# 2021 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 the domain of soft nanomaterials.

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

Founded in 2008, AMI is in many aspects unique in the the Swiss research landscape. 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, more generally, improve the quality of life.

Our researchers are currently organized in four research groups, which offer complementary expertise and interests in strategically important areas: BioNanomaterials, Polymer Chemistry & Materials, Soft Matter Physics, and Biophysics. 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 our world-class research facilities make AMI a desirable destination for master's and PhD students, postdocs, and senior researchers.

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# Connections
## _ A message from the Director

Professor Christoph Weder

It is with great pleasure that I present to you the Adolphe Merkle Institute's 2021 annual report, in which we look back to our most important activities, accomplishments, and developments.

While the pandemic continued to impact lives for a second year, our researchers were able to pursue their experimental work without major limitations and their efforts led to exciting outcomes that we would like to share in this report.

Members of our BioPhysics group demonstrated how metabolic waste can be transformed into electrical energy. Their results may pave the way for "body batteries" that can be used to power wearable or implantable electronics. The BioNanomaterials group applied their expertise in detecting nanoparticles in complex media to a broad variety of materials. In a recent investigation, they investigated the release of nanoplastics from teabags. Such studies provide fundamental data that are relevant in the context of possible environmental and health impacts of artificial nanomaterials. Researchers from our Soft Matter Physics group are making progress towards the development of new metamaterials that can trap and store light. The possibility to confine light waves was theoretically predicted a century ago, whereas experimental investigations are a more recent development. Finally, the Polymer Chemistry and Materials group continued its work on healable polymers. Deploying a newly developed method, they demonstrated that fully mending two severed surfaces requires the formation of an interphase that is ten times thicker than previously thought.

In the context of Switzerland's new role as a non-associated third country in the European Union's Horizon Europe program, we also take a look at the Institute's many collaborations, within Europe and beyond. The international network that we have established during more than a decade has allowed us to join, and in many cases lead, significant international consortia and connect with leading researcher groups in their respective fields. In spite of the quarrels regarding Switzerland's status, AMI researchers were involved in three successful applications for EU funding in 2021, notably as leads of a multi-institutional EU Pathfinder project.

Coverage of other achievements and highlights from the past year are covered in our "In Brief" section, ranging from awards for junior and senior researchers, events hosted and attended by AMI members, such as the University of Fribourg's Explora open day, or celebrating women in science. Finally, we meet some of our alumni active both in academia and industry as we learn where their careers have taken them.

We hope you enjoy the lecture of this report and thank you for your interest in our institute, our team, and our activities.

**Christoph Weder**
AMI Director and Professor for Polymer Chemistry & Materials

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# Pursuing excellence

# Global reach

## _ International networking a pillar of AMI success

Prof. Michael Mayer (BioPhysics) and group leaders Dr. Alessandro Ianiro (BioPhysics) and Dr. José Berrocal (Polymer Chemistry and Materials) launched the successful INTEGRATE proposal

**International collaborations play a vital role in the Adolphe Merkle Institute's research. In recent years, AMI has had established connections with over 80 institutions abroad.**

At the Institute, the belief is that collaborations contribute to better science. Successful research is often the result of working with the right partners beyond the confines of one's own laboratory. Many of these collaborations are informal, and emerge as parts of individual projects. But there are also other forms of research partnerships, some of them strategically important for the development of long-term objectives, others that require large consortia to succeed, that require a more formal framework and also substantial funding. AMI's track record of establishing such international research ventures has been outstanding in recent years, with the Institute taking on the leadership or playing vital roles in many consortia. In 2021, AMI researchers were for example involved in three successful applications for large-scale programs funded under the EU's Research and Innovation program Horizon 2020.

The INTEGRATE project, which was awarded € 3 million from the EU's Pathfinder fund, was the biggest new research program launched by AMI researchers in 2021. The goal of the program, which is led by AMI group leaders Dr. Alessandro Ianiro and Dr. José Berrocal from the BioPhysics and Polymer Chemistry and Materials groups, is to develop artificial muscles powered by metabolic energy. In addition to the AMI researchers, the consortium involves four leading research institutions in Italy, the Netherlands, France, and Belgium. Pathfinder grants, awarded by the European Innovation Council, support the exploration of bold ideas for radically new technologies. They are extremely competitive, with just 6 % of submitted projects receiving funding. INTEGRATE was the only one of the 56 recipients with a Swiss leading house.

Another European project with AMI participation launched in 2021 is ULTRHAS (ULtrafine particles from TRansportation – Health Assessment of Sources). For this activity, the Institute has entered a partnership with researchers from Norway, Finland, and Germany. The consortium, backed with €4 million of EU funding, is testing a broad range of transport mode emissions, both exhaust and non-exhaust, under laboratory conditions. It will provide a detailed analysis of the physical and chemical characteristics of these ultrafine particles and their biological effects. AMI Prof. Barbara Rothen-Rutishauser, co-chair of the BioNanomaterials group, is leading one of seven work packages, which will identify potential adverse effects of the particles beyond the lung, using advanced tissue models.

“Not being able to apply for ERC grants and/or taking the lead in network grants hurts us financially, but also prevents us from further developing our network across Europe.”
*Prof. Ullrich Steiner, Soft Matter Physics.*

The third new European-funded project at AMI in 2021 is AirToxMonitor, a collaboration between the AMI BioNanomaterials group, the AMI spinoff NanoLockin, and the German company Vitrocell. The aim is to develop a novel platform for non-invasive monitoring of airborne nanoparticles and environmental atmospheres in cell or tissues. This could be especially useful for work environments where for example carbon-based particles such as graphene or carbon nanotubes could be present. The grant, worth €1.7 million, is provided via the Eurostars funding mechanism, which supports innovative SMEs and project partners in EU countries and others affiliated with the Eureka research initiative, including Switzerland.

European and international collaborations are thus an essential part of the Institute’s makeup. In recent years, AMI has participated in or lead consortia for EU-funded Innovative Training Networks (PlaMatsu and CityCare), or transnational programs (PATROLS). The Institute is also the only Swiss entity involved in a Partnerships for International Research and Education (PIRE) collaboration (bioinspiredPIRE) with American universities, in which 14 PhD students at four different US universities as well as a British university, and 5 PhD students at the AMI collaborate to develop and apply bio-inspired materials.

These international collaborations are important because they allow us to fully realize our ideas, access resources and knowledge that we otherwise might not be able to, and develop our research network,” explains the AMI chair of Polymer Chemistry and Materials Prof. Christoph Weder. “They clearly are instrumental for AMI to maximize its scientific impact.”

Competitive international funding for individuals has also been important for AMI. Two of its professors, Weder and the chair of Soft Matter Physics Prof. Ullrich Steiner, have been recipients of prestigious European Research Council (ERC) Advanced Grants, worth several million euros each, for cutting-edge projects. Postdoctoral researchers have also benefited from fellowships granted as part of the Marie Skłodowska-Curie Actions, the European Union’s flagship funding program for doctoral education and postdoctoral training of researchers.

However, opportunities to pursue European funding have been compromised by the Swiss federal government’s decision in 2021 to end negotiations with the EU over an institutional framework agreement. The agreement was intended to safeguard Switzerland's access to the European single market and to provide a basis for expanding that access. According to the government, it would have fundamentally changed Swiss-EU relations. Talks foundered mainly because of issues surrounding wage protection, rules on state subsidies, and EU citizens’ access to Swiss social security benefits. One unwelcome effect was however the downgrading of Switzerland’s participation in the Horizon Europe program, a political decision by the European Union.

Steiner points out that this outcome has a number of negative effects. “Not being able to apply for ERC grants and/or taking the lead in network grants hurts us financially, but also prevents us from further developing our network across Europe,” he warns. European money is a vital element of AMI’s financial structure. It represents 12% of the Institute’s third-party research funding, alongside grants from the Swiss National Science Foundation and other sources.

So how can AMI overcome restrictions on European funding? The Swiss National Science Foundation has promised to make up the shortfall by directly funding grants that would have been provided by the EU. Swiss researchers will also be able to join consortia, but will not be allowed to take on project leadership roles.

“Not being able to take the lead in large European research cooperations takes away our ability to define new programs aligned with our research priorities,” adds Weder. “Instead, we’ve become dependent on other researchers inviting us to join a consortium. Compensatory measures funded at the national level may help in some cases, but losing our leadership at the international level is damaging. What is equally more critical, is that we stand the risk to lose the most

talented young researchers to universities outside Switzerland, where they are eligible for ERC starting grants, which have become an important instrument to boost the careers of young researchers. Replacement grants that don't mitigate these problems are unlikely to help Switzerland to maintain a leading position in the long run."

## Completed projects

**PlaMatSu (total EU funding €2.34 million)**

PlaMatSu (Plant Materials and Surfaces, 2016 – 2020) was an Innovative Training Network (ITN), funded by the European Commission's Marie Skłodowska-Curie Actions. It allowed nine PhD students (three at AMI) to work at three leading European universities in the field of bio-inspired materials: the University of Fribourg (Switzerland), the University of Freiburg (Germany) and the University of Cambridge (UK). Led by AMI's Prof. Nico Bruns (now at TU Darmstadt), PlaMatSu brought together plant biologists, polymer chemists and soft matter physicists to study the development, structure, and properties of multifunctional plant cuticles on a fundamental level and to create novel materials and surfaces based on the working principles of cuticles. This academic network of excellence was strengthened by industrial partners such as Germany's BASF, and students spent part of their training on secondment with these companies. The aim is to boost scientific excellence and business innovation, and to enhance researchers' career prospects through developing their skills in entrepreneurship, creativity, and innovation.

**CityCare (total EU funding €773,000)**

CityCare (2017 – 2021) was another ITN, bringing together the University of Fribourg via AMI (Prof. Barbara Rothen-Rutishauser), the University of Ferrara (Italy) and Dow Silicones Belgium. Three PhD students (one at AMI) investigated the damaging effects of air pollutants on cutaneous responses, with the aim of providing innovative solutions for better skin protection against environmental stressors. The project's other target was to stimulate entrepreneurship and innovation in the fields of skin protection and well-being. The three students developed a state-of-the-art, customizable, 3D skin model, which served as the project's key tool for evaluating the effects of various environmental stressors on cutaneous tissue. It was then used to evaluate the effects of diesel exhaust, cigarette smoke, or ozone on the skin.

**PATROLS (total EU funding €13.1 million)**

PATROLS (Physiologically Anchored Tools for Realistic nanOmateriaL hazard aSsessment, 2018 – 2021) was an international project bringing together academics, industrial scientists, government officials and risk assessors to deliver advanced and realistic tools and methods for nanomaterial safety assessment. Nanotechnology promises significant benefits, but its use


The PlaMatSu consortium trained nine PhD students in three different countries

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## NATIONALITIES

PRESENT AT AMI WITH REPRESENTATIVES FROM ALMOST EVERY CONTINENT.

6

## PROFESSORS

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

58%

## 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

6,800

## CITATIONS

OF AMI PUBLICATIONS IN THE SCIENTIFIC LITERATURE IN 2021.

37

APPLICATION-ORIENTED

## PROJECTS

INCLUDING RESEARCH MANDATES.

99

## SCIENTIFIC PUBLICATIONS

IN JOURNALS SUCH AS THE JOURNAL OF THE AMERICAN CHEMICAL SOCIETY, SMALL, NATURE CHEMISTRY, CHEMICAL SOCIETY REVIEWS, ADVANCED MATERIALS, ACS NANO, ANGE-WANDTE CHEMIE, NATURE COM-MUNICATIONS, NANOMATERIALS, MATERIALS HORIZONS, CHEMIS-TRY OF MATERIALS, POLYMER CHEMISTRY.

400+

## ALUMNI

INCLUDING POSTDOCTORAL RESEARCHERS, PHD STUDENTS AND INTERNS.

is beset by widespread concerns over safety. Classical hazard testing strategies to define the human and environmental health impact of engineered nanomaterials (ENMs) also commonly apply unrealistic in vitro models that do not reflect the *in vivo* environment. Twenty-four partners in Europe, North America, and Asia took part in the project, coordinated by Swansea University. AMI's participation was led by Prof. Barbara Rothen-Rutishauser (BioNanomaterials), with one PhD student and one postdoctoral researcher. Patrols notably produced a series of 55 standard operating procedures (SOPs) that cover a range of assessment methods, from physical chemistry to *in vitro* toxicology and ecotoxicology. Each SOP has a guidance document providing a description of the method and a procedure for applying it and where relevant, provides links to publications that have made use of the SOP. The procedures are publicly available and are accessible to other scientists for their own use.

## Other projects

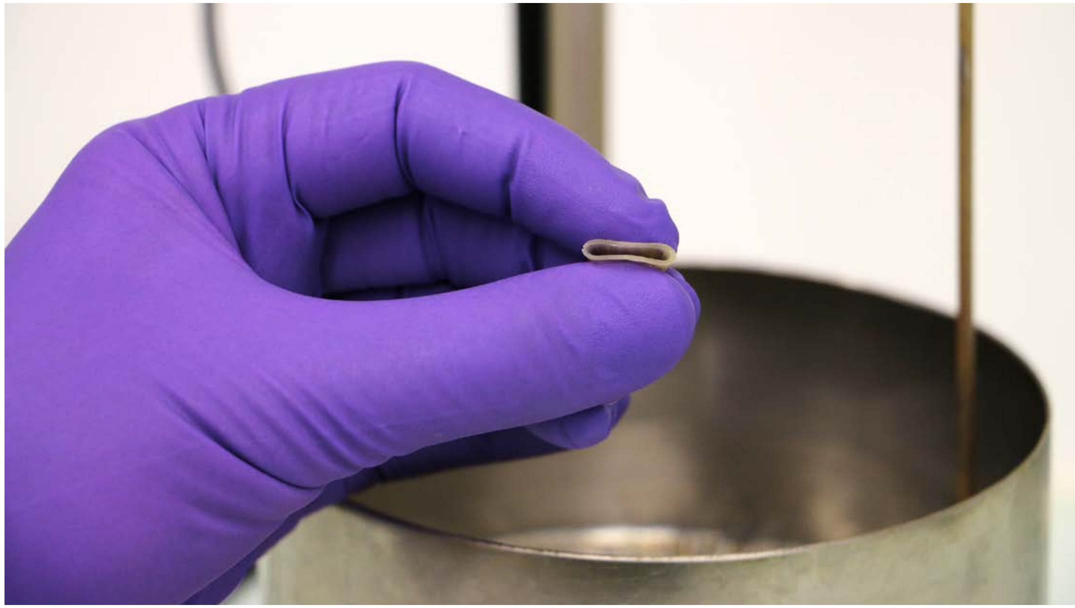
**SPIRIT**

A research collaboration between the Adolphe Merkle Institute and Thailand's Chulalongkorn University was awarded special funding from the Swiss National Science Foundation in 2021 as part of the agency's new SPIRIT program. The project participants are investigating new types of bio-inspired polymer membranes with directional and/or switchable water transport characteristics, developing a fundamental understanding of the structure-property relationships of these systems, and creating the scientific knowledge that may serve as basis for the future development of advanced membrane technologies. The project builds on research carried out previously at both institutions. Prof. Christoph Weder's Polymer Chemistry & Materials group and those of his colleagues Profs. Hathaikarn Manuspiya and Stephan Dubas is focusing both on the development of nonporous membranes, whose characteristics will be optimized for smart packaging applications, and of porous membranes, whose properties will be tailored for use in oil/water separations. The collaboration emerges from a long-standing partnership between AMI and the Petroleum and Petrochemical College at Chulalongkorn University, where Weder has served as a visiting Professor since 2003, co-advised more than a dozen MS and PhD researchers, and collaborated with several faculty members, including Manuspiya and Dubas. The AMI also regularly hosts visiting MS and PhD students from the College and recruited several PhD students and postdoctoral researchers from the program.

> "Not being able to take the lead in large European research cooperations takes away our ability to define new programs aligned with our research priorities."
> *Prof. Christoph Weder,*
> *Polymer Chemistry and Materials*

The SPIRIT program aims to facilitate knowledge exchange between Swiss researchers and colleagues in selected countries. Funding is awarded to projects with clearly defined goals that are submitted by research consortia from two to four countries. The grants contribute to the education of researchers in all participating countries, and supports the new membrane research with a total of CHF 500,000 over four years.

# Intellectual property
## _ Sharing the outcomes of AMI research



Shape-memory polymers have been developed at AMI in collaboration with industrial partners

**The valorization of research results is one of the Adolphe Merkle Institute's key missions, notably by actively promoting technology transfer and through a culture of open innovation with partners. AMI's research strategy is based on the philosophy of exploiting synergies that arise through the dual role of "early-stage research", which allows scientists to advance fundamental science and generate knowledge that is of value to industrial partners.**

AMI's four research groups – BioNanomaterials (Profs. Fink/Rothen-Rutishauser), BioPhysics (Prof. Mayer), Polymer Chemistry and Materials (Prof. Weder), and Soft Matter Physics (Prof. Steiner) – all contribute to the development of novel materials-based innovations by collaborating with implementation partners along the value chain. The professional support offered by AMI's technology transfer office also guarantees a clear and efficient execution of collaboration schemes. The application of AMI's research outcomes and exploiting the knowledge of AMI researchers to advance new technologies, takes multiple forms. While creating startups such as NanoLockin is just one obvious possibility, industrial partnerships are another possibility to valorize the Institute's research. AMI partners include established companies such as Covestro, Sonova, Pirelli, Oxford Nanopore, as well as start-ups such as NanoCleanAir and SimpliNext, but also institutional partners such as Zurich's cantonal archive.

Usually companies interested in collaborating contact our professors," explains Dr. Valeria Mozzetti, AMI's Head of Technology Transfer and Innovation. "They have become aware of our research either through our publications, or presentations at conferences."

Publishing scientific results and securing intellectual property (IP) are not considered contradictory at AMI, and its researchers are well aware of the value of IP. Together with its cooperation partners, the Institute undertakes all necessary efforts to guarantee adequate protection of its research results. AMI's strategy is first and foremost to maximize collaborations, and not profits. This aligns it with the best practices of professional technology transfer between academia and industry. These collaborations also benefit the Institute in other ways, such as translating research into marketable technology, getting feedback from companies, or generating new ideas says Mozzetti.

Collaborations with industry are supported by various mechanisms. The most direct approach is a bilateral interaction, in which an industrial partner funds an application-oriented project that is of mutual interest. In exchange for the financial support, the partner company usually receives the rights to commercially exploit any IP generated in the project in their field of use, while AMI retains any other IP rights, while exclusive rights for the company can be negotiated on a case-by-case basis.

"These collaborations also benefit the Institute in other ways, such as translating research into marketable technology, getting feedback from companies, or generating new ideas."
*Dr. Valeria Mozzetti, AMI Head of Technology Transfer and Innovation*

Publicly-private funded research and development projects are also possible, whereby a funding organization such as Swiss Innovation Agency Innosuisse pays AMI to help industry partners enhance existing products or create new ones. These projects require the company to guarantee its collaboration, through a cash and an in-kind contribution. In this case, IP rights are attributed according to the rules of the funding organization, for example in the case of Innosuisse projects at least a non-exclusive license to the IP created inside a company's field of use.

Further forms of collaboration include joint research teams, in which mixed teams of researchers from AMI and companies work together on strategic long-term collaborations. The funding and collaboration framework are then negotiated by the partners.

Finally, AMI also takes on short-term research mandates. These are often first feasibility studies for a company to explore a new concept or to provide test results for materials of interest, such as analyses carried out by AMI's Swiss NanoAnalytics platform. Such mandates are possible as long as the project is in field of AMI research competences and interests and could potentially lead to future research collaborations.

Potential applications of AMI research:

- Adhesives
- Automotive parts
- Biomedical implants
- Dental materials
- Drug development & testing
- Magnetic resonance imaging
- Mechanically adaptive materials
- Flavor and fragrances
- Mechanical stress sensors
- Nanocomposites
- Product security
- Packaging materials
- Rapid prototyping
- Solar cells

# Careers

## — AMI alumni paths lead in different directions

Prof. Johan Foster left AMI in 2014

**Prof. Johan Foster**

Johan Foster was a group leader in Prof. Christoph Weder's Polymer Chemistry and Materials group between 2010 and 2014. He then joined Virginia Tech (USA) as an Associate Professor in Materials Science and Engineering, from where he was recruited away by the University of British Columbia (Canada) in 2020. Foster now holds the Canfor/NSERC Industrial Research Chair in Advanced Bioproducts in the Department of Chemical and Biological Engineering at the Faculty of Applied Science. He has co-authored over 120 original research papers, and holds three patents. His research focuses on the design, synthesis and engineering of bio-inspired functional polymers and nanocomposites, often using nanocellulose as a starting material. Novel bio-derived materials developed through his research are finding use in a wide range of commercially relevant products, from cement to electrical boards, through to implantable materials and smart applications.

**Dr. Sandra Camarero Espinosa**

Sandra Camarero Espinosa joined AMI in 2011 as a PhD student in the Polymer Chemistry and Materials group, where she initiated research on new scaffolds for tissue regeneration. After completing her thesis in 2015, Sandra headed to the University of Queensland (Australia) as a Swiss National Science Foundation (SNSF) Mobility Fellow to pursue postdoctoral work on stem cells and signaling pathways. In 2017 she joined the MERLN Institute for Technology-Inspired Regenerative Medicine at Maastricht University (the Netherlands) to further her knowledge of biofabrication techniques and supervise PhD and Masters' students. Since 2020, Camarero Espinosa has her own laboratory at the University of the Basque Country's POLYMAT research center in her native Spain. Her research focuses on the regeneration of complex tissues, notably the bioinspired design of hierarchical bio(nano)materials whose physicochemical properties can be tuned, and their effect on cell phenotype and matrix deposition. Her work has been recognized by a number of prestigious fellowships, including a Marie Skłodowska-Curie Actions Fellowship, an Ikerbasque Research Fellowship, and more recently a La Caixa Foundation grant to investigate a new method to treat the imbalanced environment of an osteoarthritic knee.

Dr. Sandra Camarero Espinosa has run her own laboratory since 2020

Dr. Daniel Hauser has made the move from academia to industry

**Dr. Daniel Hauser**

After graduating from the University of Bern with a Masters' degree in molecular life sciences, Daniel Hauser joined the AMI BioNanomaterials group (Profs. Alke Fink and Barbara Rothen-Rutishauser) in 2015 as a PhD student, funded by the Swiss National Science Foundation as part of the National Center of Competence in Bio-Inspired Materials. He completed his doctoral studies focused on the synthesis and applications of polydopamine / protein nanoparticles. Awarded a mobility grant from the SNSF, he then took up a postdoctoral position at University College London (UK), where he designed and executed experiments in the fields of bionanomedicine and oncology. Early in 2021, Hauser switched from academia to industry, taking up a position at Bühlmann Laboratories near Basel as a development scientist, working on *in vitro* diagnostics. This includes creating, designing, and executing experiments, as well as analyzing project data. He also leads these projects by defining timelines and strategies to overcome potential hurdles.

**Dr. Jared Houghtaling**

Jared Houghtaling joined the Institute in 2016 from the University of Michigan, where he was already working towards his PhD under the supervision of Prof. Michael Mayer. Following his supervisor, who joined AMI as new Chair of BioPhysics, Houghtaling took his project focused on nanopore-based protein analysis to Fribourg. He successfully defended his thesis, awarded by the University of Michigan, on "Label-free Characterization of Single Proteins Using Synthetic Nanopores" in 2019. He then took up a postdoctoral position funded by the Belgian American Educational Foundation at KU Leuven, one of Belgium's leading universities, where he worked on software development for applications in acoustic-based medical diagnostics. In 2020, Houghtaling joined the Belgian company edenceHealth as a data scientist, where he facilitates data harmonization projects to create clinically-relevant technologies for physicians and researchers. His work includes standardizing and extracting insights from data gathered from millions of patients across Europe. Jared has not completely abandoned academia as he has recently taken up a part-time research position at KU Leuven where he analyzes and extracts features from acoustic recordings collected during music performances.

Dr. Jared Houghtaling's interests span both industry and academia

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## ACTIVE RESEARCH PROJECTS

IN FIELDS SUCH AS BIO-INSPIRED MATERIALS, PEROVSKITE SOLAR CELLS, PHOTONIC STRUCTURAL MATERIALS, MECHANOCHEMISTRY, SUPRAMOLECULAR POLYMERS, DETECTION AND CHARACTERIZATION OF NANOPARTICLES, NANOPORE FABRICATION, SINGLE-MOLECULE DETECTION.

# CHF 10.1 M

## SPENT IN 2021

RESEARCH EXPENDITURES AMOUNTED TO ALMOST CHF 9 MILLION.

# 40%

## OF STAFF AT AMI ARE WOMEN

# 18

## SEMINARS

GIVEN BY EXTERNAL RESEARCHERS, AND AMI STUDENTS (12 ONLINE OR HYBRID).

# 106

## PEOPLE

WORKED IN 2021 AT AMI INCLUDING PHD STUDENTS, POSTDOCTORAL RESEARCHERS, PROFESSORS, SUPPORT STAFF, AND INTERNS.

# 60%

## OF THE AMI RESEARCHERS

ARE DOCTORAL STUDENTS.

# In memoriam

## _ Remembering young scientists

Marco Mareliati

Livia Bast

**In 2021, AMI mourned the loss of PhD students Marco Mareliati and Livia Bast, who died in separate, tragic accidents shortly before the completion of their thesis.**

Marco Mareliati earned a Bachelor's degree in Chemistry and a Master's Degree in Advanced Chemical Methodologies from the University of Turin in Italy, before he joined AMI's Polymer Chemistry and Materials group in 2017 as a PhD student. Under the supervision of Prof. Christoph Weder and Dr. Stephen Schrettl, and in collaboration with researchers from tiremaker Pirelli S.p.A., Marco investigated new approaches towards adaptive rubbers that contain metal-ligand complexes. These non-covalent bonds become dynamic at high temperature and under large forces and can act as reversible cross-links. Marco demonstrated that this design approach allows creating elastic materials in which the complexes act under high-stress conditions as sacrificial bonds and dissipate energy. His findings may pave the way to future generations of advanced tire materials. Marco lost his life on January 31, 2021 in an avalanche while snowboarding.

Livia Bast joined Prof. Nico Bruns' Macromolecular Chemistry group in 2016, beginning her PhD as one of the nine early-stage researchers of the EU-funded Innovative Training Network Plant-Inspired Materials and Surfaces (PlaMatSu). Livia had previously obtained her Master's degree in Chemistry from the Technische Universität Dortmund in Germany, where she studied polymer-antibiotic conjugates. At AMI, Livia worked on cuticle-mimetic polymeric materials that contain proteins as functional building blocks. With collaborators in Finland, she developed an infiltration method of silk proteins into cellulose nanocrystal structures. Together with researchers in Thailand, she explored new polymer-conjugates, and with an industrial partner of PlaMatSu, a protein-based surface coating for lubrication applications was developed. Livia passed away on July 10, 2021 in an accident on a mountain hike.

Livia and Marco are deeply missed and fondly remembered by their AMI family. To honor their achievements and keep their legacies alive, procedures for the award of posthumous PhD degrees are underway.


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# _Research at AMI

# Carbon capture

## _ Breathing new life into monitoring devices

**Metabolic waste could in the future power wearable or implantable electronics. The AMI BioPhysics group has developed a prototype device that is fueled by carbon dioxide from a person's breath and can provide enough energy to power a light-emitting diode.**

Wearable and implantable technologies are redefining how we exchange information, receive entertainment, and monitor health and fitness. Although traditional batteries can be used to power these electronics, their limited lifetime and lack of biocompatibility are not ideal for powering devices that interface with the human body. The ongoing integration of this technology into living organisms thus requires new power sources and countless implantable devices such as heart pacemakers, sensors, drug delivery pumps, or prosthetics would benefit from self-charging power systems. The possibility to generate electricity inside the body would eliminate the need for replacement surgery, however minor, and could also provide sustained power for wearable devices such as electrically active contact lenses with an integrated display.

Biomedical devices that harvest energy from human metabolites are already under development, for example in the form of implantable chips that can monitor diabetes patients' blood sugar levels by oxidizing glucose. Another approach for monitoring is to explore novel power sources that can be fueled by the activity of the wearer. Without needing to be "plugged in", these sources could integrate seamlessly into daily life.

The AMI researchers investigated the development of a sustainable process to recharge a bio-inspired battery, using carbon dioxide ($CO_2$) from a person's breath. To demonstrate this concept, the researchers developed a prototype device based upon reverse electrodialysis. This method is already used to harvest energy from waters having different salt concentration, such as seawater and freshwater, and exploits the ion gradient between them. The AMI researchers exploited that such ion gradients can also be generated by dissolving $CO_2$ in water and demonstrated that the electrical power that can be generated is sufficient to drive small electronic devices, such as a light-emitting diode.

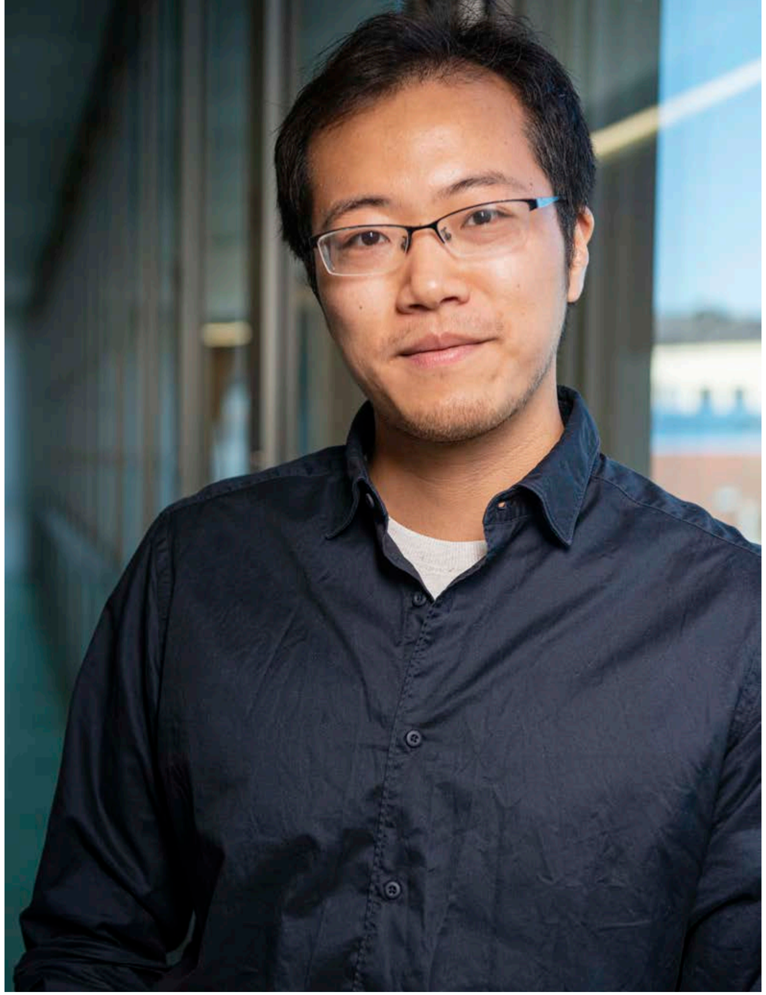
"This work is about using a metabolic waste product in conjunction with ion-gradient-based power generation to develop a wearable or implantable power source that could potentially be recharged indefinitely," explains the AMI BioPhysics chair Prof. Michael Mayer. "This is one more step towards having a battery that never needs to be plugged in, recharging passively, relying on ion transport rather than on chemical reactions to make it happen."

The research should benefit another of the group's ongoing projects funded by the European Union's Pathfinder program called INTEGRATE, which aims to build and power artificial muscles. "The ability to convert metabolic energy for powering artificial muscles would be another step towards the enhanced integration of prostheses into the human body" says Alessandro Ianiro, a group leader in the BioPhysics group, who heads the INTEGRATE project.

The AMI researchers were originally inspired by the electric eel, before pivoting to the electric organ of the torpedo ray. To create their devices, they developed a hybrid material by infusing paper with an ion-conducting hydrogel. This allowed them to create, organize, and reconfigure stacks of thin, arbitrarily large gel films with differences in salt concentration. Their project demonstrated that the biological mechanism of generating significant electrical power is possible with benign and soft materials in a portable size. The next challenge is to improve the longevity and robustness of these "body batteries".

### Reference

Kalkus, T. J.; Guha, A.; Scholten, P. B. V.; Nagornii, D.; Coskun, A.; Ianiro, A.; Mayer, M. The Green Lean Amine Machine: Harvesting Electric Power While Capturing Carbon Dioxide from Breath. *Advanced Science*, **2021**, 2100995.



Shuran Xu joined AMI in 2017 as a PhD student, after completing his Master's degree in applied bioinformatics at Cranfield University in the United Kingdom. He is currently developing hydrodynamic simulations as well as investigating solid-state nanopores.

## BioPhysics

### Team

Prof. Michael Mayer, Dr. Saurabh Awasthi, Dr. Louise Bryan, Jessica Dupasquier, Dr. Anirvan (Gogol) Guha, Stéphane Hess, Dr. Alessandro Ianiro, Trevor Kalkus, Edona Karakaci, Dr. Vandana Kushwaha, Yuanjie Li, Dr. Peng Liu, Dr. Tianji Ma, Dr. Jonas Pollard (Macromolecular Chemistry), Dr. Samuel Raccio (Macromolecular Chemistry), Marian Reincke, Dr. Christian Sproncken, Dr. Maria Taskova, Anna Wald, Wachara Chanakul, Shuran Xu, Dr. Cuifeng Ying.

### Key Publications


1. Guha, A.; Kalkus, T. J.; Schroeder, T. B. H.; Willis, O. G.; Rader, C.; Ianiro, A.; Mayer, M. Powering Electronic Devices from Salt Gradients in AA-Battery-Sized Stacks of Hydrogel-Infused Paper. *Advanced Materials* **2021**, 33 (31), 2101757.

2. Alfaro, J. A.; Bohländer, P.; Dai, M.; Filius, M.; Howard, C. J.; van Kooten, X. F.; Ohayon, S.; Pomorski, A.; Schmid, S.; Aksimentiev, A.; Anslyn, E. V.; Bedran, G.; Cao, C.; Chinappi, M.; Coyaud, E.; Dekker, C.; Dittmar, G.; Drachman, N.; Eelkema, R.; Goodlett, D.; Hentz, S.; Kalathiya, U.; Kelleher, N. L.; Kelly, R. T.; Kelman, Z.; Kim, S. H.; Kuster, B.; Rodriguez-Larrea, D.; Lindsay, S.; Maglia, G.; Marcotte, E. M.; Marino, J. P.; Masselon, C.; Mayer, M.; Samaras, P.; Sarthak, K.; Sepiashvili, L.; Stein, D.; Wanunu, M.; Wilhelm, M.; Yin, P.; Meller, A.; Joo, C. The Emerging Landscape of Single-Molecule Protein Sequencing Technologies. *Nat Methods* **2021**, 18 (6), 604–617.

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

4. Guha, A.; McGuire, M. L.; Leriche, G.; Yang, J.; Mayer, M. A Single-Liposome Assay That Enables Temperature-Dependent Measurement of Proton Permeability of Extremophile-Inspired Lipid Membranes. *Biochimica et Biophysica Acta (BBA) – Biomembranes* **2021**, 1863 (4), 183567.

# Analysis

## _ Not as simple as making a cup of tea

**Figuring out how much plastic is possibly released from a teabag into a cup of tea is, as the AMI BioNanomaterials group has shown, far from simple, and requires advanced analytical methods.**

Research into the detection of plastic particles, especially in the micro-, sub-micro-, and nano-size ranges, in food and beverages has been gaining traction in the scientific community. The recent surge in interest has on the one hand been motivated by the fact that the growing use of plastic materials promotes their widespread accumulation in the environment, where they degrade, are taken up by plants and animals, and via the food chain transfer to humans. But since most drinks and food products are sold in plastic packaging, there is also the question if and how much of that plastic finds its way into our meals and potentially impacts our health.

While research has shown that larger microplastic particles can been detected in food and beverages such as bottled water, confirming, and quantifying the presence of small nanoplastic contaminants is more challenging. Studies of these particles in complex environments, which contain large amounts of other organic or inorganic matter, are plagued by a number of issues. These are related to nanoplastics' mostly carbon structures, low densities, size, and generally low estimates of their concentrations in samples.

This has not prevented AMI researchers from attempting to tackle the problem, choosing teabags, and investigating just how many plastic particles leach out while steeping a cup. Researchers at other institutions had previously attempted to answer this question, but their results suggest that the application of known analytical methods and the interpretation of the data that they afford is not necessarily straightforward.

"For example, other researchers have used a method called Fourier transform infrared spectroscopy to detect plastic particles leached from teabags, but this method cannot be used to directly assess individual particles, but only yields an average composition of an up-concentrated sample" explains PhD student Jessica Caldwell. "Using electron microscopy to distinguish between nanoplastics and other organic materials can also be fraught with difficulty." One key problem is to differentiate between plastic particles and other organic matter, for example the ingredients extracted from the tea itself, tea leaf-based particulate matter, or dust.

To overcome these limitations, tests were carried out at the behest of Switzerland's Federal Food Safety and Veterinary Office. The AMI researchers conducting these analyses say that greater care must be given to sample preparation and data interpretation to ensure accurate results. One approach that they investigated involved purifying samples by applying chemical digestion protocols that were designed to remove non-plastic compounds from the samples. Yet, despite using potassium hydroxide and hydrogen dioxide, both known for their capacity to eliminate organic matter, signs of the latter could still be observed in the samples assessed by the AMI researchers. Further testing on empty control teabags also indicated that such chemical purification steps may also degrade the plastic particles that should be observed.

To circumvent this problem, the BioNanomaterials group researchers have proposed that future studies should investigate the possibility of using enzymes for the purification step. These bio-catalysts can be expected to digest exclusively bio-based organic matter and avoid plastic degradation. "We want to establish protocols for this type of analysis and establish our expertise in this field, as part of our wider research on plastic particles in complex environments", explains Prof. Alke Fink. Alongside this, more sensitive analytical techniques such as surface-enhanced Raman spectroscopy could provide the finesse required to analyze samples at the single-particle or single-material basis.


### References

Caldwell, J.; Taladriz-Blanco, P.; Rothen-Rutishauser, B.; Petri-Fink, A. Additional Commentary on the Detection and Quantification of Plastic Micro- and Nanoparticles in Tea Samples. *CHIMIA* **2021**, 75 (10), 882–882

Caldwell, J.; Taladriz-Blanco, P.; Rothen-Rutishauser, B.; Petri-Fink, A. Detection of Sub-Micro- and Nanoplastic Particles on Gold Nanoparticle-Based Substrates through Surface-Enhanced Raman Scattering (SERS) Spectroscopy. *Nanomaterials* **2021**, 11 (5), 1149.

Jessica Caldwell first joined AMI as a Master's student in 2017 from Indiana University-Purdue University Columbus in the United States, finishing her degree in 2019. Since 2020, she has been a PhD student in the BioNanomaterials group, where she investigates the preparation, detection, and characterization of micro- and nanoplastics.

# BioNanomaterials

## Team

Prof. Alke Fink, Prof. Barbara Rothen-Rutishauser, Liliane Ackermann, Mauro Sousa de Almeida, Dr. Sandor Balog, Dr. Anne Bannuscher, Dr. Amélie Bazzoni, Nils Berger, Jessica Caldwell, Shui Ling Chu, Irini Dijkhoff, Dr. Barbara Drasler, Manuela Estermann, Bihter Geers, Dr. Christoph Geers, Christina Glaubitz, Gowsinth Gunasingam, Laetitia Haeni, Dr. Ruiwen He, Dr. Begum Bedia Karakocak, Daria Korejwo, Aaron Lee, Henry Lee, Dr. Roman Lehner,Dr. Céline Loussert, Andriy Lubskyy (Macromolecular Chemistry), Sergio Mingo, Aura Maria Moreno Echeverri, Dr. Roberto Ortuso, Dr. Michela Pellizzoni (Macromolecular Chemistry), Benedetta Petracca, Alain Rohrbasser, Dr. Fabienne Schwab, Dr. Dedy Septiadi, Giovanni Spiaggia, Lukas Steinmetz, Eva Susnik, Dr. Patricia Taladriz, Dr. Dimitri Vanhecke, Phattadon Yajan.

## Key Publications


1. Rüggeberg, T.; Milosevic, A.; Specht, P.; Mayer, A.; Frey, J.; Petri-Fink, A.; Burtscher, H.; Rothen-Rutishauser, B. A Versatile Filter Test System to Assess Removal Efficiency for Viruses in Aerosols. *Aerosol Air Qual. Res.* **2021**, 21 (12), 210224.

2. Buitrago, E.; Novello, A. M.; Fink, A.; Riediker, M.; Rothen-Rutishauser, B.; Meyer, T. NanoSafe III: A User Friendly Safety Management System for Nanomaterials in Laboratories and Small Facilities. *Nanomaterials* **2021**, 11 (10), 2768.

3. Lee, A.; Septiadi, D.; Taladriz-Blanco, P.; Almeida, M.; Haeni, L.; Spuch-Calvar, M.; Abdussalam, W.; Rothen-Rutishauser, B.; Petri-Fink, A. Particle Stiffness and Surface Topography Determine Macrophage-Mediated Removal of Surface Adsorbed Particles. *Advanced Healthcare Materials* **2021**, 10 (6), 2001667.

4. Bas, A.; Burns, N.; Gulotta, A.; Junker, J.; Drasler, B.; Lehner, R.; Aicher, L.; Constant, S.; Petri-Fink, A.; Rothen-Rutishauser, B. Understanding the Development, Standardization, and Validation Process of Alternative In Vitro Test Methods for Regulatory Approval from a Researcher Perspective. *Small* **2021**, 17 (15), 2006027.

# Fixing things

## _ Watching polymers heal

**Researchers from AMI's Polymer Chemistry and Materials group have developed a method to monitor the healing process of polymers. They discovered that a much thicker interphase is required for these materials to recover their original mechanical properties than previously thought.**

Self-healing or healable polymers can recuperate their function after sustaining physical damage. Such materials have many interesting applications, including automotive paints, display covers, and varnishes for floors or furniture. As such, this class of materials has attracted considerable interest and first systems are transitioning from research labs into technological applications.

The healing of damaged polymers is often possible by heating them just above the melting temperature, so that separated interfaces can weld together. The process itself is quite complex and involves multiple effects that occur at different length scales. On the macroscopic and microscopic levels, the surfaces need to rearrange, approach each other, and wet. On a nanometer scale, individual polymer molecules must move across the severed interfaces and re-mix, until the original structure and properties of the material are restored. The fundamental importance of the processes occurring on the nanoscale has long been recognized, but monitoring them proved to be extremely challenging. A team of AMI researchers led by Professor Christoph Weder and Dr. Stephen Schrettl has shown that is possible to precisely track the healing process while it happens. In a collaborative effort involving researchers at EPF Lausanne, ETH Zurich, and Martin Luther University Halle-Wittenberg, Germany, the team succeeded in imaging the movement of molecules across the healed interface and was able to correlate this process with the recovery of the material's mechanical properties. As it turns out, a much wider interface than previously assumed is required for complete healing to occur, at least in the particular materials studied.

The team carried out their studies with a pair of virtually identical supramolecular polymers. Unlike conventional polymers, which consist of long chain-molecules that are formed through irreversible chemical bonds between monomeric building blocks, supramolecular polymers are comprised of chain-like assemblies in which the monomers are connected through weak, reversible interactions. The healing of such materials is greatly accelerated, because the supramolecular assemblies disassemble into smaller molecules when the material is heated or irradiated with ultraviolet light. When the healing process is complete, the material automatically reassembles.

The two supramolecular polymers used by the AMI researchers were based on the same building blocks, which were however assembled with the help of two different metal ion complexes. The two materials exhibit very similar properties, but the two metal ions can be distinguished. "The possibility to heal interfaces between two practically identical, yet easily distinguishable polymers allowed us to study the healing process by monitoring the positions of the metal ions with high spatial resolution using fluorescence imaging and X-ray spectrum imaging, while the movement of the different blocks is identical and unaffected by the nature of the metals," says AMI alum Dr. Laura Neumann.

The researchers discovered that the original properties are only restored after the thickness of the healed interphase exceeds 100 nanometers. This value is about ten times higher than previously reported for conventional glassy polymers. The findings suggest that relatively straightforward microscopic techniques should be suitable to uncover previously unobservable aspects of the healing process in a wide range of materials, guiding the design of new polymers with improved healing characteristics.

With the objective to move healable polymers closer to application, PhD student Franziska Marx is currently investigating how the findings can be used to modify commercially used materials in order to render them healable. "Our goal is to develop a readily scalable approach to create materials that offer a combination of efficient healing at elevated temperature and mechanical characteristics at normal usage temperature that are comparable to those of currently used polymers" says Marx.

### Reference

Neumann, L. N.; Oveisi, E.; Petzold, A.; Style, R.; Thurn-Albrecht, T.; Weder, C.; Schrettl, S.; Dynamics and Healing Behavior of Metallosupramolecular Polymers; *Science Advances* **2021**, 7 (18), eabe4154.

Franziska Marx joined AMI's Polymer Chemistry and Materials group in 2019, after completing her Master's degree at the Albert-Ludwigs-Universität in Freiburg (Germany). Her research on stimuli-responsive, healable supramolecular polymers is funded through the NCCR Bio-Inspired Materials.

# Polymers

## Team

Prof. Christoph Weder, Malte Beccard, Dr. José Berrocal, Véronique Buclin, Claudio Cappelletti, Estelle Cariou, Dr. Jessica Clough, Gwendoline Delepierre, Dr. Andrea Dordero, Dr. Visuta (Kan) Engkakul, Marianne Fauvin, Stefan Frech, Luca Grillo, Dr. James Hemmer, Xueqian Hu, Dr. Sètuhn Jimaja, Patricia Johnson, Aris Kamtsikakis, Derek Kiebala, Davide Lardani, Youwiei Ma, Chaninya Mak-lad, Marco Mareliati, Franziska Marx, Baptiste Monney, Dr. Guillaume Moriceau, Livius Muff, Ilaria Onori, Laura Perrin, Dr. Subhajit Pal, Chris Rader, Anita Roulin, Dr. Philip Scholten, Dr. Stephen Schrettl, Hanna Traeger, Sandra Wohlhauser.

## Key Publications


1. Hemmer, J.R.; Rader, C.; Wilts, B.D.; Weder, C.; Berrocal, J.A.; Heterolytic Bond Cleavage in a Scissile Triarylmethane Mechanophore; *J. Am. Chem. Soc.* **2021**, 143 (45), 18859–18863.

2. Traeger, H.; Kiebala, J.; Schrettl, S.; Weder, C.; Folded Perylene Diimide Loops as Mechanoresponsive Motifs; *Angew. Chem. Int. Ed.* **2021**, 60 (29), 16191–16199

3. Sagara, Y.; Traeger, H.; Jie, L.; Okado, Y.; Schrettl, S.; Tamaoki, N.; Weder, C.; Mechanically Responsive Luminescent Polymers Based on Supramolecular Cyclophane Mechanophores; *J. Am. Chem. Soc.* **2021**, 143 (18), 5519–5525.

4. Delepierre, G.; Traeger, H.; Adamcik, J.; Cranston E.D.; Weder, C.; Zoppe, J.O.; Liquid Crystalline Properties of Symmetric and Asymmetric End-grafted Cellulose Nanocrystals; *Biomacromolecules* **2021**, 22 (8), 3552–3564.

5. Kamtsikakis, A.; Baales, J.; Zeisler-Diehl, V.V, Vanhecke, D.; Zoppe, J.O.; Schreiber, L.; Weder, C.; Asymmetric water transport in olive cuticles and cuticle-inspired, compositionally graded membranes; *Nature Communications* **2021**, 12 (1), 1267.

# Confining light

## _ Understanding an exotic state of affairs

**Physicists at the Adolphe Merkle Institute are investigating new methods to trap light, in order to control it precisely. Their findings may be useful to develop nano-lasers, sensors, and integrated circuits.**

The researchers from the Soft Matter Physics group are focusing on bound states in the continuum (BICs), which are waves whose existence was first proposed in the context of quantum mechanics in the 1920s. However, only more recently physicists have begun to investigate these waves experimentally and to consider their potential applications more closely. In simple terms, BICs are waves that are completely trapped or confined in a medium. The partial trapping of waves is a common phenomenon that naturally leads to resonances. For example, resonant sound waves bounce back and forth within musical instruments until they eventually find an exit. The same effect is used in optical fibers or lasers, in which light waves are reflected many times before they leave the device. BICs take such confinement to another level. In a perfect BIC structure, the waves could never escape, bouncing back and forth forever. This situation is in a way similar to an electron (which can be thought of as a quantum-mechanical wave) bound to a molecule. The bound electron, however, lacks the necessary energy to take flight, while BICs remain perfectly localized even though they have sufficient energy to "break out". This behavior defies conventional wisdom and makes BICs extremely interesting from both a fundamental and an application perspective.

BICs have been studied in a wide variety of systems that are able to confine waves for very long periods. These include photonic crystals, optical fibers, quantum dots, and graphene. What is important is just how long, even if the trapping time is measured in nanoseconds! Nevertheless, this means that the wave bounces back and forth inside the material a million times before escaping, leading to a large number of potential applications, including coherent light generation, sensing, filtering, and integrated circuits.

The AMI researchers are investigating BICs in photonic structures based on metallic metamaterials. These materials are engineered to display unusual optical properties that are not found in nature. Theoretical evidence suggests that these innovative BICs can trap light more efficiently than previous designs. The metamaterials envisaged by the AMI researchers consist of two intertwined, spatially separated metallic networks, such that each network acts like an electromagnetic plasma – something like a soup of charged particles. Charge oscillations in the two plasmas lead to waves with vanishing macroscopic electric fields and perfect confinement.

According to Plasmonic Networx group leader Dr. Matthias Saba, these double-net BICs therefore eliminate the need for an engineered solution and show an improved stability against experimental imperfections or other natural fluctuations when compared to existing designs. "This is exactly what you would want for example when designing a lasing cavity for a nano-laser," Saba explains "We generally want to use BICs to boost and study quantum emission inside metamaterials." This involves placing fluorescent molecules or quantum dots into the metamaterial. According to Saba, exciting fluorescent species normally leads to the emission of incoherent light. If created within a BIC metamaterial, however, the waves would be highly uniform. They would all have the same frequency, and move in a preferred direction, with a particular polarization profile. Polarization coherence is important in that polarization itself contains information that is used for communication, molecule sensing, or even astrophysics.

The scientists have so far developed a theory for microwave frequencies, which they are preparing to test in detail with an experimental setup. "For other applications, such as nano-lasers, we would have to progress to much higher frequencies," explains Saba. "The challenge now is to demonstrate that our double-net BICs still exist at these higher frequencies, and fabricate the associated metamaterials. We know that our theory can be employed for terahertz applications and have preliminary results, which indicate that infrared frequencies used for telecommunications are feasible."

### Reference

Wang, W.; Günzler, A.; Wilts, B. D.; Saba, M. Unconventional Bound States in the Continuum from Metamaterial Induced Electron-Acoustic Plasma Waves. *arXiv* **2022**, 2112.13711

Matthias Saba earned his PhD from the University of Erlangen-Nuremberg in Germany, followed up with a postdoctoral stay at Imperial College London. He joined AMI's Soft Matter Physics group, where he is a group leader, in 2019, to investigate the fundamental nature of network-like metamaterials.

## Soft Matter Physics

### Team

Prof. Ullrich Steiner, Prof. Jovana Milic, Doha Abdelrahman, Narjes Abdollahi, Martino Airoldi, Viola Bauernfeind, Johannes Bergmann, Dr. Esteban Bermudez, Kenza Djegdhi, Parnian Ferdowsi, Dr. Reza Ghanbari, Antonio Guenzler, Dr. Ilja Gunkel, René Iseli, Dr. Cédric Kilchoer, Mirela Malekovic, Dr. Guillaume Moriceau, Tri Minh Nguyen, Dr. Efrain Ochoa, Andrea Palumbo, Alessandro Parisotto, Cristina Prado, Alexandre Redondo, Dr. Matthias Saba, Cédric Schumacher, Dr. Wenhui Wang, Dr. Bodo Wilts.

### Key Publications


1. Ochoa-Martinez, E.; Ochoa, M.; Ortuso, R. D.; Ferdowsi, P.; Carron, R.; Tiwari, A. N.; Steiner, U.; Saliba, M. Physical Passivation of Grain Boundaries and Defects in Perovskite Solar Cells by an Isolating Thin Polymer. *ACS Energy Lett.* **2021**, 6 (7), 2626–2634.

2. Bergmann, J. B.; Redondo, A.; Steiner, U.; Wilts, B. D.; Moatsou, D. Insect Antiadhesive Surfaces Using Electrosprayed Wrinkled Ethyl Cellulose Particles. *ACS Appl. Mater. Interfaces* **2021**, 13 (7), 9232–9238.

3. Günzler, A.; Bermúdez-Ureña, E.; Muscarella, L. A.; Ochoa, M.; Ochoa-Martínez, E.; Ehrler, B.; Saliba, M.; Steiner, U. Shaping Perovskites: In Situ Crystallization Mechanism of Rapid Thermally Annealed, Prepatterned Perovskite Films. *ACS Appl. Mater. Interfaces* **2021**, 13 (5), 6854–6863.

4. Malekovic, M.; Bermúdez-Ureña, E.; Steiner, U.; Wilts, B. D. Distributed Bragg Reflectors from Colloidal Trilayer Flake Solutions. APL *Photonics* **2021**, 6 (2), 026104.

5. Hua, X.; Eggeman, A. S.; Castillo-Martínez, E.; Robert, R.; Geddes, H. S.; Lu, Z.; Pickard, C. J.; Meng, W.; Wiaderek, K. M.; Pereira, N.; Amatucci, G. G.; Midgley, P. A.; Chapman, K. W.; Steiner, U.; Goodwin, A. L.; Grey, C. P. Revisiting Metal Fluorides as Lithium-Ion Battery Cathodes. *Nat. Mater.* **2021**, 20 (6), 841–850.

# In brief

## Celebrating women in science

To celebrate Women's Day 2021 and the 50th anniversary of women's right to vote in Switzerland, all 22 National Centers of Competence in Research across the country joined forces to publish a series of videos showcasing their women researchers. As part of the #NCCRWomen campaign, the videos, aimed at women and girls of school and undergraduate age, sought to showcase typical working days of female scientist to make these jobs more accessible. Each NCCR produced a week's worth of short films covering a variety of research fields on different social media channels. The NCCR Bio-Inspired Materials was featured in September, with five videos that included AMI's Prof. Barbara Rothen-Rutishauser, postdoctoral researcher Dr. Maria Taskova, and PhD student Hanna Traeger. The complete series of videos can be viewed on the special #NCCRWomen YouTube channel.

#NCCRWomen
Women in Swiss Research

## Lifetime award

### The Adolphe Merkle Institute's BioNanomaterials co-chair, Prof. Barbara Rothen-Rutishauser was honored with the International Society for Aerosols in Medicine (ISAM) 2021 Career Achievement Award.

This award is presented to a senior investigator whose body of work demonstrates a lifetime of outstanding achievement in aerosol science. Rothen-Rutishauser is a pioneer in the development of human 3D lung models. In combination with air-liquid cell exposure systems, these models are applied to assess effects of aerosolized drugs and nanomaterials. She has published over 300 peer-reviewed papers, and is an associate editor of the journal "Particle and Fibre Toxicology". Her work includes successful collaborations with implementation partners, ranging from regulatory bodies and federal agencies to industry partners. Rothen-Rutishauser is currently a member of the Swiss Federal Commission on Air Hygiene and an extraordinary member of Swissmedic's Human Medicines Expert Committee (HMEC). She has also served as an international expert for bodies such as the Organization for Economic Co-operation and Development, and the World Health Organization.

Rothen-Rutishauser has been an active ISAM member for many years. After receiving the society's Young Investigator Award in 2009, she served as a board member from 2011 to 2015 and chaired the organization's annual conference in Montreux, Switzerland, in 2019. Since May 2021, Rothen-Rutishauser serves as president of ISAM, a position she will hold for two years.

## New microscope

A new Leica Microsystems Stellaris 5 confocal microscope was added to the instrument platform at the Adolphe Merkle Institute.

Co-financed by the NCCR Bio-Inspired Materials and the University of Fribourg's Department of Chemistry, the instrument replaces an older system that was used for more than ten years and provided over 30,000 hours of usetime for our researchers and guests. Confocal microscopy is primarily used to study the localization and distribution of submicron-sized objects in three dimensions, for example polymer aggregates within a matrix, and four dimensions, such as nanoparticle uptake dynamics in human immune cells.

## Faculty recognition

Adolphe Merkle Institute alumni were among the University of Fribourg's Faculty of Science and Medicine 2021 prize winners.

Dr. Anirvan (Gogol) Guha was awarded the 2021 Vigener Prize, which was instituted in 1908 with a donation from Joseph Vigener and endowed with CHF 2,000. Each of the university's faculties can reward outstanding doctoral research. Guha, who carried out his doctoral research in AMI's BioPhysics group, successfully defended his PhD thesis on "Bio-Inspired Energy-Converting Materials" at the end of 2020. His work focused notably on the development of bio-inspired battery systems, focusing on the morphology of the Atlantic torpedo ray, the most powerful electric fish known.

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

## Travel grant

PhD Student Hanna Traeger of the Polymer Chemistry and Materials group was awarded a travel grant by the Platform Chemistry of the Swiss National Academy of Sciences and the Swiss Chemical Society. The grant provides funding to participate in an international conference. Traeger used the support to attend the 2022 spring meeting of the American Chemical Society in San Diego, California, and to present her work on "Loop structures as non-covalent mechanochromic motifs". She successfully defended her PhD thesis on "Exploiting Loop Structures as Non-covalent Mechanochromic Motifs" in spring 2022.

## Faculty appointment

Dr. Bodo Wilts, a group leader at the Adolphe Merkle Institute, was appointed as Professor of Materials Physics at the University of Salzburg, where he assumed his position in October 2021.

Wilts joined AMI's Soft Matter Physics group in 2014 and established a research program focused on the investigation of photonic structures in nature. In 2020 he was the first AMI researcher to complete a habilitation, an important step towards an independent academic position. While at AMI, Wilts received a Swiss National Science Foundation Ambizione fellowship, a prestigious and competitive grant that supports young researchers who wish to conduct, manage, and lead an independent project at a Swiss higher education institution.

## Explora

The Adolphe Merkle Institute team was out in strength in September for the University of Fribourg's Explora Open Day, which was held under the motto “Food for the brain”.

As part of this campus-wide outreach event, AMI researchers were on hand to present their research on bio-inspired nanotechnology and structural color in nature, or discuss nanofertilizers at the local organic market for example. They also cycled around the city with science experiments, and staffed the ever-popular graffiti tower.

## Nanomaterials safety

AMI BioNanomaterials co-chairs Professors Alke Fink and Barbara Rothen-Rutishauser and colleagues at the Federal Institute of Technology in Lausanne (EPFL) and the Swiss Centre for Occupational and Environmental Health (SCOEH), have updated their risk assessment tool for working with nanomaterials.

Engineered nanomaterials (ENMs) are becoming more widely used in research and industry, in sectors such as food technology, medicine, medical devices, composite materials, and textiles. As a result, more and more researchers and workers are exposed to ENMs in their workplace, and a comprehensive and easy-to-use tool for risk assessment is required for a safe handling of nanomaterials in laboratory settings.

After the first release of the classification tool in 2016, tests with collaborators revealed that some material classes were difficult to classify. New data was also considered to update the questions used for assessments. This third iteration of the risk assessment tool is aimed at closing the gap between current regulations and recent developments in nanomaterials.

## Government visit

In July, AMI hosted the general secretaries of the Swiss federal government's different ministries as part of their annual excursion, which took them to the canton of Fribourg. AMI Director Prof. Christoph Weder gave an overview of the Institutes' activities, followed by a tour of the laboratories. Over two days, these administrative leaders of the federal ministries also visited the Agroscope research center near Fribourg, as well as the Federal Institute of Technology in Lausanne (EPFL) and Geneva's Biotech Campus.

## Science slam

AMI's PhD students did particularly well in the 2021 University of Fribourg science slam in May. Alessandro Parisotto (Soft Matter Physics) took top honors with his talk on why he investigates weevils ("Why I study bugs"), while Trevor Kalkus (BioPhysics) rounded out the podium with his bioinspired slam ("A charged subject: ionic interactions for soft robotics and other bio-inspired applications"). Parisotto also participated in the university's 3-minute thesis French-language competition in April, and finishing third.

## Honorary speaker

In November, AMI hosted a conference by Prof. Susan Gasser, molecular biologist and former head of the Friedrich Miescher Institute for Biomedical Research in Basel, and the most recent recipient of a honorary doctoral degree of the University of Fribourg's Faculty of Science and Medicine. In her seminar, Gasser gave participants insights into viral invaders in human genomes, as well as gender equality in science. Gasser has received her honorary degree in recognition of her epigenetic research, as well as her pioneering work to increase the presence of women in Swiss research. She is the recipient of a number of important awards, including the national Latsis prize.


## Poster prizes

AMI's PhD students continued winning awards at conferences in 2021, highlighting AMI's research.

Derek Kiebala (Polymer Chemistry and Materials), was the winner of the Macromolecular Chemistry and Physics"award for the best ePoster presentation (Deformation Signaling in Polymeric Materials via Supramolecular Interactions") at the Bayreuth Polymer Symposium.

Jessica Caldwell of the BioNanomaterials group was the winner of the best poster prize ("Detection of Various Nanoplastics via Gold Nanoparticle-Based Surface-Enhanced Raman Spectroscopy Substrates") at the 2021 Confocal Raman Imaging Symposium.

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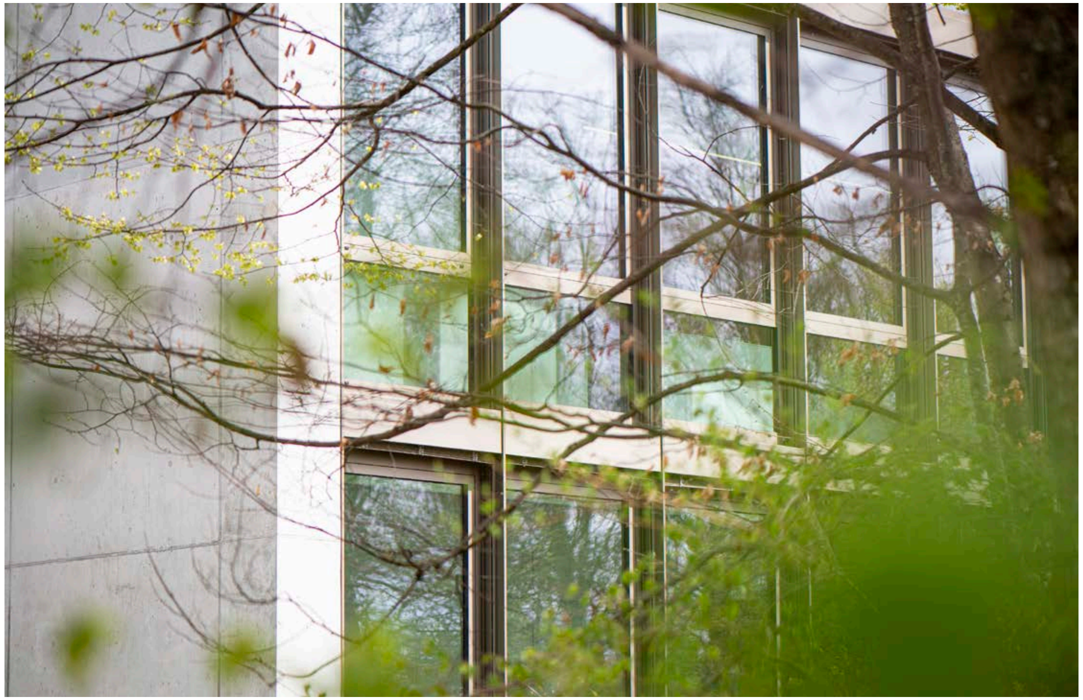
# Finance & Organization

# Finance

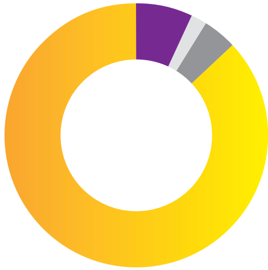
## _ Cost structure at AMI



The Adolphe Merkle Institute's overall expenditures in 2021 were CHF 10.1 million. 87% of this sum was spent on research, while an additional 4% was invested in research equipment. Around 2% of the budget supported valorization activities such as technology transfer, and communication and marketing, with another 7% used for administration costs.

## Overall expenses 2021

CHF 10.1 million



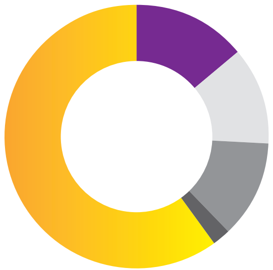
Research / 87%
Administration / 7%
Valorization / 2%
Research equipment / 4%

## Funding sources of overall expenses 2021

Adolphe Merkle Foundation / 33%
Grants / 49%
University of Fribourg / 10%
Industry / 8%

## Third-party funding 2021

CHF 5.8 million



SNSF / 60%
Industry / 14%
Innosuisse / 12%
EU / 12%
Other sources / 2%

# 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 chairs are members of this management body. 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**

***Peter Huber (President)***
Administrator, Sublevo AG, Kloten, Switzerland

***Jean-Pierre Siggen***
State Minister in charge of Education, Culture and Sport of canton Fribourg

***Chantal Robin***
Director, Fribourg Chamber of Commerce and Industry

***Prof. Rolf Mülhaupt***
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**

***Prof. Astrid Epiney (President)***
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 in the Department of Informatics, University of Fribourg

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

## Scientific Advisory Board

**Members**

***Dr. Alan D. English (President)***
Senior Research Fellow, DuPont Central Research and Development, USA

***Prof. Luisa De Cola***
Institute of Supramolecular Science and Engineering (ISIS), University of Strasbourg, France

***Prof. Giovanni Dietler***
Head Laboratory of Physics of Living Matter, EPFL, Switzerland

***Prof. Alex Dommann***
Head of Department "Materials meet Life", Empa, St. Gallen, Switzerland

***Prof. em. Heinrich Hofmann***
Former head of the Powder Technology Laboratory, EPFL, Switzerland

***Dr. Alexander Moscho***
Executive Vice President Chief Strategy Office, UCB

***Prof. Dieter Richter***
Head Institute of Solid State Research, Forschungszentrum Jülich, Germany

## Executive Board

***Prof. Christoph Weder***
Director and Chair of Polymer Chemistry & Materials

***Prof. Alke Fink***
Co-Chair of BioNanomaterials

***Prof. Michael Mayer***
Chair of Biophysics

***Prof. Barbara Rothen-Rutishauser***
Co-Chair of BioNanomaterials

***Prof. Ullrich Steiner***
Deputy Director and Chair of Soft Matter Physics

## Administration

***Scott Capper***
Responsible for Communications & Marketing

***Melissa Forney-Hostettler*** *(until April 2021)*
Secretary

***Carine Jungo***
Secretary

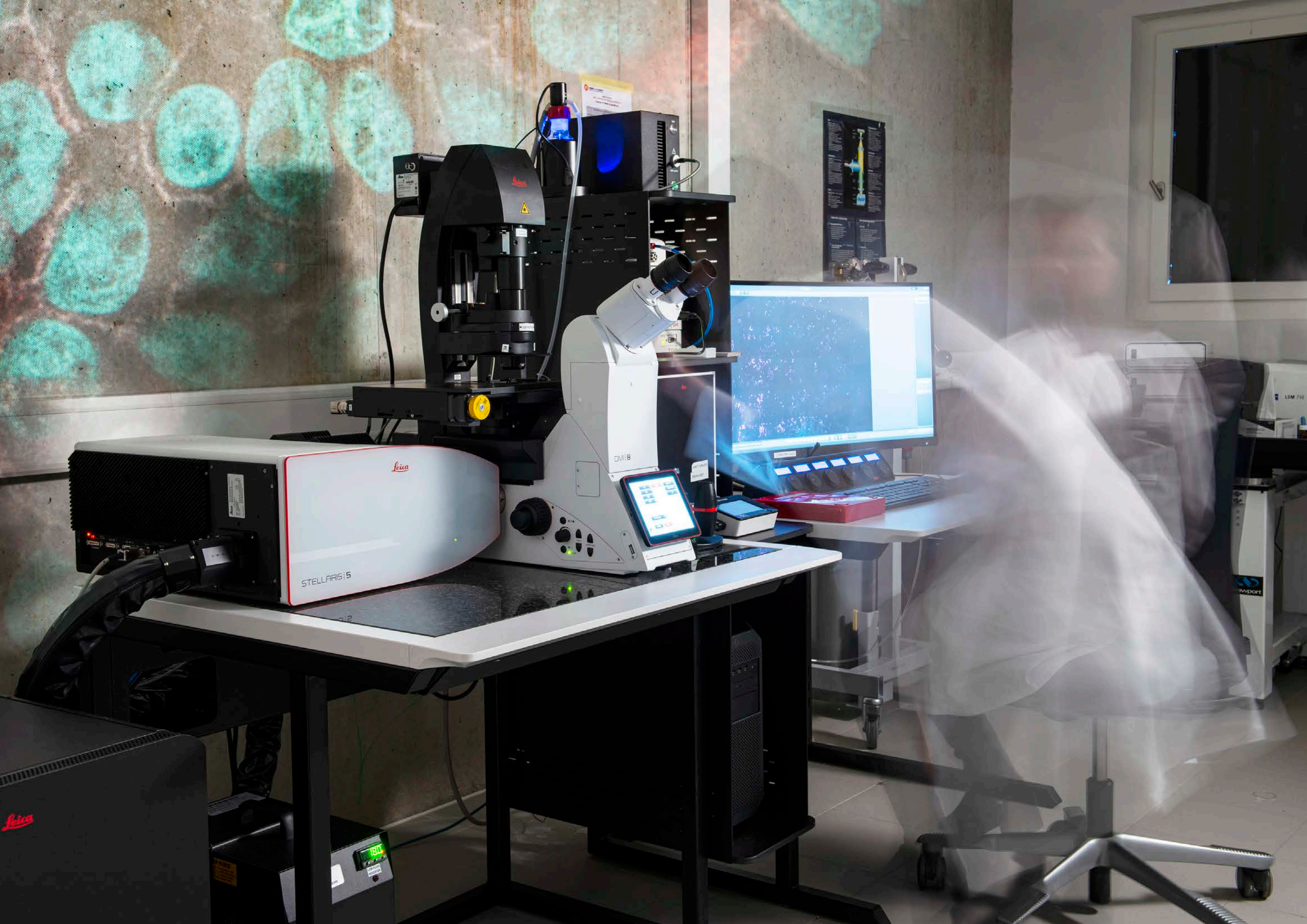
***Catherine Jungo***
Chief Administrative Officer

***Anna Lamelza*** *(from August 2021)*
Responsible for Finance & Controlling

***Thierry Mettraux*** *(until July 2021)*
Responsible for Finance & Controlling

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

***Tomas Perez***
Responsible for IT Support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# PhDs & Alumni

# PhDs

## Our new doctors

***Narjes Abdollahi***
(Soft Matter Physics)
“3D Metallic Gyroid Nanostructures: Preparation, Characterization and Stability”

***Johannes Bergmann***
(Soft Matter Physics)
“Bio-inspired wrinkled surfaces with anti-adhesive properties against insects”

***Gwendoline Delpierre***
(Polymer Chemistry and Materials)
“Symmetric and Asymmetric End-grafted Cellulose Nanocrystals”

***Manuela Estermann***
(BioNanomaterials)
“Design of a human omentum tissue model to investigate ovarian cancer cell adhesion and invasion”

***Antonio Günzler***
(Soft Matter Physics)
“Light in Periodic Structures: Crystallization of Optoelectronic Perovskites & Eigenmodes of Optical Metamaterials”

***Trevor Kalkus***
(BioPhysics)
“Ion Gradients for Bio-Inspired Applications”

***Aris Kamtsikakis***
(Polymer Chemistry and Materials)
“Nanocomposite membranes inspired by the architecture of plant cuticles”

***Baptiste Monney***
(Polymer Chemistry and Materials)
“Photo-patternable, Mechanically Adaptive Polymers for Neural Interfaces”

***Benedetta Petracca***
(BioNanomaterials)
“Effects of ozone on the biophysical properties and biological responses of human skin”

***Alexandre Redondo***
(Soft Matter Physics)
“Cellulose-Reinforced Polyurethane Nanocomposites: Processing, Structure and Mechanical properties”

***Felipe Saenz***
(Polymer Chemistry and Materials)
“Nanostructured Polymers Enabling Stable Low-Intensity Light Upconversion”

***Sandra Wohlhauser***
(Polymer Chemistry and Materials)
“One-component nanocomposites materials based on polymer-decorated cellulose nanocrystals”

# Alumni

## People who left AMI in 2021

***Narjes Abdollahi***
(Soft Matter Physics)

***Artin Aslanzadeh***
(Soft Matter Physics)

***Anne Bannuscher***
(BioNanomaterials)

***Johannes Bergmann***
(Soft Matter Physics)

***Esteban Bermudez***
(Soft Matter Physics)

***Louise Bryan***
(BioPhysics)

***Gwendoline Delpierre***
(Polymer Chemistry & Materials)

***Irini Dijkhoff***
(BioNanomaterials)

***Visuta Engkagul***
(Polymer Chemistry & Materials)

***Manuela Estermann***
(BioNanomaterials)

***Mélissa Forney***
(Administration)

***Arnivan (Gogol) Guha***
(BioPhysics)

***Trevor Kalkus***
(BioPhysics)

***Aris Kamtsikakis***
(Polymer Chemistry & Materials)

***Cédric Kilchoer***
(Soft Matter Physics)

***Vandana Kushwaha***
(BioPhysics)

***Roman Lehner***
(BioNanomaterials)

***Peng Liu***
(BioPhysics)

***Tianji Ma***
(BioPhysics)

***Thierry Mettraux***
(Administration)

***Baptiste Monney***
(Polymer Chemistry & Materials)

***Subhajit Pal***
(Polymer Chemistry & Materials)

***Jonas Pollard***
(Macromolecular Chemistry)

***Benedetta Petracca***
(BioNanomaterials)

***Alexandre Redondo***
(Soft Matter Physics)

***Philip Scholten***
(Polymer Chemistry & Materials)

***Dedy Septiadi***
(BioNanomaterials)

***Giovanni Spiaggia***
(BioNanomaterials)

***Patricia Taladriz***
(BioNanomaterials)

***Lan Tran***
(Macromolecular Chemistry)

***Bodo Wilts***
(Soft Matter Physics)

***Cuifeng Ying***
(BioPhysics)

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