2016 _Annual Report

UNIVERSITÉ DE FRIBOURG
UNIVERSITÄT FREIBURG

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 Foundation bearing his name with the goal of strengthening research and teaching at the University of Fribourg. This in turn led to the constitution of AMI. His CHF 100 million endowment remains 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 five research groups that offer complementary expertise and interests in strategically important areas: BioNanomaterials, Macromolecular Chemistry, Polymer Chemistry & Materials, Soft Matter Physics, and BioPhysics. Interdisciplinary collaborations between our researchers are the basis for the successful and efficient execution of complex research projects that transcend the boundaries of traditional scientific disciplines. This environment and our world-class research facilities make AMI a desirable destination for master's and PhD students, postdocs, and established researchers.

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Sharing our passion

A word from the Director

Christoph Weder

Many of my colleagues tell me that they consider working at AMI a privilege. We love what we do and the institute provides us with a fantastic environment to conduct world-class interdisciplinary soft nanomaterials research, innovate, and educate and inspire the next generation of scientists. Sharing our successes, and sometimes also failures, is an important aspect of our profession. Most of our knowledge transfer activities target our scientific peers. Indeed, we spend a considerable amount of time publishing our results in research journals and presenting our findings at scientific conferences. Many of our communication efforts, however, are directed towards other audiences. For example, last year, we hosted the Expo Nano, a travelling exhibition that attracted, among other visitors, several high school classes. We also presented our work in *Einstein*, the premier science broadcast on Swiss national television. We welcomed many visitor groups, ranging from government agencies and companies to non-profit organizations. Each year, we also enjoy producing this annual report, which is yet another opportunity to convey to the public the fruits of our research, innovation, and education endeavors and their importance for society. Moreover, we hope that it also expresses and transmits the passion we feel for our work.

As every year, research is at the heart of this report. Our Biophysics group, established only in 2015, published a seminal study on protein fingerprinting, which represents an impressive step towards a diagnostic tool for the identification of complex biomolecules. The Polymer Chemistry and Materials team reported the development of a new type of self-healing materials, while the Soft Matter Physics group forged on with their groundbreaking work on the development of next-generation solar cells. The BioNanomaterials group pursued the vital task of defining nanosafety for consumers, and researchers investigated new methods that could improve drug delivery. One of the final contributions from the Self-Assembly team led by SNSF Professor Marco Lattuada, who has in the meantime assumed a permanent position in the University of Fribourg's Department of Chemistry, focused on the treatment of blood infection using magnetic nanoparticles.

This year's issue also emphasizes education, one of the key missions of our institute. With the launch of our new specialized Master in Science, "Chemistry and Physics of Soft Materials," and the Innovative Training Network "Plant Materials Surfaces" (PlaMatSu), our training activities received a major boost. Both programs integrate education and research, emphasize scientific excellence and innovation, and seek to enhance researchers' career prospects through fostering transferable skills. We are also proud to introduce some of our most promising young scientists and share with you how experiences at AMI have contributed to the careers of some of our first alumni.

Thank you for your interest in our work and for supporting our efforts to realize Adolphe Merkle's vision of establishing AMI as a leading competence center for fundamental and applied interdisciplinary research in the field of soft nanomaterials.

Christoph Weder
AMI Director and Professor for Polymer Chemistry
& Materials


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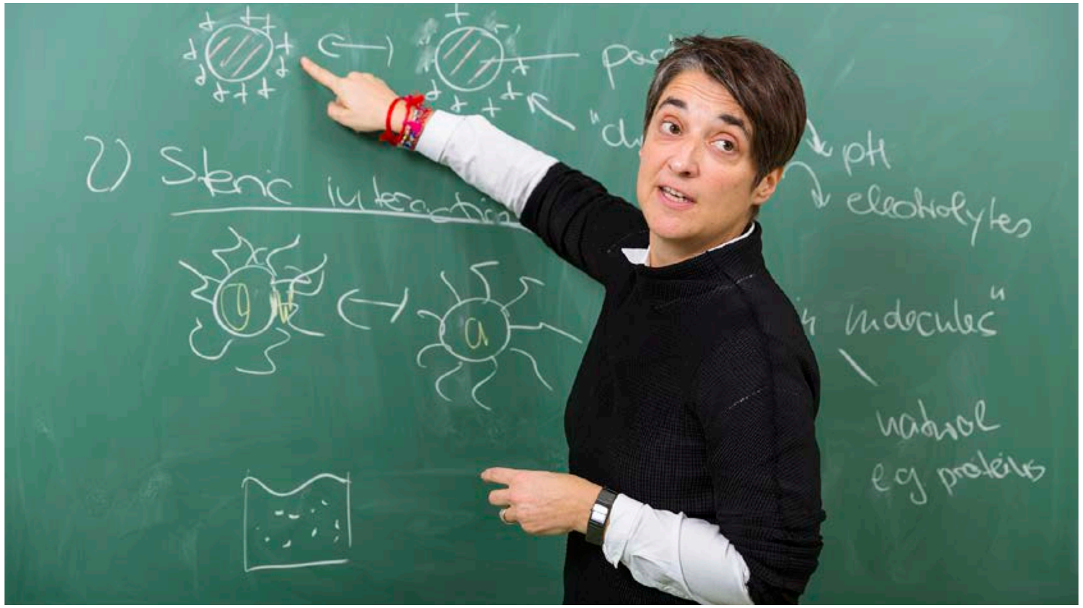
Sailer

7

_Pursuing excellence

Education

_ Preparing a new generation of scientists



Professor Alke Fink has spearheaded the new AMI master program with Professor Ullrich Steiner

The Adolphe Merkle Institute has always put a strong emphasis on education. This aspect has been reinforced recently with AMI's promotion of a unique master's program focusing on soft materials in collaboration with the University of Fribourg. The institute also continues to provide its PhD students with unique training opportunities and to help them prepare for the next step in their careers.

The creation of the Master in Science program, "Chemistry and Physics of Soft Materials," was a major milestone for AMI. Its goal is to provide participants with a strong understanding of soft materials by offering them a unique two-year interdisciplinary curriculum at the University of Fribourg at the interface of physics, chemistry, biology, and materials science. "We have tried to offer something that is not readily available, and our expertise is handsomely completed with that found in the physics and chemistry departments at the University of Fribourg," says AMI BioNanomaterials co-chair Professor Alke Fink, who is responsible for the program, along with the institute's Soft Matter Physics chair, Professor Ullrich Steiner.

Master students participate in ongoing research projects as part of their curriculum with the goal of learning the techniques related to the project, as well as acquiring new skills to deal with obstacles facing a group's research.

"We teach how science works, make the students understand that everything doesn't always work out as anticipated, that ideas do not guarantee a working result," explains Fink. "There is also a sense of satisfaction when a project is successful, as it helps justify all the efforts made."

One of the motives for setting up the master program was also to train candidates for AMI's own PhD program, particularly by showing them the many domains covered at the institute as well as its offer of a broad palette of scientific knowledge in a multicultural environment.

"We have a lot to offer at AMI, there is a constellation of opportunities. This is worth showing to students who are interested in variety beyond the scope of traditional disciplines," adds Fink. "What sets us apart from other research centers is our promotion of the role research plays in the value chain of innovation as part of our training, which is a benefit of our structure at AMI."

Training PhD students is one of the institute's core missions, and around half of AMI's staff is working its way towards a doctorate, the final stage before they embark on their careers. Fink says that professors have a duty to provide students with guidance and thereby ensure that the students are ready to make the next step after three to four years at the institute. "I want our students to be decent people, to acquire social skills, and to be prepared to take responsibility for others," she declares. "This can truly make a difference when they start looking for a position. This often becomes apparent to PhD students six months before the end of their thesis, when they realize that they have to decide what their future direction will be."

However, it's not just about fundamental and applied science. Transmitting AMI researchers' passion for science to the wider public, an important stakeholder, is also part of the institute's educational mission.

"It's important that we go outside the university to get children, teenagers, and adults interested in science. Projects like KidsUni, which brings science to primary schoolchildren, or open days have a role to play," says Fink. "In the current political climate, where science is being challenged – rightly or wrongly – we have to get our message out. But it is just as important to have a dialogue. We have to provide relatable information so there can be an exchange between both sides."

AMI will continue to pursue its educational mission by training well-rounded – and well-grounded – scientists of the highest caliber, who are capable of finding their place in society and pursuing significant and relevant research.

Communicating science

_ Reaching every stakeholder

Professor Ullrich Steiner says that scientists must clearly identify their audience when communicating

Communication is an important part of any researcher's activity. Traditionally, this task was limited to publishing peer-reviewed articles and giving talks to other scientists. In recent years, this has changed, with increasing interest from funding agencies and other stakeholders to better understand the outcome and potential future impact of sponsored research projects, as well as to make knowledge accessible to non-experts. However, researchers at the Adolphe Merkle Institute see this as more than just a duty: communication is a natural extension of their passion for science. The head of the Soft Matter Physics group at the Adolphe Merkle Institute, Professor Ullrich Steiner, explains the changing communications landscape.

23

NATIONALITIES

ARE PRESENT AT AMI, WITH STAFF COMING FROM EUROPE, NORTH AMERICA, SOUTH AMERICA, AFRICA AND ASIA.

6

PROFESSORS

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

56%

OF ALL RESEARCH EXPENDITURES

WERE COVERED BY THIRD-PARTY FUNDING FROM SOURCES SUCH AS THE SWISS NATIONAL SCIENCE FOUNDATION, THE EUROPEAN UNION, INDUSTRIAL PARTNERS, AND THE SWISS COMMISSION FOR TECHNOLOGY AND INNOVATION.

2064

CITATIONS

OF AMI PUBLICATIONS IN 2016.

9

PROJECTS

WITH INDUSTRY PARTNERS INCLUDING 2 RESEARCH MANDATES.

90

SCIENTIFIC PUBLICATIONS

IN PEER-REVIEWED JOURNALS INCLUDING CHEMICAL SOCIETY REVIEWS, NATURE NANOTECHNOLOGY, NATURE COMMUNICATIONS, NATURE MATERIALS, ADVANCED ENERGY MATERIALS, ADVANCED MATERIALS, NANOSCALE, MATERIALS HORIZONS, ACS NANO.

170

ALUMNI

INCLUDING POSTDOCTORAL RESEARCHERS, PHD STUDENTS, AND INTERNS.

To what extent is science communication part of a researcher's job?
Ullrich Steiner: It's one of the most important aspects of good research. We have realized that scientists can no longer hide in an ivory tower and must communicate with multiple stakeholders. This is something I try to teach all my students.

The whole purpose of science is making results publically available. Besides discussing our results with our peers, we also need to communicate with the general public. If you do great work, you have to let people know about it. While many researchers actually love to talk about their work, their passion, interfacing with the general public requires skills that scientists aren't usually taught: making science understandable to non-expert audiences. Concepts are hard enough for researchers to understand at times, but explaining them to a wider public requires an even deeper understanding, as well as the ability and willingness to simplify. For some people, this comes naturally, but this doesn't hold true for everyone.

It is also important to communicate our results to our sponsors, because they hold us accountable, especially with the pressure to justify budgets and support, and they need to see that significant progress is being made.

So do researchers have to adapt their message?
Absolutely! Science communication has multiple stakeholders. For researchers, the first target group is their peers as they try to disseminate results. The second group is the funding agencies, who need to be convinced of the value of the research. Finally, the third group is the public, who want to see their money spent well. Besides these groups, we have to work out how to interest youngsters in science careers, how to convey our passion, or how to communicate the value of our research to potential industrial partners. Each time a scientist has to communicate, he or she has to figure out who the audience is. The biggest failure would be to misjudge that.

Publishing in specialized journals is a large part of that communication. How important is it for careers?
The key channel for communicating scientific results among researchers remains our papers, often referred to as "the currency of our trade." Of course, measuring the impact of a researcher's output based on his or her papers is a science in itself. The value of our papers is based mainly on the merit of the science they present. But if you can present that science as a well-crafted story, and make it more accessible and more attractive to read, it becomes easier to publish one's work and garner the attention of a wider audience.

What are the biggest challenges scientists face now with regards to communication?
Scientists need to maintain a link with the wider public. With the "no truth, just opinions" movement, there are additional challenges when trying to get ideas across. This is especially hard for scientists, who don't deal with absolute truths, but elaborate hypotheses based on research. Opinions, on the other hand, are just absolutes. This disadvantage for researchers means they have an even bigger responsibility to set the record straight whenever possible. The other problem is that science has expanded to the point where it is hard to stand out in the crowd, as there is so much going on.

Reaching a wider public ideally involves communicating something new and exciting. How do you reconcile this parameter with the reality that science is mostly slow and incremental?
When you are talking to a general audience, you have to provide the big picture, describe how knowledge is advancing in the field, and infuse some passion. When you talk to your peers, you tend to present incremental changes. What you have to keep in mind, though, is that all those incremental changes can add up to something big happening.

How difficult is it for scientists to get their message across to the public in this day and age?
In terms of the message we want to get to the public, we have to explain that the world is complex. To better achieve this, we may have to teach young scientists during their studies the best way to communicate with the general public. Nothing can be explained as a simple truth: if you do that, the only thing you will achieve is to dumb down the discussion.

People might also believe false ideas because we as scientists don't defend the right ones well enough. At the same time, there is too much scaremongering going on. So the onus is on us to stay enthusiastic, keep the passion alive, to maintain a reasonable dialogue with the public, and to be worthy of their trust.

NanoLockin

_ Optimizing magnetic nanoparticles to beat cancer

Samples are prepared for testing with the NanoLockin system

A new cancer therapy using nanoparticles to treat tumors is beginning to attract attention across Europe. However, the therapy is still in its infancy. AMI BioNanomaterials researchers have been exploring the use of aviation imaging technology to improve the selection of the particles used in this promising method.

Most people know someone who is suffering from, or has suffered from, cancer. This is not surprising: the World Health Organization names cancer as one of the leading causes of mortality around the world, with approximately 14 million new cases diagnosed every year. With each form of cancer comes a cohort of often harsh treatments ranging from surgery to chemotherapy and radiation therapy.

A new type of treatment, magnetic hyperthermia, promises less pain and fewer side effects. The treatment involves injecting a tumor site with iron oxide nanoparticles, then heating the particles using an alternating magnetic field. If successful, the heat generated destroys the tumor. Some medical specialists are already calling this technique the fourth pillar of cancer treatment, alongside the more traditional approaches.

> "With NanoLockin, producers of therapeutic nanoparticles have a tool to easily and precisely control, as well as improve, their products."
> *Christoph Geers, NanoLockin*

However, the therapy, which is being tested in a number of European hospitals, has its pitfalls. To work efficiently, the dosage of nanoparticles has to be exactly right and the particles must have consistent properties, something that is never certain when working at the nanoscale. Even minor variations can diminish the likelihood of a positive outcome.

"Current measurement systems used to characterize these particles rely on fiber optics plunged into a nanoparticle suspension, but this method is less than reliable and suffers from various disadvantages, such as low reproducibility, long measurement times, and the risk of biased data treatment," says AMI researcher Dr. Christoph Geers.

To overcome these problems, AMI scientists developed a way of characterizing the nanoparticles. In order to be able to visualize the reactions of particles heated by a magnetic coil, they chose lock-in thermography, an imaging technology originally developed for the quality control of aircraft parts, as the starting point for their project.

The scientists at AMI, led by the BioNanomaterials group co-chair, Professor Alke Fink, together with Dr. Mathias Bonmarin of the Zurich University of Applied Sciences (ZHAW), developed what they called the NanoLockin method, which can precisely measure the distribution of the nanoparticles as well as the heat they generate.

This technology relies on applying an alternating magnetic field and infrared imaging to precisely measure the heat produced by the nanoparticles. The results are then evaluated using software developed especially for this system. An algorithm provided by the ZHAW is used to determine the nanoparticles' heating properties based on how they react to the magnetic field.

There is also no contact between the measurement device and the sample, meaning nanoparticles can also be observed in realistic environments, such as tissue samples. Therefore, by using the NanoLockin method, production and dosing of those nanoparticles can be optimized.

"If we want to pursue the development of magnetic hyperthermia, it is extremely important to precisely measure and understand the properties of the nanoparticles being used," says Geers. "With NanoLockin, producers of therapeutic nanoparticles have a tool to easily and precisely control, as well as improve, their products."

When nanoparticles are used for cancer therapy, for example, this would mean that the particle concentration is optimized for its target. Consequently, this would also mean that the treatment would work faster, more successfully, and at a lower cost.

According to Geers, this method of measurement has been validated. The team has built two prototypes and established an initial business concept. They have also managed to attract attention to their idea, particularly by placing third in the Ypsomed Innovation Fund's 2017 Innovation Award for research, development, and technology transfer.

Now, the NanoLockin team would like to build on this success. "In the next stages, we must focus on the market and develop potential customer contacts," Geers asserts. "With customer feedback, we can challenge our business idea and start to establish an even more solid business plan that we hope to finalize by the end of 2017."

Malaria diagnosis

_ A simple test to reduce uncertainty

A new diagnostic method for malaria that is currently under development at the Adolphe Merkle Institute could help to eradicate the disease, improve treatment protocols for patients, and help reduce healthcare costs.

The World Health Organization (WHO) estimates that worldwide, there were approximately 212 million new cases of malaria in 2015, while more than 490,000 people died as a result of the illness. However, between 2010 and 2015, disease and mortality rates for malaria declined 21% and 29%, respectively, thanks to improved detection, prevention, and treatment.

Current WHO practices recommend diagnostic testing for all suspected malaria cases before treatment is administered. “There are different reasons for this,” says AMI PhD student Jonas Pollard. “Problems to avoid include overtreatment, boosting the resistance of the malaria parasite, and wasting resources when funding is thin on the ground.”

Rapid diagnostic testing, introduced in recent years, helps distinguish between malarial and non-malarial fevers. Medical staff can then decide on an appropriate course of treatment. This inexpensive solution has become a favored method of testing for malaria, with approximately 270 million test kits sold in 2015. However, these tests are not always as reliable as they should be.

For countries where malaria has almost disappeared, the biggest concern is detecting human carriers of the disease in order to avoid fresh cases. A person can be infected with malaria without displaying any physiological signs of infection, meaning there is a risk of unwanted transmission and of the parasite returning to an area from which it had been previously eradicated.

It is especially these carriers that are the prime target of the diagnostic method being developed at AMI by members of Professor Nico Bruns’ Macromolecular Chemistry group. “You want to be able to check if someone is an asymptomatic carrier,” explains project leader Pollard. “That way the spread of the disease can be limited, for example by carrying out checks at a border, and our method is far more sensitive than the rapid diagnostic tests that are currently on the market.” The test developed at AMI is based on an exceedingly simple yet powerful principle. At each stage of its life cycle, the malaria parasite produces a biomarker, which is present in a patient’s blood even if no other symptoms of an infection are apparent. AMI researchers discovered that this biomarker also happens to be an efficient catalyst for certain polymerization reactions, and they recognized that this effect can be used to devise an amplification scheme that permits the detection of even ultra-low concentrations of the malaria marker. Indeed, one marker molecule can initiate and mediate the formation of many polymer molecules. Thus, if a blood sample from an infected patient is combined with a suitable monomer, the latter is polymerized by the malaria marker, causing the easily detectable clouding of the test solution. By contrast, if the malaria marker is absent, the test solution remains clear, indicating that the individual is not infected.

> “There are currently no tools on the market that allow for an accurate and ultra-sensitive malaria diagnostic with high throughput.”
> *Jonas Pollard, PhD student*

However, the advantages of this method do not end there. The amount of the biomarker in a person’s blood can also be estimated, as the speed of the polymerization reaction depends on how much of the biomarker is present in the sample. This could be applied to determine if the condition of a patient being treated for malaria is improving, for example.

Another advantage is the stability of the reagents used for the test. Most rapid diagnostic tests require cooling to keep the antibodies they use from degrad-

Jonas Pollard conducts a malaria test

ing, and this is not always possible in regions where the disease is most prevalent. The AMI method, on the other hand, has been tested after the materials were stored at temperatures up to 50 °C over several months and the compounds used remained stable. In addition, its estimated cost is not higher than that of other tests already in use.

Pollard is optimistic that there is a market for this new technology, which is why he and his colleagues filed a provisional patent in May 2016. “There are currently no tools on the market that allow for an accurate and ultra-sensitive malaria diagnostic with high throughput,” he adds. “Our product would fill a crucial niche in the elimination of this parasitic disease.”

The malaria detection project also fulfills another important criterion for research at AMI, according to the institute’s vice-director and head of for technology transfer, Dr. Marc Pauchard. “With this type of project, we can fulfill Adolphe Merkle's vision of creating significant impact for society based on our research,” he points out. “Ideally, it will live up to its potential and lead to the creation of a technological start-up.”

Alumni

_ Working up the career ladder

Corinne Jud is a division head at the Swiss federal center of excellence for agricultural research

Since its launch in 2008, the Adolphe Merkle Institute has been a workplace and place of learning for many people. There are around 170 alumni affiliated with the institute: former interns, master students, PhD students, post-doctoral researchers, administrative staff, technicians, and professors. They form a worldwide network, working in sectors such as public service, academia, and industry.

Corinne Jud is a case in point. She joined AMI early on in 2010 to pursue post-doctoral research in Professor Peter Schurtenberger's Soft Nanosciences group, where she investigated the structural and dynamic properties of eye lens proteins. She transferred to Professors Alke Fink and Barbara Rothen-Rutishauser's BioNanomaterials group in 2011, where she focused on a human air-blood barrier cell culture model. She was also a member of the team that planned the construction and the acquisition of laboratory equipment for AMI's new buildings at the University of Fribourg.

Jud has an extremely positive view of her time spent at AMI. "It was amazing to work in such a dynamic and interdisciplinary environment," she said. "Especially in the beginning, the pioneer spirit seized us all and everyone contributed actively in developing the institute in one way or another."

She left the institute in 2013 to take up a position at Agroscope, the Swiss federal government's center of excellence for agricultural research. Today, she is a member of Agroscope's executive board as well as the head of the Method Development and Analytics division with over 120 collaborators.

Jud says that her work at AMI helped her actively prepare for the next stage of her career, acquiring a number of skills that have served her well ever since.

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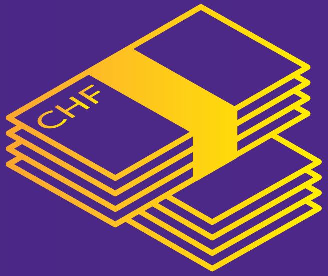
ACTIVE RESEARCH PROJECTS

IN FIELDS SUCH AS SELF-HEALING BREATHABLE MEMBRANES, OPTICAL METAMATERIALS, TARGETED CELL KILLING, BIOENGINEERING OF FUNCTIONAL 3D LUNG TISSUE, AND MECHANICALLY RESPONSIVE POLYMERS.

CHF 8.8 mio



SPENT IN 2016

RESEARCH SPENDING ROSE FROM CHF 7 MILLION IN 2015 TO CHF 7.5 MILLION.

38%

WOMEN

62%

MEN

WORKING AT AMI.

94

PEOPLE

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

45%

OF OUR STAFF

ARE PHD STUDENTS.

"AMI's interdisciplinary approach allowed me, for example, to broaden my scientific vocabulary," she reveals. "Since the activities of the competence division that I am currently leading range from biology to chemistry and physics, the ability to communicate easily with all collaborators is essential."

Agroscope is currently undergoing significant changes, building new facilities at a number of its sites. For Jud, the experience she garnered working on the AMI building project has proven to be invaluable. Being part of the extended management also allowed her to sharpen her leadership skills and to contribute to the shaping of the institute. "All of this is more than helpful in my current position," she adds.

Last but not least, she learned how important networking and marketing are for careers. "The best results are worth nothing if you are not able to present them to the right audience in the right way," Jud insists.

Yoan Simon, a former member of Professor Christoph Weder's Polymer Chemistry and Materials group concurs. "Salesmanship and story-telling are very important aspects of academic life," he says. "It's not enough to have good results; you must present them well, too."

Simon, who was a group leader until the end of 2015, has followed what many consider the traditional academic path, which has led to his current position as Assistant Professor in the School of Polymers and High Performance Materials at the University of Southern Mississippi in the United States. However, his path was far less linear than what most people imagine. His time at AMI was vital in helping him advance in his career.

"It helped me rekindle my passion for what I do," he explains. "I was not so sure about my academic calling anymore and working at the institute reminded me of why I was set on a faculty position."

"It allowed me to get mentorship and a well-funded research environment, and probably blossom to a level that may not have been possible if I had been thrown in at the deep end in the US system for instance," Simon says. "I needed some time to mature and get ready for my current position. I was able to develop my own style and experiment in ways that may not have been possible otherwise."

> "I needed some time to mature and get ready for my current position. I was able to develop my own style and experiment in ways that may not have been possible otherwise."
> *Professor Yoan Simon,*
> *University of Southern Mississippi*

He also learned valuable managerial skills that come from developing a research group, from instrument ordering and safety coordination to grant writing and people management.

"It confronted me with the demands of managerial positions and the difficulty to get the most out of your students, whose interests may not perfectly align with yours," he admits. "This is still a work in progress, but I am definitely grateful for the past experience."

Christian Heinzmann is one of the many former AMI researchers who have now made their way into the industrial sector. After finishing his PhD with the Polymer Chemistry and Materials group in 2015, he started working as a technical author for Bachem, a Swiss producer of active ingredients for the pharmaceutical sector.

Heinzmann says that the international environment at the institute deeply influenced him. He appreciated the interactions with staff from over 20 countries and considers being able to rely on such a diversity of professional backgrounds and skill sets a major advantage while preparing a PhD.

"You face many challenges during that journey," he points out. "The better you can handle this, the better you will be prepared for what comes next."

Every year, anywhere between 15 and 25 people leave the institute, moving on to the next stage of their careers. These are some of AMI's best ambassadors, extending its reputation for scientific and educational excellence around the world, now and in the future.

Up and coming

_ Young researchers boost their academic credentials

The Adolphe Merkle Institute is home to many talented researchers. We have chosen to highlight 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 which are aimed at young researchers who wish to conduct, manage, and lead an independent project; and Marie Sklodowska-Curie Individual Fellowships awarded by the European Commission to the best, most promising individual researchers from all over the world.

Barbara Drasler

Barbara Drasler joined the BioNanomaterials research group at AMI as a post-doctoral research fellow in 2016. Prior to this position, she studied at the University of Ljubljana, Slovenia, in the Nanobiology and Nanotoxicology research group, where she completed her undergraduate biology studies and obtained a PhD in nanoscience. Her main research interest has been the use of nanomaterials in the medical field, particularly regarding their safety when intentionally used within medical applications, as well as the occupational hazards of nanomaterials.

In 2016, Drasler was awarded a fellowship by the Peter and Traudl Engelhorn Foundation for the Advancement of Life Sciences. Her project, “Targeting of macrophages by specific nanocarriers using the inhalatory pathway,” aims to deliver drugs to specific parts of the lung via inhalation. These novel nanocarriers will be applied onto a 3D lung model that mimics the deepest regions of the lungs via an aerosolization system simulating realistic inhalation conditions. This approach profits from the advantages of small carriers by using an existing pharmaceutical tool as a nebulizer-based treatment to target specific cells in the lung.

Bodo Wilts

Bodo Wilts was born and raised in Leer (Ostfriesland), Germany. He earned his Diploma in Physics (equivalent to a master’s degree) at the University of Göttingen in 2009, before moving on to Groningen in the Netherlands to start a PhD on biophotonic structures. After completing his PhD in 2013, he joined Professor Ullrich Steiner’s group at the University of Cambridge, expanding his research portfolio to include optical metamaterials and floral photonic structures. Wilts moved to the Adolphe Merkle Institute with the rest of the Steiner group in 2014 and now holds a Senior Scientist position at AMI. In 2016, he was awarded an Ambizione grant by the Swiss National Science Foundation.

His project, “Smart Optical Materials Inspired by Nature,” investigates the optical and physical properties of nanostructured ordered and disordered materials. Inspiration for this work is found in the colors of bird feathers or butterfly wing scales. The project aims to understand the fundamentals of light-matter interactions within these structures and use these insights to manufacture novel optical materials. His long-term goal is to secure a faculty position, while still having fun science.

Lucas Montero

Lucas Montero grew up and studied chemistry in Madrid, Spain, before moving to the University of Tarragona, where he obtained his PhD in polymer chemistry. After holding postdoctoral positions in Germany at the University of Potsdam and the Karlsruhe Institute of Technology, he joined AMI in 2013 as a postdoc in Professor Christoph Weder's group. In 2014, he was awarded an Ambizione grant by the Swiss National Science Foundation to study structure-property relationships in a new class of supramolecular polymers and to explore their potential for technological applications.

Montero's project aims to synthesize materials combining seemingly incompatible properties, such as the excellent mechanical properties of epoxy resins and a very low melt viscosity comparable to that of honey. The goal is to synthesize very stiff supramolecular polymer networks that disassemble into their liquid monomeric constituents when heated above a threshold temperature. These properties are especially relevant for recycling purposes and in the context of technological applications in which very low melt viscosities are required, such as the processing of polymers via injection molding.

Ilja Gunkel

Ilja Gunkel was born in Halle/Saale, Germany, where he earned both his Diploma and PhD in Physics at the Martin Luther University of Halle-Wittenberg. After postdoctoral work with Tom Russell at the Lawrence Berkeley National Laboratory (Berkeley Lab), he joined AMI in 2014. His research focuses on controlling polymer self-assembly for the fabrication of functional nanostructured materials. Gunkel was awarded a Marie Skłodowska-Curie Individual Fellowship in 2016.

For his fellowship project, he uses polymers that can self-assemble into ordered nanostructures as a template for the fabrication of new materials. Transferring the polymer nanostructure into another material often leads to a dramatic change of the optical properties: nanostructured gold, for example, does not only change its color, but can even be made transparent. However, creating materials with the desired (optical) properties requires precise control of self-assembled nanostructures. To achieve this, Gunkel combines traditional annealing of polymer films while applying external fields (such as an electric field) and an in-situ structural characterization using X-ray scattering techniques.

Dafni Moatsou

Dafni Moatsou studied Materials Science and Technology at the University of Crete, Greece, and obtained her master's degree working on polymer-functionalized inorganic nanoparticles at the Foundation of Research and Technology – Hellas (FORTH). She then moved to the United Kingdom, where she obtained a PhD in Chemistry from the University of Warwick in 2015 working on precision polymer synthesis, polymer-protein bioconjugates, and functional nanogels. Moatsou joined Professor Christoph Weder's group at AMI soon afterwards, initially working on bio-inspired mechanically-adaptive polymers. Since September 2016, she has also been developing supramolecular copolymers for photonics as part of her Marie Skłodowska-Curie Individual Fellowship.

Her project aims to develop a method that allows for easy preparation of photonic structures through the use of immiscible polymers that are linked via weak and reversible interactions. Nanodomains are quickly formed, while the dissociation of the reversible bond allows for the easy removal of a single polymer, leaving behind a void that can be filled with a metal, thus forming the photonic structure.

Sandor Balog

Sandor Balog joined AMI in 2012 as 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). He is fascinated by anything that can be expressed with mathematical models and later tested by experimental means. Balog's interests revolve around the theory, practice, and application of measurements and instrumentation, mostly in the field of soft matter sciences.

He is currently working on the characterization of nanoparticles in microfluidic flows. He believes that resolving this type of essential problem could help many scientists tackle interface phenomena occurring on the surface of nanoparticles when suspended in complex fluids such as blood, saliva, food, and cosmetics.

Inspiration from nature

_ Bio-inspired projects drive AMI research

Bio-inspiration has always played a major role at the Adolphe Merkle Institute, but the concept became particularly prominent in 2014 with the creation of the National Center of Competence in Research (NCCR) Bio-Inspired Materials.

The center, headed by AMI Professor Christoph Weder, has been striving to become an internationally recognized hub for paradigm-shifting research, innovation, and education in the domain of so-called "smart" materials inspired by nature.The NCCR, which is financially backed by the Swiss National Science Foundation (SNSF), has around 100 researchers, one fifth of whom work at AMI.

Since the beginning, the development of biologically inspired nanomaterials and the study of the interactions of these materials with biological systems have emerged as research topics in which all of AMI's research groups share a common interest.

Before the NCCR's start, AMI researchers had worked separately on projects such as mechanically adaptive nanocomposites inspired by sea cucumbers, nanoparticle-cell interactions, and optical elements that emulate the nanoscale patterns found in butterfly wings.

However, the creation of the NCCR led to an increase of research projects that harness synergies within the institute and helped develop research collaborations with other groups of the center, bringing together complementary forms of expertise. The BioNanomaterials team, for instance, has been working with cancer specialists at the University of Fribourg to develop a diagnostic test for circulating tumor cells using nanoparticles. The Polymer Chemistry & Materials group has collaborated with groups in the Department of Chemistry at the University of Fribourg to investigate and create mechanically responsive polymers.

Besides providing additional resources that help facilitate more research, the development of the center has also strengthened recruitment efforts. For example, the head of the Biophysics group, Professor Michael Mayer, cites the existence of the NCCR as one the factors that attracted him to take up his position in 2015. The competences in bio-inspired research that have been developed since the center was launched have also helped attract additional funding. The Innovative Training Network Plant Material Surfaces, coordinated by AMI Professor Nico Bruns, is a good example of this. Without a successful track record, it is unlikely that the European Union would have granted CHF 2.6 million in funding over three years to support this project.

While specialists recognize the quality of the research being carried out, it is more difficult to communicate the center's goals to non-specialists. One of the biggest difficulties is explaining the difference between bio-inspiration and biomimicry. Inspired by nature is a simple concept in essence, but is open to different interpretations. Professor Christoph Weder, who has been working on mechanochromic materials, says that this difference is fundamental. One only has to look at his research.

> "With the support of the Swiss National Science Foundation, the University of Fribourg, and our other partner institutions, we will be ready to move on to the next stage of our activities in 2018."
> *AMI director Professor Christoph Weder*

"The concept of color-changing materials may be reminiscent of chameleons or octopuses, which can alter their appearance to camouflage or indicate their mood, but our mechanochromic materials are based on a mechanism that is very different from those at play in these animals," he notes.

Investigating beetles helps understand structural colors for example

He adds that his interest lies in a more general design concept that is omnipresent in nature. “Most living species have developed ways to sense and adapt to mechanical forces. The underlying signaling processes are exceedingly complex and difficult to emulate precisely, but the fundamental concept of translating mechanical forces into useful chemical reactions has attracted widespread interest over the past decade.”

Members of the NCCR are generating more and more results as the center reaches the end of its first phase, which will have lasted four years when it is completed in 2018. Weder and his colleagues are already in the process of organizing the second phase.

“With the support of the Swiss National Science Foundation, the University of Fribourg, and our other partner institutions, we will be ready to move on to the next stage of our activities in 2018. I am also hopeful that more research groups will join our program,” he states.

The NCCR’s second phase will be funded until 2022.

New materials

_ Safety comes first for researchers and the public

Good practices start at home, and this is certainly true for researchers at the Adolphe Merkle Institute. Safety rules are strictly enforced: lab coats, glasses, and gloves constitute the required uniform for anyone working in a laboratory. However, when it comes to the so-called nano powder labs, security measures escalate an extra level and there are many measures designed to prevent dust from getting out: access is restricted, shoe covers are compulsory, specific masks must be worn, and scientists and technicians are required to change in an airlock.

Would the escape of dust from a nano powder lab really be harmful? This is just one of the questions that AMI researchers have been trying to answer since the institute was created in 2008. Although many nanoparticles have been used in products since the early 20th century and are generally considered to be safe, the public tends to be wary of nanotechnology. In addition to already known materials, new nanoparticles are on the verge of entering the market due to promising characteristics such as antibiotics, solar cell materials, or surface finishes. However, a lack of experience with these new materials has led to public concerns about their potential adverse effects on people's health and the environment. This is partly due to the fact that there is a lack of specific frameworks for risk assessment that can be applied during the production and usage of these materials at the national and international levels.

Currently, a lot of research is focused on determining which nanomaterials actually represent a danger to humans and the environment and at what dosage. For the time being, the consensus is to exercise a precautionary principle with these novel materials until more knowledge is acquired by researchers.

AMI staff members have been actively working on hazard assessment and supporting regulatory stakeholders with their expertise. BioNanomaterials co-chair Professor Barbara Rothen-Rutishauser, along with eight of her European colleagues, recently presented a document on the reliability of methods and data for the assessment of nanomaterial risks. This report provided the basis for a recent Organization for Economic Co-operation and Development (OECD) conference.

"This science-based document will form the basis for recommendations to policy makers, regulators, and industry on how to test and assess the effects and risks of nanomaterials," adds Rothen-Rutishauser.

The experts' report is an evaluation of over 1,000 peer-reviewed publications, highlighting how to integrate science-based data on nanomaterials in risk assessment, its selection, and acceptance of preferred methods. The aim is to develop an improved regulatory review process for nanomaterials despite the complexities related to their physicochemical properties.

> "The decision tree is a simple and easy to use tool not only for safety specialists, but also for researchers to rapidly evaluate the preventive and protective measures in a nanomaterial research environment." *Professor Barbara Rothen-Rutishauser*

This is one of the biggest challenges concerning the study of nanomaterials. There is a distinct lack of internationally accepted and standardized methods, such as a method to measure the potential impact of nanomaterials on living organisms. At the same time, there are approximately 200 nano-enabled products entering the market every year, according to Nanosolutions, a project funded by the European Commission that is aimed at providing a means to develop a safety classification for engineered nanomaterials.

To overcome the lack of acknowledged tests, Rothen-Rutishauser is working, for example, on the design of an in vitro test to predict the development of lung fibrosis in humans following exposure to nanomaterials, such as multi-walled carbon nanotubes. The aim is

A glove for every occasion in the laboratory

to develop a standardized test that will be accepted by OECD member states, with the added benefit of reducing animal-based testing.

Scientists in Switzerland have been heavily engaged with risk-benefit analysis of nanomaterials over the past few years as part of the national research program, “Opportunities and Risks of Nanomaterials.” Rothen-Rutishauser and AMI Professor Christoph Weder were both part of this venture, whose research phase ended in 2016. They collaborated, for example, on a study of the behavior of lung cells exposed to different cellulose nanofibers that are expected to hit the market soon, resulting in the assessment that these fibers pose no short-term risk if inhaled.

“By using a 3D lung cell model to simulate the impact of cellulose dust on the lungs, clear differences between short and long fibers were observed,” says Rothen-Rutishauser. “Although no acute stress or inflammation was seen, the lung cell system efficiently eliminated short fibers while longer ones stayed on the cell surface, thus the use of shorter and more flexible fibers instead of long and rigid ones is recommended.”

The creation of novel nanoparticles in research labs evolves at a fast pace, and with it the need to protect scientists and other collaborators from potential harm. One measure that can be implemented in a research environment is hazard assessment. Rothen-Rutishauser and her BioNanomaterials co-chair, Professor Alke Fink, along with colleagues from the Federal Insititute of Technology in Lausanne, have developed a simple tool to achieve this: a decision tree that allows researchers to determine hazard levels when dealing with nanomaterials. In just three steps, a scientist can evaluate the level of risk he or she faces.

“The decision tree is a simple and easy to use tool not only for safety specialists, but also for researchers to rapidly evaluate the preventive and protective measures in a nanomaterial research environment,” explains Rothen-Rutishauser. “Reading of the publication is mandatory for each new student working at AMI.”

In the AMI labs, where safety measures are strictly enforced, problems are likely to be an exception. Particle concentrations measured in the labs are even lower than those found outside, where natural and non-natural nanoparticles are omnipresent. The head of the institute’s safety committee, Professor Nico Bruns, says that even the smallest details can make a considerable difference.

“For example, proper handling of nano powders in AMI’s laboratories requires that dust not be released into the lab’s atmosphere during sample manipulation,” Bruns elaborates. “That’s why weighing nano powders is carried out in special enclosures that cover the scales.”

It is details such as this that ensure that potential risk factors are kept to a minimum. By maintaining its high safety standards, the AMI staff will continue to ensure that their work is safe for themselves and for the general public. In the end, not all the materials investigated in the research labs will make it to the market, with regulations in place to ensure that those that do are the safest possible.

PlaMatSu

_ Inspiration from the plant world

Graduate student training at the Adolphe Merkle Institute took another step forward in 2016, when a prestigious European training grant worth CHF 2.6 million was awarded to a research consortium led by AMI Professor Nico Bruns. The Innovative Training Network (ITN) on Plant Inspired Materials and Surfaces (PlaMatSu), the first ITN to be coordinated by a faculty member of the University of Fribourg, allows nine students to carry out their PhD research on materials inspired by plants at the universities of Fribourg, Freiburg (Germany), and Cambridge (UK).

The objective is to allow students to pursue their academic training within an international, multidisciplinary framework, along with completing temporary industrial internships. The funding is provided as part of the European Commission's Marie Skłodowska-Curie Actions that encourage transnational and interdisciplinary mobility.

"It was a chance to intensify our links with the University of Freiburg and the University of Cambridge," says PlaMatSu coordinator Bruns. "It was also a great opportunity to create a training and research network that complements the National Center of Competence in Research (NCCR) Bio-Inspired Materials, to which all of the AMI professors belong. And finally, we get to carry out exciting research."

During the PlaMatSu project, the students will benefit from direct access to multidisciplinary laboratories, working in the fields of soft matter physics, polymer chemistry, and plant biology, and have the opportunity to sharpen their research and development skills there. Workshops will also allow them to develop their soft skills in technology transfer, management, writing, and communication.

The research they will carry out will focus on plant cuticles. This external layer, which protects plant leaves and petals, is made of bio-polymers and wax and has a hierarchical structure. It can, for example, regulate water permeability or lead to the development of colored, sticky, and smooth surfaces.

"Many researchers and engineers look at insects and mammals for bio-inspiration," explains Bruns. "Plants are underrepresented, except for some classical examples like the lotus effect, Velcro (plant burrs), and tree-like engineering in construction. The driving forces for our ITN were our contacts with the two botanists involved, who already have a long track record of bionic and bio-inspired research."

The researchers want to investigate the formation and properties of cuticles in order to gain a fundamental genetic, developmental, and physical understanding, and then exploit this knowledge to create artificial polymeric materials with advanced functionalities such as insect repellency, tunable friction properties, or color.

The first plants to go under the microscope will be the Queen of the Night Tulip, the Hibiscus trionum (also known as the flower-of-the-hour), and the grapevine, with more species to follow as the project progresses. The potential applications include natural colors for foods, optical materials, non-toxic insecticides, semipermeable membranes, and self-lubricating surfaces.

> "It was a great opportunity to create a training and research network that complements the National Center of Competence in Research (NCCR) Bio-Inspired Materials."
> *Professor Nico Bruns*

Given that the project is also a collaboration between academics and industry, partners BASF, Mars, Fischer, and Tillwich will offer internships to the PlaMatSu students. These companies, whose sizes range from a family-owned business to multinational corporations, are already involved in biomimetic research and development (R&D), or have bio-inspired prod-

Professor Nico Bruns says the Innovative Training Network is an opportunity to strengthen ties with the universities of Freiburg and Cambridge

ucts on the market. Each student will spend at least a month working in one of the companies' facilities.

"These are great training opportunities for the students, as they get exposed to an industrial R&D setting," adds Bruns. "For the participating professors, these are good contacts for possible future collaborations."

The internships are designed to complement the students' academic training and increase their employability. They will also experience immersion in the industrial world, come into contact with different schools of thought and innovation culture in companies, as well as learn to work under more regulated conditions than in academia.

The Association of German Engineers (VDI) and Wikimedia Switzerland have also been recruited for the PlaMatSu program. They will both provide specific training modules in biomimetic technology transfer, bionic engineering, and public outreach via web-based media.

At the end of the project, the PhD students will have not only completed their thesis in a novel field, but also benefited from exposure to a wide variety of approaches in research and valorization – characteristics that should make them particularly attractive to future employers in the academic and industrial sectors.


THF
TOLUENE
DICHLOROMETHANE
DMF
SOLVCOL

29

_Research at AMI

Fresh energy

_ Developing a new breed of solar cells

Bringing down the cost of solar technology is one of the major challenges faced by researchers seeking to boost renewable energies in the 21st century. For the Soft Matter Physics group at the Adolphe Merkle Institute, the focus is on improving a new type of solar cell that has the potential to enter the solar market as a more efficient solution than those currently available.

Until now, solar cell technology has been almost exclusively based on silicon technology. Prices have dropped over the years while efficiency has increased. However, further improvements have become increasingly difficult. There are many hurdles, such as the complexity and the energy requirements of silicon solar cell production.

One promising avenue currently being explored is the potential of so-called perovskite solar cells. “These cells are based on novel materials, which can be processed at lower temperatures using established printing processes,” says Antonio Abate, who was until recently the leader of photovoltaics in AMI’s Soft Matter Physics group.

In just a few years, the efficiency of perovskite cells has reached the point where they can compete with silicon devices. They can also be processed at low temperatures in a normal laboratory environment, unlike silicon-based cells, which need to be produced in a clean room. Thus, perovskites seem to be prime contenders to become the basis of next-generation photovoltaics.

“The idea is to develop solar cells for large power, such as major plants, and small distributed energy production like that found on rooftops,” says Abate. “Integration in portable electronics and automotive application would also be possible.”

However, these new cells, which are based on a thin crystalline structure, are not yet stable enough in comparison to silicon devices, which will function for 25 years or more. Understanding the factors that govern long-term stability in perovskite systems is therefore a major field of research.

Abate has been working on improving perovskite cells, investigating a variety of possible methods with his colleagues at AMI and the Federal Institute of Technology in Lausanne (EPFL), where he has been working with Professor Michael Grätzel’s team.

AMI researchers were able to show that adding rubidium, a metallic element, to the composition of the solar cell material leads to increased efficiency. Improvements can also be obtained by modifying the production process to slow down the crystallization process of the perovskite in order to ensure a more uniform crystalline layer.

The current short lifespan of perovskite solar cells is one of the biggest hurdles to their potential commercialization. “The long-term stability of these cells is crucial for their economic viability, and yet this criterion is still barely studied,” Abate points out.

This instability is largely caused by ions migrating within the crystal structure, leading to defects that can degrade a cell. However, AMI researchers have been able to show that this might be less of a problem than previously feared. Under a simulated day-night cycle, they demonstrated that although cells suffered a substantial loss in efficiency under daylight conditions, this deficiency was compensated for if the perovskites were left to regenerate overnight.

Abate wants to follow this line of research further, notably by improving knowledge of the optoelectronic mechanisms leading to the degradation of materials inside perovskite solar cells. He will pursue his work in Germany, after being recently awarded a Young Investigator grant at the Helmholtz-Zentrum Berlin for Materials and Energy, allowing him to set up his own research group, and to continue to collaborate with his AMI colleagues on perovskite-related projects.

Reference

Seo, J.; Matsui, T.; Luo, J.; Correa-Baena, J.P.; Giordano, F.; Saliba, M.; Schenk, K.; Ummadisingu, A.; Domanski, K.; Hadadian, M.; Hagfeldt, A.; Zakeeruddin, S.M.; Steiner, U.; Grätzel, M.; Abate, A. Ionic Liquid Control Crystal Growth to Enhance Planar Perovskite Solar Cells Efficiency, *Adv. Energy Mater.,* **2016**, 6: 1600767

Originally from Italy, **Antonio Abate** has carried out research at the universities of Oxford and Cambridge in England, as well as at the Federal Institute of Technology in Lausanne (EPFL). He headed the photovoltaic activities at the Adolphe Merkle Institute before moving recently to Berlin’s Helmholtz Zentrum to lead his own group.

Soft Matter Physics

Team

Prof. Ullrich Steiner, Dr. Antonio Abate, Narjes Abdollahi, Esteban Bermudez, Michael Fischer, Dr. Ilja Gunkel, Dr. Hua Xiao, Cédric Kilchoer, Karolina Korzeb, Mirela Malekovic, Bart Roose, Saeed Sadeghi, Sandy Sanchez, Dr. Alessandro Sepe, Sheng Xiaoyuan, Preston Sutton, Dr. Bodo Wilts, Vjollca Zenko

Key Publications

1. Roose, B.; Gödel, K.C.; Pathak, S.; Sadhanala, A.; Correa Baena, J.P.; Wilts, B.D.; Snaith, H.J.; Wiesner, U.; Grätzel, M.; Steiner, U.; Abate, A. Enhanced Efficiency and Stability of Perovskite Solar Cells Through Nd-Doping of Mesostructured TiO2, *Adv. Energy Mater.,* **2016**, 6, 1501868

2. Roose, B.; Correa Baena, J.P.; Gödel, K.C.; Grätzel, M.; Hagfeldt, A.; Steiner, U.; Abate, A. Mesoporous SnO2 electron selective contact enables UV-stable perovskite solar cells, *Nano Energy,* **2016**, 30, 517

3. Wilts, B.D.; Wijnen, B.; Leertouwer, H.L.; Steiner, U.; Stavenga D.G. Extreme Refractive Index Wing Scale Beads Containing Dense Pterin Pigments Cause the Bright Colors of Pierid Butterflies, *Adv. Opt. Mater.,* **2016**, 5, 3, 1600879

4. Dolan, J.A.; Saba, M.; Dehmel, r.; Gunkel, I.; Gu, Y.; Wiesner, U.; Hess, O.; Wilkinson, T.D.; Baumberg, J.J.; Steiner, U.; Wilts, B.D. Gyroid Optical Metamaterials: Calculating the Effective Permittivity of Multidomain Samples, *ACS Photonics,* **2016**, 3, 1888

5. Gödel, K.C.; Steiner, U.; Thin film synthesis of SbSI micro-crystals for self-powered photodetectors with rapid time response, *Nanoscale,* **2016**, 8, 15920

Filtering blood

_ Using magnets to clean up sepsis

Blood poisoning by bacteria can be lethal. In fact, it is still fatal in over half of all diagnosed cases. Fortunately, it can be beaten if treated at an early enough stage. However, because speed is of the essence, the treatment of choice for sepsis has traditionally been a course of antibiotics before the presence of bacteria is even ascertained.

While a few years ago, this treatment was the first and only option, since the advent of antibiotic resistance, this approach is being seriously reconsidered. According to the World Health Organization, “antibiotic resistance is one of the biggest threats to global health, food security, and development today.”

Professor Marco Lattuada, who left the Adolphe Merkle Institute in 2016 to take up a position at the University of Fribourg’s Department of Chemistry, is one of many researchers studying how to circumvent antibiotic resistance. Lattuada, along with colleagues from the Swiss Federal Laboratories for Materials Science and Technology (Empa) and the Harvard Medical School, has been developing a technique involving the magnetic purification of blood.

The proposed approach involves injecting the patient with magnetic iron nanoparticles coated with an antibody capable of finding and latching onto bacteria in the bloodstream. The bacteria are only present in the blood in small concentrations and are difficult to detect. However, if they bind to the nanomagnets, they can be easily filtered from the blood using a magnetic field.

The project was carried out in two stages, one theoretical and the other experimental. Lattuada, the lead author of a recent publication presenting the project results, was responsible for the initial modelling stage. “The aim was to quantify the right concentration of particles to be used, and the time required for them to adsorb on bacteria,” he explains.

While the theory may seem straightforward, putting it into practice is a little more complicated. Until now, it has only been possible to coat the iron particles with antibodies that recognize only one type of bacteria, so magnetic dialysis, as this process is called, still relies on determining the type of bacteria present. In order to get this right, medical personnel need to determine which pathogen is poisoning the blood, a time-consuming procedure at a time when speed is a vital ingredient to ensure a successful treatment.

Lattuada’s colleagues at the Harvard Medical School, led by Professor Gerald Pier, have circumvented this problem by developing a sort of universal antibody, one that can bind to almost all types of bacteria responsible for blood poisoning. This means that a magnetic treatment could be implemented immediately rather than waiting for an analysis to determine the type of pathogen lurking in the patient’s blood.

Clinical trials are still quite some time off. Researchers at Empa, led by Dr. Inge Herrmann, are attempting to determine if the antibody developed at Harvard can bind to more than one bacterium at a time. They also want to investigate what effects the iron particles might have on the body, particularly if they are entirely flushed out by the dialysis and thus would cause no harm.

“In vivo testing is the next step, and is as usual critical, because the response of the immune system to the particles needs to be evaluated,” says Lattuada. Herrmann’s team has already managed to assemble the iron particles into larger clusters, making them more responsive to the magnetic field. In vitro testing has shown that the particles also break down completely after five days.

Ideally, this method should allow medical staff to avoid the initial use of antibiotics if a patient is believed to be suffering from blood sepsis. While the blood is being cleansed by magnetic dialysis, analysis would determine which bacteria are present and if antibiotic therapy is required as an additional treatment. Furthermore, treating sepsis might just be the beginning. According to Herrmann, the approach could be further extended to be able to remove other types of contaminants from the body, such as poisons.

Reference

Lattuada, M.; Ren, Q.; Zuber, F.; Galli, M.; Bohmer, N.; Matter, M. T.; Wichser, A.; Bertazzo, S.; Pier, G. B.; Herrmann, I. K. Theranostic Body Fluid Cleansing: Rationally Designed Magnetic Particles Enable Capturing and Detection of Bacterial Pathogens, *J. Mater. Chem. B* **2016**, 4 (44), 7080.

Professor **Marco Lattuada** is an Italian citizen. He worked at AMI as the beneficiary of a Swiss National Science Foundation professorship between 2012 and 2016. He joined the Department of Chemistry at the University of Fribourg last year as an associate professor. His interests include the control of nanoparticle self-assembly, synthesis, and modelization.

Nanoparticles Self-Assembly

Team

Prof. Marco Lattuada, Dr. Adriano Boni, Dr. Florian Guignard, Golnaz Isapour Laskookalayeh, Dr. Julio Cesar Martinez

Key Publications

1. Lattuada, M.; Zaccone, A.; Wu, H.; Morbidelli, M. Population-balance description of shear-induced clustering, gelation and suspension viscosity in sheared DLVO colloids, *Soft Matter,* **2016**, 12, 5313.
2. Lazzari, S.; Nicoud, L.; Jaquet, B.; Lattuada, M.; Morbidelli, M. Fractal-like structures in colloid science, *Adv. Colloid Interface Sci.,* **2016**, 235, 1.
3. Harshe, Y.M.; Lattuada, M. Universal Breakup of Colloidal Clusters in Simple Shear Flow, *J. Phys. Chem. B,* **2016**, 120 (29), 7244.
4. Monnier, C.A.; Lattuada, M.; Burnand, D.; Crippa, F.; Martinez-Garcia, J.C.; Hirt, A.M.; Rothen-Rutishauser, B.; Bonmarin, M.; Petri-Fink, A. A lock-in-based method to examine the thermal signatures of magnetic nanoparticles in the liquid, solid and aggregated states, *Nanoscale,* **2016**, 8(27):13321.
5. Schaefer, M.; Içli, B.; Lattuada, M.; Weder, C.; Kilbinger, A.F.M.; Simon, Y.C. The role of mass and length in the sonochemistry of polymers, *Macromolecules,* **2016**, 49, 1630.

5-D fingerprints

_ Finding the culprit

The AMI Biophysics group has developed a method for identifying proteins more quickly and in more detail, a technique that could lead to a more rapid diagnosis of neurodegenerative diseases.

Identifying a person based on their height and weight is almost impossible, as there are simply too many people with any given combination of the two. This is also true for proteins. These large molecules are vital components of all living organisms as they are essential to the function of every cell. They can be found in muscle tissues and hair, collagen, or serve as enzymes and antibodies, for example. The body manufactures them in a variety of complex shapes that can transmit messages between cells, carry oxygen, and perform other important functions. However, identifying the type of protein is a lengthy process.

Measuring proteins in blood and other body fluids is important as it can unlock valuable information about the state of a person's health. For example, proteins do not always form properly. Scientists believe that some types of these misshapen proteins, called amyloids, can clump together in the brain. The sticky tangles block normal cell functions, leading to brain cell degeneration and diseases such as Alzheimer's and Parkinson's. Yet the processes of how amyloids form and clump together are not well understood. This is due in part to the fact that there is currently no optimal method to study them.

"Current techniques are expensive, time-consuming, and difficult to interpret, and can only provide a broad picture of the overall level of amyloids in a patient's system," says the Biophysics chair Professor Michael Mayer.

AMI researchers say current techniques for identifying proteins are much too general to be effective. Along with colleagues at the University of Michigan, they believe that they could help solve this problem by measuring an individual molecule's shape, volume, electrical charge, rotation speed, and propensity to bind with other molecules. This information, which they call a "5-D fingerprint," adds more descriptors, making it simpler to identify specific proteins. The researchers believe that this method could uncover new information that may one day help doctors track the status of patients with neurodegenerative diseases, help researchers gain a better understanding of exactly how amyloid proteins are involved in these illnesses, and possibly even lead to the development of new treatments.

To obtain these detailed measurements, the research team uses a nanopore, a surface passage that is just 10 to 30 nanometers wide – so small that only one protein molecule can fit through at a time. The nanopore is filled with a salt solution through which an electric current is passed.

As a protein molecule tumbles through the nanopore, its movement causes tiny measurable fluctuations in the electric current. By carefully measuring this current, researchers can determine the protein's unique five-dimensional signature and identify it nearly instantaneously.

"Amyloid molecules not only vary widely in size, but they tend to clump together into masses that are even more difficult to study," says Mayer, who launched this research project at the University of Michigan and is pursuing it at AMI. "Because it can analyze each particle one by one, this new method gives us a much better window into how amyloids behave inside the body." Ultimately, the team aims to develop a device that doctors and researchers could use to quickly measure proteins in a sample of blood or other body fluid. This goal is likely several years off; in the meantime, they are working to improve the technique's accuracy, honing it in order to get a better approximation of each protein's shape. They believe that in the future, the technology could also be useful for measuring proteins associated with heart disease as well as for a variety of other applications.

Reference

Yusko, E.C.; Bruhn, B.R.; Eggenberger, O.M.; Houghtaling, J.; Rollings, R.C.; Walsh, N.C.; Nandivada, S.; Pindrus, M.; Hall, A.R.; Sept, d.; Li, J.; Kalonia, D.S.; Mayer, M. Real-time shape approximation and fingerprinting of single proteins using a nanopore, *Nat. Nanotechnol.,* **2016**.

Jared Houghtaling was born in Seattle, Washington, where he grew up and earned his bachelor's degree in bioengineering at the University of Washington. He began his PhD in Biomedical Engineering at the University of Michigan (Ann Arbor) in 2014, working on the protein detection project, and moved to AMI with the BioPhysics Group at the start of 2016.

BioPhysics

Team

Prof. Michael Mayer, Dr. Lennart de Vreede, Olivia Eggenberger, Dr. Aziz Fennouri, Gogol Guha, Jared Houghtaling, Tom Schroeder, Dr. Cuifeng Ying, Simon Mayer, Julie Ducrey

Key Publications

1. Koyanagi, T.; Leriche, G.; Onofrei, D.; Holland, G.P.; Mayer, M.; Yang, J. Cyclohexane Rings Reduce Membrane Permeability to Small Ions in Archaea-Inspired Tetraether Lipids, *Angew. Chem. Int. Ed.,* **2016**, 55, 1890.

2. Yusko, E.C.; Bruhn, B.R.; Eggenberger, O.M.; Houghtaling, J.; Rollings, R.C.; Walsh, N.C.; Nandivada, S.; Pindrus, M.; Hall, A.R.; Sept, d.; Li, J.; Kalonia, D.S.; Mayer, M. Real-time shape approximation and fingerprinting of single proteins using a nanopore, *Nat. Nanotechnol.,* **2016**.

3. Jessica L. Cifelli, Tim S. Chung, Haiyan Liu, Panchika Prangkio, Mayer, M.; Yang, J. Benzothiazole Amphiphiles Ameliorate Amyloid ß-Related Cell Toxicity and Oxidative Stress, *ACS Chem. Neurosci.,* **2016**, 7, 682.

4. Koyanagi, T.; Leriche, G.; Yep, A.; Onofrei, D.; Holland, G.P.; Mayer, M.; Yang, J. Effect of Headgroups on Small-Ion Permeability across Archaea-Inspired Tetraether Lipid Membranes, *Chem. Eur. J,* **2016**, 22, 8074.

5. Schroeder T.B.H.; Leriche, G.; Koyanagi, T.; Johnson, M.A.; Haengel, K.N.; Eggenberger, O.M.; Wang, C.L.; Kim, Y.H.; Diraviyam, K.; Sept, D.; Yang, J.; Mayer, M. Effects of Lipid Tethering in Extremophile-Inspired Membranes on H+/OH— Flux at Room Temperature, *Biophys. J.,* **2016**, 110, 2430.

Setting new standards

_ Tracking hidden nanoparticles

Researchers at the Adolphe Merkle Institute are investigating how nanoparticles can be rapidly and reliably detected in consumer products. Standardized protocols are needed to enable companies and government agencies to ensure compliance with new legislation.

Since the mid-20th century, small particles have been used as additives in commodity products to improve the materials' properties. The most prominent examples are nanoparticulate carbon (carbon black) that is used in car tires to reduce their wear, fumed silica as an anti-caking agent in food products, and titanium dioxide as a color additive used, for instance, in paint or toothpaste. Originally, the term "nano" was not associated with these materials and many current applications of nanomaterials were still not identified. For example, today, silver nanoparticles are being used in textiles because of their antimicrobial properties, and carbon nanotubes can be found in tennis rackets and automotive parts. Healthcare, energy, transport, and security are the economic sectors expected to benefit most from such enhanced materials.

In 2008, the Swiss government approved an "Action plan for synthetic nanomaterials," which creates the legal basis for the safe handling of nanomaterials. For the time being, legislation regarding chemicals, foodstuffs, the environment, and pharmaceutical products also applies to nanomaterials, while work is underway to adapt these guidelines if necessary.

In 2011, the European Commission published a recommendation concerning the definition of nanomaterials and decreed that "all ingredients present in the form of engineered nanoparticles must be clearly indicated in the list of ingredients, followed by the word 'nano' in brackets for consumer products." An EU regulation is already in place for cosmetic products and similar guidelines are currently under discussion to be implemented for all consumer products in the near future. Swiss regulatory agencies are also working on possible adaptations for existing federal legislation.

There is, however, still no internationally approved method on how to detect or determine the size distribution and quantification of nanoparticles in consumer products. Laboratories are currently working to develop standardized analytical methods for the detection and size distribution determination of nanoparticles to satisfy these EU regulations.

At the Adolphe Merkle Institute, several projects are dedicated to this dilemma. "Our goal is to apply our competences to develop methods that will be useful in this context. This way, we can help to implement regulations, guaranteeing that consumers can make their own decisions about their purchases," says Miguel Spuch-Calvar, the lead researcher of one of the projects.

The detection, characterization, and quantification of engineered nanoparticles pose tremendous challenges, such as the low concentration of the nanoparticles in the formulations, the complexity and variability of the particles' environments (including powders, solids, and oils), the presence of organic molecules, proteins, and lipids, or the change of nanoparticle composition (dissolution), dispersion state (agglomeration), or surface chemistry.

"Clearly, such projects can only be carried out in highly interdisciplinary research groups, which is what we have here at AMI and which makes it motivating for all people involved in the project," says the co-chair of the BioNanomaterials group, Professors Alke Fink.

So far Spuch-Calvar and his colleague Laura Rodriguez-Lorenzo have been relying on a combination of commonly used sophisticated nanotechnology techniques that cannot necessarily be applied continuously by laboratory technicians.

The AMI researchers are making progress in developing novel, rapid, low-cost, and less expertise-dependent analytical tools for the detection of nanoparticles in consumer products to address this issue. However, developing a method recognized in Switzerland and abroad will take time, as it will not only have to be validated by scientific review, but also have to be accepted by regulatory authorities everywhere.

In the meantime, AMI researchers are collaborating with the Swiss authorities to develop their method and to lobby international bodies for its acceptance.

Laura Rodriguez-Lorenzo and Miguel Spuch-Calvar are both Spanish postdoctoral researchers. Rodriguez-Lorenzo joined the BioNanomaterials group at AMI in August 2012. Spuch-Calvar, a physical chemistry specialist, joined the Institute in 2016 to lead the “inorganic nanoparticle detection in consumer products” project.

BioNanomaterials

Team

Prof. Alke Fink, Prof. Barbara Rothen-Rutishauser, Liliane Ackermann, Dr. Sandor Balog, Hana Barosova, Christoph Bisig, Pauline Blanc, Dr. Mathias Bonmarin, David Bossert, Joel Bourquin, David Burnand, Savvina Chortarea, Federica Crippa, Leopold Daum, Dr. Barbara Drasler, Dr. Estelle Durantie, Christoph Geers, Laetitia Haeni, Daniel Hauser, Sandra Hocevar, Philipp Lemal, Dr. Laura Rodriguez-Lorenzo, Ana Milosevic, Christophe Monnier, Dr. Thomas Moore, Dr. Dedy Septiadi, Dr. Miguel Spuch-Calvar, Yuki Umehara, Dominic Urban, Dr. Dimitri Vanhecke

Key Publications

1. Fytianos, K.; Drasler, B.; Blank, F.; von Garnier, C.; Seydoux, E.; Rodriguez-Lorenzo, L.; Petri-Fink, A.; Rothen-Rutishauser, B. Current in vitro approaches to assess nanoparticle interactions with lung cells, *Nanomedicine,* **2016**, 11(18):2457

2. Kinnear, C.; Rodriguez-Lorenzo, L.; Clift, M.J.; Goris, B.; Bals, S.; Rothen-Rutishauser, B.; Petri-Fink, A. Decoupling the shape parameter to assess gold nanorod uptake by mammalian cells, *Nanoscale,* **2016**, 8(36):16416

3. Monnier, C.A.; Lattuada, M.; Burnand, D.; Crippa, F.; Martinez-Garcia, J.C.; Hirt, A.M.; Rothen-Rutishauser, B.; Bonmarin, M.; Petri-Fink, A. A lock-in-based method to examine the thermal signatures of magnetic nanoparticles in the liquid, solid and aggregated states, *Nanoscale,* **2016**, 8(27):13321

4. Groso, A.; Petri-Fink, A.; Rothen-Rutishauser, B.; Hofmann, H.; Meyer, T. Engineered nanomaterials – toward effective safety management in research laboratories, *J Nanobiotechnology,* **2016**, 14:21

5. Geers, C.; Rodriguez-Lorenzo, L.; Placencia Peña, M.I.; Brodard, P.; Volkmer, T.; Rothen-Rutishauser, B.; Petri-Fink, A. Distribution of Silica-Coated Silver/Gold Nanostars in Soft- and Hardwood Applying SERS-Based Imaging, *Langmuir,* **2016**, 32(1):274

Scratch and fix

_ Healing polymers with light

Whether it is a scratch on your car door, broken glass on your smartphone, or a scrape on your watch, there are many situations in which the ability to repair damages to a specific materials system would be beneficial. Researchers from the Polymer Chemistry & Materials group at the Adolphe Merkle Institute have been working on healable polymers and have recently developed a new type of polymer that can be repaired using ultraviolet light.

A few years ago, AMI Professor Christoph Weder's team reported that supramolecular polymers are uniquely suited to be healed using light. Unlike conventional polymers, which typically consist of long, chain-like macromolecules with thousands of atoms, supramolecular polymers are composed of much smaller molecules whose two ends are equipped with "sticky" binding motifs. Thanks to supramolecular interactions, these binding motifs can bind to each other and the small molecules are thereby assembled into polymer-like materials.

However, this assembly is reversible and dynamic: when an appropriate stimulus is applied, for example if the material is heated or irradiated with UV light, the supramolecular polymer is disassembled into its building blocks. As a result, the material becomes liquid and can readily fill any cracks or scratches that may be present. Upon cooling the material or switching off the UV light source, the process is reverted and the original supramolecular polymer is reformed, leaving the object healed.

> "We seem to be well-positioned to take the next steps towards the technological application of healable polymers."
> *Professor Christoph Weder*

Previously, the use of this approach had been limited to relatively soft polymers, whereas corresponding hard materials, as required for the applications mentioned above, proved difficult to make. To solve this problem, PhD student Diederik Balkenende modified the original concept and created several types of supramolecular building blocks containing three sticky ends, as opposed to two.

This seemingly simple modification leads to significant changes of the supramolecular polymers' structures and properties: instead of linear, chain-like assemblies, supramolecular network structures are formed and the resulting materials are much harder than previously available supramolecular polymers. At the same time, they can still be disassembled and liquefied easily by applying ultraviolet light, allowing scratches in a coating to be repaired within seconds.
"One limitation that still needs to be remedied is that the new materials are quite brittle," says Weder. "But we have already made significant progress to also solve this problem, and have materials in hand that are based on industrial building blocks and which were made using readily scalable chemistry. Thus, we seem to be well-positioned to take the next steps towards the technological application of healable polymers." To protect this discovery, AMI has already filed a patent application covering the technology.

Reference

Balkenende, D.W.R.; Olson, R.A.; Balog, S.; Weder, C.; Montero de Espinosa, L.; Reconfigurable supramolecular epoxy resin mimics; *Macromolecules* **2016**, 49, 7877.

Professor **Christoph Weder** joined AMI in 2009 as head of the Polymer Chemistry & Materials group, becoming the director of the Institute the following year. Since 2014, he has also headed up the National Competence Center in Research Bio-Inspired Materials based at the University of Fribourg.

Polymer Chemistry & Materials

Team

Prof. Christoph Weder, Mathieu Ayer, Diederik Balkenende, Véronique Buclin, Céline Calvino Carneiro, Dr. Anselmo del Prado Abellan, Anne-Cécile Ferahian, Diana Hohl, Marc Karman, Anna Lavrenova, Worarin Meesorn, Dr. Dafni Moatsou, Dr. Lucas Montero, Jens Natterodt, Laura Neumann, Apiradee Nicharat, Luis Olaechea, Saikaew Pom-Rateeya, Anita Roulin, Felipe Saenz, Janak Sapkota, Julien Sautaux, Dr. Stephen Schrettl, Anuja Shirole, David Thévenaz, Roberto Vadrucci, Dr. Ester Verde Sesto

Key Publications

1. Thévenaz, D.C.; Monguzzi, A.; Vanhecke, D.; Vadrucci, R.; Meinardi, F.; Simon, Y.C.; Weder, C.; Temperature-responsive low-power light upconverting polymeric nanoparticles, *Mater. Horiz.,* **2016**, 3, 602

2. Balkenende, D.W.R.; Monnier, C.A.; Fiore, G.L.; Weder, C.; Optically responsive supramolecular polymer glasses; *Nature Communications* **2016**, 7, 10995.

3. Sagara, Y.; Lavrenova, A.; Crochet, A.; Simon, Y.C.; Fromm, K.M.; Weder, C.; A Thermo- and Mechanoresponsive Cyano-substituted Oligo(p-Phenylene Vinylene) Derivative with Five Emissive States, *Chem. Eur. J,* **2016**, 22, 4374

4. Camarero-Espinosa, S.; Rothen-Rutishauser, B.; Weder, C.; Foster, E.J.; Directed cell growth in multi-zonal tissue engineering scaffolds for cartilage regeneration, *Biomaterials,* **2016**, 74, 42

5. Sagara, Y.; Yamane, S.; Mitani, M.; Weder, C.; Kato, T.; Mechanoresponsive Luminescent Molecular Assemblies: An Emerging Class of Materials, *Adv. Mater.,* **2016**, 28, 1073

Breaking right

_ Using mechanical forces to release compounds

The controlled and triggered release of chemical compounds from nanocapsules could potentially be important for many applications, such as for curing polymer resins, the triggered release of fragrances on textiles, or for drug delivery. Researchers in Professor Nico Bruns' Macromolecular Chemistry group are investigating mechanical forces that could be used to achieve such a release.

The AMI team has been focusing on polymerosomes, hollow nanoscale polymer capsules that can be dispersed in fluids such as inks or that can circulate in the bloodstream. They have the advantage of being able to encapsulate water-soluble compounds or to transport non-water-soluble compounds in their interior. They can also hold larger molecules such as proteins or DNA, which are increasingly being used for medical therapy.

Until now, polymersomes have been engineered to release their load after exposure to a variety of stimuli such as light, a change in the acidity of the environment, or temperature. However, the Bruns group is tackling something entirely new: polymersomes that could selectively respond to mechanical stimulation. There are plenty of examples of force-responsive membranes in nature. The senses of touch and hearing as well as the regulation of blood pressure are all the result of efficient stress sensing systems in cell membranes.

> "We are trying to mimic certain chemical reactions that lead to stress or force-induced permeability changes in biomimetic polymer membranes."
> *Omar Rifaie Graham, PhD student*

"To establish these concepts as an example for shear-responsive membranes, we are trying to mimic certain chemical reactions that lead to stress or force-induced permeability changes in biomimetic polymer membranes," explains PhD student Omar Rifaie Graham.

These natural systems are, however, far more complex than anything that could be developed in a laboratory. To overcome this hurdle, the AMI team used functional groups that can undergo hydrogen bonding, a simpler concept that can also be found in nature.

Hydrogen bonds are considered dynamic because, just as they form quickly and easily, they also break easily under biological conditions. This makes them extremely important in biological systems. They stabilize and determine the structure of large macromolecules like proteins and nucleic acids. By making changes to the membranes of the polymersomes, AMI researchers took advantage of these properties. When shear forces are applied to solutions containing these nanocontainers, a compound held inside the capsule could be freed without disrupting the overall structure of the nanocapsules.

The team is now working towards using these force-responsive polymersomes in a variety of applications, including the controlled release of curing agents, drug delivery, and force-responsive nanoreactors.

Omar Rifaie Graham joined AMI in 2014 after graduating with a pharmacy degree from the Complutense University of Madrid and working as a Research Assistant at the University College London. His research interests include polymersome-based nanoreactors and drug delivery systems.

Macromolecular Chemistry

Team

Prof. Nico Bruns, Edward A. Apebende, Livia Bast, Bernadetta Gajewska, Nikolas Galensowske, Dr. Clément Mugemana, Jonas Pollard, Samuel Raccio, Omar Rifaie Graham

Key Publications

1. Bruns, N. & Kilbinger, A.F.M. eds. Bio-Inspired Polymers, *Royal Society of Chemistry,* **2016** (book)

2. Nussbaumer, M.G.; Duskey, J.T.; Rother, M.; Renggli, K.; Chami, M.; Bruns, N. Chaperonin-Dendrimer Conjugates for siRNA Delivery, *Adv. Sci.,* **2016**, 3, 1600046

3. Fodor, C.; Gajewska, B.; Rifaie-Graham, O.; Apebende, E.A.; Pollard, J.; Bruns, N. Laccase-catalyzed controlled radical polymerization of N-vinylimidazole, *Polym. Chem.,* **2016**, 7, 6617

4. Nussbaumer, M.G.; Bisig, C.; Bruns, N. Using the dendritic polymer PAMAM to form gold nanoparticles in the protein cage thermosome, *Chem. Commun.,* **2016**, 52, 10537

5. Rother, M.; Nussbaumer, M.G.; Renggli, K.; Bruns, N. Protein cages and synthetic polymers: a fruitful symbiosis for drug delivery applications, bionanotechnology and materials science, *Chem. Soc. Rev.* **2016**, 45, 6213

In brief

Einstein

The Adolphe Merkle Institute hosted an episode on nanotechnology as part of the Schweizer Radio und Fernsehen (SRF; Swiss Radio and Television) science program *Einstein*. This television show is one of the most important science broadcasts for the general public in Switzerland. The program focused on the risks and opportunities of nanotechnology. Professors Christoph Weder, Alke Fink, Barbara Rothen-Rutishauser, and Ullrich Steiner were all featured in the broadcast. Professor Steiner talked most notably about bio-inspiration, giving examples of how insect structures could provide ideas for new materials.

Chorofas Prize

Adolphe Merkle Institute graduate Roberto Vadrucci was awarded the 2016 Chorafas Prize for the best doctoral thesis in natural sciences at the University of Fribourg.

Vadrucci's thesis "New Organic Materials for Low-Intensity Light Upconversion" presents a groundbreaking study on the investigation and development of new materials that permit the transformation of low-power light into radiation of higher energy.

This mechanism is potentially useful for applications that range from biomedical imaging to solar harvesting technologies. For example, upconverting materials can increase the efficiency of photovoltaic devices by capturing the parts of sunlight that cannot be used by conventional solar cells. The photophysical effect used by Vadrucci was already shown to occur in solutions containing special dye combinations approximately 50 years ago, but it was only recently that the group of Professor Christoph Weder, the awardee's PhD advisor, demonstrated its feasibility in solid polymers, which are much easier to integrate in practical devices than solutions.

Explora

The Adolphe Merkle Institute took part in the University of Fribourg's 2016 open day, Explora, on September 24.

The institute was represented by PhD student **Tom Schroeder**, who presented his ongoing project on batteries inspired by electric eels. AMI joined departments from the various faculties in the main hall at the University's Miséricorde campus in the center of Fribourg. Around 2,000 people attended the open day, whose goal was to present lesser known aspects of the University.

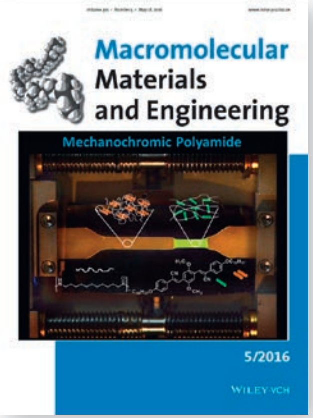
Driving force

AMI vice-director and head of technology transfer Marc Pauchard was the recipient of the Swiss Academy of Engineering Sciences (SATW) "Outstanding Achievement Award 2016."

Pauchard was recognized for his leading contribution to the development and positioning of the academy's "Transferkolleg" program. The program – funded by SATW and the federal Commission for Technology and Innovation – provides seed financing and advice for mixed teams from academia and industry to help translate ideas into industrial production.

SwissLitho

Students from the Adolphe Merkle Institute successfully collaborated on a project called "Nano-security features using fluorescent supramolecular glassy materials" that received third place in the international Young Researcher Idea Competition hosted by SwissLitho. Along with his teammate Samuel Zimmermann of the Federal Institute of Technology in Lausanne (EPFL), PhD student Diederik Balkenende (second from left) put a proof-of-concept together, creating a microscale fluorescent Quick Response (QR) code with a hidden embedded security feature – in this case a nanoscale AMI logo – that is not visible under a fluorescence microscope. In order to do this, they used a nanoscale heatable tip, an element used in a nanofabrication tool (NanoFrazor) developed by the SwissLitho company. Their project, which was developed with another AMI PhD student, Anna Lavrenova, was presented in Zurich in January 2016 at the 3rd Thermal Probe Workshop organized by SwissLitho. Over 100 participants from more than 15 countries took part in the firm's first ever Young Researcher Idea Contest, working in fields as diverse as nanophotonics, plasmonics, and biology.



On the cover

A high school student project carried out at the Adolphe Merkle Institute was selected for the cover of the May 2016 edition of the journal Macromolecular Materials and Engineering. Adrien Holtz, who is a student at Fribourg's Gambach college, worked with AMI PhD student Anna Lavrenova of the Polymer Chemistry & Materials group.

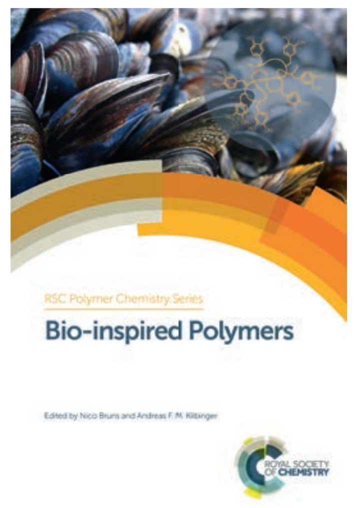
Adrien, who will graduate in 2017, had to execute an individual research project as part of the baccalaureate requirements. With the support of his chemistry teacher, he was able to undertake it at AMI. Professor Christoph Weder, who leads the Polymer Chemistry & Materials group set Adrien up to work on mechanochromic polymers, materials that change their absorption color in response to mechanical action. The aim was to show that a specific type of material – a polyamide – could change color under mechanical stress if blended with a specific dye.

Bio-inspired book

A new Royal Society of Chemistry book on bio-inspired polymers, edited by Adolphe Merkle Institute Professor Nico Bruns and his University of Fribourg colleague Professor Andreas Kilbinger, was released in 2016.

“Bio-inspired Polymers” aims to show how naturally occurring polymers, such as polysaccharides, proteins, and DNA – all key components of life – are inspiring scientists to design new polymeric materials with specific functions, for example, responsive, adaptive, and self-healing materials.

“Bio-inspired Polymers” covers many aspects of the subject, ranging from the synthesis of novel polymers and structure-property relationships to materials with advanced properties and applications of bio-inspired polymers in fields such as drug delivery, tissue engineering, optical materials, and lightweight structural materials. The book also contains contributions from other Adolphe Merkle Institute staff including Professor Christoph Weder, Dr. Dafni Moatsou, Professor Ullrich Steiner, Dr. Jose V. Araujo, Omar Rifaie-Graham, and Edward A. Apebende.



Expo Nano

In September, the Adolphe Merkle Institute hosted the Expo Nano, a travelling exhibition set up as part of the National Research Programme “Opportunities and Risks of Nanomaterials” (NRP 64). Divided into various sections, Expo Nano gave insights into the latest research as well as discussed issues such as nanoparticles in the environment or their application in medical treatments. Many classes from local high schools visited the exhibition, where AMI staff provided additional information.

PhDs

- Dirk Balkenende (Polymer Chemistry & Materials)
- Christoph Geers (BioNanomaterials)
- Christian Heinzmann (Polymer Chemistry & Materials, 2015)
- Dagmar Kuhn (BioNanomaterials)
- Anna Lavrenova (Polymer Chemistry & Materials)
- Christophe Monnier (BioNanomaterials)
- Janak Sapkota (Polymer Chemistry & Materials)
- David Thévenaz (Polymer Chemistry & Materials)
- Roberto Vadrucci (Polymer Chemistry & Materials)

Summer students

In 2016, the Adolphe Merkle Institute hosted 15 undergraduate students from universities across Europe and North America as summer research students.

These students were invited to Switzerland as part of the NCCR Bio-Inspired Materials Undergraduate Summer Research Internships program and each spent between eight and twelve weeks as researchers in one of the AMI groups. Zahra Gallagher, (left, Virginia Polytechnic Institute and State University), who worked in the Polymer Chemistry & Materials group, and Mirae Parker (Stanford University), who was an intern in the Soft Matter Physics team during her stay, shared the award for the best poster presented at the program's concluding mini-symposium.

VIP visits

In April, United States Ambassador to Switzerland, **Suzie LeVine**, and her husband Eric were invited by AMI and the NCCR Bio-Inspired Materials to participate in a roundtable talk about careers, providing interesting perspectives on the subject of equality as experienced by both. This was followed by a public presentation by the ambassador comparing innovation in Switzerland and in the US.

Switzerland's State Secretariat for Economic Affairs' top management visited AMI in September as guests of Fribourg's cantonal government. This was an opportunity for institute director Professor Christoph Weder to present some of AMI's latest research as well as the NCCR Bio-Inspired Materials.

Career move

AMI Swiss National Science Foundation Professor Marco Lattuada made the step up to a permanent position in 2016.

He assumed an associate professorship in the Department of Chemistry at the University of Fribourg and completed the move with his group in the second half of the year. He will continue his ongoing collaborations with AMI and remains a Principal Investigator of the National Center of Competence in Research (NCCR) Bio-Inspired Materials based in Fribourg.

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_Finance & Organization

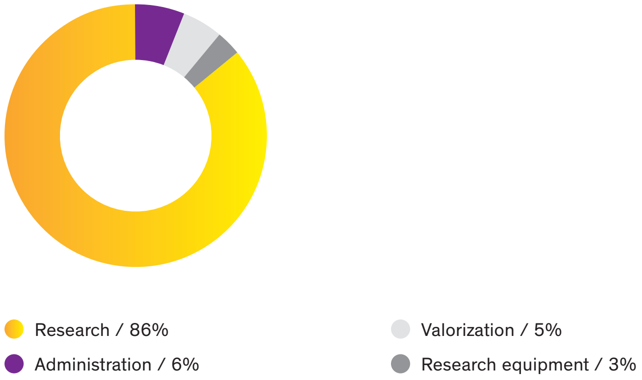
Finance

_ Cost structure at AMI

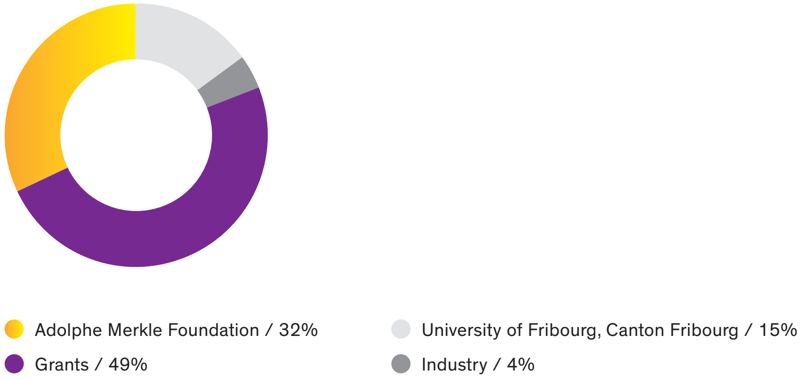
The Institute's overall expenditures in 2016 were CHF 8.8 million. Research spending increased to CHF 7.5 million, up from CHF 7 million in 2015. 86% of the expenses were related to research and an additional 3% was invested in research equipment. Around 5% of the budget supported valorization activities such as technology transfer and communication & marketing, while 6% was used for administration services. Third-party funding of research projects was CHF 4.2 million, covering 56% of all research expenditures. The most important sources were the Swiss National Science Foundation (SNSF), the European Union, industrial partners, and the Swiss Commission for Technology and Innovation (CTI).

Overall expenses 2016

CHF 8.8 million

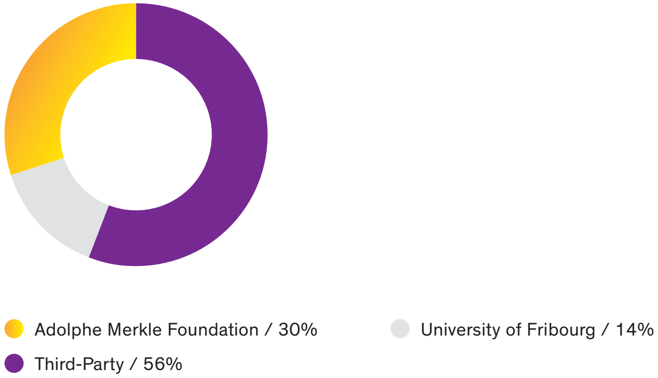


Funding sources of overall expenses 2016



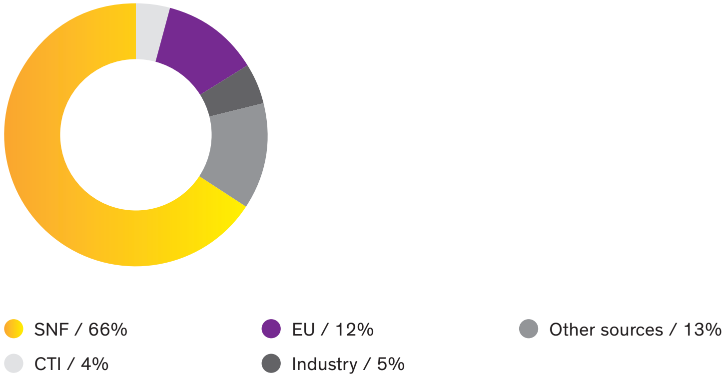
Funding sources of research projects 2016

CHF 7.5 million



Third-party funding of research projects 2016

CHF 4.2 million



Organization

In late 2007, Adolphe Merkle set up the Adolphe Merkle Foundation and donated CHF 100 million to support the University of Fribourg. The donation has been used primarily to support the Adolphe Merkle Institute, which was established in 2008 in a public/private partnership with the University of Fribourg.

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

Foundation Board

Members

Prof. Joseph Deiss (President)
Former member of the Swiss Government, former President of the General Assembly of the United Nations, Professor emeritus, University of Fribourg

Isabelle Chassot
Head of the Federal Office of Culture, former State Minister in charge of Education, Culture and Sport of canton Fribourg, former President of the Swiss Conference of Cantonal Ministers of Education

Peter Huber (joined 2016)
Group Director S&M, Meggitt PLC, UK, President of Meggitt Sensing Systems SA, Switzerland

Prof. Rolf Mülhaupt (joined 2016)
Managing Director Freiburg Center of Interactive Materials and Bioinspired Technologies, University of Freiburg, Germany

Dr. Peter Pfluger
Consultant, former CEO of Tronics Microsystems, Phonak Group and the Swiss Center of Electronics and Microtechnology (CSEM)

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

Dr. Hans Rudolf Zeller (until 2016)
Former Vice-President of Technology & Intellectual Property at ABB Semiconductors

André Broye (Managing Director)

Institute Council

Members

Dr. Hans Rudolf Zeller (President)
Former Vice-President of Technology & Intellectual Property at ABB Semiconductors

Prof. Astrid Epiney (Vice-President)
Rector of the University of Fribourg, Professor at the Faculty of Law, University of Fribourg

Dr. Peter Pfluger
Consultant, former CEO of Tronics Microsystems, Phonak Group and the Swiss Center of Electronics and Microtechnology (CSEM)

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Chair Professor of Chemistry, Hong Kong University of Science and Technology, China

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Director and Chair of Polymer Chemistry & Materials

Dr. Marc Pauchard
Associate Director and Head of Knowledge and Technology Transfer

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Co-Chair of BioNanomaterials

Prof. Michael Mayer
Chair of Biophysics

Prof. Barbara Rothen-Rutishauser
Co-Chair of BioNanomaterials

Prof. Ullrich Steiner
Chair of Soft Matter Physics

Prof. Nico Bruns
SNSF Professor of Macromolecular Chemistry

Prof. Marco Lattuada (until 2016)
SNSF Professor of Nanoparticles Self-Assembly

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Scott Capper
Responsible for Communications & Marketing

Melissa Forney-Hostettler
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Cyrille Girardin
Grant writer

Carine Jungo
Secretary

Catherine Jungo
Responsible for Human Resources

Samuel Laubscher
Responsible for IT Support

Luc Tinguely
Responsible for Finance & Controlling

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PhDs & Alumni

PhDs

Our new doctors

Diederik Balkenende
(Polymer Chemistry & Materials)
"Stimuli-Responsive Functional Supramolecular Materials"

Christoph Geers
(BioNanomaterials)
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Christian Heinzmann (2015)
(Polymer Chemistry & Materials)
"Supramolecular Polymers used as Reversible Adhesives"

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"Uptake and fate of different nanoparticles in cells"

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"Mechanochemistry Based on Supramolecular Interactions"

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"Processing, Structure, and Properties of Cellulose Based Nanocomposites"

David Thévenaz
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"Metal-Complex-Containing Luminescent Polymeric Nanoparticles"

Roberto Vadrucci
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"New Organic Materials for Low-Intensity Light Upconversion"

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Impressum

Editorial: Christoph Weder / Marc Pauchard / Scott Capper

Text: Scott Capper / Editing & proof-reading: Annika Weder

Photos: BM Photos, Marly / Scott Capper (pages 4, 42, 44, 45) / ZHAW (page 12) / Corinne Jud (page 16) / Charly Rappo (page 42) / SATW (page 43) / SwissLitho (page 43) / Charles Ellena (page 45) / Rainer Sohlberg (page 48) / Sandor Balog (page 52)

Illustrations: Noun Project, created by Anbileru Adaleru, Dan Garzi, Roy Verhaag, Norbert de Graaff, Creative Stall, Icon Island, Tania Jiménez, Tony Michiels, Milky (Digital innovation), Mauro Lucchesi

Graphic design: Manuel Haefliger, Grafikraum, Bern

Printer: Canisius Impression & Graphisme

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