oliva went straight from completing his doctorate to a job at SBB

Many graduates of the SNI PhD School choose to stay in research and continue their scientific career with a postdoc position. Dr. Paolo Oliva, however, made a deliberate decision not to stay on an academic track. As soon as his virtual defense was behind him, he started a job with Swiss Federal Railways.

All in all, most of the doctoral students finishing in 2020 were not too badly affected by the Covid-19 pandemic. The situation will be a very different one for those who are nearing the end of their doctorate, but have not yet been able to complete the practical side of their projects.

In some cases, restricted lab opening hours and delivery problems with certain items have led to delays. Nevertheless, as labs have largely been able to resume normal operation for the rest of the year after the lockdown period, they too will hopefully be able to bring their exciting time at the SNI PhD School to a successful conclusion in 2021, without further restrictions.

Fond memories

In 2016, Dr. Paolo Oliva began a doctoral thesis on the development of a new imaging platform to measure the mass, stiffness and viscosity of liquid biological samples, under the supervision of Dr. Thomas Braun, Professor Ernst Meyer and Professor Henning Stahlberg. Paolo thoroughly enjoyed his time at the SNI PhD School. "The group was great, and I was very happy to have the opportunity to take part in the various SNI events and build a network," he recalls.

First virtual defense at the SNI

Contrary to his initial expectations, however, the experience did not culminate in a dissertation defense in a packed lecture theatre, but alone at home in front of his computer screen.

In June 2020, in-person events were out of the question, so Paolo Oliva became the first doctoral researcher at the SNI to defend his dissertation virtually, before an audience that was also attending via computer. This was no problem for Paolo, as he told us. "I wasn't nervous at all. I gave my presentation, and then I was subjected to a very fair examination by my four examiners," he reports. Once his excellent grade had been awarded, he was presented with a very real doctoral cap made by some of his fellow doctoral candidates, and enjoyed a small private celebration with his lab colleagues in the evening.

Although Paolo enjoyed his work and the scientific challenges involved, he had no desire to continue academic research after his doctorate, so in mid-January he began applying for various jobs in the region. By March, he had three interesting options to choose from. The one he felt most drawn to was a job as a RAM (Reliability, Availability, Maintainability) engineer at Swiss Federal Railways (SBB).

As the interviews had all been held early in the year, Paolo had the chance to meet his future employer in person. By the time social distancing rules came into force in spring, he had already signed his contract. This meant he was able to get started in his new job just a week after defending his dissertation.

A new work environment

Paolo's daily routine is now nothing like it was a year ago. He and his colleagues are responsible for ensuring the reliability and availability of SBB's trains, and making sure they can be duly maintained.

For instance, he works with the infrared sensors in passenger compartments that can be used to determine the number of passengers occupying them. In another project, he monitors the performance of a particular locomotive model in which the power converter and compressed air supply system have been replaced. "I do a lot of analysis, calculations and programming," he explains. He enjoys being involved in completely different projects: "There are always new circumstances that I have to adapt to."

Well prepared

The interdisciplinary approach to working and thinking developed during his doctorate is now serving him well. "In my dissertation I did everything from design to production. I also learned to think analytically, besides numerous programming languages. All of that is now helping me a great deal," says Paolo.

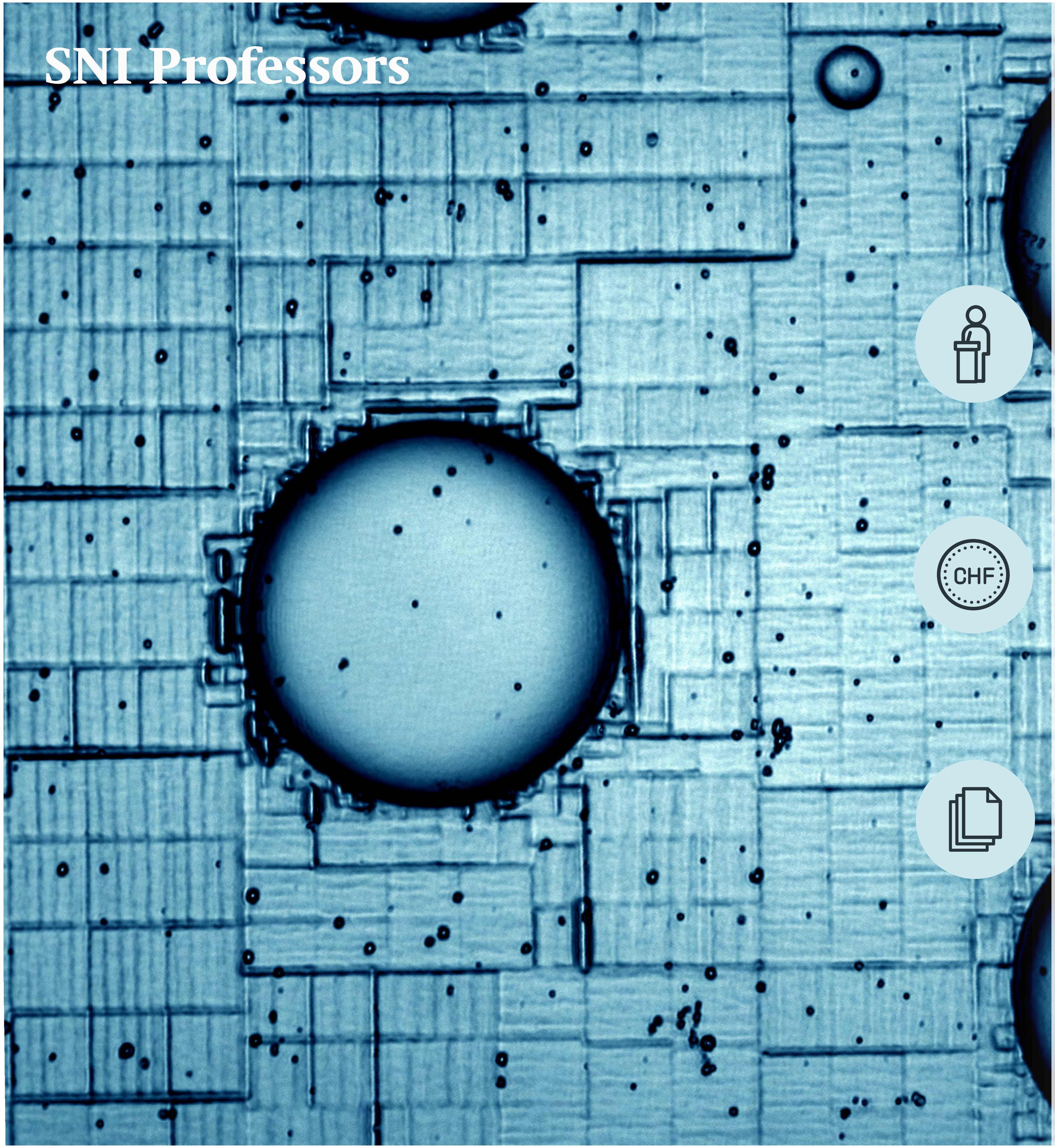
It is always important for the SNI to hear that its young researchers leave with an outstanding education that opens doors on the job market. Paolo is a great example of a successful transition to the world of work.

Paolo's daily routine is now nothing like it was a year ago. (Image: P. Oliva)

"The SNI gave me the opportunity to establish a broad network and attend numerous interdisciplinary events."

Dr. Paolo Oliva, former SNI PhD student, now employed at SBB.

SNI Professors



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The SNI financially supports five professors. Argovia Professor Martino Poggio works at the Department of Physics, Argovia Professor Roderick Lim at the Biozentrum at the University of Basel. Thomas Jung, Michel Kenzelmann and Frithjof Nolting are titular professors, who teach at the University of Basel and lead research teams at the Paul Scherrer Institute. Thomas Jung also has a research group at the University of Basel.

1.4 M

In 2020, the Argovia Professors Martino Poggio and Roderick Lim managed to attract about CHF 1.4 million in external funding for their research.

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The Argovia Professors and their teams published ten scientific papers and gave six talks at various national and international conferences.

The image shows circular depressions in a nickel layer made by electroplating. The depressions are about 1 µm in depth and 20 µm in diameter. The cubic lattice of nickel presumably creates the tiled surroundings. (Image: M. Marhöfer, INKA, School of Engineering, FHNW)

Magnetic or superconducting

Argovia Professor Martino Poggio uses special cantilevers to study a broad range of materials

For the first time ever, the team led by Argovia Professor Martino Poggio recently succeeded in examining the magnetic properties of tiny magnetic crystals consisting of magnetic nanoparticles. The ability to measure these very faint magnetic forces using cantilever magnetometry opens the door to an array of potential applications. A very different kind of cantilever is at the heart of a European Horizon 2020 project approved in 2020, to be coordinated by Martino Poggio over the next four years. The international project team plans to use focused ion beam technology to manufacture sensors directly on the cantilever tip that can also be used to examine superconducting materials.

Materials with novel properties

Numerous materials with special properties occur in nature. Researchers around the world are busy adding to this list in the lab, creating new substances with optical, electrical or magnetic properties not found in the natural world.

For example, nanoparticles that self-assemble as if by magic can be used to create crystal superstructures. If researchers use magnetic nanoparticles in this process, under the right conditions they will come together to form magnetic mesocrystals that can reach a size of up to several micrometres. Examining the magnetic properties of these mesocrystals has so far not been possible, as their total magnetic moment is very small, and their orientation on a surface is random rather than orderly.

Cantilevers are key

In collaboration with researchers from Germany, Belgium and Sweden, however, the team led by Argovia professor Martino Poggio has now succeeded in precisely measuring the magnetic properties of these mesocrystals. A paper recently published in the scientific journal *Physical Review B* describes how Poggio's team used highly sensitive dynamic cantilever magnetometry to analyze the magnetic forces at work in mesocrystals.

To this end, postdoc Dr. Boris Gross and doctoral researcher Simon Philipp of Poggio's team applied individual mesocrystals of maghemite (γ-Fe_2O_3) to a cantilever. The cantilever was then exposed to a magnetic field in order to observe the magnetic behavior of the crystals.

Simon Philipp was able to optimize the procedure in such a way that individual maghemite mesocrystals on the surface – on which they are arranged at random following self-organization – can be selected, imaged and examined in different orientations. As a result, the researchers were able to study not just the magnetism of the crystal superstructure, but also that of the minute nanoparticles themselves.

Magnetization with a preferred orientation

The measurements revealed that the magnetization of the mesocrystals exhibits a cubic preferred orientation. Known in expert circles as anisotropy, this orientation is dependent on the shape of the mesocrystal, and results from the fact that the individual nanoparticles are themselves tiny cubic crystals arranged in a lattice.

The ability to examine the magnetism of mesocrystals opens up a broad range of potential applications. "Biologists, for instance, are discussing the possibility of using magnetic mesocrystals as transporters for a cargo that could be guided to the intended destination with the help of magnets," Martino Poggio remarks. "Before the magnetic properties of mesocrystals can be adjusted and altered for applications of this sort, we need a precise method with which to analyze their magnetism."

In charge of a FET OPEN project

Another highlight of 2020 for Martino Poggio was the approval of a project under the EU Horizon 2020 program.

Working with researchers from IBM Zurich, Germany and Spain, over the next four years the Poggio team will develop a new production method for exceptionally sensitive and precise probes for scanning probe microscopy that can be used to examine current, magnetization, dissipation, and topography on the nanometer-scale.

Under the FET OPEN funding program, established to support European cooperations developing radically innovative technologies, the researchers will receive almost three million euros for the creation of the groundbreaking sensors.

The interdisciplinary team began the project, which revolves around the use of focused ion beam (FIB) technology, in October 2020. Using this technology, available to the researchers in the SNI's Nano Imaging Lab, Poggio's team will manufacture tiny, highly sensitive sensors directly on the tip of cantilevers that can be used to image new and poorly understood condensed matter phenomena, including, for example, superconductivity, highly insulating states, and magnetism in 2D materials. The probes, which will contain nanometer-sized Josephson junctions (JJs) and superconducting quantum interference devices (SQUIDs), will serve to image magnetic fields and susceptibility, besides enabling measurement of electrical currents and their losses.

A productive start

For the first few months of the project, the team focused primarily on the design of the new cantilevers, which the experts at IBM have already begun manufacturing. Meanwhile, Martino Poggio's group in Basel began creating an initial protoype from commercially available cantilevers, using FIB technology to cut the cantilevers to size and coating them with the superconducting material niobium.

A new era for scanning probe microscopy

At a later stage, the cantilevers will be created especially for different fields of application, and fitted with the appropriate probe at the tip.

The application focus will initially be on studying magnetic fields in two-dimensional van der Waals materials. The researchers are especially interested in mapping the transport of charges and imaging edge states and correlated electronic states. The examinations can be performed at comparatively high temperatures of up to 80 Kelvin (-193°C), with a spatial resolution of up to 10 nanometers.

"With this project, we hope to usher in a new era for the already highly successful field of scanning probe microscopy. This will allow us to tackle poorly understood phenomena in physics, chemistry and materials science that can't be studied using current technology," said Poggio.

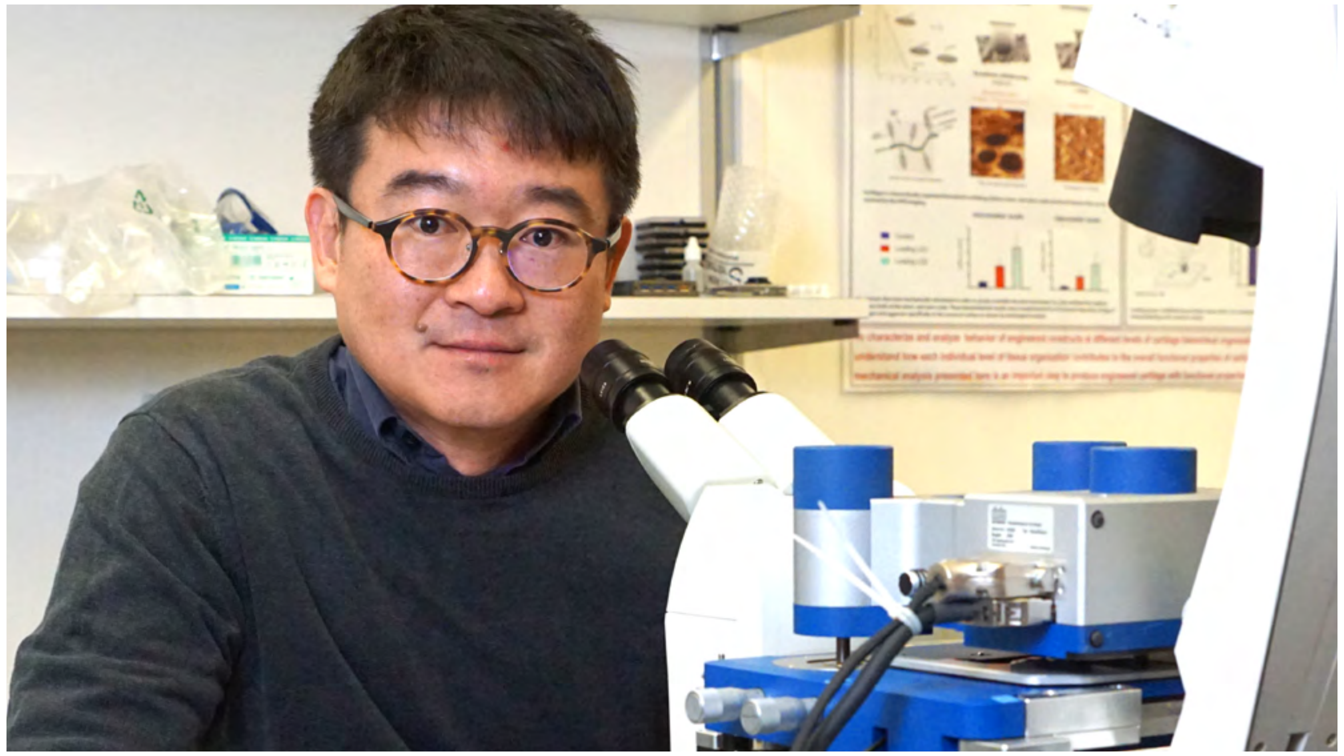
For more information about this and other projects from Poggio's lab, visit https://poggiolab.unibas.ch

Over the next few years, Argovia Professor Martino Poggio will lead a project in the EU Horizon program. The project will use focused ion beam technology to produce sensors directly at the tip of a cantilever that can also be used to study superconducting materials.

Inspiring students

For Argovia Professor Roderick Lim, teaching is an important aspect of his work

In addition to research, teaching plays a key role for lecturers from the SNI network. For Argovia Professor Roderick Lim, who teaches and leads a research group at the Biozentrum of the University of Basel, it is important to vividly demonstrate to students that nanoscience fulfills a key role in studying biological function. Here, his enthusiasm for research is closely tied to his passion for teaching and imparting scientific know-how to students. Together with his team, he mastered the difficult situation in 2020 and developed new approaches to teaching that will endure, at least in part.



It is important to Argovia professor Roderick Lim to impart knowledge to students in an inspiring way and to introduce them to the elegance of science.

New forms of teaching

In 2020, lecturers spent a considerable amount of their time trying to make teaching as attractive as possible despite strict coronavirus safety requirements, and to ensure that students were not disadvantaged. In the case of lectures and seminars, this was comparatively easy to accomplish. They were either delivered live online or recorded on videos that were made available to the students. The students even gave feedback that a video lecture certainly had advantages, since it could be viewed at any time and repeated as desired.

In contrast, the execution of block courses, in which students on the biology and nanosciences program normally gain their first practical experience in various working groups, was considerably more difficult.

Specially built stations

Argovia professor Roderick Lim faced the challenge in summer 2020 of organizing the block course "Structural Biology and Biophysics" lasting several weeks for nearly 50 molecular biology students within a few weeks and under strict safety conditions.

At its heart, Structural Biology and Biophysics relies heavily on cutting-edge instrumentation and is methods-intensive. Hence, in pre-pandemic times, undergraduate students normally work in PI-led research labs.

However, to prevent excessive intermingling, Lim and his colleagues at the Biozentrum decided to set up laboratory stations in lecture halls specifically for the block course. At these stations, students were then able to get to know and use various devices in groups of four and, at the same time, were well protected from coronavirus infection thanks to the safety concept.

The Lim team itself introduced nanotechnological tools such as the atomic force microscope and the plasmon resonance spectroscope in this block course. As this equipment could not be easily moved to a lecture hall, Lim lab members Dr. Larisa Kapinos and Dr. Richard Newton produced insightful videos that explained the theory behind the methods and provided detailed instruction on how to use the equipment. Meanwhile their experiments were broadcast live so that the students were able to follow the application, whilst providing them with data to analyze for their report.

Advantages of small groups

In 2020, the nanoscience students who had registered for their block course in the fall semester were able to benefit especially from the fact that they typically work in small groups. In this way, they were still able to study under individual supervisors from the Lim lab and to learn how to operate state-of-the-art equipment such as high-speed atomic force microscopy and fluorescence spectroscopy themselves – almost as in normal times.

Nanoscience is important

"It is important to me not only to impart knowledge to students, but also to introduce them to the elegance of science," Roderick Lim answers when asked what he teaches undergraduate and graduate students. "I want to inspire them and show them how essential nanoscience is to (nano)biology and our understanding of the processes of life."

Lim works a lot with images, as they are often worth a thousand words. For example, every year in the "Nano I" lecture, in which the various research groups active in nanoscience introduce themselves, he greets nanoscience students with a quote that appears on Google Scholar: "On the shoulders of giants." Applied concretely to his research, this means that past achievements have enabled us to question and discover new science – such as how nano-sized nuclear pore complexes regulate molecular transport into and out of the cell nucleus as studied by the Lim team.

Early integration into the working group

Lim also believes in supporting and training committed students who show an interest in research early on during their undergraduate education and thus providing them with unique insights into lab life and culture. The plan for 2020 was to have one or two interested students propose a weekly schedule to work with a post-doc or PhD student during the semester, thereby giving them exposure to current research very early in their education. "The coronavirus made this impossible, but we are sticking to this plan for the future," Lim reports.

Virtual meeting with TU Delft

Another project planned by Lim was a complete success, not in spite of the pandemic but perhaps because of it. Together with the study association for Nanobiology (i.e. S.V.N.B. "Hooke") at the Technical University of Delft (The Netherlands), Lim organized an interactive meeting for nanoscience students from Basel and nanobiology students from Delft and then held it virtually via Zoom in early 2021.

Altogether, forty young nanoscientists from Basel and Delft were given an introduction to the SNI followed by three exciting nanobiology-related seminars given by professors from the SNI PhD School.

The students were then treated to two inspiring presentations from two former Basel nanostudents, Tobias Appenzeller and Joel de Beer. Interestingly, both Appenzeller and de Beer are co-founders of start-ups, specifically ARTIDIS AG and Anjarium Biosciences AG, respectively. In this context, ARTIDIS, the start-up in which Tobias Appenzeller is Head of Quality and Clinical Operations, is particularly close to Lim's heart. ARTIDIS, which uses AFM-based technology to rapidly diagnose cancer grew out of his lab.

> "Even in post-pandemic times, virtual meetings like this will provide our students with excellent opportunities to communicate, learn from and share ideas with others."

Argovia Professor Roderick Lim, Biozentrum University of Basel

Support for titular professors at the PSI

Work by two research groups under Thomas Jung leads to synergies

Professor Thomas Jung is in charge of two closely cooperating research groups – the NanoLab at the University of Basel's Department of Physics and the Molecular Nanoscience group at the Paul Scherrer Institute (PSI). Together, the teams explore the mechanical, magnetic and electrical properties of molecules and nanostructures on surfaces. The different technical equipment installed in the two labs means the same samples can be analyzed using a variety of techniques. An example of this cooperation is the spectroscopic and microscopic examination of the same materials by both of Jung's teams.

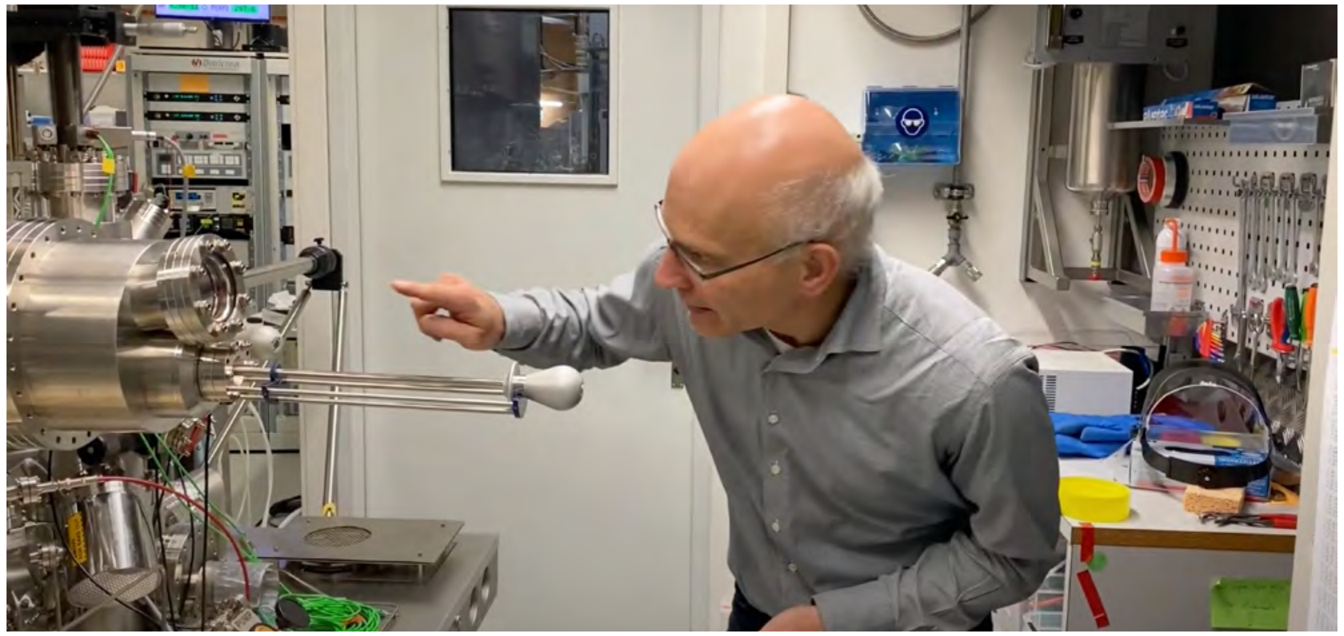
Experimental station at the synchrotron

Some twenty years ago, researchers from the University of Basel, the PSI, Empa, the University of Zurich and the University of Fribourg formed a consortium to set up an experimental station at the PSI's Swiss Light Source (SLS) with the goal of conducting spectroscopic and microscopic examinations of different materials in combination.

The two physics professors Thomas Jung and Ernst Meyer from the SNI network are members of this consortium. The measurement station was established and is operated by Dr. Matthias Muntwiler, a member of the Molecular Nanoscience team. Muntwiler uses the synchrotron's special light for his own research at the PEARL Beamline, as the station is known, besides making it available to external research groups and customers from industry as a "user lab".

Wavelike boron nitride

In 2020, for example, in collaboration with the University of Zurich and the Federal University of ABC (Brazil) he was able to show that an atomic layer of hexagonal boron nitride on rhodium takes on a wavelike structure. Earlier examinations with the scanning tunneling microscope had already suggested this outcome, but it was only thanks to the synchrotron measurements that the material's exact shape could be determined.



Thomas Jung examines samples using a scanning tunneling microscope. (Image: M. Wegmann, SNI)

In another example, Jung's team works with magnetic molecules hovering above a substrate. The molecules change or lose their magnetization depending on their orientation, if they are located above a network with pores, for instance. This gives the researchers a better understanding of elementary magnetism, allowing them to develop new magnetic materials – for applications in quantum technology, for instance.

"Combining microscopy at the atomic scale with different forms of spectroscopy that measure electronic, optical or magnetic properties using synchrotron light is crucial to progress in nano and materials science today," Thomas Jung remarks. "The cooperation between the University of Basel and the PSI is an important contribution in this regard."

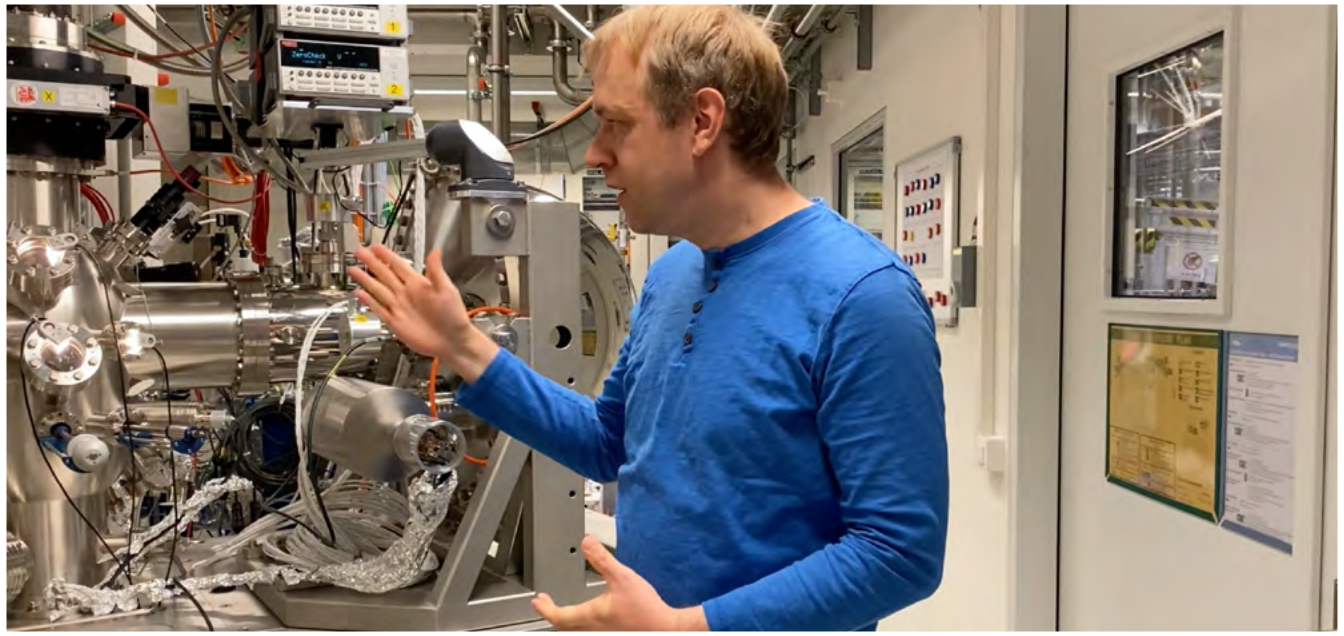
Preparing for a new light source

In 2025, the synchrotron at the PSI will be upgraded to an even better light source. Numerous PSI employees are already busy planning for this transition. Matthias Muntwiler and Thomas Jung, along with their colleagues at the PSI, have been hard at work making sure that "spectro-microscopy correlation experiments" can still be conducted with the "brighter" light generated by the new light source.

"In 2020 the strategy for the adjustment of the experimental station to the even more powerful light source was approved, which was an important milestone for us," Jung explains. There is a great deal of work still to be done over the next few years to ensure that the measurement station remains available to researchers both from Switzerland and all of Europe.

"Combining microscopy at the atomic scale with different forms of spectroscopy that measure electronic, optical or magnetic properties using synchrotron light is crucial to progress in nano and materials science today. The cooperation between the University of Basel and the PSI is an important contribution in this regard."

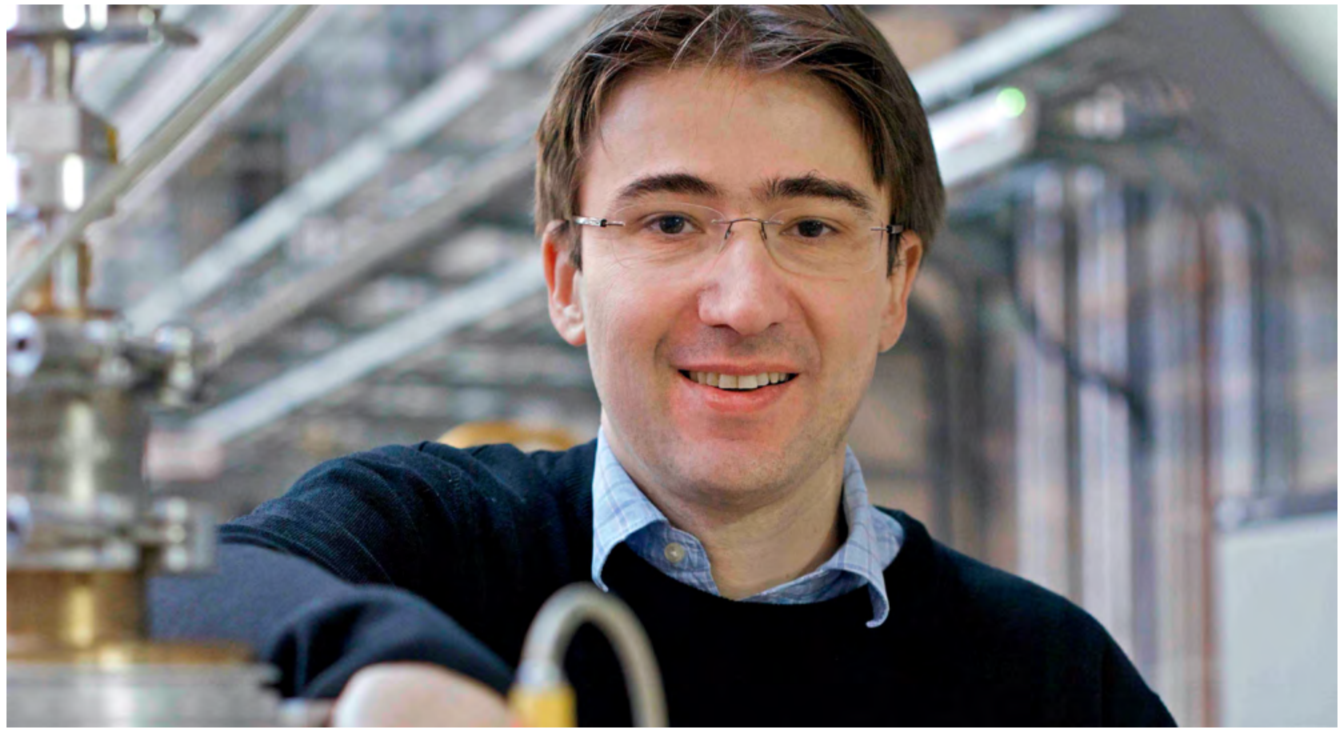
Professor Thomas Jung, Department of Physics of the University of Basel and the Paul Scherrer Institute



Matthias Muntwiler uses the synchrotron's special light to provide spectroscopic data. (Image: M. Wegmann, SNI)

Michel Kenzelmann is fascinated by exotic magnetic quantum materials

Professor Michel Kenzelmann is a specialist in materials with unusual magnetic properties. He is head of the Laboratory for Neutron Scattering & Imaging at the Paul Scherrer Institute and teaches students of physics and nanosciences at the Department of Physics of the University of Basel. The SNI supports his research activities, which center on topics such as quantum spin liquids — materials with entangled electrons even at temperatures close to absolute zero.



Michel Kenzelmann and his team conduct research into exotic magnetic quantum materials. (Image: Paul Scherrer Institute)

Special magnetic properties

In an article in the journal *Quantum Materials* in 2020, Michel Kenzelmann's team published results of their experimental analysis of a two-dimensional honeycomb spin lattice made of ytterbium(III) bromide. The researchers were able to show that the colorless crystals of ytterbium(III) bromide belonged to the group of materials known as quantum spin liquids, which are characterized by highly unusual magnetic properties.

In a conventional magnetic material, the electron spins all adopt the same alignment at temperatures close to absolute zero (-273.15°C). In quantum spin liquids, however, the spins remain entangled with one another and continue to fluctuate even at low temperatures.

Honeycomb lattice meets requirements

The PSI team led by Michel Kenzelmann carried out the research in collaboration with scientists from the Universities of Bern and Freiburg, as well as ETH Zurich. In their experiments, the researchers have now succeeded in demonstrating that there is no static alignment of spins in the analyzed ytterbium(III) bromide lattices down to a temperature of 100 millikelvin — in other words, that the material has the properties of a quantum spin liquid and that the spins of honeycomb lattice plaquettes are entangled.

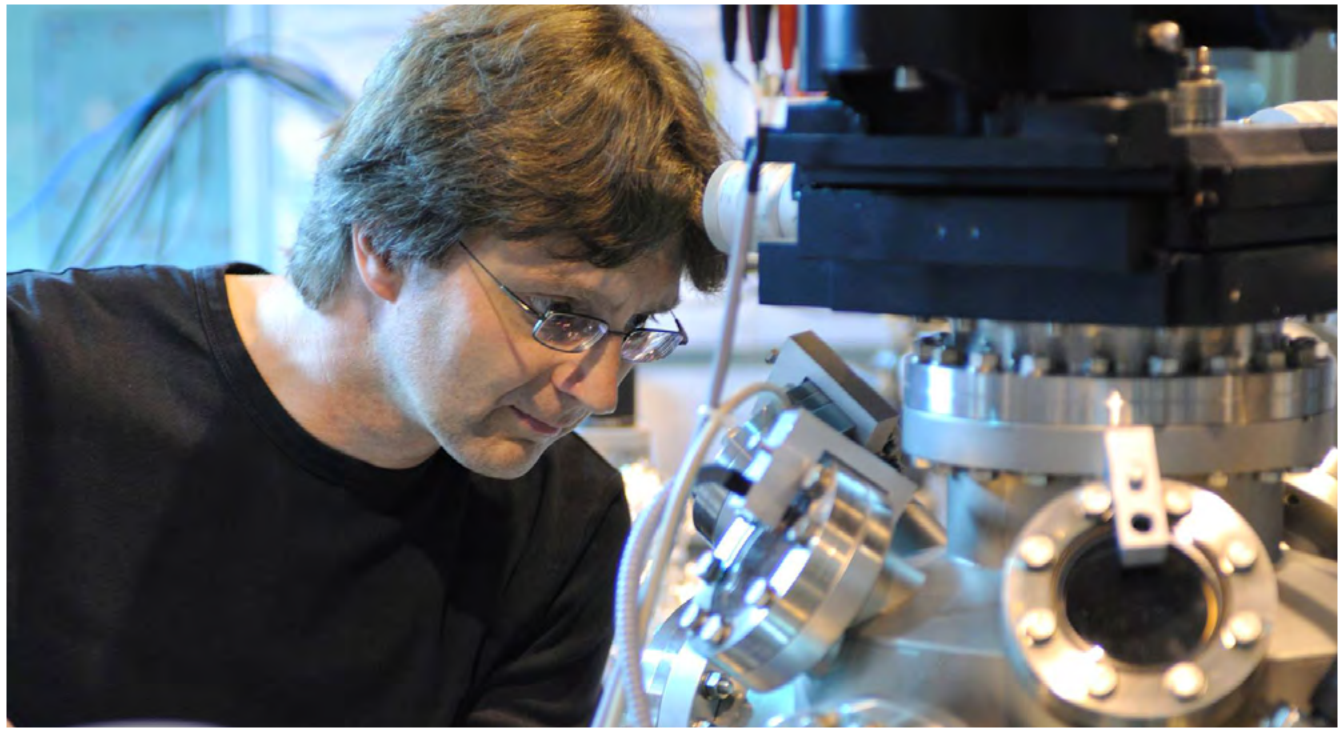
The reason why quantum spin liquids are so exciting for researchers is that the numerous quantum fluctuations taking place within them have interesting potential applications in future quantum information technologies.

Studies of quantum spin liquids are a great help when it comes to understanding events that take place spontaneously in the seemingly incomprehensible quantum world. For example, novel particles can be created in quantum liquids that have the peculiar property of being their own antiparticles and have been proposed for the development of fault-tolerant quantum computers.

Original article:
https://www.nature.com/articles/s41535-020-00287-1

Frithjof Nolting researches magnetism of individual nanoparticles

Professor Frithjof Nolting is head of the Laboratory for Condensed Matter in the Photon Science Division at the Paul Scherrer Institute (PSI). He also teaches as an titular professor at the University of Basel's Department of Physics and is chairman of the ANAXAM association. Nolting's own research activities deal with magnetism on the nanoscale, and in 2020 he worked with an international team to study how lasers could be used to manipulate the magnetism of individual nanoparticles.



Frithjof Nolting studies magnetism on the nanoscale. (Image: Paul Scherrer Institute)

Controlled using laser pulses

Laser-induced manipulation of magnetism could potentially be used in spintronics, as there are certain conditions in which ultrafast laser pulses can control the spin state in nanoscale magnetic components.

Writing in the journal *Physical Review B*, Frithjof Nolting's team and other researchers from the PSI, ETH Zurich and the Universities of York (United Kingdom) and Antwerp (Belgium) describe the reactions of a model system that they excited using laser pulses of varying intensity and polarization.

For this, the scientists used individual cobalt nanoparticles with sizes ranging from 8 to 20 nanometers. They excited the particles with laser pulses lasting just a few femtoseconds (10^{-15} seconds) and analyzed their magnetism, chemical composition and morphology using X-ray photoemission electron microscopy and scanning electron microscopy.

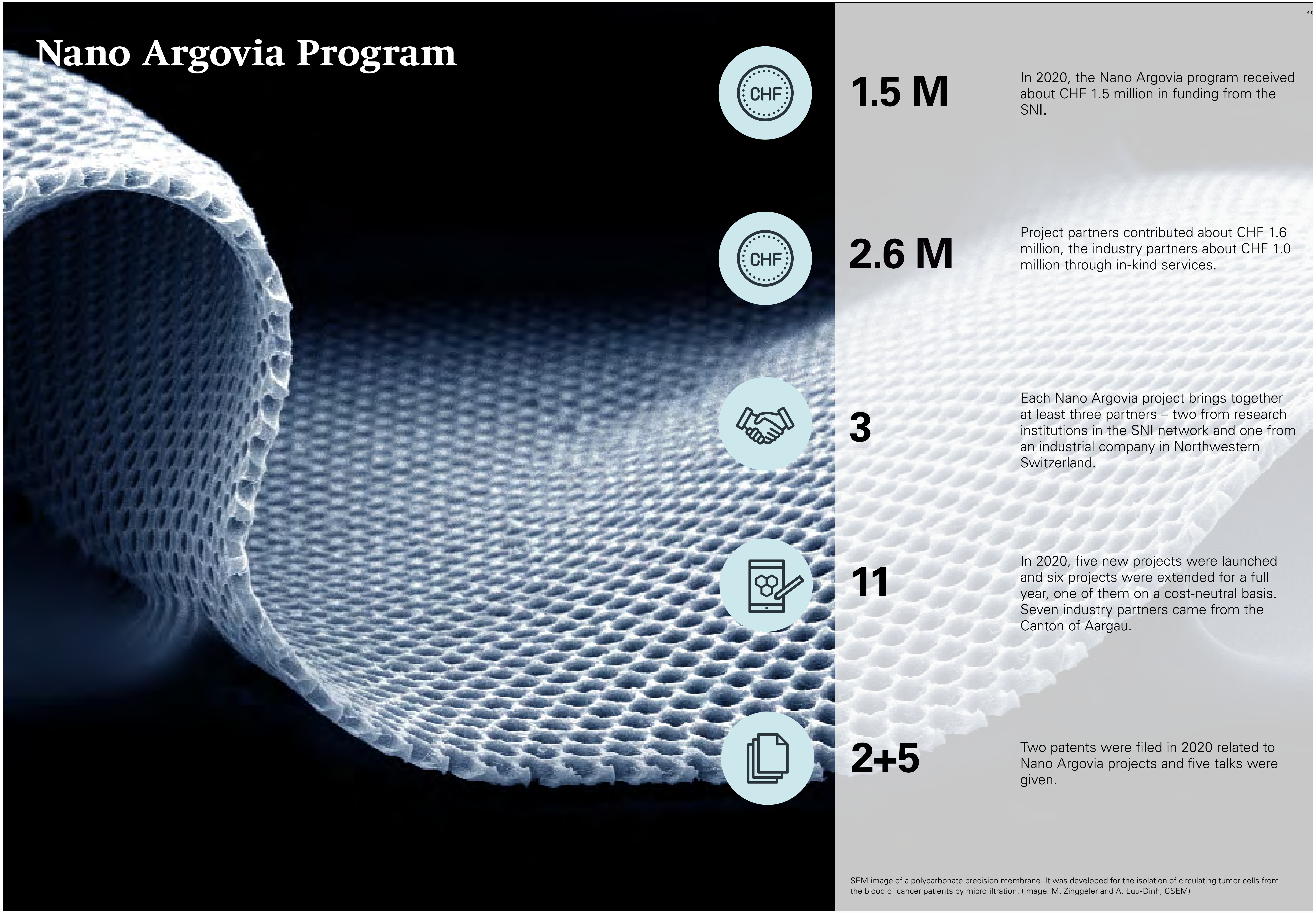
Irreversible change in magnetic properties

Up to a certain laser intensity, the researchers observed no reversal of the magnetization of the nanoparticles. Above a certain intensity, however, the nanoparticles underwent a photochemical reaction with their protective layer, resulting in an irreversible change in the magnetic properties.

The findings lend support to the definition of conditions required for achieving laser-induced switching in isolated nanomagnets and therefore a potential application in spintronics.

Original article: https://journals.aps.org/prb/abstract/10.1103/PhysRevB.102.205418

Nano Argovia Program



1.5 M

In 2020, the Nano Argovia program received about CHF 1.5 million in funding from the SNI.

2.6 M

Project partners contributed about CHF 1.6 million, the industry partners about CHF 1.0 million through in-kind services.

3

Each Nano Argovia project brings together at least three partners – two from research institutions in the SNI network and one from an industrial company in Northwestern Switzerland.

11

In 2020, five new projects were launched and six projects were extended for a full year, one of them on a cost-neutral basis. Seven industry partners came from the Canton of Aargau.

2+5

Two patents were filed in 2020 related to Nano Argovia projects and five talks were given.

SEM image of a polycarbonate precision membrane. It was developed for the isolation of circulating tumor cells from the blood of cancer patients by microfiltration. (Image: M. Zinggeler and A. Luu-Dinh, CSEM)

New projects in applied research

In 2020, five new projects were launched as part of the Nano Argovia program. For three of the projects, the respective company partners came from the Canton of Aargau, for two of the projects they came from one of the two Basel half-cantons. The projects investigated various medical technology topics, functionalized surfaces and worked on the detection of nanoparticles in food additives.

Mechanosensitive liposomes

In the Nano Argovia project ForMeL, a research team is developing liposomes that can be loaded with pharmaceutical agents which are subsequently released in response to changes in pressure. Mechanoresponsive liposomes of this kind could be used to directly target blood clots in vessels affected by arteriosclerotic narrowing, dissolving them without the need to flood the patient's entire body with anticoagulants.

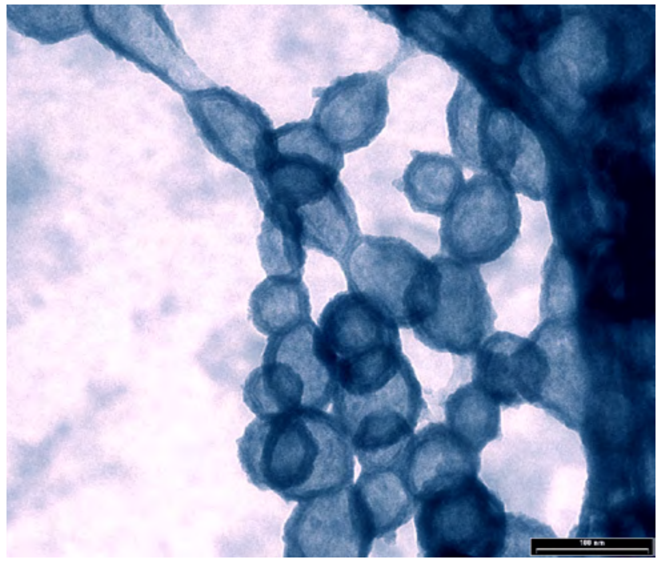
Narrowing of a blood vessel – caused by sclerotic deposits, for instance – can increase the shear forces exerted in the bloodstream by at least an order of magnitude. It is possible to manufacture synthetic lipid membrane vesicles (liposomes) that break apart when subjected to these increased shear forces. The company Acthera Therapeutics hopes to exploit this principle to develop a procedure for delivering pharmaceutical agents directly to the narrowed area.

Under the coordination of Professor Dr. Oliver Germershaus (FHNW), researchers from the industry partner Acthera Therapeutics AG in Basel, the School of Life Sciences (FHNW), and the ANAXAM Technology Transfer Center have worked closely together to pursue this goal.

The team conducted research on the production and formulation of the liposomes at laboratory scale including analytic methods for liposome characterization and optimization of the loading process with an appropriate agent. They also develop a freeze-drying process that ensures safe storage of the manufactured liposomes. The team started to extrapolate every step in the production, formulation and freeze-drying to the pilot scale to enable production of material for the first preclinical trials.

"For a recently formed start-up like ours, the Nano Argovia program is an ideal opportunity to create the technical prerequisites for preclinical and clinical testing of mechanoresponsive liposomes."

Dr. Andreas Zumbühl, Chief Scientific Officer, Acthera Therapeutics AG (Basel)



In the Nano Argovia project For MeL, researchers studied mechanosensitive liposomes. (Image: FHNW and Nano Imaging Lab, SNI)

A ceramic coating for titanium implants

In the Nano Argovia project Promucola, the project team has developed and assessed post-processes for a ceramic coating of titanium implants to make them more resistant to abrasion.

Titanium implants are a viable alternative to cobalt-chrome alloys for joint implants due to their high biocompatibility and mechanical strength. However, when subjected to constant movement, as is the case with knee, shoulder or elbow joints, untreated titanium surfaces are too susceptible to abrasion.

"With this project, we hope to further exploit the potential of plasma-based ceramic coatings in order to develop a robust ceramic surface for titanium implants that protects them against wear."

Dr. Armando Salito, Director of Coating Innovation, Orchid Orthopedics Switzerland GmbH

In the Nano Argovia project Promucola, an interdisciplinary team with researchers from the School of Life Sciences (FHNW) has worked in close collaboration with the ANAXAM Technology Transfer Center (Villigen) and the company Orchid Orthopedics Switzerland GmbH (Baden-Dättwil). Under the leadership of Professor Michael de Wild (FHNW), the team investigated post-treatments of a robust ceramic coating to protect titanium implants against wear.

The team applied a ceramic coating to titanium substrates using the plasma spray method, a procedure in which the biocompatible powder mixture is injected into a flame to be sprayed onto the surface.

The rapid cooling of the particles on the surface not only leads to the desired layers but also to the formation of metastable phases, which are characterized by specific crystallographic phases, microstructure, hardness and resistance to abrasion.

The researchers explored the conditions under which these metastable layers form, and how they can subsequently be modified. The obtained results, for example of high-resolution Synchrotron-XRD (synchrotron X-ray diffraction) and SXRµCT (synchrotron X-ray microcomputed tomography) will be used to optimize production and develop a procedure for post-processing the implants on an industrial scale.

The samples were coated with a ceramic layer using the plasma spray method, which is then closely examined and post-treated.

Functionalized surfaces without fingerprints

In the Nano Argovia project ReLaFunAF, a team of researchers from the FHNW School of Engineering, the Paul Scherrer Institute, and the company RadLab AG in Killwangen is developing a method for functionalizing surfaces with coatings that can repel fingerprints. Surfaces like this are valuable for decorative items or in the automotive and electronics industries.

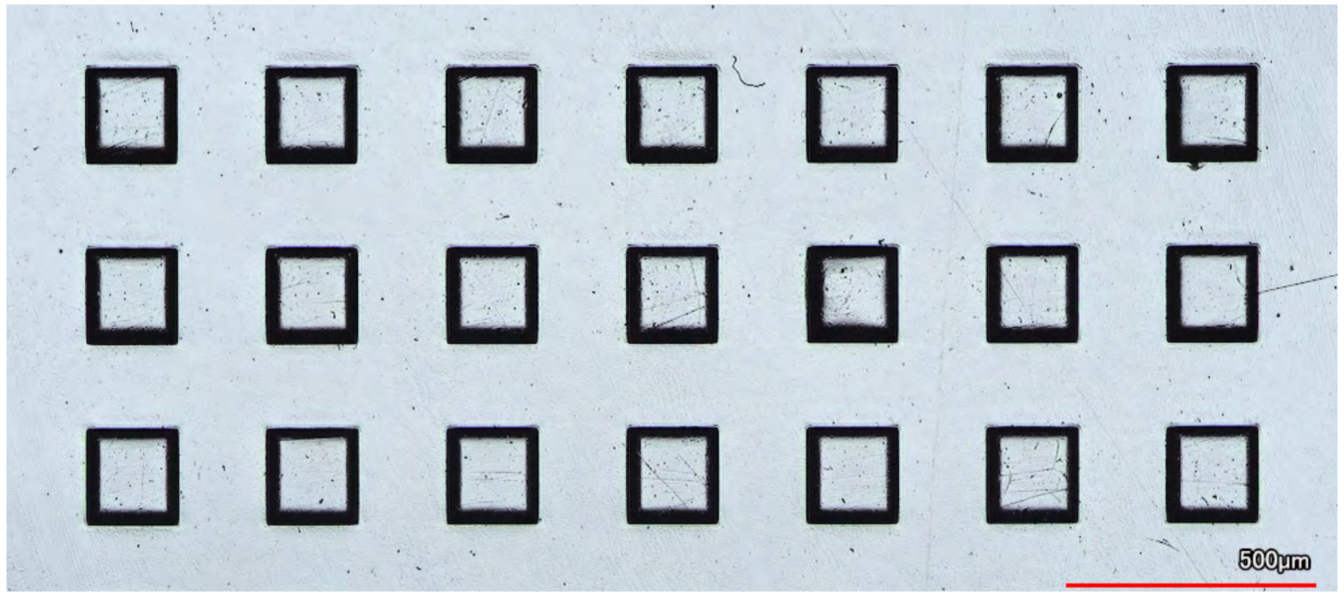
Numerous applications involve treating surfaces with coatings that are cured under UV light. The use of modern UV LEDs often results in the formation of "sticky" layers, as the surface cannot be fully cured.

The team led by Dr. Sonja Neuhaus of the FHNW Institute of Polymer Nanotechnology (INKA) used the reactive groups of these sticky surfaces to covalently bind functional molecules in a second coating step. An additional round of curing fixes these in place. Using this process, the functional layer does not come into contact with the original substrate. This allows functionalizations that would otherwise not properly adhere to the sample – a crucial benefit of the chosen method.

The project team has looked into how this process can be adapted to create anti-fingerprint surfaces. They tested combinations of properties – for example, lipophilic and hydrophilic – using structuring through a mask and backfilling. Moreover, the extent to which the architecture of the network at the nanoscale influences the repellent effect is under investigation.

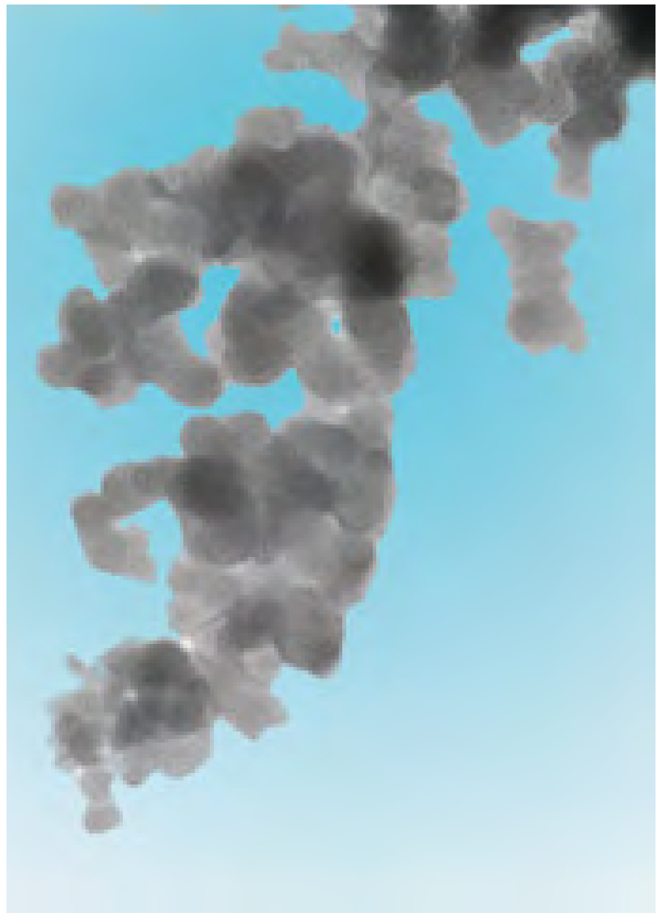
"Ongoing refinement of coating procedures is crucial to our success. For this Nano Argovia project we have the perfect team with which to successfully hone the ReLaFun process in response to a specific issue."

Dr. Anna Di Gianni, Technical Director of RadLab AG



In the Nano Argovia project ReLaFunAF, the project team is developing a method for functionalizing surfaces with coatings that can repel fingerprints. The figure shows a coating structured with the ReLaFun process. (Image: INKA, FHNW)

Analysis of silicon oxide nanoparticles in complex mixtures



In the Nano Argovia project SiNPFood, methods for characterizing silicon oxide nanoparticles (SiNPs) are being investigated. (Image: FHNW)

In the Nano-Argovia project SiNPFood, a team of researchers from the FHNW School of Life Sciences, the Department of Chemistry of the University of Basel, and the industry partner DSM Nutritional Products AG (Kaiseraugst) is pooling their expertise to develop a reliable method for the characterization of nanoparticles in complex mixtures.

Silicon oxide and tricalcium phosphate are approved processing aids for food ingredients and are used at low concentrations to improve the handling of food additives in powder form.

By covering the surface of the particles, they reduce the friction between them and thereby improve material flow. For technical reasons, these processing aids may also contain a certain amount of smaller particles (<100 nanometers in diameter). Regulatory bodies are currently developing new guidelines for the use and detection of these nanomaterials in foods.

The industry partner DSM aims to contribute to the development of these new standards and regulations with a new analytical method for the determination and quantification of silicon oxide nanoparticles (SiNPs). Under the leadership of Dr. Sina Saxer (FHNW), the team has focused on typical product formulations in the food industry so that food additives can be analyzed in a standardized manner using efficient and reliable detection methods – even on the nanoscale.

The team used a range of characterization methods to analyze nanoparticles at the various stages of production. They are currently developing a standardized and automated process that does not modify the SiNPs.

"The Nano Argovia project SiNPFood supports DSM in its efforts to develop a reliable method for the determination of nanoparticles in food ingredients. This will help us to provide controlled (or certified) nanoparticle-free products."

Dr. André Düsterloh, Principal Scientist at DSM Nutritional Products AG

Bactericidal properties for titanium implant surfaces

In the Nano Argovia project TiSpikes, an interdisciplinary team has investigated how a nanostructure can deter bacterial growth and how biofilms are formed on titanium implants. Researchers from the University of Basel's Department of Physics and Department of Dental Medicine were working closely with the School of Life Sciences (FHNW) and Institut Straumann AG.

Undesired bacteria on implants can cause infections that can ultimately lead to the loss of the implant. Their growth can be suppressed to some extent by antibiotics. However, more and more bacteria are acquiring resistance to antibiotics. Once a biofilm has formed, even powerful antibiotics are often of no use as only the outer layer of bacteria comes into contact with them. It is therefore desirable to find a solution that prevents bacteria from colonizing the implant in the first place.

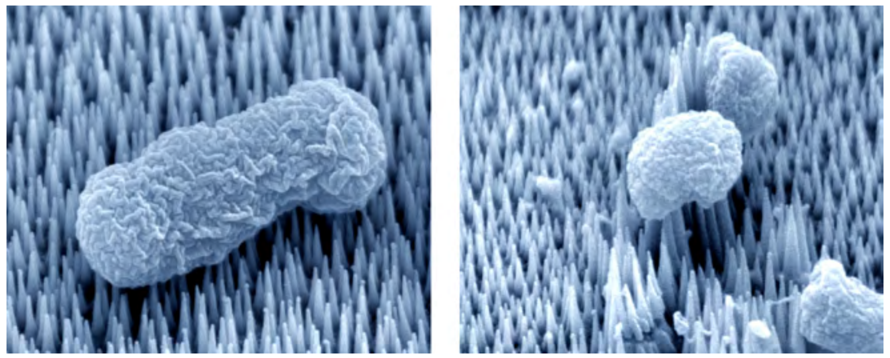
Nature offers multiple examples of structured surfaces that remain sterile with no need for antibiotics. Under the guidance of Dr. Laurent Marot and Dr. Khaled Mukaddam (both from the University of Basel), the TiSpikes project team has structured titanium and titanium alloys in different ways. The researchers have tested which structures are most effective at thwarting bacteria of different sizes. They have applied different microscopic methods, including scanning probe microscopy to determine the adhesive forces in place between the bacteria and the various surfaces. Additionally, they studied which structures promote the adhesion of the surrounding tissue cells as this is also essential to minimize bacterial colonization in the space between implant and tissue, thereby preventing infections.

"The project brought together partners from different areas of expertise in academia and industry.

We are planning to test these new nanostructured surfaces *in vivo* for preclinical assessment with the clear goal of providing our customers with the best possible solutions."

Dr. Raphael Wagner, Head of Surfaces Research, Institut Straumann AG

Dental implants made of titanium will be equipped with a textured surface. (Image: Institut Straumann AG)



Different surface structures are produced to prevent growth of bacteria and formation of biofilms. (Image: Dental Medicine/Nano Imaging Lab, University of Basel)

Extended projects in applied research

In 2020, six Nano-Argovia projects that had been started in previous years were extended for another year. Four of the industrial partners came from the Canton of Aargau, two from Basel-Stadt.

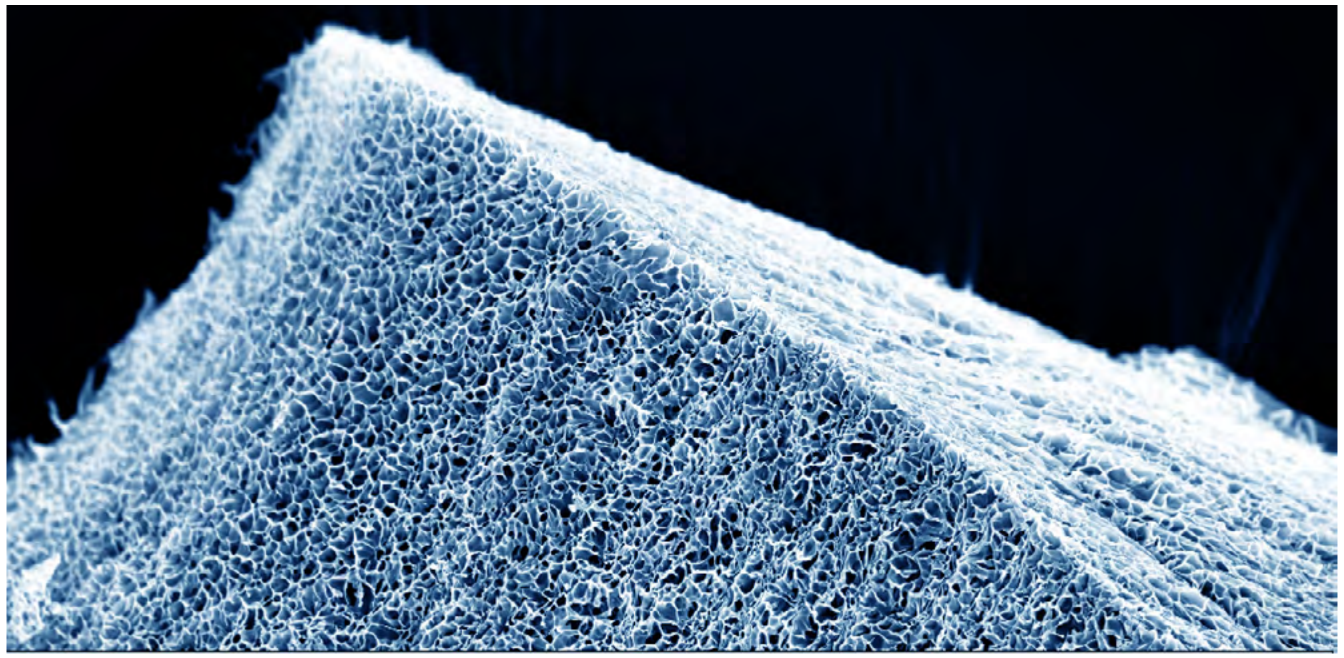
Portable system for drinking water analysis

In the Nano Argovia project DeePest, scientists from the Schools of Life Sciences and Engineering at the University of Applied Sciences Northwestern Switzerland (FHNW) were working alongside industry partner Mems AG (Birmenstorf) to develop a fully automatic sensor for detecting pesticides in drinking water. The system offers a cost-effective extension for existing analysis methods and is intended to continuously detect the presence of a wide range of pesticides in drinking water systems.

The researchers first concentrated the pesticides by several orders of magnitude so that, in the subsequent analysis, they could use cost-effective methods whose sensitivity is tailored to the expected substrate concentrations. Working under project leader Professor Dr. Joris Pascal (FHNW), the interdisciplinary team based its analysis on two different sensors, which exploit different physical properties and can therefore detect different classes of substances.

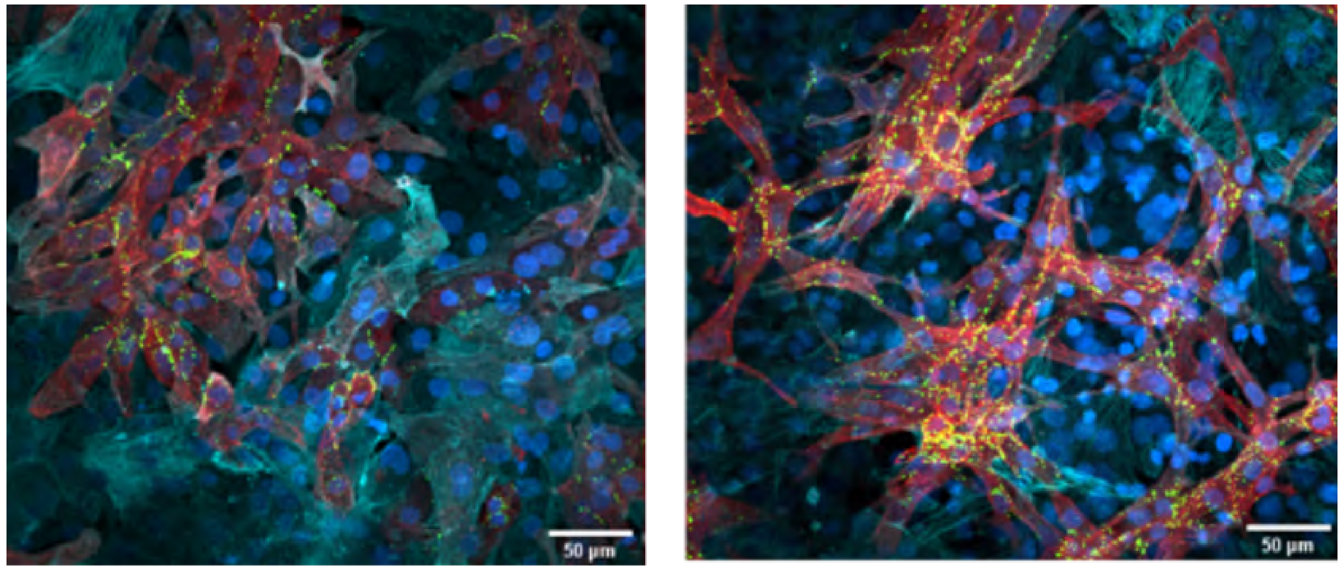
"The DeePest project has made it possible to experimentally validate a large number of hypotheses toward the industrialization of a portable and inexpensive pesticide detector for drinking water."

Dr. Daniel Matter, Mems AG



Researchers in the DeePest project use hydrogels to concentrate various pesticides from drinking water. (Image: M. Olesinska, FHNW)

Heart model inspired by origami



Researchers in the Nano Argovia project KOKORO investigate different culture media to provide optimal conditions for both vascular cells and cardiac muscle cells. (Image: FHNW)

In the Nano Argovia project KOKORO (Japanese for "heart"), a team of researchers under the guidance of project leader Dr. Maurizio Gullo (School of Life Sciences at FHNW) has developed a novel, three-dimensional heart model.

The artificial model will be used to investigate various tissue parameters, as well as contractility, volume changes and functionality of a "paper heart". It provides ideal means to test therapeutic approaches for treating heart strokes and other forms of cardiovascular disease.

During the last few months, the industry partner Omya developed a suitable cellulose paper whose nanostructures provide an ideal culture scaffold for myocardial cells. Using a 3D bioprinting process, research groups from the FHNW applied thin coatings of myocardial cells onto the cellulose layer and thereby build the cardiac tissue. The team from the Department of Biomedicine (DBM) at the University of Basel created the vascular cell network which will ensure an optimal nutrient supply of the cardiac tissue.

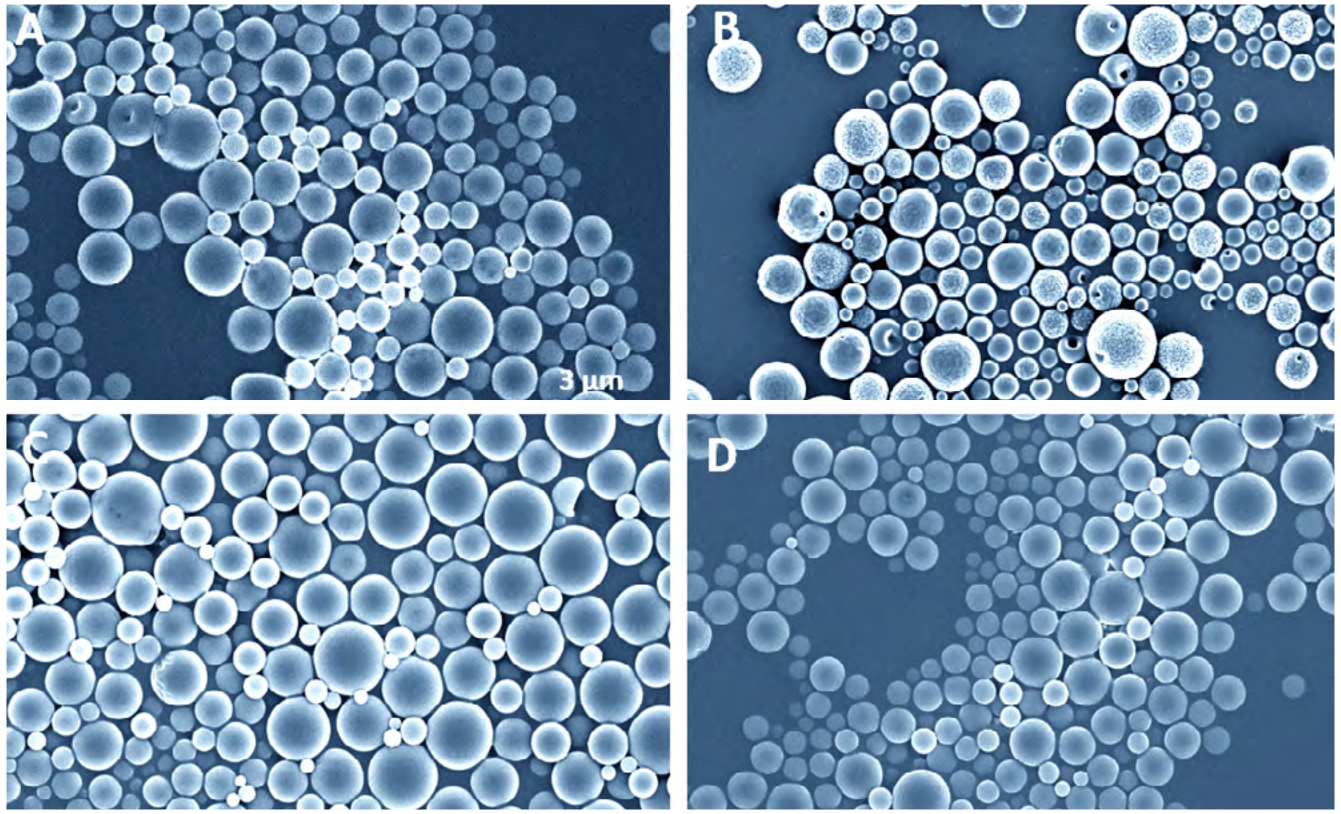
The resulting tissue layers were then folded similar to paper origami. The model is cultured while being mechanically and electrically stimulated. Such physiological stimuli are similar to those experienced by native cardiac tissue and will help to achieve optimum tissue maturation before the heart model undergoes in-depth characterization and physiological assessment.

"Cellulose-based fiber networks are increasingly being used as frameworks for tissue cultures.

It’s amazing to see how such substrates can enable culturing of complex and fragile multicellular tissues. In particular, papers preformed into origami shapes might open the pathway toward large numbers of mechanically active tissue models."

Dr. Joachim Schoelkopf,
Head of New Applications Research
at Omya International AG

Combating inflammation around dental implants and supporting tissue regeneration



In the PERIONANO project, researchers studied particles loaded with antimicrobial agents (A +B) or with substances of plant origin (C+D). (Image: FHNW)

"The Nano Argovia program strengthens our innovative power and enables us to conduct targeted and applied research and development of new products. The excellent and close exchange with our partners at the FHNW enables us to combine application observations with the latest research results and to improve the products."

Michael Hug, COO at credentis AG

In the Nano Argovia project PERIONANO, scientists from the FHNW School of Life Sciences and the Hightech Research Center of Cranio-Maxillofacial Surgery (University of Basel) were working with industry partner credentis AG (Windisch, Aargau) to investigate a new approach for the treatment of inflammation around dental implants (peri-implantitis). The scientists have developed an easy-to-use system based on a peptide hydrogel with embedded particles that successively release antimicrobial active substances and also promote regeneration.

In many cases, dental implants are accompanied by inflammation due to bacterial colonization, resulting in the degradation of the surrounding soft tissue and bone (peri-implantitis) and potentially leading to the loss of the implant.

Peri-implantitis is usually treated using local or systemic antibiotics, but there is currently no treatment that acts against the bacteria while simultaneously encouraging regeneration of the damaged tissue.

The PERIONANO team working under project leader Dr. Franziska Koch from the School of Life Sciences used peptides that can form a fibrous network and incorporated a variety of particles that release active substances little by little.

They achieved the localized release of various active substances, which then combat different pathogenic species of bacteria in their vicinity. The fibrous scaffold of peptides additionally promotes the regeneration of damaged soft and bony tissue.

Nanoparticles to defeat cancer

In the Nano Argovia project NCT Nano, three interdisciplinary teams were collaborating to characterize a novel, targeted immuno-oncology approach.

Scientists from TargImmune Therapeutics AG (Basel), the Department of Chemistry at the University of Basel, and the Department of Biosystems Science and Engineering at ETH Zurich in Basel (D-BSSE) have studied nanoparticles that smuggle a specific cargo into cancer cells.

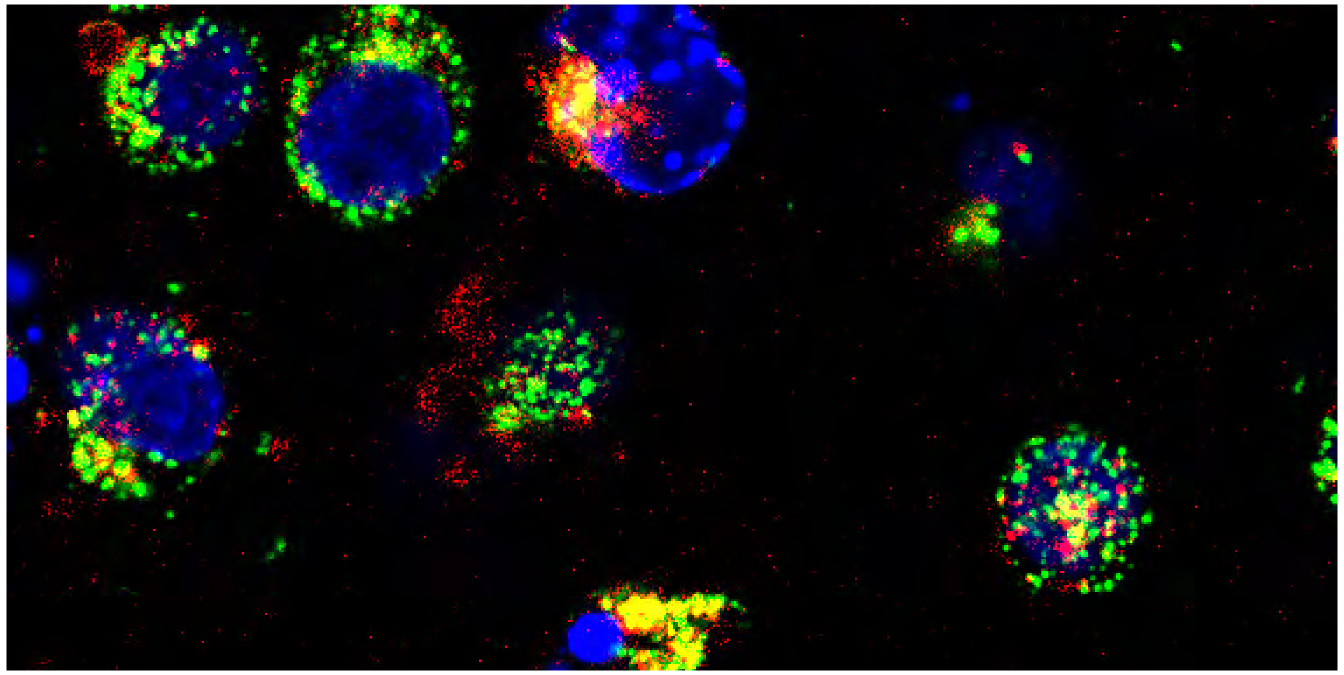
The platform technology, developed by TargImmune, is based on the chemical vectors that selectively enter cancer cells and deliver an active ingredient, simultaneously triggering cell death and an immune response against the tumor. Critical steps enabling development of these nanoparticles into a clinical-stage product involve stability and safe delivery of the cargo in patients. The latter is controlled by ensuring that the cargo remains intact and reaches the targeted cancer cells without affecting healthy non-cancerous cells.

Under the leadership of project manager Dr. Maya Zigler (TargImmune), the different research groups studied factors that affect nanoparticle stability, including physico-chemical properties, reproducibility and quality control. Using various microscopy techniques, the scientists analyzed how the particles deliver the cargo into the targeted cells. Additionally, they investigated the activity of the novel nanoparticles in a variety of cell lines. These activities enhanced the understanding of the critical qualities attributes and mechanism of action of the drug.

"The Nano Argovia project NCT Nano significantly enhanced our understanding of the mechanism of action and the characteristics of the drug contributing to the development of our drugs to the clinic.

Our novel approach results in potent anti-cancer activity and is expected to have a significant impact on cancer patients life."

Dr. Maya Zigler, project manager of NCT Nano and head of research at TargImmune Therapeutics



Selective internalization of nanoparticles by cancer cells. Components of the nanoparticles were stained red and green with fluorescent dye and nuclei of the cancer cell were stained with blue fluorescent dye. The image was taken with a laser scanning confocal microscope (X20).
(Image: M. Saxena, TargImmune Therapeutics and M. J. Skowicki, C. Palivan, University of Basel)

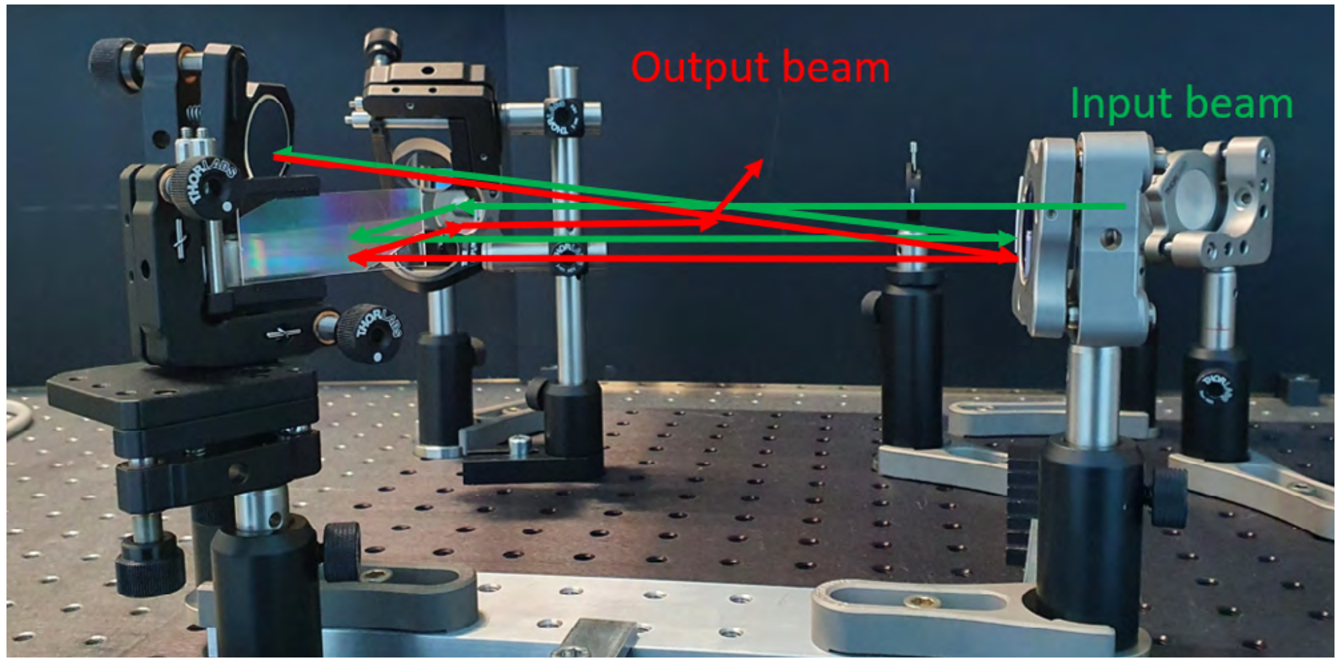
A new type of laser system

In the Nano Argovia project UltraNanoGRACO, a team of researchers from CSEM Muttenz, School of Engineering (FHNW), and the startup Menhir Photonics AG (Basel) were examining a new type of laser pulse compressor to be combined with an ultrafast laser. The laser system is intended to produce extremely short, high-intensity light pulses.

Ultrafast lasers have many potential applications, ranging from telecommunications through metrology and machining metals to medical engineering. The light pulses from these lasers have a duration of less than 1 picosecond (10^{-12} seconds). Some applications require the pulses to be amplified. To ensure that excessive pulse intensity does not damage the amplifiers, the light pulses are first stretched and then compressed again once they have passed through the amplifier.

The compression quality is a decisive factor for the final length of the pulse and the maximum intensity. These are parameters that have to be optimized for different applications.

In this Nano Argovia, researchers led by Dr. Fabian Lütolf from CSEM Muttenz were examining a new type of laser pulse compressor for ultrafast lasers that is intended to enable increased intensity. The stretched light pulses pass through newly developed optical gratings. The gratings cause the wavelengths, which were previously temporally and spatially separated, to be superimposed again and produce a shorter and more intense light pulse. The new compressor also meets the requirements for stability and economic viability with an optimized design.



In the Nano Argovia project UltraNanoGRACO, novel gratings are used to generate shorter and more intense light pulses. (Image: CSEM and FHNW)

"The Nano Argovia project UltraNanoGRACO with our partners from CSEM and FHNW has been an excellent collaboration to demonstrate and validate technical concepts that will allow Menhir Photonics to offer laser systems with strong business advantages in the future."

Dr. Florian Emaury, CEO and co-founder of Menhir Photonics AG

Innovative energy storage

In the Nano Argovia project MEGAnanoPower, a team of scientists from the School of Life Sciences (FHNW), CSEM Muttenz and the industrial partner Aigys AG (Othmarsingen, AG) worked closely together to further develop the redox flow battery (PowerCell®) patented by Aigys.

Redox flow batteries are rechargeable batteries in which the electrical energy is stored in the form of electrolytes. The PowerCell® does not use dissolved chemical compounds, but finely distributed solids as charge carriers. The aim of this project was to develop stable nano-dispersions as high-capacity energy storage media and to use surface-enhanced nano/microstructured electrodes as efficient current collectors.

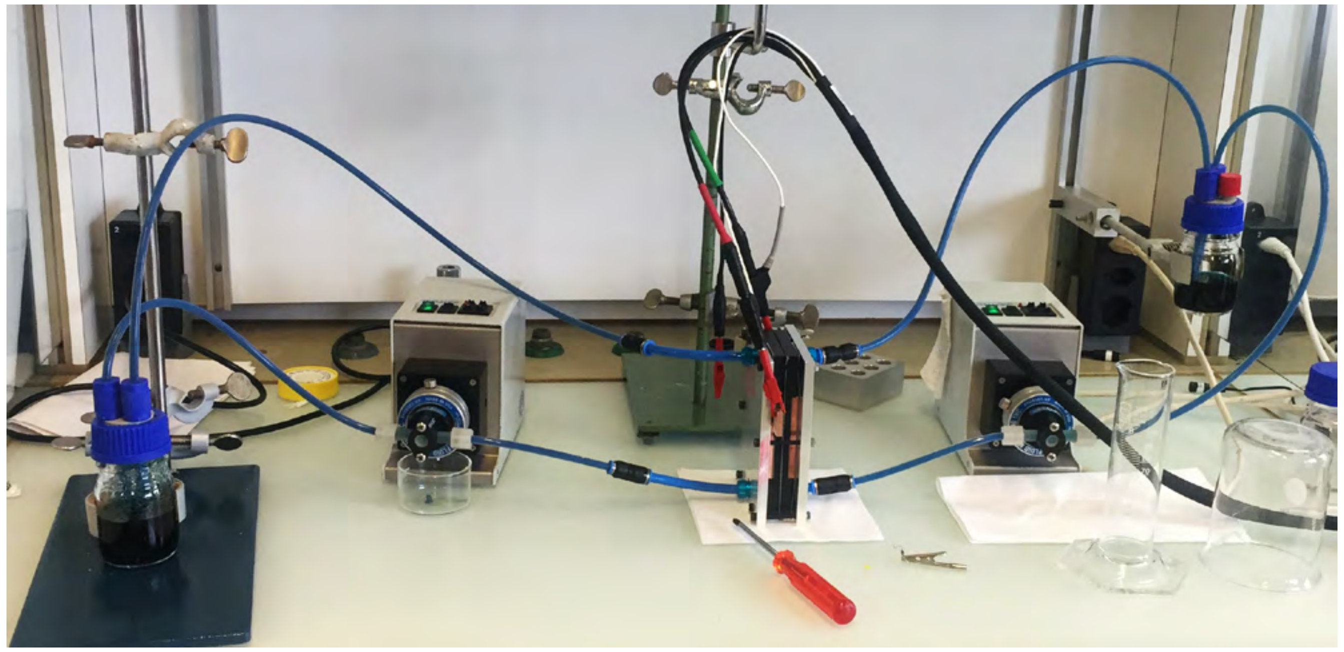
In the first phase of the project, electrolyte dispersions of known lithium-based compounds were used to test the working principle of a solid-based redox flow battery and to understand the basic behavior of particle-based electrolyte dispersions.

The second phase of the project focused on the development of a water-based battery consisting of environmentally friendly, non-toxic and non-hazardous active components. A screening of potential materials already used as active components for batteries led to iron oxides that met a variety of the required criteria.

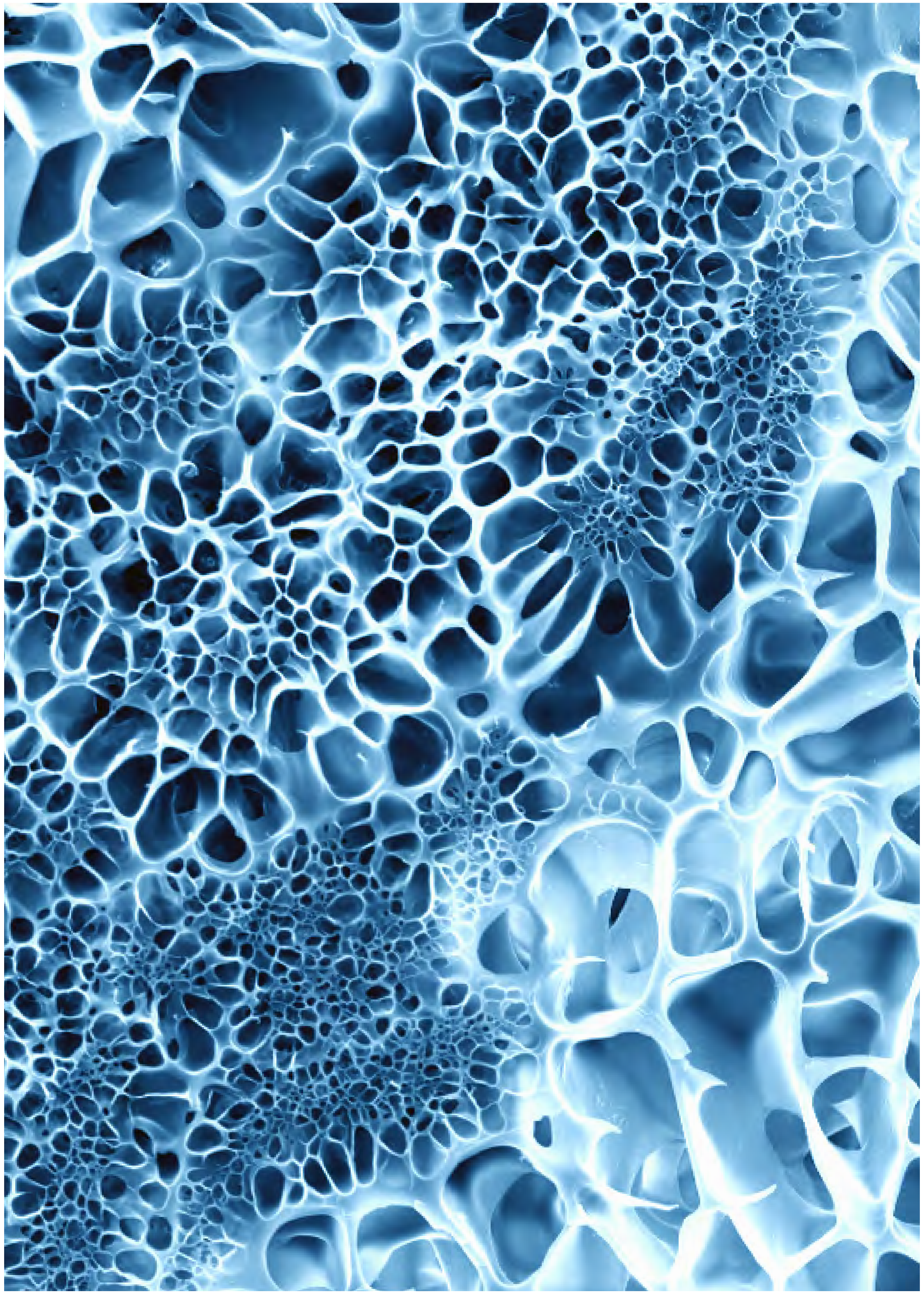
The team was able to formulate stable nano-dispersions of iron oxides and to demonstrate their use in redox flow batteries. However, further investigation and development of the nano-dispersions as well as the flow cell are necessary to increase the capacity and stability of such redox flow batteries.

"It is great to see the commitment and enthusiasm with which the team is working on the project and how well the collaboration between FHNW and CSEM is working."

Dipl.-Ing. Andreas Schimanski, CEO at Aigys AG

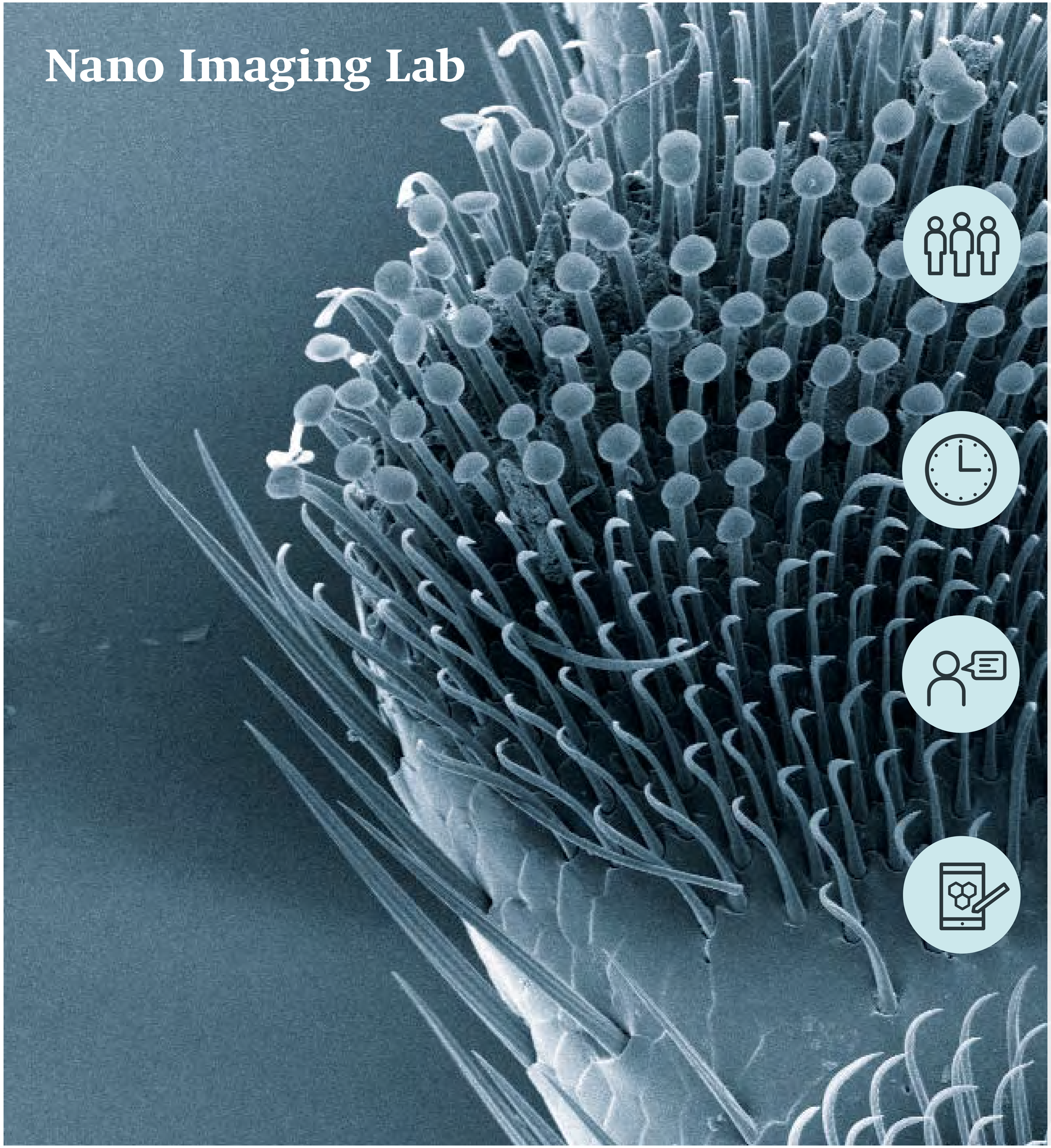


Prototype of the new redox flow cell: In the center is the cell in which the electrochemical reaction takes place. Storage vessels with the electrolytes are placed at the outside and in between, pumps transport the electrolytes in the two separate circuits. (Image: FHNW and CSEM)



The hydrogels used in the Nano Argovia project DeePest support the accumulation of pesticides, which are then detected in a second step. (Image: M. Olesinska, FHNW)

Nano Imaging Lab



5

At the Nano Imaging Lab, a team of five experienced, expert staff work to fulfill customers requests as well as advising on and researching a variety of topics.

2,740

Despite the Covid-19 pandemic, the associated lockdown and the restricted access to the NI Lab, the various microscopes in the Nano Imaging Lab were in operation for approximately 2,740 hours in 2020.

100

In 2020, the Nano Imaging Lab team worked for 100 different customers.

155

The Nano Imaging Lab has processed 155 orders, 28 of which were from industry. Orders often include several working steps and can last a few hours to several weeks or months.

Feet of a ladybird (Image: S. Erpel, Nano Imaging Lab, Swiss Nanoscience Institute, University of Basel).

Virtual tour and instructions
Videos used for block courses

The annual block courses are an intensive and exciting time for members of the Nano Imaging Lab (NI Lab). As part of the block courses, the lab's well-coordinated team offers students of molecular biology and the nanosciences an insight into the world of electron microscopy. In 2020, the coronavirus pandemic meant it was impossible to run the courses as normal, and so the NI Lab team produced several videos in order to present the lab and demonstrate the sample preparation process to students.

Too many students for classroom teaching
This year, 49 microbiology students had registered for the "Praktikum Mikroskopie" block course, which is always held at the start of the fall semester. Although things were a bit more relaxed in terms of the coronavirus situation over summer, it was already clear in August that such a large number of students could not be taught onsite. The NI Lab team therefore decided to introduce the students to the fascinating world of electron microscopy by video.

By way of introduction, Dr. Markus Dürrenberger and Dr. Christel Möller created a virtual tour of the NI Lab's facilities. During the tour, Markus Dürrenberger briefly explained how an electron microscope works. The students then learned about all of the microscopes available at the NI Lab and were given an overview of the features of various devices by the NI Lab staff.

Detailed introduction to sample preparation
More in-depth detail was provided by two further videos, in which Evi Bieler, Susanne Erpel and Daniel Mathys demonstrated the preparation of samples that are to be examined using the two scanning electron microscopes.

The first step in preparing individual cells for analysis is to subject the samples to a step-by-step drying process using liquid carbon dioxide. The samples are then coated with an extremely thin layer of gold to allow them to be examined with an electron microscope. In one video, Susanne Erpel not only showed the individual steps but also gave a clear explanation of the theory behind them.

Evi Bieler demonstrated how the surfaces of plants must be treated prior to examination with a cryo-scanning electron microscope (cryo-SEM). Rapid freezing of the sample in liquid nitrogen, combined with low temperatures during analysis, results in the preservation of even the tiniest structures such as villi, wax structures on leaf surfaces, or mycelium and allows them to be examined in detail with the cryo-EM.

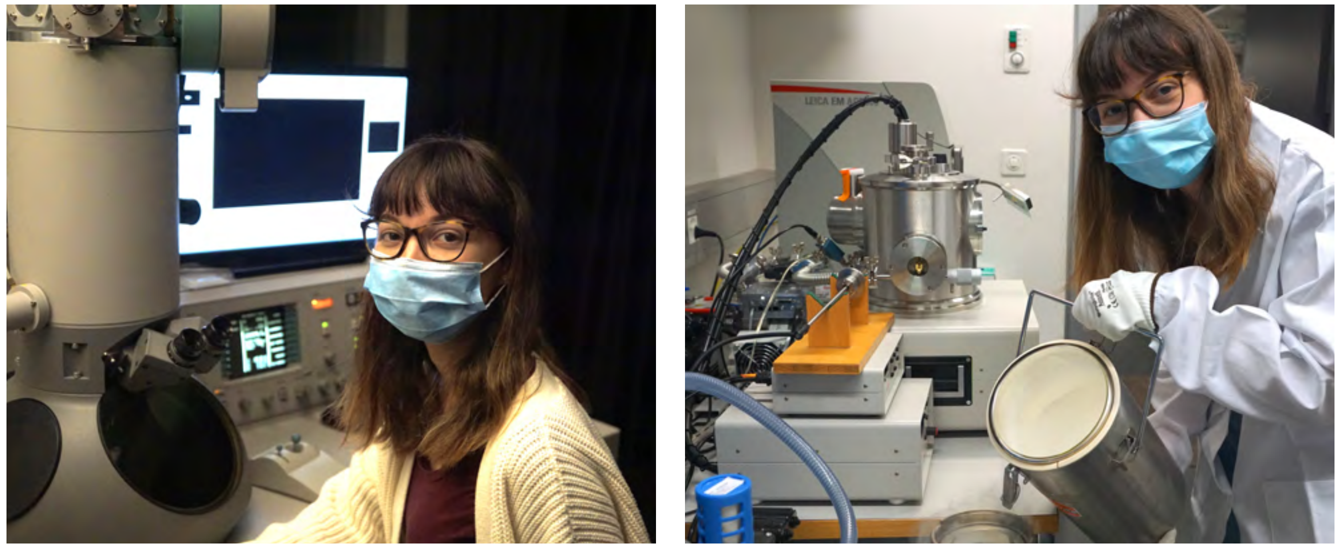
Little time for preparation

"I want to thank the Nano Imaging Lab team, who did everything they could to make it a successful and interesting block course despite the current situation.

The images produced during the REM session certainly drew a lot of enthusiastic looks from fellow students!"

Alexa Dani, bachelor's student on the nanosciences degree program

The cryo-EM is cooled using liquid nitrogen so that the samples remain deep-frozen even during analysis and tiny structures are therefore preserved.



Nanoscience students had the chance to gain some practical experience.

The NI Lab team produced the videos at short notice and without much planning so that the block course could at least take place in digital form. Several other videos on YouTube showing the application of the microscopes were used as additional teaching materials, along with the usual written instructions.

A change of plans
This fall's three-week block course for budding nanoscientists was actually planned as a classroom course, as the intake of nine students allowed good compliance with the protective measures stipulated by the University of Basel. Spread across different rooms and microscopes, the first week of the course was delivered almost as normal, allowing all of the students to create a few images of their own on the cryo-SEM.

In the first few days of the course, however, there were already a number of absences as students had to go into quarantine. Then, the University's protective measures were changed at short notice, preventing the remainder of the course from being held. In the end, the nanoscience students therefore also had to be taught virtually.

Materials can continue to be used
As in so many areas, the coronavirus pandemic has necessitated a high degree of flexibility – and a switch-over to virtual methods – when it comes to the block courses operated by the Nano Imaging Lab.

In the future, however, the resulting video materials will continue to be useful for demonstration purposes once everyone is able to meet onsite at the laboratory again.

In addition, a short version of the virtual tour is now used on the website to provide potential customers with a brief introduction to the Nano Imaging Lab (https://nanoscience.ch/de/services/nano-imaging-lab/).

Despite the safety concept, the Nano Imaging Lab team was unable to hold the block courses in person in 2020. Instead, the team produced videos presenting the NI Lab and demonstrating various different methods.

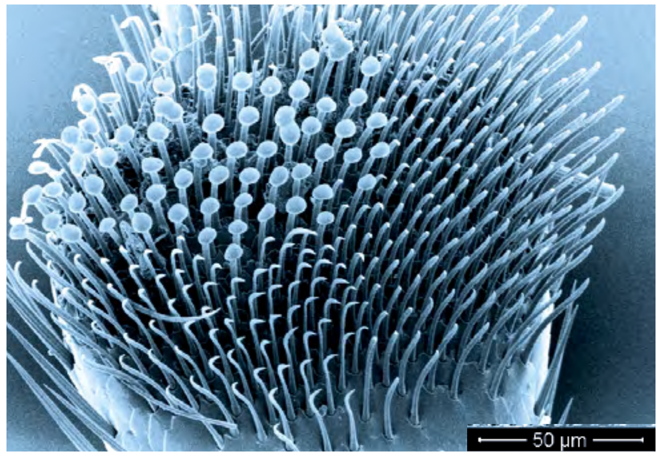
Sticky feet and formidable jaws

Nano Imaging Lab lends a hand with pupils' research projects

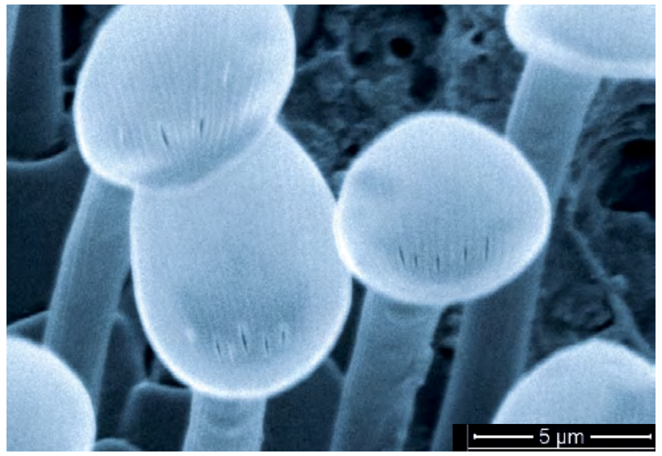
In 2020, the Nano Imaging Lab (NI Lab) once again supported projects by pupils taking part in the "Jugend forscht" youth science competition in Germany. Striking images taken with a scanning electron microscope provided important insights and substantially enriched the impressive projects. Insects were the focus of both projects this year: one examined ladybirds and their ability to adhere to vertical surfaces, while the other was about leafcutter ants and their preference for sweet leaves.

Walking up walls

The first team of pupils – Leonhard Roth and Martin Scholten from the Hans-Thoma-Gymnasium in Lörrach (Germany) – wanted to find out whether the ability of ladybirds to adhere to vertical surfaces could be explained by capillary forces. The pair had pondered this fascinating question with Dr. Thilo Glatzel of the University of Basel's Department of Physics, working at the phænovum research center in Lörrach. Thilo Glatzel, a long-standing SNI member, has been active at the phænovum center for years, supervising pupils who tackle nanoscience-related research issues in their free time.



Ladybird feet are covered in numerous tiny hairs, of which there are four different types. (Image: S. Erpel, Nano Imaging Lab, SNI, University of Basel)



Some of the hairs exhibit small slits that release a special secretion. (Image: S. Erpel, Nano Imaging Lab, SNI, University of Basel)

The two young researchers began by studying the morphology of ladybird feet with a scanning electron microscope (SEM) at the Nano Imaging Lab (NI Lab). NI Lab employee Susanne Erpel instructed and assisted the pupils so as to enable them to capture their own SEM images, which revealed that the feet are covered in tiny hairs. They were able to distinguish four different types of hair, besides observing that the insects' middle foot had a different structure to the front and back feet. One of the hair types featured tiny slits, which they presumed to be outlets for a liquid secretion that might play a key role in adhering to surfaces.

Theory confirmed

Leonhard and Martin started breeding their own ladybirds to make sure they always had plenty of specimens on hand for their research. They allowed the tiny beetles to walk across carefully cleaned microscope slides, and then examined the resulting tracks under the atomic force microscope. In the images obtained, they were able to identify not just the footprints, but even the marks left behind by each individual hair as well. These tracks confirmed their theory that the hairs toward the front of the foot release a secretion that contributes significantly to the insects' grip.

Finally, the two pupils measured the adhesive forces at play in a ladybird's footprint. "The figure we reached was many times greater than the adhesion a ladybird would need to hang upside down from the ceiling," the two young researchers report.

Sweet tooth or clever gardening technique?

The second project supported by the NI Lab was devoted to leafcutter ants. Julia Kernbach and Noah Hohenfeld, also from the Hans-Thoma-Gymnasium and the phænovum center in Lörrach, had already discovered in a project carried out in cooperation with the Natural History Museum in Basel that the leafcutter ant *Atta cephalotes* prefers to harvest rose petals over leaves.

In that project, the two young researchers had figured out that this preference was connected to the sugar contained in the petals. However, it remained unclear whether it was the ants themselves that preferred the sugary treats, or whether this was a clever gardening technique for the benefit of the fungus they cultivate.

Optimizing fungus growth

In a second study, this time involving *Atta colombica* ants – and once again supervised by Dr. Christiane Talke-Messerer and Dr. Ulla Plappert of the phænovum center – Julia and Noah fed the ants privet leaves that they had previously doctored with different substances. They observed that the ants were especially quick to choose leaves that had been soaked in glucose – the higher the concentration, the better.

What is more, the fungus that the ants cultivate and feed on grows faster in a culture medium containing glucose or malt extract – lending support to the hypothesis that the ants select the leaves they cut up and feed the fungus with deliberately to accelerate its growth.

Dr. Monica Schönenberger of the NI Lab helped the team identify the fungus using laser scanning microscopy, while Susanne Erpel used a scanning electron microscope to image the mouthparts of the various ant types, responsible for different tasks in the colony.

These images confirm that both the size of the ants and the structure of their mouthparts are heavily dependent on their role in the community.

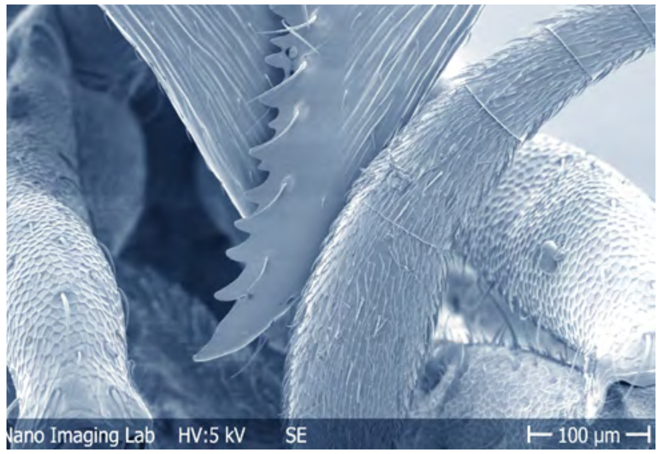
Although the two pupils were unable to come to the NI Lab themselves due to the coronavirus restrictions, they were delighted with the images sent to them by their supervisor and Susanne Erpel. "We observed that toward the end of the experiment the ants in the colony were only cutting a very small number of leaves," the two young researchers report. "The images from the NI Lab revealed that the mouthparts of the forager ants were heavily worn." This provided additional evidence for the theory that the ant colony, which the pupils had received from the University of Würzburg, was in a terminal stage in which no new offspring are hatched.

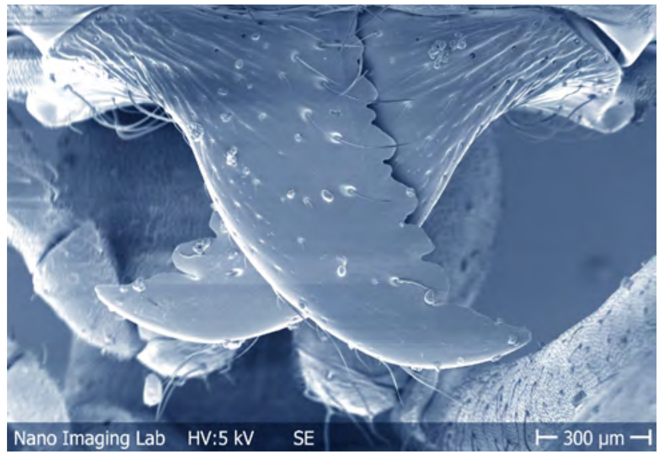
Best of luck

Both projects were submitted to the "Jugend forscht" regional competition at the end of February 2021 in Freiburg (Breisgau), and with a little luck the young researchers will progress to subsequent competitions at the state and national level.

"We were delighted with the fantastic images and helpful support!"

Dr. Christiane Talke-Messerer, department head at the phænovum center in Lörrach (Germany)





Leafcutter ants perform different functions within the colony. This is reflected not just in the variation in body size, but also in the different constitution of their mouthparts. (Images: S. Erpel, Nano Imaging Lab, SNI, University of Basel)

Positive Feedback
Nano Imaging Lab surveys its customers

To form a clearer picture of its customers' satisfaction level and wishes, the Nano Imaging Lab team conducted a short customer survey. Responses were submitted by around 10 percent of those contacted, all of whom were satisfied with the services offered by the NI Lab. They were especially impressed by the employees' high level of expertise and the usefulness of the results achieved by them. A few comments included suggestions for potential improvements to the NI Lab's equipment portfolio.

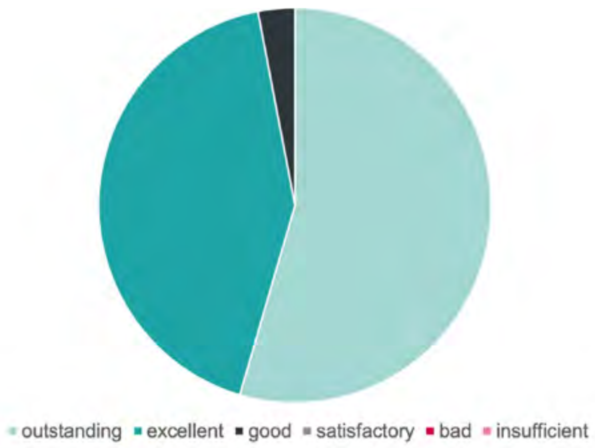
Wide-ranging service
The Nano Imaging Lab offers its customers an extensive range of imaging services. The lab's five experienced employees can either conduct sample preparation and measurements themselves, or advise customers on using the nine microscopes available in the lab. Depending on their specific research question, customers can choose from scanning electron microscopy, transmission electron microscopy, atomic force microscopy, confocal microscopy and focused ion beam technology.

The NI Lab team generally receives positive feedback from its customers. However, in order to find out where exactly it could do better, what its customers appreciate and what they feel is missing, the NI Lab decided to survey everyone who has made use of the NI Lab's services in the last few years.

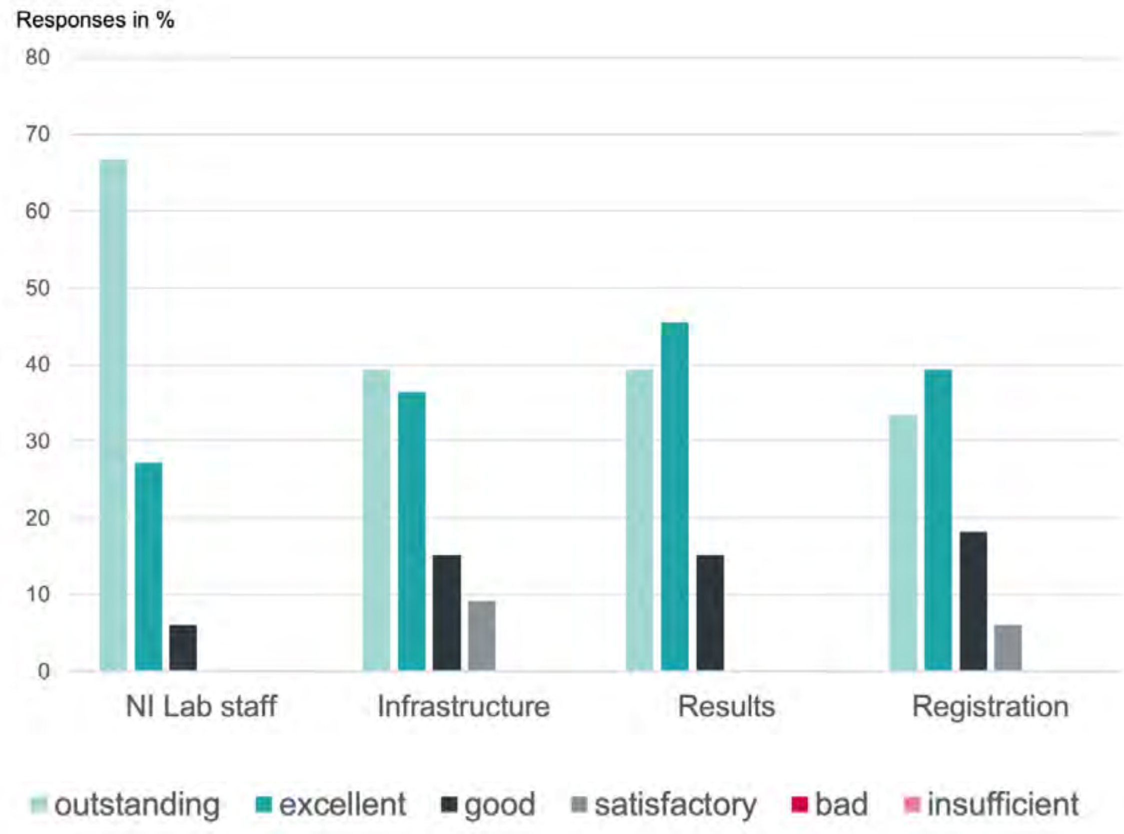
Feedback primarily from within the University of Basel
Thirty-three people responded to the survey. Over 80% of them belong to the University of Basel, compared to 12% from industry or a start-up. The majority work in the field of physics and materials science (60%), though researchers from the life sciences also frequently engage the NI Lab's services (22% of all customers). Chemistry-related disciplines comprise a somewhat smaller segment (15% of customers).

Most of the respondents heard about the NI Lab from a colleague or supervisor (57% and 39% respectively). Only 12% of customers found out about the lab's extensive range of services via its website. Nevertheless, the information available there is rated very highly, with over 60% of respondents describing the information provided on the website as "excellent" or "outstanding".

Top marks for service
A very gratifying result of the survey is the general level of satisfaction with the service provided by the NI Lab team, which 97% of customers rated either "excellent" or "outstanding".



A total of 97% of survey respondents reported a high level of satisfaction with the Nano Imaging Lab's service, rating it either "excellent" or "outstanding".



The responses show that overall, customers were very pleased with the expertise and skills of the NI Lab employees and the results of the analyses performed. The technical infrastructure was rated "good" or higher by over 90% of respondents, while most were also happy with the registration process.

In particular, customers praised the NI Lab employees' expertise and skills. A total of 94% of customers who gave feedback described the employees as excellent or outstanding.

All of the respondents expressed satisfaction with the results they received from the NI Lab. The technical infrastructure also received an overall rating of "good" or higher. In most cases, the registration process also went smoothly, earning it a positive assessment.

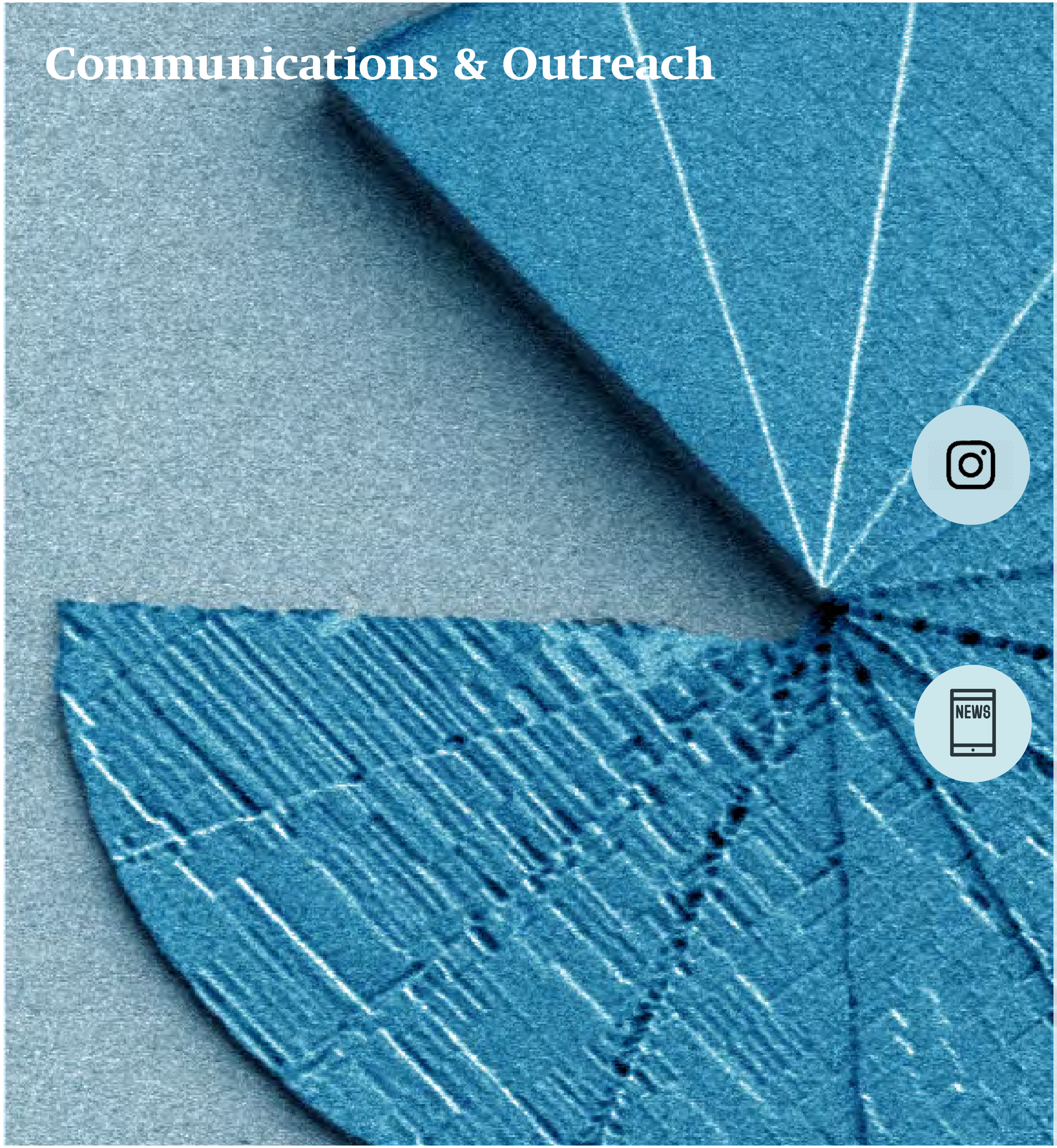
The survey respondents used very different equipment at the NI Lab. Around 30% worked with the transmission electron microscope, 36% used one of the three scanning electron microscopes, and 39% used an atomic force microscope.
Suggestions under consideration

Overall, the NI Lab team is very pleased with the customer feedback it received. Several comments mention some very specific points that will be carefully examined and addressed over the next few months.

"Collaboration with the Nano Imaging Lab is outstanding. The equipment is of a very high standard, and extremely helpful to our research. Thanks to the team's highly competent and helpful efforts, we have been able to generate and jointly publish numerous new scientific findings. In other words, we see no reason to change anything."

Comment from a customer whose name is unknown due to the anonymous nature of the survey

Communications & Outreach



> 1,940

By the end of 2020, the SNI's social media channels had 1,942 followers: 1,332 were interested in the SNI on LinkedIn, 326 on Twitter, 149 on Instagram, and 135 on YouTube. The SNI attracted more than twice the number of followers in comparison with 2019 (2019: 822 followers).

> 250

In 2020, we collected more than 250 media reports about the SNI's research and activities. For the most part, these were based on fourteen media releases drafted by the SNI in collaboration with the communications department of the University of Basel.

Using grayscale electron beam lithography, tiny three-dimensional structures can be produced. (Image: T. Mortelmans, SNI PhD Student, PSI and University of Basel)

Flexible solutions
Communication and outreach during the coronavirus pandemic

The SNI communication and outreach team had so much planned for 2020, but many of the events had to be shelved for the time being due to the coronavirus pandemic. Rather than interacting with visitors in person at the Swiss NanoConvention, at science fairs and on school visits, the team opted to produce digital programs instead. Thanks to a great deal of enthusiasm and imagination, this initiative resulted in a diverse collection of videos that were met with a very positive response and will prove useful for subsequent outreach activities.

A difficult year for events

For the SNI team, holding the Swiss NanoConvention was expected to be one of the highlights of 2020, and preparations for the event were in full swing at the start of the year. Given the uncertain circumstances, however, the organizing committee decided in May to postpone the international conference until 2021. Numerous other activities, such as school visits, the SNI's internal annual event or the Nano-Tech Apéro, which all entail direct contact and face-to-face discussions, were initially planned but then canceled – with a heavy heart – due to safety concerns.

"At the start of the year, we were still confident that we'd be able to hold the SNC and a number of other events," recalls Dr. Kerstin Beyer-Hans. "By spring, however, it had become clear that this would not be possible and that the year would be very different from the one we had planned."

New plans implemented on a flexible basis

In March, all SNI staff suddenly found themselves working from home – and, from one day to the next, contact with visitors or researchers was no longer possible. Faced with this situation, Dr. Michèle Wegmann, Dr. Kerstin Beyer-Hans and Dr. Christel Möller came up with the idea of producing short videos of experiments at home. The aim was for the experiments shown in the videos to be easy to perform using household materials. "We wanted to encourage people to take advantage of the unusual, shared experience of the coronavirus pandemic, with children not going to school or kindergarten for some time, in order to carry out experiments together as a family," explains Michèle Wegmann.

It began with an experiment in which red cabbage juice was used as an indicator for the pH of different solutions, such as lemon juice or household cleaner. This was followed by various experiments examining the miscibility of different substances. As well as the construction of a magnetic racetrack, there were also experiments relating to magnetism and ice. The team showed that fascinating experiments can lead to eureka moments even with more-abstract topics such as sound, electricity and air.

The SNI team produced numerous short videos about experiments that everybody can perform at home with household materials, and provided easy-to-understand explanations of the various exciting phenomena.

"We really appreciate the series of experiments from the Swiss Nanoscience Institute because they're such a good opportunity to get to know the world of natural sciences by experimenting together at home and using common household materials."

Heusler family, Basel

Experiments relating to sound were also the theme of the UniKids Camp that children attended in summer. This was one of the few events that could be held in person this year – albeit subject to safety measures.

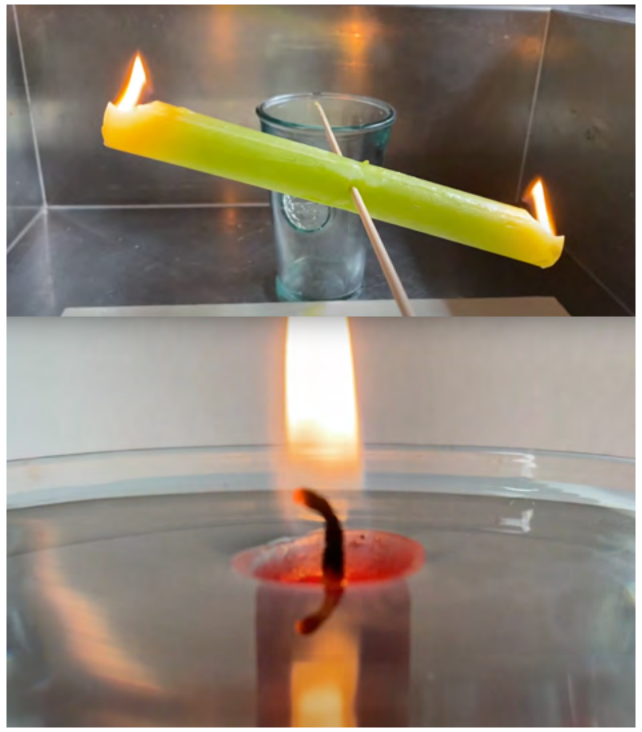
Numerous visitors to the YouTube channel

For the experiment-at-home campaign, the staff from the SNI created a dedicated "Experiments and projects" page on the SNI website and uploaded all of the videos to the SNI YouTube channel. The number of visitors to the channel peaked over Easter after several local newspapers reported on the campaign and recommended the experiments relating to eggs in particular. There was a similar response when new, festive experiments were added during Advent. From the start of the experiment-at-home campaign to the end of the year, the YouTube channel was visited by a total of 32,000 people of a wide range of ages – with the age group between 35 and 44 being the most active.

Prizes for active feedback

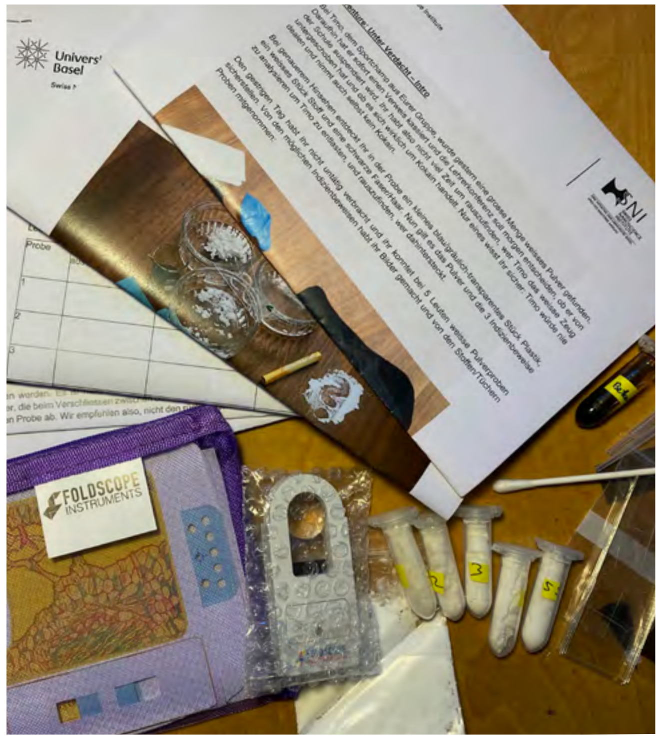
In order to obtain feedback and encourage as many children and adults as possible to get involved, regular competitions – with book vouchers as prizes – were held until July for those who submitted photos or videos of their experiments. "We were actually hoping to receive images of the experiments we'd presented, and we were pleasantly surprised when people sent in completely new experiments of their own," says Christel Möller.

To round off this spontaneous campaign, the SNI team raffled off an iPad mini at the start of September. The six-year-old winner, Alyssa, was delighted with her prize and will remember the numerous experiments for a long time.

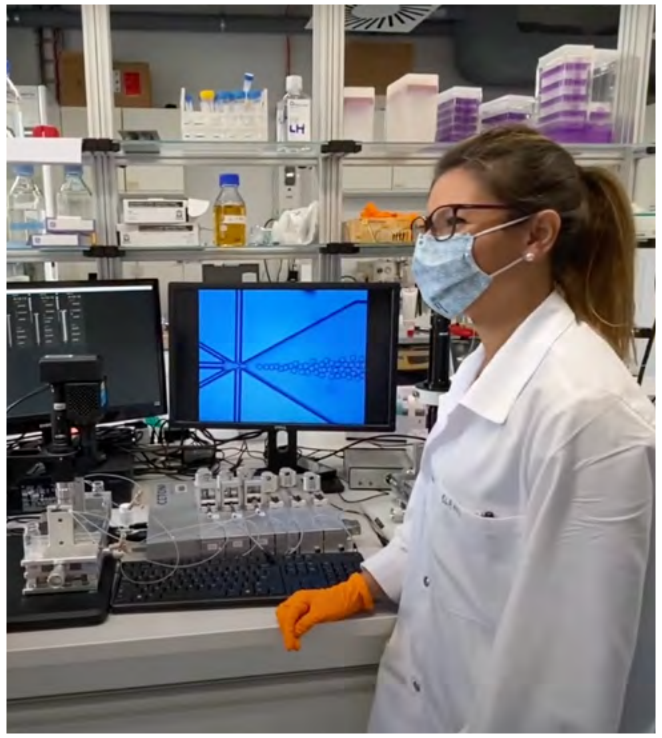


The atmospheric experiments during the holiday season were very well received.

Alyssa experimented a lot and then was the lucky winner.



At the Science Days digital, young researchers were able to solve a fictional criminal case.



Short videos also illustrated scientific news in 2020 and helped to promote new projects in the SNI PhD School.

Part of the virtual Science Days
The videos, over 40 of them in total, were also used for the Science Days of Europa Park Rust. This 20-year-old science festival was held virtually this year, offering school groups as well as other children and young people the chance to take part in numerous virtual events from 19 October to 29 November – what they did, as the number of 79,000 visitors on the main web page of the Science Days digital demonstrates.

The SNI also made its experiment videos available for the festival. In addition, Kerstin Beyer-Hans had developed a series of experiments that could be used to solve a fictional criminal case. School classes and individuals were sent a set of various tests that – if interpreted correctly – would lead them to the "culprit". Videos and descriptions also helped the detectives reach the right conclusion.

Videos about research projects
In early fall, when things were a bit more relaxed in terms of the coronavirus situation, the SNI team also had the chance to produce a number of videos about research projects.

Firstly, project leaders beginning a new project at the PhD School in 2021 had the opportunity to present their project in a video. Secondly, short videos on new developments in research served as an excellent accompaniment to media releases. The videos offered an entertaining way to present a number of research topics and circulate them on social media.

“I really enjoyed the experiments.
The set was well designed and very comprehensive, and everything worked perfectly – the instructions were great, and I felt like I was in a real experimental lab. I hope there’s a new case to solve one day.”

Mika Jehle, Wintersweiler, Germany

The SNI team continued to expand its use of social media in 2020. The SNI's LinkedIn page was particularly successful. By the end of the year, it had attracted more than 1,300 followers. The total of 61 updates generated over 70,000 impressions. The 86 tweets on the SNI Twitter channel generated over 95,000 impressions. 326 followed the SNI Twitter channel by the end of the year.

Exhibition at the museum
In 2019, the outreach and communication team had already participated in the planning and implementation of an exhibition about soap at Museum Burghalde in Lenzburg. Although the exhibition "Saubere Sache" was actually supposed to open in March 2020, the temporary closure of all museums meant it would be June before the first visitors to the museum could experience the fascinating world of soap – a topic that has become more pertinent than ever as a result of the coronavirus pandemic.

The SNI team contributed videos explaining how soap works and its production from a chemical perspective, and describing how surfaces stay clean in nature without any soap at all.

In addition, the SNI staff developed instructions for small experiments that visitors can perform at any time in the exhibition’s soap lab. They also provided materials for the nano-themed island all about the lotus effect as part of the special exhibition, as well as for a pop-up exhibition at the museum.

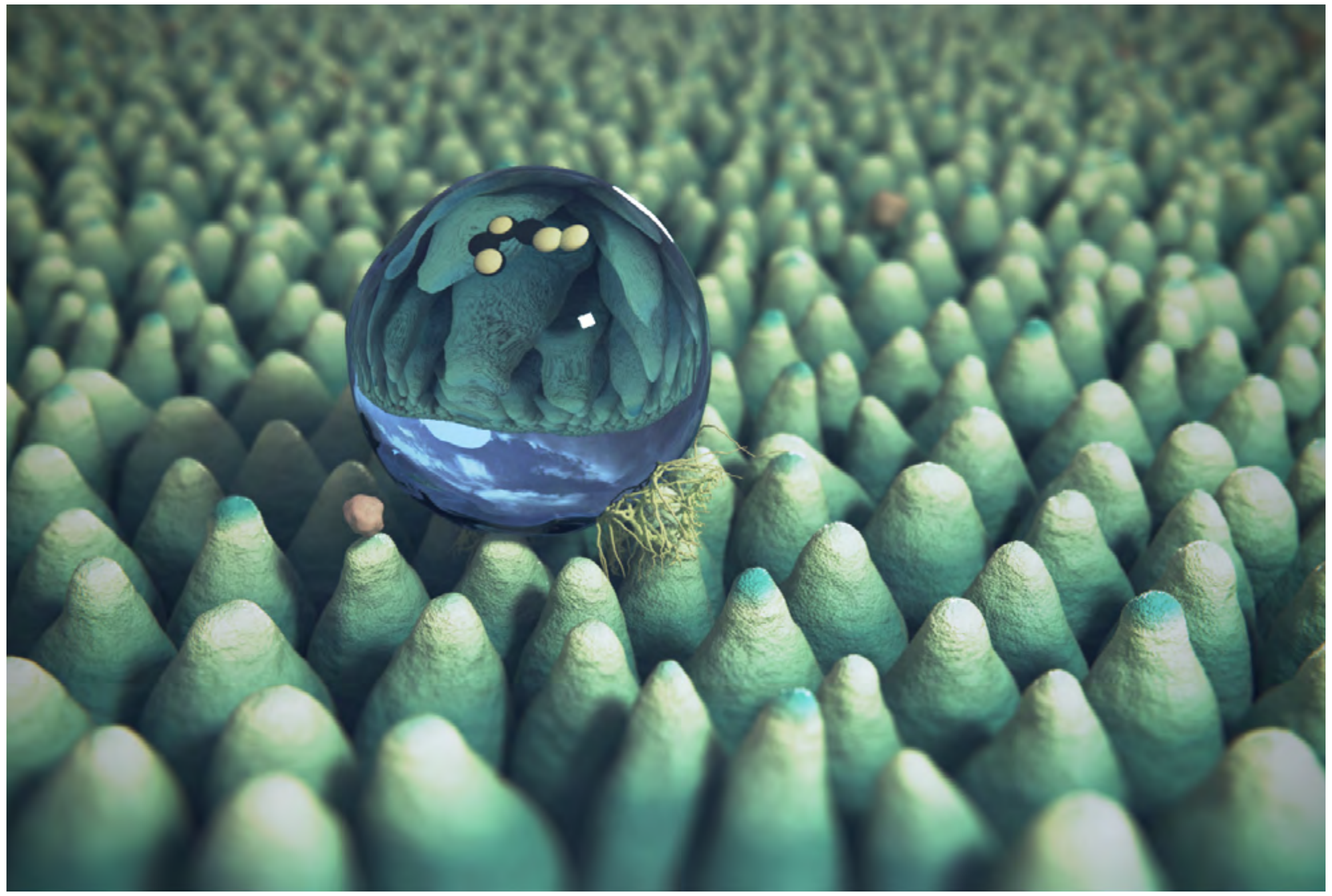
Moreover, the team also participated in a "soap weekend" in August and offered workshops where children and adults could create their own favorite soaps.

TecDays now also online
The TecDays organized by the Swiss Academy of Engineering Sciences was also largely canceled this year. As the year drew to a close, however, the first virtual TecDay was held in Wohlen and featured a new program on nanomedicine that the SNI team had developed for the event.

SNI lecture on SARS-CoV-2
In September 2020, the SNI had hoped to meet for its annual event in Lenzerheide. As infection numbers began to rise again at the end of summer, however, the SNI management team took the decision to cancel the event.

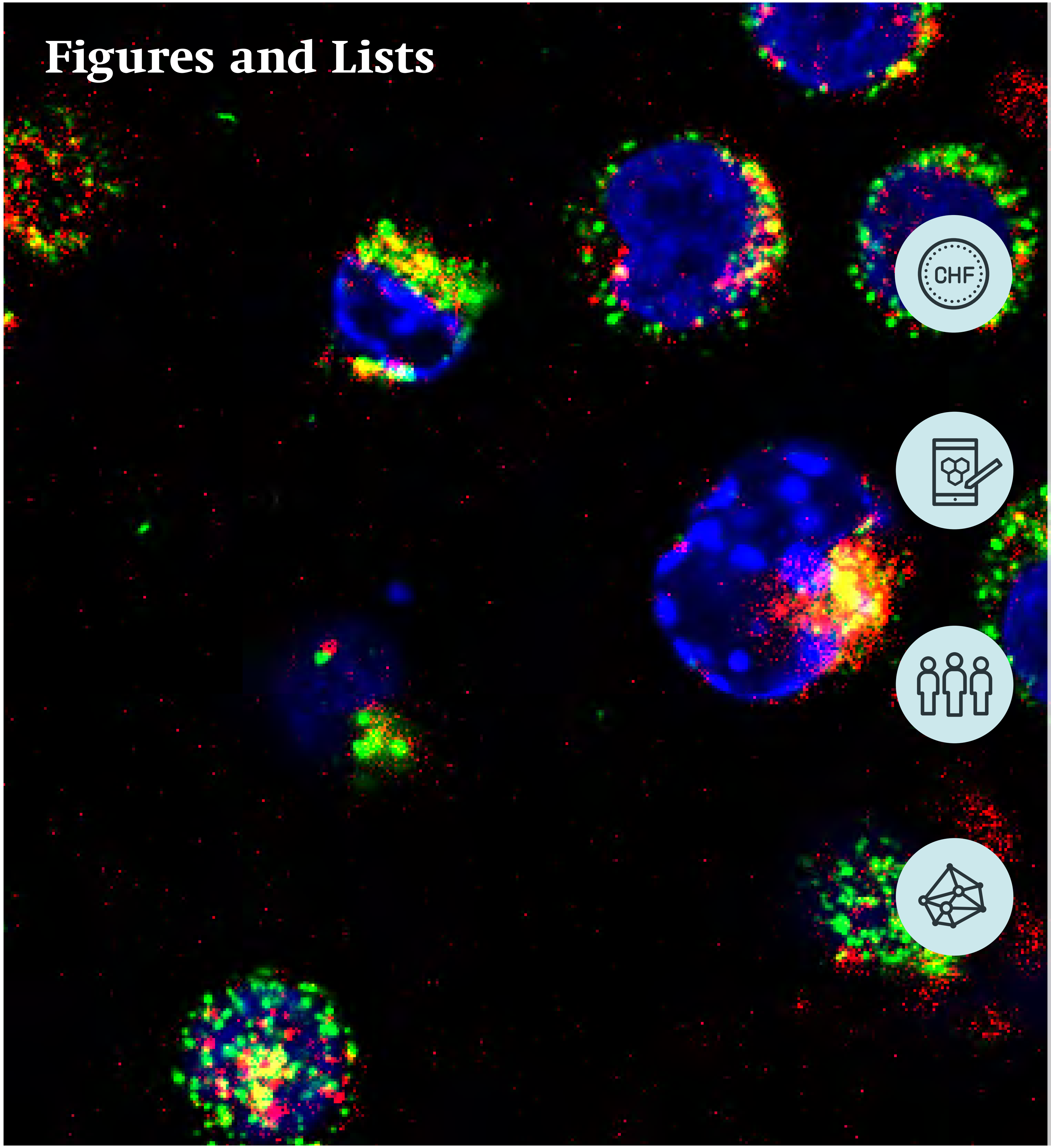
Nevertheless, Professor Richard Neher from the Biozentrum of the University of Basel delivered the planned late-night lecture virtually, allowing him to reach a larger audience than would have been present at the SNI Annual Event. His interesting talk on the SARS-CoV-2 virus offered participants a fascinating insight into the spread and development of the virus that has had such a profound impact on the way we live and work in 2020.

YouTube channel: https://www.youtube.com/channel/UC-bR9khNxj-XbhcSu7_cCOVw/featured
Twitter account: https://twitter.com/SNIunibas
Linkedin company page: https://www.linkedin.com/company/swiss-nanoscience-institute/?viewAsMember=true



The SNI produced videos for the exhibition "Saubere Sache" at the Burghalde Museum in Lenzburg that explain how soap works and how plants keep their surfaces clean even without soap thanks to the lotus effect. Due to tiny, wax-like structures, water simply rolls off the surfaces, taking dirt particles with it. (Image: scixel)

Figures and Lists



> 8 M

In 2020, the SNI had expenditures of more than CHF 8 million of which 5.4 million were covered by the Canton of Aargau and 2.7 million by the University of Basel.

50

The SNI supported 50 research projects, 11 in the applied Nano Argovia program and 39 in the SNI PhD School.

151

In 2020, the SNI had 151 members.

9

Nine partner institutions belong to the SNI network. This includes the University of Basel, the School of Life Sciences and School of Engineering at the University of Applied Sciences and Arts in Northwestern Switzerland (FHNW), the Paul Scherrer Institute, the Department of Biosystems Science and Engineering at the Federal Institute of Technology (ETH) Zurich in Basel, the Centre Suisse d'Electronique et de Microtechnique (CSEM) in Muttenz, and the technology transfer center ANAXAM. The Hightech Zentrum Aargau and BaselArea. swiss supplement the network.

Selective internalization of nanoparticles by cancer cells. Components of the nanoparticles were stained red and green with fluorescent dye and nuclei of the cancer cell were stained blue fluorescent dye. The image was taken with a laser scanning confocal microscope (X20)
(Image: M. Saxena, TargImmune Therapeutics and M. J. Skowicki, C. Palivan, University of Basel)

Financial report

The Swiss Nanoscience Institute (SNI) was founded at the University of Basel in 2006. It was initiated by the Canton of Aargau with the goal of gaining new insights through scientific research, supporting knowledge and technology transfer in collaboration with industrial companies from Northwestern Switzerland, and serving as a center for the training of young scientists. These core aspects – teaching, basic research, applied research, along with knowledge and technology transfer – are reflected in the SNI's finances.

Focus on basic research
Basic research plays a vital role at the SNI. Accordingly, the SNI supports the work of the two Argovia Professors at the University of Basel, Roderick Lim and Martino Poggio, as well as that of three titular professors at the PSI. In all, the funding for these professors amounts to roughly CHF 1.5 million. In 2020, both Argovia Professors once again made a substantial contribution to the SNI's outstanding global reputation with their scientific research and the papers published by their teams. Together, Roderick Lim and Martino Poggio secured external funding of around CHF 1.4 million from Switzerland and beyond in 2020. Martino Poggio is also active in the ANAXAM technology transfer center, and represents the SNI on the association's board.

A substantial amount of basic research is conducted by the doctoral students at the SNI PhD School, founded in 2012. A total of 39 doctoral students were enrolled in the SNI PhD School in 2020. While their doctorates will all be awarded by the Faculty of Science at the University of Basel, much of their work takes place at various institutions of the SNI network. The SNI PhD School had outgoings of more than CHF 1.7 million in 2020. Six doctoral students completed their dissertations in 2020. In 2020, we temporarily increased the number of new PhD projects to eight, and were able to fill the corresponding positions over the course of the year.

Transfer to industry plays central role
The highly successful Nano Argovia program allows findings from basic research to be passed on to industrial companies in Northwestern Switzerland. Along with PR measures (knowledge and technology transfer: KTT & PR), the Nano Argovia program received around CHF 1.7 million in 2020.

Launched in 2007, the Nano Argovia program is tailored to the needs of industrial companies and is now very well established. Undaunted by the difficulties arising from the coronavirus pandemic, numerous teams from the SNI network once again applied for the chance to execute their applied research ideas in collaboration with an industrial company from Northwestern Switzerland.

Fourteen Nano Argovia projects were active in 2020, four of which had been extended for a number of months on a cost-neutral basis (only one project was granted a cost-neutral extension until the end of the year, meriting an entry in the annual report). Ten of the industry partners were from the Canton of Aargau.

The project partners contributed approximately CHF 1.6 million to the applied Nano Argovia projects via public research funding instruments (e.g. Innosuisse, Swiss National Science Foundation, EU funding) and funding from the research institutions themselves. The industrial partners contributed around CHF 1 million in the form of in-kind services.

Outstanding service
The services and research of the Nano Imaging Lab (NI Lab) have made it a fundamental part of the SNI. The lab provides a valuable service, supporting the imaging requirements of research projects. In 2020, the NI Lab was involved in projects in collaboration with the ANAXAM technology transfer center for the first time. Despite the lockdown restrictions and coronavirus-related safety measures, in 2020 the team was once again able to offer SNI members, companies and academic partners valuable analyses and microscope imaging (electron microscopy and scanning probe microscopy) of nanoscale samples, in addition to advising partners on their research projects.

Study and outreach
In all, 79 students were enrolled in the nanoscience program in 2020 – 47 in the bachelor's and 32 in the master's program. The budget for this item is over CHF 0.4 million. Efforts to advertise the nanoscience study program were hindered by the coronavirus pandemic. The scope for attending fairs or visiting schools was severely limited. Accordingly, the SNI had to limit communications to electronic formats and adverts to let people know about the challenging study program, which remains the only one of its kind in Switzerland.

Other outreach activities in 2020 also had to be canceled or moved online as a result of the pandemic. As a result, only CHF 35,000 were spent on outreach in 2020. Meanwhile, increased social media activity meant that spending in the field of management rose in relation to 2019. Furthermore, the organization and execution of the Swiss NanoConvention had been planned for 2020, for which a trainee had been hired.

Investments for the future
In 2020, the SNI made a number of investments that will enhance the value of the SNI to its members and to the Northwestern Switzerland region over the next few years. These include investments in infrastructure and expenditure associated with the ANAXAM technology transfer center, of which the SNI is a founding member.

As a result, earmarked funds fell somewhat to CHF 7.7 million as of 31 December 2020. It should be noted in this regard that funding for projects at the PhD School must be planned for a period of 48 months, which means the funds are tied up for four years.

Other funds are already earmarked in connection with investments made by the SNI in infrastructure for the future that have not yet been activated. One such project is the partnership with ELDICO Scientific AG, headquartered at Park Innovaare. The SNI is contributing CHF 0.5 million to the "Electron Diffraction" innovation platform to be built at the Innovation Park Basel Area in 2021.

Accordingly, CHF 1.2 million that will not come into effect until 2021 are to be deducted from this balance, yielding an actual balance of around CHF 6.5 million.

To conclude, we would like to extend our hearfelt thanks to the Office of Finance and Controlling at the University of Basel for its efficient reporting. Many thanks are also due to the Cantons of Aargau, Basel-Stadt and Baselland for supporting the SNI. The commitment of these three cantons is what makes it possible for us to train outstanding young scientists, conduct research at the highest level and transfer our findings to companies in the region.

The following table shows expenses for 2020 by category in accordance with the financial report of the University of Basel dated 26 February 2021.

Expenditure 2020 in CHF

		Univ. Basel	Canton AG	Total
Management	Personnel and operational costs	445'200	277'276	722'476
	Overhead	—	650'000	650'000
Infrastructure	Infrastructure building	—	—	—
	Infrastructure equipment	54'143	663'217	717'360
KTT & PR	Personnel and operational costs	55'586	303'506	359'091
	Nano Argovia projects	—	1'350'584	1'350'584
Outreach	Operational costs	14'971	19'258	34'229
Support	Argovia professorships	586'090	928'879	1'514'967
	PSI professors	—	52'999	52'999
Nano Study	Bachelor and master programs	257'305	177'623	434'927
Nano Imaging Lab	Personnel and operational costs	461'162	—	461'162
SNI PhD School	Research projects	786'762	961'598	1'748'360
Total expenditure 2020 in CHF		**2'661'219**	**5'384'940**	**8'046'159**

The following table shows the SNI balance sheet as of 31 December 2020.

SNI balance sheet 2020 in CHF

	Univ. Basel	Canton AG	Total
Grants	2'729'857	5'000'000	7'729'857
Investment income	73'715	292'681	366'396
Income	**2'803'572**	**5'292'681**	**8'096'253**
Expenditure	**2'661'219**	**5'384'940**	**8'046'159**
Balance year 2020	**142'353**	**(92'259)**	**50'094**
SNI assets per 01/01/2020	**1'716'787**	**5'950'611**	**7'667'398**
Annual balance	142'353	(92'259)	50'094
SNI assets per 31/12/2020 in CHF	**1'859'140**	**5'858'352**	**7'717'492**

SNI members

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S. Chambers (Coordination Nanocurriculum)
J. Isenburg (Coordination Nanocurriculum) (until 31 January 2020)
Dr. K. Beyer-Hans (Communications & Outreach)
S. Hüni (Communications & Outreach)
Dr. C. Möller (Communications, media contact & social media)
Dr. M. Wegmann (Communications, outreach & social media)

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Dr. M. Dürrenberger (NI Lab, SNI)
Prof. Dr. C. E. Housecroft (Chemistry)
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Prof. Dr. H.-F. Zeilhofer (Associate Vice President Innovation, University of Basel)

Nano Imaging Lab
E. Bieler
Dr. M. Dürrenberger
S. Erpel
D. Mathys
Dr. M. Schönenberger-Schwarzenbach

Principal Investigators, project partners, and associated members
Prof. Dr. J. P. Abrahams, Biozentrum, University of Basel and Paul Scherrer Institute
PD Dr. A. Banfi, Department of Biomedicine, University of Basel and University Hospital Basel
Dr. A. Barfuss, Semiconductors, Automotive Electronics, Robert Bosch GmbH
Dr. A. Baumgartner, Department of Physics, University of Basel
Prof. Dr. J. Benenson, Department of Biosystems Science and Engineering (D-BSSE), ETHZ Basel
Dr. P. Boillat, Laboratory for Neutron Scattering and Imaging, Paul Scherrer Institute
Dr. F. Braakman, Department of Physics, University of Basel
Dr. T. Braun, Biozentrum, University of Basel
Prof. Dr. M. Calame, Department of Physics, University of Basel and Empa
Prof. Dr. E. Constable, Department of Chemistry, University of Basel
Dr. M. Delley, Department of Chemistry, University of Basel
Prof. Dr. M. de Wild, School of Life Sciences, University of Applied Sciences Northwestern Switzerland
Dr. J. Dreiser, Microscopy and Magnetisms, Paul Scherrer Institute
Dr. Y. Ekinci, Laboratory for Micro- and Nanotechnology, Paul Scherrer Institute
Prof. em. Dr. A. Engel, SNI Honorary Member, TU Delft
Dr. T. Einfalt, Department of Pharmaceutical Sciences, University of Basel
Dr. R. Ferrini, CSEM SA, Muttenz (BL)
Dr. S. Fricke, CSEM SA, Muttenz (BL)
Dr. B. Gallinet, CSEM SA, Muttenz (BL)
Prof. Dr. C. Gerber, SNI Honorary Member, Department of Physics, University of Basel and NanoMotion
Prof. Dr. O. Germershaus, School of Life Sciences, University of Applied Sciences Northwestern Switzerland
Dr. M. Gerspach, BÜHLMANN Laboratories AG
Dr. T. Glatzel, Department of Physics, University of Basel
Prof. Dr. J. Gobrecht, SNI Honorary Member
Dr. T. Grüne, Centre for X-ray Structure Analysis, Faculty of Chemistry, University of Vienna
Dr. C. Grünzweig, Technology transfer center ANAXAM
Dr. M. Gullo, School of Life Sciences, University of Applied Sciences Northwestern Switzerland
Dr. V. Guzenko, Laboratory for Micro- and Nanotechnology, Paul Scherrer Institute
Dr. M. Held, Department of Biosystems Science and Engineering (D-BSSE), ETHZ Basel
Prof. Dr. S. Hiller, Biozentrum, University of Basel
Dr. A. Hofmann, SNI Honorary Member, School of Education, University of Applied Sciences Northwestern Switzerland
Prof. Dr. R. Holtz, School of Engineering, University of Applied Sciences Northwestern Switzerland
Prof. Dr. C. Housecroft, Department of Chemistry, University of Basel
Prof. Dr. J. Huwyler, Department of Pharmaceutical Sciences, University of Basel
PSI Prof. Dr. T. Jung, Laboratory for Micro- and Nanotechnology, Paul Scherrer Institute and Department of Physics, University of Basel
Dr. S. Keller, The University of Tokyo
PSI Prof. Dr. M. Kenzelmann, Laboratory for Scientific Developments and Novel Materials, Paul Scherrer Institute
Dr. A. Kleibert, Microscopy and Magnetism, Paul Scherrer Institute
Prof. Dr. J. Klinovaja, Department of Physics, University of Basel
Dr. F. Koch, School of Life Sciences, University of Applied Sciences Northwestern Switzerland
Dr. J. Köser, School of Life Sciences, University of Applied Sciences Northwestern Switzerland
Prof. Dr. P.M. Kristiansen, School of Engineering, University of Applied Sciences Northwestern Switzerland
Prof. Dr. S. Kühl, Oral Health & Medicine, University of Basel
Prof. Dr. M. Kuentz, School of Life Sciences, University of Applied Sciences Northwestern Switzerland
Prof. Dr. A. von Lilienfeld, Department of Chemistry, University of Basel
Argovia Prof. Dr. R. Y. H. Lim, Biozentrum, University of Basel
Prof. Dr. G. Lipps, School of Life Sciences, University of Applied Sciences Northwestern Switzerland
Prof. Dr. D. Loss, Department of Physics, University of Basel
Dr. F. Lütolf, CSEM SA, Muttenz (BL)
Prof. Dr. C. Ludwig, Chemical Processes and Materials, Paul Scherrer Institute
Prof. Dr. T. Maier, Biozentrum, University of Basel
Dr. L. Marot, Department of Physics, University of Basel
Prof. Dr. P. Maletinsky, Department of Physics, University of Basel
PD Dr. A. Marsano, Department of Biomedicine, University of Basel and University Hospital Basel
Prof. Dr. M. Mayor, Department of Chemistry, University of Basel
Prof. Dr. W. Meier, Department of Chemistry, University of Basel
Prof. Dr. E. Meyer, Department of Physics, University of Basel
Prof. Dr. B. Müller, Biomaterials Science Center, University of Basel
Prof. Dr. D. Müller, Department of Biosystems Science and Engineering (D-BSSE), ETHZ Basel
Dr. M. Muntwiler, Laboratory for Micro- and Nanotechnology, Paul Scherrer Institute

Prof. Dr. M. Nash, Department of Chemistry, University of Basel
Dr. S. Neuhaus, School of Engineering, University of Applied Sciences Northwestern Switzerland
Prof. Dr. E. van Nimwegen, Biozentrum, University of Basel
PSI Prof. Dr. F. Nolting, Laboratory Condensed Matter Physics, Paul Scherrer Institute
Dr. J. Overbeck, Empa
Dr. B. Osmani, Biomaterials Science Center, University of Basel
Dr. C. Padeste, Laboratory for Micro- and Nanotechnology, Paul Scherrer Institute
Prof. Dr. C. Palivan, Department of Chemistry, University of Basel
Prof. Dr. S. Panke, Department of Biosystems Science and Engineering (D-BSSE), ETHZ Basel
Prof. Dr. J. Pascal, School of Life Sciences, University of Applied Sciences Northwestern Switzerland
PD Dr. V. Petkovic, Department of Biomedicine, University of Basel
Prof. Dr. U. Pieles, School of Life Sciences, University of Applied Sciences Northwestern Switzerland
Argovia Prof. Dr. M. Poggio, Department of Physics, University of Basel
Prof. Dr. S. Reddy, Department of Biosystems Science and Engineering (D-BSSE), ETHZ Basel
Prof. Dr. B. Resan, School of Engineering, University of Applied Sciences Northwestern Switzerland
J. Rüegger, SNI Honorary Member
Dr. S. Saxer, School of Life Sciences, University of Applied Sciences Northwestern Switzerland
Dr. V. Scagnoli, Mesoscopic Systems, Paul Scherrer Institute
Dr. H. Schift, Laboratory for Micro- and Nanotechnology, Paul Scherrer Institute
Prof. Dr. G. F. X. Schertler, Division of Biology and Chemistry, Paul Scherrer Institute
Prof. Dr. C. Schönenberger, Department of Physics, University of Basel
Prof. Dr. P. Shahgaldian, School of Life Sciences, University of Applied Sciences Northwestern Switzerland
Prof. Dr. C. Sparr, Department of Chemistry, University of Basel
Prof. Dr. H. Stahlberg, Biozentrum, University of Basel
Dr. S. Stübinger, Hightech Research Center of Cranio-Maxillofacial Surgery, University of Basel
Dr. A. Testino, Chemical Processes and Materials, Paul Scherrer Institute
Prof. Dr. K. Tiefenbacher, Department of Chemistry, University of Basel
Prof. Dr. P. Treutlein, Department of Physics, University of Basel
Dr. S. Tsujino, Laboratory for Micro- and Nanotechnology, Paul Scherrer Institute
Prof. Dr. R. Warburton, Department of Physics, University of Basel
Prof. Dr. T. Ward, Department of Chemistry, University of Basel
Prof. Dr. E. Weingartner, School of Engineering, University of Applied Sciences Northwestern Switzerland
Prof. Dr. S. Wendeborn, School of Life Sciences, University of Applied Sciences Northwestern Switzerland
Prof. Dr. O. Wenger, Department of Chemistry, University of Basel
Prof. Dr. S. Willitsch, Department of Chemistry, University of Basel
Prof. Dr. I. Zardo, Department of Physics, University of Basel
Prof. Dr. D. Zumbühl, Department of Physics, University of Basel
Dr. L. Zweifel, Biozentrum, University of Basel

PhD students
T. Aderneuer (associate), CSEM SA Muttenz (BL)
M.-E. Alaball Pujol, Biozentrum, University of Basel
C. Alter, Department of Pharmaceutical Sciences, University of Basel
D. Bracher, Microscopy and Magnetism, Paul Scherrer Institute
M. Carrillo, Mechano-Genomics Group, Paul Scherrer Institute
S. Di Leone, Department of Chemistry, University of Basel
V. Doffini, Department of Chemistry, University of Basel
L. Driencourt, CSEM SA Muttenz (BL)
P. Fountas, Department of Chemistry, University of Basel
A. Fränkl, Biozentrum, University of Basel
L. Gubser, Department of Physics, University of Basel
M. Heydari, Department of Physics, University of Basel
A. Huber, Department of Chemistry, University of Basel
I. Incaviglia, Department of Biosystems Science and Engineering (D-BSSE), ETHZ Basel
D. Jäger, Department of Physics, University of Basel
J. López Morales, Department of Chemistry, University of Basel
T. Karg, Department of Physics, University of Basel
T. Kozai, Biozentrum, University of Basel
I. Martyn, Department of Chemistry, University of Basel
T. Mortelmans, Laboratory for Micro and Nanotechnology, Paul Scherrer Institute
A. Ollier, Department of Physics, University of Basel
P. Oliva, Biozentrum, University of Basel
M. Ramezani, Department of Physics, University of Basel
N. Ritzmann, Department of Biosystems Science and Engineering (D-BSSE), ETHZ Basel
E. Rousounelou, Department of Biosystems Science and Engineering (D-BSSE), ETHZ Basel
A. Ruffo, Electrochemistry Laboratory, Paul Scherrer Institute
D. Sharma, Laboratory for Micro- and Nanotechnology, Paul Scherrer Institute
G.-L. Schmid, Department of Physics, University of Basel
L. Schneider, Department of Physics, University of Basel
S. Singh, Biozentrum, University of Basel
L. Sponfeldner, Department of Physics, University of Basel
W. Szmyt, School of Engineering, University of Applied Sciences Northwestern Switzerland
S. Tarvirdipour, Department of Chemistry, University of Basel
P. Thakkar, Nano-Diffraction, Paul Scherrer Institute
S. Treves, Department of Physics, University of Basel
J. H. Ungerer, Department of Physics, University of Basel
L. Wang, Department of Physics, University of Basel
M. Weegen, Department of Chemistry, University of Basel
F. Züger, School of Life Sciences, University of Applied Sciences Northwestern Switzerland

Projects of the SNI PhD School 2020

Project	Principle Investigator (PI) and Co-PI	PhD student
P1304 Folding mechanisms of beta-barrel outer membrane proteins and their catalysis by natural holdases and foldases	S. Hiller (Univ. Basel) D. Müller (D-BSSE)	N. Ritzmann
P1310 Plasmonic sensing in biomimetic nanopores	Y. Ekinci (PSI) R. Y. H. Lim (Univ. Basel)	D. Sharma
P1402 Lightweight structures based on hierarchical composites	C. Dransfeld (FHNW) C. Schönenberger (Univ. Basel)	W. Szmyt
P1407 Coupling a single ion to a nanomechanical oscillator	S. Willitsch (Univ. Basel) M. Poggio (Univ. Basel)	P. Fountas
P1501 Nanomechanical mass and viscosity measurement-platform for cell imaging	T. Braun (Univ. Basel) E. Meyer (Univ. Basel)	P. Oliva
P1502 Investigating individual multiferroic and oxidic nanoparticles	A. Kleibert (PSI) M. Poggio (Univ. Basel)	D. M. Bracher
P1503 Watching giant multienzymes at work using high-speed AFM	T. Maier (Univ. Basel) R. Y. H. Lim (Univ. Basel)	S. Singh
P1504 Valleytronics in strain-engineered graphene	C. Schönenberger (Univ. Basel) M. Calame (Univ. Basel)	L. Wang
P1505 A programmable e-beam shaper for diffractive imaging of biological structures at Å resolution	S. Tsujino (PSI) J. P. Abrahams (Univ. Basel)	P. Thakkar
P1601 Optical plasmonic nanostructures for enhanced photochemistry	E. Constable (Univ. Basel) S. Fricke (CSEM Muttenz)	L. Driencourt
P1602 Self-assembly and magnetic order of 2D spin lattices on surfaces	T. A. Jung (Univ. Basel) J. Dreiser (PSI)	M. Heydari
P1603 A mechano-optical microscope for studying force transduction in living cells	R. Lim (Univ. Basel) E. Meyer (Univ. Basel)	T. Kozai
P1604 Selective reconstitution of biomolecules in polymer-lipid membranes	W. Meier (Univ. Basel) U. Pieles (FHNW)	S. Di Leone
P1606 Smart peptide nanoparticles for efficient and safe gene therapy	C. Palivan (Univ. Basel) J. K. Benenson (D-BSSE, ETHZ Basel	S. Tarvirdipour
P1607 Understanding and engineering of phonon propagation in nanodevices by employing energy resolved phonon emission and adsorption spectroscopy	I. Zardo (Univ. Basel) C. Schönenberger (Univ. Basel)	L. Gubser
P1701 Van der Waals 2D semiconductor nanostructures with superconducting contacts	A. Baumgartner (Univ. Basel) C. Schönenberger (Univ. Basel)	M. Ramezani
P1702 Single organelle size sorting by a nanofluidic device	Y. Ekinci (PSI) H. Stahlberg (Univ. Basel)	T. Mortelmans
P1704 Evolving protease enzymes with new sequence specificity using peptide-hydrogel cell encapsulation	M. Nash (Univ. Basel) S. Reddy (D-BSSE, ETHZ Basel)	J. López Morales
P1705 Genetic selection of nanocatalysts	S. Panke (D-BSSE, ETHZ Basel) T. Ward (Univ. Basel)	E. Rousounelou
P1706 Ultrasensitive force microscopy and cavity optomechanics using nanowire cantilevers	M. Poggio (Univ. Basel) F. Braakman (Univ. Basel)	D. Jäger
P1707 Nano-photonics with van der Waals heterostructures	R. Warburton (Univ. Basel) I. Zardo (Univ. Basel)	L. Sponfeldner
P1708 Non-visual effects of LED lighting on humans	R. Ferrini (CSEM) E. Meyer (Univ. Basel)	T. Aderneuer
P1801 Bioinspired nanoscale drug delivery systems for efficient targeting and safe *in vivo* application	J. Huwyler (Univ. Basel) C. Palivan (Univ. Basel)	C. Alter
P1802 From Schrödinger's equation to biology: Unsupervised quantum machine learning for directed evolution of anti-adhesive peptides	M. Nash (Univ. Basel) A. von Lilienfeld (Univ. Basel)	V. Doffini
P1803 Nanoscale mechanical energy dissipation in quantum systems and 2D-materials	E. Meyer (Univ. Basel) M. Poggio (Univ. Basel)	A. Ollier
P1804 Picoscopic mass analysis of mammalian cells progressing through the cell cycle	D. Müller (ETHZ D-BSSE) W. Meier (Univ. Basel)	I. Incaviglia
P1805 High-throughput multiplexed microfluidics for antimicrobial drug discovery	E. van Nimwegen (Univ. Basel) V. Guzenko (PSI)	M.-E. Alaball Pujol
P1807 Andreev Spin Qubit (ASQ) in GeSi nanowires	C. Schönenberger (Univ. Basel) F. Braakman (Univ. Basel)	J.H. Ungerer
P1808 Quantum dynamics of an ultracold ion coupled to a nanomechanical oscillator	S. Willitsch (Univ. Basel) M. Poggio (Univ. Basel)	M. Weegen
P1901 Microfluidics to study Huntington's Disease by visual proteomics	T. Braun (Univ. Basel) H. Stahlberg (Univ. Basel)	A. Fränkl
P1902 Directional 3D nanofiber network to mimic in-vivo myocardial syncytium towards guiding contraction patterns in *in-vitro* heart models	M. Gullo (FHMW Muttenz) M. Poggio (Univ. Basel)	F. Züger
P1903 Neutron nanomediators for non-invasive temperature mapping of fuel cells	M. Kenzelmann (Univ. Basel/PSI) P. Boillat(PSI)	A. Ruffo
P1904 Revealing protein binding dynamics using time-resolved diffraction experiments at SwissFEL	C. Padeste (PSI) T. R. Ward (Univ. Basel)	M. Carrillo
P1905 Magnetic force microscopy with nanowire transducers	M. Poggio (Univ. Basel) E. Meyer (Univ. Basel)	L. Schneider
P1906 Machine learning assisted design of heteromeric self-assembled molecular capsules Spin-opto-nanomechanics	K. Tiefenbacher (Univ. Basel) A. von Lilienfeld (Univ. Basel)	I. Martyn
P1907 Spin-opto-nanomechanics	P. Treutlein (Univ. Basel) P. Maletinsky (Univ. Basel)	G.-L. Schmid
P1908 Chiral recognition in molecular nanowires from square-planar Platinum(II) complexes	O. Wenger (Univ. Basel) C. Sparr (Univ. Basel)	A. Huber

Nano Argovia Projects

Projects started in 2020

Project	Project leader	Project partner
A15.01 ForMel – Mechanoresponsive Liposomen – Entwicklung einer präklinischen Formulierung und eines Herstellungsprozesses im Pilotmassstab	O. Germershaus (FHNW)	C. Grünzweig (ANAXAM), M. Kuentz (FHNW), A. Zumbühl (Acthera Therapeutics AG, Basel)
A15.08 Promucola – Protective multi-component layer	M. de Wild (FHNW)	C. Grünzweig (ANAXAM), A. Salito (Orchid Orthopedics Switzerland GmbH, Baden-Dättwil)
A15.09 ReLaFunAF – Reactive Layer functionalization of UV curable coatings using microscale patterning and nanoscale architecture design for anti-fingerprint properties	S. Neuhaus (FHNW)	C. Padeste (PSI), A. Di Gianni (RadLab AG, Killwangen)
A15.10 SiNPFood – Characterization of silica nanoparticle contamination in complex nutritional products	S. Saxer (FHNW)	C. Palivan (Univ. Basel), A. Düsterloh (DSM Nutrition Products AG, Kaiseraugst)
A15.11 TiSpikes – Antibacterial titanium nanostructures by helium plasma irradiation	Dr. L. Marot (Univ. Basel)	E. Meyer (Univ. Basel), S. Kühl (Univ. Basel, K. Mukaddam (Univ. Basel), J. Köser (FHNW), R. Wagner (Institut Straumann AG, Basel), J. Hofstetter (Institut Straumann AG, Basel)

Extended projects

(with and without financial support, with report in the scientific supplement)

Project	Project leader	Project partner
A13.08 MEGAnanoPower – Disruptive power storage technology applying electrolyte nano dispersions and micro/ nano structured electrodes	U. Pieles (FHNW)	S. Fricke (CSEM Muttenz), A. Schimanski (Aigys AG, Othmarsingen)
A14.04 DeePest – A detector for pesticides in drinking water	J. Pascal (FHNW)	P. Shahgaldian (FHNW), E. Weingartner (FHNW), D. Matter (Mems AG, Birmenstorf)
A14.07 KOKORO – Origami heart model based on nano-patterned paper scaffold for directed cardiac tissue engineering	M. R. Gullo (FHNW)	J. Köser (FHNW), A. Banfi (Univ. Basel), A. Marsano (Univ. Basel), J. Schoelkopf (Omya International AG, Oftringen)
A14.13 NCT Nano – Novel cancer-targeted nanoparticles	M. Zigler (TargImmune Therapeutics, Basel)	C. Palivan (Univ. Basel), I. Craciun (Univ. Basel), Y. Benenson (ETH D-BSSE)
A14.15 PERINANO – Nano^2: A bioresponsive nano-in-nano composite for drug delivery and tissue regeneration in peri-implantitis	F. Koch (FHNW), O. Germershaus (FHNW)	U. Pieles (FHNW), S. Stübinger (Univ. Basel, M. Hug (credentis AG, Windisch)
A14.19 UltraNanoGRACO – Customized, nanostructured grating compressors for high repetition rate ultrafast lasers	F. Lütolf (CSEM)	G. Basset (CSEM), B. Resan (FHNW), F. Emaury (Menhir Photonics AG, Basel)

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Scientific part of the Annual Report

If you are interested in detailed reports about Nano Argovia projects and SNI PhD School projects, please scan the QR code or send an email so that we can send you a printed version of the scientific supplement. (c.moeller@unibas.ch).

Scientific supplement

About this publication

Concept and layout: Christel Möller
Texts: Christel Möller, Christian Schönenberger with support of Michèle Wegmann, Claudia Wirth, PIs, and PhD students
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University of Basel
Petersplatz 1
P.O. Box 2148
4001 Basel
Switzerland

www.unibas.ch

Swiss Nanoscience Institute
University of Basel
Klingelbergstrasse 82
4056 Basel
Switzerland

www.nanoscience.ch