2015 Annual Report

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adolphe merkle institute
excellence in pure and applied nanoscience

About the
Adolphe Merkle Institute

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

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

Founded in 2008, AMI is in many aspects unique in the landscape of Switzerland's research institutions. Its focus on soft nanomaterials is unmatched in Switzerland and beyond. Research at the institute 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.

AMI researchers are currently organized in six research groups, which offer complementary expertise and interests in strategically important areas: BioNanomaterials, Macromolecular Chemistry, Nanoparticles Self-Assembly, Polymer Chemistry & Materials, Soft Matter Physics, and Biophysics. Interdisciplinary collaborations between AMI researchers are the basis for the successful and efficient execution of complex research projects that transcend the boundaries of traditional scientific disciplines. This environment and world-class research facilities make AMI a desirable destination for master's and PhD students, postdocs and senior researchers.

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— A message from the director

Christoph Weder

The production of the Adolphe Merkle Institute's annual report is always an excellent opportunity to reflect on our institute's recent activities and achievements, as well as on its development in general. Looking back at 2015, I feel for the first time that the long phase of building the institute might finally be nearing its end.

Indeed, after we moved our institute into our new facilities in the final trimester of 2014, our operations quickly went back to normal with the building functioning as planned and the new infrastructure soon operating as advertised. With the recruitment of Professor Michael Mayer as AMI's new chair of Biophysics we also completed our faculty team. Michael joined us from the University of Michigan in October. While his group is still in its launch phase, their planned activities hold the promise of finding some of the keys to Alzheimer's disease, overcoming chemotherapy resistance, and finding better ways of characterizing proteins. I am also certain that Michael's presence will be a cornerstone of further interdisciplinary activities between AMI's research teams.

While our latest major initiative, a new Specialized Master Program in Chemistry and Physics of Soft Materials, will only be launched this fall, the planning for this venture was a major undertaking last year. I am thrilled with the new curriculum, which I think is unique in central Europe, builds on our institute's interdisciplinary strengths, and will be a great opportunity for us to integrate research and education. I also believe that the new program will be an excellent feeder for AMI's PhD program. As every second staff member at AMI is working towards a PhD degree, setting up a talent pipeline and the possibility of providing some extra polish to students' skill sets before tackling a doctorate can only benefit the institute.

While planning for the future, we have not forgotten our core mission: research that deserves the byline "excellence in pure and applied nanoscience." I invite you to read the newly designed research section of this report, which highlights some of our latest work on nanoscale structures, how nanoparticles interact with the body, as well as innovative surfaces and membranes.

If you have read our report in previous years, you will hopefully notice some changes. After six years, we felt that it was time for rejuvenation and have given it a makeover. Please let us know what you think of the new format. Our most important asset is a unique team of extraordinarily talented people with complementary backgrounds. I hope the new format of our annual report reflects our pride in their work and the extent of their talent.

At AMI, we continue to value our partnerships and are once again grateful for all the interest, courtesy, and support that we received throughout 2015. We will continue 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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_ Life at AMI

Biophysics

_ The final piece of the puzzle

Michael Mayer says his overall research goal is to improve human health

Professor Michael Mayer joined the Adolphe Merkle institute (AMI) at the end of 2015 as the chair of Biophysics. His arrival from the University of Michigan was significant as he was the last full professor to be hired by the institute, finalizing the plan to create an interdisciplinary team focusing on polymer science, bionanomaterials, physics and biophysics. AMI sat down with Mayer to learn more about what brought him to Fribourg and what his plans are for his research.

First perhaps, just what is biophysics in a nutshell?

Michael Mayer: Biophysics looks quantitatively at biological and biochemical processes. That includes cell biology and physiology. The goal is to measure, understand, and predict reactions that are relevant for living systems. A good example is the structure of proteins. You determine the exact placement of each atom in the molecule and that helps understand how it behaves, what its function might be, or how it might interact with a pharmaceutical. The double helix structure of DNA is another example: it is quintessential biophysics in how it explains the ability of living cells to copy their genetic material and to pass it on to their offspring.

My first contact with biophysics came through undergraduate research on enzymes and electrodes. My initial interest was in the marriage between biochemistry and the physical measurement. Then I became fascinated with how single molecules function. It is amazing to literally watch a single protein in action and see how it can act as a nanoscopic machine, valve, or converter. The goal in biophysics is to understand processes in biology to the point where you can make predictions by developing models, like how a cell communicates, responds to stimuli, or deals with toxins.

What is the main thrust of the research you wish to pursue at AMI?

We apply biophysics with the goal to improve human health by examining aspects of physiology and pathophysiology. We hope that the resulting insight will reveal strategies toward early-stage diagnostics as well as fresh approaches to therapeutic intervention.

What are the specific projects you believe will have the biggest impact in terms of research and why?

I see three main thrusts. One involves Alzheimer's disease. We use nanopores to examine Alzheimer amyloid clumps, proteins that are believed to be involved in disease development. We examine those clumps to understand which ones are the most harmful. They come in different sizes and shapes, so their impact is variable. Single molecule biophysics allows us to use tailor-made approaches to examine these proteins and their neurotoxic activity. Identifying and quantifying the most toxic amyloid assemblies may help to deactivate such toxins.

Another thrust is resistance to chemotherapy in cancer treatment. One resistance mechanism is related to so-called pump proteins found in cells all over the body. Usually these proteins remove toxic chemicals by pumping them out of the cells, which is why they are sometimes called the vacuum cleaners of the cell. During chemotherapy, cancer cells, which happen to be equipped with many of these vacuum cleaner proteins, have an advantage because they keep the concentration of the chemotherapeutic medicine in the cancer cells low and allow them to multiply despite aggressive treatment. After some time, the remaining cancer cells are packed full with these vacuum cleaner proteins and resistant to the treatment. The cancer then continues to grow and even switching therapy does not solve the problem because these vacuum cleaners kick out other medicines as well.

We are interested in these pump proteins. We want to know how they work and how, for instance, the electrical potential across the membrane of the cancer cell controls their function. We hope this insight may help to fight resistance by turning the activity of these pumps against the cancer cells.

Finally, we want to detect, characterize, and count proteins one-by-one in biofluids with the aim of discovering biomarkers for disease but also with the aim of improving traditional protein analysis. Every "bio" lab around the world runs traditional gel electrophoresis for protein detection. But this is a somewhat antiquated way of doing things. Using nanopores, tiny holes in a very thin insulating film, we should be able to do the same, but much faster, with smaller samples and with higher quality data. Ultimately, we envision a desktop detection system with standardized nanopore chips that count and identify molecules one-by-one in a matter of seconds.

"Research support at AMI is on the level of the Swiss Federal Institutes of Technology."

You were working at a major US university (Michigan) as a professor. What made you consider a job in Switzerland?

I was interested in an exciting opportunity to come back to Europe that could compare favorably with top-notch research institutions in the US. Once I visited, I liked the atmosphere, colleagues and infrastructure. I saw an excellent fit with my research, in particular the bio-inspired aspect. Having worked previously in Switzerland, I knew its potential for high-level research – and, it didn't hurt that I knew the beauty of the country.

What specifically attracted you to the AMI?

The NCCR Bio-Inspired Materials played a big role. The leadership and caliber of the colleagues at the institute was also important, along with the whole atmosphere and the support that is available. For me, research support at the AMI is on the level of the Swiss Federal Institutes of Technology and may even exceed it in some aspects. It was clear as well that there is an excellent infrastructure and funding environment available. The AMI has a well-selected and unique position among the country's main research hubs. The research in my lab is also very interdisciplinary, so there is an excellent fit for my group to collaborate with the other groups at AMI.

Biophysics is in a sense a hybrid. How do you see that fitting with the research environment at AMI?

If you look at the ongoing projects here at AMI, many of them take inspiration from biology or examine the interaction of nanomaterials with biology. Our research can strengthen these projects by developing assays and models that allow us to understand, predict, and enhance their function and performance.

Biography

Michael Mayer joined the AMI team in 2015. Previously, he was a professor of biomedical engineering and biophysics at the University of Michigan in Ann Arbor where he had been working since 2004. He completed his PhD at the Federal Institute of Technology in Lausannne, followed by postdoctoral research at Harvard University. A German national, he received his Master in biotechnology from the Braunschweig University of Technology.

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NATIONALITIES

CALLED AMI HOME, WITH STAFF COMING FROM EUROPE, NORTH AMERICA, SOUTH AMERICA, AFRICA AND ASIA .

7

PROFESSORS

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

60%

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.

1691

CITATIONS

OF AMI PUBLICATIONS IN 2015. OUR PUBLICATIONS ARE CITED ON AVERAGE NEARLY 650 TIMES EVERY YEAR SINCE 2008.

81

SCIENTIFIC PUBLICATIONS

IN PEER-REVIEWED JOURNALS INCLUDING ADVANCED MATERIALS, NANOSCALE, NANOMEDICINE, BIOMATERIALS, ACS APPLIED MATERIALS AND INTERFACES, MACROMOLECULES.

8

PROJECTS

WITH INDUSTRY PARTNERS INCLUDING 3 RESEARCH MANDATES.

9

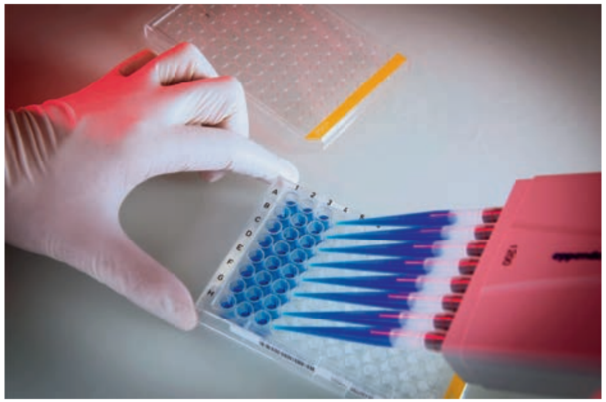
GROUP VISITS

INCLUDING SWISSNEX DAY ATTENDEES, CANTON FRIBOURG’S ENVIRONMENT SERVICE, THE ROBERT MATHYS FOUNDATION AND SPECIAL NEEDS CHILDREN FROM FRIBOURG’S ST JOSEPH INSTITUTE.

Education
_ Mastering research

The Adolphe Merkle Institute has launched a new Master program aimed at students interested in the chemistry and physics of soft matter. Its goal is to provide participants not only with a strong understanding of soft materials, but also to give them a first experience of work on an ongoing research project.

At the interface between physics, chemistry, biology and materials science, the two-year course at the University of Fribourg will offer a unique interdisciplinary curriculum in the field of Soft Materials, or Soft Matter as it is sometimes called.



The program integrates research and education

"We have developed a center of excellence in research at the AMI," says Professor Ullrich Steiner. "The aim of the master program is to complement it with excellence in education in the field of soft matter." This broad class of materials includes polymers, colloids, foams, gels and biological tissue along with others that are part solid and part liquid and are often easily deformable. Soft materials are everywhere and many industries, including the traditional materials sector as well as the medical, pharmaceutical, and food industries, depend increasingly on professionals with specific training in this domain. The Master program therefore provides students with an excellent basis for employment in industry or to launch an academic career.

"They'll graduate as highly skilled individuals with strengthened language and communication skills, who are capable of conveying ideas and concepts and discuss projects on a very high scientific level," says AMI Professor Alke Fink.

"Many of them are likely to pursue doctoral studies after the program, where they will deepen their disciplinary and interdisciplinary expertise and are prepared for leadership roles in industry and academia." Those doctoral studies could include extending a master student's stay at the AMI.

Soft matter science is by its very nature interdisciplinary, bridging not only chemistry, physics and biology, but also materials science and engineering.

The Master program itself consists of compulsory and elective courses. Students must also complete two small research projects as well as the one required for their thesis. These courses include varied topics such as nanomaterials, microscopy and scattering techniques, soft matter and biophysics, polymer chemistry, fundamental cell biology but also science writing and ethics as well as innovation. The students will be trained to conduct research in contemporary fields of materials chemistry and physics.

"Interdisciplinary research requires broad knowledge, motivation and mutual respect. In order to understand and solve problems with roots in multiple disciplines, we will teach students how to fuse different concepts," adds Fink. "Our goal is to help students develop an appreciation of the differences between disciplines on how to approach a problem."

What is crucial though is that their work will be integrated into ongoing research projects. "I think that it is important for students to be integrated into a real working environment and be part of a research team," points out Fink. "It is also important for them to feel that their work will have a real impact rather than just show they have mastered some techniques. Taking this approach will ensure that they consider a career as a working scientist as a worthwhile long-term objective."

The launch of the program also opens the door for potential developments. "We could imagine setting up a graduate school in soft nanomaterials, offering an integrated teaching program across the master and PhD levels, along the lines of what is done in the United States," says Steiner. Students for the master program, which will emphasize quality over quantity, are selected on a competitive basis. The first students could begin their courses in autumn 2016.

Adding value

_ Developing an innovation culture

Marc Pauchard (left) helps students like Omar Rifaie Graham understand the innovation process

Innovation is a buzzword that is frequently used by politicians, business people and the media, and not just in Switzerland. Its meaning is however not always clear. For the Adolphe Merkle Institute Associate Director and technology transfer specialist Dr. Marc Pauchard, innovation is more than just new products.

Innovation means many different things to different people. How do you define innovation at the Adolphe Merkle Institute?

Marc Pauchard: The word “innovative” is often used to describe an original or unexpected solution to a problem. This can be everything from a new diet to a new way a city tackles traffic problems. In the context of companies, innovation means the successful transformation of a new idea or technology into something of real value to a customer, enough at least to convince that customer to pay for it. This allows the company to generate revenues that cover its costs and finance the development of new products. AMI plays a very specific role at the beginning of this chain as we don’t develop or sell products. Our contributions are knowledge, expertise and technology that can support or stimulate innovation.

To what extent is AMI involved with industry? What effect does it have on the research activities?

Every year, we talk with over 30 companies from around the world. They approach us first because they are convinced that the institute might help them innovate. We learn about their needs, competences, challenges and new ideas. Ideally, AMI can contribute to potential solutions and we then agree with the companies on research collaborations. Our competences are best used if the project is organized so that the collaboration generates more than just the expected results outlined at the beginning. An academic research institute like ours is ideally positioned to investigate novel concepts. We work for example on adhesives, but instead of tweaking known products and improving their properties by a small amount, we investigate completely new concepts. We are for example developing adhesives that can be switched between sticky and non-sticky by exposing them to ultraviolet light and other stimuli. This type of project can lead to radical innovations for the companies involved and contribute simultaneously to the general growth of knowledge, which is in line with the mission of our institute.

Does that mean the AMI is focused solely on working with companies?

The institute strives to carry out fundamental and application-oriented research that matters and has an impact. Working with companies or creating start-up companies is one important way of adding value to our research, but not the only one. Most of our research projects do not involve industrial funding.

How do you square the AMI concept of innovation with academic settings where working with private third parties is not always welcomed or understood?

One important outcome at AMI is successfully training young people, because they are the workforce of the future. As most of them will work for companies after their PhD or postdoc, it is very important for them to understand at an early stage how companies operate and to develop their personal network outside of academia.

The primary goal of most research projects is to learn and understand; in this respect we are not different to any other academic research entity. But we are convinced that besides increasing scientific knowledge, we can use our results to have a wider impact. One way of achieving this is to work with companies that deliver direct value to customers. Another possibility is to work with authorities, non-profit organizations or foundations. Here we do not contribute towards the creation of new products, but for example by helping to establishing new protocols such as in vitro tests that could replace animal studies as well as defining guidelines and standards.

A common misunderstanding is that working with private parties will restrain the freedom of research or infringe on scientists' independence. At AMI we have clear values and ethical standards and will not compromise them. This ensures that we work with the right partners on the right projects.

It seems that innovation is also a state of mind at the AMI. How do you transmit that idea to the students?

Innovation is bringing a successful product to the market. It's not simple to help students understand this when they are not immersed in this process every day. We do our best to get them involved in discussions with industry partners and support their projects when it comes to securing intellectual property or presenting research results to an audience outside of the scientific community.

> "Innovation is a truly multidisciplinary field, where people must learn to overcome barriers and to collaborate efficiently."

The most important question is always "how can this create value?" Students are very open-minded about this. The most important step is that they broaden their horizon and understand the basic principles that lead from research to application.

How does the institute try to contribute to innovation culture in Fribourg?

What is true for our students is also true for almost all other students in Fribourg. Innovation is the result of many factors coming together. The successful interplay between technical, design, commercial, organizational and other aspects is crucial for a successful innovation process. So, innovation is a truly multidisciplinary field, where people must learn to overcome barriers and to collaborate efficiently.

Together with like-minded people, we recently founded the Association for Student Innovation (ASI) with professors, students and other key stakeholders to support inter-institutional activities in this field. We want to tear down the walls between disciplines and make people interact more. But to avoid an institutional perspective, we decided to create an independent association, where only personal membership is possible and hierarchies or politics play no role. It's about the people who want to change something independently of their status or affiliation.

The most important initiative today is the "Innovation Club", which is becoming the main community in Fribourg where students and interested other people meet and interact. I am convinced that with all the initiatives and talent in Fribourg, we have the critical mass to stimulate great new innovations. What we need now is to get them together and enable them. The students must realize what opportunities they have, but they also need role models and support to make the switch from being learners to becoming actors.

Biography

Marc Pauchard is AMI's Associate Director and is responsible for Knowledge and Technology Transfer within the Institute. Marc studied chemistry at the University of Fribourg and earned his PhD at the University of Bern in 2001. After his postdoctoral stay at UC Santa Barbara he worked for Ilford Imaging. He led a research team there before joining AMI in 2009 where he is also in charge of the administrative team.

Future energy

_ Searching for more efficient solar devices

Developing new, reliable sources of energy is a major challenge for the 21st century. Coupled with the need to mitigate the effects of climate change, research leading to innovative solutions to harvest and distribute renewable energies as well as to improve overall energy efficiency is all the more important.

The Soft Matter Physics group at the Adolphe Merkle Institute is highly involved in energy research, especially photovoltaics and storage. There are multiple challenges from the start says senior scientist Alessandro Sepe.

"First you have to improve the efficiency of these systems, then you need to increase their stability," he points out. "Finally, you have to improve reliability since photovoltaic systems degrade over time."

Silicon-based solar cells are the most widespread photovoltaic system currently available, but remain relatively expensive despite mass production and their efficiency is not always the best. However, given that solar power is one of the prime sources of renewable energy available to mankind, scientists are considering all possible options to develop low-cost photovoltaic (PV) devices.

The Soft Matter group is looking at hybrid organic/quantum dot systems to supplement silicon-based solar cells. Quantum dots are nanoscale semiconductors whose properties can be easily manipulated and are considered prime candidates for PV devices. These tiny crystals also emit a brilliant, single-color glow when excited by electricity or light.

"Our research falls into the segment of low-cost solar cell devices that can be processed at low temperatures, and make use of established industrial printing processes," says Soft Matter Physics professor Ullrich Steiner.

Science is just starting to come to grips with this concept though. Most devices developed using this system have relied on a "trial-and-error" process for optimization. Little is known about how the processing of the constituent elements determines the assembly of the different materials or how that assembly will affect the electronic properties of the device. If developments are based on trial-and-error, minor changes or new materials can take all the work back to square one.

The AMI physics team is taking a particular interest in so-called nanocrystal quantum dots (NCQD). While promising, they are often hampered though by electronic defects caused by an uneven morphology and crystalline structure.

Furthermore, even their processing can cause problems when it shouldn't. Therefore ideally some form of structural order needs to be achieved to make PV devices more stable. To achieve this, the AMI researchers are trying to understand the relationship between structure and function in hybrid NCQD-based photovoltaic devices.

This passes notably through understanding how the photoactive layers form at different stages of processing. This requires the use of advanced X-ray scattering techniques, using the most advanced synchrotrons such as those found at Switzerland's Paul Scherrer Institute or the Diamond Light Source in Britain.

> "Our research falls into the segment of low-cost solar cells devices that can be processed at low temperatures, and making use of established industrial printing processes".

The goal is then to develop a sufficiently powerful and flexible computational framework to conduct simulations and provide accurate so-called Big Data models. This is being done in collaboration with scientists at the Lawrence Berkeley National Laboratory in the United States and the Swiss National Supercomputing Centre (CSCS) in canton Ticino. The result should help provide sufficient information leading to a more rational design of efficient photovoltaic devices.

More sustainable projects like Fribourg's Bluefactory require renewable power sources such as solar energy

Another approach favored by AMI researchers involves converting low-energy, long wavelength light such as found in the infrared spectrum into radiation with a shorter wavelength and higher energy such as ultraviolet light, thanks to a process known as upconversion.

The Polymer Chemistry & Materials group has developed so-called optically active upconversion organogels, substances which in this case efficiently convert lower energy green light into higher energy blue light. Potential applications range from better solar cells to improved photochemical reactors. In both cases, the efficiency of the devices is increased because a larger portion of the solar spectrum is used.

“Solar cells could benefit from new layers that upconvert infrared light efficiently,” says AMI researcher Roberto Vadrucci. “The absolute maximum possible gain in efficiency due to upconversion is difficult to assess, but theoretical calculations predict an improvement of up to 47.6% for non-concentrated sunlight.”

Organogels, which are mostly an organic liquid immobilized by a three-dimensional polymer network, are a concept of efficient host materials for upconversion. These materials are the most recent development of AMI research focused on optically active solid materials and a continuation of studies performed on glasses, different types of rubber and nanoparticles. They combine the advantages of solids and rubbery materials.

The research carried out at AMI shows that the most efficient upconversion is observed in solutions. Organogels are very efficient since they mostly consist of solvent. But at the same time, they are also solids, making them easier to handle than solutions. For example, they can more easily be integrated into a device.

“Theoretical calculations predict an improvement of up to 47.6 % for non-concentrated sunlight”.

The AMI Polymer group was the first to propose these new organogels, and other researchers have already followed that lead to perform photochemical reactions. The design approach opens the perspective of a new class of materials with unique properties. It could also be applied to other materials based on different solvents and polymer networks.

“We are currently investigating other materials concepts, which are even more versatile and at the same time more efficient than gels,” says Vadrucci. Yet another indicator that energy will continue to be a major research focus at AMI in the years to come.

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Methods
_ Counting nanoparticles

Transmission electron microscopy has traditionally been the first step for observing nanoparticles.

One of the biggest challenges for scientists currently working at the nanoscale is the characterization of particles. The reliable measurement of nanoparticle size is one of the main tasks facing researchers. At the Adolphe Merkle Institute, a variety of methods have been developed to provide some answers to these fundamental queries.

One challenge is determining size distribution, in other words the relative amount of particles present according to their size. EU legislation requires for example that the so-called nanoparticle number weighted size distribution be determined for samples containing nanoparticles. Typically the size of a representative number of nanoparticles is evaluated using high resolution transmission electron microscopy (TEM).

In this type of microscope, nanoparticles deposited on an ultra-thin carbon film are probed with an electron beam, and these electrons interact with the sample as they pass through. This interaction of the electrons and the sample leads to a “shadow image” of the specimen. During sample preparation, however, nanoparticles often aggregate, making it difficult both to count them and to determine if the particles were already aggregated beforehand. This renders automatic counting systems useless as well, leaving researchers with the huge task of interpreting images manually.

“Research moves quickly, so faster, more efficient and more exact methods allow better characterization of materials. This is crucial if we want to develop better materials.”

To prevent artifacts from sample preparation and simplify interpretation, researchers from the AMI BioNanomaterials group have implemented a method using a low-cost protein derived from cow blood plasma and widely used in laboratories. The method requires nanoparticles to be dispersed in the presence of this protein before preparing the sample for electron microscopy. The approach relies on the stabilization of the nanoparticles against aggregation during sample preparation.

Not all nanoparticles are created equal though. Depending on type, size and the concentration of the original nanoparticle dispersion, the protein concentration needs to be determined. The AMI scientists have simplified this step with a free online tool

MORE THAN

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ACTIVE RESEARCH PROJECTS

IN FIELDS SUCH AS MECHANICALLY AND STIMULI RESPONSIVE POLYMERS, NANOFIBER COMPOSITES, DIESEL FUME TOXICITY, PHOTOVOLTAICS AND BATTERIES, AND THE SURFACE, PROTEIN AND CELL INTERACTIONS OF NANOPARTICLES.

CHF 8.6 mio

SPENT IN 2015

RESEARCH SPENDING ROSE FROM CHF 5.9 MILLION IN 2014 TO CHF 7 MILLION LAST YEAR.

38%

WOMEN

62%

MEN

WORKING AT AMI.

50%

OF OUR STAFF

ARE PHD STUDENTS.

95

PEOPLE

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

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AVERAGE AGE OF STAFF

(bsa.bionanomaterials.ch). The method can also be used to characterize commercial powders, where particles are not always produced as precisely as in a research environment.

The reactions to the proposed method have been positive according to BioNanomaterials researcher Christoph Geers. “Researchers from around the world are frequently visiting the webpage to help determine the required protein concentration to add to their nanoparticle dispersions,” he points out.

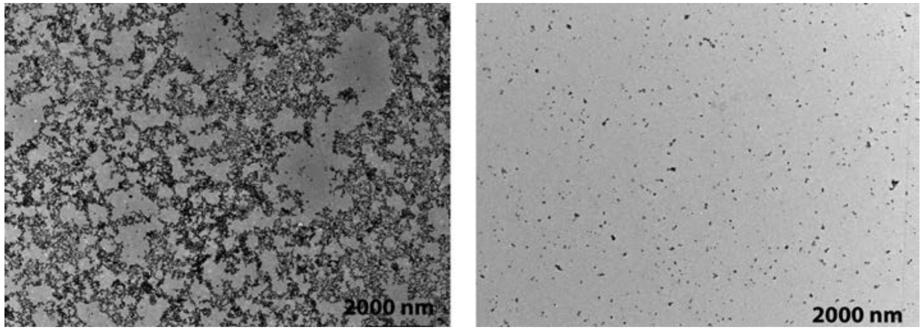
The method still needs improvements though to increase its field of application says Geers. “The method is not always applicable to more complex nanoparticle systems. Our current research focuses on other molecules suitable for stabilizing different nanoparticles,” he adds.

“The group is also working on complementary techniques to characterize the size distribution of nanoparticles such as light scattering.”

This approach is used to meet the challenge of precisely characterizing nanoparticles in optically complex suspensions such as biological and physiological media. These can be colloids for example, where at least two different types of nanoparticles are present in a liquid medium.

Dynamic light scattering (DLS) has been used as one of the techniques available to adequately characterize those nanoparticles in real time and in situ. Particle size is determined by measuring random changes in the intensity of light scattered from a suspension. This is because each type of nanoparticle affects the light that strikes it in a specific way.

However, when faced with complex media such as physiological fluids, DLS struggles to distinguish relevant optical signals from irrelevant ones. AMI researchers address this shortcoming by using depolarized light scattering. This technique adds a linear polarizer that changes the balance of the light passing through the system and filters out unwanted scattering signals from the fluid such as those stemming from biomolecules, while providing information that can be interpreted much more easily.



TEM images of zinc oxide nanoparticles without (left) and with (right) the use of the BSA protocol.

AMI scattering specialist Sandor Balog says this is important because nanoparticles in suspension can be studied without worrying about the protein content of the fluid. While interpretation is simplified, it remains however a difficult task for most scientists.

“It involves a lot of mathematics and data processing, so extracting the information from the results is far from simple for non-specialists,” admits Balog.

Besides providing measurements for academic research, the method is also currently applied for industrial partners with an interest in particle measurement.

“Since the EU legislation requires that industries report particle sizes using number weighted size distribution, they could use these methods to do automated image processing,” says BioNanomaterials professor Alke Fink.

These new methods have an additional advantage according to Fink. “Research moves quickly, so faster, more efficient and more exact methods allow better characterization of materials. This is crucial if we want to develop better materials,” she adds.

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In brief

In the news

AMI researchers were regularly sought out as experts by the media in 2015.

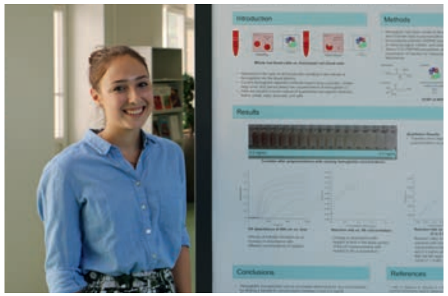
Prof. *Barbara Rothen-Rutishauser* was interviewed for a documentary broadcast by the French/German broadcaster Arte about the risks of diesel particles for human health. Prof. *Alke Fink*'s kidsUni program collaborated with the Migros Magazine, a free weekly published by Switzerland's biggest retailer, to show how fun chemistry can be for children. Prof. Fink's work for the National Research Program 62 (Smart Materials) on vesicles that transport drugs that are set free using a magnetic field was highlighted in the press, as was Prof. *Christoph Weder*'s contribution to new materials whose softness varies depending on humidity levels, a property that could be applied to tires.

Summer interns

AMI hosted a group of undergraduate research interns from the United States over the summer. The eight students hailed from Cleveland's Case Western Reserve University, the Massachusetts Institute of Technology, the University of New Hampshire, Virginia Tech and John Carrol University.

Their eight-to-twelve-week stay in Switzerland was financed by the National Center of Competence in Research (NCCR) Bio-Inspired Materials as part of its Undergraduate Summer Internship program. The students worked on a project alongside AMI PhD students and postdoctoral researchers.

Besides their research activities, interns also attend scientific lectures, social and networking events. At the end of the summer, the interns presented the results of their research projects in a poster session followed by a summer party. *Annabelle Davey* (below) of Case Western Reserve University, who worked with PhD students *Jonas Pollard* and *Omar Rifaie Graham* of Prof. *Nico Bruns*' Macromolecular Chemistry group, was awarded first prize for her poster on "Polymerization Reactions as a Novel Diagnostic Tool for Hemolytic Anemia".



Equal opportunities

AMI BioNanomaterials Prof. *Barbara Rothen-Rutishauser* was instrumental in promoting equality and career building at the institute in 2015 as well as within the NCCR Bio-Inspired Materials where she is responsible for equal opportunity initiatives. This included the organization of bimonthly roundtable sessions at AMI open to all students and postdoctoral researchers of the NCCR. Guest speakers are invited to exchange on subjects as varied as work-life balance, how to find a job outside academia, project management or whether women lead differently to men.

Prof. Rothen-Rutishauser was also invited in May to moderate a roundtable discussion at the first national colloquium on job-sharing in Fribourg organized by the State Secretariat for Economic Affairs. This was notably an opportunity to present with her BioNanomaterials co-chair Prof. *Alke Fink* their job-sharing arrangement at AMI.

21

_Research Stories

Puncture-proof

_ A new perspective on self-sealing breathable membranes

Companies supplying outerwear for the general public have a holy grail: find a textile membrane that will keep out the heaviest of downpours while remaining breathable and comfortable during a physical effort. Over the past few years, textiles have been continuously improved, but these improvements come with a hefty sticker price that only some customers can really afford. And to make matters worse, these same textiles are often easily damaged or punctured once they are taken out into the great outdoors, the environment the outerwear was designed for. Even the tiniest of holes can cause a leak.

Nico Bruns and his colleagues at the Adolphe Merkle Institute, the University of Basel and the University of Applied Sciences and Arts Northwestern Switzerland have developed a composite membrane to overcome at least part of these problems, a membrane that remains water-tight even if punctured with a sharp item.

Their idea was to take a thin breathable membrane and then add to it a so-called amphiphilic polymer co-network (APCN). APCNs are rubbery materials that swell when they come into contact with water. "The nanostructure of hydrophilic and hydrophobic domains allows for efficient water transport across the material, while at the same time rendering them exceptionally durable," says AMI Professor Nico Bruns, lead researcher on the project.

If the membrane is punctured, the APCN layer immediately seals the hole, withstanding water pressure of at least 1.6 bar, or around half of what comes out of a garden hose. This pressure is the same as a water column of 16,000 mm, which is high for textiles. A membrane is considered waterproof at just 1,300 mm. Despite the high level of waterproofness, the extra layer does not stop liquid evaporating through the membrane though.

Bruns and his colleagues also tested their concept in the context of medical cooling garments, such as those used to alleviate multiple sclerosis (MS) symptoms. Up to 80 per cent of MS patients are affected by heat sensitivity, which is strongly correlated with disabling symptoms such as fatigue, pain, and difficulty concentrating according to a Swedish 2011 study. Measurements showed that the new membrane could be an alternative to current materials used for these devices.

Self-sealing materials are not a new concept. They were used for self-repairing tires and for bulletproof aircraft fuel tanks during the Second World War. Nature also uses self-sealing mechanisms. A liana found in the eastern United States, pipevine, has its own system to close off defects. However, none of these concepts combines self-sealing properties of the new material with the ability for water to permeate through the sealing layer, which is essential for the evaporation of moisture.

> "The aim is that self-sealing membranes for medical cooling textiles and for outdoor garments enter the consumer market."

"We are now going to work with industrial partners and with the financial support of the Swiss Commission for Technology and Innovation to take our research from the lab to scalable production," says Bruns. "The aim is that that self-sealing membranes for medical cooling textiles and for outdoor garments enter the consumer market."

Reference

Rother, M., Barmettler, J., Reichmuth, A., Araujo, J. V., Rytka, C., Glaied, O., Pieles, U. and Bruns, N. (2015), Self-Sealing and Puncture Resistant Breathable Membranes for Water-Evaporation Applications. *Adv. Mater.* **2015**, 27: 6620–6624.

Professor Nico Bruns joined AMI in 2013. He is the beneficiary of a Swiss National Science Foundation professorship and a principle investigator of the National Center of Competence in Research Bio-Inspired Materials. His interests include macromolecular chemistry, enzyme catalysts, nano-reactors and polymer-protein hybrid materials.

Macromolecular Chemistry

Team

Edward Apebende, Dr. Jose V. Araujo, Dr. Csaba Fodor, Bernadetta Gajewska, Omar R. Graham, Jonas Pollard

Key Publications

1. Filling Polymersomes with Polymers by Peroxidase-Catalyzed Atom Transfer Radical Polymerization Maria Valentina Dinu, Mariana Spulber, Kasper Renggli, Dalin Wu, Christophe A. Monnier, Alke Petri-Fink, Nico Bruns, *Macromol. Rapid Commun.,* **2015**, 36, 507–514

2. Reduction-Sensitive Amphiphilic Triblock Copolymers Self-Assemble Into Stimuli-Responsive Micelles for Drug Delivery, Smahan Toughraï, Violeta Malinova, Raffaello Masciadri, Sindhu Menon, Pascal Tanner, Cornelia Palivan, Nico Bruns, Wolfgang Meier, *Macromol. Biosci.,* **2015**, 15, 481–489

3. Polymeric Particulates for Subunit Vaccine Delivery, Thomas Schuster, Martin Nussbaumer, Patric Baumann, Nico Bruns, Wolfgang Meier, Anja Car, *Advances in Delivery Science and Technology,* **2015**, Springer Science + Business Media, 181–201

Breathe easy?

_ Tracking nanoparticles past the lung barrier

A new approach to understand how inhaled nanoparticles enter the body's circulatory system and translocate into secondary organs could provide a cheaper and as efficient approach as animal testing in the future.

Nanotechnology holds great promise in fields as varied as electronics, energy and drug delivery. However the health and environmental risks posed by new materials are difficult and time-consuming to assess, requiring the development of innovative testing methods.

Researchers from the Adolphe Merkle Institute (AMI) have worked with their colleagues from the Federal Institute of Technology in Zurich (ETHZ) to develop a new approach to understand how different sized gold nanoparticles can pass through the lung barrier and how they spread in the human body.

"You can use the lung as an organ to deliver inhaled biomedical nanoparticles," explains AMI Professor Barbara Rothen-Rutishauser. "On the other hand, you also have to do risk assessment for any particles that are released into the environment, for example when you are talking about occupational exposure."

The lung's epithelial tissue, which usually fends off unwanted materials, is the main entry point for aerosolized (a fine spray of) nanoparticles. This tissue is made up of a very thin layer in the alveolar region, and particles which are deposited on the lung surface can, depending on their physico-chemical properties, pass through.

Little is known so far though about which nanoparticles can percolate through the lung tissue, to what extent and how they reach the rest of the body. To figure out how certain types of particles interact with the tissue, the AMI researchers and their ETHZ colleagues initiated a two-step process.

First they exposed in vitro single layers of lung epithelial cells to an aerosol containing gold nanoparticles of variable sizes to see how these would move through the cell layer.

Cell samples were placed in an Air-Liquid Interface Cell Exposure (ALICE) system at the AMI. It consists of a cell exposure chamber, which is temperature and humidity controlled. The system is designed to ensure fast, spatially homogeneous, controllable and efficient delivery of nanoparticles or dissolved substances over the lung cell surface. After defined time points the translocated nanoparticle fraction was measured by a chemical analytical method.

In a second stage, the distribution to other organs of the body was simulated using a so-called pharmacokinetic model – a mathematical model simulating the transport of nanoparticles inside the body – which was developed by Dr. Natalie von Goetz and her PhD student Gerald Bachler at ETHZ. To do this, values from the experimental stage were fed into the model.

Different sizes of gold nanoparticles were used for this approach, and the translocation process was studied in both human and mouse cells. While the process remained similar for human and animal cells, results showed that the passage of the nanoparticles through the air-blood barrier, although very low for all particles tested, was dependent on their size. So the smaller the nanoparticle, the more likely that it will cross the air-blood barrier if inhaled and deposited onto the lung surface.

"This approach allows us to test the uptake of different sized nanoparticles in a short time, so it could simplify the screening process for the biological effect of particles," says Rothen-Rutishauser.

These results were consistent with data found in animal (in vivo) models, opening new perspectives for testing the translocation of other nanoparticles with the new approach.

It could for example be considered to reduce some animal testing. "Given the 3R research principles – refine, reduce and replace – there is certainly a need for realistic and reliable testing strategies in this field of study," adds Rothen-Rutishauser. The next steps for the project are to develop a model that predicts the translocation of inhaled nanoparticles.

Reference

Bachler G., Losert S., Umehara Y., von Goetz N., Rodriguez-Lorenzo L., Petri-Fink A., Rothen-Rutishauser B., Hungerbuehler K. Translocation of gold nanoparticles across the lung epithelial tissue barrier: Combining in vitro and in silico methods to substitute in vivo experiments. *Part Fibre Toxicol.* **2015** 12(1):18.

Professor Barbara Rothen-Rutishauser (right) and Professor Alke Fink have co-chaired the BioNanomaterials group at the Adolphe Merkle Institute since 2011. Rothen-Rutishauser is an expert in the field of cell-nanoparticle interactions in the lung. Fink is a material chemist with expertise in nanoparticle synthesis, derivatization, and characterization.

BioNanomaterials

Team

Liliane Ackermann, Dr. Sandor Balog, Hana Barosova, Pauline Blanc, Christoph Bisig, David Bossert, Joel Bourquin, David Burnand, Savvina Chortarea, Dr. Martin Clift, Federica Crippa, Leopold Daum, Dr. Jean-François Dechezelles, Dr. Estelle Durantie, Christophe Geers, Laetitia Haeni, Daniel Hauser, Sandra Hocevar, Dr. Lenke Horvath, Philipp Lemal, Dr. Laura Rodriguez-Lorenzo, Ana Milosevic, Christophe Monnier, Dr. Thomas Moore, Dr. Mariangela Mortato, Yuki Umehara, Dominic Urban, Dr. Dimitri Vanhecke, Fikad Zermimariam

Key Publications

1. Chortarea S, Clift MJD, Vanhecke D, Endes C, Wick P, Petri-Fink A, Rothen-Rutishauser B. Repeated exposure to carbon nanotube-based aerosols does not affect the functional properties of a 3D human epithelial airway model. *Nanotoxicology,* **2015**, 1-11.

2. Jud C, Ahmed S, Muller L, Kinnear C, Vanhecke D, Umehara Y, Frey S, Liley M, Angeloni S, Petri-Fink A, Rothen-Rutishauser B. Ultrathin ceramic membranes as scaffolds for functional cell coculture models on a biomimetic scale. *Biores Open Access,* **2015**, 4(1): 457–468.

3. Moore, T. L.; Rodriguez-Lorenzo, L.; Hirsch, V.; Balog, S.; Urban, D.; Jud, C.; Rothen-Rutishauser, B.; Lattuada, M.; Petri-Fink, A. Nanoparticle colloidal stability in cell culture media and impact on cellular interactions. *Chem. Soc. Rev.,* **2015**, 44 (17), 6287–6305.

4. Balog, S.; Rodriguez-Lorenzo, L.; Monnier, C. A.; Obiols-Rabasa, M.; Rothen-Rutishauser, B.; Schurtenberger, P.; Petri-Fink, A. Characterizing nanoparticles in complex biological media and physiological fluids with depolarized dynamic light scattering. *Nanoscale,* **2015**, 7 (14), 5991–5997.

5. Rodriguez-Lorenzo, L.; Rothen-Rutishauser, B.; Petri-Fink, A.; Balog, S. Nanoparticle Polydispersity Can Strongly Affect In Vitro Dose. *Part. Part. Syst. Charact.,* **2015**, 32 (3), 321–333.

Aches and pains

_ Fixing defective joints

As people get older, one of the tell-tale signs of ageing is joint pain and arthritis. This can be due to the body wearing down naturally or through injury due to overuse such as carrying heavy loads or too much sport. Either way, musculoskeletal issues are the leading cause of hospital admissions in Switzerland, with arthritic problems accounting for more than half of those. Much of the wear and tear occurs in the cartilage, which serves as a low-friction cushion in joints such as the knee and elbow and is vital for skeletal movement. Unfortunately, cartilage is unable to heal and once it is damaged or diseased, surgery is often needed to restore functionality. Some repair is possible, but often a prosthetic replacement is the only solution.

It had been thought that cartilage would be the easiest tissue to create artificially, because it contains no blood vessels, it is made up of just one cell type, and its function as a "flat lubrication layer" seemed easy to mimic. However, the ultimately rather complex architecture and biomechanical properties of the native tissue proved difficult to reproduce.

PhD student Sandra Camarero-Espinosa, senior scientist Dr. Johan Foster, and Professor Christoph Weder from the Polymer Chemistry & Materials group at the Adolphe Merkle Institute took on this challenge, and designed, created, and together with AMI biologist Professor Barbara Rothen-Rutishauser explored a novel type of artificial scaffold onto which chondrocytes, the cells found in healthy cartilage, could grow and eventually form cartilaginous tissue that could then be used as an implant.

Camarero Espinosa found her inspiration in the Gothic churches found across Europe. "Collagen fibers in cartilage create a structure that resembles the arcades found in some cathedrals where they play a very important structural role," she says. "I thought that mimicking this structure and other features found in cartilage would represent a key parameter for the design of a proper tissue engineering scaffold."

The design of the polymer nanocomposite scaffolds created by the AMI researchers is based on the observation that in mature articular cartilage, the organization, orientation and shape of the cells and the extracellular matrix components vary. In fact, three different zones or layers can be clearly distinguished. It is this complex architecture that bestows natural cartilage with unique mechanical properties, allows a firm connection with the underlying bone, and renders the surface slippery.

Grown outside the body, cartilage cells would normally not grow into such complex structures – unless they are given "directions", which is effectively what the new AMI scaffolds do: these microporous structures were designed to serve as "molds" in which the size, shape, and orientation of the pores, as well as chemical cues present at their surface would guide the morphology, orientation, and appearance of cultured cells. In addition, the scaffolds were designed to ensure the integration with the underlying bone, providing adequate mechanical support until the newly grown tissue would be ready to fully take over, and degrade to leave only the regenerated cartilage behind.

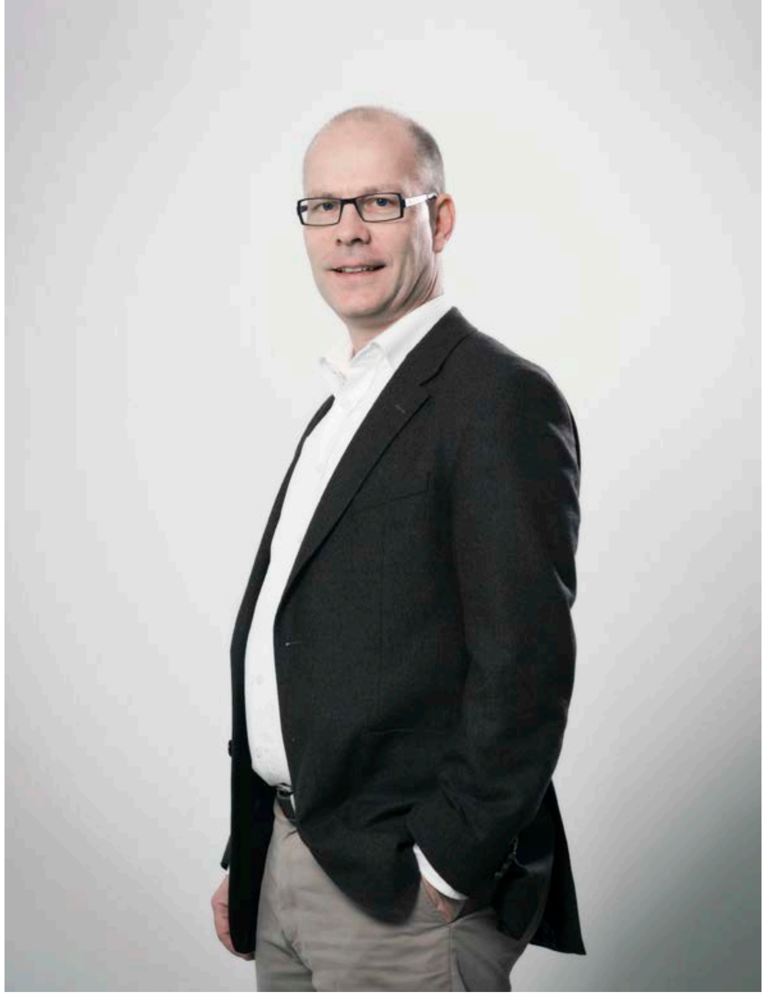
First attempts confirmed that the new approach to cartilage engineering is highly promising. Already after only two weeks of culture, the tissue-scaffold constructs displayed mechanical properties that are comparable to those found in mature cartilage. Perhaps more importantly, it was shown that the new template can guide the morphology, orientation, and phenotypic state of cultured cells so that the engineered tissue emulates the corresponding features of native cartilage.

This design approach is modular and individual components can be readily modified. "We mimicked the structure and the composition of our scaffolds in the macro and micro scales but, we also have the capability of controlling the nanoscale," adds Camarero Espinosa. "The next step would be to create materials with pre-defined chemistries and mechanical properties that allow us to control the response of single cells and thus orchestrate the development of the tissue."

In the future, it could be applied to a broad range of tissues and push regenerative medicine to a new level of precision to the extent that damaged zones could be fully restored.

Reference

Camarero-Espinosa, S.; Rothen-Rutishauser, B.; Weder, C.; Foster, E. J. Directed Cell Growth in Multi-Zonal Scaffolds for Cartilage Tissue Engineering. *Biomaterials,* **2016**, 74, 42–52.



Professor Christoph Weder joined AMI from Case Western Reserve University (Cleveland, USA) in 2009 as head of the Polymer Chemistry & Materials group. He became 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

Mathieu Ayer, Diederik Balkenende, Véronique Buclin, Sandra Camamero, Céline Calvino Carneiro, Anne-Cécile Ferahian, Dr. Alexander Haehnel, Christian Heinzmann, Dr. Burçak Icli, Marc Karman, Tobias Kuhnt, Anna Lavrenova, Worarin Meesorn, Dr. Dafni Moatsou, Dr. Lucas Montero, Jens Natterodt, Laura Neumann, Apiradee Nicharat, Luis Olaechea, Steponas Raisys, Anita Roulin, Janak Sapkota, Julien Sautaux, Dr. Stephen Schrettl, Anuja Shirole, Dr. Yoan Simon, David Thevenaz, Roberto Vadrucci, Dr. Ester Verde Sesto

Key Publications

1. Heinzmann, C.; Lamparth, I.; Rist, K.; Moszner, N.; Fiore, G.; Weder, C.; Supramolecular Polymer Networks made by Solvent-Free Copolymerization of a Liquid 2-Ureido-4[1H]pyrimidinone Methacrylamide; *Macromolecules,* **2015**, 48, 8128–8136.

2. Lavrenova, A.; Farkas, J.; Weder, C.; Simon, Y.C.; Visualization of polymer deformation using microcapsules filled with charge-transfer complex precursors; *ACS Appl. Mater. Interfaces,* **2015**, 7, 21828–21834.

3. Endes, C.; Müller, S.; Kinnear, C.; Vanhecke, D.; Foster, E.J.; Petri-Fink, A.; Weder, C.; Clift, M.J.D.; Rothen-Rutishauser, B.; Fate of cellulose nanocrystal aerosols deposited on the lung cell surface in vitro; *Biomacromolecules,* **2015**, 16, 1267-1275.

4. Montero de Espinosa, L.; Fiore, G.L.; Weder, C.; Foster, E.J.; Simon, Y.C.; Healable Supramolecular Polymer Solids; *Prog. Polym. Sci.,* **2015**, 49-50, 60-78.

5. Vadrucci, R.; Weder, C.; Simon, Y.C.; Organogels for Low-Power Light Upconversion; *Mater. Horiz.,* **2015**, 2, 120-124.

Beetle inspiration

_ More than your usual white

In nature, the hallmark of many insects is their vibrant colors. The shimmering greens and blues found in some butterflies and beetles for example are the result of the ordered structure of their outer shells or the layering of the scales on their wings. White beetles are less common though and how their color comes about is less well understood.

Cyphochilus beetles from southeastern Asia are one example. They are as white as paper, but their color-producing layer is about 100 times thinner. Researchers at the Adolphe Merkle Institute are trying to understand how these beetles manage to scatter light of all colors equally with just a very thin and lightweight shell.

How difficult is this? Well consider that when we see a single color from the light reflecting off a surface, this is only due to one event – light of a specific wavelength not being absorbed by the object it hits, but reflected towards the observer. A colored film such as a soap bubble can therefore be extremely thin, somewhere on the hundred nanometer scale (comparable to a fraction of the light wavelength).

White, which is a combination of all colors, means on the other hand that light of all wavelengths is being scattered by the materials. To succeed at doing this, a surface material such as paper needs to be thicker. Thinner paper would simply be transparent and lose the whiteness that is sought.

Figuring out how this works for the beetle could lead to a variety of applications, for example how to make that elusive thinner and whiter paper. Standard white paper is at least 20 to 100 times thicker than the beetle shell. Providing a structure similar to the beetle's for paint could also help reduce the amount needed to cover a wall to achieve the same opaque effect.

> "Materials that scatter light are needed everywhere where color plays a role."

AMI scientists in the Soft Matter Physics group are combining X-ray nanotomography, which uses x-rays to create cross-sections from a 3D-object, and computer modelling to precisely understand the morphology of the beetle shell and its optical function.

To carry out the measurement, a tiny piece of beetle shell is glued to a platinum tip, which is then rotated around a central axis to ensure the sample is scanned from all sides. This is then reconstructed into a virtual 3D model.

"This type of visualization helps us extract important parameters such as size and length statistics," says post-doctoral researcher Bodo Wilts. "With these results, we hope to gain an insight into what actually makes the beetle white."

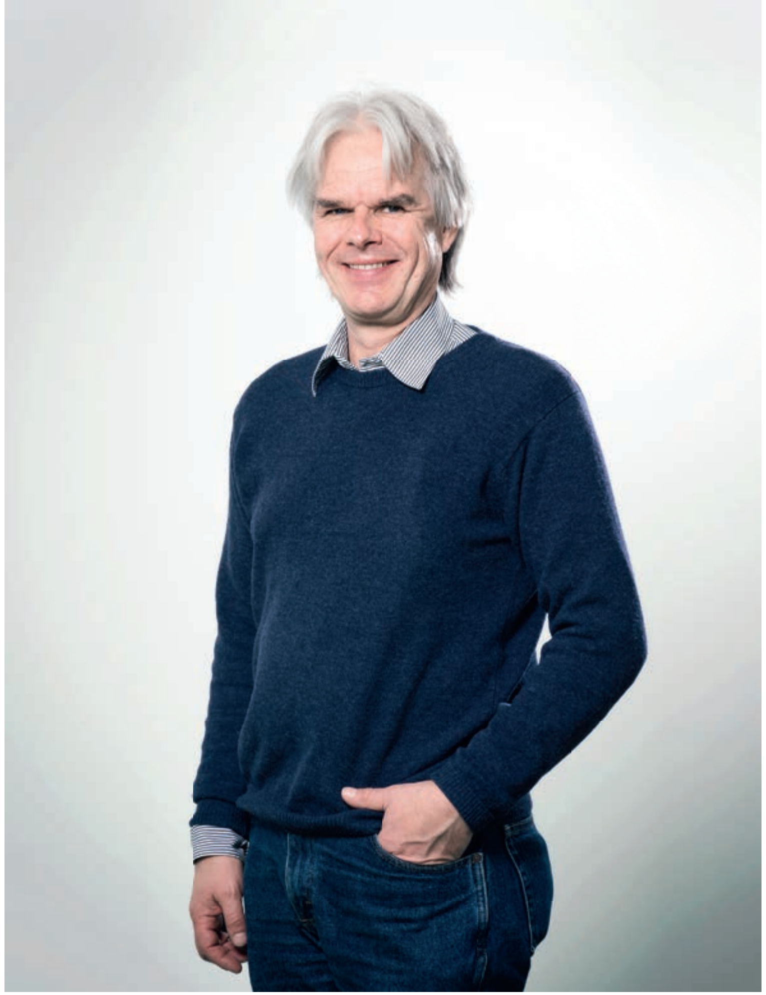
The modelling has confirmed that the beetle shell structure is responsible for its whiteness. It also gives the researchers the leeway to play with different parameters to simulate possible changes in the structure.

Applications such as thinner paper or improved paint are obvious uses for any findings made by the Soft Matter Physics group. There could be many more though according to Wilts.

"Materials that scatter light are needed everywhere color plays a role," he points out. "Paint and paper are the easiest to grasp, but you might want use this type of structure as a material in solar cells for example to improve their light absorption or in displays."

Reference

Burresi, M.; Cortese, L.; Pattelli, L.; Kolle, M.; Vukusic, P.; Wiersma, D. S.; Steiner, U.; Vignolini, S. Bright-White Beetle Scales Optimise Multiple Scattering of Light. *Scientific Reports,* **2014**, 4, 6075.



Ullrich Steiner joined AMI in 2014 as Professor of Soft Matter Physics. He worked beforehand at the universities of Cambridge, Groningen and Konstanz as well as at Israel's Weizmann Institute. His research interests include bio-inspired materials, photovoltaics and new materials.

Soft Matter Physics

Team

Dr. Antonio Abate, Michael Fischer, Dr. Ahu Gumrah Parry, Dr. Ilja Gunkel, Dr. Hua Xiao, Manuel Kolly, Karolina Korzeb, Mirela Malekovic, Bart Roose, Sandy Sanchez, Dr. Alessandro Sepe, Sheng Xiaoyuan, Preston Sutton, Dr. Bodo Wilts

Key Publications

1. Optical Properties of Gyroid Structured Materials: From Photonic Crystals to Metamaterials James A. Dolan, Bodo D. Wilts, Silvia Vignolini, Jeremy J. Baumberg, Ullrich Steiner, Timothy D. Wilkinson, *Advanced Optical Materials,* **2015**, 3, 12–32

2. 3D Nanostructured Conjugated Polymers for Optical Applications, Raphael Dehmel, Alexandre Nicolas, Maik R. J. Scherer, Ullrich Steiner, *Adv. Funct. Mater.,* **2015**, 25, 6900–6905

3. Efficient room temperature aqueous Sb2 S3 synthesis for inorganic-organic sensitized solar cells with 5.1% efficiencies, Karl C Gödel, Yong Chan Choi, Bart Roose, Aditya Sadhanala, Henry Snaith, Sang Il Seok, Ullrich Steiner, Sandeep K. Pathak, *Chem. Commun.*, **2015**, 51, 8640–8643

4. Controlling the coassembly of highly amphiphilic block copolymers with a hydrolytic sol by solvent exchange, Stefan Guldin, Morgan Stefik, Hiroaki Sai, Ulrich Wiesner, Ullrich Steiner, *RSC Adv.,* **2015**, 5, 22499–22502

5. The flower of Hibiscus trionum is both visibly and measurably iridescent, Silvia Vignolini, Edwige Moyroud, Thomas Hingant, Hannah Banks, Paula J. Rudall, Ullrich Steiner, Beverley J. Glover, *New Phytologist,* **2015** 205, 97–101

Slick

_ Better than a lotus leaf

Researchers from the Adolphe Merkle Institute have developed a new surface that outdoes the famed lotus leaf when it comes to shedding water.

The lotus leaf is perhaps one of the most studied plants around, and not just by botanists. Since the 1960s, scientists have been fascinated by its unique capacity to evacuate water from its surface. Water simply rolls off the leaf, a phenomenon due to a combination of its superhydrophobic nature and low adhesion.

These properties are due to the surface's hierarchical architecture at the nano- and micro- scales. Wax hair-like nanostructures sit on top of microscopic protuberances, or papillae as they are called.

AMI researchers have been seeking bio-inspiration from the lotus leaf to develop novel surfaces, working at both scales, although the original idea came about from simple observation.

"My PhD student Simonetta Rima noticed by accident a strong resemblance of the microstructures of the surfaces of silica-coated amyloid fibrils and lotus leaves," says Prof. Marco Lauttadua, head of the Nanoparticles Self-Assembly group. To replicate the leaf properties, his team focused first on the microscale, producing an ordered structure using standard polymer colloid beads. They were able to fine-tune the distance between these particles so that the surface imitated the papillae cells of the lotus leaf without the nanostructures.

Nanotubes based on silica-coated amyloid fibrils were then layered onto the polymer base layer. These fibrils are made from beta-lactoglobulin, a whey protein found in cow and sheep milk, and previously used by the Lattuada group members in their research.

> "It is easily scalable, and the design of the nanostructure and microstructure to determine the surface's final hydrophobicity is very rational."

"Beta-lactoglobulin is one of the most common and cheapest proteins that can be used to form amyloid fibrils," adds Lattuada. "The fibrils are also very long, and their aspect ratio can be easily tuned."

To ensure that the new surface was fully hydrophobic, the fibrils were then functionalized by adding specific molecules known as alkyls, chemical groups containing combinations of carbon and hydrogen. The final result is a surface that outdoes the lotus leaf, shedding water even more easily.

"Our approach has two main advantages," says Lattuada. "It is easily scalable, and the design of the nanostructure and microstructure to determine the surface's final hydrophobicity is very rational."

According to Lattuada, there are many potential applications. The main property of a lotus leaf, and of the novel surface, is their self-cleaning behavior for example.

The same approach could be tuned to create surfaces with different properties, such as oil repellency. "The trick is to play with the type of particles used and the way of combining them," explains Lattuada.

More research is still required as these surfaces suffer from limited resistance to scratching. Micro and nanostructured surfaces are easily damaged by abrasion, leading to a loss of their properties. Improving their resistance is the next big challenge for Lattuada's team.

Reference

"Nanocomposite Materials and Bioinspired Surfaces via Hetero-Aggregation of Colloidal Nanoparticles" PhD thesis, Simonetta Rima, 2015

Professor Marco Lattuada is an Italian citizen. He is the beneficiary of a Swiss National Science Foundation professorship. His interests include the control of nanoparticle self-assembly, synthesis and modelization.

Nanoparticles Self-Assembly

Team

Florian Guignard, Golnaz Isapour Laskookalayeh, Zhiqiang Ren, Simonetta Rima, Dr. Julio Cesar Martinez

Key Publications

1. Moore T.; Rodriguez-Lorenzo L.; Hirsch V.; Balog S.; Urban D.; Jud C.; Rothen-Rutishauser B.; Lattuada M.; Petri-Fink A. “Nanoparticle colloidal stability in cell culture media and impact on cellular interactions”, *Chem. Soc. Rev.,* **2015**, 44, 6287–6305

2. Nicoud L.; Lattuada M.; Yates A.; Morbidelli M. “Impact of aggregate formation on the viscosity of protein solutions”, *Soft Matter,* **2015**, 11 (27), 5513–5522.

3. Nicoud L.; Lattuada M.; Lazzari S.; Morbidelli M. “Viscosity scaling in concentrated dispersions and its impact on colloidal aggregation”, *Physical Chemistry Chemical Physics,* **2015**, 17 (37), 24392–24402.

4. Ren Z.; Harshe Y.; Lattuada M. “Influence of the potential well on the breakage rate of colloidal aggregates in simple shear and uniaxial extensional flows”, *Langmuir,* **2015**, 31 (21), 5712–21.

5. Guignard F.; Lattuada M. “Template-assisted synthesis of janus silica nanobowls”, *Langmuir,* **2015**, 31 (16), 4635–43.

In brief

Culture

The Adolphe Merkle Institute was invited to take part in the Belluard Bollwerk Festival in Fribourg, an annual cutting-edge contemporary arts festival whose theme this year was Fortress Europe, focusing on the continent's attempts to stem the flow of refugees. BioNanomaterials co-chair Professor *Alke Fink* took part on June 28 in an event called the Cabinet des Réalités, where she discussed "Nanoparticle and biological cell interactions" with members of the public, focusing notably on how the body fights to exclude foreign particles.

Promoting AMI

The Adolphe Merkle Institute was invited by the canton to represent Fribourg as a science and innovation center at the Swiss Economic Forum held in early June in the city of Interlaken.

This was an opportunity for the Polymer Chemistry & Materials group PhD students *Diederik Balkenende* (right) and *Christian Heinzmann* (left) to demonstrate self-healing and debonding on-demand technology to the attendees of a special evening hosted by the canton.

Throughout the year, the AMI also hosted a large number of visitors such as the Swiss Christian Entrepreneurs Association, the rectors' association of Switzerland's French and Italian-speaking colleges, the Robert Mathys Foundation, the canton Fribourg environmental service and the Ambassador of Georgia to Switzerland.

Career shift

The Adolphe Merkle Institute's reputation for excellence and the quality of its staff has opened the door to two faculty appointments abroad.

Yoan Simon (right) of the Polymer Chemistry & Materials group was appointed Assistant Professor of Polymer Science at the University of Southern Mississippi in the United States. *Martin Clift* (left) of the BioNanomaterials group has moved to Swansea University in Great Britain where he has taken up a position as a Lecturer in Nanotoxicology.

Awards

Sandra Camarero Espinosa was awarded the Swiss Chemical Society's Division of Polymers, Colloids & Interfaces PhD Thesis Award for her work on "Multi-layer Cellulose Nanocrystal/Polymer Scaffolds for Cartilage Tissue Engineering". PhD student *Mathieu Ayer* of the group received the runner-up prize for best poster in the Polymers, Colloids & Interfaces section at the Swiss Chemical Society Fall Meeting. Postdoc *Kleanthis Fytianos* of the Bionanomaterials group was awarded the Prize for the Best Oral Presentation at the International Society of Aerosols in Medicine 2015 conference in Munich. *Diederik Balkenende* of the Polymer group was granted a 2015 Chemistry Travel Award. This CHF 1,000 grant is provided to a select group of PhD students by the "Platform Chemistry" of the Swiss Academy of Sciences, together with the Swiss Chemical Society and the Swiss Society for Food and Environmental Chemistry. *Yoan Simon*, a group leader in the Polymer group, was named the 2015 Hans and Marlies Zimmer International Scholar by the Department of Chemistry at the University of Cincinnati where he was invited for an extended visit.

Future scientists

AMI hosted parents' day activities on November 12.

These days are aimed giving children between the ages of 10 and 11 an insight into their parents' professions. AMI's lab technicians (Anita Roulin, Pauline Blanc, Liliane Ackermann and Laetitia Haeni) provided support throughout the day to the children, who were able to learn some basic aspects of chemistry and biology, as well delve into the mysteries of microscopes. As part of these annual activities, the children are expected to describe their experience to their classmates when they return to school.

Regional personality

Adolphe Merkle Institute post-doctoral researcher *Laura Rodriguez Lorenzo* was named one of the French-language news magazine L'Hebdo's 100 personalities for 2015.

Laura is a member of the BioNanomaterials team, where she is notably working on the modulation of the cellular uptake of nanoparticles as well as the aggregation behavior of nanoparticles in the biological environment. Laura was the recipient of a L'Oréal-UNESCO Fellowship "For Women in Science" in 2013 for a one-year project.

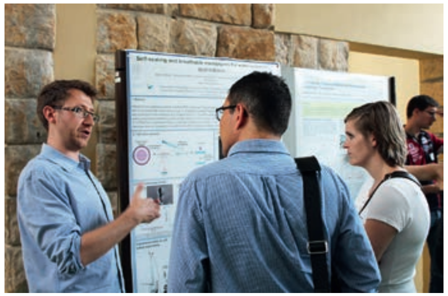
L'Hebdo, a French-language Swiss magazine, has drawn up a list every year since 2005 of the 100 people from Western Switzerland it considers the most influential. The theme for 2015 was "emerging talents", with names selected by the editors from the fields of business, politics, culture or science for example.

Events

The Adolphe Merkle Institute hosts two major national scientific meetings.

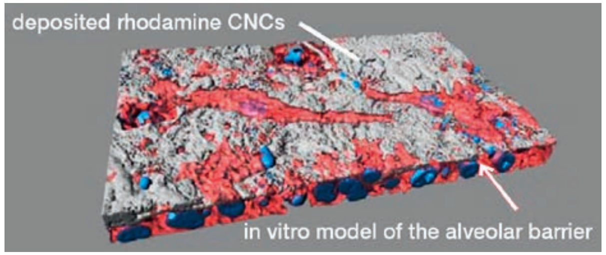
On July 3, Professor *Nico Bruns*, head of the Macromolecular Chemistry group, organized the annual meeting of the Division of Polymers, Colloids and Interfaces of the Swiss Chemical Society.

Professor *Marco Lattuada* of the Nanoparticle Self-Assembly group organized along with his colleagues *Véronique Trappe* and *Andreas Zumbühl* of the physics and chemistry departments of the University of Fribourg the 17th Swiss Soft Day workshop on October 5. These twice-yearly workshops are aimed at emerging researchers, especially assistant professors, post-docs and PhD students and provide them with an opportunity to connect with their peers in a still emerging field of research.



All about size

The Swiss National Science Foundation chose to highlight a collaboration between the BioNanomaterials and the Polymer Chemistry & Materials groups at the Adolphe Merkle Institute as one of the highlights of the recently concluded National Research Programme "Opportunities and Risks of Nanomaterials" (NRP 64). The project led by Professors *Barbara Rothen-Rutishauser* and *Christoph Weder* was able to demonstrate that plant-based cellulose nanofibers, especially short ones, do not pose a short-term health risk. However lung cells are less efficient at eliminating longer fibers.



PhDs

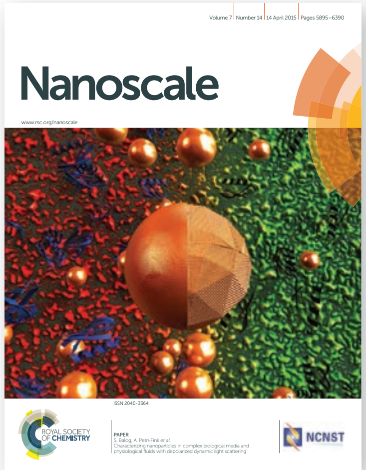
Seven PhD students successfully completed their studies at the Adolphe Merkle Institute in 2015: *Sandra Camarero Espinosa* (Polymer Chemistry & Materials), *Carola Endes* (BioNaonomaterials), *Kleanthis Fytianos* (BioNanomaterials), *Florian Guignard* (Nanoparticles Self-Assembly), *Tobias Kuhnt* (Polymer Chemistry & Materials), *Zhiquiang Ren* (Nanoparticles Self-Assembly), *Simonetta Rima* (Nanoparticles Self-Assembly).

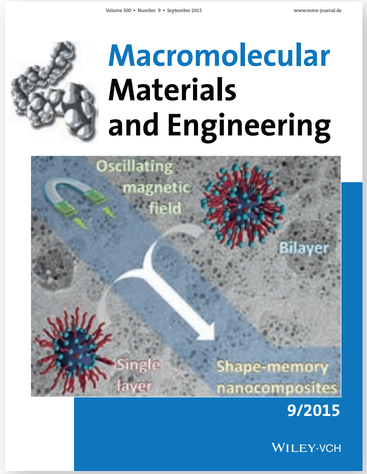
Women in science

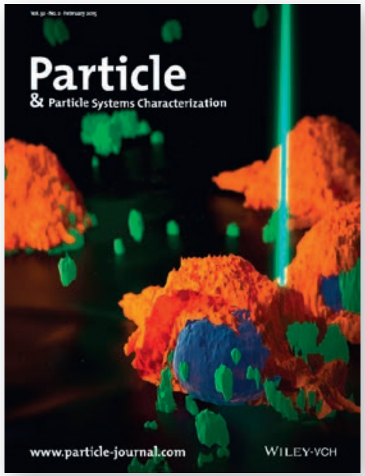
As part of the Women In Science and Technology program run by the University of Fribourg and the canton's School of Engineering and Architecture, a group of 20 teenagers from local colleges was able to learn more about how research is conducted under the guidance of PhD student *Céline Calvino Carneiro* of the Polymer Chemistry & Materials group and with the support of the AMI's technical staff. The two-day internship in March was also aimed at encouraging more women to take up scientific careers.

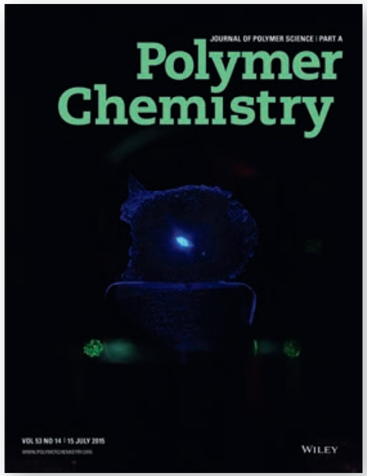
Scientific journals

— AMI on the cover










SIGMA-ALDRICH

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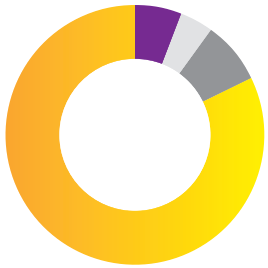
_Finance & Structure

Finance

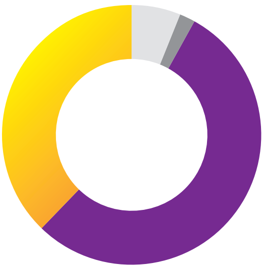
_ Cost structure at AMI

The Institute's overall expenditures in 2015 were CHF 8.6 million. Research spending rose to CHF 7 million, up from CHF 5.9 million in 2014. 82 % of the expenses were related to research and an additional 8 % was invested in research equipment. Around 4 % of the budget supported valorization activities such as technology transfer and communication & marketing. About 6 % was used for administration. Compared to the previous year, third-party funding of research projects increased by CHF 0.6 million to CHF 4.2 million, covering 60 % of all research expenditures. Here, the most important sources were the Swiss National Science Foundation (SNF), the European Union, industrial partners, and the Swiss Commission for Technology and Innovation (CTI).

Overall expenses 2015



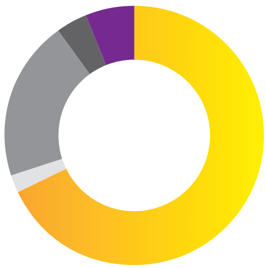
Funding sources of overall expenses 2015



Funding sources of research projects 2015

Total research expenditures of CHF 7 million

Third-party funding of research projects 2015



Organization

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

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

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

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

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

Foundation Board

Members

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

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

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

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

André Broye (Managing Director)
Administrator Gran Plasa SA

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
Former CEO of Tronics Microsystems, former CEO of the Phonak Group and of the Swiss Center for Electronics and Microtechnology (CSEM SA), Technology and Management Consultant

Prof. Rolf Ingold
Vice-Rector for Research, University of Fribourg, Professor, Department of Informatics, University of Fribourg

Scientific Advisory Board

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Former Head of Biointerface Group at Department of Materials, ETH Zürich, Switzerland

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

Dr. Alan D. English
Senior Research Fellow, DuPont Central Research and Development, USA

Prof. Paula Hammond
David H. Koch Professor in Engineering, and Executive Officer, MIT, USA

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

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

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

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

Prof. Alke Fink
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
SNSF Professor of Nanoparticles Self-Assembly

Administration

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

Scott Capper
Responsible for Communications & Marketing

Melissa Forney-Hostettler
Secretary

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

Sandra Camarero
(Polymer Chemistry & Materials)
"3D-Multilayered Cellulose Nanocrystal based Biocomposites for Articular Cartilage Tissue Engineering"

Carola Endes
(BioNaonomaterials)
"An Advanced in vitro Testing Strategy for Alveolar Interactions of Cellulose Nanocrystal Aerosols"

Kleanthis Fytianos
(BioNanomaterials)
"A study of gold nanoparticles – immune cell interactions in vitro"

Florian Guignard
(Nanoparticles Self-Assembly)
"Janus Nanoparticles: From Synthesis to Self-Assembly"

Tobias Kuhnt
(Polymer Chemistry & Materials)
"Controlled Fragrance Release under Mild Reaction Conditions from Carbohydrate based Pro-fragrances"

Zhiqiang Ren
(Nanoparticles Self-Assembly)
"Simulation for the breakup dynamics and hydrodynamic properties of colloidal clusters using Stokesian dynamics method"

Simonetta Rima
(Nanoparticles Self-Assembly)
"Nanocomposite Materials and Bioinspired Surfaces via Hetero-Aggregation of Colloidal Nanoparticles"

Alumni

People who left AMI in 2015

Sandra Camarero
Polymer Chemistry & Materials
Martin Clift
BioNanomaterials
Jose V. de Araujo
MacroMolecular Chemistry
Jean-François Dechezelles
BioNanomaterials
Carola Endes
BioNanomaterials
Csaba Fodor
MacroMolecular Chemistry
Kleanthis Fytianos
BioNanomaterials
Parry Ahu Gumrah
Soft Matter Physics
Alexandre Haehnel
Polymer Chemistry & Materials
Noushin Hassanabadi
Nanoparticles Self-Assembly
Christian Heinzmann
Polymer Chemistry & Materials
Lenke Horvath
BioNanomaterials
Burçak Icli
Polymer Chemistry & Materials
Keiichi Imato
Polymer Chemistry & Materials
Calum Kinnear
BioNanomaterials
Manuel Kolly
Soft Matter Physics
Dagmar Kuhn
BioNanomaterials
Tobias Kuhnt
Polymer Chemistry & Materials
Mariangela Mortato
BioNanomaterials
Steponas Raisys
Polymer Chemistry & Materials
Zhiqiang Ren
Nanoparticles Self-Assembly
Simonetta Rima
Nanoparticles Self-Assembly
Yoshimitsu Sagara
Polymer Chemistry & Materials
Yoan Simon
Polymer Chemistry & Materials
Christa Waeber
Administration


CAUTION
ABET TECHNOLOGIES
ET TECHNOLOGIES
Sun 3000
Solar Simulator
DELL

Impressum

Editorial: Christoph Weder / Marc Pauchard / Scott Capper

Text: Scott Capper

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