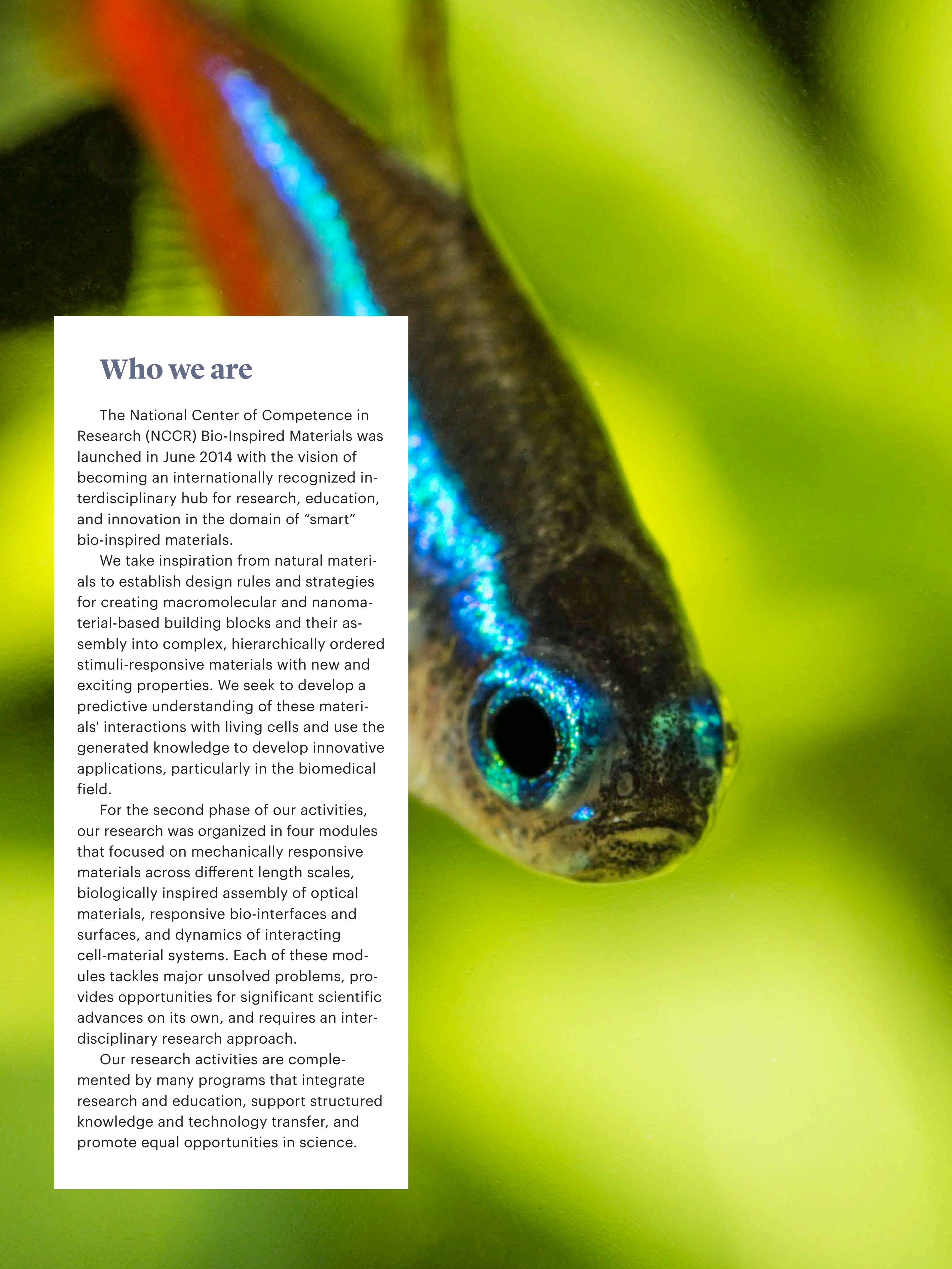
Activities report 2021–2022

National Center of Competence in Research Bio-Inspired Materials

Swiss National Science Foundation

BIO-INSPIRED MATERIALS
NATIONAL CENTER OF COMPETENCE IN RESEARCH



Who we are

The National Center of Competence in Research (NCCR) Bio-Inspired Materials was launched in June 2014 with the vision of becoming an internationally recognized interdisciplinary hub for research, education, and innovation in the domain of "smart" bio-inspired materials.

We take inspiration from natural materials to establish design rules and strategies for creating macromolecular and nanomaterial-based building blocks and their assembly into complex, hierarchically ordered stimuli-responsive materials with new and exciting properties. We seek to develop a predictive understanding of these materials' interactions with living cells and use the generated knowledge to develop innovative applications, particularly in the biomedical field.

For the second phase of our activities, our research was organized in four modules that focused on mechanically responsive materials across different length scales, biologically inspired assembly of optical materials, responsive bio-interfaces and surfaces, and dynamics of interacting cell-material systems. Each of these modules tackles major unsolved problems, provides opportunities for significant scientific advances on its own, and requires an interdisciplinary research approach.

Our research activities are complemented by many programs that integrate research and education, support structured knowledge and technology transfer, and promote equal opportunities in science.

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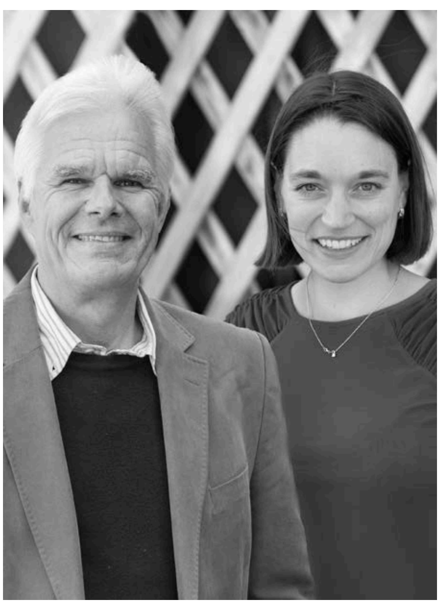

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Message from the directors

Dear reader

The NCCR Bio-inspired Materials has just started its third and final funding phase with the aims to strengthen its interdisciplinarity, foster the translation of the Center's research output, renew the success of its education, equal opportunities, and outreach programs, and consolidate its structural impact at the University of Fribourg.

While the Center will continue to group its research activities into three topical modules, the research groups will no longer belong to specific modules. They will combine their expertise as part of interdisciplinary projects with a robust collaborative component. An essential objective of the third phase is the translation of the technologies developed by the Center during the first two phases. Two new associate groups from Empa and CSEM will support this goal, and a new Translation Module including four projects that will seek to work towards applications of new bio-inspired materials in close collaboration with companies. We look forward to all these new developments, and wish to thank the Swiss National Science Foundation and the University of Fribourg for their continuous and generous support.

In the transition to the third funding phase, a large fraction of the NCCR PhD students graduated, and many others joined the Center to start their theses. This generation change was visible at this year's Annual Center Conference, where we had the opportunity to meet the new members and welcome them to the NCCR. The last twelve months have also seen a return to normalcy with the end of the covid-related restrictions. Travelling to conferences resumed, and the NCCR-branded international conference on Bio-inspired Materials finally took place with great success in Andermatt (Switzerland). The Center could again organize in-person internal meetings and conferences.

Our NCCR remained active in various fields, including its participation in Explora, the open doors days of the University of Fribourg, the organization of the third Swiss Forum for University and Student Innovation, and the publication of an outreach book in collaboration with partners at the Espace des Inventions (Lausanne), EPFL and the Scienscope of the University of Geneva.

This activities report collects a selection of highlights from the last year of the second funding phase of the second funding phase of our NCCR. We invite you to browse it and hope it will spark your interest in the activities and programs of our Center. On behalf of the NCCR Bio-inspired Materials, we wish you a pleasant reading and look forward to interacting with you in the future.

Ullrich Steiner & Esther Amstad
Directors NCCR Bio-Inspired Materials

Research

What we do

The overarching research theme of the NCCR Bio-Inspired Materials is to use nature's inspiration to design of artificial materials that can change their properties on command, or, in other words, in response to an external stimulus. These materials, sometimes referred to as “smart” or “intelligent”, are of fundamental scientific interest and potentially valuable for countless applications that range from climate control for buildings to drug delivery systems in the body.

Recently, scientists have begun to consider nature’s principles as inspiration for designing artificial materials with intriguing stimuli-responsive properties. Previous examples of materials studied by the Center's research groups include mechanically adaptive nanocomposites inspired by sea cucumbers, drug-delivery nanoparticles that mimic the structure and stealth behavior of viruses, and optical elements that emulate the nanoscale patterns found in butterfly wings.

To carry out paradigm-changing scientific breakthroughs and harness the enormous innovation potential in this domain, the Center has developed into a large-scale interdisciplinary effort that merges competencies in chemistry, physics, materials science, biology, and medicine.

At the start, the Center comprised three modules that emphasized research on mechanically responsive materials, responsive materials made by self-assembly, and the interactions of responsive materials with living cells, respectively. As hoped and expected, the boundaries between the original projects and modules have started to blur, and several new research endeavors take full advantage of the Center’s interdisciplinary environment.

Nanoscale characterization

Finding defects in two-dimensional materials

A new imaging approach developed by NCCR Bio-Materials researchers could help zoom in on the workings of cells. This innovative compact platform could constitute an important step toward getting unprecedented insights into nanoscale processes.

Microscopes have been around since the 16th century, but their basic design barely changed as it has proven challenging to miniaturize. Now, NCCR Bio-inspired Materials researchers at Lausanne's Federal Insitute of Technology (EPFL) have developed a super-compact, high-resolution imaging platform that may find important applications in biology.

"In microscopes, you have a sample stage, you have objectives, you have lenses, you have detectors, and you typically have a laser or some illumination part, which is often very big," says NCCR Principal Investigator Prof. Aleksandra Radenovic, who leads the Laboratory of Nanoscale Biology at EPFL. "Our goal was to make a platform that would shrink the microscope to a very, very small chip."

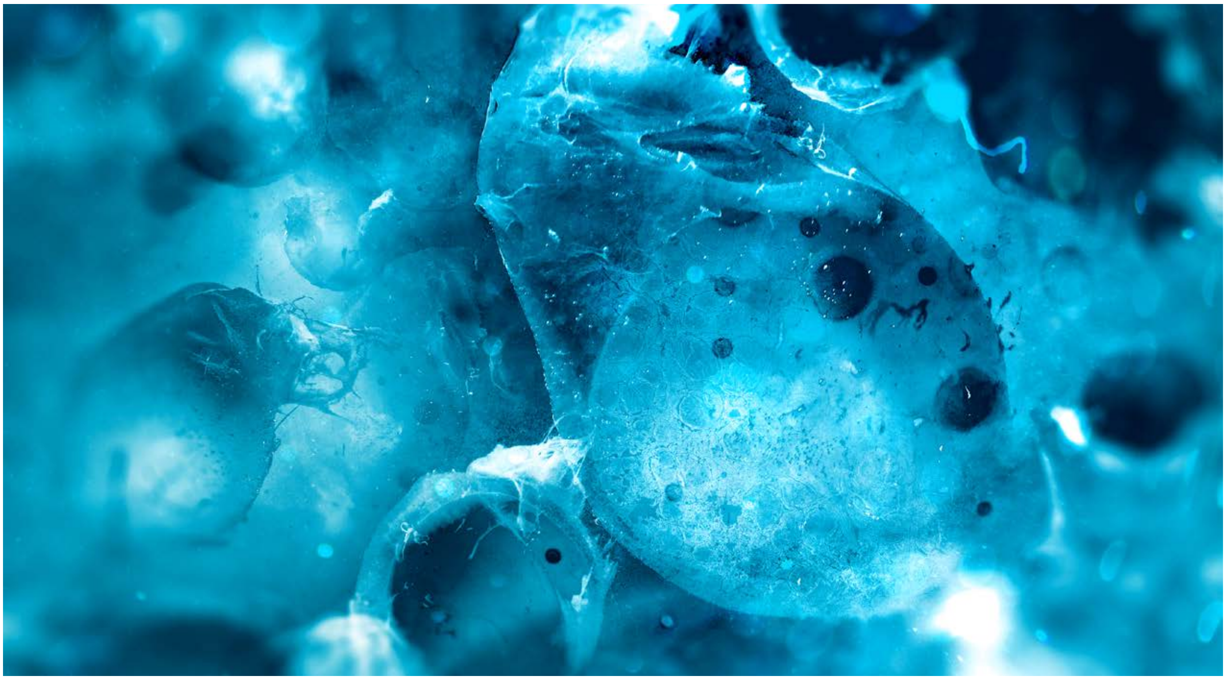
Previous work by Radenovic's team produced tiny optical waveguides, about 100 micrometers in size, which the researchers used to image 2D crystals – a class of materials characterized by a single layer of regular atomic structures. Such materials can be used in wide-ranging applications, including electronics and biosensors.

However, transferring 2D crystals from the growth substrate to the imaging chip can introduce contamination, which may prevent researchers from accurately characterizing the crystals' structure and properties.

> "This novel platform could help us to look at ion concentration and temperature changes as a cell engages in metabolic processes."
>
> Prof. Aleksandra Radenovic

To make up this shortfall, Radenovic and her colleagues developed an approach to grow a widely used 2D crystal directly on the optical waveguides of a chip. Each chip contains tens of thousands of waveguides on which the researchers grew their material. Then, they shed a laser light into the waveguides to image and characterize defects in the intact 2D crystal.

Although the 2D crystal is typically non-fluorescent, small defects within it are fluorescent.



The new imaging approach could help understand the inner workings of cells

Such defects are reminiscent of nanosized diamond particles that are used as miniaturized sensors of magnetic or electrical fields, temperature and ion concentration. “Measuring temperature, magnetic field or electrical field at nanoscales can be super interesting in biology,” Radenovic says.

Because of the similarities between 2D crystals and nanodiamonds, the new imaging approach could be used to provide insights into key biological phenomena. “We know that genetically identical cells could produce completely different amounts of proteins because of small local changes,” Radenovic says. “This novel platform could help us to look – locally and non-invasively – at ion concentration and temperature changes as a cell engages in metabolic processes.” In such a scenario, researchers would grow cells directly on the chip and use the optical waveguides coupled with 2D crystals or nanodiamonds as a probe.

The chip is easily manufactured, can operate on many different microscopes and sustain harsh treatments, including the high temperatures that are used for growing 2D materials and nanodiamonds, Radenovic says. In the future, she adds, “one could even imagine to shrink it further.” The findings were published in the journal ACS Photonics.

The development of this and other approaches to access the world of nanoscale materials was made possible thanks to the interdisciplinary nature of the NCCR Bio-inspired Materials, Radenovic says. “Together, we are pushing the frontiers of where and what one can measure.”

Reference

Glushkov, E.; Mendelson, N.; Chernev, A.; Ritika, R.; Lihter, M.; Zamani, R. R.; Comtet, J.; Navikas, V.; Aharonovich, I.; Radenovic, A. Direct Growth of Hexagonal Boron Nitride on Photonic Chips for High-Throughput Characterization. ACS Photonics 2021, 8 (7), 2033–2040.

32

Research Projects

CHF 9 million

of funding including CHF 4.5 million from the SNSF

Partners

University of Fribourg (Home Institution), Federal Institutes of Technology Lausanne and Zürich

21

Research groups

at three universities

7

international conferences supported

2

industrial associates

2

Innosuisse projects

worth over CHF 1.4 million in total

1

Saltire Facilitation Network Award

from the Royal Society of Edinburgh to establish a European Network on Nature-Inspired Materials between the Universities of Strathclyde and Freiburg and our NCCR

Note: All figures between June 1, 2021 and May 31, 2022

Revealing shapes

Microbe response inspires tools to study proteins

NCCR Bio-Inspired Materials researchers at the Adolphe Merkle Institute have developed tunable nanopores that may help decipher the structure and function of proteins. Their approach is modelled on how immune system recognizes pathogens.

Proteins are the foundation for all biological processes in living organisms, and working out the shape of a protein enables scientists to understand how that protein functions. Building on their previous work, the scientists at the University of Fribourg have designed tunable nanosized tubes, called nanopores, that can help to reveal the shape of a protein – and even its orientation in the 3D space.

The approach could find applications not only in detecting and characterizing proteins, but also as a tool to deliver drugs inside cells – or even as a miniature weapon to kill cancer cells and bacteria. The inspiration for the nanopores came indeed from the way our body fights pathogens: when the immune system recognizes a harmful microbe, it activates a complex of proteins that kills the pathogen by punching tiny holes through its cell membrane. "If we could use that killing machine to our advantage, it would be very powerful," says study senior author and NCCR Principal Investigator Prof. Michael Mayer.

To develop the nanopores, Mayer's team took advantage of a peptide called CtxA, which a fly native to sub-Saharan Africa produces to protect its eggs from bacteria. A handful of CtxA peptides typically assemble to form molecular-scale tubes that can kill microbes – very much like our immune system does with pathogens.

First, the researchers had the CtxA peptide synthesized in the lab; then, they attached a DNA strand to it. "We created a peptide-DNA hybrid," Mayer explains. Because DNA is made of complementary sites that can bind to one another, individual molecules of the right sequence will self-assemble, forcing the structure to form a desired shape.

By creating structures with 4, 8 or 12 peptide-DNA hybrids, the researchers were able to tune the diameter of the nanopores, making the inner tube bigger. They also attached to the structure a fatty molecule, which increases the affinity of the nanopore to the lipid membrane of cells. The findings were published in the journal ACS Nano.

This is not the first time that researchers have made nanopores: the tiny tubes are already used to sequence DNA molecules. When a nanopore

The CtxA peptides used for the project originated in medflies

inserts into a membrane that separates two liquid compartments – one with a positive charge and one with a negative charge – it opens a path for charged particles, or ions, to flow from one compartment to the other. When ions move through a nanopore, they create an electrical current. But when a DNA molecule enters the pore, it reduces the flow of ions across the membrane. By monitoring changes to the electrical current produced by this flow of ions, researchers can determine the sequence of a specific DNA strand.

Previous work by Mayer's team showed that it's possible to use nanopores to identify the fingerprint of specific proteins. "The blockade is not just proportional to the volume of a protein, but it also represents its orientation," Mayer says. "We use that signal to make estimates about the shape of a protein, which is important to understand its function."

However, analyzing the shape of proteins with nanopores presents many challenges, Mayer says. For one, proteins are substantially bigger than DNA molecules, so larger pores would be helpful, but Mayer notes that bigger pores seem to be less stable than smaller ones. "Nature doesn't normally make those bigger pores, except to kill microbes."

For this reason, the team is now trying to build nanopores using one of the proteins that make up the immune system's 'killing machine.' Preliminary results suggest that using this approach, it's possible to make stable nanopores that are up to 12 nanometers in inner diameter. "They might actually work for what we want to do," Mayer says. "At the end, we're using exactly what nature uses – of course, we need some tricks to make this work in a test tube, but the results look very promising."

Reference

Fennouri, A.; List, J.; Ducrey, J.; Dupasquier, J.; Sukyte, V.; Mayer, S. F.; Vargas, R. D.; Pascual Fernandez, L.; Bertani, F.; Rodriguez Gonzalo, S.; Yang, J.; Mayer, M. Tuning the Diameter, Stability, and Membrane Affinity of Peptide Pores by DNA-Programmed Self-Assembly. ACS Nano 2021, 15 (7), 11263–11275.

Circular approach

Food digestion points the way to more efficient plastic recycling

The way nature processes old proteins to create new ones has led NCCR Bio-Inspired Materials researchers at Lausanne's Federal Institute of Technology (EPFL) to develop a potentially more efficient approach to plastic recycling.

More than 400 million tons of plastics are produced every year, and dozens of them end up in the natural environment, making plastic pollution one of the most pressing global issues. The NCCR scientists decided to tackle the problem by investigating how nature degrades proteins. These molecules, much like plastic, are polymers made by several building blocks, or monomers. "Proteins are the most abundant polymers on earth, and they're sustainable," explains NCCR Principal Investigator Prof. Francesco Stellacci, who co-led the research at EPFL's School of Engineering.

Unlike synthetic polymers, proteins are sequence-defined polymers, which means that the sequence of their building blocks is essential – as it determines a protein's structure and function – and is dictated by the genetic instructions 'written' in the DNA.

When we digest food, proteins break up into their constituent parts. Then, cells put these building blocks back together in different orders to form new proteins, depending on the cell's specific needs. To try to replicate this natural cycle outside a living cell, Stellacci and his colleagues selected specific proteins and chopped them up into individual building blocks. Then, they put the building blocks into a system containing the cellular machinery that translates genetic instructions into proteins.

Using this approach, the researchers were able to transform silk and a mixture of hormones into a specific protein that emits fluorescence when exposed to light. The findings were published in the journal Advanced Materials.

> "The dream is that we'll be able to throw a bunch of old plastics together and transform them into plastic that is as good as new plastic."
>
> Prof. Francesco Stellacci

"This is a great nature-inspired approach to recycling, where you take a random mixture of the starting material, digest it in its components, and build from it what you need," Stellacci says. He notes that proteins produced with this approach have the same quality of a newly made protein,

Plastics need to be recycled more to reduce their impact on the environment

whereas plastic loses some of its quality every time it is recycled in a conventional way.

The study is a proof of concept that a similar recycling approach could be used also for plastic. The idea, according to the researcher, is that in the future, plastic polymers should also be sequence-defined, just like proteins. They would then be degraded in a 'maxi stomach', which would break them into single monomers. Finally, a computer would instruct a polymer-making machine about the type of polymer to produce. "One day it may be a soft polymer to make clothes, the day after it may be a hard polymer to make chairs, pens or computers," Stellacci says.

However, he adds, it will take years – if not decades – before this approach can be applied in the real world. For one, every cell has a polymer-making machine, called the ribosome, that is able to translate genetic instructions into new proteins. "For synthetic polymers, we don't have a ribosome," Stellacci points out. And to make plastic recycling sustainable, he adds, we would need ribosomes on industrial scales. "The challenges are huge."

Next, the researchers hope to scale up their approach to recycle grams of synthetic polymers into materials. "Now, we are doing this at microgram level," the NCCR PI explains.

Despite all the challenges, this protein-inspired approach represents a new way of looking at recycling, he says. "The dream is that we'll be able to throw a bunch of old plastics together and transform them into plastic that is as good as new plastic and is different every day."

Reference

Giaveri, S.; Schmitt, A. M.; Roset Julià, L.; Scamarcio, V.; Murello, A.; Cheng, S.; Menin, L.; Ortiz, D.; Patiny, L.; Bolisetty, S.; Mezzenga, R.; Maerkl, S. J.; Stellacci, F. Nature-Inspired Circular-Economy Recycling for Proteins: Proof of Concept. Advanced Materials 2021, 33 (44), 2104581.

Force-sensing probe

Signaling when a material is about to fail

NCCR Bio-Inspired Materials researchers at the University of Fribourg's Adolphe Merkle Institute have created a force-sensing probe, called a mechanophore, that rapidly and reversibly changes its fluorescence color when activated by a strain.

Molecules that change color or fluorescence characteristics in response to mechanical stress can warn of damage to materials such as polymers used in construction, potentially avoiding catastrophic failures. A new mechanophore could help researchers study the effects of mechanical stress on materials. In the future, it may also serve as an early warning for material failure, says NCCR Principal Investigator Prof. Christoph Weder, who co-led the study.

Several physiological processes, including hearing, rely on a phenomenon called mechanotransduction, which translates mechanical stimuli into a chemical response. Inspired by such behavior of biological systems, Weder's team has been exploring ways of making stress sensors out of force-sensitive molecules.

Past efforts resulted in molecules that did not return to their original state or were extremely difficult to produce. This time around, the researchers connected two fluorescent molecules, called perylenes, with a spacer. Then, they incorporated the perylenes in the center of polymer chains that make up a rubbery material known as an elastomer.

The team tested their probe by subjecting the elastomer to different levels of mechanical stress. Perylenes act like molecular magnets, so in the absence of stress, the attractive interactions between perylene molecules leads to the formation of loops and the production of orange fluorescence.

> "In principle, one could equip polymers with the ability to indicate failure and render the polymers healable."
>
> Prof. Christoph Weder

However, when the researchers applied force to stretch the elastomer, the perylene loops untangled, and their fluorescence changed to green. "If the loops experience a sufficiently high force, the perylene magnets are pulled apart," Weder explains.

The color change took place instantaneously and reflected how much stress the elastomer had experienced. The effect was reversible, with the fluorescence reverting to orange as soon as the

Hearing is an example of mechanical stimuli that are transformed into a chemical response

force was removed. Producing the new mechanophore only involves three steps and the probe can be incorporated into several polymers, including rigid materials such as Plexiglas, Weder says. The findings were published in the journal Angewandte Chemie.

Next, Weder's team plans to look at the response of other polymers to investigate failure mechanisms. "If you look at rigid polymers, they typically fail because they develop a microscopic defect – a crack," he adds. "Our question is, how does the crack start in the first place, and can we predict where it will develop?"

Although the new mechanophore is just a research tool for now, in the future it may have practical applications in all sorts of materials. For example, understanding how failures happen at the molecular level may inform the creation of more resistant polymers. "We are also interested in healable polymers, so in principle one could equip polymers with the ability to indicate failure and render the polymers healable," Weder says.

The new mechanophore may also enable biologists to measure forces on molecular scales and understand how cells react to mechanical stress. "Biologists also use force probes, but so far there has been little interaction between polymer science and biology with respect to such probes," Weder points out. "In the next phase of the NCCR Bio-Inspired Materials, we would like to bridge this gap."

Reference

Traeger, H.; Sagara, Y.; Kiebala, D. J.; Schrettl, S.; Weder, C. Folded Perylene Diimide Loops as Mechanoresponsive Motifs. Angewandte Chemie International Edition 2021, 60 (29), 16191–16199.

Photonics

Creating structural color with polymers

NCCR Bio-Inspired Materials researchers at the Adolphe Merkle Institute (AMI) have drawn inspiration from nature to develop nanoscale structures that display bright colors with potential industrial applications. These so-called photonic particles could be employed in a broad range of products, from coatings to cosmetics.

The dazzling hues of the wings of some insects and birds originate from tiny structures that diffract light differently. Mimicking those structures will allow scientists to create new materials that produce color in a more efficient, economical, and sustainable way, says Dr. Ilja Gunkel, a group leader in the AMI Soft Matter Physics group.

Part of Gunkel's research is inspired by how animals such as butterflies and beetles get their vibrant hues. These colors are called 'structural' because they're produced by light scattering from a regular array of structures, for example scales on a butterfly wing. The scales are typically made of natural polymers that arrange into microscopic layers, which reflect light in ways that produce bright colors.

To imitate these structures, Gunkel and his colleagues created a comb-shaped polymer, a type of polymer consisting of a main polymer chain and a series of side chains made of a different molecule. Under the right conditions, these polymers self-assemble into onion-like microstructures made of layers that are about 160 nanometers thick.

Using a specific protocol, which they detailed in the journal Macromolecular Rapid Communications, the researchers succeeded in producing spheres that measure about 10 micrometers in diameter and show intense coloration.

"We can create structural color with a simple and scalable process."

Dr. Ilja Gunkel

The first particles produced were only green, but now the researchers are able to create particles of all different colors. "The trick is simple," Gunkel explains. When making the comb-like polymer, the researchers add different amounts of the additional molecule to the main polymer chain. This results in onion-like structures with layers of either increased or decreased thickness, which reflect different portions of the light spectrum.

The particles are non-iridescent, meaning that their hue does not depend on the angle they're viewed from. "Typically, one wants the color of a device or a wall to look exactly the same, no

Brilliant butterfly colors are often due to the structure of the insect's wing scales

matter under which angle one looks at it," Gunkel adds. What's more, the particles can be suspended in water or used as a powder. Due to these characteristics, the particles hold promise as non-iridescent photonic pigments, he says. "We show that we can create structural color with a simple and scalable process."

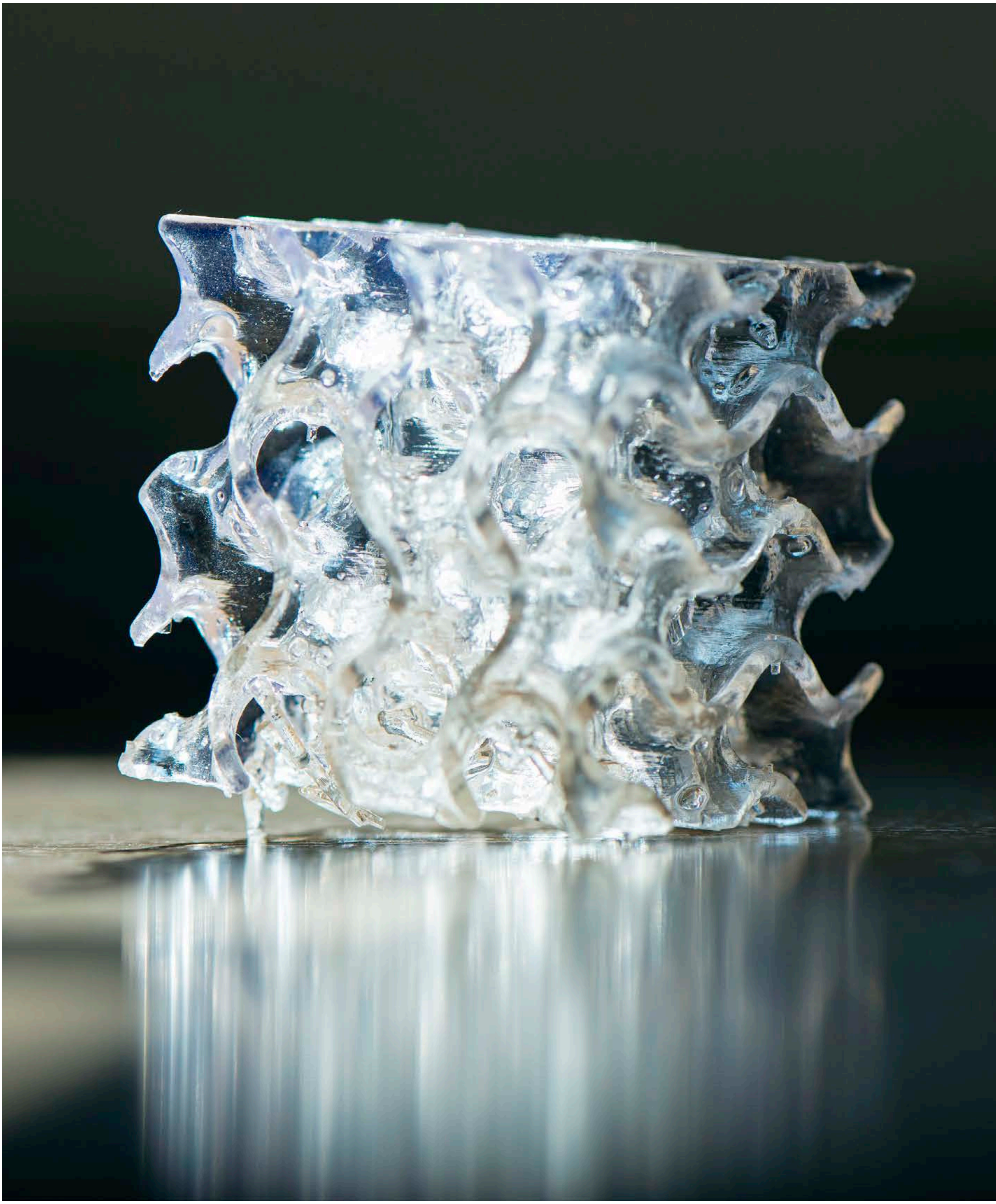
However, the particles are not yet ready for practical applications, Gunkel notes. One reason is that the color is not visible to the naked eye, but is only detectable using a microscope. Also, light bounces multiple times between different particles – a phenomenon called scattering, which makes the particles appear white.

To get around the problem of scattering, the team is again drawing inspiration from nature: animals often combine structural colors with pigments, which absorb scattering light. The researchers now plan to introduce such pigments in their onion-like particles. "We want to have pigments in the center of a particle to make sure that only a certain portion of light is reflected – and that only reflection, rather than scattering, takes place," Gunkel says.

In the future, he adds, the particles may find use as paints or colorants that are more stable than traditional ones, which tend to fade over time. "We have all the ingredients, we just need to get the pigments incorporated into our onion-like particles."

References

Moriceau, G.; Kilchoer, C.; Djeghdi, K.; Weder, C.; Steiner, U.; Wilts, B. D.; Gunkel, I. Photonic Particles Made by the Confined Self-Assembly of a Supramolecular Comb-Like Block Copolymer. Macromolecular Rapid Communications 2021, 42 (24), 2100522.



137

Researchers

incl. PhD students, postdocs, senior researchers and professors

Gender balance

45% of the NCCR Ph.D. students were women

28% female postdocs and senior researchers

37 Nationalities

including Switzerland, Argentina, Austria, Belgium, Brazil, Bulgaria, China, Croatia, Estonia, Ethiopia, France, Germany, Hungary, India, Italy, Kenya, Lebanon, Lithuania, Luxembourg, Macedonia, Netherlands, New Zealand, Peru, Poland, Portugal, Russia, Serbia, Slovakia, Slovenia, South Africa, Spain, Taiwan, Turkey, UK, Ukraine, USA, Vietnam

68

oral presentations at conferences (including 37 keynote and plenary lectures at international conferences)

65

Papers

including 60 original contributions, 4 reviews and 1 editorial

78%

of open access publications

following the Gold or Green roads and through institutional agreements

Note: All figures between June 1, 2021 and May 31, 2022

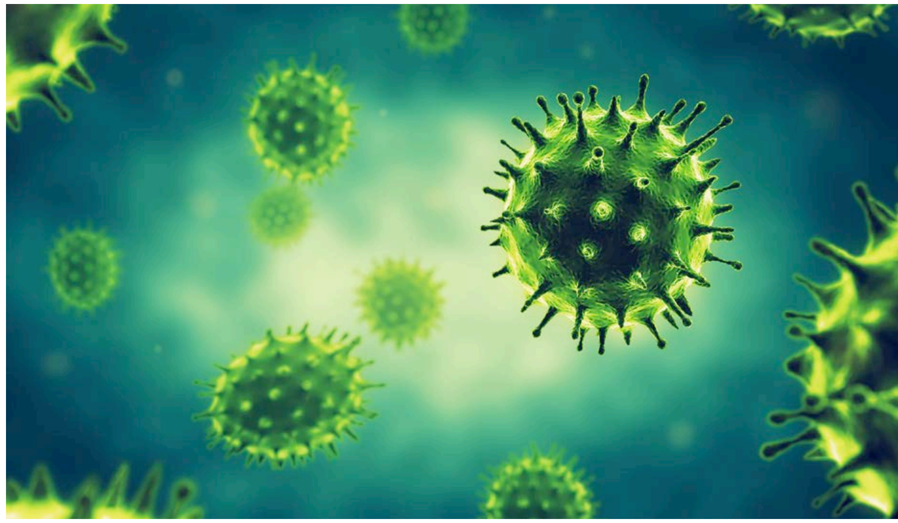
In brief

Special issue

NCCR Bio-Inspired researchers have been helming a special Issue in the journal Materials (MDPI), entitled “Advances in Bio-inspired Materials for Medical Applications”.

Edited by NCCR Principal Investigators Profs. Alke Fink and Barbara Rothen-Rutishauser (AMI), in collaboration with NCCR alumni Dr. Barbara Drasler and Dr. Dedy Septiadi, the special issue emphasizes the entire range of bio-inspired materials used in medical applications. It includes the synthetic approaches of formulating functional systems that can be used in drug and molecule (gene) delivery, bioimaging, and biosensing, regenerative medicine, and cancer treatment. In addition, the physico-chemical characterization strategy for bio-inspired materials, as well as (mathematical) modeling structure–property relationships, will be covered by the issue, along with principles in developing safe-by-design bio-inspired nanomaterials for medical application.

The mosquito can inspire ideas for biomaterials and medical devices



Asterivir's molecules aim to prevent viruses binding to healthy cells

Company launch

NCCR Principal Investigator Prof. Francesco Stellacci (EPFL) has launched a start-up focused on broad-spectrum antiviral technology developed with NCCR support.

Asterivir is developing virucidal molecules that attack virions in the body before they can bind to healthy cells, destroying the virus. Positive results have been obtained against numerous viruses such as influenza, HSV2, HPV, Lentivirus, Zika virus and RSV through testing in accepted in vitro, ex vivo and/or in vivo models. Two of its molecules have shown in vitro effectiveness against SARS-CoV-2.

Explora

NCCR Bio-Inspired Materials researchers and staff joined colleagues at the University of Fribourg for the institution’s Explora open day in September 2021.

The event was held under the motto “Food for the brain”. The NCCR researchers notably powered a cargo bike with slime experiments across the city, while also staffing a KidsUni stand on the university’s main Miséricorde site, or presenting and exhibit on photonics and art.

The NCCR was present at Fribourg’s organic market

The NCCR was also present at the organic market held in the city center at the same time, presenting a nanofertilizer project, and engaging with the public on the issue of crop protection.

Lifetime award

NCCR Principal Investigator Prof. Barbara Rothen-Rutishauser (AMI) was awarded the International Society for Aerosols in Medicine (ISAM) 2021 Career Achievement Award.

This award is presented to a senior investigator whose body of work demonstrates a lifetime of outstanding achievement in aerosol science. Rothen-Rutishauser is recognized as a pioneer in the development of human 3D lung models. In combination with air-liquid cell exposure systems, these models are applied to assess effects of aerosolized drugs and nanomaterials. She has published over 300 peer-reviewed papers, and is an associate editor of the journal "Particle and Fibre Toxicology". Rothen-Rutishauser has been an active ISAM member for many years. Since May 2021, Rothen-Rutishauser has been serving as president of ISAM, a position she will hold until May 2023.

NCCR PI Prof. Barbara Rothen-Rutishauser

Student innovation

The virtual 3rd Swiss Forum for University and Student Innovation was co-organized by the Knowledge Transfer and Innovation Manager Dr. Eliav Haskal in September 2021.

The forum targets education, support activities and ecosystem development for innovation and entrepreneurship at federal and cantonal universities, and universities of applied sciences in Switzerland. The latest edition featured talks by Alisée de Tonnac, the co-founder and co-CEO of Seedstars, a Swiss investment holding, and Prof. Bill Aulet, the managing director of the Martin Trust Center for MIT Entrepreneurship at the Massachusetts Institute of Technology.

De Tonnac's Seedstars works in over 90 countries in partnership with governments, development agencies, corporate partners, and private donors to develop emerging market entrepreneurship ecosystems, create jobs and fuel income growth. It invests in high growth technology companies in those markets, and supports them with capital, knowledge and introductions. Aulet is an award-winning educator and author whose current work is built off the foundation of his 25-year successful business career first at IBM, and then as a three-time serial entrepreneur.

PhDs

Dr. Subhajit Pal was awarded the University of Fribourg's 2021 Chorofas Prize, worth USD 5,000, for the best doctoral thesis in natural sciences, which he carried out under the supervision of Prof. Andreas Kilbinger in the Department of Chemistry.

Pal was also awarded a highly competitive SNSF Postdoc. Mobility fellowship, allowing him to join the research group of Prof. Philip Messersmith at the University of California, Berkeley.

NCCR PhD Student Hanna Traeger (AMI Polymer Chemistry and Materials group) was awarded the runner-up prize for best oral presentation (Polymers, Colloids & Interfaces section) at the 2021 fall meeting of the Swiss Chemical Society. Her AMI colleague Derek Kieblala was the recipient of the Macromolecular Chemistry and Physics Best Poster Award at the virtual Bayreuth Polymer Symposium in 2021, followed by another poster prize at the EyCheM2022 online conference.

Dr. Subhajit Pal

Travel award

NCCR PhD Student Hanna Traeger of the AMI Polymer Chemistry and Materials group was awarded a travel grant by the Platform Chemistry of the Swiss National Academy of Sciences and the Swiss Chemical Society.

The grant provides funding to participate in an international conference. Traeger used the support to attend the spring 2022 meeting of the American Chemical Society in San Diego, California, and to present her work on “Loop structures as non-covalent mechanochromic motifs”.

Dr. Hanna Traeger

Science communication

The NCCR Bio-Inspired Materials helped bring the 10th edition of ScienceComm to the University of Fribourg through its sponsorship and in-kind support from the NCCR management team.

The two-day event, which brought together 200 science communicators from all over Switzerland, took place in September 2021 under the motto “Science Communication in a Period of Crisis”.

URI program

After a year’s pause due to the pandemic, the summer Undergraduate Research Internships program was able to take place once again in 2021.

Twenty students from the United States and Europe were able to make their way to Switzerland to carry out their research stays with one of the NCCR’s groups. The winner of the now-traditional poster prize was Hugo Brummer (Hanze University of Applied Sciences, Groningen, the Netherlands), for his project “Design of mechano-pigments for high dynamic range mechano-sensing in polymeric materials”.

Hugo Brummer (left) was the winner of the student poster prize

Entrepreneurial force

NCCR Principal Investigator Prof. André Studart was among the winners in 2021 of the inaugural Dandelion Entrepreneurship Award, which recognizes professors for their outstanding efforts to promote entrepreneurship at Zurich’s Federal Institute of Technology (ETHZ).

The professors are nominated by ETHZ students, PhD candidates, and postdoctoral researchers for the award, which aims to recognize the most entrepreneurial friendly professors at the institute Based on the nominations, a jury picked a winner for each department. Startups launched from Studart’s Complex Materials laboratory include NCCR supported companies Spectroplast, Microcaps, and FenX.

Sponsoring

The NCCR Bio-Inspired Materials regularly sponsors scientific conferences, workshops, and other events.

In January 2022, the Center provided support for the European Young Chemists’ Meeting (EYCheM2022) that was to take place in Fribourg, focusing on the design, synthesis and utilization of new materials for energy applications. Due to the Covid pandemic, the conference was however moved to an online format.

EYCheM2002 had to transition online

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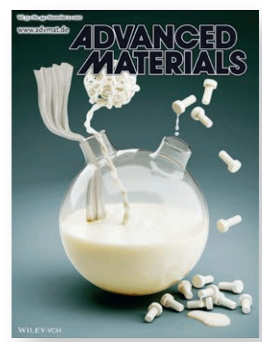


Outreach

In November 2021, the Center took part in a new format of the Zukunftstag/Future en tous genres as part of its equal opportunities' and outreach activities.

These days are usually organized every year so primary schoolchildren can learn more about their parents' jobs. For the first time however, female high school students were invited to learn more about STEM studies and professions, from the NCCR's Outreach Officer, Dr. Sofia Martin Caba, and find out that science is not just for men.

NCCR PI Prof. Barbara Rothen-Rutishauser also participated in the Swiss Academy of Engineering Sciences TecDay at Zurich's Freie Gymnasium in November 2021. In her module, she gave an introduction on nanoscience to to college students in their final years of study.

An opportunity to learn more about STEM careers for women

Drawing to a conclusion

Collaborative projects become focal point for final four years

The NCCR Bio-inspired Materials recently started its third and final funding phase. For this period, its researchers will continue to build on their earlier success, but will focus more intensely on collaborative interdisciplinary projects, in particular on potential applications of earlier studies.

Since its launch in 2014, the NCCR has contributed to advance the field of bio-inspired materials research and to position Switzerland internationally in this strategic domain. The Center's impact has also reached various structural levels at its Home Institution, the University of Fribourg, including the orientation of the Faculty of Science and Medicine strategy towards materials science, the establishment of a critical mass of research groups working on bio-inspired materials, new education and training programs, and the creation of equal opportunities and innovation cultures that will outlast the Center beyond its official end in May 2026.

In terms of research impact, the NCCR has bundled previously isolated, individual research activities in the field of bio-inspired materials to create a clear strategic focus in the Swiss research landscape. Compared to the pre-NCCR era, the Swiss groups working on bio-inspired materials are now well coordinated and this will help maintaining the international recognition of Swiss researchers in the field after the end of the NCCR. It is now clear that many of the outcomes of the Center would not have been possible without the framework provided by the NCCR, which has been instrumental in catalyzing collaborative work between different research groups and across disciplines. This is exemplified by the research module "Dynamics of interacting cell-material systems", launched in the second funding phase as a highly interdisciplinary and collaborative initiative, which has provided the foundations for organoids-on-a-chip that could represent a paradigm shift in biology, especially by enabling the generation of physiologically relevant human tissues, organs and diseases. Other examples where the Center has opened new research areas and new research opportunities in existing areas include Nature-inspired polymer recycling, high-throughput emulsification, or new sensors based on mechanical forces.

At the international level, the scientific exchanges at the NCCR have led to the generation of three international networks on bio-inspired materials science. The first is the Swiss-US PIRE

Collaboration is key to the final success of the NCCR

network “Bio-inspired Materials and Systems”, co-led by NCCR Principal Investigator (PI) and former director Prof. Christoph Weder, which linked six NCCR research groups with seven US research groups across five US research institutes. A second network is the Horizon 2020 Innovative Training Network “Plant Inspired Materials and Surfaces” (PlaMatSu), led by NCCR PI Prof. Nico Bruns, with eight research groups spanning across four Universities in Switzerland, Germany, and the UK. A third international network recently launched is a Saltire Facilitation Award of the Royal Society of Edinburgh, which is funded by the Scottish Government to create collaborative Scotland – EU/CH partnerships. This two-year collaboration involves research groups from Glasgow, Freiburg (Germany) and the NCCR under the topic of nature-inspired materials. Furthermore, the NCCR was instrumental for the permanent relocation of the biannual Gordon Research Conference “Bio-inspired Materials” to Switzerland, and both the former and present NCCR Directors, Profs. Christoph Weder and Ulli Steiner, will be involved in its organization as chairs and vice-chairs. This is now further reinforced by the NCCR-branded international conference on bio-inspired materials, which had its first two editions in 2019 and 2022, and is planned to run again during the NCCR’s third funding phase. In addition to the widespread links formed by individual NCCR PIs, these international consortia and conferences have formed an international research community that will outlast the NCCR. At the international level, the NCCR has also contributed to raising the profile of the University of Fribourg in the domain of materials research, which led to Nature Index ranking the university sixth in Europe among the fastest rising institutions in the field in 2019.

> “In the domain of knowledge and technology transfer, the NCCR has successfully enabled many technology transfer projects with industry.”

Besides conducting excellent research, the NCCRs support the career advancement of young researchers, implement gender equality measures, promote innovation and create links to society through outreach actions and targeted knowledge transfer. To this end, our NCCR has developed a comprehensive education and training program covering the entire spectrum of ages and academic positions, and runs every year its successful summer internships for undergraduate student. This program brings to Switzerland twenty students from universities worldwide including top institutions such as the University of Cambridge, University College London, MIT and the University of Chicago to name a few. The Center has also become a reference for gender equality at the University of Fribourg with regular round tables and programs geared to providing female role models for research leadership to primary and high school children. For these activities, the NCCR received external recognition through the 2019 Materials Today Agents of Change award, received by NCCR PI and equal opportunities faculty delegate Prof. Barbara Rothen-Rutishauser, NCCR PI Prof. Alke Fink and Dr. Sofía Martin, the NCCR’s outreach coordinator. Perhaps the most successful program launched by the NCCR in this domain is the WINS Fellowships, a program that funds female postdoctoral researchers to develop their own projects for a period of two years. Remarkably, to date, 50% of the fellows made a clear step towards scientific independence by securing assistant professorships, lecturer positions, or permanent research staff positions immediately after their fellowships.

In the domain of knowledge and technology transfer, the NCCR has successfully enabled many technology transfer projects with industry, launched four spinoffs of which three are now incorporated, and successfully contributed to develop an environment of innovation at the University of Fribourg. It is worth highlighting the leading role of the NCCR in the launch of the organization of the Swiss Forum for University and Student Innovation, a unique national-level event that was co-organized by Dr. Eliav Haskal, the NCCR’s KTT manager, and which has already taken place on three occasions. The transfer of knowledge to society has been an important focus of our Center as exemplified by the exhibit “Inspiration Natur e”, which was shown at the Fribourg Museum of Natural History from October 2018 to March 2019, gathered over 30,000 visitors, and included multiple parallel activities such as company and school visits, spaghetti evenings and afterwork guided visits. In the domain of science outreach, the NCCR reached over 1700 children and high school students through multiple outreach programs, either by launching its own activities or leveraging existing programs at the University and Canton of Fribourg, and at the national level. Additionally, the Center recently edited the book "Pschitt", which collects experiments for children formerly published by the Migros magazine, in collaboration with the Espace des Inventions in Lausanne, the EPFL and the University of Geneva's Scienscope.

Building on the experience and outcomes of the first two funding phases, and with the continuous and generous support from the Swiss National Foundation and the University of Fribourg, the NCCR has started its last four-year funding period. In this final phase, as most notable change, the Center is moving away from single PI-led projects into a truly collaborative mode. While the projects remain grouped in three topical modules, the groups collaborate in these projects across discipline and module boundaries. These changes reflect the evolution of our scientific network over the past eight years, during which many collaborations formed and joint articles were published. On one hand, the three modules continue the research themes our NCCR is known for: mechanically responsive materials, photonic materials, and responsive bio-interfaces. On the other hand, the PIs working between modules brings new perspectives for the application of the materials developed in Modules 1 and 3, and shifts the orientation of Module 2 from the characterization of photonic biological materials towards their biomimetic manufacture. Several projects of the NCCR's Phase 3 research program are further linked to greater societal challenges including future energy (batteries, solar energy), public health (anti-viral, anti-bacterial applications), future medicine (organs-on-a-chip), and carbon capture.

A further important aspect of this third phase is the translation of the research output of the Center towards applications. While many of the projects have that potential, the NCCR has launched a research module with four translation-oriented projects that build on recent exciting fundamental NCCR research in the fields of soft actuators, bio-inspired photonic materials, healable plastics and the 3D printing of microporous materials. In addition, the NCCR can now count on the expertise of two new Associate PIs from TT-oriented institutions, Dr. Luciano Boesel at Empa, and Dr. Raphaël Pugin at CSEM, who will support the translation objectives of the Center.

In what concerns the Education and Equal Opportunities programs, the NCCR will resume all the activities and programs of the second funding phase with a focus on initiatives with potential for stabilization at the University of Fribourg's Faculty of Science and Medicine. The successful outreach and training activities of the NCCR will thus be resumed in Phase 3 and the Center will seek the creation of a new Materials Science Doctoral School at the University of Fribourg. The NCCR will also continue promoting gender equality through round tables and workshops, and by leading initiatives at the Faculty level. The WINS Postdoctoral Fellowships will also be continued in Phase 3 with four new positions and female-only postdoctoral positions will be awarded to the most successful projects on a competitive basis. All these activities will continue to be marketed and communicated through a wide range of channels including the Center's website, themed flyers, the yearly activities report, continuous media and social media presence, participation in fairs and conferences, and ad-hoc communication support.

Ultimately, the NCCR aims at having a meaningful and sustainable structural impact in its Home Institution and more generally in the Swiss higher education system. The past contributions and future plans reviewed here show that the Center is making clear steps towards this goal and highlight the productive collaboration with the University of Fribourg, which has been and remains an excellent and supportive host institution, and the Swiss National Science Foundation.

Outreach

New book of experiments promises fun for kids

The NCCR Bio-Inspired Materials, in collaboration with partners from the Universities of Fribourg and Geneva, EPFL and Lausanne's Espace des Inventions, recently published a collection of fun science experiments for primary-school children. The result is a book that teachers and parents alike can use to entertain and educate.

From 2015 to 2018, the Migros Magazine, a weekly newspaper owned by Switzerland's biggest retailer, published almost 200 weekly science activities for children in collaboration with the book's partners. Now a selection of the best experiments is available as a book or online. The book's title, "PSCHITT!", is a French onomatopoeia for the sound gas makes escaping from a container.

"Over the years, there was a substantial personal investment for everyone involved in the Migros project," explains Dr. Sofia Martin Caba, the NCCR's outreach officer. "It seemed a pity to have all that material, and not do anything with it."

Aimed squarely at children attending primary school and their teachers, "PSCHITT!" provides easy-to-follow instructions in French for each of the 43 selected experiments, which can be safely attempted in the kitchen or the schoolroom. Each activity - covering domains as varied as mathematics, chemistry, biology, biochemistry, or physics - can be carried out using elements that can be found at home or easily purchased. Children can also attempt the experiments safely by themselves.

"Each activity comes with detailed explanations that children over the age of eight can easily understand," says Martin Caba. "Most of what we have included in the book can also interest younger kids with the help of their parents – the main thing is to have fun." She points out that children are naturally curious, and want to know how things work. "Our goal was to encourage that curiosity, and make them want to learn more," she adds.

The book also comes with a weighty recommendation from Switzerland's 2017 Nobel Chemistry Prize winner Prof. Jacques Dubochet, who wrote the foreword. "I see it as the happy pathway leading to that quiet confidence that nature is by essence subtle, but with a little work, it can be understood," he writes. "If anything, it is a call to follow that path and to embrace life."

"PSCHITT!" is not original is the sense that the activities it contains are novel or unheard of. "There are plenty of ideas in other books, on the internet, or even in our daily lives," explains Martin Caba. "We took those ideas, but then you have to rework them to explain what is going on and how to make that comprehensible for children. That's a real challenge because some of the concepts behind the experiments are quite complex."

Each experiment is presented the same way, starting with a list of "ingredients" required for the activity, followed by an illustrated "recipe" that

Pschitt! was available in a book format

children can follow. This is completed by a short explanation of the phenomena involved in the experiment, and a lengthier summary of the actual science behind it. This can be chemical formulas, descriptions of optical phenomena, or algorithms but to name a few.

Fun though is the main ingredient here. The learning experience is part of the package rather than the main goal, and all the experiments have been successfully tested with young participants. Making elephant toothpaste or slime is more amusing than learning multiplication tables or grammar rules.

The book has distributed to schools across French-speaking Switzerland, with the entire run now out of print. It is however still available online. A German version is also being prepared and should be released in the coming months.

On the web:
www.pschitt.ch

Partners:

- **KidsUni – University of Fribourg**
- **Espace des inventions – Lausanne**
- **Science Outreach Department, EPFL**
- **Scienscope, University of Geneva**
- **NCCR Bio-Inspired Materials**

Partnerships

Extended network to boost NCCR results

The NCCR Bio-Inspired Materials wishes to benefit from external expertise as it moves into its third and final, more applied, phase, as well as maintain ongoing relationships with former members of the Center. It now benefits from the input and knowledge from four external groups in Switzerland and abroad.

Dr. Raphaël Pugin of CSEM is collaborating with NCCR Principal Investigators Profs. Frank Scheffold and Ullrich Steiner to replace titania with edible white pigments. Titania (anatase or rutile TiO2) is an extremely wide-spread compound used to modify the optical appearance in applications, ranging from powder-coatings to food products. Because of suspected health implications, colloidal formulations of titania have been outlawed in France, and the EU has recently tightened regulations concerning its use. The importance of TiO2 lies in its high refractive index, providing effective light scattering for the efficient creation of the "color" white, which is also used as optical brightener in color formulations. The goal is to produce, using sustainable, benign materials inspired by nature, a "white" pigment capable of replacing the TiO2 industry standard. Dr. Pugin's CSEM group specializes in nanostructuring of surfaces and nanofabrication, replication techniques, as well as the development of nanostructured materials for life science.

Founded in 1984 and headquartered in Neuchâtel, CSEM is an internationally recognized innovation specialist. As a public-private, non-profit organization partially funded by the Swiss government, its mission is to support the innovation of Swiss companies, and strengthen the economy through ongoing collaboration with leading universities, research institutes, and industrial partners.

Dr. Luciano Boesel of the Empa (Swiss Federal Laboratories for Materials Science and Technology) in St Gallen, has joined "Transiently pulsating materials inspired by the heart" project headed up by NCCR postdoctoral researcher Dr. Rafael Libanori and NCCR Principal Investigator Prof. André Studart and Associate PI Prof. Nico Bruns. This project aims to mimic the working principle of the heart muscle by creating polymersome-laden hydrogel materials that change their size and mechanical properties after being triggered by an external stimulus, stay in this altered state for a defined time, and then revert back to their original size and mechanical properties.

Dr. Boesel is the head of the Adaptive Hydrogels group in the Laboratory for Biomimetic Membranes and Textiles at Empa. The laboratory develops novel smart fibers, textiles and membranes for body monitoring, drug delivery and tissue engineering applications. His projects include wearable textile sensors to protect against pressure ulcers, adaptive materials for tailored transdermal

The NCCR Bio-Inspired Materials also collaborates with institutions abroad such as the University of Salzburg

delivery applications, and fluorescence sensors for the monitoring of chronic and acute wounds.

Empa is a major part of the Swiss Federal Institutes of Technology Domain (ETH). Since the late 1980s it has developed into a modern research and development institute. Research is concentrated in five Research Focus Areas: "Nanostructured Materials," "Sustainable Built Environment," "Health and Performance," "Natural Resources and Pollutants," and "Energy".

Prof. Nico Bruns of TU Darmstadt, has been a member of the NCCR since its launch in 2014, first at the University of Fribourg's Adolphe Merkle Institute, then the University of Strathclyde (United Kingdom), before moving to Germany in 2021. He leads the projects "Mechanically responsive block copolymer nanoreactors inspired by the marine bioluminescence of dinoflagellates", and "Development of cargo carriers". He is also involved in six other projects.

The first of these two projects is inspired by the marine bioluminescence caused by a family of unicellular plankton called dinoflagellates. These organisms possess micron-sized reaction compartments (organelles) in which the enzyme luciferase and its substrate luciferin are encapsulated. They respond to mechanical stimuli by triggering a biochemical reaction that produces a flash of light. The project's goal is to develop mechanically switchable biocatalytic nanoreactors. The second aims to develop stimuli-responsive polymersomes that can package and deliver key morphogenetic factors to developing organoids growing on a chip in a spatio-temporally controlled and in vivo-like manner.

The Technische Universität Darmstadt is a research university in the city of Darmstadt, Germany. It was founded in 1877. Its research activities are focused notably in three fields: energy and environment, information and intelligence, and matter and materials. The Bruns group's research is directed towards the development of sustainable functional polymers, combining synthetic polymer chemistry with the engineering of proteins and enzymes.

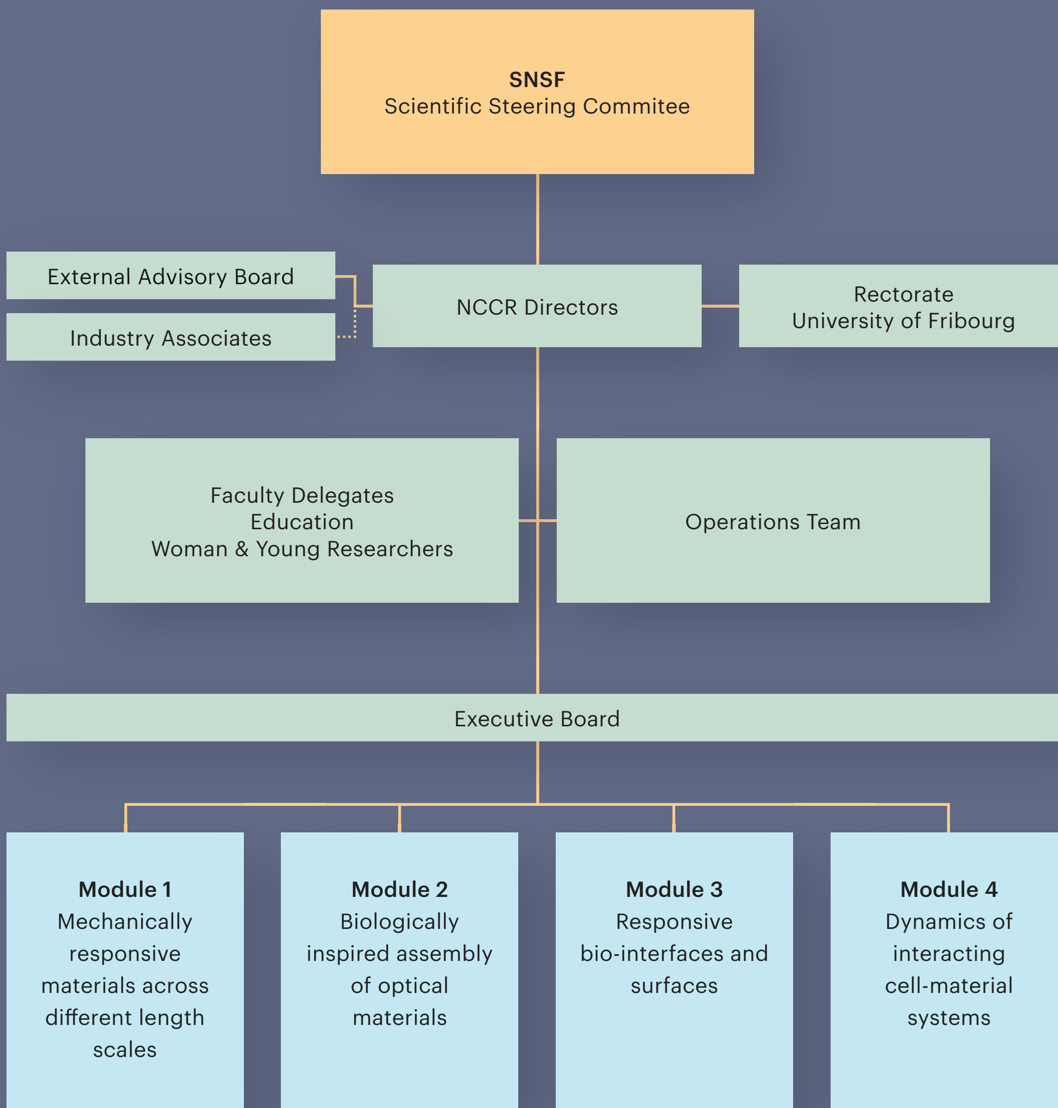
Prof. Bodo Wilts of the the Paris Lodron University of Salzburg (Austria) also joined the

Center during its first phase, as a group leader in the group of NCCR Principal Investigator Prof. Ullrich Steiner at the Adolphe Merkle Institute. He is involved in three current projects: “Interplay of order and disorder in biophotonic materials”, “Complete photonic band gap materials made by self-assembly of bottlebrush block terpolymers”, and “Enhancing structural colour through absorption”. These collaborations with NCCR PIs Profs. Steiner, Dufresene, Latttuada, Kilbinger, and Scheffold draw on the computational physics and optics specialist’s knowledge of structural color in nature.

The first project aims to unravel the order-disorder interplay in natural photonic materials, and to develop strategies to manufacture photonic materials with “dialled-in” disorder. The second project could lead to the creation of a 3D photonic material which reflects light for all orientations by harnessing polymer self-assembly and sol-gel processes. The third aims to enhance the generation of structural coloration in periodic lattice materials by tuning the refractive index.

The University of Salzburg is an Austrian public university in Salzburg, named after its founder, Prince-Archbishop Paris Lodron. Established in 1622, the university was closed in 1810 and re-established in 1962. Wilts joined the university in 2021 as professor of materials physics and is based at the department of Chemistry and Physics of Materials.

Organization Phase II



Who is who

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- Prof. Ullrich Steiner (AMI)
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- Prof. Esther Amstad (EPFL)
  Deputy director
- Prof. André Studart (ETHZ)
  Leader Module 1
- Prof. Frank Scheffold (UniFR)
  Leader Module 2
- Prof. Alke Fink (AMI/UniFR)
  Co-leader Module 3
- Prof. Barbara Rothen-Rutishauser (AMI)
  Faculty Delegate for Women and Young Researchers, co-leader Module 3
- Prof. Andreas Kilbinger (UniFR)
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- Viola Bauernfeind, Doctoral student
- Kenza Djeghdi, Doctoral student
- Dr. Andrea Dodero, Postdoctoral researcher
- Dr. Antonio Günzler, Postdoctoral researcher
- Dr. Ilja Gunkel, Senior researcher
- Prof. Jovana Milic, Assistant Professor
- Minh Tri Nguyen, Doctoral student
- Alessandro Parisotto, Doctoral student
- Dr. Bodo Wilts, Senior researcher

Stellacci group (EPFL)

- Prof. Francesco Stellacci
- Matteo Gasbarri, Doctoral student
- Simone Gavieri, Doctoral student
- Dr. Quy Ong, Senior researcher
- Laura Roset, Julia Doctoral student
- Vincenzo Scaramacio, Doctoral student

Studart group (ETHZ)

- Prof. André Studart
- Dr. Ahmet Demirörs, Senior researcher
- Alessandro Dutto, Doctoral student
- Nadia Enrriquez, Doctoral student
- Dr. Anton Igorevich Kan, Postdoctoral researcher
- Julie Laurent, Doctoral student
- Iacoppo Mattich, Doctoral student
- Dr. Mathias Steinacher, Postdoctoral researcher
- Dr. Elena Tervoort, Postdoctoral researcher

Vanni group (UniFR)

- Prof. Stefano Vanni
- Dr. Pablo Campomanes, Senior researcher
- Emanuele Petretto, Doctoral student

Weder group (AMI)

- Prof. Christoph Weder
- Dr. Jessica Clough, Postdoctoral researcher
- Dr. Sètuhn Jimaja, Postdoctoral researcher
- Derek Kiebala, Doctoral student
- Franziska Marx, Doctoral student
- Anita Roulin, Laboratory technician
- Dr. Stephen Schrettl, Postdoctoral researcher
- Hanna Traeger, Doctoral student

Support staff

- Dr. Jozef Adamcik, Senior researcher (AMI)
- Dr. Sandor Balog, Senior researcher (AMI)
- Véronique Buclin, Laboratory technician (AMI)
- Dr. Aurélien Crochet, Senior researcher (UniFR)
- Laetitia Häni, Laboratory technician (AMI)
- Anita Roulin, Laboratory technician (AMI)
- Dr. Dimitri Vanhecke, Senior researcher (AMI)

Alumni

- Dr. Maxime Bergman (Postdoctoral researcher, Scheffold group)
- Dr. Nicolas Broguière (Postdoctoral researcher, Lütolf group)
- Nicola Carrara (Doctoral student, Klok group)
- Antonius Chrisandy (Doctoral student, Lütolf group)
- Dr. Ahmet Demiroers (Senior researcher, Studart group)
- Alessandro Dutto (Doctoral student, Studart group)
- Nadia Enrriquez (Doctoral student, Studart group)
- Nathan Fuchs (Doctoral student, Scheffold group)
- Dr. Mark Gontsarik (Postdoctoral researcher, Salentinig group)
- Dr. Antonio Günzler (Postdoctoral researcher, Steiner group)
- Dr. Hwanseok Jang (Postdoctoral researcher, Lütolf group)
- Dr. Anton Igorevich Kan (Postdoctoral researcher, Studart group)
- Dr. Begum Karakocak (Postdoctoral researcher, Rothen group)
- Dr. Kuljeet Kaur (Postdoctoral researcher, Klok group)
- Julie Laurent (Doctoral student, Studart group)
- Chuen-Ru Li (Doctoral student, Amstad group)
- Michal Macha (Doctoral student, Radenovic group)
- Dr. Andrea Manfrin (Senior researcher, Lütolf group)
- Iacoppo Mattich (Doctoral student, Studart group)
- Joelle Medinger (Doctoral student, Lattuada group)
- Zhao Meng (Doctoral student, Amstad group)
- Friederike Metze (Doctoral student, Klok group)
- Vytautas Navikas (Doctoral student, Radenovic group)

- Dr. Roberto Ortuso (Postdoctoral researcher, Fink group)
- Dr. Guido Panzarasa (Postdoctoral researcher, Dufresne group)
- Dr. Mauricio Pilo-Pais (Postdoctoral researcher, Acuna group)
- Arielle Planchette (Doctoral student, Radenovic group)
- Dr. Manuel Rodriguez Perdigon (Postdoctoral researcher, Rüegg group)
- Sabrina Sant (Doctoral student, Klok group)
- Dr. Stephen Schrettl (Senior researcher, Weder group)
- Dr. Fabienne Schwab (Senior researcher, Rothen group)
- Dr. Mathias Steinacher (Postdoctoral researcher, Studart group)
- Dr. Robert Style (Senior researcher, Dufresne group)
- Dr. Maria Taskova (Postdoctoral researcher, Mayer group)
- Lucie Tillard (Other staff, Lütolf group)
- Alexandre Torzynski (Doctoral student, Dufresne group)
- Lorenzo Turetta (Doctoral student, Lattuada group)
- Dr. Bodo Wilts (Senior researcher, Steiner group)
- Ran Zhao (Doctoral student, Amstad group)

Summer students 2021

- Pui Ting Ho (University of Manchester)
- Arpan Grover (University of British Columbia)
- Natalia Gosnell (University of British Columbia)
- Justas Mikutavicius (University of Cambridge)
- Caitlin Shanahan (Lewis University)
- Valerie Pascetta (University of New Hampshire)
- Mia Harris (Durham University)
- Arya Roshanfekr (University College London)
- Sankalp Sharma (University of California, Berkeley)
- Neelai Patel (University College London (UCL))
- Andrew Smith (University of California, Irvine)
- Fraser Birks (University of Cambridge)
- Joni Wildman (University of Cambridge)
- Ethan Lim (University College London)
- Marcel Mordarski (University College London)
- Alfred Corrigan (University College London)
- Hugo Brummer (University of Groningen and Hanze University of Applied Sciences)
- Parth Patel (Case Western Reserve University)
- Apoorv Singh (EPFL)
- Kaylon Draney (University of Utah)

External advisory board

- Prof. Helmut Coelfen, Department of Chemistry, University Konstanz, Germany
- Prof. Ursula Graf-Hausner, graf 3dcellculture, Switzerland
- Prof. Takashi Kato, Department of Chemistry and Biotechnology, University of Tokyo, Japan
- Prof. LaShanda Korley, Department of Macromolecular Science and Engineering, Case Western Reserve University, USA
- Dr. Christiane Löwe, Director Equal Opportunities Office, University of Zurich, Switzerland
- Dr. Katharina Maniura, Materials Meet Life Department, EMPA, Switzerland
- Dr. Martin Michel, Food Science and Technology Department, Nestlé Research Center, Switzerland
- Prof. Marek Urban, Department of Materials Science and Engineering, Clemson University, USA

Abbreviations:

AMI: Adolphe Merkle Institute;
UniFR: University of Fribourg;
UniGE: University of Geneva;
EPFL: Federal Institute of Technology Lausanne;
ETHZ: Federal Institute of Technology Zurich

Projects

Module 1: Mechanically responsive materials across different length scales

1. Mechanically responsive and mechanically adapting polymers
2. Mechanically responsive block copolymer nanoreactors inspired by the marine bioluminescence of dinoflagellates
3. Auxetic polymer networks
4. Mechanoresponsive materials enabled by 3D Printing and high-throughput microfluidics
5. Adaptive functional polymers and nanocontainers
6. Mechano-responsive CaCO3-based coatings
7. Biomechanically-responsive nanoparticles

Module 2: Biologically inspired assembly of optical materials

8. Design of novel optical materials through self-assembly of patchy particles
9. Interplay of order and disorder in biophotonic materials
10. Structurally colored micron scale pigments for inkjet printing
11. Physical mechanisms underlying the self-assembly of living optical materials
12. Disguising the core: Photonic core-shell particles
13. Bioinspired DNA self-assembly of nano-photonic devices

Module 3: Responsive bio-interfaces and surfaces

14. Novel antiviral supramolecular materials
15. NanoRoomba®: Cellular uptake and durotaxis on ''soft and rigid'' nanoparticles carpet
16. Stimulation of cellular endocytosis for sensing and enhancing nanoparticle uptake
17. Self-assembly of DNA- or RNA-triggered ion channels for targeted cell killing and nanopore sensing
18. Trapping cancer cells with self-assembling biomolecules (DNA)
19. Fluorescent nanodiamonds as quantum bio-molecular probes for live cell imaging and sensing
20. Characterizing nanoparticle-membrane interactions via molecular dynamics simulations
21. Steering tissue morphogenesis via programmable microgel assemblies
22. Design of digestion-inspired functional food nano-biointerfaces

Module 4: Dynamics of interacting cell-material systems

23. Development of a microfluidic platform
24. Development of controlled delivery systems for organ-on-chip devices
25. Development of cargo carriers
26. Development of Tumor/Immune Cell Organoid Model

NCCR Collaborative Projects

27. Detection of circulating tumor cells by SERS using DNA based systems as signal amplifier
28. Development of a cross-departmental platform for optical micromanipulation
29. Ion-selective membranes for power conversion from salinity gradients with unprecedented efficiency

WINS Fellowships projects

30. Responsive pigments for Pointillist mechanosensing
31. Unified approach for intracellular delivery of multi-modified oligonucleotide sequences
32. Swelling-driven mechanical activation of polymers at interfaces and in the networks

Publications

Module 1

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Module 3

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Module 4

Demirörs, A. F.; Aykut, S.; Ganzeboom, S.; Meier, Y. A.; Poloni, E., Programmable droplet manipulation and wetting with soft magnetic carpets, PNAS, 2021, 118, e2111291118.

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WINS and Collaborative projects

Borge-Durán, I.; Grinberg, I.; Vega-Baudrit, JR.; Nguyen, M.T.; Pereira-Pinheiro, M.; Thiel, K.; Noeske, P-L. M.; Rischka, K.; Corrales-Ureña, Y. R., Application of poly-L-lysine for tailoring graphene oxide mediated contact formation between lithium titanium cxide LTO surfaces for batteries, Polymers, 2022, 14, 2150.

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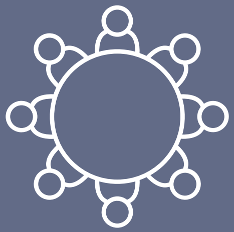
Mechanical Allostery:

Headquarters

Adolphe Merkle Institute, University of Fribourg. AMI is an independent competence center that focuses on research and education in the domain of soft nanomaterials

7



round tables

and workshops on topics related to equal opportunities and personal and professional development

4

start-up companies

incorporated (Nanolockin GmbH, Spectroplast AG, Microcaps AG and FenX AG) and one additional spin-off technology (Nanofertilizer)

Over

120

children

and high school students participated in NCCR outreach activities

15

cooperations

national and international cooperation projects with research institutions

Note: All figures between June 1, 2021 and May 31, 2022

Seminars

The NCCR organizes seminars on a regular basis throughout the academic year. These seminars are both an excellent opportunity to learn about recent scientific advances from prominent researchers as well as a meeting point for NCCR participants to network and exchange ideas.

Speaker	Talk	Home Institution	Date
Dr. Guillaume De Bo	Controlling reactivity under tension	University of Manchester, UK	June 10, 2021
Prof. David Pine	Self-assembly of colloidal diamond for photonics	New York University, USA	September 29, 2021
Prof. Augustin Mihi	Creating photonic architectures by nano-imprinting unconventional materials	Institut de Ciència de Materials de Barcelona (ICMAB-CSIC), Spain	November 12, 2021
Prof. Cecilia Leal	Synergistic behavior of polymer-lipid hybrid membranes	University of Illinois, Urbana-Champaign, USA	November 18, 2021
Dr. Gioele Balestra, Raphaël Wenger	Challenges and opportunities of the inkjet technology and its application to bioprinting	iPrint, School of Engineering and Architecture of Fribourg, Switzerland	December 2, 2021
Rafic Hanbali	Technology and sustainability – the architecture of tomorrow	Kromatix, Switzerland	December 13, 2021
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