ANNUAL REPORT 2014

adolphe merkle institute
excellence in pure and applied nanoscience

UNIVERSITY
OF FRIBOURG
SWITZERLAND

ami

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Message from the director

Christoph Weder
Director and Professor for Polymer Chemistry and Materials

When I wrote the introductory words to AMI's last annual report, we were still occupying the temporary quarters that we rented on the former Ciba-Geigy/Ilford site in the suburbs of Fribourg. In the meantime, we have finally moved into our new home on the campus of the University of Fribourg's faculty of science, a move that has already given us much satisfaction and promises so much more.

Since its launch in 2008 AMI grew from a small team into an institution that now counts five research groups with over 80 researchers. Our new facilities in the former "Clinique Garcia" offer great, if not absolutely ideal boundary conditions for our institute that will help us to take our work to the next level. On the occasion of our building's inauguration, I highlighted several aspects that I deem particularly important, including the highly specific and well-thought-out technical infrastructure of our laboratories, several architectural elements that support the dialogue between researchers and contribute to transdisciplinary interactions, as well as the beauty and the dimensions of our new space.

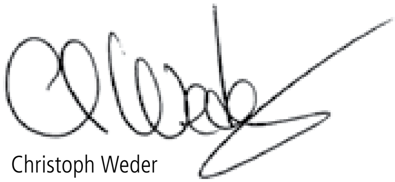
An important element of the relocation is that our new home on Fribourg's Plateau de Pérolles is in the heart of our university's science campus. We are now within walking distance of our colleagues in other departments at the university as well as the nearby School of Engineering and Architecture and the School of Management, which makes interdisciplinary collaborative research and training activities notably easier.

I expect this proximity to be particularly relevant for the activities of the new National Center of Competence in Research (NCCR) Bio-Inspired Materials, which was launched in June 2014 and has its headquarters at AMI. The center integrates some of our institute's research activities in the domain of stimuli-responsive materials with those of ten partner groups from the University of Fribourg's departments of chemistry, medicine, and physics, as well as at the University of Geneva and the Swiss Federal Institutes of Technology in Zurich and Lausanne. It will serve as a platform to train new talent in important areas of soft matter and is overall well-poised to serve as an international hub for smart materials research, education, and innovation.

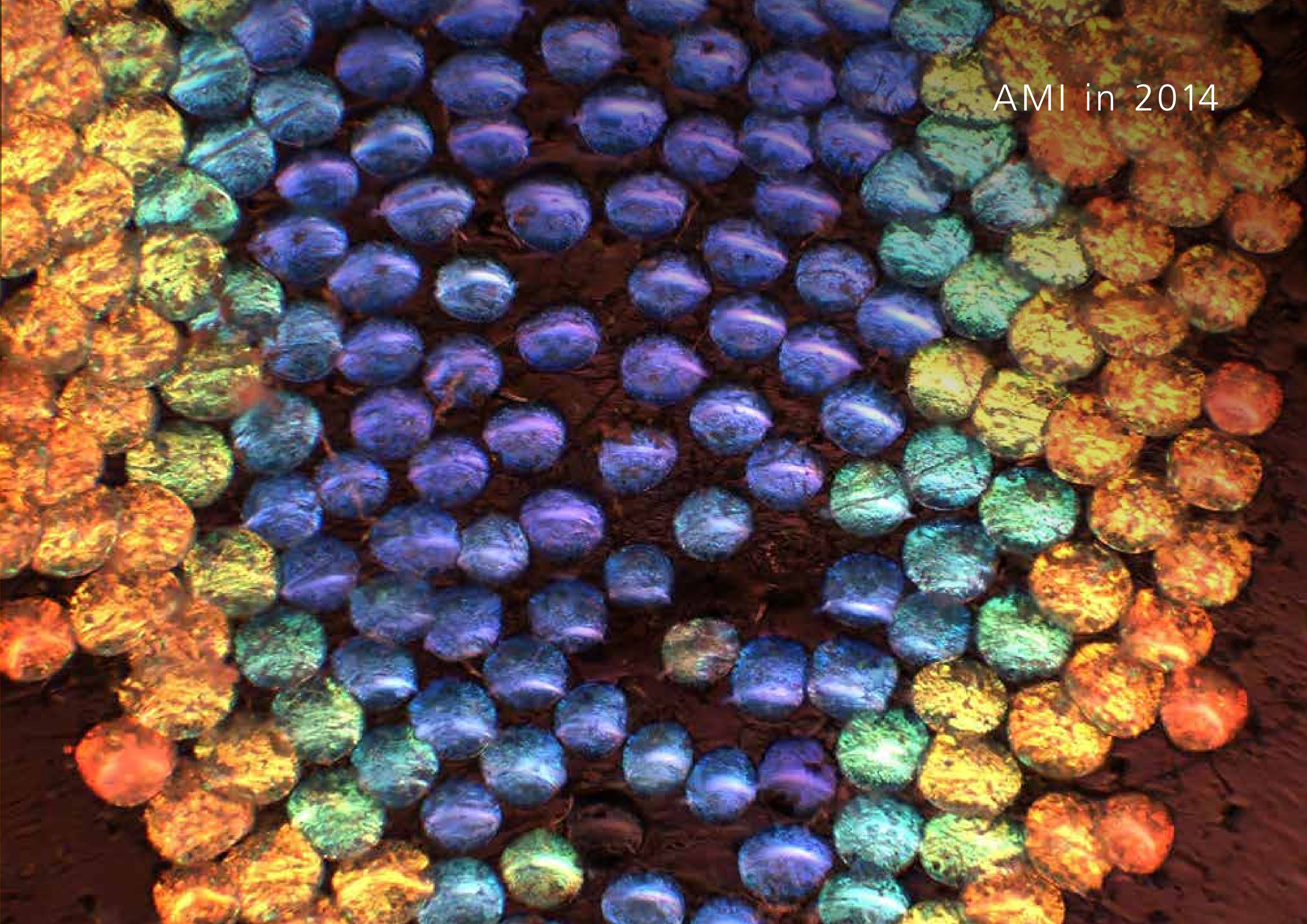
AMI's overall strategy also emphasizes interdisciplinary collaborations within the institute. In this context, I am delighted that we could welcome Prof. Ullrich Steiner as our new chair for Soft Matter Physics. His group complements the expertise of the other chairs in an ideal manner and is destined to make significant contributions to our institute's research and training efforts in the coming years.

Despite the considerable efforts associated with our relocation and the temporary slow-down of our laboratory work during that time, AMI researchers were highly productive, contributing more than 90 publications to the scientific literature and depositing several patent applications. The research section of this year's annual report showcases some of our application-oriented research endeavors. I invite you to read about making polymers with the help of enzymes, reinforcing polymers with protein fibrils, adhesives that bond and de-bond on demand, the preservation of wood with the help of nanoparticles and the study of natural structures that could lead to the improvement of the performance of solar cells, switchable displays, or batteries.

At AMI, we continue to value our partnerships and are once again grateful for all the interest, courtesy, and support that we received throughout 2014. We will pursue our efforts to ensure that Adolphe Merkle's vision of developing at the University of Fribourg a leading competence center for fundamental and application-oriented interdisciplinary research in the field of soft nanomaterials becomes reality.



Christoph Weder
Director Adolphe Merkle Institute and Professor
for Polymer Chemistry and Materials



AMI in 2014

AMI in 2014

AMI continued to grow in 2014, in particular by welcoming the new Soft Matter Physics research group to the team and moving into new premises that will allow the institute to continue its development under the best possible conditions. The institute's activities were boosted further by the official launch of the National Center of Competence in Research on Bio-Inspired Materials, which began its operations in the summer of 2014.

A new home

After six years in their temporary location in nearby Marly, AMI researchers finally moved into their new buildings in September 2014, which were completed after two-and-a-half years of construction. A mix of the old and the new, the site located at the University of Fribourg's science faculty has been optimized for the institute's activities. Parts of AMI are housed in the renovated historical buildings of the former "Clinique Garcia", while a new wing was added to host state-of-the-art laboratories including several that permit the safe handling of nanomaterials and a clean room. Altogether, the facilities offer 47 laboratories, office space for almost 150 co-workers and students, conference rooms as well an auditorium that can welcome 120 guests.

Adolphe Merkle Foundation president Joseph Deiss compared AMI to the European Space Agency's Rosetta mission

Canton Fribourg construction minister Maurice Ropraz (left) cuts the ribbon with Mrs. Simone Merkle and the rector of the University of Fribourg, Guido Vergauwen

The official opening ceremony took place on November 28, 2014, in presence of over 200 distinguished guests, including the State Secretary for Education, Research and Innovation, Mauro Dell'Ambrogio and Mrs. Simone Merkle, the widow of Dr. Adolphe Merkle, AMI's main benefactor. Cantonal construction minister Maurice Ropraz said that the AMI buildings "encapsulated the ambitions, the wishes and the dreams of an entire canton." The Adolphe Merkle Foundation president, the former Swiss federal government minister Joseph Deiss, compared AMI to the European Space Agency's Rosetta mission, stating though that unlike the final frontier of outer space, the institute was looking in "the abyss of the infinitely small."

The open day that followed the inauguration was the last event of the University's 125th anniversary celebrations program. It attracted nearly 1,500 visitors and allowed the general public to interact with AMI researchers and learn more about the institute's activities.

National Center of Competence in Research launched

Half a year after being awarded a four-year, CHF 12 million grant by the Swiss National Science Foundation, the new National Center of Competence in Research (NCCR) Bio-Inspired Materials began its operations in summer 2014. With its headquarters located in the AMI building, the center connects AMI researchers with colleagues in other departments at the University of Fribourg as well as at the University of Geneva

The NCCR held its first annual conference at AMI in November and the Federal Institutes of Technology in Lausanne and Zurich. The NCCR focuses on smart materials inspired by nature. The center's research aim is to design artificial materials that can change their properties "on demand", with the vision to become an internationally recognized hub for smart materials research, education, and innovation.

Fifteen research groups, including the five working at AMI, are part of the center, which held its first annual conference at the institute in October. More than 80 researchers from across the country have already joined the center's research efforts, which are organized in three modules that focus on mechanically responsive materials, responsive materials made by self-assembly and interactions of responsive materials with living cells. Each of these modules tackles major unsolved problems, provides opportunities for great scientific advances on its own, and requires an interdisciplinary research approach. In the long term, the interconnection of these themes through cross-cutting projects and the common goal of being technologically relevant will create substantial synergies, which can only be harnessed if addressed within a multidisciplinary center.

A new research group

The Soft Matter Physics group was established in July 2014 with the arrival of Prof. Ullrich Steiner from Cambridge University, where he had been leading research in Thin Films and Interfaces at the prestigious Cavendish Laboratory. Prof. Steiner was the recipient last year of the Macro Group UK Medal awarded annually to a British-based scientist who has made a significant and substantial contribution to the development of polymer science. Prof. Steiner's team at AMI focuses on so-called optical metamaterials, nanostructured energy materials, flexible optical structures, structured materials in nature and the properties of macromolecules far from thermodynamic equilibrium. The potential applications of this research range from developing better polymer films, creating non-bleaching colored materials and improving the efficiency of certain types of solar cells for example.

AMI's interdisciplinary research team will be completed in the near future by a fourth chair who will spearhead activities in the area of biophysics.

AMI actively participated in the University's jubilee celebrations, notably getting involved in the roadshow

University jubilee

The University of Fribourg celebrated its 125th anniversary in 2014. AMI was part of the celebrations, highlighting some of its research as part of the University's jubilee roadshow. A specially reconfigured bus donated by the regional transport company TPF travelled across canton Fribourg and other regions of Switzerland where many of its students come from. The roadshow presented the University and some of its projects along the way under the theme "Sharing knowledge". AMI researchers prepared exhibits about nanocapsules used for medication delivery and cellulose-based polymer nanocomposites, two of 12 scientific endeavors presented on the bus. AMI director Christoph Weder also participated in the jubilee, speaking both at the University's main anniversary celebration, taking the audience on a journey to the very heart of materials, and addressing the University's alumni in St Gallen at their annual reunion. For the jubilee, professors Alke Fink and Marco Lattuada also met the public at one of the University's regular science cafés, held in the town of Bulle, to discuss the pros and cons of nanotechnology and Dr. Marc Pauchard shared the fascination of bio-inspired materials.

Awards and prizes

In 2014 AMI researchers were recognized for significant contributions to their different fields. Barbara Rothen-Rutishauser, co-chair of the BioNanomaterials group, was awarded the CHF 10,000 "Egon Naef Prize" for research on in vitro alternative methods. The prize recognized her long-standing efforts on developing a new artificial lung testing method that should help reduce animal experimentation.

Sandro Steiner of the same group received in November the Swiss Lung Foundation's Swiss Aerosol Award for his work on improving toxicity tests for vehicle emissions. This prize worth CHF 10,000 is awarded every year. PhD student Christoph Geers received the International Research Group on Wood Protection's Ron Cockroft Award in May. Another PhD student, Kleanthis Fytianos, was given a scholarship to attend the NANOTOX2014 meeting in Turkey in April.

Mehdi Jorfi of the Polymer Chemistry & Materials group was awarded the 2014 science faculty prize in experimental sciences for his PhD thesis "Physiological Responsive Mechanically Adaptive Polymeric Materials for Biomedical Applications". His group colleague Lucas Montero was the first AMI researcher to accept an Ambizione grant from the Swiss National Science Foundation (SNSF). This grant is aimed at young researchers who wish to conduct, manage and lead an independent project at a Swiss higher education institution.

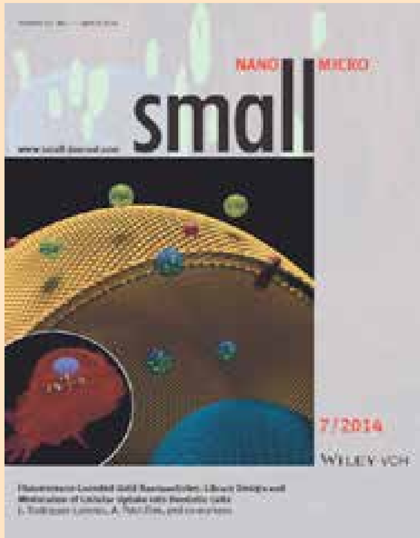
PhD student Simonetta Rima of the Nanoparticles Self Assembly group was given the award for the most original contributions of young scientists at the tenth International Conference on Physics of Advanced Materials in Romania in September.

Nico Bruns, head of Macromolecular Chemistry group, was honored as Emerging Investigator by the Journal of Materials Chemistry A, published by the Royal Society of Chemistry. His paper, "Mechanical Unfolding of Fluorescent Protein Enables Self-Reporting of Damage in Carbon-Fibre-Reinforced Composites", was published as a part of a themed issue on emerging investigators highlighting a select number of researchers. The article demonstrated that carbon fiber composites could be functionalized with fluorescent proteins and could be implemented as a safety feature into composites. In March, his group member Csaba Fodor was recognized for his scientific discoveries in the field of physical-chemistry of polymers over the past five years with the Michael Polanyi Award of the Hungarian Academy of Sciences.

The following young AMI researchers were also given a boost to their careers after being awarded a SNSF Early Postdoctoral Fellowships: Sandra Camarero, Calum Kinnear, Soo-Hyon Lee, Burçak Içli.

High impact research

AMI researchers continued to produce high-quality research in 2014, their work being selected on a number of occasions to feature as editor's choices and journal covers. This included interdisciplinary research carried out at the institute.



The BioNanomaterials group's research on fluorescence-encoded gold nanoparticles made the back cover of the journal Small

Prof. Barbara Rothen-Rutishauser receiving the E. Naef Prize in January

AMI students explained the finer points of chemistry to a young audience on open day

AMI professors gave conferences to packed audiences on open day

A collaboration between the BioNanomaterials and Self-Assembly research groups led to the publication of the article "Insertion of Nanoparticle Clusters into Vesicle Bilayers" in the journal ACS Nano. This research showed that larger than expected nanoparticle clusters could be trapped inside the thin vesicle membrane, expanding the potential uses of these hybrid vesicles.

Another interdisciplinary effort between the BioNanomaterials and the Polymer Materials and Chemistry groups was published in Particle and Fibre Toxicology, "A systematic in vitro approach towards mimicking the inhalation of high aspect ratio nanoparticles". This article highlighted an advanced technological and mechanistic approach to realistically and efficiently determine the in vitro hazards associated with inhalation exposure of high aspect ratio nanofibres.

The Polymer Materials and Chemistry group's research into adhesives that bond and de-bond on demand (page 24) that was picked up by the media and published in ACS Applied Materials and Interfaces was selected to be an editor's choice as well as the journal cover. It was also among the ten most read articles of 2014.

The Polymer team's article "Reinforcement of optically healable supramolecular polymers with cellulose nanocrystals" in the journal Macromolecules was also among the ten most read publications of that journal last year. This research is the continuation of previous and widely reported work on healable coatings.

The Soft Matter Physics group published "Digital Color in Cellulose Nanocrystal Films" in the journal ACS Applied Materials and Interfaces, which showed that the self-assembly of cellulose nano-crystals is far more complex than previously thought. The article suggests that producing advanced optical materials based on self-assembly will require new approaches.

Open day

In 2014, AMI's open day was its most high profile public event of the year, coming less than 24 hours after the official inauguration of its new buildings in November. A huge effort was put in by the staff to present all aspects of the institute's research as well as the state-of-the-art premises. Nearly 1,500 people visited AMI, far more than was initially expected. The first visitors turned up before opening time and the last ones were still arriving shortly before closing.

AMI professors gave individual conferences to packed audiences before becoming tour guides, leading visitors on a circuit through the buildings. Presentations were set up in different laboratories by students who had the challenging task of explaining complex research to the general public in a short time. Younger visitors were also catered for with the kids' laboratory, an opportunity for the children to discover some basic chemistry.

Feedback from the visitors was extremely positive, tinged with some nostalgia as many came to see as well what had become of the former clinic where many locals were born or hospitalized.

Press coverage of the event in the media was extensive, both before and after. Media representatives were made aware of the open day and the inauguration a few weeks in advance, thanks to a special press day, giving them time to prepare individually crafted reports for their publications and broadcasters. Reports were notably published in La Liberté, Le Temps and the WOZ, while French-language public broadcaster RTS provided slots in its radio and television programs to present the new buildings and an overall view of AMI research. German-language public broadcaster SRF also presented the institute ahead of the open day, while the local newspaper Freiburger Nachrichten gave widespread coverage of all these events.

Media

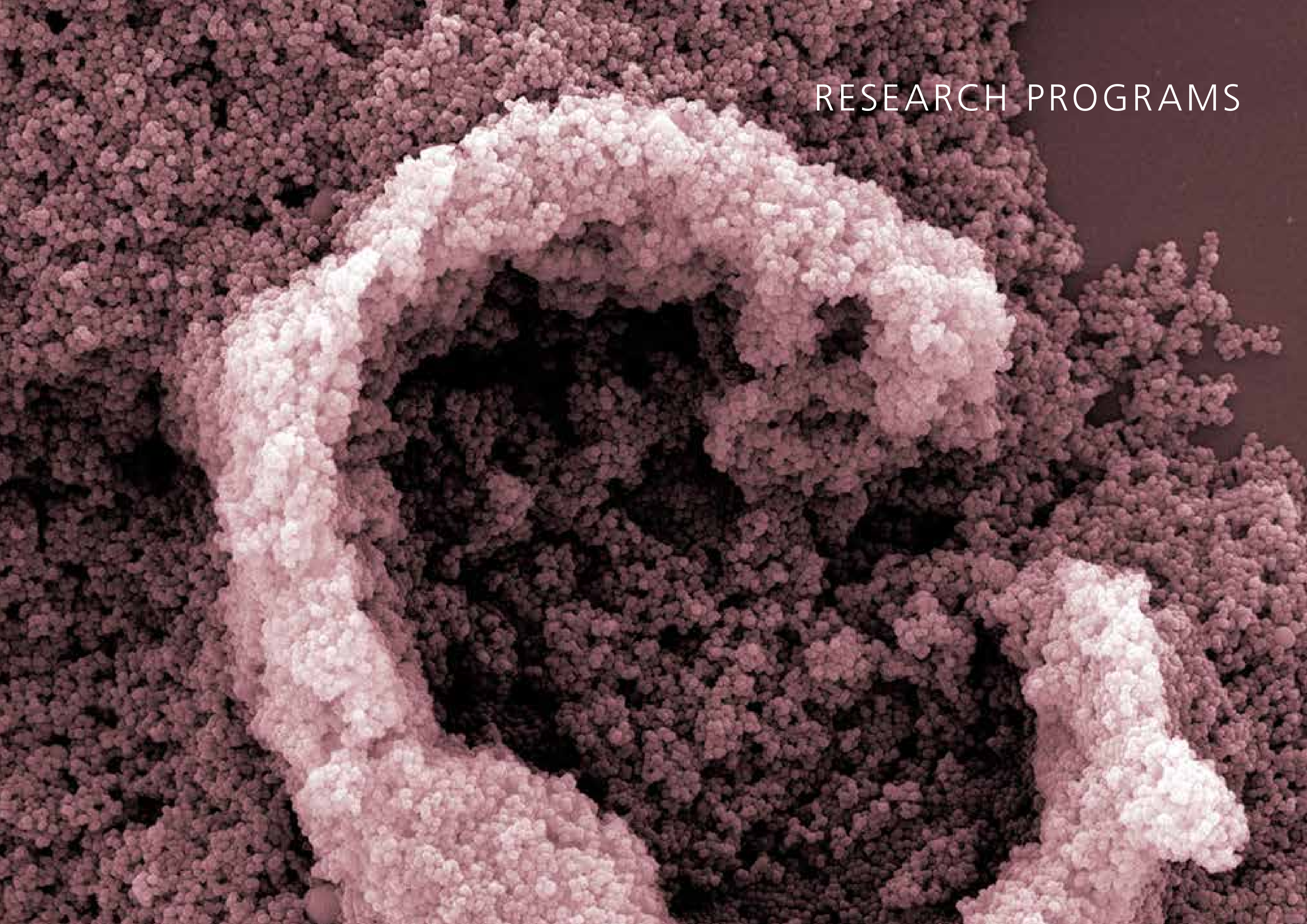
AMI continued to have a regular presence in the media throughout the year. The press also took an interest in the work and expertise of the institute's researchers. Lung-particle interactions were once again the focus of media attention. The work carried out with the institute's 3D bioprinter was highlighted in Fribourg newspaper La Liberté in May, drawing attention to the new artificial lung testing method developed by Barbara Rothen-Rutishauser's team. Prof. Rothen-Rutishauser's expertise on particle-lung interactions was on show once again in Swiss public broadcaster RTS' health program 36.9 in November as part of a wider story on the effects of air pollution on people. This research has also begun attracting an audience beyond people interested in health issues, with German magazine Auto Bild mentioning it extensively in an April article, while Petrosphère, the newsletter of the Swiss petrol importers' association chose it as a highlight in its March edition.

Glue that bonds and de-bonds on demand developed by Prof. Christoph Weder's group also caught media attention after a university press release in May. This was picked up by the Swiss News Agency, which provides content to virtually every news service in the country.

Prof. Ullrich Steiner's arrival at AMI was highlighted at the annual University of Fribourg press conference. His decision to move to Fribourg was presented as a major gain by the rectorate.

AMI staff such as Prof. Christoph Weder fielded many media requests before the inauguration

RESEARCH PROGRAMS



Research Programs

COMBINING FUNDAMENTAL AND APPLICATION-ORIENTED RESEARCH

AMI's interdisciplinary research activities continue to revolve around the development and investigation of soft nanomaterials with novel functions and the investigation of the interactions of these materials with biological systems. While the current initiatives involve various scientific concepts and material types, most of the programs pursue a two-pronged research approach with the goal to advance fundamental knowledge and address practically relevant problems at the same time.

Basic research – fundamental theoretical or experimental investigative research – and applied research, which aims to solve practical problems, have been viewed traditionally as separate, if not incompatible forms of advancing knowledge. Many scientists interested in fundamental research frowned upon applied work because it lacked depth, whereas engineers would not engage in fundamental research, because it was too detached from real-world problems. In this tradition, many academic institutions still separate "science" and "engineering" activities along lines that rarely cross.

In reality, however, most modern research endeavors, both in academia and in industry, are a combination of knowledge generation, problem-solving as well as innovation, and the difference between basic and applied science is often just a matter of time. With this perspective, AMI's research vision is rooted in the notion that the integration of basic and application-oriented research is not a contradiction, but a powerful framework that can maximize the impact of fundamental scientific discovery and is essential to solve important relevant practical problems.

In the domain of nanomaterials, fundamental and relevant practical research endeavours are often intimately intertwined. For example, developing a fundamental understanding of nanoparticle-cell interactions, intracellular trafficking mechanisms, and nanoparticle and cellular fate is essential before one can apply rational design rules to develop nanoparticle-based drug delivery systems and vaccines or understand the origin of possible health effects of engineered nanoparticles. At the same time, the prospective medical applications and the health concerns associated with the emerging use of artificial nanomaterials serve to guide fundamental research by defining important questions. Similar arguments can be made for the investigation of charge separation effects in structured nanomaterials for photovoltaic power conversion, stress transfer mechanisms in mechanically adaptive polymer nanocomposites that AMI researchers develop for biomedical implants, and many other projects, some of which are highlighted in the following pages.

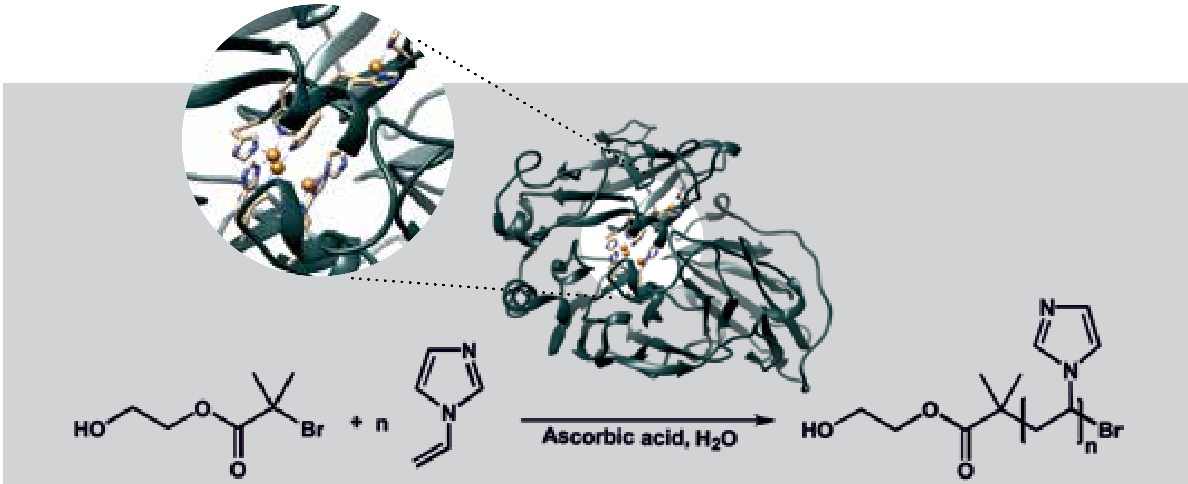
In 2014 AMI's major research programs included:

- The development and use of multifunctional engineered nanoparticles as e.g. biocidal wood preservatives or novel nanocarriers for vaccination and drug-delivery
- The development of sophisticated in vitro models for reliable high-throughput risk assessment of nanomaterials
- The determination of health risks associated with the inhalation of specific nanomaterials, including diesel exhaust, silver nanoparticles, and nanocellulose
- The utilization of mechanically adaptive materials for biomedical implants
- The development of supramolecular polymers as healable materials and adhesives that enable bonding and debonding on demand
- The use of cellulose nanocrystals as a basis for bio-based nanocomposites, aerogels, and delivery systems
- The development of extremely tough composite materials using amyloid fibril reinforcement
- The creation of asymmetric nanoparticles and nanobowls, with self-propelling and self-assembly properties
- The development of simulations to determine the fate of nanoparticle clusters, with the aim of understanding the conditions of particle re-dispersion
- The use of enzymes as non-toxic catalysts for polymerization reactions
- The development of fluorescent fiber-reinforced composites that can self-report damage
- The development of high-performance electrode materials for solar cells and batteries
- Performance optimization of organic solar cells
- The development of nanostructured optical materials
- The use of nanocellulose to manufacture sustainable, edible color materials


NEXUS

A FUNGAL ENZYME AS A NON-TOXIC CATALYST FOR POLYMERIZATIONS

Polymers containing the monomer N-vinylimidazole play an important role in industrial applications ranging from washing powder ingredients to filtration membranes for alcoholic beverages. They also have promising properties in potential biomedical applications, for example as drug and gene delivery agents. These polymers could be intriguing building blocks for nanostructures, nano-sized drug delivery vehicles and advanced surfactants, if poly (N-vinylimidazoles) with defined molecular masses and narrow molecular weight distributions were available. Unfortunately, the synthesis of such well-defined polymers is extremely difficult.



Enzymatic ATRP of N-vinylimidazole. The structure of the enzyme laccase shows the four copper atoms of the active site in orange and the amino acid residues that tightly complex the metal ions (graphic: N. Bruns)

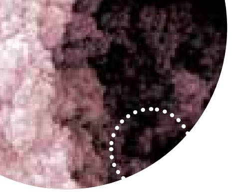
The most popular approach to synthesize precise polymers is atom transfer radical polymerization (ATRP). However, this controlled radical polymerization fails in the case of N-vinylimidazole, one reason being that the monomer and the resulting polymer strongly bind metal ions and therefore destroy conventional ATRP catalysts. The Macromolecular Chemistry group at AMI has now solved this problem. The fungal enzyme laccase, a copper-containing oxidoreductase, was found to catalyze ATRP of N-vinylimidazole. Laccase is an enzyme which is already produced on an industrial scale for paper pulp processing and denim bleaching, making it readily available for chemical processes. Polymers with narrow molecular weight distribution were synthesized. The molecular weight of the polymers increased with conversion and was close to those expected, while the reaction followed first order kinetics. These results prove that the biocatalytic reaction is a controlled radical polymerization. Therefore, it allows the production of poly(N-vinylimidazole) with predetermined molecular weights. Laccase-catalyzed ATRP works because the enzyme keeps a tight grip on its copper metal centers. In contrast, other ATRPases, such as hemoglobin or peroxidase, did not control the polymerization of N-vinylimidazole efficiently, because their metal centers were stripped from the protein during the reaction.

Residual copper ions in ATRP-derived polymers are a major drawback of conventional ATRP, since the transition metal that is needed for the catalysts is mildly toxic and hampers the use of these polymers in biomedical applications. Enzymes can be removed by simple means from a reaction mixtureby precipitation. Biocatalytically produced poly(N-vinyl imidazole) had very low residual metal contents after removal of the enzyme. Enzymatic polymerization is not only a major breakthrough in the synthesis of well-defined poly(N-vinylimidazoles), but also a viable route to virtually metal-free ATRP-derived polymers. The products of this polymerization could be used to create self-assembled nanostructures, e.g., for nano-sized gene-delivery vectors.The biocatalytic polymerization also offers the possibility of tailoring properties and increasing the performance of N-vinylimidazole-containing polymers in many applications.

References:
"Atom Transfer Radical Polymerization of Monomers with Nitrogen-Containing Heterocyclic Aromatic Functional Groups Utilizing Biocatalysts"
N. Bruns, C. Fodor, Adolphe Merkle Institute, Switzerland, US 62/034,254, **2014.**

Contact: Prof. Nico Bruns

Turkey tail mushroom (Trametes versicolor), the source of the enzyme laccase. (Photo by Hans-Martin Scheibner, under Creative Commons Attribution-ShareAlike 3.0 Unported)



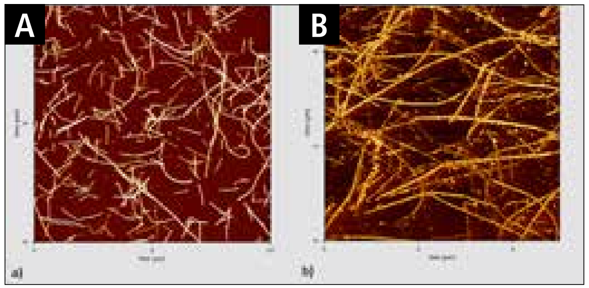
AS STRONG AS SILK

Fibers have always fascinated mankind. Most textile products are made of fibers, which for centuries have been obtained from natural sources. Many biological materials use nano fibers as a building block. One of the best examples is spider webs. The incredible properties of spider silk fibers, with their exceptional toughness, have prompted scientists to investigate their structure in the hope of creating lightweight but highly resistant materials. Even a famous web slinger owes his fame to the special spider fibers that allow him to jump from one building to the next. But given the difficulty in working with silk proteins, AMI researchers have used amyloid fibrils, which are less known but have similar mechanical properties to silk and are much easier to prepare, to create an entire new class of reinforced rubber materials.

Recently, there has been a growing interest in understanding nanoscale structures and recovering the basic components of natural fiber-based materials. This includes cellulose nanowhiskers, keratin nanofibers and silk nanofibers. Many of these natural nanocomponents have been successfully blended with and incorporated into synthetic polymers, with the goal of creating nanocomposites that exploit the exceptional properties of these natural nanofillers.

Other natural fiber-based systems have been less scrutinized for material science applications. A particularly interesting example is amyloid fibrils. Protein fibrils are self-assembled structures resulting from the partial denaturation and resulting aggregation of certain proteins. These structures are characterized by an extremely high aspect ratio, with a diameter in the range of few tens of nanometers and a length of a few microns. Amyloid fibrils have been infamously linked to neurodegenerative diseases such as Alzheimer's, where they are suspected to be one of the causes of the illness.

What is less known is that protein fibrils have excellent mechanical properties, with elastic moduli rivaling those of silk fibers, but retaining considerable flexibility and elasticity, which motivated AMI researchers to try and incorporate them into a rubber matrix for the first time at high concentrations. We have used fibrils from β-lactoglobulin, a major whey protein of cow and sheep's milk, as shown beneath.



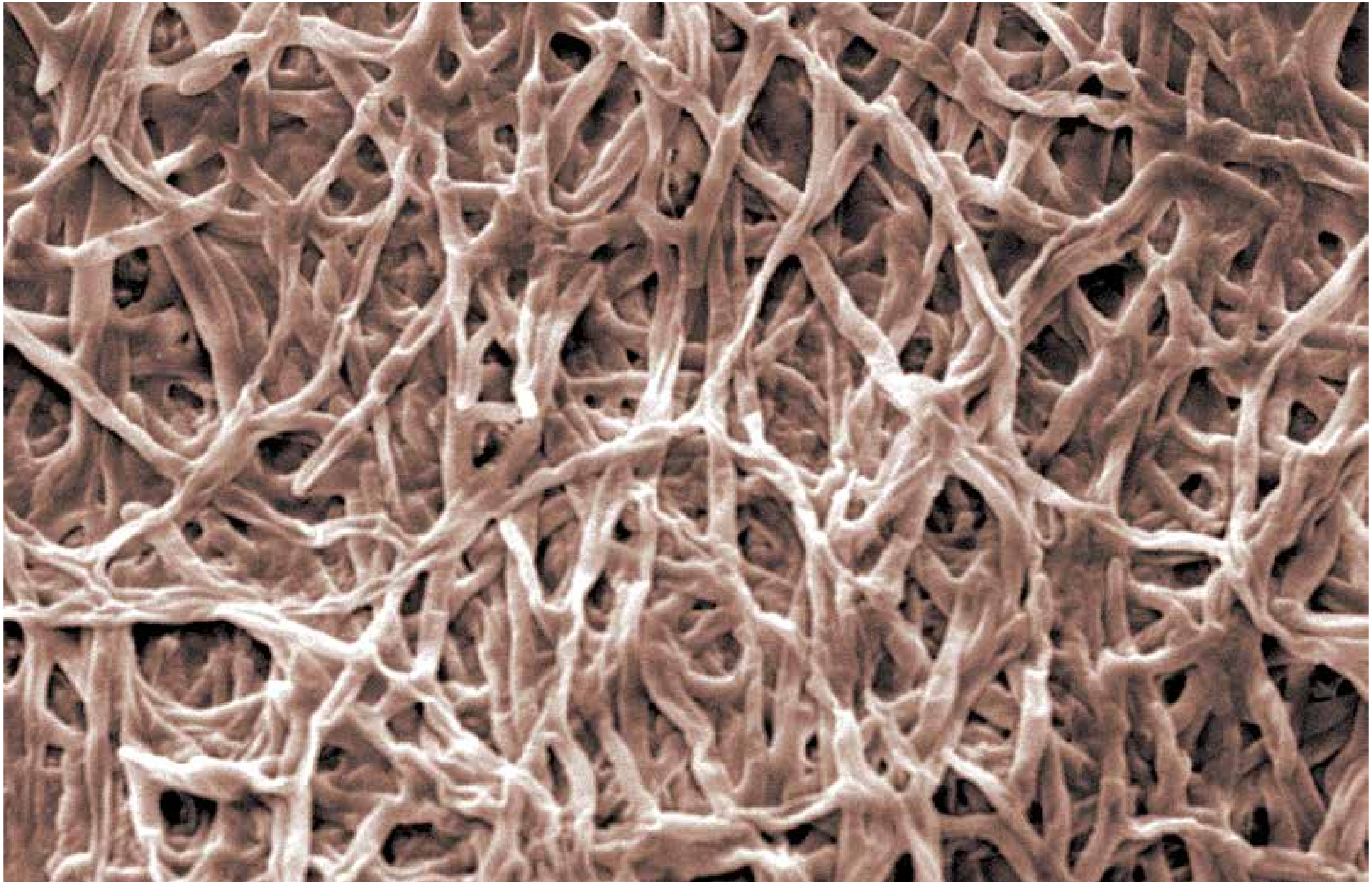
Atomic force microscopy pictures of β-lactoglobulin fibrils (pictures: S. Rima)

The process we adopted to incorporate these fibrils is unique. To make the most of amyloid fibrils' natural environment of, i.e., water, we started with a suspension of rubber particles in water, which are then mixed with the fibrils in an aqueous phase. The final material is obtained by removing the water, and hot-pressing the dry composite. The polymer particles become the matrix of the final composite material. An example of the structures formed when a few particles and fibrils come together is shown in the main picture (right page). The presence of the fibrils appears to induce an assembly of the polymer particles into large micron-sized fiber-like structures.

Some particularly striking features are apparent from the mechanical properties of the samples. Adding amyloid fibrils to a rubber matrix not only increases the composite's elastic modulus – its capacity to resist being deformed non-permanently - but also the tensile strength of the material. While pure rubber probes can sustain maximum elongation of less than 200 percent, samples containing fibrils can sustain deformations between 300 and 400 percent. The increase in material toughness is over one order of magnitude. Another extraordinary example of the properties of materials reinforced by fibrils is that they can be combined with other typical inorganic fillers, such as silica nanoparticles or graphene oxide nanosheets. The combination of fibrils with inorganic fillers leads to a unique combination of properties. The reinforcing effect of the inorganic fillers, which can be observed as an increase in the Young modulus (the tendency of an object to deform along an axis), is combined with a tremendous increase in toughness provided by the fibrils.

It is amazing how such fibrils, which are sometimes an unwanted side product of milk processing, caused by denaturation and destabilization of its high protein content, can become such powerful reinforcing agents.

Contact: Prof. M. Lattuada



Scanning electron microscope picture of poly-butyl acrylate particles combined with β-lactoglobulin fibrils (picture: S. Rima)

PRESERVING WOOD WITH NANOPARTICLES

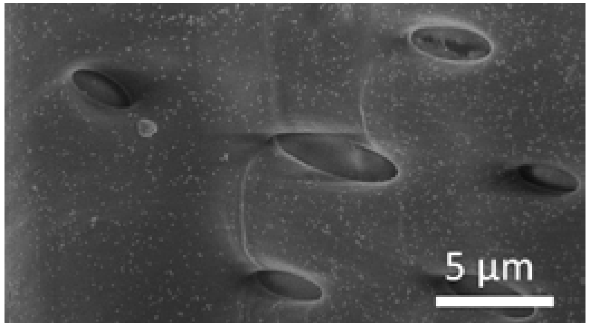
Throughout history wood has been used for a variety of purposes. Although wood is now used less as fuel, it is still appreciated as a building material for homes, bridges, or furniture. Protecting this wood from decay and decomposition is a huge challenge though. Using nanoparticles to protect and preserve this wood could be one of the biggest potential applications of this technology, although risks must be clearly determined.

Most types of wood are prone to decomposition or deterioration by insects and fungi when in contact with the ground or exposed to excessive moisture [1]. The majority of wood (products) for outdoor use requires a preservative to slow down decay and degradation [2]. In recent years, preservatives containing solid metal (copper) particles have emerged and started competing with aqueous wood preservatives that contain dissolved or complexed copper compounds.

These relatively recent metal particle systems are increasingly used in today's North American wood preservation market [3]. However, the efficiency or feasibility of the treatment depends, amongst others, on the particles. There is very little information of the effect of particle properties such as surface, size and size distribution on the characteristics of (nano)particle treated wood or its performance [4]. In order to truly evaluate the potential of nanotechnology in wood preservation, AMI researchers started addressing such fundamental questions in the framework of the National Research Programme "Resource Wood" (NRP66). The goal of this project is to systematically study the reciprocity between well-defined, ultrasmall particles of various sizes on the one hand, and different wood types, on the other. It was shown that wood impregnation efficiency strongly depends on particle size and on the wood type. The main picture (right page) shows the structural differences between the studied wood types, beech and spruce. From the scanning electron and laser scanning microscopy images it becomes apparent that in beech wood the model nanoparticles used are impregnated in vessels, the cells responsible for water conduction in a living tree, and the main entry route of materials entering wood.

Wood is essentially composed of cellulose, hemicellulose, and lignin, the latter of which is shown in the laser scanning image of beech (left) and pine (right) wood in the main picture. These three components vary strongly in terms of hydrophilicity, localization and function in the wood and are prone to different interaction mechanisms with the impregnated particles depending on the particles' surfaces. This interaction between particles as a function of their surface and the wood chemistry constitutes the second research question in this project.

Clearly, there is great potential for further optimization of the systems. On the other hand, concern has been expressed about the potential adverse effects resulting from leaching of nanoparticles from materials and subsequent accumulation in ground water or soil and the impact of nanoparticles on the health of people who are exposed to them [5]. Since the successful integration of nanotechnology in wood preservation would make wood protection one of the world's largest end uses of nanotechnology, a proactive approach to understanding potential environmental and health impacts is recommended by experts [6]. Therefore, the third part of the project is dedicated to risk evaluation by simulating wood combustion from nanoparticle impregnated wood species and direct exposure of the exhaust onto the lung cell surface in vitro.



Scanning electron micrograph of nanoparticles in a beech wood vessel after impregnation. The small white dots correspond to the impregnated nanoparticles. The holes represent pits, which build a connection between wood cells, to allow an exchange of fluids (picture: C. Geers)

References:

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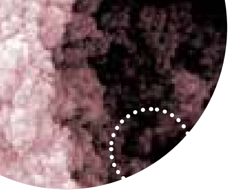
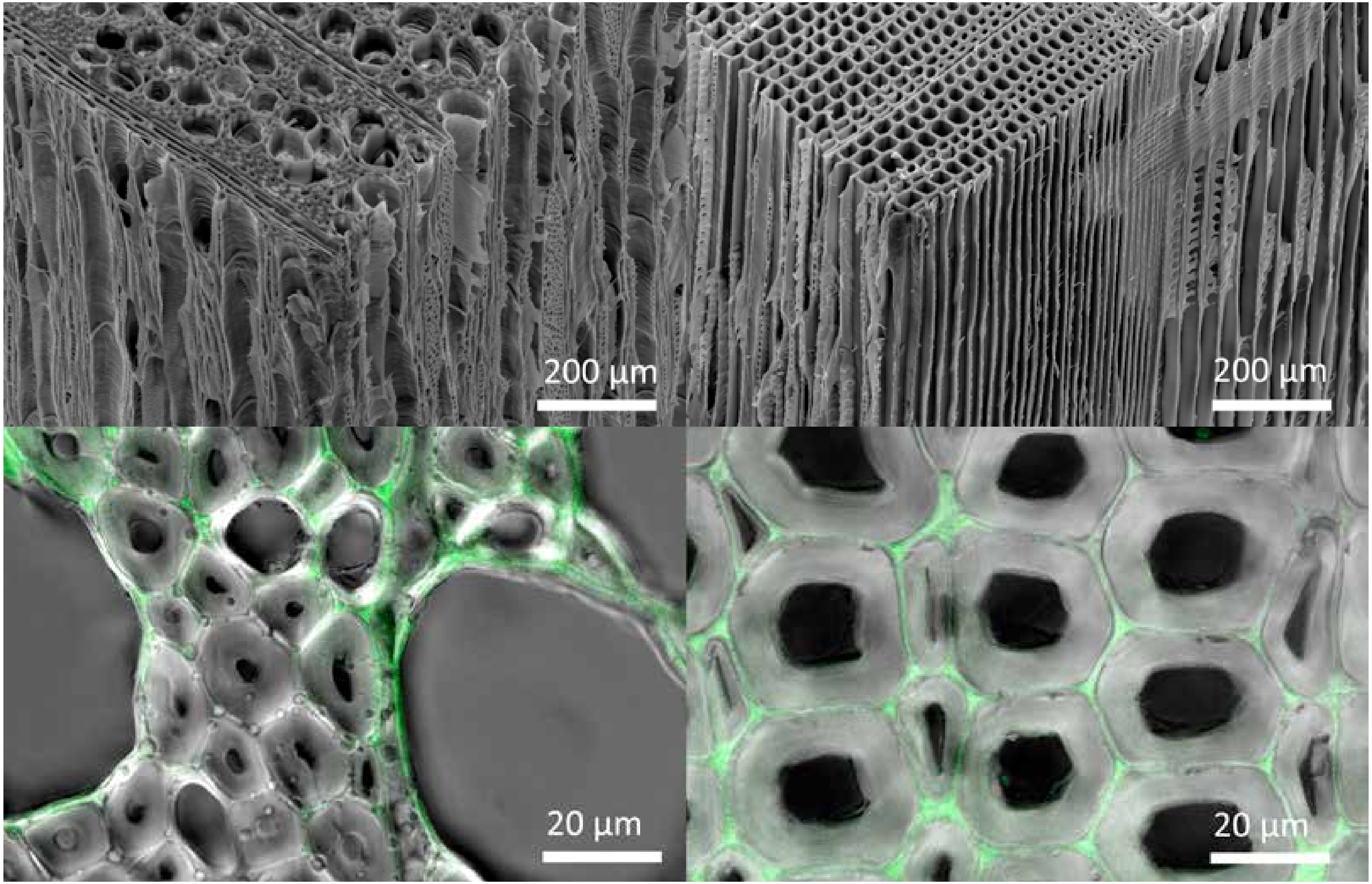
Contact: Prof. Alke Fink and Prof. Barbara Rothen-Rutishauser



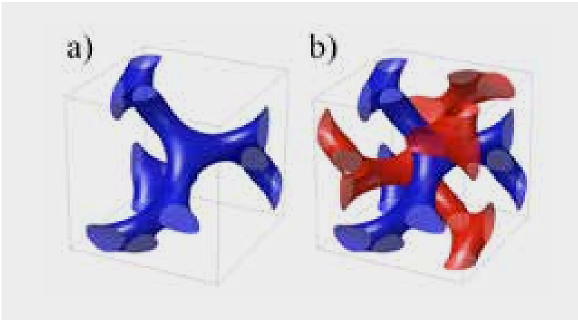


Top: scanning electron micrograph of beech (left) and spruce (right); Bottom: laser scanning image of beech (left) and pine (right) wood. The green overlay shows an auto fluorescence signal of lignin at an excitation wavelength of 488 nm (pictures: C. Geers)

FROM BUTTERFLIES TO NOVEL FUNCTIONAL MATERIALS

Nature is full of unusual geometries that often perform specific functions – ranging from sticky gecko feet to sparkling colours reflected from animals. One of nature's most complicated three-dimensional structures is the gyroid, a continuous structure with an inherent twist that invokes interesting properties. Gyroid morphologies form through self-assembly and can be found in a variety of natural and synthetic systems, from the coloured wing scales of butterflies to man-made polymers. At AMI, researchers in the Soft Matter Physics group study the optical properties of natural gyroids and also put together novel gyroid-structured materials with optical properties not seen in nature. In addition, natural structures also serve as inspiration to create functional materials that aim to improve the performance of solar cells, switchable displays or batteries.

The optical properties of matter are intrinsically linked to its morphology. It is the vast range of possible morphologies and their characteristic length scales, which give rise to the great wealth of optical phenomena that we observe in everyday life – a soap bubble is a prime example. Of direct importance are structures found in nature, where seen and being seen often have a severe impact on the survival of animals. Nature has evolved a huge diversity of optical structures that serve in signalling, but also for camouflage. Interestingly, some butterflies feature a unique morphology, the gyroid, in their wing scales that can effectively scatter incident light and strongly reflect certain colours (main picture). This scattered light is a deep green, allowing these butterflies to perfectly blend into the background foliage. The gyroid morphology appears to be an ideal lightweight structure that allows effective optical in the visible wavelength range.



Sketches of gyroids. (a) The single gyroid structure can be found in butterflies and gives rise to strong colours. (b) The double gyroid structure is formed by polymer self-assembly and is used to create novel functional materials (picture: B. Wilts)

To produce gyroids in the lab, the self-assembly properties of block copolymers (BCPs) are used to fabricate macroscopically large samples with a complex three-dimensional structure and features on the nanometre scale, but structurally similar to the wing scale structures of butterflies [1]. Selective etching of individual BCP blocks results in a porous structure that can be used as scaffold for metals to create novel materials with specific optical properties, an elegant method of replicating these complex self-assembled polymeric structures with inorganic materials such as metals. It is possible this way to create gold networks with gyroid morphology whose structures are about five to ten times smaller than that of a butterfly. These so-called metamaterials have unusual optical properties that cannot be found in nature, for example a negative refractive index, which deserves further future research and could lead to the production of novel optical materials.

Current research work in the soft matter physics group at AMI is strongly focused on materials featuring the gyroid morphology. Together with its high surface area, the gyroid is a perfect three-dimensional, chiral candidate structure for novel nanodevices, not limited to optical materials alone. For the manufacture of novel functional materials with new properties, the self-assembled gyroid structure is used and replicated with metals and metal-oxides, such as titanium or vanadium oxides. These materials feature a range of exciting applications and could lead to improvements in performance for future, novel devices, such as more efficient solar cells, faster switching displays [2] and battery materials where using the gyroid structure might lead to higher storage capacities and longer-lasting mobile phones.

References:
[1] Dolan JA et al. "Optical Properties of Gyroid Structured Materials: From Photonic Crystals to Metamaterials", Advanced Optical Materials **2015,** 3: 12–32.
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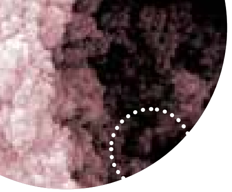
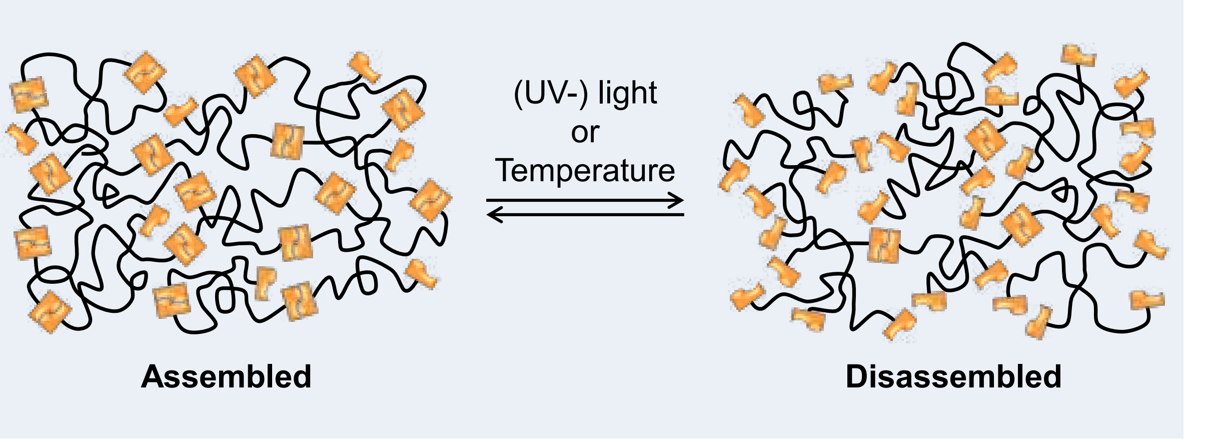
Contact: Prof. Ullrich Steiner

The ultrastructure of butterfly wing scale of the green-colored butterfly, *Erora opisena,* from Mexico (inset, picture copyright K. Garwood). Light interaction with these gyroid-structured networks in the scales result in the stunning green colour of these insects. (main picture: B. Wilts)



BONDING AND DEBONDING ON DEMAND

Something needs a quick fix? No problem, superglue will help. Taking parts that are already bonded cleanly apart, however, might prove to be more difficult. To circumvent this problem, AMI researchers are investigating supramolecular polymers as adhesives that allow bonding and debonding on demand.



Schematic representation of the reversible disassembly of supramolecular polymers using light or heat (graphic: C. Heinzmann).

Whether it is the poorly fixed soup bowl, a defective dental implant, or a temporary fixture used in a microfabrication process, there are many examples of adhesive applications where being able to separate bonded parts would be beneficial. AMI researchers have shown that this is possible by using adhesives based on supramolecular polymers.

Unlike conventional polymers, which in many cases consist of long, chain-like molecules that comprise thousands of covalently connected atoms, supramolecular polymers are composed of much smaller molecules. These building blocks contain chemical binding motifs that are designed to bind with each other and promote the assembly into longer, polymer-like chains (see graphic), even though no permanent chemical bonds are formed between the individual molecules. Materials made on the basis of such supramolecular assembly schemes behave in many ways like normal polymers. But when heated, the binding motifs readily disassemble and the material becomes liquid. Upon cooling, the process is reverted and the original supramolecular polymer is reformed.

Working initially with previously studied, rubbery supramolecular polymers based on linear building blocks that carry just one supramolecular binding motif at each end (see graphic), AMI researchers demonstrated the usefulness of such materials as reversible adhesives. Under ambient conditions, the materials readily bond glass, metal, and other substrates, but lose their adhesive properties within seconds upon heating. The temperature at which the debonding occurs can be programmed via the choice of the binding motif. Exploiting a light-heat conversion process, it was also possible to utilize ultraviolet light to trigger the debonding (main picture). This feature appears to be particularly attractive for applications in which the bonded parts are difficult to access or in situations where heating the surrounding area is undesirable.

With the aim of tailoring the properties of similar supramolecular adhesives for possible applications and to develop a fundamental understanding of the relations governing the structure of such materials, AMI researchers are continuing to apply the design approach to other structures. These include supramolecular networks, composed of building blocks comprisd of more than two binding motifs. Some of the materials made this way are glassy and therefore much harder and stronger than the materials initially studied.

References:
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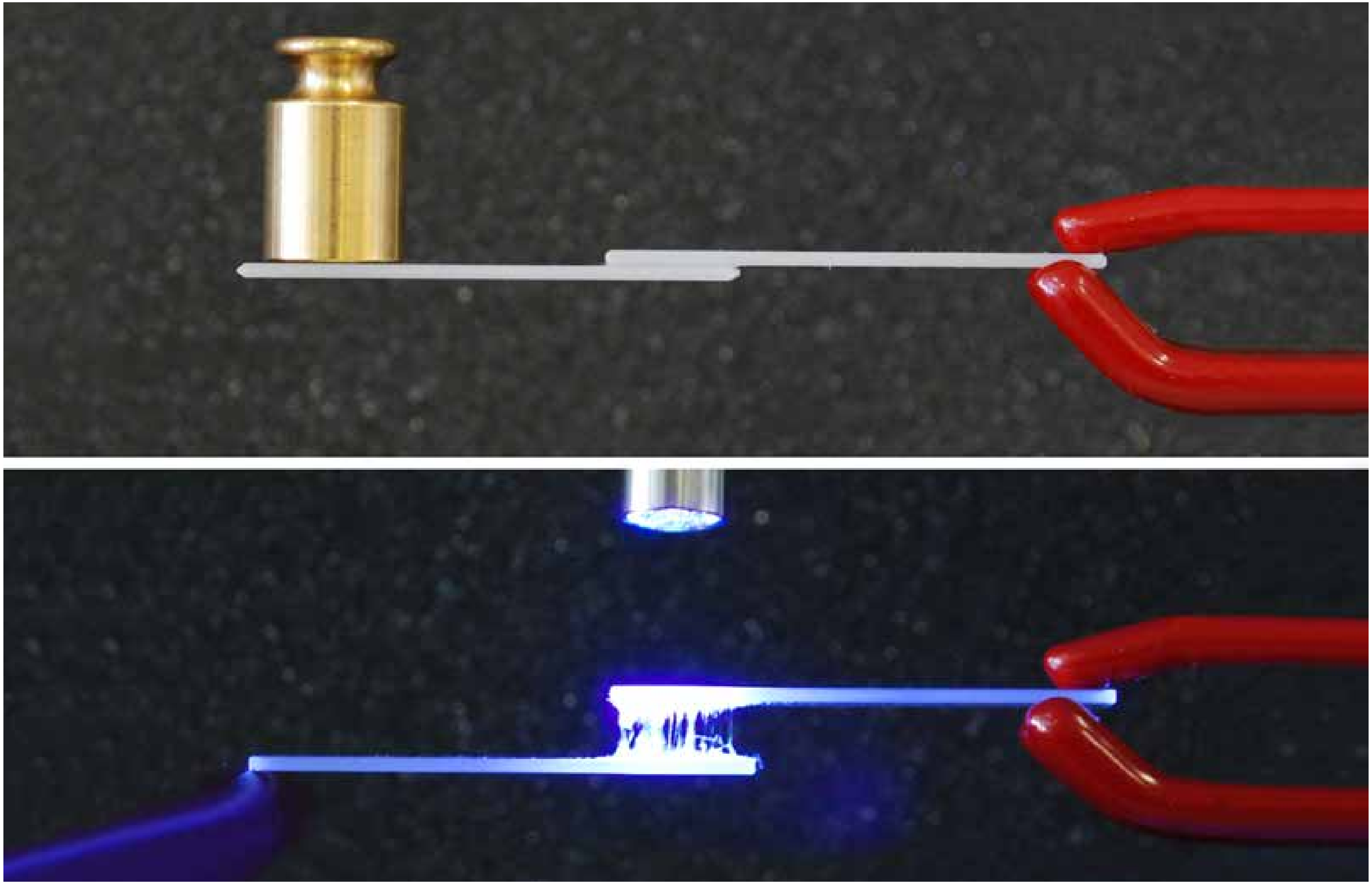
Contact: Prof. C. Weder



Visualizing the light-induced debonding feature of the supramolecular polymers used by AMI researchers. Under ambient conditions, the materials are powerful adhesives (top), whereas they liquefy and lose their adhesive properties upon heating or irradiation with ultraviolet light (bottom) (pictures: C. Heinzmann).

List of research projects

PROJECTS FINANCED BY THE SWISS NATIONAL SCIENCE FOUNDATION

Bio-inspired mechanically responsive polymer nanocomposites
01.01.2010–28.02.2015
C. Weder

This experimental research program targets the design, synthesis, processing, investigation, and application of a new family of bio-inspired polymer nanocomposites with stimuli-responsive mechanical properties. The program focuses on the fundamental aspects of materials which contain cellulose nanowhiskers and change their mechanical properties on command. Such materials are of interest for potential use in biomedical and other applications.

Cellulose-based nanocomposite building materials: solutions and toxicity
01.12.2010–30.06.2015
C. Weder, E.J. Foster, M.J.D. Clift

This research program seeks (i) to develop new high-performance polymer nanocomposites containing rigid cellulose nanofibers and (ii) to investigate the potential health risks associated with these materials. These novel, value-added nanocomposites are designed for use in construction material applications. The investigation of the health risks of nanomaterials is an up and coming research focus at AMI.

Processing of polymer/cellulose nanofiber composites
01.08.2012–31.12.2016
C. Weder

This project seeks to develop robust, cost-effective, and scalable methods for the mixing and processing of nanocomposites of technologically relevant polymers and cellulose nanocrystals isolated from wood.

Stimuli-Responsive Metal-Containing Polymers
01.04.2014–31.03.2017
C. Weder

This project pursues the synthesis and characterization of functional, metal-containing polymers, including metallosupramolecular polymers with photo-healable adaptive properties, multifunctional materials with orthogonal supramolecular motifs, and metal-containing materials that undergo low-power upconversion.

NCCR Bio-Inspired Materials – Functional Polymers though Mechanochemistry
01.06.2014–31.05.2018
C. Weder

This program targets the design, synthesis, processing, exploration and exploitation of a new family of bio-inspired, mechanically responsive polymers in which mechanical stress provides the activation energy to trigger specific pre-programmed supramolecular events.

Simplified supramolecular polymers: from fundamental studies to a new generation of reversible two-component resins
01.11.2014–31.10.2017
L. Montero

The project seeks to investigate the structure-property relationships of supramolecular polymers based on the hydrogen bond between isophthalic acid and pyridine units, and to explore the potential of these polymers as the base of tunable two-component resins.

Smart vesicles for drug delivery
01.05.2010–28.02.2015
A. Fink

The goal of this project is to develop double-walled nanocontainers, so-called vesicles, whose outer wall mimics cell membranes. Equipped with functionalized surface features to selectively target specific mammalian cells (e.g. cancer cells), these vesicles are designed to dock with the cells or even merge with the cells' membranes.

Nanotechnology: Implications for the Wood Industry
01.01.2012–31.07.2016
A. Fink

The key objectives of this research project are (a) to understand the properties and mode of action of new engineered nanomaterials in wood science and technology, (b) to use such nanomaterials as carriers for biocides in solid wood, and (c) to evaluate the potential environmental and health related risks of nano-treated wood. With this, we will thoroughly evaluate the potential opportunities of nanotechnology to improve the properties of one of the world's most important raw materials.

Nanoparticles: Surfaces, protein & cell interaction
01.10.2013–30.09.2015
A. Fink

This follow-up project is situated at the interface between nanomaterials science and nanobiology and shall investigate three research questions, which are of uttermost importance in the field. As such, the project will investigate 1) how nanoparticle-protein interactions change when nanoparticles are internalized into cells, 2) the effect of conformation and density of polymers attached to nanoparticles on cellular response and 3) the extent and geometry of anisotropic nanoparticle surface functionalization and the impact on cellular interaction.

Biomedical Nanoparticles as immune-modulators
01.09.2011–30.11.2015
B. Rothen-Rutishauser

In order to harness the unique properties of nanoparticles for novel clinical applications in the treatment of allergic respiratory diseases, AMI researchers are developing and testing specifically designed nanoparticles in order to investigate their immune-modulatory effects in the lung.

NCCR Bio-Inspired Materials – Magneto-responsive cell culture substrates that can be modulated in situ under conditions compatible with live cells
01.06.2014–31.05.2018
A. Fink

The project is focused on the design of new types of cellular substrates to study dynamic cellular responses using hybrid magneto-responsive materials. The former will be based on a synergetic combination of magnetic nanoparticles embedded in a thermo-responsive polymer film.

NCCR Bio-Inspired Materials – Intelligent nanomaterials to reveal their behavior in complex media and cells
01.06.2014–31.05.2018
R. Rothen-Rutishauser

The aim of this project is to use intelligent nanoparticles – with magnetic properties or nanoparticles with pH sensitive dyes – to understand what a particle looks like at the cell membrane and/or inside the cell, how a particle crosses tissue as well as cell membranes, enters intracellular trafficking and elicits cellular responses. The knowledge about nanoparticle behavior at the biological interface will enable us to optimize the design of new particles for diagnostic or biomedical applications.

Realistic exposure scenarios to study nanoparticle-lung cell interactions
01.01.2012–30.06.2015
B. Rothen-Rutishauser, A. Fink, M.J.D. Clift

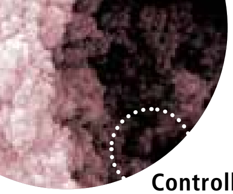
The use of sophisticated, dose-controlled nanoparticle (NP) exposure devices in combination with lung cell cultures at the air-liquid interface has become more common. However so far such studies have only considered acute exposures (i.e. a single exposure of NPs). We aim to optimize our established and advanced 3D lung cell culture models to be cultured at the air-liquid interface for a prolonged period (several days to weeks). These cultures will then be used to address the questions about differences in chronic (i.e. repeated exposures as well as prolonged exposures), and acute NP exposure toxicity. In addition, co-exposure studies are planned in the second part of the project to evaluate the effects of two different NPs when combined.

Nanoparticles self-assembly: a tool for the rational design of novel materials
01.01.2012–31.12.2015
M. Lattuada

The goal of this project is the preparation of complex nanoparticles, the understanding their self-assembly behavior and their utilization to prepare novel materials. The research activity is divided into three main projects. The first project aims to prepare nanoparticles with structured morphologies, via emulsion-based methods. The second project aims to create new polymeric and composite materials by blending together different components starting from aqueous suspensions of ultra-small nanoparticles. The last project is a computational work aimed at investigating the rheology of suspensions of colloidal particles undergoing self-assembly in the presence of flow fields.

NCCR Bio-Inspired Materials – Ultrafast Stimuli-responsive Color-Changing Hydrogels
01.06.2014–31.05.2018
M. Lattuada

The aim of this project is the preparation of materials with the ability to change color extremely fast, mimicking the mechanism of the octopus skin. The materials will be prepared from the co-assembly of stimuli-responsive microgels and dye particles to generate large clusters capable of high volume changes in response to a stimulus.



Controlled Radical Polymerization catalyzed by Enzymes: From Fundamentals to Applications
01.10.2013–30.09.2017
N. Bruns
Controlled radical polymerizations allow the synthesis of polymers with a defined size and molecular architecture. Such polymers are essential building blocks for soft nanomaterials. This project investigates enzymes as environmentally friendly catalysts for atom transfer radical polymerizations (ATRP). The biocatalysts are an alternative to conventional toxic catalysts.

NCCR Bio-Inspired Materials – Responsive and self-reporting block copolymers for self-assembled biomimetic structures, smart surfaces and bulk materials
01.06.2014–31.05.2018
N. Bruns
Mechanically responsive block copolymers are synthesized. Their self-assembly into micelles, polymersomes and nano-structured bulk materials are being studied and their application as force-responsive nanoreactors, drug-delivery vehicles and self-reporting materials will be investigated.

PV2050: Novel PV Technologies for optimum Space Usage and Efficient Electricity Production – Novel Generation Perovskite Devices
01.01.2015–31.12.2017
U. Steiner
This project aims to improve the efficiency of perovskite-based solar cells to the 20% range. Our part of this joint project is to explore the interplay within the electrode meso-structure with perovskite crystallinity and its role in the performance of solar cell devices.

Hierarchically structured materials for super-capacitors and batteries
01.10.2014–30.09.2018
U. Steiner
The capacity of Li-ion batteries is not only determined by the lithium chemistry taking place between the anode and cathode, but also by the accessible surface area of the two electrodes. Nanostructuring these electrodes has been shown to be highly effective, but large batteries of this type cannot be built in a scalable fashion. In this project, we are planning to combine micro- and nano-structures in battery electrodes to improve the performance of Li-ion batteries.

PROJECTS FINANCED BY THE EUROPEAN RESEARCH COUNCIL

Mechanically Responsive Polymers
01.06.2012–31.05.2017
C. Weder
This program targets the design, synthesis, processing, exploration and exploitation of a radically new family of bio-inspired, mechanically responsive polymers in which mechanical stress provides the activation energy to trigger specific pre-programmed chemical reactions.

CARINHYPH – Bottom-up fabrication of nano carbon-inorganic hybrid materials for photocatalytic hydrogen production
01.07.2014–31.12.2015
U. Steiner
The core of this project is the development of new materials that allow the splitting of water into hydrogen and oxygen by light. Rather than expensive catalytic metals, the goal is to explore the efficacy of metal-oxide/carbon hybrid materials as catalysts for water splitting. Our role in this European collaboration is the manufacturing of nanostructured photo-catalytic materials.

PROJECTS FINANCED BY OTHER PUBLIC FUNDING AGENCIES

Supramolecular Polymers With Multiple Types of Binding Motifs: From Fundamental Studies to Multi-functional Materials, US Army Research Office
2012–2015
C. Weder
In this project, hybrid stimuli responsive materials that incorporate multiple functionality into a polymer matrix are being investigated.

Assessing the toxicity of Ag nanoparticles at the air-liquid interface using a 3D model of the epithelial airway barrier in vitro, Federal Office of Public Health
01.02.2010–31.12.2014
B. Rothen-Rutishauser
Silver nanoparticles are currently used for a wide range of consumer, industrial, and technological applications. Despite this, the effects of silver nanoparticles on the environment and human health are not fully understood. This project aims to use the in vitro human epithelial airway model combined with a battery

of experimental tests to determine the different toxicological endpoints that might be involved in xenobiotic-induced toxicity, specifically in connection with silver nanoparticles.

An innovative bio-printing platform to engineer lung tissue for standardized risk assessment of inhaled drugs and ambient pollutants, Swiss Lung Association
01.04.2014–31.03.2015
B. Rothen-Rutishauser
The project aims to develop a viable high-throughput platform to print 3D lung tissues from a technological proof-of-concept into a standardized and versatile model. This promises to be a high-impact project for the Swiss Lung Association and the Lung Society worldwide since such a model would enable the replacement or the reduction of animal testing in the area of inhalative risk assessment, the study of lung diseases, and drug development.

Surface-enhanced Raman Scattering (SERS)-based Imaging and ultrasensitive-detection of Biomarkers in Biological Samples, L'Oreal
01.08.2013–31.12.2014
L. Rodriguez Lorenzo
Our main objective in this research project is the design and development of new protocols for routine diagnosis based SERS-imaging-ultra-detection methods. We are looking to build a sensor that can be used for both imaging and sensing, allowing early-stage disease detection.

TRIPDIFF – Triplet Diffusion in Sensitized Upconversion, Rectors' Conference of the Swiss Universities
01.11.2014–31.05.2015
Y. Simon
The project aims to understand the importance of triplet diffusion in molecular and polymer glasses in low-power light upconversion via triplet-triplet annihilation (TTA-UC). The proposed collaboration will help untangle the impact of triplet diffusion and the triplet-triplet annihilation step in the overall TTA-UC efficiency.

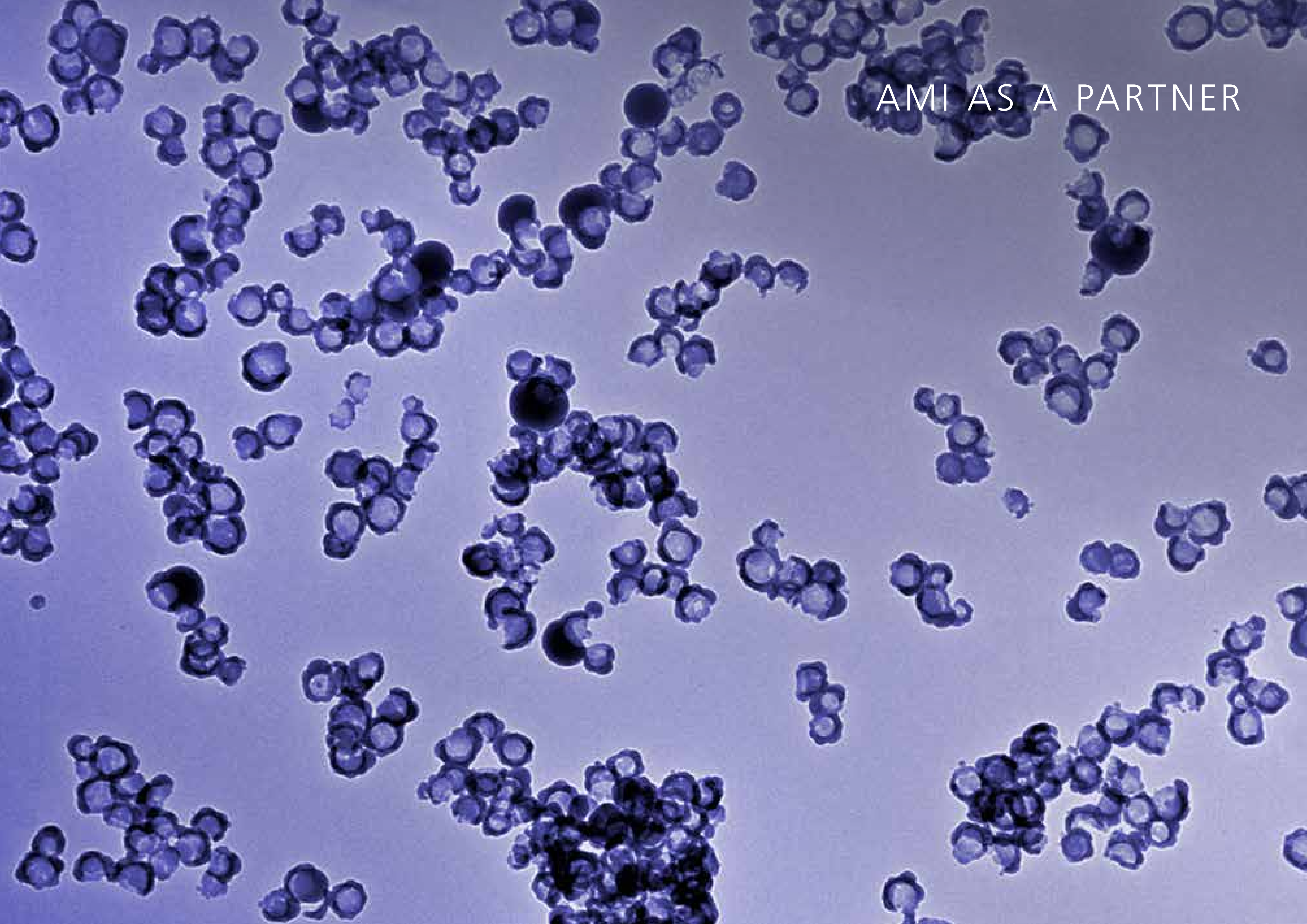
TOXBRAWE, Composition of airborne brake wear debris particles and lung cell response in vitro – is there any correlation? Rectors' Conference of the Swiss Universities
01.11.2014–31.10.2015
B. Rothen-Rutishauser
We aim to assess a possible correlation of brake pads composition and the physico-chemical characteristics of the released particles, and the possible negative impact of those particles thanks to an in-vitro 3D-lung model. First, an in-depth understanding of the physic-chemical properties of brake wear debris particles, dependent on the initial brake pad material, is required. Second, we need a realistic exposure method to assess the risks by considering the exposure route, since suspension lung cultures do not represent the real inhalation of exhaust and might lead to artefacts, and the use of a sophisticated cellular model which consists of multiple cell types that combine the most important cells of the human lung. Our working hypotheses are: (i) the composition of aerosolized brake wear particles can be correlated with the type of brake pad composite used, (ii) the in-vitro 3D-lung model and realistic air-liquid exposures to different sources of brake wear debris particles is a reliable tool for providing an experimental data risk assessment of these particles from different brake pad compositions, and (iii) the cellular responses are related to the specific brake wear debris particle characteristics.

Toxizität von Abgasen aus Fahrzeugen mit neuer Dieseltechnologie
1.1.2014–31.12.2016 Federal Office for the Environment
B. Rothen-Rutishauser
This project aims to investigate the different compounds, i.e. gaseous, semi volatile and solid, from exhaust emissions released by various engines. With a recently established system we can perform a comparison of exhaust composition and biological responses in lung cell cultures from freshly produced exhaust exposed directly at the air-liquid interface.

PROJECTS WITH INDUSTRY

Six projects with industry partners were carried out in 2014.

AMI AS A PARTNER



AMI as a partner

PARTNERSHIPS

Strategic partnerships are important to AMI in order to leverage research results and foster their translation into useful applications. The creation of a National Center of Competence in Research (NCCR) Bio-Inspired Materials in Fribourg, the strengthening of ties with the National Thematic Network (NTN) Innovative Surfaces and the participation in a strategic partnership between canton Fribourg and the French Alsace region were some key activities in 2014.

NCCR Bio-Inspired Materials

The newly founded NCCR began its operations in June 2014 at the University of Fribourg (home institution), with its operational office in the new AMI premises at the Faculty of Sciences. The national dimension of the center, with a special focus on the design of stimuli-responsive materials inspired by nature, makes it a magnet for talented students and an interesting collaboration partner for innovative companies. The knowledge and technology transfer activities optimally complement the efforts of the involved institutions by promoting novel findings and technologies and helping to identify commercial opportunities. Special programs such as the Industry Associates Program, where companies can enter into a strategic relationship and benefit from prime access to research and expertise, will also help leverage translational research efforts.

NTN Innovative Surfaces

AMI has been an institutional partner of this network since its creation in 2013. To facilitate its activities and outreach in the western part of Switzerland, the NTN Innovative Surfaces established its regional hub at AMI. This office in Fribourg will help build a bridge between the different regions of Switzerland and strengthen interactions with academic and institutional partners in Fribourg and beyond.

BioValley Alsace

In the framework of a strategic partnership established in 2014 between canton Fribourg and the Alsace region, AMI contacted Alsace BioValley, a French cluster dedicated to therapeutic innovations in the French-German-Swiss BioValley. After meetings in Fribourg and Strasbourg, AMI was able to identify opportunities for potential collaborations with companies and research institutions, some of which are now being pursued.

INNOVATION CULTURE

Since its launch in 2012, the Innovation Club aims to foster innovation culture among students with the support of AMI and the Fribourg School of Management. Fribourg, with 13’000 students following courses in economics, social sciences, law, IT, natural sciences, engineering and many other fields, promises to become a fertile ground for an interdisciplinary community of innovation driven students.

Over the past two years, the student-led club was able to convince the University of Fribourg and the Fribourg School of Engineering and Architecture to provide further institutional support, build up its operations and organize an attractive mix of activities. The “Speaker Series” brought enthusiastic drivers of new technologies into contact with students interested in exchanging ideas about subjects such as augmented reality, 3D-printing or urban networks. The “Innovation on Campus” format opened up the access to the local innovation scene, for example through a visit of the BlueFactory innovation park and coaching for the pitching contest VentureIdeas. During a visit to the Northeastern Entrepreneurs Club in Boston in spring 2014, the AMI representative in the club’s Advisory Board was also able to garner valuable insights of a similar initiative.

Event of the Innovation Club in the Speaker Series about “Urban Networks”

INDUSTRY COLLABORATIONS

Several research projects that AMI researchers carried out over the past four years led to interesting results with potential technological relevance.

For some of these technologies intellectual property and know-how was secured and licensed to industry partners and are being further developed for specific applications in collaboration with industry.

One specific example of such collaboration is the application of supramolecular polymers in dental cements. Until today, such cements are designed for permanent fixation of the dental prosthesis. However, in many cases, for example ceramic chipping or accidents, clinical complications, and in case of the formation of secondary decay or undesirable discoloration, the easy removal of dental prosthesis would simplify the dentist's work. The removal of the classical adhesives or cements is very uncomfortable for the patient, very time consuming and often destructive to the subjacent tooth structure. Remaining cement on the tooth structure often has to be removed with diamond or hard metal burs in a second step.

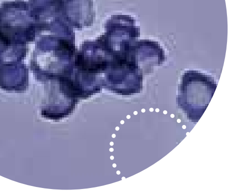
Ivoclar Vivadent AG (IVAG), a leading international dental care company with a comprehensive product and system range for dentists and dental technicians, approached AMI with a confirmed need for adhesive materials or cements that permit strong fixation of a dental prosthesis while allowing an efficient and complete removal on demand.

Technology platform	Characteristics of technology	Potential applications
Mechanically adaptive materials	Cellulose nanofiber reinforced polymers that can switch on/off the fiber interactions and therefore change mechanical properties (stiffness) drastically	Stiff polymeric materials that soften once implanted in biological tissue, e. g. biomedical implants: cortical electrodes, optical fibers for optogenetics, adaptive canulas
Fluorescent mechanical stress indicator	Substances at the interface of structural fibers (carbon, glass) and matrix polymers (epoxy,…) that switch their fluorescence on/off indicating structural failure.	Fluorescence indication of fiber failure in high performance parts (automotive, aeronautics,…)
3D-lung model	In vitro model of air-blood tissue barrier of human lungs, including immune responsive cells	Testing platform for: Risk assessment or airborne pollutants or synthetic nanoparticles. Delivery of inhaled drugs into the (diseased) lung
Bio-catalysts for polymerization reactions	Natural enzymes from horseradish, fungi or red blood cells that catalyze Atom Transfer Radical Polymerizations (ATRP)	Controlled polymerization of n-vinyl imidazole for use as functional polymer
Supramolecular polymers	Polymers composed of small building blocks that form larger polymers through non-covalent interactions and therefore can polymerize and de-polymerize easily	Self-healing varnishes and coatings on demand adhesives

Current cement solution to fix a dental prosthesis.

In a project that started in 2012, AMI researchers developed in collaboration with IVAG novel materials, which can be used as components of strong dental cements or adhesive materials. They enable a targeted debonding under oral conditions in a convenient timeframe without damaging the substrates.

In parallel to this development, AMI researchers also continued to investigate possibilities to create light-induced bonding and debonding with supramolecular adhesives. The latest publication of these results in the journal ACS Applied Materials and Interfaces generated significant interest in the scientific community, but also among companies that see a specific application potential.



NETWORKING AND PUBLIC RELATIONS

As part of its mandate, AMI continually seeks new partners to further develop its activities. It also reaches out to its stakeholders, including the general public, to present the institute's activities, nanoscience in general as well as discuss the potential benefits and risks of nanotechnology.

Outreach in 2014

AMI researchers continued to meet and debate with the public in 2014. Professor Barbara Rothen-Rutishauser travelled to Spreitenbach in canton Aargau to present the world of nanotechnology at a public conference organized as part of Expo-Nano, a touring exhibition that was launched in 2013. This exhibition featured contributions from AMI, including information on smart capsules for drug delivery and a demonstration of cellulose-reinforced plastics.

As part of the University of Fribourg's jubilee, professors Alke Fink and Marco Lattuada joined the public in Bulle, canton Fribourg's second-biggest town, in May to discuss nanotechnology. This event was part of the university's regular "cafés scientifiques" (science cafés). These events, which are not conferences but what is termed a free-flowing discussion, are organized to debate in a friendly atmosphere issues related to the sciences and technology.

High school students were also given the opportunity to learn more about nanotechnology risks and opportunities. AMI PhD student Dagmar Kuhn gave public lectures to pupils attending high school in Sissach and Muttenz near Basel. She provided them with information about AMI research peppered with real-life examples, such as one famous brand of candy containing titanium dioxide nanoparticles, and answered the students' queries.

"It's important to let them ask questions," say Dagmar. "You have to give them precise answers though and be on top of your game. But it's a great way of promoting AMI and to encourage young people to pursue a career in this field."

Outreach went beyond the scientific scope though. Career development and advice were also part of the activities in 2014. Professors Alke Fink and Barbara Rothen-Rutishauser were asked to present the AMI job sharing model at a conference organized by the Fribourg section of the women's Zonta service club. This model was also the focus of an article in the German language weekly, WOZ.

Alke Fink took part in the University of Fribourg's Career Day in January, participating in a round table discussion on how to find the perfect job in industry.

Discussions on career development at AMI have also become a regular feature thanks to the establishment of the NCCR. Barbara Rothen-Rutishauser, as the NCCR Delegate for the Advancement of Young Researchers and Women, has launched a regular round-table discussion on careers that kicked off in December 2014.

Making connections

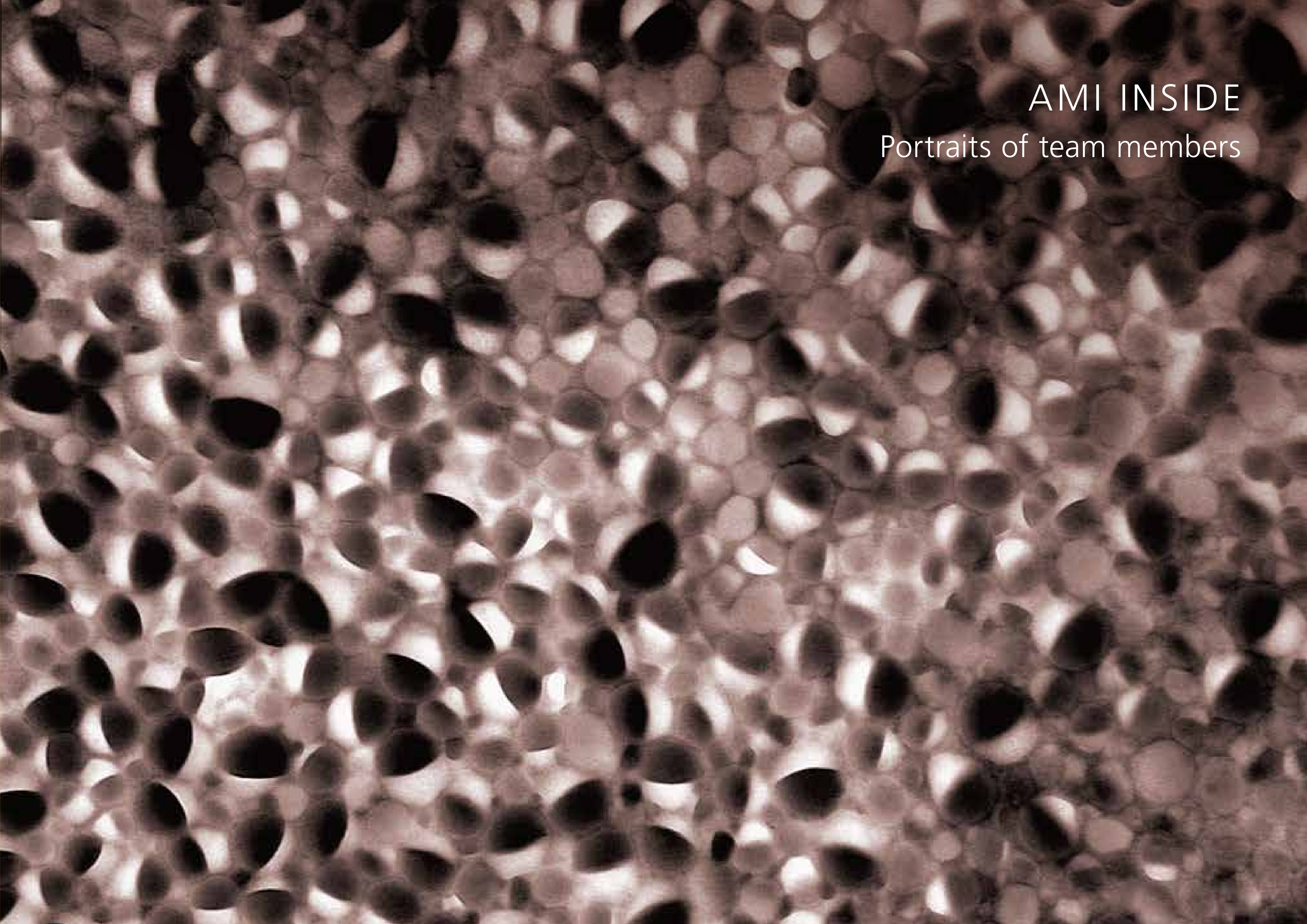
If the open day was an opportunity to present the institute to a wider public, AMI continued to welcome other groups.

AMI hosted the general assembly of the Swiss Society of Industrial Pharmacists (SSIP) in May. The SSIP is an association of pharmacists and other life-science professionals working in the Swiss pharmaceutical industry. This visit was an opportunity to present AMI research activities in more detail to potential partners who are particularly interested in establishing contacts and sharing knowledge.

The first major group to visit AMI after the inauguration of the new buildings was the Fribourg Industrial Association. It represents a broad cross-section of the local industry sector, with over 100 members and more than 13,000 employees. The association usually visits member sites, but it chose to highlight AMI and its work in December. Attendees were given an overview of the institute's activities and a much appreciated guided tour of the new facilities.

A more focused visit finally was that of the Cardiocentro Ticino, a clinic specialized in cardiology, cardiac surgery and cardiac anaesthesia and an associated institute of the University of Zurich. Its management made the journey to Fribourg to discuss potential collaborations with AMI and the NCCR as well as present its own activities, especially those in the field of research.

AMI INSIDE
Portraits of team members



LUCAS MONTERO

Lucas was born in Madrid (Spain), where he grew up and earned his bachelor's degree in chemistry at the Universidad Complutense de Madrid. He obtained his PhD from the Universitat Rovira i Virgili in Tarragona (Spain) and then moved to Germany, where he made postdoctoral stays at the universities of Potsdam and Karlsruhe before joining AMI in April 2013 as a member of the Polymer Chemistry and Materials group. Lucas' research at AMI focuses on studying the relationships between the solid state assembly of supramolecular polymers and their macroscopic properties.

When he is not working, Lucas spends most of his free time climbing, hiking or skiing near Fribourg, in the Valais Alps or in the Bernese Oberland, but also in the Spanish Pyrenees with his family, who are to blame for his mountain addiction.

MANUEL KOLLY

Manuel (left in the picture) comes from Rechthalten, Switzerland, a small village near Fribourg. After studying mechanical engineering – specializing in micro- and nanosystems – in Lausanne, Waterloo (Canada) and Zurich, he began his PhD at AMI in December 2014, joining the Soft Matter Physics Group of Prof. Ullrich Steiner. His work focuses on the interplay of order and disorder in photonic materials, which occasionally allows him to look at butterflies and beetles.

He chose to move back to Fribourg, not only because of the mountains, the snow and the chocolate, but also because of its mix of French and German-speaking cultures. In his spare time, Manuel plays center back for FC Rechthalten-St.Ursen football club. He also has a passion for cooking with eggs and recently bought two ostrich eggs, although he has not decided yet whether to boil or fry them.

REBECCA OLSON

Becky is currently pursuing a Bachelor's degree in Macromolecular Science and Engineering at Case Western Reserve University in Cleveland, Ohio. She spent the summer of 2014 as an intern at AMI researching recyclable epoxy resins. This opportunity allowed her to learn more about chemical synthesis, practice her German, work with people from around the world, travel throughout Europe, and experience European culture.

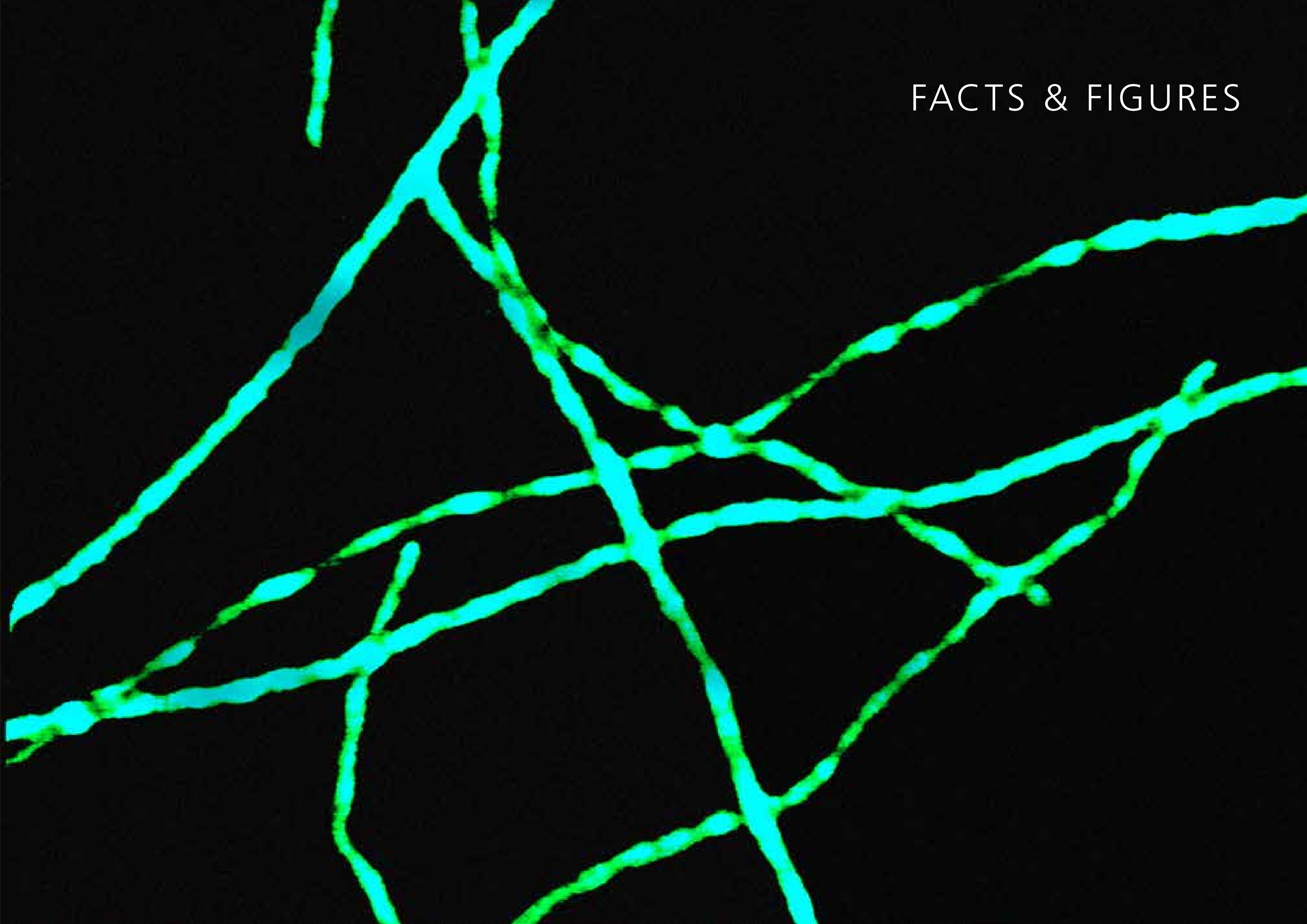
She says her stay in Fribourg opened her eyes to the stunning beauty of Switzerland and sparked a desire to travel more. Outside of going to class or conducting research, Becky spends time cooking, hanging out with friends, or sitting down with a good book. She plans to pursue a PhD in Polymer Chemistry.

BARBARA ROTHEN-RUTISHAUSER

Barbara joined AMI in 2011 as the chair of the BioNanomaterials group, a position shared with Alke Fink. She studied cell biology at the Federal Institute of Technology in Zurich and after her PhD thesis and a postdoc there, Barbara worked for ten years at the University of Bern in the field of nanoparticle-lung cell interactions.

Barbara lives with her husband and the two teenage boys between Bern and Fribourg. Besides travelling around the world to visit former colleagues, as a true Swiss she likes chocolate, cheese and a glass of red wine from her home region, the "Siblinger Eisenhalde". She likes to spend her free time outdoors and often goes running – seeking inspiration for her new research projects.

FACTS & FIGURES

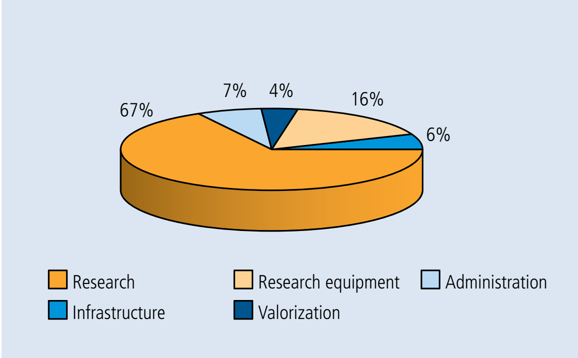


Facts & Figures

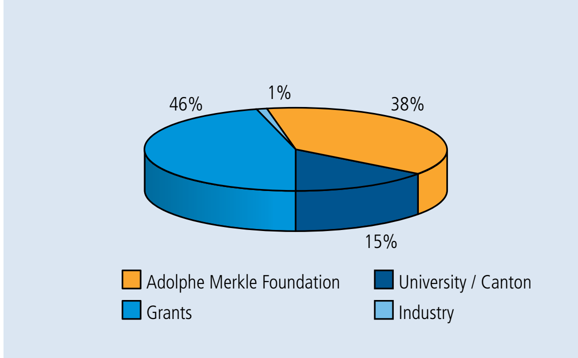
FINANCES

The institute's overall expenditures in 2014 grew to CHF 8.8 million. Sixty-seven percent of the expenses were spent on research and an additional 16% were invested in research equipment. About 4% of the budget supported valorization activities such as technology transfer and communication & marketing. Around 6% were used for general infrastructure and 7% for administration. The main sources of income were the Adolphe Merkle Foundation, competitive funds from funding agencies and industry, as well as the University and Canton of Fribourg.

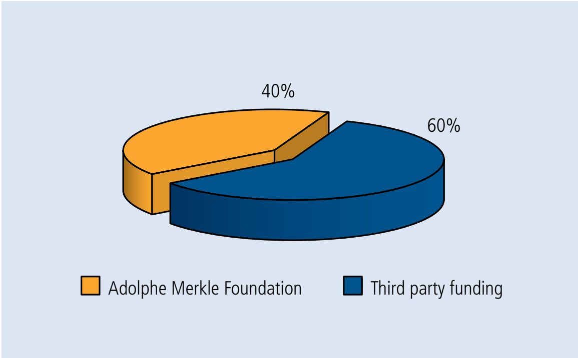
Compared to the previous year, third-party funding of research projects increased by CHF 0.5 million to CHF 3.6 million, covering close to 60% of all research expenditures. The most important sources were the Swiss National Science Foundation (SNF), the European Union, industrial partners, and the Swiss Commission for Technology and Innovation (CTI).



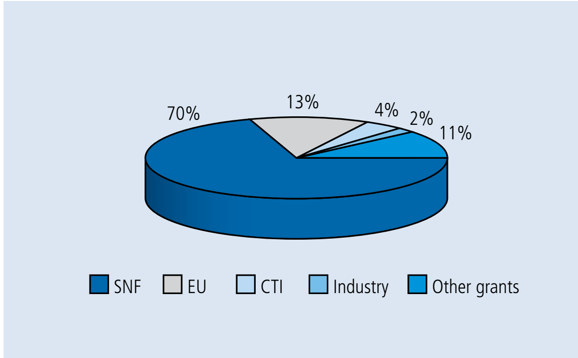
Overall expenses in 2014 by cost type
Total expense of CHF 8.8 million



Funding sources of overall expenses in 2014



Funding sources of research projects in 2014
Total research expenditures of CHF 5.9 Mio.

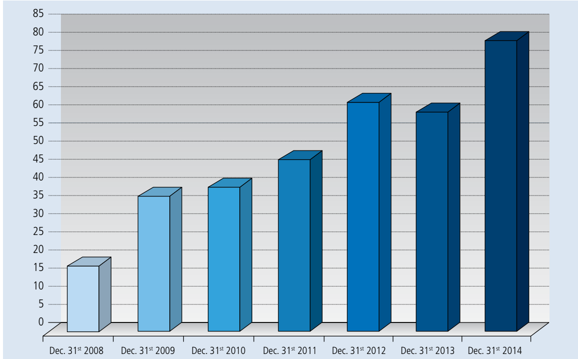


Third party funding of research projects 2014
Total of CHF 3.6 million

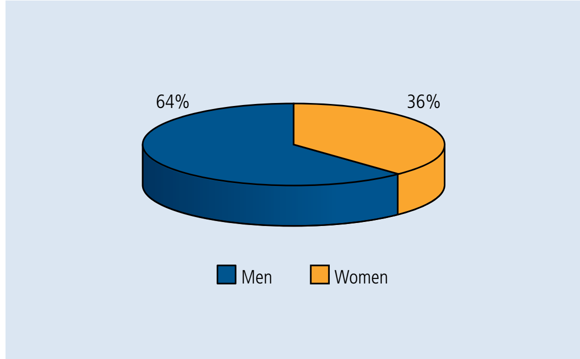
PERSONNEL

In 2014, 29 new collaborators joined AMI, while 14 people left the Institute as a result of natural fluctuation. As of December 31, 2014, 80.4 full-time positions were occupied at AMI. 93 percent of all employees were active in research. Almost half were PhD students and another 21% postdoctoral researchers, reflecting the educational and research mission of the institute.

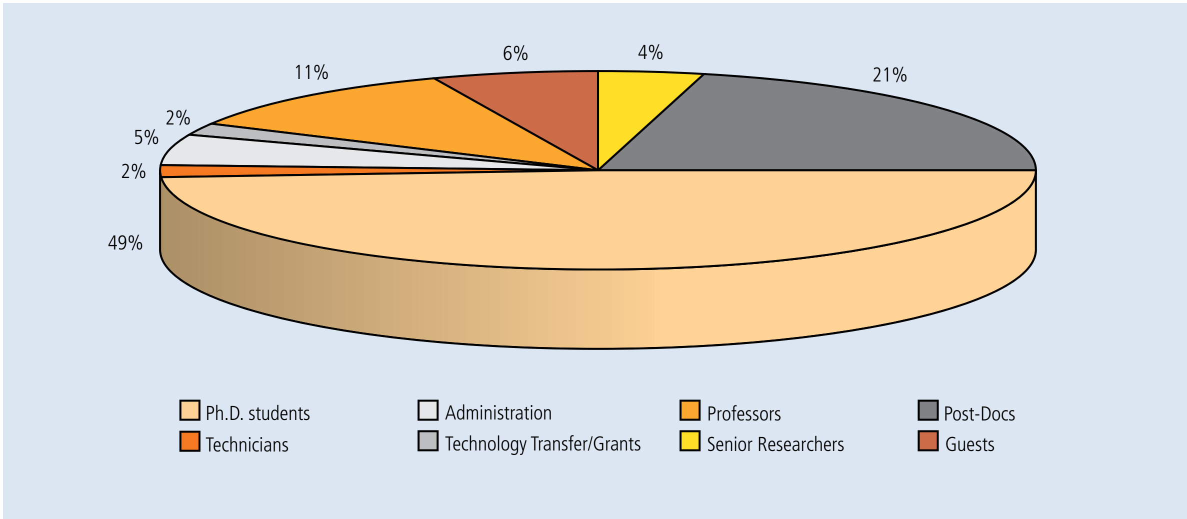
The AMI team remains strongly multinational, with 25 different nationalities. The average age of AMI employees is 32 years and 36 percent of the employees are women.



Development of personnel over a six-year period, in full-time equivalents



Gender distribution at AMI on December 31, 2014



Composition of personnel on December 31, 2014

GOVERNING BODIES OF AMI (31.12.2014)

Executive Board

Prof. Christoph Weder
(Director)

Dr. Marc Pauchard
(Associate Director)

Prof. Alke Fink
Prof. Barbara Rothen-Rutishauser
Prof. Ullrich Steiner
Prof. Marco Lattuada
Prof. Nico Bruns

Institute Council

Prof. Guido Vergauwen
(President)
Rector of the University of Fribourg,
Professor at the Faculty of Theology, Universtiy of Fribourg

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

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

Prof. Titus Jenny
Professor of Organic Chemistry at the Department of Chemistry and Vice-Rector for Research, University of Fribourg, Former Dean of the Faculty of Science, University of Fribourg

Scientific Advisory Board

Prof. Marcus Textor
(President)
Former Head of the Biointerface Group at the Department of Materials, ETH Zurich, Switzerland

Prof. Giovanni Dietler
Head Laboratory of Physics of Living Matter at Ecole Polytechnique Federal de Lausanne (EPFL), Switzerland

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

Prof. Paula Hammond
Bayer Chair, Professor of Chemical Engineering, and Executive Officer at Massachusetts Institute of Technology, USA

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

Prof. Ben Zhong Tang
Chair Professor of Chemistry at the Hong Kong University of Science and Technology (HKUST), China

Adolphe Merkle Foundation

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
Director of Federal Office of Culture, former Minister of Public Education, Culture, and Sport of the Canton of Fribourg

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

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)

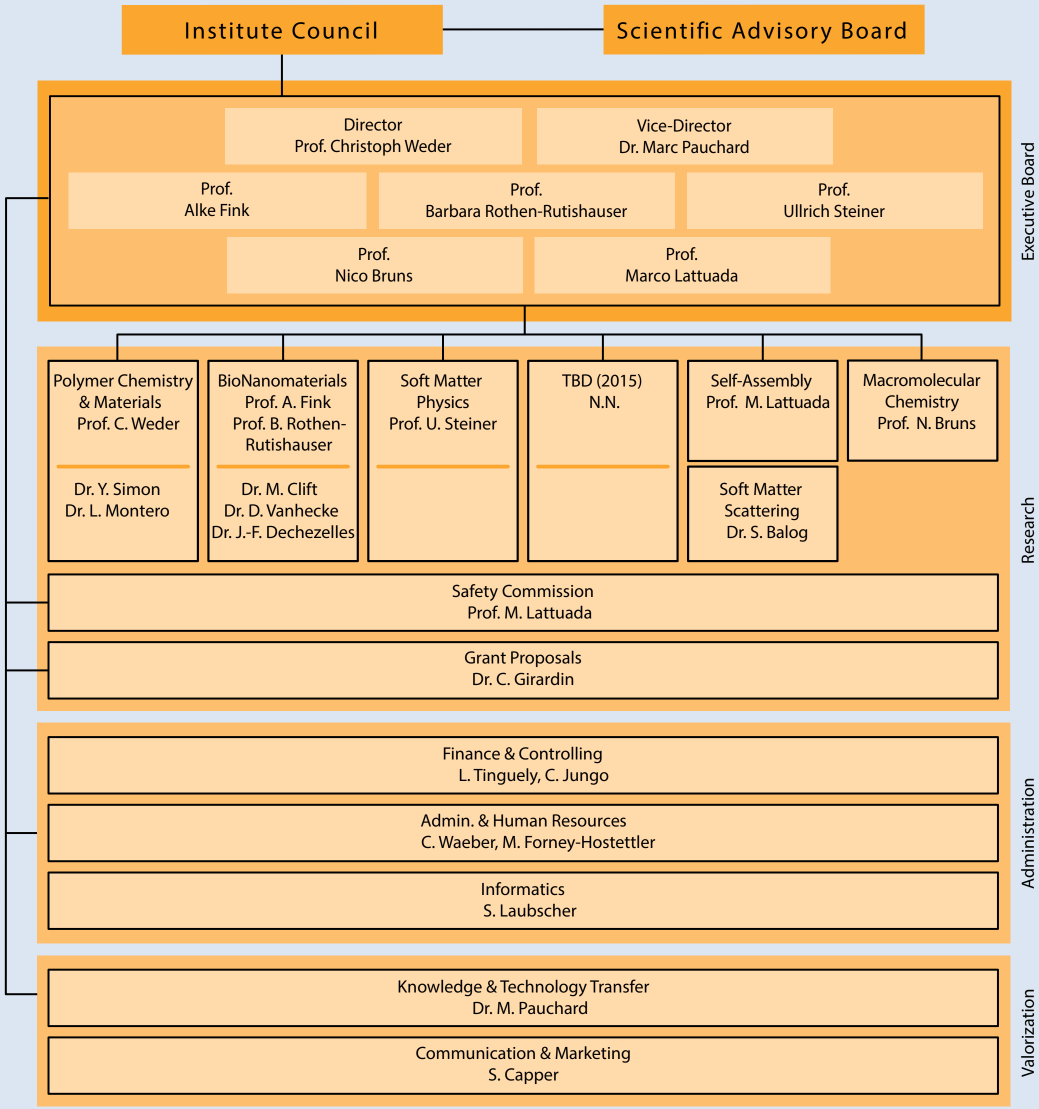
ORGANIZATIONAL CHART

AMI has the formal status of being an independent institute of the University of Fribourg, whose scientific, administrative, and strategic leadership rest with its executive board. An Institute Council composed of representatives of the University of Fribourg and the Adolphe Merkle Foundation provides oversight and serves as a platform in which AMI's main stakeholders can dialogue. An independent external advisory board composed of scientists with outstanding international reputations advises the Institute Council and AMI executive board on strategic and scientific matters.

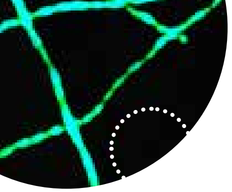
AMI's research departments form the core of the institute. In 2014, AMI was comprised of three research departments (Polymer Chemistry & Materials, BioNanomaterials, Soft Matter Physics) and three small research groups (Nanoparticles Self-Assembly, Macromolecular Chemistry and Soft Matter Scattering). The current development plan foresees continued growth, with one department planned for 2015. Average department sizes of about 30 researchers are envisioned.

In addition to a small administrative team, several comprehensive services endorse the strategic activities of the institute:

- Safety Committee: guarantees safe research operations.
- Grant Proposals: professional support in project proposal writing guarantees AMI's efficient participation in competitive research programs.
- Knowledge and Technology Transfer: sets the basis for successful collaborations with industry and supports researchers in the further valorization of their results.



Status December 2014



SCIENTIFIC OUTPUT

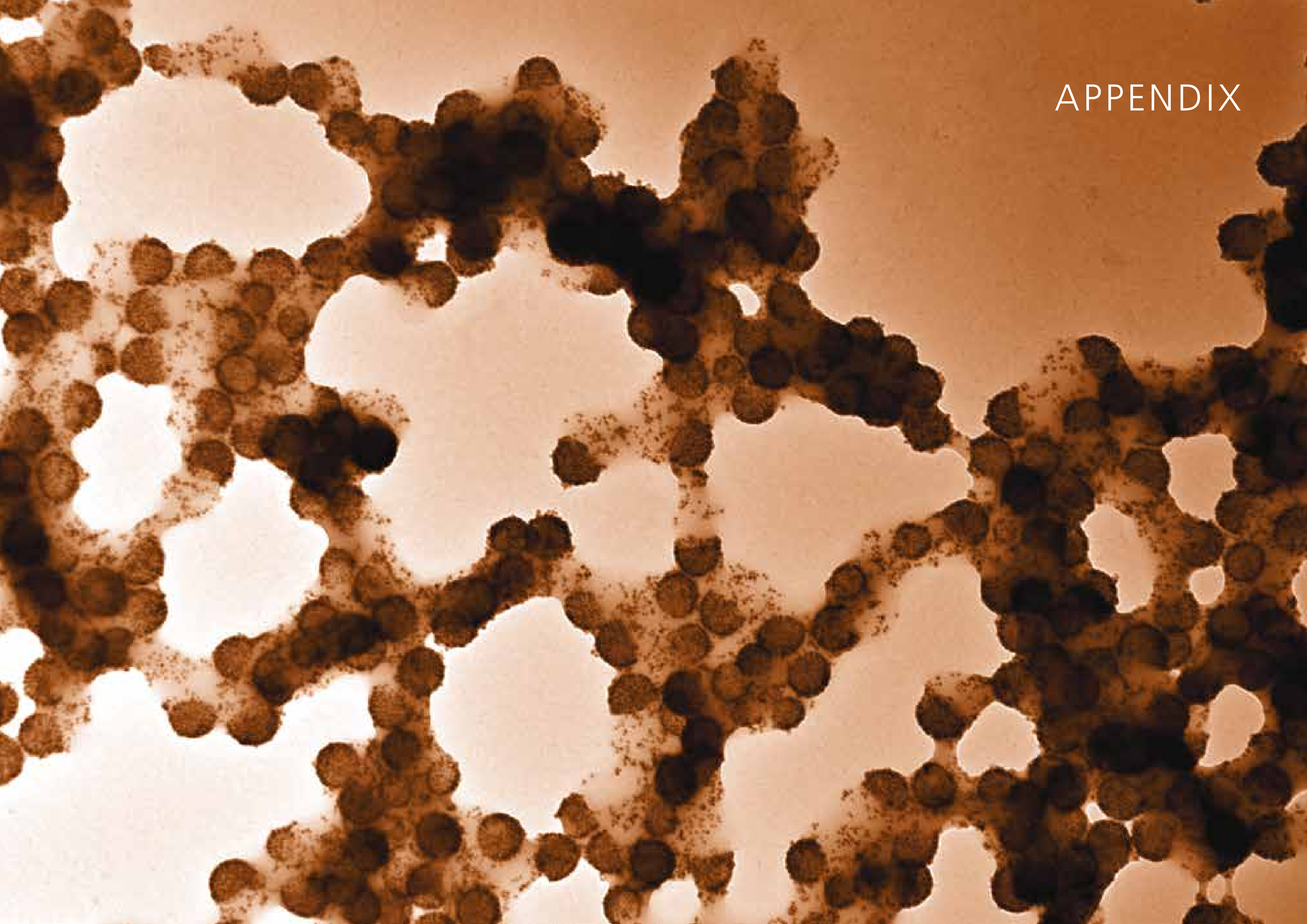
2014 proved to be another successful year for AMI researchers, with more than 90 publications in total. Their work was published in several high impact journals, including the Beilstein Journal of Nanotechnology, Angewandte Chemie International Edition, Biomacromolecules, Langmuir, the Journal of the American Chemical Society and ACS Nano.

AMI researchers participated in 19 international and national conferences and eight seminars, representing the institute at events hosted by network members such as the American Chemical Society, the Swiss Chemical Society, FriMat, the European Colloid and Interface Society, the American Institute of Chemical Engineers, the British Association for Lung Research, and the Swiss MNT Network.

SCIENTIFIC OUTPUT

Publications:	
Scientific journals:	86
Book Chapters:	5
Contributions at conferences and workshops:	
Plenary and keynote lectures	4
Invited lectures, talks and seminars	66
Talks and oral presentations	57
Posters	25

APPENDIX



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Book chapters

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CONFERENCES, SEMINARS AND TALKS

University of Akron, Department of Polymer Engineering, Akron, OH, USA, January 10, 2014
Invited Talk, "Materials with unusual optical and mechanical properties", Y.C. Simon

Institute of Pharmaceutical Technology, Pharmacenter, University of Basel, Basel, Switzerland, January 13, 2014
Oral Presentation, "An innovative bio-printing platform to engineer lung tissue", L. Horvath, B. Rothen-Rutishauser, A. Fink

RBNI, Technion, Israel Institute of Technology, January 15, 2014
Invited Talk, "3D models of the human epithelial airway/alveolar barrier for risk assessment of inhaled nanomaterials", B. Rothen-Rutishauser

Career Day, University of Fribourg, Fribourg, Switzerland, January, 15, 2014
Session Chair, "How to find the perfect job in industry, round table discussion", A. Fink

Wissenschaftliche Grundlagen zur Regulation von Nanomaterialien, Oekotoxzentrum, Dübendorf, Switzerland, January 20–21, 2014
Invited Talk, "Interaktion von Nanopartikeln mit biologischen Systemen", B. Rothen-Rutishauser

Bio-inspired technologies towards Horizon 2020, Cambridge, UK, January 22, 2014
Invited Talk "Combining Polymers with the Functionality of Proteins", N. Bruns

Swiss Plastics, Lucerne, Switzerland, January 22, 2014
Invited Talk, "Playing with force, magnets and light", Y.C. Simon

Texas State University, Department of Biochemistry and Chemistry, San Marcos, USA, January 24, 2014
Invited Talk, "Smart Nanocomposites Materials based on Cellulose Nanocrystals", E.J. Foster

University of Southern Mississippi, Department of Polymer Science, Hattiesburg, USA, January 27, 2014
Invited Talk, "Smart Nanocomposites Materials based on Cellulose Nanocrystals", E.J. Foster

Department of Chemistry, University of Liverpool, Liverpool, UK, January 29, 2014
Seminar, "Stimuli-Responsive (Metallo)Supramolecular Polymers", C. Weder

Expo Nano, Umwelt Arena, Spreitenbach, Switzerland, February 22, 2014
Invited Talk, "Kleine Zwerge ganz gross: Faszinierende Einblicke in die Nanowelt", B. Rothen-Rutishauser

Makromolekulares Kolloquium Freiburg, Freiburg, Germany, February 27, 2014
Invited Lecture, "Stimuli-Responsive Metallosupramolecular Polymers", C. Weder

Medical Department Seminar, University of Fribourg, Fribourg, Switzerland, March 2014
Invited Talk, "Studying nanofibre genotoxicity in vitro", M.J.D. Clift

SPP1313 "Bio-Nano-Responses", Fulda, Germany, March 3–5, 2014
Oral Presentation, "When Nanomaterials meet Cells – Towards a Fundamental Understanding of the Bio-Nano-Interface", B. Rothen-Rutishauser

Progress meeting of the NRP 64, Zurich, Switzerland; March 6–7, 2014

Oral Presentation, "Cellulose-based nanocomposite building materials: solutions and toxicity", C. Endes, B. Rothen-Rutishauser, A. Fink

247th ACS Meeting, Dallas, TX, USA, March 16–20, 2014

Invited Talk, "Mechano-responsiveness: stimulating polymer chemistry", Y.C. Simon

Oral Presentation, "Cellulose Nanocrystal Based Nanocomposites: From New Biorenewable Nanocrystals to Healable Materials", E.J. Foster

Oral Presentation, "Magnetically responsive materials", A. Fink

5th VERT Forum, EMPA Dübendorf, Schweiz, March 21, 2014

Oral Presentation, "In vitro genotoxicity of filtered diesel exhausts: impact of catalysis", S. Steiner, B. Rothen-Rutishauser, A. Fink

Sekundarschule Sissach, Basel, Switzerland, March 21, 2014

Invited Lecture, "Nanotechnologie: Chancen und Risiken", D. Kuhn, B. Rothen-Rutishauser, A. Fink

University of Fribourg, Fribourg, Switzerland, March 27, 2014

Talk, "Engineering Materials from Nanoparticles Self-Assembly: following Nature's footsteps", M. Lattuada

Analytica 2014, Aerosol and Health: A challenge for chemical and biological analysis, Munich, Germany, April 1, 2014

Invited Talk, "Combining 3D lung cultures and aerosol exposures at the air-liquid interface – a new generation of realistic risk assessment systems", B. Rothen-Rutishauser

EU FP7 ITN Project NanoTOES Final Conference, Siena, Italy, April 3-4, 2014

Invited Talk, "The epithelial airway barrier in vitro: A valuable tool for studying nanomedicine?", M.J.D. Clift

South African-Swiss Nano-Workshop, iThemba Labs, Stellenbosch, South Africa April 4, 2014

Invited Talk, "Bio-inspired Nanotechnology: From Stimuli-Responsive Materials to Nanoreactors", N. Bruns

NRP 66 Progress Meeting, Murten Switzerland, April 10, 2014

Oral Presentation, "Nanotechnology in the service of wood preservation", C. Geers, B. Rothen-Rutishauser, A. Fink

2014 Frontiers in Nanotechnology, ETH Zürich, Zurich, Switzerland, April 14, 2014

Invited Lecture, "From bionanomaterials to a controlled interaction with cellular systems", B. Rothen-Rutishauser

Fifth Research Symposium on Petrochemical and Materials Technology and the 20th PPC Symposium on Petroleum, Petrochemicals, and Polymers, Bangkok, Thailand, April 22, 2014

Oral Presentation, "Stimuli-responsive drug delivery vehicles", A. Fink

Karlsruhe Institute of Technology, Karlsruhe, Germany, April 25, 2014

Invited Talk, Responsive materials with uncommon optical and mechanical properties, Y.C. Simon

7th International Nanotoxicology Congress Nanotox, Nanoparticles & Biological Barriers, Antalya, Turkey, April 23–26, 2014

Invited Talk, "Nanoparticles and lung epithelial barriers – what we know and where to go from here", B. Rothen-Rutishauser

Invited Lecture, "How to use advanced in vitro models in nanotoxicology", B. Rothen-Rutishauser

Cost Action FP1205: Nanocellulose: advanced characterization and potential uses, Bologna, Italy, May 6, 2014

Keynote Lecture, "Nanocellulose based composites for biomedical and advanced materials applications", E.J. Foster

Universidad Politécnica de Valencia, Departamento de Ingeniería Mecánica y de Materiales, Valencia, Spain, May 7, 2014

Invited Talk, "Biomimetic Smart Materials", E.J. Foster

Jahresversammlung der SGP 2014, Interlaken, Switzerland, May 8–9

Oral Presentation, "A new approach to engineer an air-blood tissue barrier", L. Horvath, B. Rothen-Rutishauser, A. Fink

45th Annual Meeting of the International Research Group on Wood Protection, St George, UT, USA, May 13, 2014

Oral Presentation, "Visualization of gold/silver nanostars in wood by surface enhanced Raman spectroscopy", C. Geers, B. Rothen-Rutishauser, A. Fink

Swiss Chemical Society, University of Geneva, Geneva, Switzerland, May 12, 2014

Oral Presentation, "Nanoparticles and Cells: what have we learnt?", A. Fink

St Gobain, Aubervilliers, France, May 15, 2014

Invited Talk, "Adaptive materials with unusual optical and mechanical properties", Y.C. Simon

Café Scientifique, Basel, Switzerland, May 18, 2014

Plenary Talk, "Schöne, heile Plastikwelt: Wir leben im Zeitalter der Kunststoffe", N. Bruns

BPPA14: International Conference on Biofriendly Polymers and Polymer Additives, Budapest, Hungary, May 19, 2014

Invited Talk, "Enzymes as environmental benign catalysts for atom transfer polymerization", N. Bruns

Zonta service club conference "Jobsharing", Fribourg, Switzerland, May 19, 2014

Plenary discussion, "Job-Sharing model at AMI", A. Fink, B. Rothen-Rutishauser

Chulalongkorn University, Bangkok, Thailand, May 20, 2014

Seminar, "Hydrogen-Bonded Stimuli-Responsive Supramolecular Polymers", C. Weder

Swiss Nanoconvention, Brugg Windisch, Switzerland, May 21, 2014

Oral Presentation, "Nanomaterials meet Cells", A. Fink

Café Scientifique, Bulle, Switzerland, May 21, 2014

Talk, "La nanotechnologie: voyage au coeur de la matière", A. Fink, M. Lattuada

EUPOC, Gargnano, Italy, May 25–29, 2014

Talk, "Incorporating weak links into polymers to generate function", Y.C. Simon

SoftComp annual meeting, Heraklion, Greece, May 26–30, 2014

Oral Presentation, "Janus Nanoparticles and Nanobowls Synthesis", F. Guignard, M. Lattuada

Chulalongkorn University, Bangkok, Thailand June 3, 2014

Talk, "Publishing in ACS (and other) Journals made Easy Experiences of an Author, Editor, Reviewer", C. Weder

Advances and Controversies in Fibre Toxicology, Cranfield University, Cranfield, UK, June 3–4, 2014

Awarded Talk, "Carbon nanotube physical properties determine their abillity to cause secondary genotoxicity within a multicellular in vitro model of the epithelial airway barrier", M.J.D. Clift

Swiss Soft Days, University of Basel, Basel, Switzerland, June 6, 2014

Oral Presentation, "Janus Nanoparticles and Nanobowls Synthesis", F. Guignard, M. Lattuada

10th International Conference on the Scientific and Clinical Applications of Magnetic Carriers, Dresden, Germany, June 13, 2014

Oral Presentation, "Janus magnetic liposomes for drug delivery", C. A. Monnier, A. Fink

PolyColl Meeting, Dübendorf, Switzerland, June 20, 2014

Invited Lecture, "Hydrogen-Bonded Stimuli-Responsive Supramolecular Polymers", C. Weder

NIST Workshop – Metrology Needs for Cellulose Nanomaterials, Vancouver, BC, Canada, June 23, 2014

Invited Talk, "Detecting Surface Chemistry of Nanocellulose", E.J. Foster

ACS Colloids, Philadelphia, PA, USA, June 22–25, 2014

Oral Presentation, "Preparation and functionalization of Janus dumbbell nanoparticles", M. Lattuada

Oral Presentation, "Nacre-like composite materials produced via magnetically-controlled sol-gel phase separation", M. Lattuada

SIS 2014, Coimbra, Portugal, June 24, 2014

Oral Presentation, "Worm-like micelles of polymerizable surfactant as a template for polymerization", S. Rima, M. Lattuada

18th ETH-Conference on Combustion Generated Nanoparticles, Zurich, Switzerland, June 25, 2014

Oral Presentation, "In-vitro genotoxicity of filtered diesel exhausts:impact of filtration and catalysis," S. Steiner, B. Rothen-Rutishauser, A. Fink

7th Clinam conference, Basel, Switzerland, June 24, 2014

Talk, "Janus Magnetic Liposomes", A. Fink

TAPPI International Conference on Nanotechnology for Renewable Resources, Vancouver, BC, Canada. June 26, 2014

Oral Presentation, "Thermally stable cellulose nanocrystals: From form to smart functionality", E.J. Foster

3D Cell Culture 2014, Advanced Model Systems, Applications & Enabling Technologies, Freiburg, Germany, June 26, 2014

Oral Presentation, "An innovative bio-printing platform to engineer lung tissue", L. Horvath, B. Rothen-Rutishauser, A. Fink

6. Wädenswiler Chemietag, Wädenswil, Switzerland, June 26, 2014

Invited Lecture, "Polymere Nanoverbundswerkstoffe mit Zellulose Nanofasern", C. Weder

FriMat Day, University of Fribourg, Fribourg, Switzerland, June 27, 2014

Oral Presentation, "Nanoparticles as building blocks: at the interface between chemistry and material science", M. Lattuada

Oral Presentation, "Janus Nanoparticles and Nanobowls Synthesis", F. Guignard, M. Lattuada

Oral Presentation, "Influence of the Potential Barrier on the Breakage of Colloidal Aggregates under External Shear", Z. Ren, M. Lattuada

Oral Presentation, "Visualization of gold/silver nanostars in wood by surface enhanced Raman spectroscopy", C. Geers, B. Rothen-Rutishauser, A. Fink

Medical Research Council (MRC) Toxicology Unit Institute Seminar, Leicester, UK, July 2014

Invited Talk, "Studying the impact of nanofibres on the lung in vitro", M.J.D. Clift

Macro IUPAC, Chiang Mai, Thailand, July 6–10 2014

Talk, "Mechanochemistry of pendant activated esters", Y.C. Simon

Talk, "Low-power light upconversion in polymeric glasses with tethered diphenylanthracenes", Y.C. Simon

Talk, "ACS Polymer Science – Editor Talk", C. Weder

Invited Lecture, "Stimuli-Responsive (Metallo)Supramolecular Polymers", C. Weder

European Environmental Mutagen Society (EEMS) Annual Meeting, Lancaster University, Manchester, UK, July 7, 2014

Invited Talk, "The role of oxidative stress in nanomaterial related genotoxicity in vitro", M.J.D. Clift

Program in Polymer Science and Technology (PPST) Seminar Series, Massachusetts Institute of Technology (MIT), Cambridge, MA, USA, July 7, 2014

Invited Seminar, "Harnessing proteins for polymer synthesis, nanoreactors, and force-responsive materials", N. Bruns

British Association for Lung Research (BALR) Annual Meeting, Imperial College London, UK, July 9–11, 2014

Invited Talk, "Studying the structure-activity relationship of carbon nanotubes relative to their genotoxicity in vitro", M.J.D. Clift

Alsace BioValley 9th Meet & Match "Surface Technologies for Medical Devices", Karlsruhe, Germany, July 10, 2014

Invited Talk, "Engineering smart nanocomposites for novel biomedical implants", E.J. Foster

NanoBio Australia 2014, Brisbane, Australia, July 10, 2014

Oral Presentation, "Nanoparticle-Cell interaction: Isolating the "shape" factor", C. Kinnear, A. Fink

Nanotexnology Conference, Thessaloniki, Greece, July 11, 2014

Oral Presentation, "Repeated exposure to carbon nanotube-based aerosols does not affect the functional properties of a 3D human epithelial airway model", S. Chortarea, B. Rothen-Rutishauser, A. Fink

Clark research group, University of California, Berkeley, CA, USA, August 8, 2014

Invited Seminar, "Harnessing proteins for polymer synthesis, nanoreactors, and force-responsive materials", N. Bruns

ACS National Meeting 2014, San Francisco, CA, USA, August 10–14, 2014

Invited Lecture, "Stimuli-Responsive Metallosupramolecular Polymers", C. Weder

Invited Lecture, "Stimuli-Responsive Hydrogen-Bonded Supramolecular Polymers", C. Weder

Talk, "Effect of molecular weight on polymer degradation by ultrasound", Y.C. Simon

Talk, "Yellow fluorescent protein senses and reports mechanical damage in fiber-reinforced polymer composites", N. Bruns

Invited Talk, "ATRPases: Iron- and copper-metalloenzymes that catalyze atom transfer radical polymerization", N. Bruns

9th World Congress on Alternatives in Animal Use in Life Sciences, Prague, Czech Republic, August 26, 2014

Oral Presentation, "Next level in vitro testing strategy to study the effects of carbon nanotube aerosols", S. Chortarea, B. Rothen-Rutishauser, A. Fink

ERC Grantees Conference, Berlin, Germany, August 28, 2014

Invited Lecture, "Mechanically (And Other) Responsive Polymers", C. Weder

University of Geneva Pharmaceutical Department Doctoral School Summer School, Zermatt Switzerland, September 2014

Invited Lecture, "Imaging the nanoparticle-cell interaction: providing an imperative insight into determining their hazard potential", M.J.D. Clift

Swiss-Chinese SSSTC Workshop on Bio-inspired Materials, Zurich, Switzerland, September 1–2, 2014

Invited Talk, "Mechanosensory pathways: inspiration for polymer chemists", Y.C. Simon

Invited Talk, "Proteins and enzymes as functional entities in bio-inspired polymers and materials", N. Bruns

2nd Biomimicry Europe Innovation and Finance Summit, Zurich, Switzerland, September 4, 2014

Plenary Lecture, C. Weder

ECIS, Limassol, Cyprus, September 9, 2014

Oral Presentation, "Preparation, Functionalization and Self-Assembly of Janus Dumbbell Nanoparticles", M. Lattuada

E-MRS Fall Meeting, Warsaw, Poland, September 15–18, 2014

Invited presentation, "Smart vesicles for drug delivery - design, characterization and application", C.A. Monnier, A. Fink

8th ECNP conference, Dresden, Germany, 17–19 September 2014

Oral presentation, "Towards low complexity in the design of mechanically robust phase-segregated supramolecular polymers", L. Montero

ICPAM 10, Alexandru Ioan Cuza University of Iasi, Iasi, Rumania, September 22–28, 2014

Lecture, "Bio-inspired composite materials obtained by magnetically-driven nano-particles self-assembly", M. Lattuada

Oral Presentation, "Janus Nanoparticles and Nanobowls Synthesis", F. Guignard, M. Lattuada

Oral Presentation, "Preparation of novel composite materials via co-Coagulation of NPs", S. Rima, M. Lattuada

Oral Presentation, "Influence of the Potential Barrier on the Breakage of Colloidal Aggregates under External Shear", Z. Ren, M. Lattuada

125th Jubilee of the University of Fribourg, Fribourg, Switzerland, September 28, 2014,

Plenary Lecture, "Reise ins Herz der Materie", C. Weder

Swiss Soft Days, 15th Edition, Ecole Polytechnique Fédérale Lausanne, Switzerland, October 2, 2014

Talk, "Structured Device Materials By Polymer Self Assembly", U. Steiner

Lung Cell Biology, Imperial College, London, UK, October 2, 2014

Invited Talk, "Nanoparticles and lung cells – from risk assessment to biomedical applications", B. Rothen-Rutishauser

Horizon 2020 Workshop "Towards NMP19 and NMP22", Munich, Germany, October 13, 2014

Invited Talk, "Self-reporting Fiber-reinforced Composites", N. Bruns

1st Homeric Fall School, Aérocampus, Latresne, France, October 13–16, 2014

Invited Talk, "Function by structure: Self-assembled solar cells", U. Steiner

University of Bern, Bern, Switzerland, October 17, 2014

Lecture, "Cutting edge microscopy lecture series: Laser scanning microscopy", B. Rothen-Rutishauser

Apéro of the Alumni of the University of Fribourg, St Gallen, Switzerland, October 23, 2014;

Plenary Lecture, "Reise ins Herz der Materie", C. Weder

International Symposium on Stimuli-Responsive Materials, Santa Rosa, CA, USA, October 27, 2014

Plenary Lecture, "Stimuli-Responsive Hydrogen-Bonded Supramolecular Polymers", C. Weder

Gymnasium Muttenz, Basel, Switzerland, October 31, 2014

Invited Lecture, "Nanotechnologie: Chancen und Risiken", D. Kuhn, B. Rothen-Rutishauser, A. Fink

IUF-Leibniz Research Institute Seminar, Dusseldorf, Germany, November 2014

Invited Talk, "Studying the fibre-cell interaction in vitro", M.J.D. Clift

University of Bern, Bern, Switzerland, November 21, 2014

Lecture, "Cutting edge microscopy lecture series: Basic introduction in electron microscopy", D. Vanhecke

AICHE Annual meeting, Atlanta, GA, USA, November 16-21, 2014

Oral Presentation, "Retarded Hydrodynamic Properties of Fractal Clusters," M. Lattuada

Oral Presentation, "Preparation, Characterization and Properties of Janus Magnetic Liposomes", M. Lattuada

Oral Presentation, "Janus Nanoparticles As Template for Silica Nanobowls Synthesis", F. Guignard, M. Lattuada

Oral Presentation, "Self-Assembly of Magnetic Janus Nanodumbbells", F. Guignard, M. Lattuada

Oral Presentation, "Preparation of Novel Composite Materials Via CO-Coagulation of Nanoparticles", S. Rima, M. Lattuada

Oral Presentation, "Worm-like Micelles of Polymerizable Surfactant As a Template for Polymerization", S. Rima, M. Lattuada

Oral Presentation, "Influence of the Potential Barrier on the Breakage of Colloidal Aggregates under External Shear", Z. Ren, M. Lattuada

Swiss Society of Industrial Pharmacists (GSIA) / Swiss Process and Chemical Engineers (SGVC) Educational Course "Nanotechnology", Basel, Switzerland, November 20, 2014

Invited Talk, "Application of Proteins Cages and Polymersomes as Nanoreactors", N. Bruns

Invited Talk, "Creation and Application of Novel Nanocarriers for Vaccination and Drug Delivery Application", B. Rothen-Rutishauser

University at Buffalo, Amherst, NY, USA, November 24, 2014

Invited Talk, "Stimulating polymer chemistry" Y.C. Simon

BIOCOMBUST, Universität Freiburg, Freiburg, Germany, November 26, 2014

Invited Talk, "Feinstaub und Lunge - Klinische Aspekte und Aktuelles aus der Forschung", B. Rothen-Rutishauser

Adolphe Merkle Institute open-door day, Fribourg, Switzerland, November 29, 2014_

Talk, "Leben im Zeitalter des Plastiks: Sind kompostierbare Kunststoffe und biologische Katalysatoren die Lösung aller Umwelt-Probleme?", N. Bruns

Talk, "Auto-assemblage des nanoparticules: du fromage aux matériaux complexes inspirés de la nature", M. Lattuada

Talk, "Chancen und Risiken von Nanomaterialien/Opportunités et risques des nano-matériaux", B. Rothen-Rutishauser

Talk, "Applications médicales des nanoparticules", A. Fink

Talk, "Biomimetische Materialwissenschaft: Lernen von Natur", U. Steiner

Talk, "Intelligente Materialen", C. Weder

CBMN, University of Bordeaux, Bordeaux, France, December 2014

Invited Talk, "Colloidal engineering: Controlled nanoparticles synthesis, surface functionailzation and design of hybrid materials", J.-F. Dechezelles

Macro Group Medals Meeting, SCI, London, UK, December 16, 2014

Invited Talk, "Function through structure", U. Steiner

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Page 37: F. Guignard, composition-anisotropic nanoparticles made of polystyrene and polylactic acid

Page 41: S. Rima, β-lactoglobulin amyloid fibrils

Page 47: F. Guignard, Janus dumbbell-shaped nanoparticles selectively heteroaggregated with superparamagnetic iron oxide nanoparticles

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