2022 Annual Report

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adolphe merkle institute
excellence in pure and applied nanoscience

About the Adolphe Merkle Institute

The Adolphe Merkle Institute (AMI) is an independent competence center at the University of Fribourg that focuses on research and education in soft nanomaterials.

We owe our existence to Dr. Adolphe Merkle, a successful local entrepreneur who established the Adolphe Merkle Foundation to strengthen research and teaching at the University of Fribourg. His CHF 100 million endowment constitutes one of Switzerland's most important private donations in favor of academic research.

Founded in 2008, AMI is, in many aspects, unique in the landscape of Switzerland's research institutions. Our focus on soft nanomaterials is unmatched in Switzerland and beyond. Our research combines fundamental and application-oriented aspects in a multidisciplinary setting. Through collaborations with industrial partners, AMI aims to stimulate innovation, foster industrial competitiveness, and improve the quality of life.

Our researchers are currently organized into four primary and two junior research groups, which offer complementary expertise and interests in strategically important areas: BioNanomaterials, Polymer Chemistry and Materials, Soft Matter Physics, Biophysics, Smart Energy Materials, and Mechanoresponsive Materials. Interdisciplinary collaborations between our researchers are the basis for the successful and efficient execution of complex research projects that transcend the boundaries of traditional scientific disciplines. This environment and world-class research facilities make AMI a desirable destination for master's and PhD students, postdocs, and senior researchers.

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Fresh ideas
_ A message from the Director

Prof. Ullrich Steiner

Dear reader,

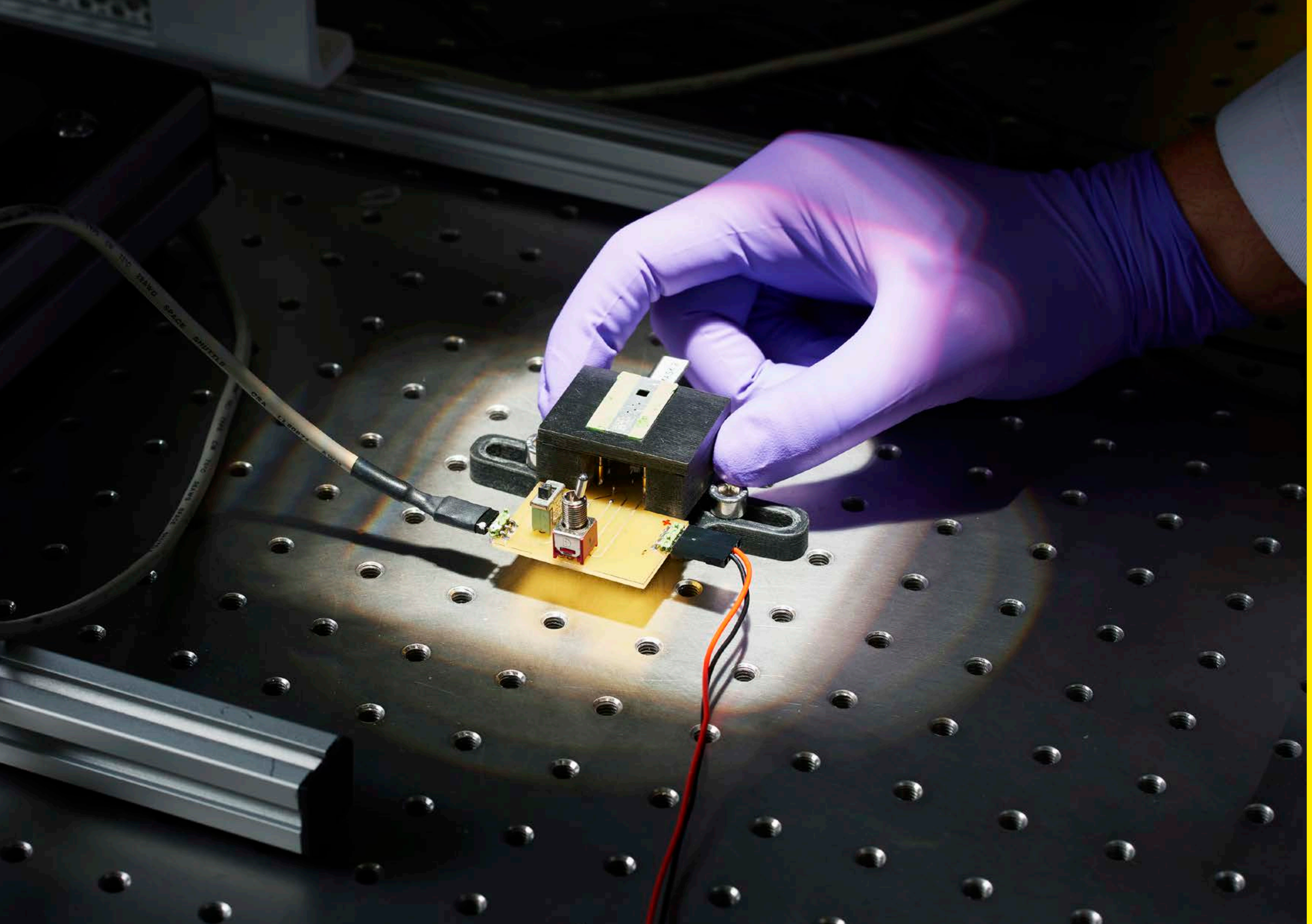
It is with great pleasure that I present to you the Adolphe Merkle Institute's latest annual report, in which we look back at the previous year's most important activities, accomplishments, and developments.

2022 marked some important changes for the Institute, the most important perhaps being Christoph Weder's decision to step down from his role as director and my appointment to the position. I want to thank Chris for his 12 years of leadership, guidance, and hard work that has allowed AMI to become an internationally recognized research institution. Our research was also bolstered by the appointment of group leader Jessica Clough as an assistant professor. Jessica received a Swiss National Science Foundation PRIMA Fellowship, allowing her to pursue her academic career under the best auspices. Finally, AMI has partnered with Pro Helvetia, the Swiss Arts Council, for a unique program bringing scientists and artists together, whose results will be visible in a few months.

As always, our research endeavors and successes remain at the heart of this annual report. The Polymer Chemistry and Materials group has developed a robotic worm as part of the PIRE collaboration with US universities. Potential uses include underground exploration of cave systems, subterranean infrastructure inspection, or surveillance operations. Our Smart Energy Materials group has been investigating applications of perovskites in hybrid materials, notably changes of color when pressure is applied. Depending on the surrounding conditions, the materials could be used in sensors that switch their hue. The BioPhysics group has developed a new method to track the aggregation of proteins responsible for several brain diseases. To achieve this, they attach a fluorescent label to a protein without affecting its aggregation behavior. The Soft Matter Physics group has pursued its research on structural color, this time investigating photonic pigments with the potential for production in large quantities. Finally, the BioNanomaterials group has been using machine learning to improve nanoparticle dispersion when using the process known as ultrasonication; and as part of the European PATROLS consortium, testing the accuracy of a system for hazard assessment of aerosolized materials, an important step in developing standardized assays for lung cell models.

You will find more coverage of some of the achievements of our researchers in our "In Brief" section, with highlights from the last year that range from significant awards to innovative collaborations and promotions. We hope you enjoy reading this report, and thank you for your interest in our institute, our team, and our activities.

Ullrich Steiner
AMI Director and Chair of Soft Matter Physics



7 _Pursuing excellence

Changes
_ A new director for AMI

Prof. Ullrich Steiner (left) took over the directorship of AMI from Prof. Christoph Weder in 2022

The Adolphe Merkle Institute underwent one of its most significant changes in over a decade in 2022, with the appointment of a new Director, Prof. Ullrich Steiner, the Chair of Soft Matter Physics. Steiner took over in May 2022 from Prof. Christoph Weder, the Chair of Polymer Chemistry and Materials, who helmed AMI for 12 years.

The board of the Adolphe Merkle Foundation appointed Steiner in agreement with the University of Fribourg. Prof. Michael Mayer, the Chair of BioPhysics, agreed to become the Institute's deputy director, taking on the role previously held by Steiner.

"Leading the institute as its director was an extraordinary privilege, and I am extremely grateful to have been allowed to serve in this role. I tremendously enjoyed helping to shape AMI and am proud of what we have achieved," says Weder. "But I held the director's position for twelve years, which is unusually long for a leadership position. After AMI reached what we defined in our initial strategic plan as a first "steady state," and with the Covid-19 pandemic starting to wane, the time seemed right to pass on the baton."

For Weder, highlights from his tenure as director include the development of a robust and efficient governance structure, the installment of four permanent research groups that perform at the top of their disciplines and live up to AMI's byline, "excellence in pure and applied nanoscience"; making good on an ambitious budget model that leverages the support from the Adolphe Merkle Foundation and the University of Fribourg with high levels of third-party funding to support a critical institute size of about 100 members; building large, transdisciplinary research networks such as the National Competence Center in Research Bio-inspired Materials; and finally, the various efforts to create an inclusive working environment that attracts talent from all over the world.

Looking further ahead, Weder believes that development potential exists for AMI with respect to collaborations with industry. "The goal to balance fundamental and applied research efforts was important to our benefactor Adolphe Merkle," he points out. "While we have logged almost 50 projects with industrial partners, secured over twenty patents – several of which have been licensed – launched a first spin-off company, and built an analytic service platform that serves many industrial customers, only a few of these outcomes impact the local industry. To address this aspect, the institute must – and has already started to – develop new strategies."

External forces have also impacted AMI and the Swiss academic landscape in recent years. For example, the pandemic has led to adaptations in scientific and labor practices, such as more possibilities for remote work or a wider acceptance of online and hybrid meetings. Weder also expects that Switzerland's non-association with Horizon Europe, the EU framework program for research and innovation, has the potential to limit AMI's development severely if not dealt with appropriately. "But to thrive or even survive, an organization cannot only respond to such major external events," he adds. "It must constantly evolve, ideally not by adapting to a changing environment but by actively driving changes. This requires a constant reflection on current affairs, a stream of fresh perspectives and new impulses, and a high level of energy and enthusiasm. Stepping down from my post was a logical consequence of this mindset."

> "With the uncertainty surrounding funding resources, especially from the EU, adding the fifth chair (at AMI) will help ensure that we can maintain a high level of infrastructure and support for our researchers through third-party funding, allowing them to focus on their science."
> *Prof. Ullrich Steiner, AMI Director*

Fifteen years after its creation, AMI faces several structural challenges under Steiner's fresh leadership to ensure a smooth future. "Chris Weder's achievement of establishing the AMI and bringing it to the international reputation it enjoys today cannot be overstated. He is leaving behind big shoes to fill," says the new director. Despite its success, guaranteeing the long-term financial stability of the institute remains a priority. "The creation of a fifth chair in food science at AMI, with the support of the foundation and the canton is vital in that aspect," he explains. "With the uncertainty surrounding funding resources, especially from the EU, adding the fifth chair will help ensure that we can maintain a high level of infrastructure and support for our researchers through third-party funding, allowing them to focus on their science." The canton has already signaled its support for the new chair, which dovetails with its project to make Fribourg an important actor in the food sector.

The possible arrival of a new tenured professor will also mark the starting point of major changes at the institute. Four of the five current tenured professors will reach retirement age within the next ten years, requiring long-term planning to ensure a smooth transition. "A number of us will be reaching that point over a fairly short time period," adds Steiner. "To ensure that AMI continues to be a leading research institution in its field of soft matter nanoscience, we have to address this transition, for which we a currently developing a strategic plan." With the National Competence Center in Research (NCCR) in Bioinspired Materials ending in 2026, it is further essential to attract large-scale funding to the institute, for example, in the form of a new NCCR".

New faces

The new director, **Prof. Ullrich Steiner**, is the AMI Chair of Soft Matter Physics since 2014. He studied at the University of Konstanz (Germany), then at the Weizmann Institute of Science in Israel (PhD, postdoc), and the University of Strasbourg (France, postdoc). In 1999, he was appointed Professor of Polymer Chemistry at the University of Groningen (Netherlands) before becoming Professor of Materials Physics at the University of Cambridge. Besides leading the institute, he is also the director of the National Center of Competence in Research (NCCR) Bio-Inspired Materials.

Prof. Michael Mayer, the new vice-director, has been the AMI Chair of Biophysics since 2015. He studied at the Technical University of Braunschweig (Germany), the Swiss Federal Institute of Technology in Lausanne (EPFL, PhD), and Harvard University (postdoc). Before his appointment in Fribourg, he was an associate professor at the University of Michigan.

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NATIONALITIES

PRESENT AT AMI WITH REPRESENTATIVES FROM EVERY CONTINENT.

7

PROFESSORS

WORKING ACROSS THE FIELDS OF POLYMER SCIENCE, MATERIALS, PHYSICS, CHEMISTRY, AND BIOLOGY.

64%

OF ALL RESEARCH EXPENDITURES

WERE COVERED BY THIRD-PARTY FUNDING. SOURCES INCLUDED THE SWISS NATIONAL SCIENCE FOUNDATION, THE EUROPEAN UNION, INNOSUISSE, AND INDUSTRIAL PARTNERS.

MORE THAN

6,700

CITATIONS

OF AMI PUBLICATIONS IN THE SCIENTIFIC LITERATURE IN 2022.

5

APPLICATION-ORIENTED

PROJECTS

FINANCED BY INNOSUISSE, THE SWISS INNOVATION AGENCY.

72

SCIENTIFIC PUBLICATIONS

IN TOP-RANKED JOURNALS SUCH AS SMALL, ACS NANO, CHEMICAL SOCIETY REVIEWS, ADVANCED MATERIALS, ANGEWANDTE CHEMIE, APPLIED PHYSICS LETTERS, NATURE COMMUNICATIONS, THE JOURNAL OF THE AMERICAN CHEMICAL SOCIETY, MACROMOLECULES, AND NANOSCALE.

450+

ALUMNI

INCLUDING POSTDOCTORAL RESEARCHERS, PHD STUDENTS AND INTERNS.

New professor
_ PRIMA grant for AMI researcher

Prof. Jessica Clough orginally joined AMI as a postdoctoral researcher, progressing to group leader before receiving her PRIMA grant

Adolphe Merkle Institute researcher Dr. Jessica Clough was awarded a PRIMA grant by the Swiss National Science Foundation in 2022 leading to her promotion as Professor. The funding will allow her to develop an independent research project at the institute over the next five years. Clough will investigate 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.

Clough, who studied at the University of Cambridge and completed her PhD at the Technical University of Eindhoven (Netherlands), joined Prof. Christoph Weder's Polymer Chemistry and Materials group at AMI in 2020 with a WINS fellowship from the National Center of Competence in Research Bio-Inspired Materials. She was a group leader for part of 2022. With her grant, she was promoted to Assistant Professor by the University of Fribourg.

According to the Swiss National Science Foundation, PRIMA grants are aimed at outstanding women researchers who demonstrate the potential required to obtain a professorship. Grantees conduct an independent research project for up to five years with their team at a Swiss research institution. Clough was one of 17 grantees, and one of three at the University of Fribourg, in 2022.

Could you tell us more about your PRIMA research?
Jessica Clough: This research aims to establish a new methodology for imaging mechanical damage in polymeric materials at the nanoscale. The approach is inspired by super-resolution microscopy, which has revolutionized the imaging of biological systems, as recognized by the award of the Nobel Prize to the pioneers of the technique in 2014. The insights gained from our research will inform the design of more durable polymers that are less likely to break and are, therefore, safer to use. In addition, they would need replacing less frequently, reducing downtime, and making their use more sustainable. From a fundamental perspective, the methodology will allow damage mechanisms to be elucidated, particularly in nanocomposite materials, where limited resolution has obscured the true nature of force-induced processes. More generally, I hope this work will stimulate the application of super-resolution microscopy to material science, which has been limited so far.

What made you choose this research focus?
I'm a chemist by training, but perhaps more of a material scientist at heart. Since early on in my career, I've been fascinated by using light to look inside materials and understand their behavior. As a chemist, I like to design and develop the sensor molecules that allow us to do this. Still, applying them to materials is equally satisfying and exciting. For example, I developed light-emitting force probes for polymers for my doctorate, and responsive photonic materials for my postdoc. Such light-based imaging techniques are particularly attractive for sensing as they offer high sensitivity and technical accessibility. A drawback of conventional light microscopy is that it cannot resolve nanoscopic features – though super-resolution microscopy shows us a way to overcome this limitation. In my PRIMA research, we aim to apply super-resolution approaches to sense material responses at the nanoscale.

Do you see yourself expanding your activities in other directions?
My primary interests relate to the development of mechano-sensing molecules and applying them to polymeric materials. Generally speaking, we tend to focus on engineering polymers commonly found in load-bearing applications, such as toughened glasses and fiber composites. However, mechanical forces impact material performance in diverse contexts: for example, in the polymer components of wearable electronics, and in hydrogel replacements for cartilage in joints. Mechanical forces also play a significant role in biological systems, such as in plant cell walls, which must withstand turgor pressures of up to 20 atmospheres (much greater than the air pressure in a car tire) that give rise to tensile stresses of up to 100 MPa. The effect of force on their growth and differentiation needs to be better understood. I think it would be fascinating to apply molecular mechano-sensors to these systems.

What are your academic and personal goals as a researcher?
My goal in my academic research is to develop imaging techniques and tools for polymeric materials that are also widely useful to other researchers. I believe that technological innovation is driven by such collective effort and collaboration. I also aspire to be a leader who supports and empowers her students to achieve their own career goals. Good leadership is based on mutual respect, fairness, and transparency, and sets a working culture in which students can be productive and feel recognized. It is an essential part of doing good science.

You are the recipient of a PRIMA grant from the Swiss National Science Foundation – how do you think this will shape your career?
It was a great honor to receive a PRIMA grant aimed at excellent female researchers with the potential to obtain a tenured professorship. It will transform my career, allowing me to build my independent research group and further develop my research profile. In addition, the SNSF also offers an accompanying leadership program of workshops and mentoring for PRIMA recipients, which has already been a positive and insightful experience for me.

The PRIMA grant is specifically aimed at female researchers. Do you feel that these types of awards are necessary?
I believe funding schemes like the PRIMA grant are valuable tools in our arsenal to tackle gender inequality and inequity in academia. By having a more balanced and diverse leadership, we can change the culture of academia and encourage more girls and young women into STEM fields. More broadly, the problem of underrepresentation in STEM is complex and should be approached with a wide range of initiatives and investments. For example, one can look to the Athena and Race Equality charters in the UK, which financially incentivize universities and research institutions to implement good employment practices with regard to underrepresented groups in particular. Initiatives in schools, such as outreach and encouraging women to teach STEM subjects, can also help change perceptions of science as male domains, often formed at a relatively young age.

You also received a NanoARTS grant to develop an art-science project with photographer Claudia Christen. What motivated you to participate in this program?
As a student at school, I enjoyed art as much as science. It was not by accident that my scientific work has been intensely visual throughout my career. In my project with Claudia Christen, I was intrigued by the conceptual possibility of using mechano-sensors not just to communicate material properties, but also an artistic message. Apart from my own personal interest, there is great value in the NanoARTS initiative as a form of outreach, and I hope that the project will allow us to reach new audiences for our scientific work.

Artistic outcomes
_ Creating a bigger picture

AMI staff were able to meet potential artistic partners at a matchmaking event at AMI before submitting a proposal

The Adolphe Merkle Institute and Pro Helvetia, the Swiss Arts Council, have begun collaborating on the NanoARTS program, which aims to bring scientists and artists together to inspire each other and develop new artistic approaches.

The program was launched in 2022, with three tandems of artists and scientists taking part. NanoARTS comes under Pro Helvetia's four-year "Arts, Science and Technology" program. It aims to foster transdisciplinary exchanges and collaborations between arts practitioners on the one hand and science and technology professionals on the other. For example, various formats (residencies, research grants, or production grants) are available for participants to explore the potential of mutual inspiration and open up spaces for new artistic approaches. The formats of this program are developed in close cooperation with well-established scientific institutions and are aimed at Swiss practitioners from all arts disciplines. These include residencies for artists at CERN or transdisciplinary collaborations with researchers at the Swiss Polar Institute. Pro Helvetia says AMI was especially interesting because of the many questions or topics related to new materials and nanotechnology and questions of ecology and sustainability, for example.

For NanoARTS, tandems of Swiss artists and AMI scientists submitted proposals exploring interfaces between art and nanoscience. A transdisciplinary jury of experts then selected three pairs out of ten applications whose collaborations are now underway and will take between 12 and 18 months to be completed. An expert in art-science mediation accompanies the selected tandems. The mediator frames and accompanies the exchange between the artists and scientists through contextualizing workshops, shared activities, and tailored coaching. Pro Helvetia has experienced in various art-science programs that artists and scientists don't always speak the same language. While both seek answers to complex questions, they use different methods to find their answers. The role of the mediator is designed to facilitate a dialogue, and help the tandem partners find common ground and guide them within their collaboration. The mediator is also present during the artistic outcome's production process and its dissemination.

AMI also considers this collaboration with artists as a significant opportunity. "A collaboration between scientists and artists can lead to a rich experience for both parties," says AMI's coordinator for the project, Dr. Sofia Martin Caba. "Both are observers; both need to pay close attention to details and the big picture to create. Art can help scientists be more creative, visualize problems, and help to understand them. This can lead to better strategies for problem-solving, and consequently, make their research richer and more effective." The three tandems chosen by the jury were:

"Painting with Light: The Darkroom of Nature"
Tandem partners Claudia Christen (visual artist) and Prof. Jessica Clough (head of the Mechanoresponsive Materials group) wish to explore the connections between nanoscience and photography. The goal is to develop new methods of drawing with light through the use of mechano-responsive molecules that fluoresce when activated by force. The tandem partners will combine their knowledge of light, optical signals, and mechanical processes in photography and nanoscience.

"Bigger Picture"
The duo of Yvo Goette (designer) and Prof. Alke Fink (co-Chair of the AMI BioNanomaterials group) have chosen scientific imaging methods used to visualize the micro- and nanostructure of materials as the starting point of their investigations. Using these techniques, the tandem will collect and translate data with the intention of building hypothetical 3D material models through parametric computer-aided design. Their goal is to use the artistic design process to reveal and solve digital structures through various media.

"Material changes"
Pedro Wirz (visual artist) and Prof. Christoph Weder (Chair of the AMI Polymer Chemistry and Materials group) are questioning the term and usage of "sustainability" through a transdisciplinary dialogue between the arts and science. The dialogue will revolve around concepts such as technology versus nature, value-added recycling and reuse, and nanostructures in natural and artificial materials. The tandem will ultimately create objects documenting their dialogue, using various synthetic and natural materials.

Art, Science, and Technology

The goals of Pro Helvetia's program are:
- Connecting arts and culture practitioners with practitioners from science and technology.
- Active promotion of projects at the interface of art, science, and technology through support in the planning, research, and production stages.
- Support in Switzerland and abroad for Swiss arts and culture practitioners working at the interface of art, science, and technology.

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ACTIVE RESEARCH PROJECTS

IN FIELDS SUCH AS BIO-INSPIRED MATERIALS, PEROVSKITE SOLAR CELLS, OPTICAL METAMATERIALS, ENERGY STORAGE MATERIALS, NANOVACCINES FOR BRAIN CANCER, RISK ASSESSMENT OF AIR POLLUTANTS, NANOPORE FABRICATION, SINGLE-MOLECULE DETECTION.

CHF 9.1 M

SPENT OVERALL IN 2022

RESEARCH EXPENDITURES WERE CHF 7.5 MILLION, DOWN FROM ALMOST CHF 9 MILLION IN 2021

44%

OF STAFF AT AMI ARE WOMEN

36

SEMINARS

GIVEN BY EXTERNAL RESEARCHERS, AND AMI STUDENTS.

89

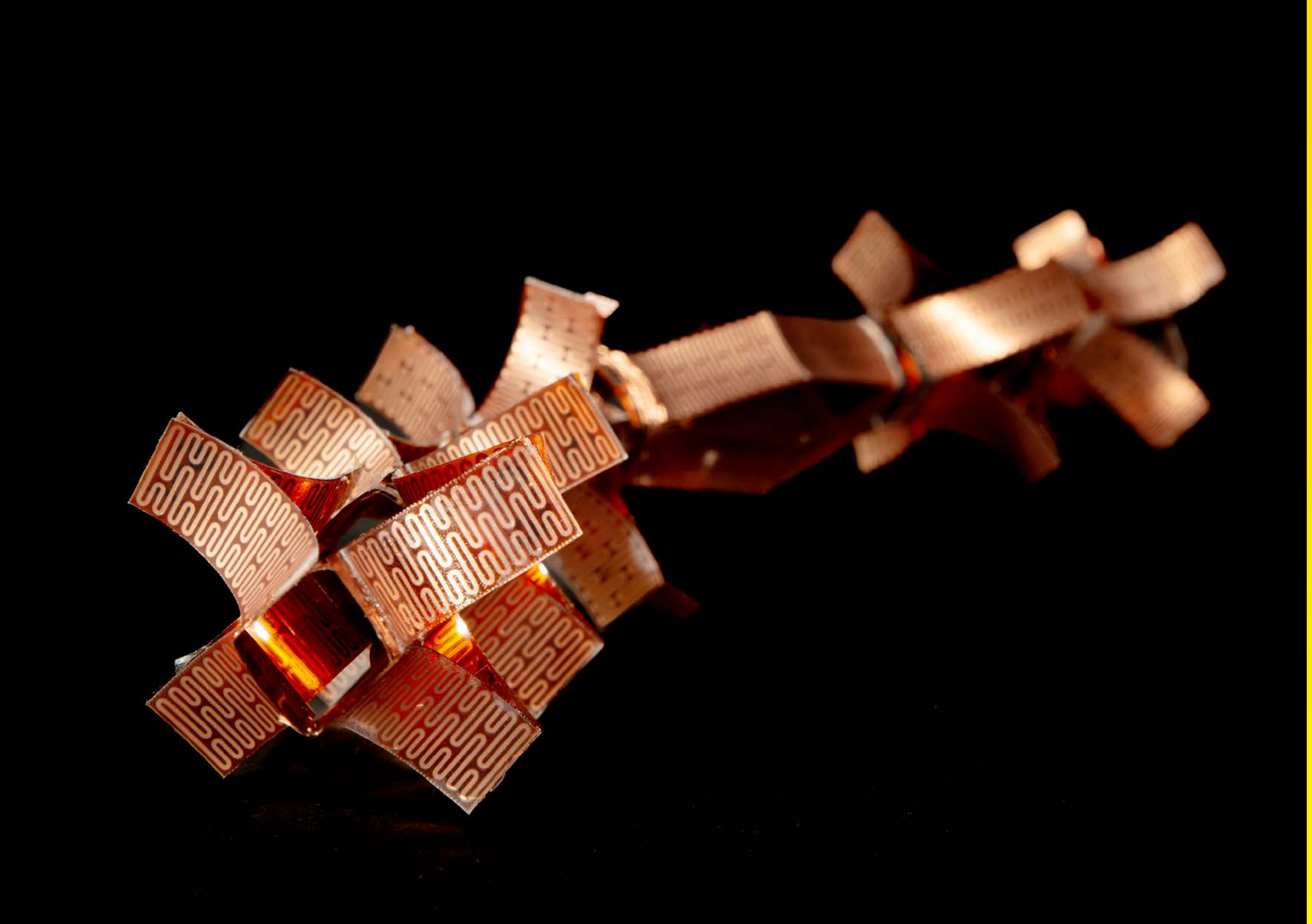
PEOPLE

WORKED AT AMI AT THE END OF 2022, INCLUDING PHD STUDENTS, POSTDOCTORAL RESEARCHERS, PROFESSORS, SUPPORT STAFF, AND INTERNS.

48%

OF THE AMI RESEARCHERS

ARE DOCTORAL STUDENTS.



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_Research at AMI

Moving forward

_ A robotic worm for tight spaces

Researchers of the Adolphe Merkle Institute's Polymer Chemistry and Materials group and their collaborators at Case Western Reserve University (Cleveland, USA) have developed a soft, worm-like robot that can wriggle itself through spaces that are considerably smaller than its cross-section. The electrically activated robot can also move across sticky or slippery surfaces in any direction.

Soft earthworm-like robots that exhibit mechanical compliance can, in principle, navigate through uneven terrains and constricted spaces that are inaccessible to other robots. Such devices are potentially useful for applications that include search and rescue operations, underground exploration, pipe inspection, and even biomedical procedures such as endoscopy or colonoscopy. However, unlike the living species that they mimic, most of the previously reported worm-like robots contain rigid components that limit their mechanical compliance, such as motors and other actuators, which limit how they can adapt or deform to various environments or obstacles. "To address this limitation, our major goal was to demonstrate a fully soft robot that capable of deformations that would not be possible with traditional rigid-bodied robots," says Prof. Christoph Weder, AMI Chair of Polymer Chemistry and Materials.

Weder and his US partners developed and investigated a highly flexible robot with a fully modular body almost entirely based on soft polymers. The device contains segments that are assembled from bilayer actuators, which reversibly change their shape when heated and cooled, respectively. "The trick for achieving a high bending deflection, and to generate large blocking forces was to use a new class of high-thermal-expansion polymers that we combined with a commercial low-thermal-expansion polyimide film," explains Dr. Livius Muff, who worked on the project as a PhD student. Building a large-scale robot required scaling up the polymer synthesis, a task that was mastered by AMI Polymer group technicians Véronique Buclin and Anita Roulin. The possibility to individually activate the bilayer actuators through electrically powered heating elements allows for highly precise control of the robot's movements. Mimicking the locomotion principle exploited by earthworms, the robot is propelled by the sequential contraction and expansion of the various segments. This operating principle also allows the robot to access spaces that are much smaller than its cross-section in the resting state might suggest.

Limitations of the first embodiment of the new robot design are that its movements are quite slow, and that its motion requires a considerable amount of energy. The researchers believe, however, that the robot's modular architecture will allow for improved performance by using faster and more energy-efficient bending actuators, without changing the overall design. Moreover, the current version is externally powered and controlled, but it could be become autonomous with the incorporation of soft batteries and independent control systems. "The robot can overcome narrow constrictions, and explore hollow spaces while suspended in mid-air," points out Muff. "These skills make future iterations of the worm potential candidates for underground exploration of cave systems, subterranean infrastructure inspection, or surveillance operations. "Furthermore, the worm robot's hollow tubular structure could be used to deliver cargo such as medication or emergency supplies to trapped individuals in collapsed buildings or rubble."

The results of this research project were published in the leading scientific journal Advanced Materials. This work was carried out with joint funding from the US and Swiss National Science Foundations as part of the Partnerships for International Research and Education (PIRE) program Bio-inspired Materials and Systems.

Reference

Muff, L. F.; Mills, A. S.; Riddle, S.; Buclin, V.; Roulin, A.; Chiel, H. J.; Quinn, R. D.; Weder, C.; Daltorio, K. A. Modular Design of a Polymer-Bilayer-Based Mechanically Compliant Worm-like Robot. *Advanced Materials* **2023**, 34, 2210409.

Véronique Buclin (left) and Anita Roulin are laboratory technicians in the Polymer Chemistry and Materials group. Véronique joined AMI as part of the NCCR Bio-Inspired Materials, while Anita has worked for the Institute since 2009, making her one of its longest-serving members.

Polymer Chemistry & Materials

Team

Prof. Christoph Weder, Prof. Jessica Clough, Irene Artignano, Dr. José Berrocal, Luca Bertossi, Véronique Buclin, Claudio Cappelletti, Valentina Dini, Matilde Folkesson, Stefan Frech, Chantal Graafsma, Luca Grillo, Dr. James Hemmer, Xueqian Hu, Dr. Sètuhn Jimaja, Derek Kiebala, Davide Lardani, Youwei Ma, Chaninya Mak-lad, Franziska Marx, Cosimo Micheletti, Livius Muff, Tatsuya Muramatsu, Marta Oggioni, Ilaria Onori, Lorenzo Paleari, Laura Perrin, Chris Rader, Anita Roulin, Iulia Scarlat, Dr. Stephen Schrettl, Dr. Athanasios Skandalis, Hanna Traeger

Key Publications

1. Thazhathethil, S.; Muramatsu, T.; Tamaoki, N.; Weder, C.; Sagara, Y.; Excited State Charge-transfer Complexes Enable Fluorescence Color Changes in a Supramolecular Cyclophane Mechanophore; *Angewandte Chemie Int. Ed. Engl.* **2022**, 134, e202209.
2. Mareliati, M.; Tadiello, L.; Guerra, S.; Giannini, L.; Schrettl, S.; Weder, C.; Metal-ligand complexes as dynamic sacrificial bonds in elastic polymers; *Macromolecules* **2022**, 55, 5164–5175.
3. Wohlhauser, S.; Rader, C.; Weder, C.; Facile method to determine the molecular weight of polymer grafts grown from cellulose nanocrystals; *Biomacromolecules* **2022**, 23, 699–707.
4. Sautaux, J.; Marx, F.; Gunkel, I.; Weder, C.; Schrettl, S.; Mechanically robust supramolecular polymer co-assemblies; *Nature Communications* **2022**, 13, 356.
5. Monney, B.; Kilchoer, C.; Weder, C.; Photolithographic fabrication of mechanically adaptive implants for optogenetics; *ACS Polymer Au* **2022**, 2, 1, 50–58.

Under pressure
_ Not just for solar cells

Materials based upon perovskites have great potential to become the backbone of the next generation of solar cells. But research carried out by the Adolphe Merkle Institute's Smart Energy Materials group demonstrates other possible uses.

For several years, perovskites have been touted as the next significant development in photovoltaics, being more efficient for power generation than silicon-based solar cells. Researchers have slowly developed these perovskite cells to the point where they can be produced by pilot plants and brought onto the commercial market. However, these materials have other potential applications.

Prof. Jovana Milic, head of AMI's Smart Energy Materials group, has investigated two variants of layered (2D) perovskites known as Dion–Jacobson and Ruddlesden–Popper phases. Each is made of thin layers of organic and perovskite material stacked on each other, the differences between the two being mainly due to how the stacking is assembled. These crystalline yet soft materials are found to be more stable than conventional 3D perovskite materials under environmental conditions, which has attracted considerable research interest for their use in stabilizing other perovskite materials.

Rather than apply these materials in solar cells, Milic and her collaborators exposed them to varying levels of mild pressure. Their investigations showed that the perovskites underwent mechanochromic effects when the pressure was applied – in other words, they changed color. This takes place because the pressure changes the structural properties of the layers. This, in turn, affects how the material interacts with light, leading to different hues. The researchers also found that they could control the color changes by adjusting the amount of pressure that they applied to the material. The effect is also reversible, with the perovskites returning to their initial state once pressure is removed, demonstrating their potential for various applications.

> "This reversibility of the mechanochromic response of layered hybrid perovskites [...] points toward the use of mechanophores in the development of smart materials and pressure sensors."
> *Prof. Jovana Milic.*

"This reversibility of the mechanochromic response of layered hybrid perovskites is of interest to their use as model systems for elucidating structure-property relationships in hybrid materials," explains Milic. "It is also relevant for the long-term stability of flexible perovskite devices, and it points toward the use of mechanophores in the development of smart materials and pressure sensors."

For example, these materials could be used in sensors that change color in response to pressure or in materials that can switch between different colors depending on the conditions they are exposed to. Their application is facilitated by the ease of solution processing onto various substrates for functional devices. Moreover, their responsiveness to mild pressure in the range comparable to levels of strain caused by internal structural rearrangements opens the perspectives for their use as scaffolds to assemble other functional dynamic materials in the future.

References

Muscarella, L. A.; Dučinskas, A.; Dankl, M.; Andrzejewski, M.; Casati, N. P. M.; Rothlisberger, U.; Maier, J.; Graetzel, M.; Ehrler, B.; Milić, J. V. Reversible Pressure-Dependent Mechanochromism of Dion–Jacobson and Ruddlesden–Popper Layered Hybrid Perovskites. *Advanced Materials* **2022**, 34 (17), 2108720.

Prof. Jovana Milic joined AMI in 2020 as an SNSF PRIMA grantee and group leader in the Soft Matter Physics group. She was later appointed Assistant Professor and now leads the Smart Energy Materials group at the Institute, focusing on hybrid photovoltaics, layered hybrid perovskite materials, and stimuli-responsive materials.

Smart Energy Materials

Team

Prof. Jovana Milic, Ghewa Alsabeh, Patricia Gaina, Weifan Luo, Dr. Efrain Ochoa,

Key Publications

1. Muscarella, L. A.; Dučinskas, A.; Dankl, M.; Andrzejewski, M.; Casati, N. P. M.; Rothlisberger, U.; Maier, J.; Graetzel, M.; Ehrler, B.; Milić, J. V. Reversible Pressure-Dependent Mechanochromism of Dion-Jacobson and Ruddlesden–Popper Layered Hybrid Perovskites. *Advanced Materials* **2022**, 34 (17), 2108720.

2. Luo, W.; AlSabeh, G.; Milić, J. V. Supramolecular Control in Hybrid Perovskite Photovoltaics. *Photochemistry: Volume 50* **2022**.

3. Almalki, M.; Dučinskas, A.; Carbone, L .C.; Pfeifer, L.; Piveteau, L.; Luo, W.; Lim, E.; Gaina, P. A.; Schouwink, P. A.; Zakeeruddin, S. M.; Milić, J. V.; Grätzel, M. Nanosegregation in Arene-Perfluoroarene π-Systems for Hybrid Layered Dion–Jacobson Perovskites. *Nanoscale* **2022**, 14 (18), 6771–6776.

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In the brain
_ Sorting out a tangled mess

Research has shown that rogue proteins are responsible for several brain-related illnesses, but how they clump together to cause slow-burn chaos is still not entirely understood. Scientists from the Adolphe Merkle Institute's BioPhysics group have developed a new technique to track some of those changes.

Tauopathies are a group of neurodegenerative diseases that affect the way our brain cells communicate among themselves. These disorders, which include Alzheimer's disease, progressive supranuclear palsy (PSP), Parkinson's disease, and some forms of dementia, are characterized by the clumping of a protein called tau inside the brain cells.

Neurons that help transmit messages and information have long, thread-like extensions called axons, which act like communication highways, allowing information to travel smoothly in the brain. In tauopathies, the tau protein that usually helps support and stabilize the axons' structure starts to clump together. These clumps, or tau tangles, disrupt the transportation of vital nutrients and molecules along the axons, hindering the smooth flow of information. This leads to problems in the communication between brain cells and can eventually cause them to become damaged or die.

The effects of tauopathies on a person can vary depending on the specific disorder and which parts of the brain are affected. Common symptoms include memory loss, confusion, difficulties with movement and coordination, and changes in behavior or personality. The exact reasons why tau tangles form have yet to be fully understood. Researchers believe that it may be due to a combination of genetic factors and environmental influences.

One approach to investigating the aggregation of the proteins is to fluorescently label them, allowing scientists to identify potential therapeutic targets. Usually, tau proteins would be labeled with a dye that bonds with residues of cysteine, an amino acid. However, these residues are implicated in the aggregation mechanism. To avoid disturbing this process, the AMI researchers developed a different strategy.

Rather than target the cysteine residues, they chose to attach a fluorophore to one of the two ends of the protein, in this case, the so-called C-terminus. To achieve this, they used a technique known as site-specific protein labeling via sortase-mediated transpeptidation. Derived from bacteria, a sortase is an enzyme that can modify surface proteins by targeting a specific amino acid sequence of a protein.

After binding the fluorophore, the researchers investigated the effects of the modifications on the protein's secondary structure and compared the aggregation kinetics with those of native tau protein in vitro. They also used transmission electron and atomic force microscopy to compare the resulting tau fibrils' morphology. Their results revealed that the native and C-terminally labeled tau proteins exhibited similar properties concerning the secondary structure, fibril morphology, and speed of aggregation.

"We think that our C-terminal labeling strategy of the tau protein may be useful for studies of tau aggregation using single-molecule fluorescence methods with minimal effects on the structure of the native protein conformation," adds AMI's Chair of BioPhysics, Prof. Michael Mayer. Therefore, these molecules may be helpful for identifying therapeutic drug candidates that inhibit the formation of toxic tau aggregates.

Reference

Bryan, L.; Awasthi, S.; Li, Y.; Nirmalraj, P. N.; Balog, S.; Yang, J.; Mayer, M. Site-Specific C-Terminal Fluorescent Labeling of Tau Protein. *ACS Omega* **2022**, 7 (50), 47009–47014.

Yuanjie Li graduated from the East China University of Science and Technology in Shanghai. He joined the AMI BioPhysics group in 2020 to pursue a PhD, where his research focuses on the development of solid-state nanopores for protein characterization.

BioPhysics

Team

Prof. Michael Mayer, Dr. Saurabh Awasthi, Dr. Mariano Barella, Wachara Chanakul, Jessica Dupasquier, Stéphane Hess, Dr. Alessandro Ianiro, Trevor Kalkus, Edona Karakaci, Dr. Yu-Noel Larpin, Yuanjie Li, Dr. Peng Liu, Dr. Tianji Ma, Dr. Pau Molet Bachs, Dr. Anasua Mukhopadhyay, Carolina Pierucci, Marian Reincke, Andrea Russo, Dr. Maria Sanz, Dr. Christian Sproncken, Dr. Maria Taskova, Anna Wald, Shuran Xu, Dr. Cuifeng Ying

Key Publications

1. Ying, C.; Houghtaling, J.; Mayer, M. Effects of Off-Axis Translocation through Nanopores on the Determination of Shape and Volume Estimates for Individual Particles. *Nanotechnology* **2022**, 33 (27), 275501.
2. Bryan, L.; Awasthi, S.; Li, Y.; Nirmalraj, P. N.; Balog, S.; Yang, J.; Mayer, M. Site-Specific C-Terminal Fluorescent Labeling of Tau Protein. *ACS Omega* **2022**, 7 (50), 47009–47014.
3. Kalkus, T. J.; Shanahan, C. J.; Smart, J.; Coskun, A.; Mayer, M. Harvesting Electrical Power during Carbon Capture Using Various Amine Solvents. *Energy Fuels* **2022**, 36 (18), 11051–11061.
4. Sousa de Almeida, M.; Rothen-Rutishauser, B.; Mayer, M.; Taskova, M. Multi-Functionalized Heteroduplex Antisense Oligonucleotides for Targeted Intracellular Delivery and Gene Silencing in HeLa Cells. *Biomedicines* **2022**, 10 (9), 2096.
5. Domljanovic, I.; Ianiro, A.; Rüegg, C.; Mayer, M.; Taskova, M. Natural and Modified Oligonucleotide Sequences Show Distinct Strand Displacement Kinetics and These Are Affected Further by Molecular Crowders. *Biomolecules* **2022**, 12 (9), 1249.

Pigmented
_ Creating more durable colors

Researchers from the Adolphe Merkle Institute's Soft Matter Physics group are developing new pigments that are potentially more environmentally friendly and durable thanks to structural color.

Photonic pigments, also known as structural colors, are pigments that do not rely on chemical dyes to produce color. Instead, they are made up of nanostructures that can manipulate light interactions with matter, causing it to reflect and refract in patterns to produce a particular color. The exact hue that is produced depends on the size, shape, and arrangement of the structures within the pigment. For example, a butterfly's wing may appear blue or green due to how light interacts with the microscopic structures on its surface. Unlike chemical pigments that can fade over time, photonic pigments aim to be highly durable and resistant to fading, making them potentially useful in applications such as cosmetics, paints, textiles, or even security features on banknotes. They also offer pure and brilliant coloration free from chemical- or photo-bleaching, potentially reducing their environmental impact.

The creation of color through photonic morphologies has focused chiefly on confining the self-assembly of colloidal particles or liquid crystals in specific geometries. However, synthesizing large quantities of photonic pigments based on these amorphous arrays results in a lack of control over how light is scattered and highlights the difficulty in producing pigments with distinct colors across the entire visible spectrum. The AMI Soft Matter Physics group has investigated, instead, as part of a European-funded project, another promising approach using 3D confined self-assembly of block copolymers – chains of different monomers linked together – in emulsion droplets to create these pigments. Previous attempts have required complex technical solutions, and developing robust fabrication processes has proven arduous, limiting its technical exploitation.

The new process involves using a block copolymer and two swelling additives in a solution, which is then emulsified using a vortex to form droplets. As solvent diffuses from the droplets, they form spheres with a lamellar, or onion-layered structure. The thickness of the lamellae can be controlled by differential swelling with the two additives, resulting in the ability to tune the color of the spheres across the entire visible spectrum.

"We were able to identify the necessary parameters that allow for the scalable, robust manufacture of these photonic pigments, which are also tunable across the entire visible range by only varying the compositions of the particles," explains lead researcher Andrea Dodero. "And importantly, all these particles can be made from the same block copolymer, and no additional synthesis is required to create different colors."

To achieve this, though, some important factors need to be considered. Of the two swelling agents required, one should strongly interact with one of the block copolymer constitutive chains. The additives should also be chosen to increase the difference in domain dielectric contrast, and the spheres need to form slowly enough to develop the layered structure that creates the colors.

The next steps for the researchers according to Dodero include combining the different photonic pigments with broadband absorbers enabling the reduction of scattering effects and enhancing the overall color appearance, and creating structurally colored photonic coatings and paints for real-life applications.

Reference

Dodero, A.; Djeghdi, K.; Bauernfeind, V.; Airoldi, M.; Wilts, B. D.; Weder, C.; Steiner, U.; Gunkel, I. Robust Full-Spectral Color Tuning of Photonic Colloids. *Small* **2023**, 19 (6), 2205438.

Steiner, U.; Dodero, A. Block Copolymer-based Photonic Pigments: Towards Structural Non-iridescent Brilliant Coloration. *CHIMIA* **2022**, 76, 829.

Dr. Andrea Dodero joined the AMI Soft Matter Physics group in 2021, before becoming a group leader the following year. He was also awarded in 2022 a prestigious Marie Sklodowska-Curie Individual Fellowship, which the European Commission awards to what it considers promising individual researchers from all over the world.

Soft Matter Physics

Team

Prof. Ullrich Steiner, Doha Abdelrahman, Bilel Abdennadher, Martino Airoldi, Viola Bauernfeind, Brian van Büren, Kenza Djegdhi, Dr. Andrea Dodero, Parnian Ferdowsi, Dr. Ilja Gunkel, René Iseli, Tri Minh Nguyen, Andrea Palumbo, Alessandro Parisotto, Cristina Prado, Dr. Matthias Saba, Cédric Schumacher, Dr. Viola Vogler-Neuling, Dr. Wenhui Wang.

Key Publications

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3. Redondo, A.; Mortensen, N.; Djeghdi, K.; Jang, D.; Ortuso, R. D.; Weder, C.; Korley, L. T. J.; Steiner, U.; Gunkel, I. Comparing Percolation and Alignment of Cellulose Nanocrystals for the Reinforcement of Polyurethane Nanocomposites. *ACS Appl. Mater. Interfaces* **2022**, 14 (5), 7270–7282.
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Methodology
_ Breaking up agglomerates with sound

Ultrasonication is a method used to re-disperse nanoparticles in liquids and dispersions, that relies on sound waves to break apart clumps of nanoparticles without changing their properties. However, the outcome is often unpredictable and lacks reproducibility, a challenge the AMI BioNanomaterials group has been investigating with machine learning.

Engineered nanoparticles (ENPs) have been used in commercial products, such as foodstuff, cosmetics, and personal care products for over two decades. Typical materials are zinc oxide (found in sunscreen), titania (toothpaste), ceria, and silica. These particles are usually produced, sold in bulk, and stored in a dry powder form. When stored this way, particles can form agglomerates – single particles clumping together. These powders must be transferred to a liquid by a process called dispersion for many applications. Ultrasonication is a widely adopted and standardized method to disperse powders in liquids and homogenize nanoparticle dispersions. It uses sound waves to break apart clumps of nanoparticles without changing their properties. However, the outcome is often unpredictable. To address this issue, Adolphe Merkle Institute researchers from the BioNanomaterials group investigated the use of machine learning to analyze the effects of ultrasonication and improve experimental design and reproducibility.

In a first step, four types of nanoparticles were considered, and supervised machine learning and dynamic light scattering were used to analyze the size of the nanoparticle aggregates after ultrasonication. The BioNanomaterials researchers relied on an experimental design that allowed them to extract maximum information from a small number of experiments. They varied the sonication parameters and particle properties to understand their effects on the degree of particle dispersion. The particles were also characterized using dynamic light scattering, which provided information about their size and polydispersity.

To establish a quantitative relationship between the input parameters and the output labels (particle size and polydispersity), the researchers trained a machine learning model to predict the outcome of ultrasonication based on various parameters, such as particle concentration, dispersion volume, sonicator type, duration of sonication, and particle properties like size and surface coating. The model was validated and tested using known data. A decision tree algorithm allowed the researchers to rank the importance of different parameters and gain insights into the underlying physical processes involved in ultrasonication.

In a second step, the researchers then performed a meta-analysis of published data on ultrasonication of different particle systems. They focused on nanoparticles commonly found in consumer products like zinc oxide, silicon dioxide, cerium dioxide, and titanium dioxide. This allowed them to compare the experimental machine-learning study results with a baseline of previous measurements.

"We observed a strong alignment between our predicted and simulated data," explains PhD student Christina Glaubitz. "This outcome instills confidence in the predictive capabilities of our model."

Overall, the study demonstrates the potential of machine learning to improve the reproducibility of nanoparticle dispersion. By understanding the complex relationships between input parameters and outcomes, researchers can optimize the ultrasonication process and avoid undesired changes in the nanoparticles' properties.

The research has the potential to be expanded further. "Our future research endeavors involve constructing a comprehensive database to develop a more inclusive model," says Glaubitz. "This model will predict the behavior of a wider range of material types and more intricate dispersants."

Reference

Glaubitz, C.; Rothen-Rutishauser, B.; Lattuada, M.; Balog, S.; Petri-Fink, A. Designing the Ultrasonic Treatment of Nanoparticle-Dispersions via Machine Learning. *Nanoscale* **2022**, 14 (35), 12940–12950.

Christina Glaubitz was awarded a Master of Science in Chemistry at the Technical University of Munich. She joined AMI's BioNanomaterials group in 2020 to pursue a PhD, where she is developing faster methods to analyze engineered nanoparticles to ensure compliance with regulatory requirements.

BioNanomaterials

Team

Prof. Alke Fink, Prof. Barbara Rothen-Rutishauser, Liliane Ackermann, Mauro Sousa de Almeida, Dr. Sandor Balog, Dr. Olexiy Balitskii, Dr. Anne Bannuscher, Laura Baraldi, Dr. Amélie Bazzoni, Jessica Caldwell, Shui Ling Chu, Christina Glaubitz, Gowsinth Gunasingam, Laetitia Haeni, Dr. Ruiwen He, Dr. Begum Bedia Karakocak, Dr. Sandeep Keshavan, Murat Kilic, Daria Korejwo, Jason Lachat, Aaron Lee, Henry Lee, Isidora Loncarevic, Dr. Céline Loussert, Andriy Lubskyy, Aura Maria Moreno Echeverri, , Dr. Roberto Ortuso, Maria Porteiro, Dr. Fabienne Schwab, Dr. Flavia Sousa, Eva Susnik, Dr. Patricia Taladriz, Dr. Dimitri Vanhecke, Mira Witzig, Phattadon Yajan

Key Publications

1. Lee, A.; Almeida, M. S. de; Milinkovic, D.; Septiadi, D.; Taladriz-Blanco, P.; Loussert-Fonta, C.; Balog, S.; Bazzoni, A.; Rothen-Rutishauser, B.; Petri-Fink, A. Substrate Stiffness Reduces Particle Uptake by Epithelial Cells and Macrophages in a Size-Dependent Manner through Mechanoregulation. *Nanoscale* **2022**, 14 (40), 15141–15155.

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3. Caldwell, J.; Taladriz-Blanco, P.; Lehner, R.; Lubskyy, A.; Ortuso, R.D.; Rothen-Rutishauser, B.; Petri-Fink, A. The Micro-, Submicron-, and Nanoplastic Hunt: A Review of Detection Methods for Plastic Particles. *Chemosphere* **2022**, 293, 133514.

4. Sousa de Almeida, M.; Taladriz-Blanco, P.; Drasler, B.; Balog, S.; Yajan, P.; Petri-Fink, A.; Rothen-Rutishauser, B. Cellular Uptake of Silica and Gold Nanoparticles Induces Early Activation of Nuclear Receptor NR4A1. *Nanomaterials* **2022**, 12(4):690.

5. Moreno-Echeverri, A.M.; Susnik, E.; Vanhecke, D.; Taladriz-Blanco, P.; Balog, S.; Petri-Fink, A.; Rothen-Rutishauser, B. Pitfalls in methods to study colocalization of nanoparticles in mouse macrophage lysosomes. J *Nanobiotechnology* **2022**, 20(1):464.

Reproducible
_ Europe-wide test of material assessment method

Adolphe Merkle Institute researchers from the BioNanomaterials group have coordinated a Europe-wide consortium in testing the accuracy of a system for hazard assessment of aerosolized materials, an important step in developing standardized assays for lung cell models.

Air-liquid interface (ALI) lung cell models are used for assessing respiratory hazards. These models involve culturing cells on permeable inserts, and exposing them to aerosolized materials. How accurate the dosage of these materials is across multiple laboratories is not entirely clear, although extremely important since results should be reproducible and comparable.

Inter-laboratory studies are essential for implementing ALI cultures used in vitro hazard assessment of materials. Furthermore, the method adopted should be both robust and reproducible to ensure regulatory acceptance. Such a comparison study should include a standardized operating procedure (SOP) for a specific method, which is necessary to ensure globally harmonized testing approaches, and should be in line with guidance from, e.g., the Organization for Economic Co-operation and Development (OECD). These guidelines were developed with the aim of reducing the uncertainties in cell and tissue-based in vitro method-derived predictions.

The AMI BioNanomaterials group collaborated with a total of seven European partners, including from the PATROLS (Physiologically Anchored Tools for Realistic nanOmateriaL hazard aSsessment) consortium, and coordinated an approach to investigate the accuracy of a commercially available aerosol-cell exposure system to deliver a controlled dose of aerosolized materials to lung cells at ALI. The researchers developed an SOP to deliver aerosolized materials with the VITROCELL® Cloud12 system. The amount of material deposited on the inserts was measured using a quartz crystal microbalance (QCM) integrated into the exposure system for the particles. The researchers also examined the shape and agglomeration state of the deposited particles using transmission electron microscopy.

The inter-laboratory comparison focused on materials, with the goal of determining if the QCM could be a reliable measurement system. Differences in aerosol deposition at the different laboratories were characterized using a deposition factor, which helps predict the material dose deposited on the inserts based on the concentration of materials in the aerosolized suspension. The SOP was continuously adapted and optimized.

The system accurately measured the deposited material dose on the inserts. For the materials, a linear relationship was observed between the concentration of materials in the aerosolized suspension and the QCM-determined dose delivered to the inserts. The results suggest that the VITROCELL® Cloud 12 system is a reliable tool for dosimetry. According to the researchers, this advancement is significant for the future implementation of lung cell cultures at ALI in regulatory-approved assessments of aerosolized materials' hazards.

Reference

Bannuscher, A.; Schmid, O.; Drasler, B.; Rohrbasser, A.; Braakhuis, H. M.; Meldrum, K.; Zwart, E. P.; Gremmer, E. R.; Birk, B.; Rissel, M.; Landsiedel, R.; Moschini, E.; Evans, S. J.; Kumar, P.; Orak, S.; Doryab, A.; Erdem, J. S.; Serchi, T.; Vandebriel, R. J.; Cassee, F. R.; Doak, S. H.; Petri-Fink, A.; Zienolddiny, S.; Clift, M. J. D.; Rothen-Rutishauser, B. An Inter-Laboratory Effort to Harmonize the Cell-Delivered in Vitro Dose of Aerosolized Materials. *NanoImpact* **2022**, 28, 100439.

Dr. Barbara Drasler joined the BioNanomaterials research group at AMI as a postdoctoral research fellow in 2016, where she investigated drug delivery to specific parts of the lung via inhalation. She currently divides her time between the NCCR Bio-Inspired Materials management team and the University of Fribourg's Knowledge and Technology Transfer Office.

A European consortium

PATROLS (Physiologically Anchored Tools for Realistic nanOmateriaL hazard aSsessment) was an international project combining a team of academics, industrial scientists, government officials, and risk assessors to deliver advanced and realistic tools and methods for nanomaterial safety assessment.

Funded under the European Union's Horizon 2020 research and innovation program between 2018 and 2021, PATROLS was set up to provide an effective set of laboratory techniques and computational tools to more reliably predict potential human and environmental hazards resulting from engineered nanomaterial (ENM) exposures. These tools aim to minimize the necessity of animal testing and support future categorization of ENMs in order to support safety frameworks.

The project's aims were to develop:
1. Realistic and predictive 3D tissue models of the lung, gastrointestinal tract and liver for ENM safety assessment, reducing the need for animal testing.
2. Innovative methods for safety assessment in ecologically relevant test systems and organisms, selected according to their position in the food chain.
3. Create robust computational methods for ENM exposure and dose modeling, as well as hazard prediction.
4. Characterize ENMs under relevant experimental conditions dictated by the advanced human and environmental model development.

The Adolphe Merkle Institute was represented by Prof. Barbara Rothen-Rutishauser, Co-Chair of the BioNanomaterials group, whose research project focused on the development of complex 3D lung tissue models to help predict the long-term effects of inhaled nanomaterials.

In brief

Promoting 3R

The Adolphe Merkle Institute BioNanomaterials co-Chair, Prof. Barbara Rothen-Rutishauser, was elected to the board of the Swiss-based Doerenkamp-Zbinden Foundation, which supports the replacement, reduction, and refinement (3Rs) of animal experimentation.

The Doerenkamp-Zbinden Foundation was created in 1982 to promote alternative testing methods to animals. It currently funds endowed chairs at universities in the United States, Germany, Switzerland, the Netherlands, and India. It also provides 3R project funding, and awards a yearly prize for distinguished services to animal protection in science.

Rothen-Rutishauser is an expert in the field of cell-nanoparticle interactions, with a special focus on 3D tissue models. Her work includes the development of alternative testing methods that can be used for hazard assessments and drug testing approaches.

Polymer awards

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

The award, which includes a medal and an honorarium, 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 of 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 science and engineering. His main research interests are the design, synthesis, and investigation of novel functional polymers, in particular stimuli-responsive polymers, bio-inspired materials, supramolecular systems, and polymer nanocomposites. Cellulose nanocrystals constitute one of the most important building blocks that his group uses to create such materials." Weder received his award at the ACS' 2023 spring meeting in Indianapolis, and was honored with a symposium and a banquet.

Weder was also the recipient of the 2022 International Biannual Award of the Belgian Polymer Group, awarded to persons with outstanding contributions to polymer science and interactions with Belgian polymer research groups.

Travel awards

AMI Polymer Chemistry and Materials PhD students Franziska Marx and Derek Kiebala were both recipients of Swiss Chemistry Travel Awards in 2022.

These awards are given out by the Swiss Chemical Society and the Platform Chemistry of the Swiss Academy of Sciences for conference travel or laboratory research visits abroad. The two students used the funding to attend the American Chemical Society's fall meeting in Chicago, where they presented their research on healable metallosupramolecular polymers (Marx) and dynamic polymer materials (Kiebala).

Nanoparticle detection

A research collaboration between NanoLockin – a spin-off of the Adolphe Merkle Institute –, the Institute, and German company Vitrocell was awarded a Eurostars grant worth €1.7 million.

Eurostars is an international funding program for innovative SMEs. The AirToxMonitor project partners are designing a versatile platform for the non-invasive monitoring of airborne nanoparticles and environmental atmospheres in cells or tissues. This system will significantly improve capabilities in the field of hazard assessment, not only for air pollution particles, but also for work environments where for example carbon-based particles such as graphene or carbon nanotubes could be found. Eurostars is a European joint program, launched by the Eureka research initiative and the European Commission in 2007. A project involves partners from at least two participating Eurostars nations. Consortia are led by an innovative SME from one of these countries and projects are funded for up to three years.

Microplastics

AMI hosted the third meeting of Swiss microplastics research community in May, bringing together scientists from all over the country. Under the aegis of microplastics.ch, and meeting for the first time since 2019, representatives from Switzerland's federal research institutes and universities, including the AMI BioNanomaterials group, presented their most current research into this expanding environmental issue.

ERC grant

Polymer Chemistry and Materials group leader José Berrocal was in 2022 the latest AMI staff member to receive prestigious European Research Council funding.

Berrocal was awarded an ERC Starting Grant worth €1.5 million over five years for his ReHuse (Reversible Heterolytic Mechanophores for Dynamic Bulk Materials) project. He will investigate stimuli-responsive polymers, focusing on inducing a change in their behavior using mechanical strength. Due to Switzerland's non-association with the Horizon Europe program, Berrocal has now taken up a position at the Institute of Chemical Research of Catalonia, in Tarragona, Spain, where he will have full access to the benefits of the ERC program.

In memoriam

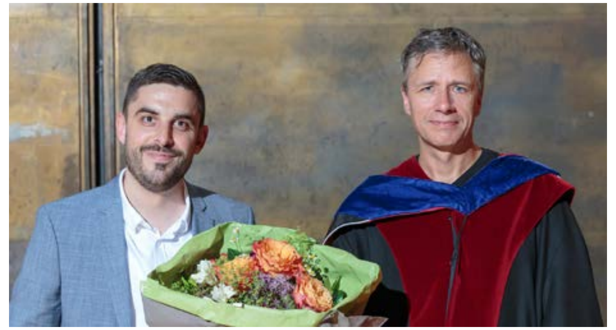
Remembering the life and research of Marco Mareliati with a special PhD defense.

The Adolphe Merkle Institute honored in 2022 the memory of late colleague and PhD student Marco Mareliati, who died in a mountaineering accident the previous year, with the public defense of his thesis "Metal-ligand complexes as dynamic sacrificial bonds in elastic polymers" by Prof. Stephen Schrettl. With his family present, it was an emotional occasion, but also a testimony of the quality of his research, which saw him awarded his doctorate by the University of Fribourg.

University recognition

Adolphe Merkle Institute alum Baptiste Monney was awarded the University of Fribourg's 2022 Thürler-Heeb Grant. This grant is awarded by the Faculty of Science and Medicine to junior researchers to assist them in the early stages of their careers.

Monney, who completed his PhD on "Photo-patternable, Mechanically Adaptive Polymers for Neural Interfaces" in 2021, was a member of Prof. Christoph Weder's Polymer Chemistry and Materials group. He graduated from the University of Fribourg with a Bachelor's in Chemistry and a Master's in Organic and Polymer Chemistry, before joining AMI in 2017 to work on stimuli-responsive, mechanically-adaptive polymer networks.



Global dialogue

The Adolphe Merkle Institute's Assistant Prof. Jovana Milic was selected in 2022 as one of 39 new members of the Global Young Academy (GYA), whose goal is to give a voice to young researchers around the world.

The GYA connects scientists from six continents, and empowers young researchers to lead international, interdisciplinary, and intergenerational dialogue. The academy also aims to elevate the voice of young scientists in global, regional, and national decision-making. The academy has 200 members, who join typically three to ten years after their PhD, and are in the early stages of their independent academic careers.

Members are selected for their scientific excellence as well as for their demonstrated societal engagement, and serve five-year terms.

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, perovskite solar cells.

Air testing

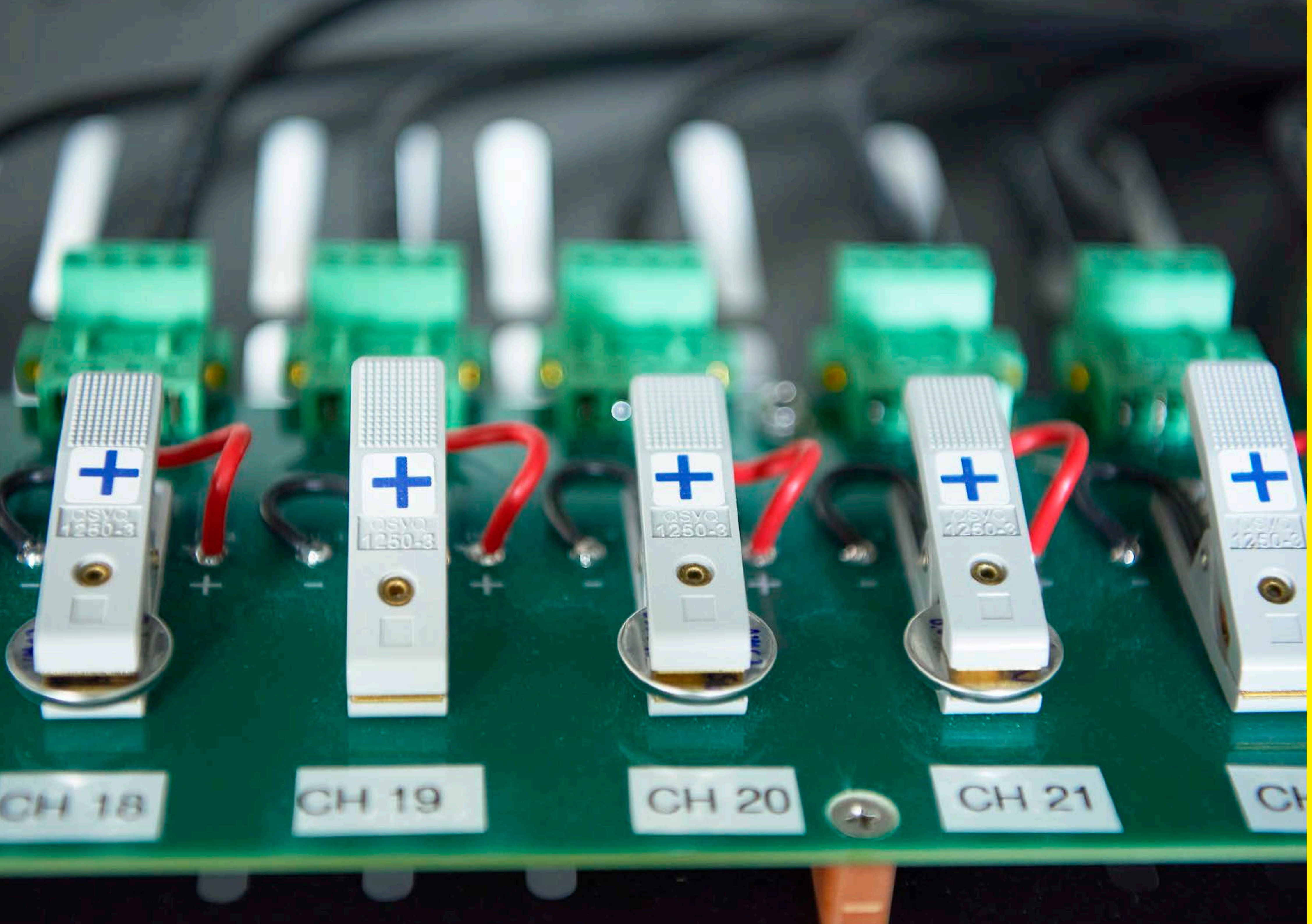
In November and December 2022, the ULTRHAS international consortium, which includes AMI BioNanomaterials researchers, conducted its first test campaign at the University of Rostock in Germany, focusing on aircraft emissions.

The consortium, which is funded by the EU and is investigating health hazards posed by ultrafine particles from traffic emissions, aims to produce guidelines for the development of measures to improve air quality and health.

Appointments

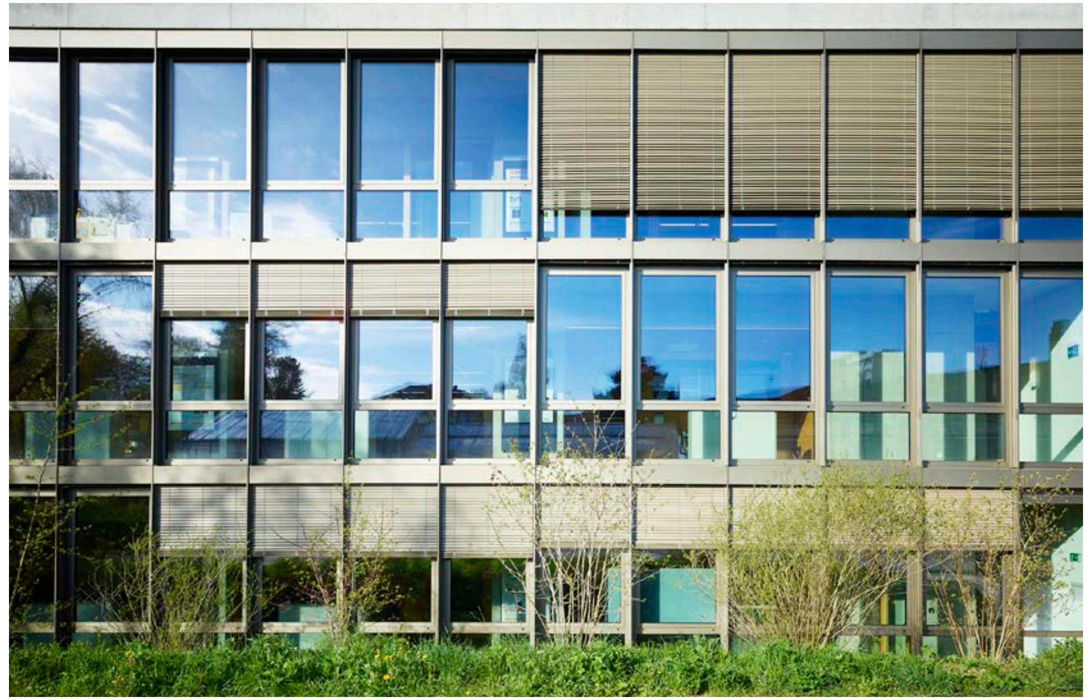
AMI BioPhysics alum Dr. Tom Schroeder was appointed to a professorship at the North Carolina State Wilson College of Textiles in the United States after completing a postdoctoral stay at Harvard University. Schroeder, who left AMI after defending his PhD in 2018, will investigate the ability of polymers and assemblies to finely control the movement of matter, heat, or electric charge.

Polymer Chemistry and Materials group leader Dr. Stephen Schrettl was appointed as an Associate Professor at the Technical University of Munich's School of Life Sciences in Germany. Schrettl holds the Professorship of Functional Materials for Food Packaging. His research will include the development of novel types of functional polymer materials, with a particular focus on applications in the domain of food packaging.



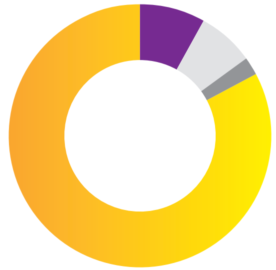
37 _ Finance & Organization

Finance
_ Cost structure at AMI



The Adolphe Merkle Institute's overall expenditures in 2022 were CHF 9.1 million. 83% of this sum was spent on research, while an additional 8% was invested in research equipment. Around 2% of the budget supported valorization activities such as technology transfer, communication, and marketing, with another 7% used for administration costs.

Overall expenses 2022
CHF 9.1 million



Funding sources of overall expenses 2022

Third-party funding 2022
CHF 4.8 million

Organization

In late 2007, Adolphe Merkle set up the Adolphe Merkle Foundation and donated CHF 100 million to support the University of Fribourg. The donation has been used primarily to establish the Adolphe Merkle Institute.

The Institute Council plays an important role in controlling and supervising the development of the Institute at the University of Fribourg's science faculty. It guarantees optimal communication and coordination between the University and the Foundation and helps the Institute to fulfill its mission and to smoothly integrate into the university.

The Scientific Advisory Board is an independent team of experts with backgrounds and expertise in fields that are relevant for AMI. It provides an external view to help position the institute in its national and international environment.

The Executive Board oversees daily operations at AMI and meets once a week. All AMI professors are members of this management body along with the Associate Director. They are responsible for ensuring that the strategy approved by the Institute Council is implemented.

The Administration team provides support in many aspects of the Institute's daily work and acts as an interface between the University of Fribourg and AMI.

Foundation Board

Members

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Administrator, Sublevo AG, Kloten, Switzerland

Jean-Pierre Siggen
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Former Managing Director Freiburg Center of Interactive Materials and Bioinspired Technologies

Prof. Claude Regamey
Former chairman of the Department of Internal Medicine, Hôpital Cantonal Fribourg, former President of the Ethical Committee of the Swiss Academy of Sciences

André Broye (Managing Director)

Institute Council

Members

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Rector of the University of Fribourg, Professor at the Faculty of Law, University of Fribourg

Peter Huber (Vice-president)
Administrator, Sublevo AG, Kloten, Switzerland

Prof. Ulrich Ultes-Nitsche
Professor, Department of Informatics, University of Fribourg

Prof. Rolf Mülhaupt
Former Managing Director Freiburg Center of Interactive Materials and Bioinspired Technologies

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Prof. Paula Hammond
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Operating partner, Triton Partners, Germany

Prof. Dieter Richter
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Prof. Marcus Textor
Former Head of Biointerface Group, Department of Materials, ETHZ, Switzerland

Prof. Ben Zhong Tang
Deng Presidential Chair Professor of Chemistry, Hong Kong University of Science and Technology, China

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Director and Chair of Soft Matter Physics

Prof. Jessica Clough
Mechanoresponsive Materials group

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Prof. Jovana Milic
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Administration

Scott Capper
Responsible for Communications & Marketing

Carine Jungo
Secretary

Catherine Jungo
Responsible for Human Resources

Anna Lamelza *(until July 2022)*
Responsible for Finance & Controlling

Thierry Mettraux *(since August 2022)*
Responsible for Finance & Controlling

Dr. Lucas Montero
Coordinator

Dr. Valeria Mozzetti
Head of Knowledge and Technology Transfer, Grant Writing

Tomas Perez
Responsible for IT Support

43 _PhDs & Alumni

PhDs

Our new doctors

Parnian Ferdowsi
(Soft Matter Physics)
"Wide Band-Gap Perovskite Solar Cells"

Derek Kiebala
(Polymer Chemistry and Materials)
"Deformation Signaling in Polymeric Materials via Non-Sacrificial Interactions"

Aaron Lee
(BioNanomaterials)
“Engineered particle surfaces to alter cell mechanotransduction and particle internalization”

Marco Mareliati
(Polymer Chemistry and Materials)
“Metal-ligand complexes as dynamic sacrificial bonds in elastic polymers”

Livius Muff
(Polymer Chemistry and Materials)
“Mechanically Morphing Polymer Systems”

Giovanni Spiaggia
(BioNanomaterials)
“Novel biocompatible substrates incorporating nanomaterials to maneuver cellular response"

Hanna Traeger
(Polymer Chemistry and Materials)
"Exploiting Loop Structures as Non-covalent Mechanochromic Motifs"

PhDs & Alumni

Alumni

People who left AMI in 2021

Jozef Adamcik
(NCCR Bio-Inspired Materials)

Irene Artignano
(Polymer Chemistry and Materials)

Mariano Barella
(BioPhysics)

Olexiy Balitskii
(BioNanomaterials)

Claudio Cappelletti
(Polymer Chemistry and Materials)

Parnian Ferdowsi
(Soft Matter Physics)

Stéphane Hess
(BioPhysics)

Sètuhn Jimaja
(Polymer Chemistry and Materials)

Begum Bedia Karakocak
(BioNanomaterials)

Anna Lamelza
(Administration)

Aaron Lee
(BioNanomaterials)

Céline Loussert
(BioNanomaterials)

Youwei Ma
(Polymer Chemistry and Materials)

Livius Muff
(Polymer Chemistry and Materials)

Efrain Ochoa
(Soft Matter Physics)

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Maria Taskova
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Shuran Xu
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Impressum

Editorial: Ullrich Steiner / Lucas Montero / Scott Capper

Text: Scott Capper

Photos: Claudia Christen (cover, pages 5, 6, 8, 10, 14, 18, 23, 25, 27, 29, 31, 33, 38, 40) / AMI Scott Capper (pages 4, 16, 14, 35, 37) / Véronique Buclin (page 20) / Christoph Schaller (page 34) / Marion Savoy (pages 34, 36) / Adobe Stock (page 35) / ULTRHAS (page 37) / Dominique Bersier UniFR (pages 35, 42)

Illustrations: Noun Project

Graphic design: Manuel Haefliger, Grafikraum, Bern

Printer: Canisius Impression & Graphisme

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