Activities report 2022–2023

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 the creation of macromolecular and nanomaterial-based building blocks and their assembly into complex, hierarchically ordered stimuli-responsive materials with new and interesting properties. We seek to develop a predictive understanding for the interactions of these materials with living cells and use the generated knowledge to develop innovative applications, particularly in the biomedical field.

For the third and final phase of our activities, our research is organized in four modules that focus on mechanically responsive materials, photonic materials, responsive bio-interfaces, and translation-focused projects. Each of these modules tackles major unsolved problems, provides opportunities for great scientific advances on its own, and requires an interdisciplinary research approach.

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

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Content

Message from the directors

New members, new collaborations

In the last year, the NCCR Bio-inspired Materials launched twenty new projects that will shape its research program during the third and last funding phase.

For a few months, these projects coexisted with several research projects from the previous funding phase that were granted extensions to compensate for COVID-related delays. One of the main objectives of our Center for this phase is to strengthen collaborations across research groups and disciplines. We are on track to achieve this goal as close to 25% of the Center's publications in the reporting period were collaborative. These numbers result from initiatives launched in the second funding phase to foster collaborations. They are expected to increase as the current projects progress since 90% involve the collaboration of up to four research groups. Besides supporting collaborative projects, our Center creates opportunities for scientific exchange between its PhD students and postdocs. One of these activities is the periodic NCCR internal conference for young researchers, the last of which was hosted by the Studart and Dufresne groups at ETHZ with a diverse agenda, including research, mentoring, and social components.

We are pleased to welcome two new Associate PIs, Professors Jessica Clough and Jovana Milic, to our NCCR. They are both based at the Adolphe Merkle Institute and will reinforce Module 1 with their expertise in mechanoresponsive materials. This development is accompanied by the restructuring of Module 3, which will decrease its project number with the goal of sharpening its *bio-interfaces* focus.

In line with the efforts of the SNSF in the domain of Open Science, our Center is quickly increasing its share of open-access publications. 86% of the articles included in this report are openly accessible, an all-time high for our NCCR that is supported by the institutional agreements established between the Swiss universities and leading publishing houses. To further strengthen this area, we have recently reinforced the NCCR's operations office with Dr. Barbara Drasler, who supports our researchers in meeting our Open Science goals.

Our Center was involved in various activities beyond research. A few examples include the German translation of the outreach book *Pschitt!*, which we published last year with partners from Lausanne and Geneva, and the inter-NCCR collaborations in which our Center was involved, namely the entrepreneurial training workshops *bench2biz* and the *#NCCRWomen* campaign.

The following pages collect a selection of recent activities of our NCCR, including research highlights, the integration of new PIs, external funding catalyzed by the NCCR, new large-scale equipment, and the main figures of the NCCR.
We hope you will enjoy the reading. Thank you for your interest in our Center, and we are looking 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 inspiration from nature for the design of artificial materials that can change their properties on command, so to speak, 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 useful in countless applications that range from climate control for buildings to drug delivery systems in the body.

In the recent past, scientists have begun to consider nature’s principles as inspiration for the design of artificial materials with intriguing stimuli-responsive properties. Previous examples of materials studied by individual research groups that belong to the Center 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.

With the aim of carrying out paradigm-changing scientific breakthroughs and harnessing the enormous innovation potential in this domain, the Center has developed into a large-scale interdisciplinary effort that merges competences in chemistry, physics, materials science, biology, and medicine.

Diagnostics

'DNA origami' sensor could help detect cancer biomarkers in blood

By engineering structures out of DNA, NCCR Bio-Inspired Materials researchers at the University of Fribourg have developed a biosensor that produces a fluorescent signal upon binding molecules found in some types of tumors. The DNA-based sensor could one day help screen a drop of blood for cancer biomarkers.

To detect cancer early on without having to do invasive surgical procedures such as tumor biopsies, scientists worldwide are racing to develop tests that detect tumor-derived nucleic acids, including DNA and short snippets of RNA called miRNAs, which are present in low abundance in the blood of cancer patients. However, the most common methods to detect these molecules are costly, time-consuming, and require trained personnel and specific chemical supplies.

To develop a more efficient strategy for cancer biomarker detection, researchers led by NCCR principal investigators Guillermo Acuña and Curzio Rüegg at the University of Fribourg turned to a technique called 'DNA origami,' which relies on the ability of the DNA molecule to fold into intricate shapes and structures.

"DNA molecules are quite fascinating because, on the one side, they carry genetic information," Rüegg says. On the other hand, he adds, because complementary sequences of DNA can bind to one another, it's possible to engineer three-dimensional structures with programmable functions. DNA can bind other molecules, serving as a scaffold for complex nanomachinery.

Using DNA origami, the researchers designed a rectangle-shaped sensor made of three building blocks containing sequences that can bind target molecules. The team then coated each building block with different fluorophores – fluorescent molecules that can re-emit light upon excitation.

> "Because complementary sequences of DNA can bind to one another, it's possible to engineer three-dimensional structures with programmable functions."
>
> Prof. Curzio Rüegg

As the biosensor is produced, its building blocks snap together to form a fully closed book-like structure. However, the presence of target molecules can displace the sequences that keep the structure closed, causing it to open. This structural modification leads to changes in the

Just a single drop of blood could suffice for a cancer diagnostic

fluorescence emitted by the fluorophores that decorate the 'book' – a signal that can be easily detected with a microscope.

The book-like biosensor could detect, at the same time, two different miRNAs from breast cancer cells within minutes and down to 600,000 molecules per microliter, the researchers reported in the journal Nanoscale.

The collaboration between Acuña and Rüegg, who are both part of the NCCR Bio-Inspired Materials program, continues to this day. Funded by an Innosuisse grant, Rüegg is working towards developing bioassays that could be used in blood tests for breast cancer monitoring. Acuña is filing a patent application to manufacture portable devices that would allow the detection of these bioassays using a smartphone. "All the experiments in our studies are performed in the lab with expensive equipment by highly trained personnel," Acuña says. In the future, he adds, "we want to use these biosensors in an affordable, portable device."

However, more work is needed to take the assays from the lab to the real world. For one, the sensors have to be more sensitive in order to detect lower amounts of miRNAs from cancer cells, Rüegg says. His team is now testing specific molecules that could improve the sensors' sensitivity. Another approach may involve isolating miRNAs from larger volumes of blood to add to the sensor, he says.

To develop cancer diagnostic tests that are as easy as a pregnancy test would also require separating the liquid portion of blood from a blood drop before analyzing it. "That would be a challenge, but it's doable," Rüegg says. "The portable device could be an application that would add a unique value to this sensor."

Reference

Domljanovic, I.; Loretan, M.; Kempter, S.; Acuna, G. P.; Kocabey, S.; Ruegg, C., DNA origami book biosensor for multiplex detection of cancer-associated nucleic acids, Nanoscale, 2022, 14, 15432–15441.

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Research Projects

CHF 6.4 mill.

of funding including CHF 3.1 million from the SNSF

Partners

University of Fribourg (home institution), Federal Institutes of Technology Lausanne and Zürich, Cornell, TU Darmstadt, Paris-Lodron-University Salzburg, CSEM, Empa

26
Research groups

at six universities

3
national cooperation

projects with industry

2
industrial associates

2
Innosuisse projects

13
national and international conferences

supported including the Swiss NanoConvention and Bioinspired2022

Note: All figures between June 1, 2022 – May 31, 2023

Reactive

Squid-inspired probe changes color in response to force

Taking a clue from squids that change color to blend into their surroundings, NCCR Bio-Inspired Materials researchers at the Adolphe Merkle Institute have designed pigments that make a material change its appearance in response to mechanically induced deformations.

The pigments could act as stress detectors in materials used for packaging as well as for structural and biomedical applications, thus helping to prevent damages and failures. Scientists could also use the pigments to study how different materials respond to stress, says NCCR principal investigator Jessica Clough, assistant professor and head of the Mechanoresponsive Materials research group at the Adolphe Merkle Institute, who led the study. The pigments, she adds, "could give us more insights into the mechanisms by which materials fail, so we can design better ones."

A long-standing challenge in materials science has been making stress sensors that are easy to incorporate into different materials and that can rapidly change their color when a force is applied. Most current sensors turn on just as the material is about to break, so one of the goals of Clough's team was to make sensors that are responsive to smaller forces.

To do so, the researchers took inspiration from squids – marine animals that can change their skin tone to match their surroundings. The squid's skin is packed with color-changing cells, each of which contains a sac full of pigments. When the animal contracts its muscles, the sac expands, making the color more visible. Underneath these cells lies a layer of mirror-like cells that are capable of reflecting all the light that hits them. By scattering this light, they create iridescent colors.

Clough and her colleagues set out to develop probes that combine the features that squids use to change color. The team designed tiny spheres made of silica nanoparticles that assemble into mirror-like photonic structures. The spheres also contain force-sensitive molecules called mechanophores, which emit fluorescence when a mechanical force brings about a structural rearrangement.

The researchers embedded these spheres, dubbed "mechano-pigments", into several polymers, including polyethylene, the most widespread plastic in the world, and polydimethylsiloxane, a rubbery material with a wide variety of uses – ranging from electronics to biomedicine. Just as color pigments give color to a paint, so the mechano-pigments make polymers change their colors in response to forces when embedded into them,

The same mechanism that allows squid to camouflage themselves could be applied in sensors

Clough says. “You don’t have to do complicated chemistry, you can just mix the mechano-pigments in.”

Compressing the materials containing the mechano-pigments changed their appearance markedly. Mechanical strains as small as 1% altered the arrangement of the photonic structures within the mechano-pigments, scattering light in ways that changed the materials’ color from bright green to pale blue. Higher strains, ranging from 30 to 70%, caused the mechanophores to emit fluorescence.

The study, published in the journal *Advanced Science*, is the first of its kind to develop mechano-pigments that combine photonic structures with mechanophores. The work also pioneered the application of these mechano-pigments in a range of polymers – from relatively stiff ones such as polyethylene to the rubbery polydimethylsiloxane. If applied to softer materials, such as hydrogels, the mechano-pigments may help scientists to better understand and predict failure in all kinds of materials, from 3D printed plastics to artificial tissues.

Clough, who had moved to Switzerland to take up a Women in Science postdoctoral fellowship from the NCCR Bio-Inspired Materials, was awarded a PRIMA grant from the Swiss National Science Foundation in 2022. The grant allowed her to start her own research group at the Adolphe Merkle Institute, where she’s working towards developing new probes of mechanical deformation in polymers. “Many macroscopic phenomena, like a crack formation, start off with a little defect that gets bigger and bigger,” she says. “We’re interested in developing a way to study this process from its nanoscopic origins.”

Reference

Clough, J. M.; Kirchner, C.; Wilts, B. D.; Weder, C., Hierarchically structured deformation-sensing mechanochromic pigments, Adv. Sci., 2023, 10, 2206416.

Forces of attraction

Revealing the interactions that bind complex metal nanoparticles

For a long time, researchers have been investigating the unique properties of nanoparticles of pure gold coated with a thin layer of specific molecules. These particles may not only find applications as drug delivery devices, but they can also help investigate the behavior of matter at tiny scales.

However, the chemical properties that cause the aggregation of these nanoparticles have been debated. Now, NCCR Bio-Inspired Materials researchers at the University of Fribourg and EPFL revealed that different types of forces contribute to the attraction between nanoscale gold particles.

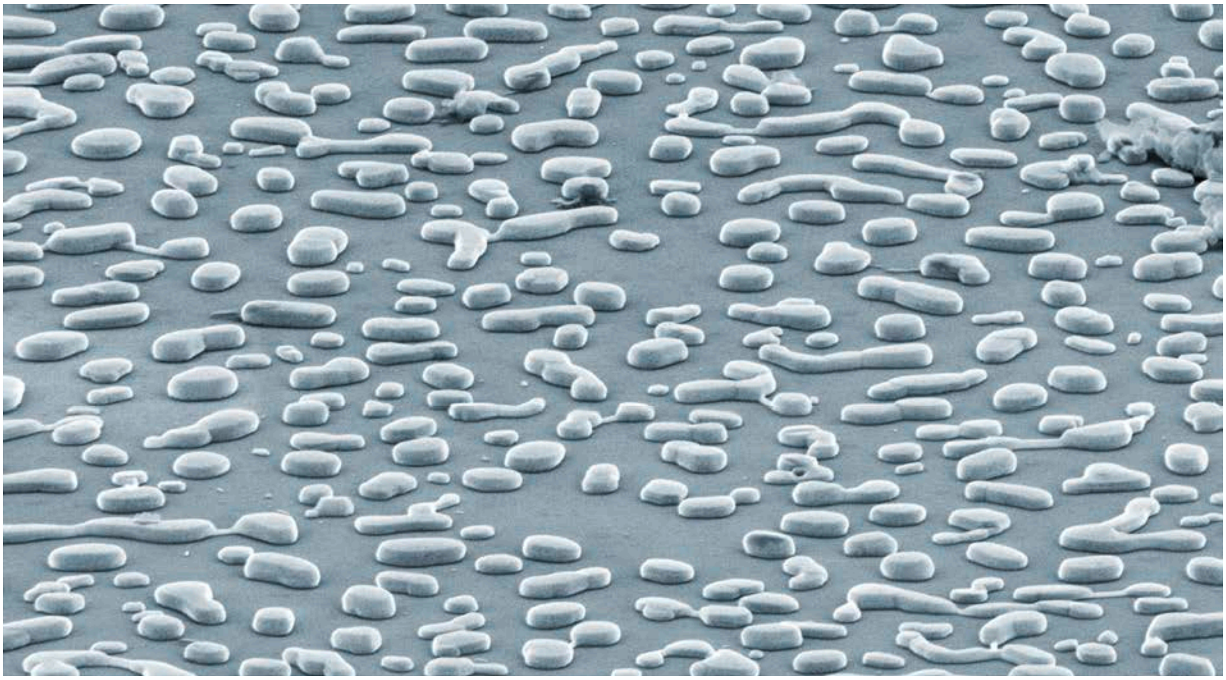
"If you want to use these nanoparticles as a therapeutic agent or a drug delivery system, you want to know how they interact with biological objects such as membranes and proteins," says NCCR principal investigator Stefano Vanni, professor of biochemistry at the University of Fribourg, who led the study. "The more you know about them, the more you can improve their design for potential applications." By looking at how these minuscule particles interact with each other, Vanni's work contributes to the understanding of how they behave.

The particles, called "monolayer-protected gold nanoparticles", are characterized by a metal core, typically measuring a few nanometers in diameter, covered by a layer of carbon-based materials that are responsible for the particles' structure and function. As a result, the chemical properties of the nanoparticles can be modified by changing the composition of their outer shell.

However, so far there's been little consensus on how chemical forces on the particles' outer layer make them come together. To address this question, Vanni and his colleagues studied monolayer-protected gold nanoparticles using computer simulations that analyze the physical movements of atoms and molecules. Then, they combined the simulations with a powerful technique for imaging structures at the individual atom level.

Hydrophobic forces – which describe the attraction between water-hating molecules – are a source of aggregation for nanoparticles. But interactions between charged molecules, known as electrostatic interactions, can also bring two or more nanoparticles together, the researchers found.

When two nanoparticles get very close to each other, their aggregation is mainly driven by hydrophobic interactions. As the distance between the particles increases, they repel each other because they have the same charge. However, there is a "Goldilocks" distance between the particles at



Nanoparticles can come together as the result of hydrophobic forces and eletrostatic charges according to Vanni

which a specific ratio of charge and hydrophobic forces make electrostatic interactions attractive. As a result, the particles come together, the researchers found.

"That happens because of the very specific orientation and arrangement of the molecules on the surface, so the nanoparticles get stuck in what is called a metastable state, which is driven by electrostatic interactions," Vanni says.

The study also revealed that this "metastable" state is mediated by a specific type of charged molecules called monovalent ions. Previous studies have suggested that monovalent ions could mediate the interaction between nanoparticles. "We found strong evidence in support of that," Vanni says.

His analysis also suggests that monovalent ions can help to stabilize or de-stabilize colloidal systems – mixtures in which very small particles of one substance are distributed evenly throughout another substance. Because hydrophobic and charged interactions play a key role in biology, the findings could help researchers better understand how proteins and other biopolymers form aggregates within cells.

The results indicate that not only the charge but also the orientation of molecules within nanoparticles is important to modulate their function. "For proteins, it depends on their three-dimensional structure, and for nanoparticles, it depends on the type of molecules used to build the particles," Vanni says.

The study, published in the journal Nanoscale, stemmed from a collaborative effort between Vanni and NCCR principal investigator Francesco Stellacci at the École Polytechnique Fédérale de Lausanne, whose team carried out experiments to validate findings from the computer simulations. The NCCR was key for the collaboration with Stellacci, Vanni says. "We met twice a year through the NCCR – that's how the project started, and we're continuing to work together on this."

Reference

Petretto, E.; Ong, Q.K.; Olgiati, F.; Mao, T.; Campomanes, P.; Stellacci, F.; Vanni. S., Monovalent ion-mediated charge–charge interactions drive aggregation of surface-functionalized gold nanoparticle, Nanoscale, 2022, 14, 15181–15192.

Targeted delivery

Researchers develop approach to advance nanomedicine, layer by layer

Short genetic fragments called small-interfering RNAs, or siRNAs, hold great promise as a tool for treating disease, as they can bind and silence specific messenger molecules that code for proteins.

However, these molecules are easily degraded and their delivery to target cells remains difficult to achieve in practice. Now, NCCR Bio-Inspired Materials researchers at the Adolphe Merkle institute have developed an approach that overcomes some of the challenges associated with the targeting and delivery of siRNAs into cells.

The work, led by NCCR principal investigators Profs. Alke Fink and Barbara Rothen-Rutishauser, may help to optimize the controlled release of multiple therapeutic agents to treat cancer and other diseases.

To improve the targeting and delivery of siRNAs to cells, Fink and her PhD student Aaron Lee turned to a technique called layer-by-layer assembly. Taking advantage of interactions between molecules of opposite charge, the researchers coated silica nanoparticles with alternating layers of siRNAs, which are negatively charged, and a positively charged polymer that helps protect the RNA from degradation. The team also included an outer coating of hyaluronic acid, a molecule that binds to receptors found on most cells.

Exploiting the material properties, the researchers then assembled the nanoparticles on a specific surface. The surface, Fink says, “can be used as a local drug delivery depot.” For example, she adds, it could be used in implants to activate immune cells that fight bacterial infections.

> “The surface [treated with nanoparticles] can be used as a local drug delivery depot.”
>
> Prof. Alke Fink

To test whether their approach could work in practice, the researchers cultured cells expressing a green-fluorescent protein (GFP), which as the name says, emits bright green fluorescence, on a surface coated with nanoparticles containing siRNAs for silencing GFP. After the cells internalized the nanoparticles, their fluorescence intensity was reduced by about 50%. The particles didn’t have any strong adverse effects on cell health and pro-

RNA fragments used in combination with silica nanoparticles and a polymer could be used to target cells or genes involved in different diseases

liferation. The findings were published in the journal ACS Applied Bio Materials.

The applications of the system are endless, as the nanoparticles can be customized to target specific cells and silence genes that are involved in different diseases. The particles could also be used for immunization to deliver antigens or nucleic acids that activate the immune system, or to carry drugs that induce death in cancer cells, Rothen-Rutishauser says.

The collaboration with Fink, who oversaw the design of the nanoparticles, was greatly facilitated by the NCCR Bio-Inspired Materials, says Rothen-Rutishauser, whose team identified the optimal cell type and marker to test whether the system worked.

In the future, the duo will continue to work together towards creating particle gradients that would allow researchers to generate a graded difference in physiological activity across cells on a surface.

Inducing a cell response at a specific site in the human body is often occurring in nature, for example when there's local infection or disease, Rothen-Rutishauser says. "This locally controlled induction of the cell response was our inspiration."

Reference

Lee, A.; Gosnell, N.; Milinkovic, D.; Taladriz-Blanco, P.; Rothen-Rutishauser, B.; Petri-Fink, A., Layer-by-layer siRNA particle assemblies for localized delivery of siRNA to epithelial cells through surface-mediated particle uptake, ACS Appl. Bio Mater., 2023, 6, 83–92.

Trapping particles

Using tiny tweezers, scientists characterize bioinspired nanocarriers

Oil and water are two very different substances that typically don't mix, except in mayonnaise, milk, salad dressings, and other so-called "emulsions" – stable mixtures of water droplets and fatty molecules. Oil and water emulsions are used in everything from drug delivery to food processing and cosmetics.

However, studying how single particles within these emulsions change in response to, for example, pH shifts in the digestive tract has proved challenging.

Now, for the first time, NCCR Bio-Inspired Materials researchers at the University of Fribourg have used "optical tweezers" to trap and characterize individual particles within an oil and water emulsion while changing the pH. Their findings may help not only to better understand how fat is digested in the body, but also inform the production of improved food formulations and drug nanocarriers.

"No one before managed to look at the ultrastructural features of a digesting oil-in-water emulsion droplet at the single-particle level in real time using optical tweezers," says NCCR principal investigator Stefan Salentinig, professor of experimental physical chemistry at the University of Fribourg.

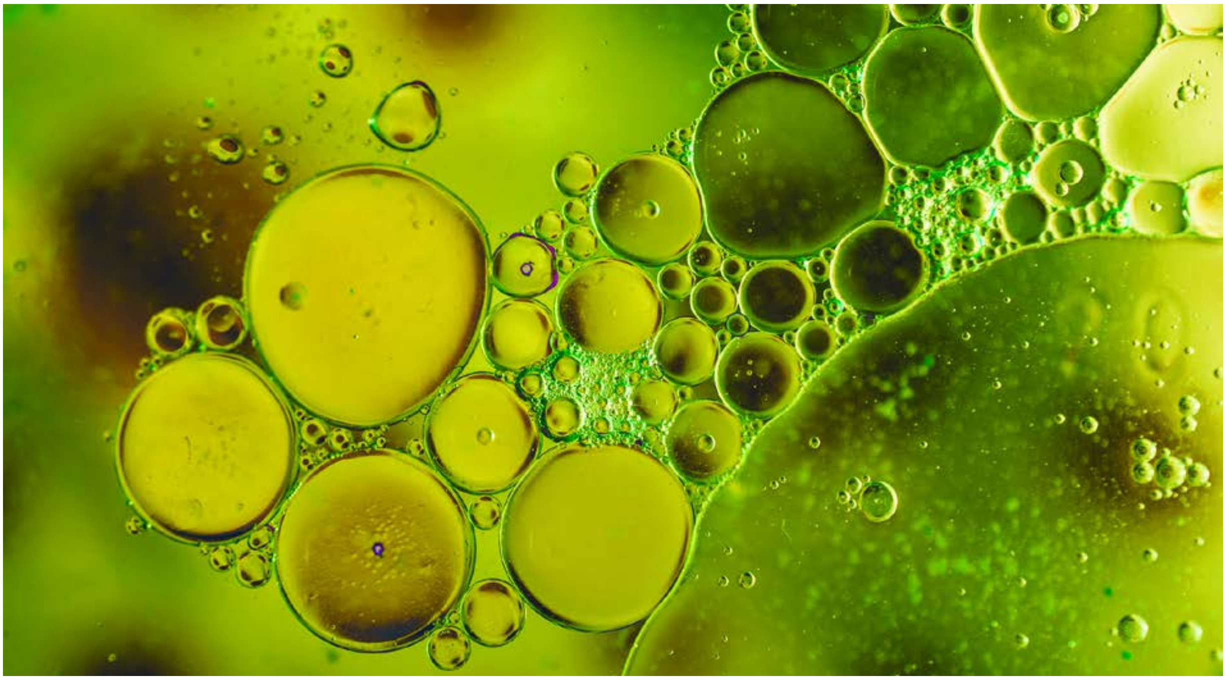
Salentinig and his team have previously found that, as milk is digested, it forms highly organized nanostructures that could be key for transporting nutrients that do not dissolve in water through the digestive tract.

The researchers also showed that these structures may be used as tiny shuttles to transport antimicrobial drugs and release the drugs in response to changes in pH. However, the effect of pH on the nanostructures remained mysterious.

> "Optical tweezers allow us to manipulate objects on the microscale."
>
> Prof. Frank Scheffold

So, Salentinig teamed up with NCCR PI Frank Scheffold, professor of physics at the University of Fribourg, whose group has been working on optical tweezers – intense beams of laser light that can be used to capture and manipulate tiny objects. This Nobel Prize-winning technology, developed in the 1970s, is now used in many applications, from trapping fat droplets inside living cells to studying the workings of individual enzymes.

"Optical tweezers are one of the most brilliant innovations in science and allow us to manipulate objects on the microscale," Scheffold says. "We adapted and contributed with new developments to this technology, in terms of making it faster and



Observing emulsions helps understand how fat is digested, but could also lead to better food formulations and drug carriers

higher-precision, and we have implemented some of these learnings in this study."

Scheffold, Salentinig, and their teams combined optical tweezers with microscopy, microfluidics and other analytic methods in a way that allowed them to capture and characterize droplets of the fatty molecule oleic acid in water under changing pH conditions.

The researchers found that at low pH, the oleic acid droplets do not have a specific structure. "They look like a simple oil droplet surrounded by water," Salentinig says. But as the pH increased, the molecules began to arrange in very specific nanostructures.

At neutral pH, water from the outside started to enter the droplets, and aggregates of oleic acid filled with water formed honeycomb-like structures. As the pH increased, these so-called liquid crystalline structures transformed into tiny fat sponges whose pores were filled with water. At high pH, onion-shaped vesicles are formed; these structures are made of several concentric layers of oleic acid and water. The researchers reported their findings in the Journal of *Colloid and Interface Science*.

"By changing the pH, one can tune the structures and induce the release of a drug, a molecule, a nutrient — whatever is loaded into these carriers," Salentinig says. Understanding how the structures of these nano-shuttles change with pH, he adds, would allow researchers to target drugs to specific organs or influence the feeling of satiety in people.

Salentinig and Scheffold continue collaborating on an ambitious new project that uses optical tweezers to capture individual droplets, manipulate their structure, and map their composition in real time using state-of-the-art techniques. Looking at the composition of the droplets in real time would allow the researchers to monitor the release of drugs and other molecules.

References

Manca, M.; Zhang, C.; Scheffold, F.; Salentinig, S., Optical tweezer platform for the characterization of pH-triggered colloidal transformations in the oleic acid / water system, J. Colloid Interface Sci., 2022, 627, 610–620.

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Researchers

incl. PhD students, postdocs, senior researchers and professors

Gender balance

48% of the NCCR Ph.D. students were women

31% of the postdocs and senior researchers were women

36 Nationalities

including Switzerland, Argentina, Austria, Brazil, Bulgaria, Canada, China, Croatia, Egypt, Ethiopia, France, Germany, Greece, India, Indonesia, Ireland, Italy, Kenya, Lebanon, Netherlands, New Zealand, Philippines, Poland, Portugal, Romania, Russia, Serbia, Slovenia, South Africa, South Korea, Spain, Thailand, Turkey, UK, Ukraine, US

72

oral presentations at conferences (including 30 keynote and plenary lectures at international conferences)

81

Papers

including 70 original contributions, 10 reviews and 1 news and views

86%

of open access publications

following the Gold or Green roads and through institutional agreements

Note: All figures between June 1, 2022 – May 31, 2023

In brief

Chorofas Prize

NCCR Bio-Inspired Materials alum Dr. Vytautas Navikas was awarded one of the two 2022 Chorafas Prizes for the best doctoral thesis at Lausanne's Federal Institute of Technology (EPFL).

Navikas completed his PhD thesis on "Biophysical applications of correlative scanning probe and super-resolution microscopy" as a member of NCCR Principal Investigator Prof. Aleksandra Radenovic's Laboratory of Nanoscale Biology.

Navikas was awarded the prize for "his outstanding contributions to the development of novel correlative single-molecule imaging and

Navikas was a member of the Radenovic lab at EPFL

single-molecule spectroscopy methods." His thesis focused on advancing state-of-the-art correlative scanning ion-conductance microscopy combined with novel super-resolution imaging techniques. The Dimitris N. Chorafas Foundation awards scientific prizes for outstanding work in selected fields in the engineering sciences, medicine, and the natural sciences.

Flavia Sousa joined the BioNanomaterials group at the Adolphe Merkle Institute for her fellowship

New WINS Fellow

Dr. Flavia Sousa joined the NCCR as the latest WINS (Women in Science) Fellow in September 2022. She is developing a novel approach to treat a form of brain cancer known as glioblastoma, with a biodegradable microneedle loaded with an RNA nanovaccine to reengineer the tumor environment.

Glioblastoma is a highly aggressive and deadly malignant primary brain tumor, with 50 per cent of patients surviving less than 15 months after being diagnosed. Her project aims to overcome current clinical limitations for the treatment of this form of cancer. This will involve the development of a biodegradable microneedle system to be implanted after tumor surgery. The vaccine itself relies on a molecule known as messenger RNA (mRNA). The mRNA instructs cells that take up the vaccine to produce proteins that may stimulate an immune response against these same proteins when they are present, in this case, in tumor cells.

The proposed nanovaccine would stimulate the in situ expression of cytokines, a type of protein, in the tumor microenvironment. Cytokines are used to stimulate anti-tumor immunity, leading to the potential elimination of cancerous cells.

Sousa, who joined the Adolphe Merkle Institute's BioNanomaterials group for her project, obtained her PhD in biomedical sciences at the University of Porto (Portugal) in 2019, followed by postdoctoral stays at Imperial College London (UK), and the Istituto Italiano di Tecnologia in Genoa (Italy). The two-year postdoctoral Fellowship Program for Women in Science of the NCCR Bio-Inspired Materials seeks to support the professional development of outstanding female researchers who have already demonstrated excellence at an early stage of their careers and wish to pursue an academic career. Since the start of her fellowship, she has also been nominated as an MIT Innovator under 35 Europe and selected as a Female Science Talent by the Falling Walls Foundation.

NCCR student awards

PhD student Ali Kaiss (University of Fribourg) was the winner of the first oral presentation prize at the International Conference on Coordination and Bioinorganic Chemistry in Smolenice, Slovakia, in June 2022.

Samuel Watts, another PhD student at the University of Fribourg, was the recipient of a poster prize at the 2022 annual meeting of the Swiss Crystallography Society held in September 2022 in Bern. Viola

Ali Kaiss was just one NCCR PhD student recognized for the quality of his work

Bauernfeind (Adolphe Merkle Institute) won two poster prizes at the Swiss NanoConvention in Fribourg in July 2022 and at the 3rd International Workshop on Insect Bio-inspired Technologies in Edinburgh in November 2022. The PhD student also had her abstract for the American Physical Society's meeting in Las Vegas in March 2023 selected for inclusion in the association's media outreach.

On the move

NCCR PI Prof. Eric Dufresne (ETHZ) was appointed to the Department of Materials Science and Engineering at Cornell University in Ithaca in the US state of New York.

He recently took up his position at the Ivy League college but remains associated with the NCCR during its third and final stage. Dufresne pursued his research in Zurich between 2016 and 2023. He had previously held a professorship at Yale University.

Dr. Stephen Schrettl (Adolphe Merkle Institute) was appointed Associate Professor of Functional Materials for Food Packaging at the Technical University of Munich, where he

NCCR PI Eric Dufresne is now collaborating from Cornell University

took up his position in the summer of 2022. Schrettl was a group leader in PI Prof. Christoph Weder's Polymer Chemistry and Materials and had been a member of the NCCR since 2017.

German version for science experiments books

The collection of fun science experiments for primary-school children published by the NCCR Bio-Inspired Materials in collaboration with partners from the Universities of Fribourg and Geneva, EPFL and Lausanne's Espace des Inventions has now been translated into German.

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. The book, with a foreword from the 2017 Nobel Chemistry Prize awardee Jacques Dubochet, contains many of those experiments. Aimed squarely at children attending primary

German and French versions of the book have been published

school and their teachers, "ZISCH!" provides easy-to-follow instructions for each experiment, which can be safely carried out in the kitchen or the schoolroom. Each activity uses elements that can be found at home or can be easily purchased.

Promoting STEMM

The NCCR Bio-Inspired Materials is part of the recent established multi-NCCR initiative "A researcher in my class", which brings female researchers to high schools.

The progression of women's careers in research is still moving ahead slowly, marked by gender inequalities in most scientific fields. The goal of this program is to establish an exchange between these female researchers and students between the ages of 15 and 18 on what motivated them to choose a research career and describe a typical

The project aims to boost women's participation in science

day in the lab. Teachers can invite one of the participating researchers to their classroom during the school year. These women are working in fields ranging from engineering to linguistics, architecture, chemistry, robotics, neuroscience, quantum physics, or microbiology. "A researcher in my class" comes under the umbrella of the Swiss National Science Foundation's NETCCWORK Ventures program. Its members hope that this initiative will inspire students and uncover vocations, while solidifying their belief that women can succeed in MINT fields.

Christoph Weder was the NCCR's first director

International recognition

NCCR PI Prof. Christoph Weder (Adolphe Merkle Institute) was honored with the 2022 Anselme Payen Award of the American Chemical Society's (ACS) Cellulose and Renewable Materials Division.

The award is given to honor and encourage "outstanding professional contributions to the science and chemical technology of cellulose and its allied products". The prize is named after Anselme Payen, a 19th-century French pioneer in the chemistry of both cellulose and lignin. His research led notably to the discovery of cellulose. In a statement, the ACS division said that Prof. Weder is known as an imaginative scientist whose research is situated at the interface of chemistry and materials. Weder was also the recipient of the 2022 International Biannual Award of the Belgian Polymer Group, given to scientists with outstanding contributions to polymer science.

Internal conference

The NCCR's PhD students organized a one-day conference for PhD students and postdocs only, with the aim of fostering communication and collaboration among each other and the integration of new members.

Researchers from the groups of PIs Studart and Dufresne (ETHZ) took the lead for the event, which took place in Zurich in June 2022 with 30 participants. The event included a talk by the Center's Scientific coordinator on funding and networking opportunities offered by the NCCR, an invited talk by Prof. G. Nyström (Empa), lectures by NCCR members, a poster session, along with group discussions on career development and PhD thesis management.

Publication highlights

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MIT in Boston has been one destination for the graduate student exchange program

International Graduate Exchange Program

The Center's PhD students continue to benefit from the NCCR International Graduate Exchange Program.

Eva Susnik (Adolphe Merkle Institute) traveled to the Nova University of Lisbon where she worked for two months on the stimulation of gold nanoparticle internalization by cells. Alessandro Parisotto (Adolphe Merkle Institute) carried out a five-month stay at the Massachusetts Institute of Technology, where he focused on the study of emulsions to generate structural coloration in food products.

Undergraduate program

The 2022 edition of the Undergraduate Research Internship program hosted over the summer 20 students coming from 15 different universities in the United States, United Kingdom, Spain, and Korea, including top institutions such as Cornell, Cambridge, and Berkeley universities.

Three groups from outside the NCCR at the University of Fribourg (departments of Physics, Biology, and Chemistry) joined the program and hosted students. The traditional best poster prize for the URIs went to Andrea Chavez Muñoz (Northeastern University) for her project on fluid exchanges between ant colony members. The undergraduate program has been a feature of the NCCR since its launch in 2014, helping students develop a strong understanding of bioinspired research.

Andrea Chavez Muñoz was recognized for her project at the University of Fribourg's biology department

The undergraduate students acquire an understanding of advanced research work and hands-on work experience, but also to develop transferable skills and network with professionals in their own field of interest.

The NCCR supported DynaMIC23 conference took place at the Adolphe Merkle Institute

Conferences

The NCCR-branded conference bioinspired2022 (Bioinspired Materials – Natural Materials and their Bio-inspired Materials Counterparts) took place in Andermatt (Switzerland) in 2022, bringing international experts together over five days in August.

This was the second edition of the conference organized by Prof. Esther Amstad (EPFL) and Dr. Stephen Schrettl (Adolphe Merkle Institute), both members of the NCCR. This conference, initiated by the NCCR, contributes to elevating the international recognition of the Center and Swiss research in the field.

The NCCR also supported the Dynamic Materials, Crystals and Phenomena conference organized by associate PI Prof. Jovana Milic (Adolphe Merkle Institute) in March 2023 at the AMI. The aim of this symposium was to bring together experts from different disciplines and provide a forum for open discussion towards deepening the understanding of dynamic materials across different material classes and length scales, including responsive molecular switches and machines, porous dynamic materials (MOFs, COFs), as well as emerging hybrid dynamic materials, such as hybrid perovskites.

International promotion

The NCCR Bio-Inspired Materials was an exhibitor at the Biomim'Expo in Paris in October 2022.

The Center presented NCCR projects with application potential to guests at the Cité de Sciences, the Paris science museum. Over two days, several hundred visitors passed through the NCCR stand. The exhibition was an opportunity to establish contacts with potential investors and business partners, including major companies, as well as meet with students interested in bioinspired research.

#NCCRwomen

Switzerland's NCCRs extended their #NCCRwomen project in 2023.

After broadcasting a series of video portraits of female scientists in 2021 to celebrate the 50th anniversary of the introduction of women's voting rights nationally, the participating Centers published a new series of web portraits. The NCCR Bio-Inspired Materials featured the PhD students Eva Baur (EPFL) and Viola Bauernfeind (Adolphe Merkle Institute), postdocs Viola Vogler-Neuling and Flavia Sousa (both Adolphe Merkle Institute), and PIs Esther Amstad (EPFL) and Katharina Fromm (University of Fribourg).

The series of portaits can be consulted here: **https://www.bioinspired-materials.ch/en/equal-opportunities/nccr-women/**

The videos can viewed here: **https://www.youtube.com/@nccrwomen4773/featured**

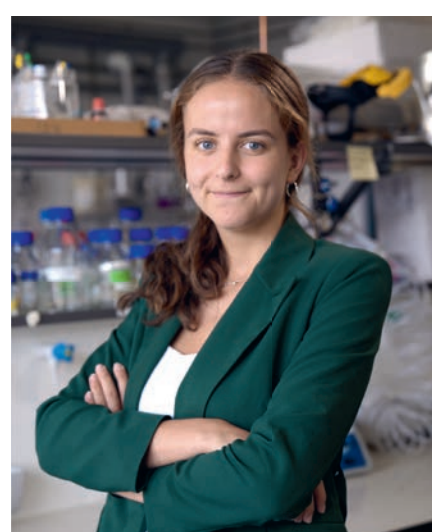
Prof. Katharina Fromm (UniFR)

Dr. Flavia Sousa (AMI)

Prof. Esther Amstad (EPFL)

Dr. Viola Vogler-Neuling (AMI)

Viola Bauernfeind (AMI)



Eva Baur (EPFL)

Impactful

New grants highlight NCCR research success

NCCR Bio-Inspired Materials researchers have been awarded two Sinergia grants by the Swiss National Science Foundation (SNSF) focusing on mussel-inspired polymers and highly reflective materials. These projects demonstrate the long-term benefits of the NCCR program.

The Sinergia program promotes the interdisciplinary collaboration of two to four research groups that propose breakthrough research. A total of four research groups, members of the NCCR at the University of Fribourg and EPFL, recently received two of these highly competitive grants. Both successful proposals were able to draw on previous research carried out by NCCR PIs, demonstrating a wider impact of the Center beyond the scope of its projects.

"It would have been more difficult to convince the reviewers of the potential of these projects without prior research within the framework of the NCCR," says the director, Prof. Ullrich Steiner. The impact of the NCCR has previously allowed its researchers to obtain additional funding, be it with projects such as the SNSF-funded Bioinspired PIRE program with the United States, the EU-funded Innovative Training Network PlaMatSu, or a grant to develop antiviral agents from the Werner Siemens Foundation. The Sinergia grants will also help guarantee the pursuit of bioinspired research beyond the term of the center's existence.

Bio-inspired fabrication of strong and tough polymer fibers

NCCR researchers at EPFL are taking their inspiration from mussels to develop tough and stiff polymers in a cost-effective, environmentally friendly way, and with minimal energy input. Possible applications could be for protective clothing, resistant filters, or even as load-bearing elements in soft robots. Fabricating such polymer-based materials with a hierarchical structure with variable length scales while controlling composition at the submicron and micron levels is a real challenge. Existing polymer processing methods fall short of what is required, whereas many living organisms can achieve this complex task under ambient conditions.

NCCR Principal Investigators Esther Amstad and Harm-Anton Klok (both EPFL) and their colleague Matthew Harrington (McGill University, Canada) have chosen to focus on the mussel

Mussels will serve as the inspiration for new polymer fibers

and its bysuss, the bundle of filaments that help attach it to rocks and other surfaces. The scientists believe it provides an excellent role model for developing bio-inspired, sustainable polymer manufacturing strategies. They propose to harness physicochemical principles underlying mussel byssus self-assembly to produce fibers that combine stiffness and toughness. The project has three distinct elements. The first is investigating transferrable design principles from how mussels use proteins to build high-performance materials with multiscale structural organization. The researchers also plan to produce mussel-inspired interconnecting polymer building blocks with different mechanical properties related to their size. Finally, they will investigate the mussel's materials processing to develop a microfluidic nozzle that can be used on a commercially available 3D printer to extrude strong and tough fibers. These fibers would have the potential to be processed into shock-absorbing materials. This Sinergia grant is worth CH 2.2 million over five years.

Strong Localization of Light through the Controlled Assembly of Amorphous Patchy Colloid Networks

NCCR researchers at the University of Fribourg are for their part investigating materials that could diffusely reflect all rays of incoming light, with long-term potential applications for example in light-based computing. Their work is inspired by clouds, milk, or bones for example. These all have one thing in common: they're white because their constituents are sized and arranged in ways that efficiently reflect light. NCCR PIs Ullrich Steiner (Adolphe Merkle Institute) and Frank Scheffold (Department of Physics, University of Fribourg) will attempt, along with their colleague David Pine (New York University), to further our understanding of reflection by creating materials that integrate a phenomenon applicable to all kinds of waves but has yet to be observed experimentally for light in bulk materials. This phenomenon was described in the 1950s by the physicist and Nobel-prize winner Philip Anderson, who showed how an electron and its quantum wave can get arrested in place in a disordered medium. This so-called 'Anderson localization' was then proposed to be applicable also to light waves.

Anderson localization of light would in theory generate perfect reflection, and anything close would generate strong reflection already for very thin layers of a material. Scheffold has already shown with computer simulations, as part of his NCCR research, that so-called disordered hyperuniform materials could reflect nearly all incoming light with the right nano-architecture. These structures, which are starting to be discovered in

> "This will allow us to explore the order-disorder parameter space in an unprecedented fashion."
>
> Prof. Ullrich Steiner

nature, fall somewhere between highly organized crystals and disordered materials. Researchers see several potential applications by creating a channel within the material. By doing so, light could not escape and be guided. This type of material could be used to develop ultrafast optical computers and devices, replacing certain types of electronics.

To create a material with strong localization characteristics, the NCCR researchers and their colleagues will develop nanoscale building blocks designed to form three-dimensional networks. The design of these blocks will allow them to tweak morphologies, from perfectly periodic lattices to almost randomly assembled networks. "This will allow us to explore the order-disorder parameter space in an unprecedented fashion, providing a new avenue in the study of light localization in disordered but highly correlated network morphologies," explains Steiner. The research is funded by a Sinergia grant worth CHF 2.77 million, also over four years.

New research groups

NCCR continues to grow

Despite being in its third and final phase, the NCCR Bio-Inspired Materials remains attractive for researchers. Two young professors, Jessica Clough and Jovana Milic, have joined the Center as PIs.

Jessica Clough

Prof. Jessica Clough of the Adolphe Merkle Institute, where she leads the Mechanoresponive Materials group, is a Swiss National Science Foundation grantee since late 2022. Her funding allows her to develop an independent research project over a period of five years. Her work focuses notably on new methods to evaluate mechanical damage on polymeric materials. This damage is poorly understood, making it difficult to determine when load-bearing polymers will fail. This research aims to establish a new methodology for imaging mechanical damage in these materials at the nanoscale. This methodology will inform the design of more durable polymers, leading for example to fewer replacements, and making their use more sustainable.

Clough, who studied at the University of Cambridge and completed her PhD at the Technical University of Eindhoven (Netherlands), joined NCCR PI Prof. Christoph Weder's Polymer Chemistry and Materials group at AMI in 2020 with a WINS fellowship from the NCCR. Her project allowed her to investigate polymeric mechano-sensors capable of reporting on a wide range of deformations. The sensors take the form of spherical, photonic assemblies of colloids, combined with a mechanosensitive chemical moiety, giving "mechano-pigments" with a novel combination of mechano-responsivities that are readily dispersed in different polymeric matrices. This approach is inspired by squid skin, which uses different responsive structures to modulate its appearance. Her NCCR project, "Responsive pigments for Pointillist mechano-sensing", aims to develop high dynamic range mechano-sensors capable of reporting on a wide range of deformations.

Jessica Clough

Jovana Milic

Jovana Milic

Prof. Jovana Milic is the Smart Energy Materials group leader at AMI, where she is investigating hybrid supramolecular materials for energy conversion, with a particular interest in a new generation of photovoltaic devices for sustainable development. She is also the recipient of a PRIMA grant. Milic is investigating hybrid materials that mimic control strategies found in nature, such as those in natural photosynthesis. Her goal is to incorporate molecular moieties in perovskites to create layered structures that resist environmental degradation, and develop materials that can purposely modify their structure to control their properties under operational conditions. According to Milic, who previously worked at the Swiss Federal Institutes of Technology in Zurich (ETHZ) and Lausanne (EPFL), this approach could be applied beyond solar-to-electric energy conversion for the development of smart nanomaterials. Milic was awarded an ERC Starting Grant in 2023, with the goal of developing smart and sustainable materials for emerging energy technologies.

Milic, in addition to her research and commitment to international multidisciplinary collaborations, has been invested in science outreach, policy, and diplomacy, connecting and supporting young scientists globally.

She has contributed to science outreach as Team Leader at the European Young Chemists' Network (EYCN) from 2019 to 2021, and as a Science for Policy Team Member at the International Younger Chemists Network since 2020. This included leading the process of establishing a science (for) policy platform for young chemists at the EYCN. This was achieved through partnerships with academic, industrial, and governmental bodies, including the European Chemical Society and the European Commission. Since 2022, she has been selected to the Swiss Young Academy and Global Young Academy, where she co-leads the Science Advice Working Group and the Swiss Young Network for Science Policy and Diplomacy (SYNESPOD), advancing global efforts to empower young scientists.

Equal opportunity

According to the Swiss National Science Foundation, PRIMA grants were aimed at outstanding women researchers who demonstrated the potential required to obtain a professorship. Grantees conduct an independent research project for up to five years, with their own team at a Swiss research institution. In 2022, the SNSF chose to integrate the program into its SNSF Starting Grants scheme. However, the PRIMA budget continues to be used exclusively for women within this program.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Problems?

Infrastructure

Building a legacy

The Department of Chemistry at the NCCR Bio-Inspired Materials' home institution, the University of Fribourg, has acquired a state-of-the-art small angle X-ray scattering (SAXS) system with a high-intensity MetalJet X-ray source, the first of its kind in Switzerland, with the Center's financial support. This purchase will help cement the NCCR's legacy beyond the end of its third and final phase in 2026.

The MetalJet SAXS system equipment allows advanced X-ray scattering and diffraction experiments on liquids, solids, and surfaces. It offers high temporal and spatial resolution previously inaccessible in laboratory settings. The capabilities of the system permit the study of structural properties from the angstrom range up to around 500 nanometers; the characterization of structures in surfaces and interfaces under environmental conditions and solvent; and the observation of stimuli-induced structural rearrangements in nanomaterials.

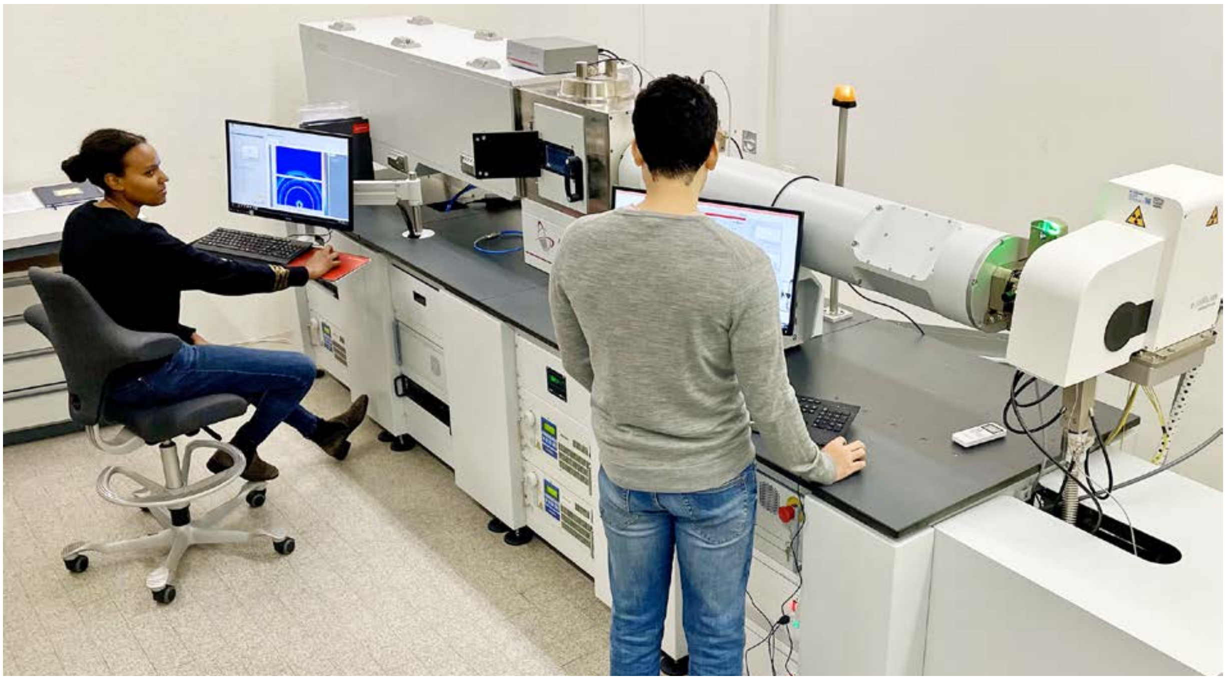
"The biggest advantage is that we can make non-invasive observations of structural changes in materials in real-time," explains NCCR PI Prof. Stefan Salentinig (Department of Chemistry, University of Fribourg). Possible applications include defining the structural changes of food materials during processing, analyzing the structure of photonic crystals, or understanding how the structures of polymers or lipid nanoparticles evolve, which can be critical for pharmaceutical development.

"This instrument has significantly strengthened our nanomaterials characterization capabilities in Fribourg and became a crucial asset for multiple projects across and beyond our faculty," points out Salenting.

Funded from multiple sources including the NCCR, the instrument is actively used and maintained by Salentinig's group. Several of the NCCR's research groups at the University of Fribourg and the Adolphe Merkle Institute have benefited from analyses and data interpretation performed by Salenting and his team. Prof. Salentinig also teaches the theory and methods related to the instrument at the MSc and PhD level to train students on this important materials characterization technique. "It significantly contributes to PhD and postdoctoral training in nanomaterials science in Fribourg," adds Salentinig.

Overall, the Fribourg Center for Nanomaterials (Frimat), the Faculty of Science and Medicine at the University of Fribourg, the Department of Chemistry, and different research groups all contributed along with the NCCR to the acquisition.

"The new experimental platform has already demonstrated its critical value for our department and the nanomaterials research in the Fribourg area," explains Salentinig. "This equipment has notably strengthened collaborations with industry partners in biomaterials, polymers, and food-related materials." This has included collaborations with other universities, institutions of the ETH domain, and companies from the nutritional sector and chemical industry.



In a short time, the new microscope has proven itself to be a valuable research tool

According to Salentinig, the MetalJet SAXS provides the university with a competitive advantage, especially with the development of a new Food Research Center at the University of Fribourg. The importance of this acquisition for future research was underlined by the organization of a workshop entitled "A Journey to the Heart of Matter" at the University of Fribourg in April 2023. It brought together leading material scientists from academia and industry, aiming to foster a platform for exchanging ideas and knowledge on material science for health and food applications, specifically focusing on small-angle X-ray scattering.

Training days

Learning to be an entrepreneur

Can a researcher take an idea from the laboratory into the marketplace, becoming an entrepreneur along the way? For over eight years, the Bench2Biz workshop spearheaded by the NCCR Bio-Inspired Materials and other NCCRs has been providing a positive answer by assisting deep-tech students or postdoctoral researchers aiming to launch a new venture.

This hands-on, intensive one-week training program is organized annually in Switzerland and is based on a concept developed in the United States. Workshop participants are guided in how to push through a deep-tech idea to the concept stage, shape their venture plan, determine the commercial value of their idea, and qualify a business plan. Furthermore, the workshop challenges the participants to define their ideas' weaker and stronger points and helps them to fix priorities or choose an exit strategy.

The workshop targets students or researchers who wish to test the validity of their research result as a venture project and are motivated to rapidly acquire fundamental knowledge and practical tools to get into the start-up ecosystem. Ten to twelve 'idea champions' chosen by the organizers are supported by a team selected from a large pool of experts: entrepreneurs, corporate leaders, technology transfer officers, legal and intellectual property (IP) specialists, and technical and business experts, who participate on an unremunerated, voluntary basis.

"The idea is to answer all potential questions that could be raised, overcome challenges, and give aspiring founders some of the tools required to succeed in competitive markets," explains NCCR Bio-Inspired Materials Knowledge Transfer and Innovation Manager and program facilitator Eliav Haskal.

Designed for high-technology ideas in life sciences, advanced manufacturing, energy, and other high-technology sectors, Bench2Biz includes fast-paced modules that test the marketability of the selected and proofed high-tech ideas; an efficient methodology to determine if high-tech or scientific inventions have commercial value and could serve as the basis for new start-up companies; and practical tools to transform an idea into a concept. The researchers also learn how to quickly assess any idea they may have in the future. And if an idea launched in Bench2Biz is not identified as a success, their experience of the program has led researchers to successful projects later.

The workshop has been held in live, hybrid, and fully remote online formats, and also involves coaches and experts from international partners to assist. Experts from Germany, Colombia, and Romania have been included in hybrid Bench2Biz workshops, allowing for exposure abroad and interesting market discussions.

Most bench2biz events take place in Bern

The program advances the Swiss National Science Foundation's goals of promoting young researchers' ideas and supporting initial entrepreneurial experiences and technology transfer in Switzerland. In addition, the workshop builds a strong network of stakeholders in the public and private sectors whose interests intersect with those of many NCCRs' domains and beyond.

Moreover, by connecting the NCCRs KTT officers, it "raises the bar" for the level of quality that the NCCRs can meet regarding technology transfer and entrepreneurship training and provides a platform for exchanges and collaborations, beyond the annual organization of the Bench2Biz workshop. "In the long-term, the aim is to consolidate Bench2Biz as a vibrant community for deep-tech innovation in Switzerland and beyond, with a strong alumni network," adds Haskal.

Some success stories from the program

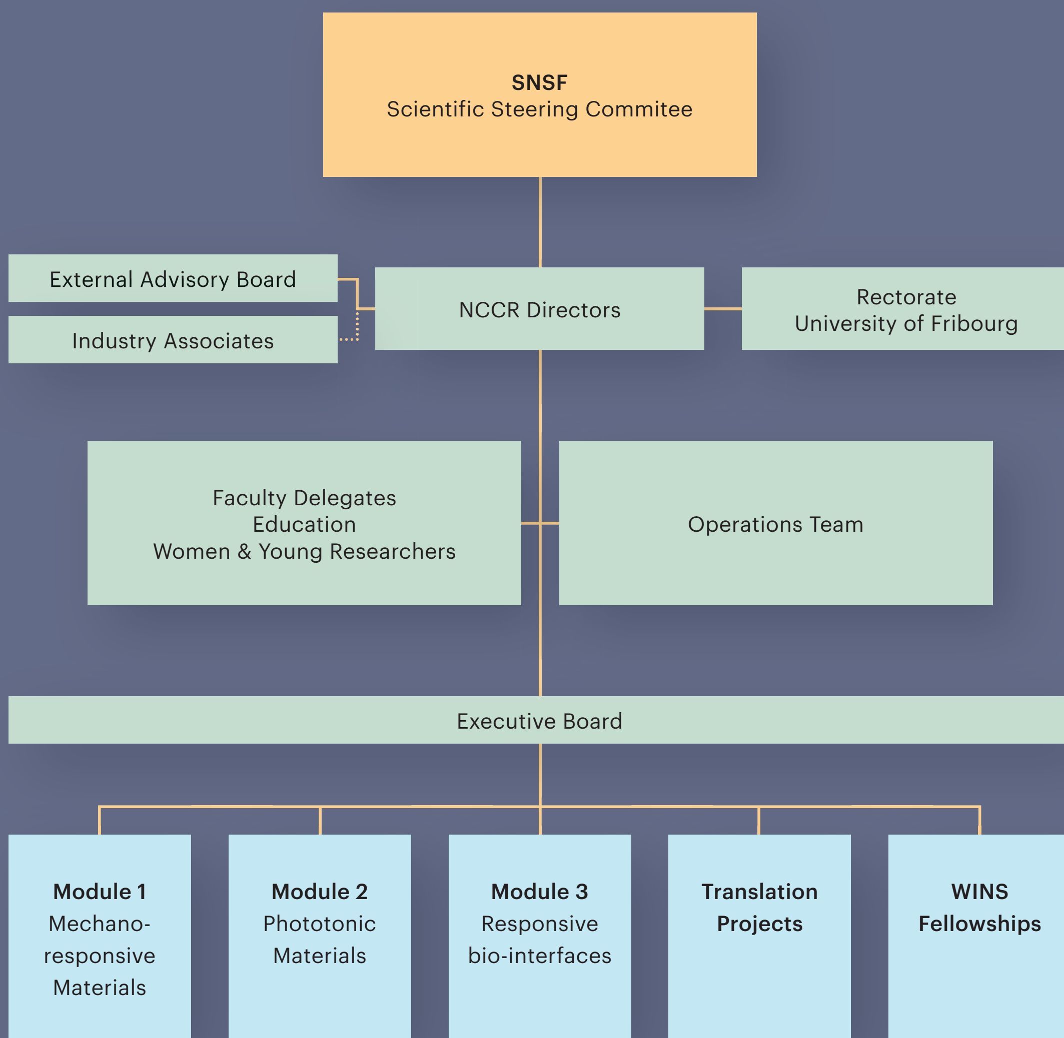
The MOF Company, Spacetek Technology AG, Fluosphera, Morphotonix, Nanolive, Adiposs, SwissDeCode

The consortium

A consortium of NCCRs (currently eight) collaborates in the Bench2Biz organization. Launched in its current format in 2019, Bench2Biz is the latest iteration of a workshop held annually in Switzerland since 2010 (under the brand names Pre-Seed Workshop, then SwissCompanyMaker). Workshop leaders from Neworks llc and the Swiss Federal Institute for Intellectual Property are event partners. The program is free of charge for the researchers, and applications are open to all researchers from Swiss academia, even if applicants from NCCRs are treated preferentially. The spirit of the workshop is friendly validation, not competition, and many past Bench2Biz participants have gone on to develop their projects successfully.

- **NCCR Bio-Inspired Materials**
- **NCCR PlanetS**
- **NCCR Automation**
- **NCCR Molecular Systems Engineering**
- **NCCR SPIN**
- **NCCR RNA & Disease**
- **NCCR AntiResist**
- **NCCR Microbiomes**
- **Neworks**
- **Swiss Federal Institute for Intellectual Property**

Organization Phase III



Who is who

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- Prof. Eric Dufresne (Cornell), Leader Module 2
- Prof. Stefan Salentinig (UniFR), Leader Module 3
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- Dr. Rafael Libanori, Senior researcher
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- Dr. Pablo Campomanes, Senior researcher
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- Franziska Marx, Doctoral student
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- Dr. Sandor Balog, Senior researcher (AMI)
- Véronique Buclin, Laboratory technician (AMI)
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- Mauro Almeida (Doctoral student, Rothen-Rutishauser group)
- Dr. Geoffroy Aubry (Senior researcher, Scheffold group)
- Dr. Saurabh Awasthi (Senior researcher, Mayer group)
- Antonius Chrisandy (Doctoral student, Lütolf group)
- Ivana Domljanovic (Doctoral student, Rüegg group)
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- Philippe Yep (Doctoral student, Fromm group)
- Dr. Lu Zhang (Postdoctoral researcher, Acuna group)

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- Laura Brown (University of Cambridge)
- Isabella Burgoyne (Columbia University)
- Jia Ning (Johnny) Cai (University of British Columbia)
- Andrea Chavez Munoz (Northeastern University)
- Felicity Ashraf Ibrahim (University of Cambridge)
- Hyeri Kim (Korea University)
- Philippa (Pip) Knight (University of Cambridge)
- Megan Loh (Stanford University)
- Eneko Lopez Berloso (University of the Basque Country)
- Gaurav Mittal (Case Western Reserve University)
- Leah Oppenheimer (Case Western Reserve University)
- Yash Patel (Lehigh University)
- Simran Patwa (Case Western Reserve University)
- Chiara Pillen (University College London)
- Madison Ross (University of Florida)
- Ben Schwabe (University of Cambridge)
- William Stephenson (Georgia Institute of Technology)
- James Tallman (Cornell University)
- Maple Wang (University of California Berkeley)
- Annie Zhi (University of Chicago)

External advisory board

- Prof. Helmut Coelfen, Department of Chemistry, University Konstanz, Germany
- Prof. Ursula Graf-Hausner, graf 3dcellculture, Switzerland
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- Prof. LaShanda Korley, Department of Materials Science and Engineering, University of Delaware, USA
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- Prof. 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;
EPFL: Federal Institute of Technology Lausanne;
ETHZ: Federal Institute of Technology Zurich

Projects

Module 1: Mechanically responsive materials across different length scales

1. Transiently pulsating materials inspired by the heart
2. Mechanochromic force transducers for biosystems and synthetic hydrogels
3. Atomically thin mechanosensitive membranes for water treatment

Module 2: Biologically inspired assembly of optical materials

4. New opportunities for tuning colloidal crystals using nanorattles
5. Complete photonic band gaps materials by self-assembly of ABC bottlebrush block polymers
6. Enhancing structural colour through absorption
7. Complex disordered photonic architectures by self-assembly
8. Bottom up meets top down: Controlling assembly from mm to nm

Module 3: Responsive bio-interfaces and surfaces

9. Dynamic surfaces for tissue engineering and tissue remodeling
10. 3D printing of functional organoids
11. Increasing dispersion stability with biocompatible small molecules
12. Antiviral Surfaces
13. Design of amphiphilic polymer nanotubes for fighting bacteria
14. DNA Origami-based sensor for the multiplex detection of mRNA in cancer
15. Ion-gradient batteries using ion-selective 2D materials to separate hydrogel compartments with different salt concentration

Translation projects

16. Bright white scatterers beyond titania
17. Healable Polymer Coatings
18. Fabrication of load-bearing, soft actuators
19. Bioinspired 3D printed porous ceramics for solar-to-fuel conversion and carbon capture

WINS Fellowships projects

20. Next generation of polymeric nanovaccine for brain cancer immunotherapy

Publications

Module 1

Bertella, S.; Bernardes Figueirêdo, M.; De Angelis, G.; Mourez, M.; Bourmaud, C.; Amstad, E.; Luterbacher, J. S., Extraction and surfactant properties of glyoxylic acid-functionalized lignin, ChemSusChem, 2022, 15, e202200270.

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Module 3

Boarino, A.; Wang, H.; Olgiati, F.; Artusio, F.; Özkan, M.; Bertella, S.; Razza, N.; Cagno, V.; Luterbacher, J. S.; Klok, H. A.; Stellacci, F., Lignin: A sustainable antiviral coating material, ACS Sustainable Chem. Eng., 2022, 19, 14001–14010.

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Module 4

Demirörs, A. F.; Poloni, E.; Chiesa, M.; Bargardi, F. L.; Binelli, M. R.; Woigk, W.; de Castro, L. D. C.; Kleger, N.; Coulter, F. B.; Sicher, A.; Galinski, H.; Scheffold, F.; Studart, A. R., Three-dimensional printing of photonic colloidal glasses into objects with isotropic structural color, Nat. Commun., 2022, 13, 4397.

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WINS and Collaborative projects

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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

5 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 250 children

and high school students participated in NCCR outreach activities

6 cooperations

national and international cooperation projects with research institutions

Note: All figures between June 1, 2022 – May 31, 2023

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
Prof. Yoan Simon	Something old, something new, something borrowed, something blue	University of Southern Mississippi, US	June 3, 2022
Prof. Bartosz Grzyboski	Reactions, materials and assemblies under rotation	UNIST/IBS, South Korea & Polish Academy of Sciences	June 13, 2022
Prof. Nasim Annabi	Microengineered bioadhesive hydrogels for drug delivery and tissue engineering	University of California, Los Angeles, US	September 20, 2022
Prof. Erica Eiser	DNA blocks and tethers for colloidal assembly and tuneable hydrogel	University of Cambridge, UK	October, 26, 2022
Prof. Joris Sprakel	Tiny Green Ninjas: How plant killers exploit soft matter mechanics to infect their hosts	Wageningen University, Netherlands	October 27, 2022
Prof. Johan Hofkens	The Power of One: From single molecule investigations to materials research and beyond	KU Leuven, Belgium	December 13, 2022
Prof. Damiano Genovese	Luminescent (nano)probes for quantitative imaging	University of Bologna, Italy	February 2, 2023
Prof. Eric Dufresne	Living Droplets Get to Work	ETH Zurich, Switzerland	February 16, 2023
Prof. Catarina Esteves	Functional polymer coatings with designed interactions with water	Eindhoven University of Technology, Netherlands	March 2, 2023
Prof. Adria LeBoeuf	Lessons from ants on collectively developing systems	University of Fribourg, Switzerland	March 16, 2023
Dr. Rosa Poetes	Why consulting? – A perspective	McKinsey, Switzerland	March 17, 2023

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