2018 _Annual Report

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UNIVERSITÉ DE FRIBOURG
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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 Switzerland 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 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 and PhD students, postdocs, and senior researchers.

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Professor Christoph Weder

In 2018, AMI celebrated its tenth anniversary with a series of events and activities that focused on outreach to our stakeholders. We opened our doors to the local population, invited children for science afternoons, and organized a reunion weekend for our alumni. We also edited a special issue of the journal *Small*, which I encourage you to review if you are interested in an in-depth overview of the scientific activities of past and current AMI researchers.

The year brought considerable changes to our management team. Dr. Marc Pauchard, AMI's long-time Deputy Director and Technology Transfer Manager, left the Institute to join the federal Innovation Agency Innosuisse. His functions at AMI were assumed by Professor Ulli Steiner (Deputy Director), Dr. Mohammed Benghezal (Managing Director), and Dr. Valeria Mozetti (Technology Transfer). The Institute also said farewell to Prof. Nico Bruns, whose Swiss National Science Foundation Professorship came to an end and who was appointed Full Professor at the University of Strathclyde in Scotland. Both Marc and Nico contributed significantly to AMI's development and achievements during their tenures and will be missed.

As every year, selected research stories form the core of our annual report. Our Soft Matter Physics group published a seminal study in *Science* that focused on increasing the stability of perovskite solar cells, which brings these devices closer to becoming a profitable, long-term solution for a sustainable energy future. The Polymer Chemistry & Materials team had a breakthrough in creating artificial membranes that mimic the structure and function of leaf cuticles and that exhibit directional transport characteristics. The BioNanomaterials group has developed a method that should lead to a better grasp of how specific nanomaterials affect cell mechanics during tissue repair. The BioPhysics group has been investigating improvements to nanopores used to measure the properties of large molecules, relying on a method that is both accessible to more scientists and simpler to apply. One of the final contributions of the Macromolecular Chemistry team led by Prof. Nico Bruns was the development of nanoreactors inspired by the mechanism by which light receptors operate in the human eye, which could lead to a new system for drug delivery.

Many of our research activities are part of the National Center of Competence in Research (NCCR) Bio-Inspired Materials, which was launched in 2014 and has its headquarters at AMI. After four very successful years, the Swiss National Science Foundation (SNSF) council not only approved the continuation of the Center in a second funding phase from 2018 to 2022, but also increased the funding level in recognition of the Center's performance.

With respect to translating our research into technologies, we are proud to report the formation of AMI's first start-up company NanoLockin, which is developing detection systems for nanoparticles in complex media. We also made significant progress on a range of technology platforms and filed a record number of patent applications.

At AMI, we continue to value our partnerships and are once again grateful for all the interest, courtesy, and support that continue to receive. We hope that the report conveys our passion and enthusiasm for our work and that you enjoy the lecture!

Christoph Weder
AMI Director and Professor for Polymer Chemistry & Materials

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Pursuing excellence

Bio-inspired

_ Successful national center transitions into second phase

Beetles serve as inspiration for AMI research on structural color

The National Center of Competence in Research (NCCR) Bio-Inspired Materials, headquartered at the Adolphe Merkle Institute, provided a substantial boost to AMI's activities during its first four-year phase, bringing researchers together to launch interdisciplinary research projects in a strategically important domain. The Center also nucleated many initiatives to promote equal opportunities (EO), as well as educational and outreach programs.

"Intelligent" materials are materials whose properties change in a selective and predictable manner in response to external stimulation, such as exposure to chemicals, heat, light, and mechanical force, or interactions with biological molecules or cells. They are of fundamental scientific interest and potentially useful in countless applications. While many intriguing stimuli-responsive materials have already been developed, their design and function appear crude in comparison to the sophistication, specificity, and functionality displayed by their counterparts found in living organisms. To close this gap, scientists began using design principles found in nature as inspiration to investigate artificial materials with stimuli-responsive properties. Recognizing that the innovation potential in this domain is enormous, and that a large-scale interdisciplinary effort is required to achieve paradigm-changing scientific breakthroughs, the NCCR Bio-Inspired Materials was launched in June 2014 with the vision of becoming an internationally recognized hub for research, education, and innovation in the domain of stimuli-responsive bio-inspired materials.

Led by AMI Director Professor Christoph Weder, and comprising all of the Institute's research groups, the Center completed in 2018 the first and started the second of three expected four-year periods. During the first phase, the Center's research activities focused on three major areas: mechanically responsive materials, responsive (optical) materials made by self-assembly, and interactions of responsive materials with living cells.

Inspired by mechanically responsive biological materials in nature that translate mechanical forces into chemical, electrical, or optical signals, NCCR researchers are mimicking such behavior in synthetic materials. In the quest to discover new mechanophores – mechanically responsive motifs that can be integrated into polymers, bestowing them with useful functions – the Polymer Chemistry & Materials group and colleagues showed that the integration of certain metal-ligand complexes can confer polymers with mechanoresponsive luminescence behavior – that is, a mechanically triggered fluorescence change – which is useful for force-and damage-sensing materials. It was also demonstrated that the mechano-responsiveness of such materials can be tailored based on the choice of the metal-ligand motif, and that in certain cases, metal ions can be mechanically released. The latter effect has clear potential for medical applications, such as for creating antibacterial materials whose function is only activated when an implant is put under mechanical load, or for the catalysis of organic reactions. NCCR researchers at AMI also introduced several other mechanophores, including sophisticated mechanically interlocked molecules known as rotaxanes, which can be activated by a much lower force and with a much higher selectivity than any other mechanophore.

By mimicking the phenomenon known as marine glow shown by the algae *Pyrocystis sp.*, which produce blue bioluminescence when mechanically disturbed by waves, ships, or swimming animals, the Macromolecular Chemistry group of AMI Professor Nico Bruns made remarkable progress in the design of mechanically responsive polymer nanocontainers that can be opened upon shearing and thus release their content upon mechanical activation. The triggered release of compounds from the nanocontainers could be useful for drug delivery, the release of fragrances, or 3D printing, for instance.

Significant efforts were also devoted to the study and application of self-assembly processes to create hierarchical structures made from natural and synthetic materials. Exploiting properties on a hierarchy of length scales is a concept commonly used by nature to design materials with exceptional properties. In terms of material properties, the research activities were directed towards photonics, which nature uses in various forms, such as for camouflage or signaling. Important technical progress was made concerning the correlation of the photonic properties of certain biological materials and their mesoscale structure. In a study published in the journal *Nature*, AMI's Soft Matter Physics Professor Ullrich Steiner and colleagues in the United Kingdom reported how bees recognize structural colors in flowers, while in another study the question of how some beetles have optimized the production of a rare white shell was answered by Steiner's team. They further characterized the enhanced refractive index scattering in butterflies and the chiral optics of self-assembled cellulose nanocrystals.

> "The emerging web of joint publications across projects, modules, and universities strikingly reflects that the Center creates and exploits significant synergies, and enables outcomes that would not be possible by funding individual research projects."
> *AMI and NCCR Director Professor Christoph Weder*

Although stimuli-responsive, "smart" nanoparticles (NPs) promise important breakthroughs in disease diagnosis and therapy, translational progress in this domain has been slow, which is attributed to many factors, including robustness of the materials and the lack of an understanding of the underlying fundamental biological interactions. With diagnostic applications in mind, NCCR teams focused their research particularly on this latter aspect. Members of AMI's BioNanomaterials group, co-chaired by Professors Alke Fink and Barbara Rothen-Rutishauser, collaborated with other teams on the optimization of polyethylene glycol (PEG) and lipoic-acid-functionalized gold NPs, which were shown to be 100 times more efficient than free antibodies in targeting breast cancer cells *in vitro*.

In another project, the impact of surface functionalization protocols on the magnetic and thermal properties of superparamagnetic iron oxide nanoparticles (SPIONs) was also investigated by the BioNanomaterials group, and a new technique for quantifying heat generated by SPIONs was established. These discoveries have great potential for scientific and commercial applications in the field of cell biology and cancer diagnostics. Furthermore, a biocompatible magneto-responsive substrate for cell cultures was developed.

Another important advance made by this group was the demonstration that NP endocytosis is cell- and particle-type dependent, and that the endocytotic uptake pathways can be modulated by specifically tailored NPs. An analytical toolbox was developed to determine the colloidal stability of NPs in a biological environment, which is significant for the design of safe and efficient nanoparticle formulations.

Overall, the research output of the Center – the integration of research efforts across the many groups at multiple partner universities and various disciplines – has progressed beyond initial expectations. "The emerging web of joint publications across projects,

25

NATIONALITIES

ARE PRESENT AT AMI, WITH STAFF COMING FROM EVERY CONTINENT.

6

PROFESSORS

SPECIALIZING IN POLYMER SCIENCE, MATERIALS, PHYSICS, CHEMISTRY, AND BIOLOGY.

57%

OF ALL RESEARCH EXPENDITURES

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

4,600

CITATIONS

OF AMI PUBLICATIONS IN THE SCIENTIFIC LITERATURE IN 2018.

6

PROJECTS

WITH INDUSTRIAL PARTNERS IN 2018.

109

SCIENTIFIC PUBLICATIONS

IN TOP-RANKED JOURNALS SUCH AS SCIENCE, JOURNAL OF THE AMERICAN CHEMICAL SOCIETY, ADVANCED MATERIALS, NATURE COMMUNICATIONS, SMALL, ANGEWANDTE CHEMIE, ACS NANO, SCIENTIFIC REPORTS, ADVANCED ENERGY MATERIALS, AND THE PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES.

250

ALUMNI

INCLUDING POSTDOCTORAL RESEARCHERS, PHD STUDENTS, AND INTERNS.

modules, and universities strikingly reflects that the Center creates and exploits significant synergies between groups at AMI, the University of Fribourg, as well as at the Federal Institutes of Technology in Lausanne (EPFL) and Zurich (ETHZ), and enables outcomes that would not be possible by funding individual research projects," explains Weder.

The NCCR is not just about research, however, but also about promoting equal opportunities (EO), and education. AMI staff have been heavily involved in the center's EO and education activities since its launch. BioNanomaterials co-chair Barbara Rothen-Rutishauser developed a successful EO program that has been cited by the Center's funding agency, the Swiss National Science Foundation, as an example to be followed. The vision of the NCCR is to offer and promote equal opportunities for all participants, as well as establish itself as a best-practice model for the advancement of young (female) scientists and the integration of women in natural and life science disciplines. The overarching aims are to provide outstanding and equal boundary conditions for all researchers, and to increase the participation of women in all functions of the NCCR.

Specific NCCR EO actions at AMI included the creation of a fellowship for female postdoctoral researchers and roundtable career discussions with distinguished guests such as former US Ambassador Suzie LeVine. Female NCCR PIs and researchers regularly participate in educational programs such as the TecDays in Swiss high schools, organized by the Swiss Academy of Technical Sciences, and the University of Fribourg's KidsUni and Women in Science and Technology programs, in which they serve as role models for elementary and high school students in an early stage of their careers. At the researcher level, the Center makes every effort to help participants with family duties to reach and maintain a family-work balance.

The NCCR's strategy with respect to education and training spans all educational levels, from elementary school to the professorial level. It has the overarching goal of providing students and researchers with skills that enable them to solve highly complex interdisciplinary problems while preparing them for successful careers in science and engineering. Some of the activities in which AMI staff participated during Phase 1 include the University of Fribourg's KidsUni, run by BioNanomaterials co-chair Professor Fink, and Scientific Afternoons, the National Future Day, school visits, mentoring high school capstone projects, and the Study Week of the Swiss Youth in Science Foundation.

A very successful initiative launched by the Center is the yearly Undergraduate Research Internships Program, which allows up to 20 talented undergraduate students from around the world to spend 12 weeks working on their own research project within one of the NCCR laboratories during the summer. Born out of a similar program developed by AMI, it has helped connect the NCCR with top international universities, including MIT, Cambridge, Stanford, and Harvard, and has also led to new scientific collaborations.

The second phase of the NCCR will see the continuation and development of the research and activities introduced during the NCCR's first four years. Based on the very successful initial outcomes, the research lines that were established will largely be continued in Phase 2. The Center's activities on mechanically responsive materials will now specifically address the consideration of different length scales, efforts on biologically-inspired assembly will be concentrated on optical materials, and biological work will focus on responsive bio-interfaces and surfaces. The knowledge generated in Phase 1 will be used to create materials with specific functions, and as the research progresses, efforts will increasingly be directed towards precise application fields. The EO activities will also be boosted, with the introduction of equal opportunities envoys at the different partnering departments at the University of Fribourg, EPFL, and ETHZ, the goal being to disseminate the best practices developed under AMI Professor Barbara Rothen-Rutishauser's guidance.

High-impact AMI NCCR publications

1. Balog S., Rodriguez-Lorenzo L., Monnier C., Obiols-Rabasa M., Rothen-Rutishauser B., Schurtenberger P., Petri-Fink A. Characterizing Nanoparticles in Complex Biological Media and Physiological Fluids with Depolarized Dynamic Light Scattering, *Nanoscale*, **2015**, 7, 5991

2. Milosevic, A., Rodriguez Lorenzo, L., Balog, S., Monnier, C. A., Petri-Fink, A., Rothen-Rutishauser B. Assessing the Stability of Fluorescently Encoded Nanoparticles in Lysosomes by Using Complementary Methods, *Angew. Chem. Int. Ed.*, **2017**, 56, 13382

3. Moyroud, E., Wenzel, T., Middleton, R., Rudall, P. J., Banks, H., Reed, A., Meller, G., Killoran, P., Westwood, M. M., Steiner, U., Vignolini, S., Glover, B. J. Disorder in Convergent Floral Nanostructures Enhances Signalling to Bees, *Nature*, **2017**, 550, 469

4. Sagara, Y., Karman, M., Verde-Sesto, E., Matsuo, K., Kim, Y., Tamaoki, N., Weder, C. Rotaxanes as Mechanochromic Fluorescent Force Transducers in Polymers, *J. Am. Chem. Soc.*, **2018**, 140, 1584

Launch pad

_ Non-tenure track professors earned their stripes at AMI

Professor Nico Bruns (University of Strathclyde)

Professor Marco Lattuada (University of Fribourg)

Over the past several years, the Adolphe Merkle Institute hosted the groups of two Swiss National Science Foundation (SNSF) professors, Nico Bruns and Marco Lattuada. Both successfully made the jump to tenured faculty positions, Lattuada joining the University of Fribourg's chemistry department as an Associate Professor in 2016, and Bruns assuming a professorship in Macromolecular Chemistry at the University of Strathclyde (United Kingdom) last year.

SNSF professorships, a program that was terminated last year and replaced by Excellenza grants, were designed to give talented researchers who were already managing a small group a chance to improve the likelihood of securing a permanent faculty position. With the SNSF providing the funds to operate a small group for a few years, the candidates were free to select a host institution. For both Bruns and Lattuada, who joined AMI in 2013 and 2012, respectively, the choice was fairly simple.

> "I can only thrive in an interdisciplinary environment, and AMI is a perfect example of this."
> *Professor Nico Bruns*

"There are only a few universities in Switzerland where polymer materials are a focus, one outstanding example being AMI," explains Bruns, who had been working at the University of Basel at the time. "I really liked its concept of interdisciplinary, yet focused research on soft materials and it seemed to be the best place to continue my career."

Lattuada, who led the Self-Assembly group at the Institute, concurs. "For someone like me doing research in the field of colloidal science, there are not many places in Switzerland that are better suited in terms of competence and equipment than AMI and Fribourg," he points out.

For both researchers, it was the first time they had been handed professorial responsibilities, including establishing and guiding an independent research group. "Fortunately, I was able to adapt fast, thanks in part to the mentoring from my professorial colleagues at AMI," says Bruns. "I also learned a lot on institutional leadership through my role as an executive board (EB) member. The way AMI is managed by the EB team is an excellent example of how an institute or a department should be run, and it was a great experience to be part of this team."

Both young professors also benefited from a certain amount of emulation of their environment to develop their research activities. "The level of research at AMI is very high, and this is a very positive stimulus to get the best out of you," points out Lattuada. "A little pressure does not hurt."

Bruns, who built up his Macromolecular Chemistry group at AMI, says that successful research is not about copycatting what senior colleagues are doing. "Every principal investigator should be as creative and independent as possible in their scientific research," he reckons. "Having said that, it is really helpful to have more senior colleagues who can advise you on how to do certain things, and who can also act as a role model and source of inspiration."

Striking out in their own directions, however, does not mean that they ignored collaboration with their AMI colleagues. In fact, the reality was quite the opposite, and these opportunities for working together forms one of the reasons the professors chose to work at AMI, explains Bruns: "My own research is inherently interdisciplinary and deals with diverse questions ranging from polymerization kinetics, to biocatalysis, bio-inspired materials and even malaria diagnostics. As a result, I can only thrive in an interdisciplinary environment, and AMI is a perfect example of this."

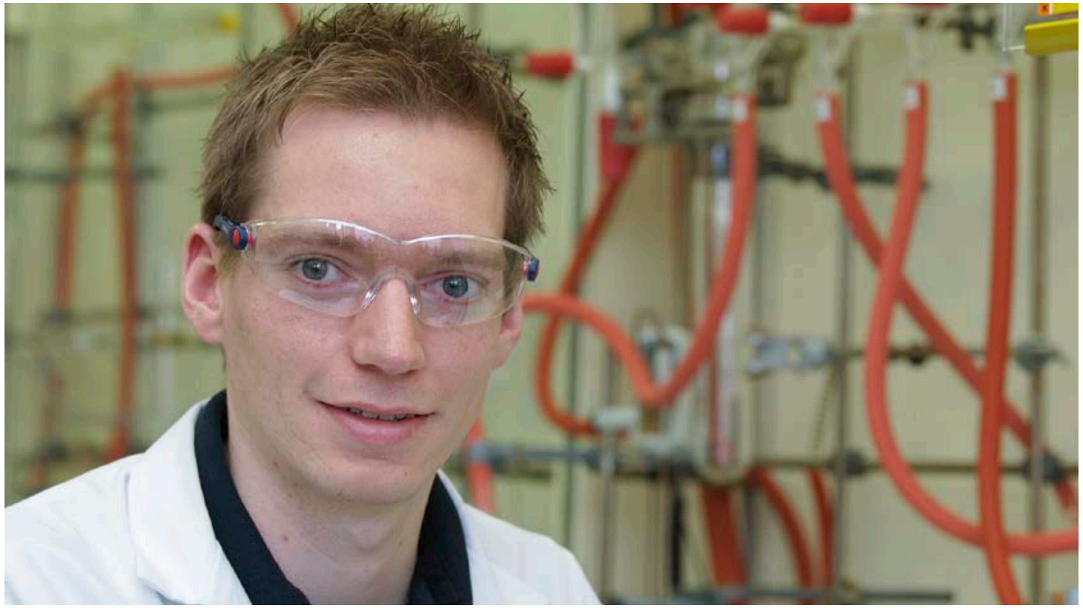
For Lattuada, the interdisciplinary character of AMI also brought other rewards. "It is what I liked the most at the Institute: it helps develop new ideas, stimulates collaborations, and allows one to work on very interesting and challenging topics. However, it also forces people from different backgrounds to talk together, which is not always easy."

These collaborations have remained intact even after the two professors' departures from AMI, with both serving as members of the National Center of Competence in Research Bio-Inspired Materials, and regular visitors at the Institute. Ultimately AMI's influence is never far away, according to Bruns: "I am trying to implement some of AMI's methods to foster inter-group collaborations in my new department at the University of Strathclyde in Glasgow. For example, I have implemented a regular cake time like there is at the Institute, and I continue to participate with my group in the Winter Schools that AMI's Soft Matter Physics chair, Professor Ulli Steiner, initiated."

Hosting junior groups for a period of time is a model that AMI will continue to pursue. "We are always on the lookout for new colleagues who would like to launch their professorial careers with an Excellenza grant or a similar mechanism at the AMI," adds AMI Director Christoph Weder. "Having talented young researchers is an asset for the Institute. They provide new impulses to the Institute and are excellent ambassadors when they move on to the next stages of their careers."

Providing career tools

_ Alumni are well prepared for industry



Dr. Mathieu Ayer is one of the many successful PhD students to have made the move to industry

Many researchers at the Adolphe Merkle Institute reach a crossroad during their time in Fribourg: after completing a PhD or a postdoctoral stay, most AMI scientists join the industrial sector, leaving academia behind, armed with valuable tools for their chosen career path.

The switch from an academic environment to industry has proven to be a less daunting thanks to the frequent exposure to research projects in collaboration with industry, and to the skills acquired while at the Institute, even over short periods of time. Some of these, for instance, are directly related to the AMI environment.

"I learned how to manage a complex project, including setting targets, reporting, and how to put in requests for financing as part of my PhD," explains Matthieu Ayer, a former member of the Polymer Chemistry & Materials group. "I also acquired some first management skills thanks to my mentorship of other students."

Ayer, who now works for the Swatch Group, says the way his PhD project was structured is also proving invaluable. "It required me not just to carry out fundamental research and develop a new material with novel properties, but also demanded that I go through a prototype cycle for a specific application," he says. "These technological applications are very important for research and development centers like the one I now work for."

Alumni have also drawn other benefits from their time at AMI, thanks to the Institute's structure. Mariangela Mortato, a former postdoctoral researcher in the BioNanomaterials group, says she was able to move out of her comfort zone. "I did not have a biological background, but I was able to develop new ideas as well as a global perspective of my work," she points out. "This is very important in the current industrial environment. Work teams are international, and interdisciplinary, in big and small companies. The main challenge in industry is to be competitive on the market by providing new ideas and solving complex problems."

Mortato, who works for Swiss firm AVA Biochem says the interdisciplinary nature of research at AMI has additional benefits. "Institute scientists have to communicate efficiently with colleagues with different backgrounds, and have to quickly learn completely new things from other scientific fields. This is helpful to broaden one's own outlook and see problems from a different perspective."

Communication is a skill that other researchers also see as important. Alexander Hähnel, a former postdoctoral researcher in the Polymer Chemistry & Materials group who now works for Freudenberg Sealing Technologies in Germany, says he learned ways of communicating that he now applies in his daily work. "When you have to explain your own project to someone from another discipline in such a way that they can understand, you need to abstract and come up with schematics. In the end, this always leads you to find answers to the questions you have about your own research as well," he points out. Hähnel adds that this approach pays dividends when working with management, as it helps clarify research challenges and find solutions to problems.

Other soft skills are also highlighted by alumni who made the transition to industry. "The support for career planning and goal setting from AMI and from my research group have been fundamental for my move outside academia," says Mortato. "I learned how important networking and marketing skills are for careers."

Another important element is that AMI entertains many research projects in collaboration with industrial partners. "Even those researchers that do not directly participate in such a project get a lot of insights as to 'how industry works'", says AMI Director Christoph Weder. "And this knowledge helps lay the groundwork for potential future industrial collaborations."

Growing up fast

_ NanoLockin strikes early success

Dr. Christoph Geers is NanoLockin's CEO

NanoLockin, the Adolphe Merkle Institute's first start-up, was officially launched in 2018. The company's shareholders, including CEO Dr. Christoph Geers, were able to count on widespread support, as shown by the firm's winning the canton's innovation prize in the startup category in November.

The company has developed a detection system for nanoparticles in complex media. Smaller than living cells, nanoparticles are frequently introduced or occur naturally in many products such as cosmetics, food, or clothing. Apparel companies, for example, have come to integrate silver nanoparticles in sports clothing to ward off bacteria. This means, however, that issues such as nanoparticle concentration in fibers for example, and whether these particles can leak off fibers and affect the wearer's skin, need to be resolved before such products can head to the market.

NanoLockin's technology, initially developed by Dr. Christophe Monnier and Dr. Federica Crippa during their PhD studies in AMI's BioNanomaterials group under the guidance of Prof. Alke Fink in collaboration with Dr. Mathias Bonmarin of the Zurich University of Applied Sciences, is designed to respond to this type of query. The technology was patented and licensed to the startup. Nanoparticles are stimulated with light to produce heat, allowing them to be detected, counted, and observed by the system's built-in infrared camera. This method has a number of advantages, including causing no damage to the sample, ease of use, and lower costs than the market competition.

Initially developed to quantify and characterize magnetic nanoparticles for a recently developed cancer therapy known as hyperthermia, the technology has evolved from a single-use product. "Focusing on the right market opportunities is a crucial step for every startup," says Geers.

The technology has proven attractive to early backers. In March 2018, NanoLockin was awarded business coaching from Fri Up – the Canton of Fribourg's official support organization for startups – during its crucial launch phase, notably to help the company develop its commercial strategy, while Fribourg's Seed Capital Foundation granted the company an interest-free loan of CHF 150,000 to serve in particular for prototype development. Geers was also awarded a personal BRIDGE proof-of-concept grant by Innosuisse and the Swiss National Science Foundation for further development of the technology. This funding is being used to translate an embryonic innovation into a full-fledged technology, enabling the pursuit of research and development that could not be carried out under the aegis of the Institute. Furthermore, Geers has received additional support via a grant from Sitem-Insel in Bern to pursue a Master of Advanced Studies (MAS) program in Translational Medicine and Entrepreneurship.

> "[NanoLockin] highlights the analytical capacities of the BioNanomaterials group in a field that is called to develop over the next few years. "
> *Professor Alke Fink,*
> *AMI BioNanomaterials co-Chair*

"Without the strong support from the different institutions, agencies, and in particular the Adolphe Merkle Institute, the start of this venture would have been extremely difficult," reckons the NanoLockin CEO.

The AMI startup was one of three finalists for the cantonal innovation prize. The CHF 30,000 given to the winner is also being invested in product development, according to Geers. The goal is to sell the system to analytical laboratories as well as industrial clients for quality control.

The company is run by the four co-founders, and the firm's strategy foresees a growth to 13 employees with a planned break-even level by 2022. To date, the instruments have been assembled in small numbers with the help of the University of Fribourg's technical services, the canton's School of Engineering and Architecture, and external companies. The long-term goal is to find multiple partners for serial production of the instrument parts, which are then assembled in the firm's own facilities.

NanoLockin's creation was a first milestone for the BioNanomaterials group, as well as for AMI. "NanoLockin is the result of an extremely lengthy and rigorous scientific process," adds Fink. "It highlights the analytical capacities of the BioNanomaterials group in a field that is expected to develop over the next few years. We would like to establish ourselves as leading experts of nanomaterial analysis and nano-bio interactions, and this is first important step forward."

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ACTIVE RESEARCH PROJECTS

IN FIELDS SUCH AS BIO-INSPIRED MATERIALS, SOLAR CELLS, MALARIA DIAGNOSTICS, ADHESIVES, BATTERIES, OPTICAL META-MATERIALS, NANOPARTICLE TRACKING IN CELLS, ENHANCEMENT OF LEGUME DEFENSES, BENCHTOP PROTEIN ANALYSIS, AND PREVENTION OF PARTICLE INDUCED LUNG DISEASES.

CHF 10.4 mio

SPENT IN 2018

RESEARCH SPENDING ROSE FROM CHF 8.5 MILLION TO CHF 8.9 MILLION.

43%

OF STAFF AT AMI ARE WOMEN

12

PATENT APPLICATIONS

FILED BY AMI RESEARCHERS.

103

PEOPLE

WORK AT AMI INCLUDING PHD STUDENTS, POSTDOCTORAL RESEARCHERS, PROFESSORS, SUPPORT STAFF, AND INTERNS.

46%

OF AMI STAFF

ARE DOCTORAL STUDENTS.

Outreach

_ Celebrating a decade of achievements

The Adolphe Merkle Institute celebrated its tenth birthday in 2018. The Institute has grown from a small group of researchers that sought to implement the vision of entrepreneur Adolphe Merkle to an established research institution with over 100 staff members that is firmly implanted at the University of Fribourg, and forms an important part of the national and international research and education landscape. Rather than holding a quiet internal party to celebrate, AMI reached out to the local population as well as its alumni over the course of the year to show how much has been achieved and what lays ahead. This included participation in the city's Museum Night, the first ever AMI-supported exhibition at Fribourg's Natural History Museum, and a special gathering of Institute alumni and current staff members.

Nanoworlds

The Institute welcomed around 150 children on two afternoons in March for a so-called “Goûter scientifique/Wissenschaft zum Zvieri,” a program that allows youngsters to discover different domains covered by the University of Fribourg's teaching and research activities, be it law, business, neuroscience, or, in AMI’s case, nanoscience. Organized by Professor Alke Fink’s KidsUni association in collaboration with the University, these events were designed to give the young attendees a fun, hands-on discovery session about science. The children were given insights by Institute staff into scale, molecule movement, plastic pollution, hydrophobic surfaces, and structural color in nature, to name just a few of the elements presented.

Children were invited to discover science hands-on

Fribourg Museum Night

In May, the Institute joined forces with the city’s main museums and a number of temporary exhibitions, including its neighbors at the Botanical Gardens and the Natural History Museum, for the Fribourg Museum Night, opening its doors to the public. Over 750 people passed through the Institute and enjoyed a program that covered nanoscience past, present, and future. Organized by BioNanomaterials Professor Bar-

Visitors were able to learn about AMI's ongoing projects bara Rothen-Rutishauser, the program included a fun Kids' Corner, presentations from the Institute's professors, information stands explaining the Institute's many activities, an entertaining Science Slam session, as well as an overview of the milestones of nanotechnology so far. Thirsty visitors were also invited to stop at the Chemistry Bar to test some original cocktails.

Explora

AMI was once again an active participant in the University of Fribourg's open day, Explora. The event was held in September at the Faculty of Science and Medicine campus, which the Institute forms a part of. AMI staff were on hand to take visitors behind the scenes, guiding them through the laboratories. Demonstrations and presentations were also part of the tours, and gave a brief overview of the Institute's research, both fundamental and applied.

For Explora, visitors were taken on tours of the AMI buildings

Former staff were able to present themselves formally at the Alumni Days

Alumni Days

AMI's many alumni were invited to return to the Institute for a two-day event in late September. More than forty of them answered the call, taking the opportunity to (re)discover the Institute's current activities and research. For many of the guests, including founding Director Professor Peter Schurtenberger, the Institute has undergone major changes since their time, including the opening of its own site on the University of Fribourg's Pérolles campus and the arrival of new research groups, taking staff numbers beyond 100. Each research group's activities were presented, while the alumni were also given an opportunity to present themselves formally to AMI's current team members. It was also a chance for Institute staff to network with the alumni over dinner and a brunch on the second day. The inaugural AMI Cup was also held with the Soft Matter Physics team taking the win in this bubble soccer tournament.

Inspiration Natur-e

The Institute's first ever participation in museum-quality exhibition took place at Fribourg's Natural History Museum, in collaboration with the National Center of Competence in Research (NCCR) Bio-Inspired Materials. Inspiration Natur-e, which ran from October 2018 to March 2019, looked at a series of scientific developments inspired by nature, ranging from hydrophobic surfaces for clothing to structural color for paint and mussel-inspired adhesives for fetal heart surgery. AMI and Fribourg-based NCCR staff took part in additional outreach events at the museum, connecting with both children and adults. Overall, more than 30,000 people saw the exhibition, which will continue to be presented elsewhere in Switzerland and abroad.

Live geckos were part of the exhibition to explain their amazing gripping prowess

Up and coming
_ AMI's young talents

The Adolphe Merkle Institute is home to many talented researchers. We have once again chosen to highlight here some of the young scientists who are making their first steps towards an independent career, notably thanks to special grants. These include Ambizione funds – which are awarded by the Swiss National Science Foundation and are aimed at young researchers who wish to conduct, manage, and lead an independent research project – and the Women in Science Fellowship awarded by the NCCR Bio-Inspired Materials

Dr. Michael Saliba

Michael Saliba

Dr. Michael Saliba was a Group Leader at the Adolphe Merkle Institute and a Marie Curie Fellow at the Federal Institute of Technology in Lausanne (EPFL). He recently left the Institute to assume a professorship at the Technical University Darmstadt (Germany). Saliba obtained his PhD from Oxford University (United Kingdom), earned an MSc at the Max Planck Institute for Solid State Research, and BSc degrees in mathematics and physics from Stuttgart University (both Germany). His research focuses on developing a deeper understanding and improved use of optoelectronic properties of emerging photovoltaic materials with an emphasis on perovskites for a sustainable energy future.

Saliba's work has been recognized internationally. In 2016, he was awarded the Young Scientist Award of the German University Association. In 2017, he was the recipient of the Science Award of the Fraunhofer UMSICHT Institute as well as the Postdoctoral Award of the Materials Research Society (MRS). He also received widespread attention after his nomination as one of the World's 35 Innovators Under 35 by the MIT Technology Review for his pioneering discoveries of perovskite optoelectronic materials. Saliba is a Member of the National Young Academy of Germany as well as the Global Young Academy.

Fabienne Schwab

Dr. Fabienne Schwab joined AMI's BioNanomaterials group in 2017 as a Senior Scientist. She earned her PhD in environmental chemistry from Zurich's Federal Institute of Technology (ETHZ), where she performed experimental research on pesticide nanoecotoxicology in green algae. After her stay at ETHZ, she worked at Duke University (United States), and for France's Geoscience and Environment Lab (CEREGE), where she focused on nanoparticle interactions with plants. Her research is devoted to nanomaterial and micropollut-

Dr. Fabienne Schwab

ant transport and fate research in the environment, bio-inspired nanomaterials science and engineering, biogeochemistry, as well as plant (nano-) ecotoxicology.

Schwab currently leads the Ambizione project "Enhancing Legume Defenses: Exploring Bioinspired Nanomaterials to Support Plant Health," with a project team consisting of a PhD student, a postdoctoral scholar, and a group of students performing field trials. The project aims to exploit plants interactions with nanoparticles, explore safe biodegradable nano-fertilizers, and to reduce conventional pesticide use.

Michela Pellizzoni

An Italian national, Dr. Michela Pellizzoni joined AMI's Macromolecular Chemistry group in 2017. Previously, she worked as a postdoctoral researcher at the University of Basel, following her PhD at the University of Milan.

In 2018, Pellizzoni was awarded an Ambizione grant – one of four granted at the University of Fribourg in 2018. With this grant directed towards young researchers, over four years, she intends to expand the catalytic repertoire of enzymes introducing "new to nature" reactivity, combining the advantages of both homogeneous and enzymatic catalysis. These new bio-

Dr. Michela Pellizzoni

compatible catalysts will be able to perform reactions under mild and physiological conditions. The development of this selective method could have a strong impact on multiple fields, such as protein engineering, synthetic biology, material science, polymer chemistry, therapeutics protein, and drug delivery and development.

Stephen Schrettl

Dr. Stephen Schrettl joined the Polymer Chemistry & Materials group at AMI in 2015, not long after receiving his PhD in Materials Science from Lausanne's Federal Institute of Technology (EPFL), and a first postdoctoral experience there. Stephen Schrettl's science career began at the Freie Universität Berlin (Germany), where he studied chemistry.

Dr. Stephen Schrettl

Since his arrival at AMI, where he has become a Group Leader, Schrettl has been investigating the structure-property relationships of supramolecular polymers, and the use of different types of non-covalent binding motifs for the preparation of stimuli-responsive polymers. His approach combines aspects of chemical synthesis, polymer chemistry, and self-assembly methods, with the goal of controlling the structure and function in different classes of polymeric materials. Schrettl is also the recipient of an Independence Grant from the National Center of Competence in Research Bio-Inspired Materials, aimed at furthering his career development.

Yendry Corrales

Dr. Yendry Corrales joined the BioNanomaterials group at AMI in 2018, after being awarded the National Center of Competence in Research Bio-Inspired Materials' Women in Science fellowship. A native of Costa Rica, where she earned a degree in chemical engineering at the University of Costa Rica, Corrales moved to Brazil for a PhD in materials science and nanotechnology at the São Paulo State University. This was followed by postdoctoral research back in her homeland, where she investigated extracellular nanostructures derived from the local biodiversity to be used as inspiration for the synthesis of novel advanced materials.

Her two-year project at AMI focuses on velvet worm slime, which she uses as an inspiration to formulate a high-strength bio-polymeric material. Corrales is investigating the chemical composition and morphology of the nanostructures present in the worm's slime, with the objective of modeling the bio-fabrication mechanism. Natural nanostructures present in the slime endow it with properties such as self-healing behavior, mechano-responsiveness, and ease of molding.

Dr. Yendry Corrales


H2O Wash
50% IPA

25

_Research at AMI

Sunny outlook

_ New perspectives for more stable perovskite materials

Researchers from the Adolphe Merkle Institute's Soft Matter Physics group have developed a new type of highly efficient next-generation perovskite solar cell that is more stable than previous models, offering prospects for future commercialization.

Until now, solar cell technology has been almost exclusively based on silicon, which is currently the leading solar cell material. Costs have dropped over the years, while efficiency has increased. However, further improvements have become more and more difficult as the theoretical limit is approached. There are many hurdles that need to be overcome in order to improve silicon solar cells, such as the material's complexity and the energy requirements.

Researchers are increasingly turning their efforts towards perovskite solar cells (PSCs), one of the most promising developments for photovoltaic energy in recent years. Despite their novelty, the efficiency of PSCs, which can absorb the high-energy blue photons of sunlight particularly well, is already approaching the performances of silicon solar cells. However, there are still a number of challenges to overcome before perovskites can effectively challenge silicon, most notably long-term stability.

"The commercialization of perovskite solar cells needs enormous efforts to develop new perovskite materials that are not only highly efficient in terms of power conversion, but also nontoxic, low cost, and most importantly stable" says AMI postdoctoral researcher Somayyeh Gholipour. The latter point is a pivotal step, which requires overcoming the stability issues of PSCs related to thermal stress, ultraviolet light, and moisture.

"The components used in perovskite materials can degrade in just hours, sometimes even minutes, under normal light conditions or in a humid environment," explains Photovoltaics Group Leader Dr. Michael Saliba. "It is a huge challenge to make them stable for years or even decades, like silicon-based cells."

Saliba has specifically addressed the problem of the highly volatile and heat-sensitive methylammonium (MA) molecule. The most efficient perovskite solar cells contain unstable MA, mainly because of their capacity to provide high-performance values.

By exchanging the organic MA with the inorganic elements rubidium and cesium, the researchers have shown that it is possible to avoid unstable MA while maintaining a similarly high efficiency. This allows for more stable solar cells, which is a key step towards eventual commercial use. "These new perovskites can also harvest more sunlight, meaning they are more efficient and therefore more profitable," says Saliba, whose results were published in the prestigious journal *Science*. "In addition, the new materials are compatible with flexible substrates, making them prime contenders for a wide variety of applications."

"Essentially, this sets perovskites on the path of becoming a profitable, long-term solution for a sustainable energy future," Saliba continues. "With small additional improvements, perovskite solar cells can become a commercial game changer within a short time."

Among the potential improvements is the combination of a layer of perovskites, which absorbs high-energy blue photons in sunlight, with standard silicon, which more efficiently absorbs lower-energy red photons. "The option of a perovskite on silicon tandem, where innovative perovskite materials boost established, reliable silicon, has the potential to become a disruptive technology," Saliba states.

The biggest challenge is to make the perovskite-silicon tandem work together efficiently in order to generate maximum current. Get it wrong, and the weakest element will limit power output. Saliba reckons, though, that eliminating silicon from the equation altogether could be the future for some forms of solar power.

"Perovskites even have the potential to replace the silicon layer, thus enabling a perovskite-on-perovskite tandem which is compatible with a flexible, lightweight substrate," he explains. "Such technology does not currently exist and could have a major impact in future innovations in the photovoltaics field."

Reference

Turren-Cruz, S.-H., Hagfeldt, A., Saliba, M. Methylammonium-Free, High-Performance, and Stable Perovskite Solar Cells on a Planar Architecture, *Science*, **2018**, 362, 6413, 449

Somayyeh Gholipour joined the photovoltaics group (Soft Matter Physics) at AMI in 2018 as a postdoctoral researcher with a Swiss government excellence scholarship. An Iranian national, she obtained her PhD from Alzahra University in Tehran, which included time at Lausanne's Federal Institute of Technology. Her research interest is nanostructured stable perovskite solar cells.

Soft Matter Physics

Team

Prof. Ullrich Steiner, Doha Abdelrahman, Narjes Abdollahi, Johannes Bergmann, Lucie Castens, Dr. Esteban Bermudez, Parnian Ferdowsi, Michael Fischer, Dr. Somayyeh Gholipour, Antonio Guenzler, Dr. Ilja Gunkel, Dr. Hua Xiao, Cédric Kilchoer, Karolina Korzeb, Mirela Malekovic, Dr. Efrain Ochoa, Andrea Palumbo, Alexandre Redondo, Dr. Michael Saliba, Sandy Sanchez, Dr. Alessandro Sepe, Preston Sutton, Dr. Bodo Wilts

Key Publications

1. Sanchez, S., Christoph, N., Grobety, B., Phung, N., Steiner, U., Saliba, M., Abate, A. Efficient and Stable Inorganic Perovskite Solar Cells Manufactured by Pulsed Flash Infrared Annealing, *Adv. Energy Mater*, **2018**, 8, 30, 1802060

2. Wilts, B. D.; Sheng, X.; Holler, M.; Diaz, A.; Guizar-Sicairos, M.; Raabe, J.; Hoppe, R.; Liu, S.-H.; Langford, R.; Onelli, O. D.; Chen, D.; Torquato, S.; Steiner, U.; Schroer, C. G.; Vignolini, S.; Sepe, A. Evolutionary-Optimized Photonic Network Structure in White Beetle Wing Scales. *Adv. Mat.*, **2018**, 30, 19, 1702057

3. Sanchez, S., Hua, X., Phung, N., Steiner, U., Abate, A. Flash Infrared Annealing for Antisolvent-Free Highly Efficient Perovskite Solar Cells. *Adv. Energy Mater*, **2018**, 8, 12, 1702915

4. Fischer, M. G., Hua, X., Wilts, B. D., Castillo-Martínez, E., Steiner, U. Polymer-Templated $LiFePO_4$/C Nanonetworks as High-Performance Cathode Materials for Lithium-Ion Batteries. *ACS Appl. Mater. Interfaces*, **2018**, 10, 2, 1646

5. Wenzel, T., Härtter, D., Bombelli, P., Howe, C. J., Steiner, U. Porous Translucent Electrodes Enhance Current Generation from Photosynthetic Biofilms. *Nat. Commun.*, **2018**, 9, 1, 1299

Bio-inspired
_ Creating new membranes to separate liquids

Researchers at the Adolphe Merkle Institute are experimenting with new types of finely tuned composite membranes inspired by leaves, designed to allow certain types of liquids to filter through, as part of a European training project.

Take any leaf and you may discover that it is covered by a thin waxy layer known as the cuticle, whose main function is to protect the leaf against water loss. Leaf cuticles are thin composite films covering the epidermal cells of leaves, consisting of a hydrophobic cutin matrix, polysaccharides, and waxes. This insulating layer protects leaves from dehydration. Take the waxes away, however, and the water permeability of the leaf increases by two to three orders of magnitude. Two parallel pathways for transport of water are present in cuticles: one through the apolar cutin and one using a polar pathway attributed to polysaccharides (pectin and cellulose fibrils) extending from the epidermal cell wall.

The Polymer Chemistry & Materials group at AMI is seeking to translate the composite “hydrophobic matrix – hydrophilic filler” structure of wax-free leaf cuticles to non-porous artificial membranes using a commercially available hydrophobic rubbery copolymer and hydrophilic cellulose-based fillers, such as cellulose nanocrystals (CNCs) and nanofibrillated cellulose (NFC). The water permeability of these composite membranes is being investigated and correlated with the membrane's architecture, notably the distribution of the fillers in the matrix.

The idea is not to mimic a leaf exactly, but to adopt a similar heterogeneous architecture. “If you look at cuticles in nature for example, they are excellent at fulfilling their role as water permeation barriers, but they have limited functionalities and are very fragile,” explains PhD student Aris Kamtsikakis.

Permeable separation membranes are not a new idea. Indeed, pervaporation – a separation process of liquid mixtures – was first described over a century ago. In this process, the separation is based on exploiting the affinity differences between the permeating substance and the membrane. Yet, it was not until the 1980s that pervaporation attracted significant industrial interest for dehydration of solvents and other liquid-liquid separations. The membranes used are extremely dense and act as a selective mass transfer barrier.

Thus, mimicking nature, the AMI researchers seek to develop thin composite membranes that are mechanically robust and selective towards specific permeating species, privileging, for example, alcohols over water. Initial results are promising: “Our first tests show that our idea works much better than we expected,” says Kamtsikakis. “Not only can the permeability be tuned easily by altering the surface chemistry of the materials, but simply flipping the direction in which liquids are directed through the membrane makes a major difference.” The next stage will be to test which liquids pass through the membrane selectively and how performance is influenced by architecture and surface chemistry. According to Kamtsikakis, potential applications could interest the food and petroleum industries.

The project is part of the Innovative Training Network PlaMatSu (Plant-Inspired Materials and Surfaces), funded by the European Commission, that allows nine PhD students to work at three institutions in the field of bio-inspired materials: AMI, the University of Freiburg (Germany), and the University of Cambridge (UK). PlaMatSu brings 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.

These training networks provide students with the opportunity to pursue their academic training within an international multidisciplinary framework along with temporary industrial internships. The aim of the program is to boost scientific excellence and business innovation, as well as to enhance researchers’ career prospects through developing their skills in entrepreneurship, creativity, and innovation.

Aris Kamtsikakis is a Marie Curie Early Stage Researcher (ESR) and part of the Innovative Training Network “PlaMatSu”. He is currently working towards his PhD as a member of the AMI Polymer Chemistry & Materials group. Kamtsikakis graduated from the National Technical University of Athens in 2015 with a chemical engineering degree.

Polymer Chemistry & Materials

Team

Prof. Christoph Weder, Véronique Buclin, Claudio Cappelletti, Céline Calvino Carneiro, Dr. Shraddha Chhatre, Dr. Anselmo del Prado Abellan, Gwendoline Delepierre, Dr. Visuta–Kan Engkakul, Anne-Cécile Ferahian, Diana Hohl, Aris Kamtsikakis, Dr. Feyza Karasu Kiliç, Marc Karman, Derek Kiebala, Marco Mareliati, Worarin Meesorn, Baptiste Monney, Livius Muff, Jens Natterodt, Laura Neumann, Luis Olaechea, Dr. Carlo Perotto, Chris Rader, Anita Roulin, Felipe Saenz, Julien Sautaux, Dr. Stephen Schrettl, Dr. Anuja Shirole, Hanna Traeger, Sandra Wohlhauser, Dr. Justin Zoppe

Key Publications

1. Karman, M., Verde-Sesto, E., Weder, C. Mechanochemical Activation of Polymer-Embedded Photoluminescent Benzoxazole Moieties, *ACS Macro Lett.*, **2018**, 7, 1028
2. Shirole, A., Perotto, C.U., Balog, S., Weder, C. Tailoring the Shape Memory Properties of Segmented Poly(ester urethanes) via Blending; *ACS Appl. Mater. Interfaces*, **2018**, 10, 24829
3. Wohlhauser, S., Delepierre, G., Labet, M., Morandi, G., Thielemans, W., Weder, C., Zoppe, J. O. Grafting Polymers from Cellulose Nanocrystals: Synthesis, Properties and Applications, *Macromolecules*, **2018**, 51, 6157
4. Sautaux, J., Montero de Espinosa, L., Balog, S., Weder, C. Multi-stimuli multi-responsive fully supramolecular interpenetrated polymer networks, *Macromolecules*, **2018**, 51, 5867
5. Di Giannantonio, M., Ayer, M., Verde-Sesto, E., Lattuada, M., Weder, C., Fromm, K.M. Triggered metal ion release and oxidation: Ferrocene as new mechanophore in polymers, *Angew. Chem. Int. Ed.*, **2018**, 57, 11445
6. Sagara, Y., Karman, M., Verde-Sesto, E., Matsuo, K., Kim, Y., Tamaoki, N., Weder, C. Rotaxanes as mechanochromic fluorescent force transducers in polymers, *J. Am. Chem. Soc.*, **2018**, 140, 1584
7. Calvino, C., Guha, A., Weder, C., Schrettl, S. Self-Calibrating Mechanochromic Fluorescent Polymers Based on Encapsulated Excimer-Forming Dyes, *Adv. Mater.*, **2018**, 30, 1704603

New approach
_ A better understanding of lung tissue repair mechanics

Researchers from the BioNanomaterials group at the Adolphe Merkle Institute have developed a method that more accurately mimics injury and wound healing response in lung epithelial tissues than previous models. Besides providing additional knowledge about regeneration after injury, this method should lead to a better understanding of how specific nanomaterials affect cell mechanics during tissue repair.

The number of *in vitro* and *in vivo* toxicity studies of nanomaterials has increased dramatically in recent years. Unfortunately, the availability of information regarding the alteration of cell mechanics in the presence of nanomaterials is still limited. These cell mechanics are critical indicators for cell functionality and health, and these processes drive important biological activities such as cell migration, differentiation, wound healing, and tissue integrity.

Wound healing assays are one method used extensively to study tissue repair mechanisms; they are typically performed by physically scratching cells to create an open space in which living cells can lodge. Yet, this is not necessarily a true reflection of what happens in real life. This method is, for example, unsuitable for studying the repair response of tissue at a small injury site where dead cells are still present. The researchers from the AMI BioNanomaterials group chose another approach by inflicting damage on a specific zone of lung epithelial tissue using photobleaching, and leaving any potential dead cells in place. "What is novel is that we took a method that was pre-existing, but that had never been used before for this type of application," explains Dr. Dedy Septiadi. This extensive photobleaching was performed by illuminating certain cell areas with a high-power ultraviolet laser in a confocal microscopy setup, and then sufficiently inducing a specific cell death mechanism, namely, apoptosis. "Our method is relatively efficient," adds Septiadi. "Much of the challenge was defining the correct parameters to carry out our experiments."

The AMI researchers found that individual healthy epithelial cells are able to clear the dead cells by pushing them to one side. Then, macrophages, the body's cellular cleaning crew, actively swallow cellular debris, creating an empty space. However, the push repair mechanism is hampered when carbon nanotubes (CNTs) with a high stiffness are introduced, suggesting CNTs can interfere with lung repair, either by delaying or hindering wound recovery. Exposure to high aspect ratio nanomaterials such as these nanotubes has been shown to induce cell death and micro-injuries in epithelial lung tissue, potentially leading to pulmonary scarring (fibrosis). The AMI research could therefore also help understand the impairment or repair mechanism induced by CNTs in a wound healing context. "Our work is focused purely on the mechanics involved," says Septiadi. "But the biological impact of CNTs is being investigated by our group separately to increase the scope of our research."

This study, the results of which were published in the leading scientific journal *Advanced Materials* are part of a wider effort undertaken by the AMI BioNanomaterials group under the leadership of group co-chair Professor Barbara Rothen-Rutishauser to comprehend wound healing at the mechanistic level, which is difficult to do in *in vivo* situations.

"It is important to understand the potential impact of inhaled CNTs, especially in an occupational setting," explains Rothen-Rutishauser. "With our research, we can help to understand pathophysiological processes in lung tissue during wound repair and how this is impacted by nanomaterials."

Reference

Septiadi, D., Abdussalam, W., Rodriguez-Lorenzo, L., Spuch-Calvar, M., Bourquin, J., Petri-Fink, A., Rothen-Rutishauser, B. Bio-nanomechanics: Revealing the Role of Epithelial Mechanics and Macrophage Clearance during Pulmonary Epithelial Injury Recovery in the Presence of Carbon Nanotubes, *Adv. Mater.*, **2018**, 30, 1870396

Dedy Septiadi, an Indonesian national, joined AMI's BioNanomaterials group in 2016 as a postdoctoral researcher after earning his PhD at the University of Strasbourg (France). His current research focuses on the development of microscopy and spectroscopy approaches to investigate cell mechanics and nanoparticle-cell interactions.

BioNanomaterials

Team

Prof. Alke Fink, Prof. Barbara Rothen-Rutishauser, Liliane Ackermann, Mauro Almeida, Hana Barosova, Christoph Bisig, Joel Bourquin, David Burnand, Jessica Caldwell, Yendry Corrales, Federica Crippa, Irini Dijkhoff, Dr. Barbara Drasler, Manuela Estermann, Dr. Khay Fong, Bihter Geers, Dr. Christoph Geers, Laetitia Haeni, Daniel Hauser, Daria Korejwo Dr. Roman Lehner, Philipp Lemal, , Mattia Maceroni, Ana Milosevic, Dr. Thomas Moore, Benedetta Petracca, Dr. Fabienne Schwab, Dr. Dedy Septiadi, Dr. Miguel Spuch-Calvar, Lukas Steinmetz, Dr. Patricia Taladriz, Yuki Umehara, Dominic Urban, Mathias Weyland

Key Publications

1. Burnand, D., Milosevic, A., Balog, S., Spuch-Calvar, M., Rothen-Rutishauser, B., Dengjel, J., Kinnear, C., Moore, T. L., Petri-Fink, A. Beyond Global Charge: Role of Amine Bulkiness and Protein Fingerprint on Nanoparticle–Cell Interaction, *Small*, **2018**, 14, 1802088

2. Drasler, B., Kucki, M., Delhaes, F., Buerki-Thurnherr, T., Vanhecke, D., Korejwo, D., Chortarea, S., Barosova, H., Hirsch, C., Petri-Fink, A., Rothen-Rutishauser, B., Wick, P. Single exposure to aerosolized graphene oxide and graphene nanoplatelets did not initiate an acute biological response in a 3D human lung model, *Carbon*, **2018**, 137, 125

3. Septiadi, D., Crippa, F., Moore, T.L., Rothen-Rutishauser, B., Petri-Fink, A. Nanoparticle-Cell Interaction: A Cell Mechanics Perspective. *Adv. Mater.*, **2018**, 30, 19, 1704463

4. Bourquin, J., Milosevic, A., Hauser, D., Lehner, R., Blank, F., Petri-Fink, A., Rothen-Rutishauser, B. Biodistribution, clearance and long-term fate of clinically relevant nanomaterials, *Adv. Mater.*, **2018**, 30, 19, e1704307

5. Crippa F, Thorén PA, Forchheimer D, Borgani R, Rothen-Rutishauser B, Petri-Fink A, Haviland DB. Probing nano-scale viscoelastic response in air and in liquid with dynamic atomic force microscopy, *Soft Matter*, **2018**, 14, 19, 3998

Malaria
_ Crystal formation holds clues to fighting disease

Researchers at the Adolphe Merkle Institute have been investigating the formation of crystals that ensure the survival of malaria parasites in the bloodstream. This interdisciplinary effort could facilitate the selection of new anti-malarial compounds and help stem the disease's progress.

Malaria occurs after infection by certain types of mosquitoes, which pass the disease from human to human as a secondary effect of their feeding habits. It is caused by the *Plasmodium sp.* parasites, which degrade and digest the hemoglobin found in blood. Yet, they cannot digest heme, an iron-containing molecule found in many living organisms that serves as an oxygen carrier. In fact, heme is actually toxic to the parasite, which has to neutralize the molecules' effects to survive. To do this, the parasite bio-crystallizes heme into insoluble crystals known as hemozoin. This survival mechanism has been targeted by some anti-malarial drugs, particularly those based on chloroquine, which have been chosen for their capacity to inhibit hemozoin formation. Over the years, however, parasites in different parts of the world where malaria is endemic have become resistant to these treatments, making their use ineffective. This has also led to an increase in malaria-related mortality, especially in Africa.

To counter this, not only new compounds are needed, but also a better understanding of the mechanism and the kinetics of the hemozoin crystallization, as well as of how it is inhibited. Researchers at the Adolphe Merkle Institute chose to investigate the biocrystallization using so-called dynamic depolarized light scattering (DDLS). This approach was selected because it is considered to be a viable method for characterizing non-spherical optical anisotropic particles, and can thus be applied to hemozoin crystals.

"It basically involves shining a laser beam on a solution containing the sample, and detecting and analyzing the statistical properties of the light that is scattered when it strikes the crystals. It is especially useful for analyzing any particulate matter that is dispersed or suspended in a liquid matrix," says Dr. Sandor Balog, one of the two researchers in charge of AMI's instrument platform, and a scattering specialist. "With light scattering, we can infer the shape and stage of development of crystals, as well as the time it takes them to form."

To test their approach, the researchers used a synthetic version of hemozoin whose properties are similar to the natural one produced by the malaria parasite. The tests were performed both in the presence and absence of a chloroquine-based anti-malarial drug. The researchers found that while the drug did not prevent the initial formation of hemozoin nuclei, it did hinder the crystals from growing substantially, as heme was inhibited from attaching itself to its surface.

For Balog, and colleagues from AMI's Macromolecular Chemistry and Soft Matter Physics groups, dynamic light scattering, and DDLS in particular, could easily find its way to anti-malarial studies addressing biocrystallization.

"More generally, the technique is suitable for any system exhibiting the physical features of self-assembly – or for that matter its reverse, dissolution – completely independently of the parameters of the system, such as the chemical reactions," adds Balog. "It could also be miniaturized and integrated into microfluidic platforms and lab-on-a-chip assays, where automation and parallelization for high throughput are desired."

This research was carried out in parallel to the development of a malaria diagnostic tool by AMI's Macromolecular Chemistry group. Their project uses hemozoin as a highly-sensitive indicator of the presence of the malaria parasite in asymptomatic carriers. It catalyzes a polymer in a solution, at temperatures close to those of the human body, changing the liquid from transparent to turbid in presence of the parasite.

Reference

Rifaie-Graham, O., Hua, X., Bruns, N., Balog, S. The Kinetics of ß-Hematin Crystallization Measured by Depolarized Light Scattering, *Small*, **2018**, 14, 1802295

Sandor Balog joined AMI in 2012 as a senior scientist. Previously, he had worked for the Paul Scherrer Institute, Lausanne's Federal Institute of Technology (EPFL), and the European Organization for Nuclear Research (CERN). Balog's interests revolve around the theory, practice, and application of measurements and instrumentation.

Instrument platform

Team

Dr. Sandor Balog, Dr. Dimitri Vanhecke

Key Publications

1. Hafner, R. J., Tian, L., Brauer, J.C., Schmaltz, T., Sienkiewicz, A., Balog, S., Flauraud, V., Brugger, J., Frauenrath, H. Unusually Long-Lived Photocharges in Helical Organic Semiconductor Nanostructures, *ACS Nano*, **2018** 12, 9116

2. Toft-Petersen, R., Abrahamsen, A. B., Balog, S., Porcar, L., Laver, M. Decomposing the Bragg glass and the peak effect in a Type-II superconductor, *Nat. Commun.*, **2018**, 9, 901

3. Luo, Z., Marson, D., Ong, Q.K., Loiudice, A., Kohlbrecher, J., Radulescu, A., Krause-Heuer, A., Darwish, T., Balog, S., Buonsanti, R., Svergun, D.I., Posocco, P., Stellacci, F. Quantitative 3D determination of self-assembled structures on nanoparticles using small angle neutron scattering. *Nat. Commun.*, **2018**, 9, 1343

4. Hauser, D., Estermann, M., Milosevic, A., Steinmetz, L., Vanhecke, D., Septiadi, D., Drasler, B., Petri-Fink, A., Ball, V., Rothen-Rutishauser, B. Polydopamine/Transferrin Hybrid Nanoparticles for Targeted Cell-Killing, *Nanomaterials*, **2018**, 8, 12, 1065

5. Durantie, E., Barosova, H., Drasler, B., Rodriguez-Lorenzo, L., Urban, D. A., Vanhecke, D., Septiadi, D., Hirschi-Ackermann, L., Petri-Fink, A., Rothen-Rutishauser, B. Carbon Nanodots: Opportunities and Limitations to Study Their Biodistribution at the Human Lung Epithelial Tissue Barrier, *Biointerphases*, **2018**, 13, 06D404

Hole in one

_ Developing bigger nanopores

Researchers from the Adolphe Merkle institute's BioPhysics group are seeking to improve nanopores used to measure the properties of large molecules, relying on a method that is simpler and therefore more accessible to a larger number of scientists.

A nanopore is a passage through a surface that is small enough that only one molecule can fit through it at a time. When used to measure properties of molecules, the nanopore is filled with a salt solution, through which an electric current is passed. As a molecule tumbles through the nanopore, its movement causes tiny, measurable fluctuations in the electric current. By carefully measuring this current, researchers can establish a number of the molecule's properties and possibly identify it based on its size, shape, and charge, for instance.

The AMI biophysicists set out to find the most efficient method for fabricating larger so-called solid state nanopores, which exhibit diameters ranging from 20 to 50 nanometers in extremely thin silicon nitride (SiNx) windows. These are especially useful for single-molecule studies of globular macromolecules. To ensure precise measurements, however, it is particularly important that the nanopores be of a size similar to that of the target molecule, such as proteins.

"Nanopores are increasingly used to analyze proteins. The challenge is that proteins come in many different sizes, often quite large, so we have to design nanopores that are big enough to let them pass through," explains Dr. Cuifeng Ying, a postdoctoral researcher in the BioPhysics group.

One method currently used to make these nanopores, with size control and broad accessibility, is known as controlled breakdown (CBD), which uses material defects controlled by an electric current to generate a passage of a specific size. "This method makes it possible to tailor the size of the pore to the molecule of interest – and the procedure can be carried out in any research lab, so that nanopores become accessible to the growing community that carries out experiments on the single molecule level," says AMI's Chair of BioPhysics, Professor Michael Mayer. Typical experiments are carried out on astronomical numbers of molecules in solution, often exceeding one billion.

Yet, the CBD technique reaches its limits at the 20-nanometer mark. Larger sizes result in the unwanted creation of multiple uneven pores instead of single, regular ones. To overcome this problem, the AMI researchers chose to follow two strategies: one approach consists of accelerating defect accumulation within a confined membrane area before breakdown, while the other calls for reducing the magnitude of the electric field applied during enlargement.

"By applying a focused laser beam on the membrane during the breakdown process, and by decreasing the electric field strength during pore enlargement, we tripled the success rate for generating single nanopores with diameters larger than 20 nanometers," explains Ying.

According to the AMI researchers, their work provides evidence that laser-induced local heating contributes to the increased rate of pore formation by controlled breakdown in the target area. A subsequent annealing (heating and cooling) step improved the success rate of coating these nanopores with a lipid bilayer, which is critical in order to be able to quantify the translational and rotational dynamics of a single molecule, without artifacts from molecules sticking to the walls of the nanopore. Future applications of these nanopores include the detection and characterization of protein clumps, so called amyloids, which are relevant in the context of neurodegenerative diseases such as Alzheimer's and Parkinson's disease. Measuring the distribution of the size and shape of amyloid particles may shed light on their toxicity to nerve cells and may serve as a measure to monitor disease progression as well as the success of therapeutic intervention.

Reference

Ying, C., Houghtaling, J., Eggenberger, O.M., Guha, A., Nirmalraj, P., Awasthi, S., Tian, J., Mayer, M. Formation of Single Nanopores with Diameters of 20–50 nm in Silicon Nitride Membranes Using Laser-Assisted Controlled Breakdown, *ACS Nano*, **2018**, 12, 11458

Cuifeng Ying joined AMI's BioPhysics group as a postdoctoral researcher in 2016, where she is investigating the development and application of nanopores, as well as single-molecule detection. Ying earned her PhD in 2013 at Nankai University in China.

BioPhysics

Team

Prof. Michael Mayer, Dr. Saurabh Awasthi, Jessica Dupasquier, Olivia Eggenberger, Dr. Aziz Fennourl, Anirvan Guha, Stéphane Hess, Jared Houghtaling, Trevor Kalkus, Dr. Jonathan List, Melissa Mcguire, Dr. Peter Nirmalraj, Dr. Tom Schroeder, Dr. Lennart de Vreede, Shuran Xu, Dr Cuifeng Ying

Key Publications

1. Nirmalraj, P., Lehner, R., Thompson, D., Rothen-Rutishauser, B. & Mayer, M. Subcellular Imaging of Liquid Silicone Coated-Intestinal Epithelial Cells. *Sci. Rep.*, **2018**, 8, 10763

2. Schroeder, T. B. H., Houghtaling, J., Wilts, B. D., Mayer, M. It's Not a Bug, It's a Feature: Functional Materials in Insects, *Adv. Mat.*, **2018**, 30, 1705322

3. Kim, Y. H., Hang, L., Cifelli, J.L., Sept, D., Mayer, M., Yang, J. Frequency-Based Analysis of Gramicidin A Nanopores Enabling Detection of Small Molecules with Picomolar Sensitivity, *Anal. Chem.*, **2018**, 90, 1635

4. Chen, C., Mordovanakis, A., Hunt, A.J., Mayer, M., Sept, D., Yamashita, Y.M. et al. Cytokine receptor-Eb1 interaction couples cell polarity and fate during asymmetric cell division, *eLife*, **2018**, 7, e33685

5. Houghtaling, J., List, J., Mayer, M. Nanopore-Based, Rapid Characterization of Individual Amyloid Particles in Solution: Concepts, Challenges, and Prospects, *Small*, **2018**, 14, 1802412

On and off

_ Using light to control nanoreactors

In nature, biochemical processes often rely on a system being pushed out of equilibrium before automatically returning to its resting state. One such instance is the mechanism by which light receptors operate in the human eye, which has inspired Adolphe Merkle Institute researchers to develop nanoreactors that function using the same principle.

A molecule within the eye's retinal receptors changes its structure when irradiated with light, and an enzymatic reaction subsequently converts the molecule back into its original form. Without this capacity to revert back to their initial state, the receptor cells would not be able to sense light repeatedly.

Researchers from Professor Nico Bruns' Macromolecular Chemistry group, along with colleagues at the Swiss Federal Laboratories for Materials Science and Technology (Empa) in St. Gallen, adopted this general principle as their blueprint for developing artificial light-responsive catalytic nanoscale systems.

"We were intrigued by a novel class of photoswitches called Donor-Acceptor-Stenhouse-Adducts (DASAs), that colleagues at the University of California, Santa Barbara, have developed," explains Bruns. "They switch from a less polar resting state to a more polar isomer in presence of visible light, and return back to their resting state when the light is switched off."

Bruns and his team integrated such DASA molecules into the membrane of polymer nanocapsules. Upon irradiation with light, the DASAs switch, increasing the polarity of the capsule membrane. As a result, the capsules become permeable for water-soluble substances. This effect can be used to trigger the release of cargo from the nanocapsules. More intriguingly, capsules that host enzymes, in other words, biological catalysts, can be switched from an inactive state in the dark to a catalytically active state when irradiated with visible light. This active state lasts as long as light is present. Once returned to darkness, these nanoreactors automatically revert back to their original state with no catalytic activity. DASAs exist in several colors, which allowed the researchers to create nanoreactors that switch on in response to light of a specified color, such as white, red, or green. By encapsulating one type of enzyme in purple nanocapsules and a second type of enzymes in blue nanoreactors, a mixture of catalysts was obtained that can control and orchestrate enzymatic cascade reactions, kick-started by the different colored lights.

"Light switches can be used for the entire spectrum of colored light from blue to red," notes Empa researcher Luciano Boesel. "This provides scope to control the release of several drugs or complex reaction cascades in a single patch."

Not every medication can be swallowed or pumped into the body with a syringe. Yet, the skin – our largest organ – offers a large permeable surface that readily absorbs active substances. Nicotine replacement, pain therapy, or contraception drugs are already applied through the skin using patches. Now, the Empa researchers are also considering these nanocapsules for use in light-switchable patches for transdermal drug delivery. This future development would enable, for instance, a non-invasive delivery method of essential drugs for premature babies. By embedding drug-filled, light-switchable nanocontainers into patches, the team aims to create the next generation of light-controlled transdermal drug delivery systems.

Work on the concept of light-switchable nanoreactors is being pursued within the framework of the National Centre of Competence in Research (NCCR) Bio-Inspired Materials. The nanoreactors could be used to produce pharmaceutical products on demand, for example within a cell, or to produce active compounds such as drugs during medical treatment in a controlled fashion.

"We have created a platform technology that is very versatile. For instance, we will investigate how to equip polymers with types of DASAs that switch at wavelengths that span the whole visible spectrum, ideally also reaching the near infrared region," Bruns reveals. "This could be very beneficial, as infrared light penetrates deeper into tissue than visible light. This way, we could create light-responsive drug delivery nanosystems that could be activated by irradiation of tissue through the skin."

Reference

Rifaie-Graham, O., Ulrich, S., Galensowske, N.F.B., Balog, S., Chami, M., Rentsch, D., Hemmer, J.R., Read de Alaniz, J., Boesel, L.F., Bruns, N. Wavelength-Selective Light-Responsive DASA-Functionalized Polymersome Nanoreactors, *J Am. Chem. Soc.* **2018**, 140, 25, 8027

Kyle Rodriguez joined AMI's Macromolecular Chemistry group in 2017 as a postdoctoral researcher. He earned his PhD at the University of New Hampshire in the United States earlier that year. His current research focuses on utilizing enzymes as catalysts for atom transfer radical polymerizations to generate materials in a more sustainable fashion.

Macromolecular Chemistry

Team

Prof. Nico Bruns, Edward Apebende, Livia Bast, Bernadetta Gajewska, Micael Gouveia, Dr. Michaela Pellizzoni, Dr. Jonas Pollard, Samuel Raccio, Dr. Omar Rifaie Graham, Dr. Kyle Rodriguez, Sebastian Ulrich, Sara Velasquez

Key Publications

1. Rifaie-Graham, O., Apebende, E. A., Bast, L. K., Bruns, N. Self-Reporting Fiber-Reinforced Composites That Mimic the Ability of Biological Materials to Sense and Report Damage, *Adv. Mat.*, **2018**, 30, 19, 1705483

2. Caciagli, A., Zupkauskas, M., Levin, A., Knowles, T. P. J., Mugemana, C., Bruns, N., O'Neill, T., Frith, W. J., Eiser, E. DNA-Coated Functional Oil Droplets, *Langmuir*, **2018**, 34, 34, 1007

3. Ulrich, S., Sadeghpour, A., Rossi, R. M., Bruns, N., Boesel, L. F. Wide Range of Functionalized Poly(N-Alkyl Acrylamide)-Based Amphiphilic Polymer Conetworks via Active Ester Precursors, *Macromolecules*, **2018**, 51, 14, 5267

4. Rodriguez, K. J., Gajewska, B., Pollard, J., Pellizzoni, M. M., Fodor, C., Bruns, N. Repurposing Biocatalysts to Control Radical Polymerizations, *ACS Macro Lett.*, **2018**, 7, 9, 1111

5. Rifaie-Graham, O., Hua, X., Bruns, N., Balog, S. The Kinetics of ß-Hematin Crystallization Measured by Depolarized Light Scattering, *Small*, **2018**, 14, 1802295

In brief

Swiss Youth in Science

The NCCR Bio-Inspired Materials participated in the 2018 Chemistry and Materials Science Study Week organized by Schweizer Jugend Forscht (Swiss Youth in Science), a program that offers high school students from all over the country the opportunity to spend a week performing a short research project in a lab at an academic institution or at a company. This year, five NCCR groups from the Adolphe Merkle Institute and the University of Fribourg's Department of Chemistry hosted students. The NCCR also coordinated the stay and activities of the participants in Fribourg, and organized the closing ceremony of the Study Week, bringing together all forty participants as well as their families and hosts took place at AMI.

Awards

Céline Calvino (Polymer Chemistry & Materials group) was the winner of one of the five Swiss Nanotechnology PhD Awards presented at the Swiss NanoConvention 2018 in Zurich. She was recognized for her work on mechanochromic materials based on non-covalent interactions.

Laura Neumann (Polymer Chemistry & Materials group) took home the Swiss Chemical Society Polycoll Best Oral Presentation Award at the 2018 SCS meeting for her talk on the "Dynamics and Welding Behavior of Metallosupramolecular Polymer Films."

Calvino and her colleague *Omar Rifiae Graham* (Macromolecular Chemistry) were both awarded Swiss National Science Foundation postdoctoral mobility grants, allowing them to join research groups at the University of Chicago and Imperial College in London, respectively, in 2019.

Science Slam

The 2018 edition of the University of Fribourg's Science Slam was once again an opportunity for AMI staff to shine.

The competition winner was PhD student Preston Sutton (Soft Matter Physics) with his provocatively titled presentation "Let's drink and drive!" which focused on batteries for autonomous vehicles. Meanwhile, his colleague Johannes Bergmann (Soft Matter Physics) finished third with his talk on bio-inspired research. AMI group leader Dr. Ilja Gunkel presided the organizing committee for this year's edition.

Bio-inspired conference

Over two days in June, AMI hosted the 24th Annual Meeting of the Swiss Society for Biomaterials and Regenerative Medicine.

In addition to presentations on the traditional topics of biomaterials and regenerative medicine, bio-inspired materials were the special focus of the conference. This included a keynote speech from AMI Director Professor Christoph Weder on Bio-inspired stimuli-responsive materials. Another highlight came when PhD student Manuela Estermann of the BioNanomaterials group was awarded the best poster prize for her work on “3-D bioprinting of a human omentum model: Mimicking the mesothelial cell layer and microenvironment *in vivo*”.

Going Wild!

AMI was present at the Zurich Zoo’s Going Wild! weekend for the second time in September 2018, along with researchers from Switzerland’s two federal institutes of technology, ETH and EPFL.

As part of the “Science inspired by nature” exhibits on show, the Soft Matter Physics group displayed butterflies and beetles to help explain structural color, while the Polymer Chemistry & Materials group was also present to demonstrate shape-changing polymers.

Career moves

AMI staff continue to move up the career ladder. Postdoctoral fellow *Dr. Khay Fong* (BioNanomaterials) was appointed to a Lecturer position at the University of Newcastle (Australia), where she is now conducting research on amphiphilic self-assembly, drug delivery, as well as colloid and interface science.

Dr. Alessandro Sepe (Soft Matter Physics) joined the Big Data Science Center of the Shanghai Synchrotron Radiation Facility at the Zhangjiang National Laboratory, which is part of the Chinese Academy of Sciences, as a Visiting Professor in 2018. He was recently appointed Full Professor and serves as director of the data science center.

Dr. Marc Pauchard, AMI’s long-time Deputy Director, joined Innosuisse, the Swiss Innovation Promotion Agency, as Head of the Knowledge Transfer & International Collaborations Division. Pauchard had been active at the Institute since 2009. His role as Deputy Director was taken over by Prof. Ullrich Steiner, AMI’s Chair of Soft Matter Physics.

Master's program

The first students to complete the two-year Specialized Master of Science in Chemistry and Physics of Soft Materials have graduated from the program.

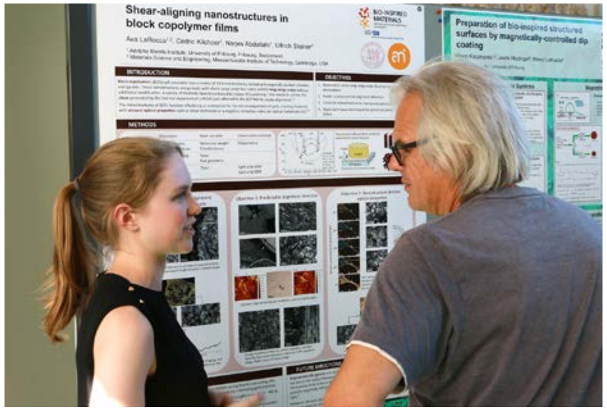
Jake Hooton successfully defended his thesis on "Graphoepitaxial Directed Self-Assembly of a Gyroid-Forming Triblock Terpolymer in Thin Films" as a member of the Institute's Soft Matter Physics group, while Phattadon ("Samat") Yajan graduated after conducting research on "Incorporation of nanofillers to prevent water uptake in epoxy-based microstructures" in the BioNanomaterials group.

Field trip

AMI Soft Matter Physics researchers Dr. Bodo Wilts and Dr. Esteban Bermudez travelled to Costa Rica to collect silver beetles *(Plusiotis optima)* for their work on structural color.

Their research project seeks to develop a fundamental understanding of the coloration in these species, and also inspires the biomimetic development of artificial structures with novel optical properties.

Thanks to a Seed Money Grant from the Swiss National Science Foundation, a cooperation partnership between the Institute and the Center for Material Science and Engineering (CICIMA) at the University of Costa Rica was established. The goal of the partnership is to study new structural color effects in beetles found in Costa Rica's cloud forests and to develop artificial optical structures inspired by the beetles by means of state-of-the-art nano- and microfabrication techniques. Two internships were also offered to students from the University of Costa Rica to develop short projects at the Adolphe Merkle Institute.



Summer research program

In 2018, AMI once again hosted 10 students from the National Center of Competence in Research (NCCR) Bio-Inspired Materials' successful Undergraduate Research Internships program. The students not only completed a research project, but also attended a special series of seminars conducted by PhD students and postdoctoral researchers and took part in team-building events. The participants, who came from universities such as Durham University (United Kingdom), Case Western Reserve University and the University of Utah (United States), or the University of Technology Eindhoven (Netherlands), were also asked to prepare poster presentations describing their projects, which were presented during a special session at the NCCR Summer Party at AMI. Ava LaRocca of the Massachusetts Institute of Technology, who was hosted by the Soft Matter Physics group, won the award for the best poster prize in 2018.

PATROLS

The Adolphe Merkle Institute has joined an international effort to address the need for safer and more effective testing of engineered nanomaterials (ENM), an area that is of crucial – and still growing – importance to billion-franc markets including cosmetics, electronics, medicine, and food. The project PATROLS (Physiologically Anchored Tools for Realistic nanOmateriaL hazard aSsessment) is financed by the European Commission's Horizon 2020 initiative at a level of €12.7 million (CHF 14.8 million) and unites 24 partners across Europe, the United States, and Asia with representatives from academia, industry, and government. Over the course of three and a half years, the PATROLS scientists aim to establish a battery of innovative, next-generation safety testing tools that more accurately predict adverse effects caused by long-term ENM exposure in humans and the environment. AMI BioNanomaterials co-chair Professor Barbara Rothen-Rutishauser serves as the leader of the module “Advanced in vitro pulmonary models for ENM assessment.”

PIRE

The international collaboration PIRE: Bio-inspired Materials and Systems held its first annual meeting in June 2018 at Case Western Reserve University in Cleveland, Ohio (United States).

Faculty members, staff members, and students from all of the Bio-inspired PIRE sites, including AMI staff members, attended and took part in discussions on updates to research, education and evaluation, as well as team-building activities. Researchers from AMI and four American universities are pursuing a novel partnership funded by the US and Swiss National Science Foundations to develop functional materials inspired by substances found in nature.

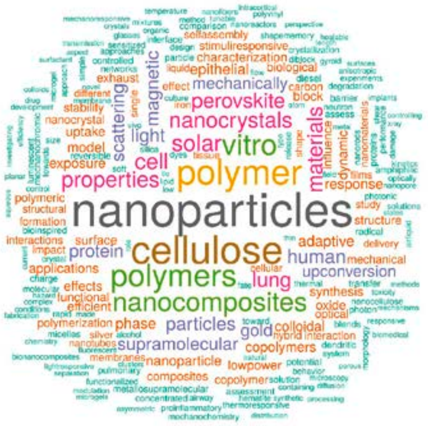
Hemolytics

The Institute’s ongoing malaria diagnostics project, Hemolytics, has managed to accrue funding from a variety of sources to cover salaries and development costs, including an extension of the BRIDGE grant from Innosuisse and

the Swiss National Science Foundation, and a grant from the Gebert Rüf Foundation worth CHF 290,000. Initial field testing was carried out in Brazil with funding from a Seed Money Grant from the Swiss National Science Foundation, providing crucial feedback for the future development of the diagnostic tool.

Special journal issues

2018 allowed AMI to leave its mark on scientific publishing, with its researchers editing two special issues of the leading journals *Advanced Materials* and *Small*.



The *Advanced Materials* special issue, published in May, and edited by AMI Professor Nico Bruns and his University of Cambridge colleague Dr. Silvia Vignolini, presented bio-inspired materials across all length scales, including wood-based water purification systems, mussel protein inspired glues, fiber-reinforced composites that indicate damage by bleeding, pigments and coatings that mimic the structural colors of insects and plants, and architecture inspired by the moving parts of plants. Papers included contributions from the groups of AMI Professors Alke Fink, Barbara Rothen-Rutishauser, Christoph Weder, Michael Mayer, and Ullrich Steiner.

To mark the tenth anniversary of AMI's creation, the Institute joined forces with *Small* – an influential, high-impact weekly peer-reviewed scientific journal covering nanotechnology – to produce a special issue showcasing research currently being pursued by the Institute's staff and alumni. Published in November, the edition comprised a range of topics that are illustrative of the Institute's interdisciplinary approach. With 20 high-quality contributions on fields as diverse as self-assembling materials, innovative detection systems, data management and nanofibers, the issue also highlighted the scientific activities of past and current staff.

Visits

AMI continues to host high-profile visits throughout the year.

In 2018, the City of Fribourg's (executive) council, led by the mayor, Thierry Steiert, was given an overview of the Institute's activities by its Deputy Director Professor Ullrich Steiner, along with a guided tour of the facilities.

Staff from a federal agency, the State Secretariat for Education, Research, and Innovation, also visited AMI as one of the highlights of a special excursion to Fribourg to learn more about the canton's scientific prowess.

Winter school

Nearly 20 AMI staff members, including PhD students, postdoctoral researchers, and professors, attended the NCCR Bio-Inspired Materials/ITN PlaMatSu Winter School in St. Moritz organized in January 2018 by Macromolecular Chemistry Professor Nico Bruns.

Sessions included talks, seminars – many delivered by the students and postdocs – and workshops. Additional talks covered standardization in biomimetics and biomimetic idea generation in industry. The winter school served to create strong ties between NCCR and ITN members that will certainly result in future collaborations.


PURE LAB HE

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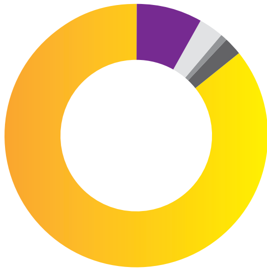
_ Finance & Organization

Finance

_ Cost structure at AMI

The Adolphe Merkle Institute's overall expenditures in 2018 were CHF 10.4 million. 86% of this sum was spent on research, while an additional 2% was invested in research equipment. Around 3% of the budget supported valorization activities such as technology transfer, and communication & marketing, with another 8% used for administration costs.

Overall expenses 2018
CHF 10.4 million



- Research / 86%
- Administration / 8%
- Valorization / 3%
- Education / 1%
- Research equipment / 2%

Funding sources of overall expenses 2018

- Adolphe Merkle Foundation / 35%
- Grants / 51%
- University of Fribourg, Canton Fribourg / 10%
- Industry / 4%

Funding sources of research projects 2018
CHF 8.9 million

- Adolphe Merkle Foundation / 32%
- Third-Party / 57%
- University of Fribourg / 11%

Third-party funding of research projects 2018
CHF 5.7 million

- SNSF / 62%
- EU / 17%
- Innosuisse / 8%
- Industry / 7%
- Other sources / 6%

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 and support 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

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Thierry Mettraux
Responsible for Finance & Controlling

Dr. Valeria Mozzetti (from June 2018)
Head of Knowledge and Technology Transfer, Grant Writing

Dr. Frédéric Pont (until May 2018)
Grant Writing

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PhDs & Alumni

PhDs

Our new doctors

Christoph Bisig
(BioNanomaterials)
"Hazard identification of gasoline engine exhausts using a multi-cellular human lung model"

Federica Crippa
(BioNanomaterials)
"Magnetic nanoparticles and cell mechanics: towards magneto-responsive substrates for cells"

Michael Fischer
(Soft Matter Physics)
"Structured battery materials by polymer self-assembly and sol-gel chemistry"

David Bossert
(BioNanomaterials)
"Nanotechnology in the service of wood protection"

Ana Milosevic
(BioNanomaterials)
"Fluorescently labeled gold #nanoparticles – interactions with biomolecules, cells and intracellular fate"

Omar Rifiae Graham
(Macromolecular Chemistry)
"Cell inspired force and light responsive polymersome nanoreactors and polymerisation based diagnostics"

Céline Calvino
(Polymer Chemistry & Materials)
"Mechanochromic materials based on non-covalent interactions"

Karolina Godlewska (née Korzeb)
(Soft Matter Physics)
"Controlled self-assembly of gyroid-forming block copolymer templates for optical metamaterials"

Dominic Urban
(BioNanomaterials)
"Adapting Taylor-Aris Dispersion Analysis to nanoparticle characterization and characterizing nanoparticles in complex physiological environments"

Sebastian Ulrich
(Macromolecular Chemistry)
"Visible light-responsive amphiphilic polymer co-networks based on DASA photoswitches"

Alumni

People who left AMI in 2018

Dr. Christoph Bisig (BioNanomaterials)
Dr. David Bossert (BioNanomaterials)
Prof. Dr. Nico Bruns (Macromolecular Chemistry)
Dr. Céline Calvino (Polymer Chemistry & Materials)
Lucie Castens (Soft Matter Physics)
Dr. Federica Crippa (BioNanomaterials)
Dr. Michael Fischer (Soft Matter Physics)
Dr. Khay Fong (BioNanomaterials)
Dr. Barbara Fraygola (NCCR Bio-Inspired Materials)
Bernadetta Gajewska (Macromolecular Chemistry)
Dr. Karolina Godlewska (Soft Matter Physics)
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Dr. Lennart de Vreede (BioPhysics)
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AMI

Impressum

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