ANNUAL REPORT 2013

adolphe merkle institute
excellence in pure and applied nanoscience

UNIVERSITY
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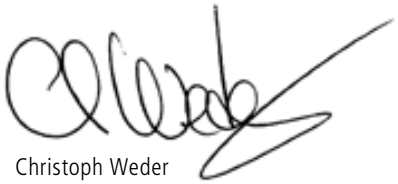
Message from the director

Christoph Weder
Director and Professor for Polymer Chemistry and Materials

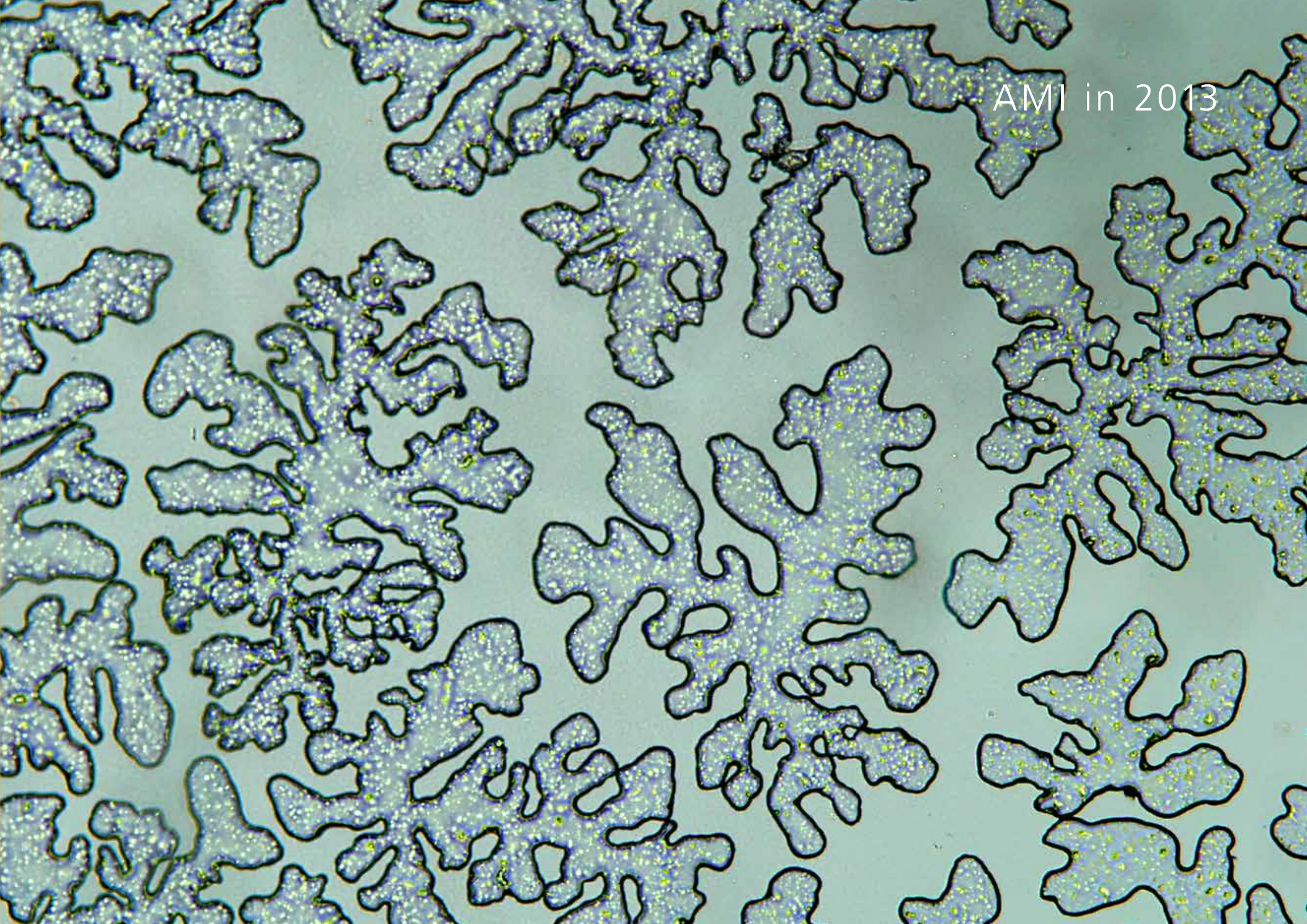
Last year, I wrote on this occasion that the development of biologically inspired nanomaterials and the study of the interactions of such materials with biological systems have emerged as research areas in which all of AMI's research groups share a common interest. In these domains, sustained interdisciplinary collaborations between several research teams with complementary competences are not a luxury, but a requirement for success. I am thus absolutely delighted that the Swiss government has decided to fund a new National Competence Center for Research (NCCR) on Bio-Inspired Stimuli Responsive Materials at the University of Fribourg. The center, which was planned and is now led by a team incorporating all of AMI's chairs, will provide long-term support for initially approximately forty researchers in fourteen groups at AMI and the University of Fribourg's departments of chemistry, medicine, and physics as well as leading research groups at the University of Geneva, the Swiss Federal Institute of Technology Zurich, and the Swiss Federal Institute of Technology Lausanne. Naturally, we are proud of having succeeded in such a rigorous and competitive selection process and we view this success as an endorsement of AMI's philosophy, vision, and track record. More importantly, the new NCCR for Bio-Inspired Stimuli Responsive Materials will be a unique opportunity to establish and sustain cutting-edge research programs that effectively integrate AMI's competences and activities in materials science and life sciences with those of other leading research groups in other parts of the University of Fribourg and around the country. It provides a basis for long-lasting collaborations on topics of strategic national importance and supports many creative initiatives for education, the promotion of women and young researchers, knowledge transfer, and interactions with industry. We are honored to have been given the responsibility of establishing the new center and will work hard to position Switzerland as an internationally recognized hub for research and innovation in this important research domain.

As you will read in this Annual Report, we are also driving future success at AMI on many other fronts. We completed our search for a chair in soft matter physics, and I am thrilled that Prof. Ullrich Steiner, who currently serves as the John Humphrey Plummer Professor of Physics of Materials at the University of Cambridge, will join our institute this Summer. We also welcomed Prof. Nico Bruns to our team, who has chosen AMI as a host institute to establish a junior research group for Macromolecular Chemistry. We advanced the planning for a new Master's Program anchored at AMI, which we plan to launch in 2015, and we initiated several other educational initiatives, such as an interdisciplinary lecture series for our PhD students and, together with partners, founded an innovation club that caters to students from all over town. Last but not least, we formalized partnerships with several research institutions in Asia and the USA to provide many of our students with meaningful international experiences. The locals among you will have noticed that our new building is continuing to take shape and our move-in date this Fall is on the horizon. I take this opportunity to invite you to our long-awaited Open Day in November 2014.

While we continued to shape the institute's bright future, we didn't forget our primary mission: to execute research worthy of the byline "excellence in pure and applied nanoscience". I invite you to read the research section of this report, which highlights recent work on enzyme-catalyzed polymerization reactions, anisotropic gold nanoparticles for applications in nanomedicine, new concepts for healable polymers, certain properties of heterogeneous nanoparticles, and the synthesis of asymmetrically functionalized polymeric dumbbells. We continued to collaborate with industry partners and also launched new collaborations, including a project with regenHu, which targets the creation of living cell assemblies for *in vitro* testing by 3D-printing. At AMI, we strive to fulfill Adolphe Merkle's vision of becoming a leading competence center for fundamental and applied interdisciplinary research in the field of soft nanomaterials. We are grateful for your interest and support, which has been a key factor in driving our success. We will continue to foster sustainable partnerships and make valuable contributions to science.



Christoph Weder
Director and Professor for Polymer Chemistry and Materials

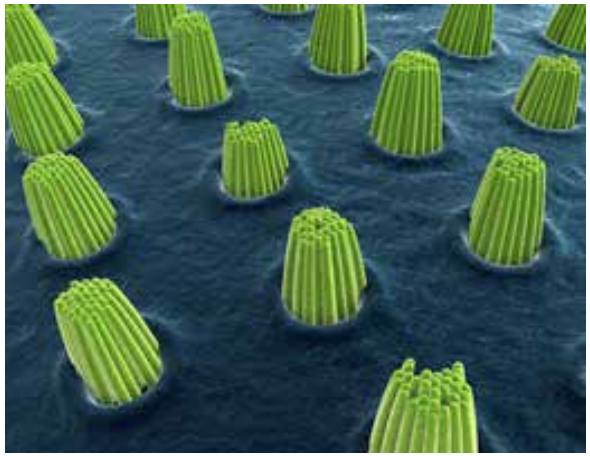

AMI in 2013

AMI in 2013

After considerable growth since its foundation in 2008, AMI attained a developmental equilibrium in 2013, reflected by expenditures, as well as the number of researchers and scientific studies published. Several developments were of considerable strategic importance and will have a significant impact on the further advancement and activities of the institute. These include the award of a National Center of Competence in Research, the hiring of SNF Professor Nico Bruns and his team of macromolecular chemists, and the appointment of University of Cambridge Professor, Ullrich Steiner, as AMI's chair for soft matter physics.

National Center of Competence in Research awarded

AMI researchers have played a major role in making the University of Fribourg the home of a new National Center of Competence in Research (NCCR) focused on smart materials inspired by nature. The center will receive a total of 12 Mio CHF in federal funding over an initial four-year operating period and is poised to grow into an international hub for research, education, and innovation in one of the most promising research domains of materials science. NCCRs generally receive federal funding over a period of 12 years. The overarching research theme of the new NCCR draws inspiration from nature in order to design artificial materials which can change their properties "on command". Such materials, sometimes referred to as "smart" or "intelligent" materials, are of fundamental scientific interest and show a lot of promise for countless applications, ranging from climate control elements for buildings to drug delivery systems. Led by AMI director Christoph Weder, the national competence center will unite over forty researchers in fourteen research groups based at AMI and in the University of Fribourg's departments of chemistry, medicine, and physics, as well as in leading research groups at the University of Geneva, the Swiss Federal Institute of Technology Zurich and the Swiss Federal Institute of Technology Lausanne.



An example of a biological system which serves as an inspiration for the stimuli-responsive materials to be studied at the Center: Hair bundles in the inner ear that transduce mechanical motion into electrical signals.

Macromolecular Chemistry Group established at AMI

Nico Bruns became the second SNF professor to join AMI's ranks in October 2013. He brought with him an international team of scientists and established an independent research group in the field of Macromolecular Chemistry. Professor Bruns graduated from the Albert-Ludwigs University in Freiburg (Germany) with diploma and doctorate degrees in Chemistry and subsequently pursued post-doctoral research at the University of California in Berkeley (USA). He then spent over four years in the Chemistry Department at the University of Basel, where he established an independent research group. His research group at AMI, which consists of scientists from Poland, France, Hungary, and Germany, investigates the following key areas: enzyme-catalyzed controlled/living radical polymerization (ATRPases), protein cages and polymersomes as nanoreactors and polymer-protein hybrid materials with the capability to self-report damage.

Professor Ullrich Steiner to join AMI as the third chair

In 2013, the third chair at the Adolphe Merkle Institute was filled with the hire of Professor Ullrich Steiner from the University of Cambridge.

As the Humphrey Plummer Professor of Physics of Materials at Cambridge, Professor Steiner headed research in Thin Films and Interfaces at the renowned Cavendish Laboratory. He has led a wide range of projects in this field, from the development of "rubbery mirrors", or distributed bragg reflector membranes, which change color across the full visible spectrum upon deformation, to the replication of the structure of a gecko's foot to create adhesion on polymeric microstructures. Numbering among Professor Steiner's accolades is the highly prestigious Raymond and Beverly Sackler Prize, awarded in 2002 for his contributions to the field of Physical Sciences. Prof. Steiner and his team will commence tenure at AMI this year upon completion of the new research facility.

Planning ahead, AMI has already launched the search for a fourth chair, scheduled to join the institute in 2015.

Construction of new research building enters final stage

Once a hospital and now under construction to serve as AMI's future home on the campus of the University of Fribourg, the former "Clinic Garcia" provides a unique environment for the growing institute. Juxtaposed with the state-of-the-art infrastructure to be housed in a new laboratory complex are the original building foundations and outer wooden facades of the clinic. The official opening ceremony is set to take place in November 2014.

AMI's future home: the former "Clinic Garcia" in Fribourg.

Continued investment in educational programs

The AMI Seminar Series provides AMI researchers with additional opportunities to exchange with local and international scientists. Since its inception, the seminar program has included experts in fields such as soft matter self-assembly, advanced material design and nanoMRI. AMI scientists have the opportunity to nominate speakers – an approach which has proven to be a successful method of ensuring intense discussion and energetic exchange on themes relevant to research at AMI. Another initiative was the launch of a new lecture series in the Spring and Fall semesters, consisting of multidisciplinary lectures on soft (nano)materials. The lectures were held by AMI professors and group leaders and were open to all AMI members as well as to interested students from other units of the Faculty of Science. The aim of the initiative is to foster a fundamental understanding between people of different backgrounds and provide the basis for interdisciplinary discussions. In 2013, the series touched on a wide range of topics, including toxicology, the fundamental functioning of a cell, the basics of polymer science, soft matter scattering techniques and technology transfer.

Laboratory facilities at Garcia under construction.

After receiving the assignment from the Rector's office of the University of Fribourg, the AMI team began to plan a new specialized master's program. The interdisciplinary master is focused on soft-matter and biomaterials and envisaged to start in 2015.

Highlights

Recognition for AMI researchers

In 2013, scientists across all research areas and levels of the institute were recognized for significant contributions to their field. Among the younger members of the AMI team to be recognized were Sandro Steiner and Anthony Redjem. Sandro Steiner was named the 2013 Concawe Young Researcher and Anthony Redjem won the first prize from Venture Ideas, Fribourg, for his innovative approach to reducing toxic emissions.

PhD students, Mehdi Jorfi and Fabian Herzog, were awarded SNSF Early Postdoctoral Mobility Fellowships in October. In addition, Mehdi is the recipient of an SCNAT/SCS Chemistry Travel Award. AMI scientist, Dr. Laura Rodriguez-Lorenzo was awarded the L'Oréal Fellowship for Women in Science. The Fellowship recognizes outstanding contributions made by female scientists to scientific progress. Laura's project, which investigates biomarkers in biological samples using surface-enhanced Raman scattering (SERS)-based imaging, will be funded with a grant of 80'000 CHF for one year.

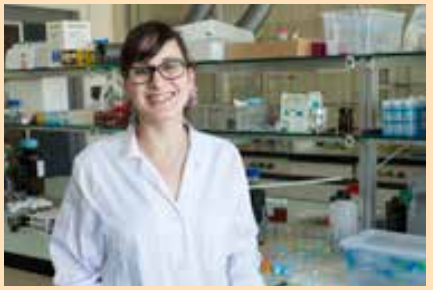
Dr. Csaba Fodor joined AMI's newly founded Macromolecular Chemistry group in October after being awarded a place in the Scientific Exchange Programme (SciEx). His arrival from the Hungarian Academy of Sciences, Budapest, signals the beginning of a close partnership between AMI and Professor Bela Ivan's research group at the Academy's Institute of Materials and Environmental Chemistry.

Also in 2013, Professor Barbara Rothen-Rutishauser received the 2nd prize from the Ypsomed Innovation Fund for Research and Development. This Innovation Award includes a grant of CHF 20'000. The prize recognizes Professor Rothen-Rutishauser's work on a new bio-printing platform to engineer 3D lung tissue of the air-blood barrier. The three-dimensional cell models developed in the laboratory can be used to assess the impact of inhalation of nanoparticles on lung tissue. The award-winning work was initiated by a collaboration with Swiss start-up regenHU, financially supported by the Innovation Fund Fribourg, in order to produce a 3D print-out of lung tissue with a bio-printer. In October, Professor Rothen-Rutishauser was awarded a prestigious grant by the Research Fund of the Swiss Lung Association, Berne, to further develop this technology.

High impact research

In 2013, Chimia published a highlight by AMI scientists, SNF Professor, Marco Lattuada, and PhD student, Florian Guignard. The article, entitled, "Asymmetrically Functionalized Polymeric Dumbbells", investigates polymeric monodisperse nanoparticles which are anisotropic in both shape and functionality.

An article published in ACS Macro Letters, written by AMI's Polymer Chemistry & Materials Group, was one of the top 5 most-downloaded articles over several months and ranked as the most cited article published by the journal last year. The paper presented findings on light-healable supramolecular nanocomposites based on modified cellulose nanocrystals.



Dr. Laura Rodriguez-Lorenzo, winner of the L'Oréal Fellowship for Women in Science, in the laboratory at AMI.

AMI Director, Professor Christoph Weder, giving a presentation at the 48th EUCHEM conference on stereochemistry, otherwise known as the "Bürgenstock Conference".

Professor Rothen-Rutishauser with two members of the jury at the PriceWaterhouseCoopers New Year Apéro in Bern, Switzerland. On the right, Hanspeter Gerber, director of PwC Bern, and on the left, Prof. Dr. Peter Mürner, member of the Ypsomed foundation board.

Edition of Nanoscale featuring research by AMI's BioNanomaterials Group on the cover.

Featured the cover of Nanoscale in May was a project carried out by the BioNanomaterials Group, entitled, "Surface charge of polymer coated SPIONs influences the serum protein adsorption, colloidal stability and subsequent cell interaction *in vitro*". In this paper, AMI researchers demonstrated how nanoparticle-protein interactions may relate to the particular physicochemical characteristics of nanoparticles in a biological fluid, and how these parameters could significantly influence the subsequent nanoparticle-cell interaction *in vitro*. The project involved collaboration with scientists at EPFL.

National and international press coverage

The joint chair for BioNanomaterials at AMI continued to attract attention in 2013 and was featured in Der Bund. The article highlighted how this unique job-sharing concept enables Professors Alke Fink and Barbara Rothen-Rutishauser to merge their expertise in materials science and biology, respectively.

The institute's bio-inspired research strategy was featured in an October issue of Bilan. The coverage highlighted several examples of bio-inspiration at AMI, including polymers inspired by sea cucumbers which can change their mechanical properties upon introduction of a stimulus, ccellulose and silica particles which self-assemble into cartilage-like structures, and liposome cages which can release drug molecules on command.

Professor Barbara Rothen-Rutishauser's success as the recipient of an Ypsomed Innovation Award and her subsequent collaboration with bio-printer producers, regenHu, stimulated significant press coverage. The ground-breaking research was documented in 20Minuten and Swiss research magazine, Horizonte.

Professor Alke Fink and her team collaborated with scientists at ETH Lausanne and the University Hospital of Geneva to devise a method for the controlled release of an active agent on the basis of a magnetic nanovehicle. The research, conducted as part of the National Research Programme "Smart Materials" (NRP 62), was covered in Swiss publications such as Interpharma, La Liberté and 20Minuten, as well as by Radio Canada and Austrian online newspaper, derstandard.at.

Government interest in materials science

Representatives of the governing bodies of the cantons of Schaffhausen and Fribourg visited AMI on October 2. AMI scientists gave interactive demonstrations of their work, as well as guided tours of the laboratories. Consuls and honorary consuls from Zurich were received at AMI on October 18 and shown around the institute. The external interest from local governments reflects Fribourg's growing reputation as a hub for cutting-edge research in the field of new materials.

RESEARCH PROGRAMS

FOUR UNIFYING MATERIALS DESIGN STRATEGIES

AMI's research activities continue to revolve around the development of soft nanomaterials with novel functions, the investigation of the interactions of these materials with biological systems, and the exploration of their use in life-science applications. While the research initiatives involve a broad array of material types and pursue a wide range of possible applications, many of the projects rely on some - if not all - of four fundamental concepts that are applied across AMI's five research groups.

Many of AMI's current projects seek *inspiration from nature.* For instance, the hierarchical structures found in naturally occurring structural materials, such as wood or cartilage, have inspired the design of colloidal assemblies with anisotropic properties and new polymer nanocomposites with property gradients. The specific architectures that enable unusual functions in nature, such as the mechanical morphing of sea cucumbers or the color-changing capabilities of octopuses, serve as blueprints for artificial materials that mimic these tricks. The fundamental chemical principles at play in mechanochemical transduction found in nature are used as a starting point for the design of artificial materials that respond to mechanical stresses in a desirable manner.

The *precision synthesis* of well-defined model or multifunctional nanoparticles and their thorough characterization are only the first steps in advancing the predictive understanding of how nanoparticles can be utilized for specific applications, such as drug delivery and early diagnostics. The next generation of functional nanoparticles is being developed at AMI through a range of projects utilizing original materials, such as magnetically responsive or shape altering nanoparticles, whereby a triggered change in the shape results in the desired biological impact. Similarly, it is essential to prepare polymers with well-defined molecular architectures, in order to tailor the properties of polymeric (nano) materials and to establish meaningful structure-property relationships. AMI researchers develop and use a variety of methods that allow the synthesis of precision polymers. This includes polymerizations in nanoreactors, controlled/living radical polymerizations catalyzed by enzymes, and polymer-analogous reactions. These efforts, and many others, leverage the unique and state-of-the-art array of instruments at the institute, along with the highly international and multidisciplinary team, to deliver novel results.

Recognizing that *processing* can have a significant influence on the final structure and therefore the properties of nanomaterials, AMI researchers develop and use highly specific processing protocols that reproducibly afford the desired architectures. For example, AMI researchers have recently introduced a new routine that minimizes drying artifacts when preparing nanoparticle samples for electron microscopy. AMI scientists also pursue the development of methods to control the dispersion of nanofibers in polymer nanocomposites and to direct the assembly of nanoparticles by application of magnetic or electrical fields.

Finally, *non-covalent interactions* play an exceedingly important role in virtually all of AMI's projects. Non-covalent interactions exert a dominant influence on the colloidal stability of nanoparticle dispersions and govern the behavior of the nanoparticles towards anything that is brought in contact with them. AMI scientists study such interactions and apply the acquired knowledge to obtain stringent control over nanoparticle surfaces, which in turn impacts on their colloidal behavior and fate, for example in biomedical applications or in the context of particle assembly. Due to their dynamic, stimuli-responsive nature, non-covalent interactions also represent a versatile design element for the creation of "smart" polymers, which change (some of) their properties in a selective, predictable, and useful manner when exposed to a specific stimulus. AMI researchers utilize hydrogen-bonds, π-π interactions, and metal-ligand binding to assemble small molecules, supramolecular polymers, and nanoparticles to create polymeric materials which can be, for example, mechanochromic, mechanically adaptive and healable.

In 2013, AMI's major research initiatives were:

- The investigation of fundamental parameters that govern nanoparticle-cell interactions
- The study of colloidal nanoparticles in complex biological environments and their impact on *in vitro* cell culture assays
- The creation and use of novel nanocarriers for vaccination and drug-delivery applications
- The development of biocidal nanoparticles for wood preservation applications
- The development of sophisticated *in vitro* models for reliable high-throughput risk assessment of nanomaterials
- The determination of potential health risks associated with the inhalation of specific nanomaterials, including diesel exhaust, silver nanoparticles, and nanocellulose
- The creation of anisotropic nanoparticles
- The simulation and experimental investigation of anisotropic materials through nanoparticle (self)assembly
- The creation of polymeric nanocomposites through co-assembly of polymers and inorganic nanoparticles
- The investigation of novel mechanically adaptive materials
- The exploration of new mechanochemical transduction processes in polymeric materials
- The development of healable polymers and materials that enable bonding and debonding on demand
- The use of cellulose nanocrystals as a basis for bio-based nanocomposites, aerogels, and delivery systems
- The investigation of metal-containing polymers with unusual optical properties
- The study of relationships between nanostructure and macroscopic properties of ion-containing polymers
- The investigation of enzyme-catalyzed controlled/living radical polymerization reactions
- The use of protein cages and polymersomes as nanoreactors
- The development of polymer-protein hybrids materials as mechanical sensing elements

ATRPASES: GREEN POLYMERIZATION MADE POSSIBLE USING NOVEL BIOCATALYSTS

Synthetic macromolecules play a central role as advanced materials in nanostructures, biomedical devices and in energy materials. Enzymes are prime examples of environmentally friendly, non-toxic reagents for the synthesis of macromolecules. They can often catalyze reactions that are different from their native ones, a phenomenon which is referred to as "enzyme promiscuity". The heme proteins, horseradish peroxidase and hemoglobin, exhibit such promiscuity and catalyze atom transfer radical polymerization (ATRP). Biocatalytic ATRP holds great promise as a green chemistry strategy for the synthesis of polymers.

The synthesis of polymers for their use in nanostructures has been revolutionized by the introduction of controlled/living radical polymerizations. These kinds of polymerization reactions enable the synthesis of well-defined polymers with complex molecular architecture, while tolerating most functional groups. Moreover, radical polymerizations can be carried out in many solvents, ranging from water to non-polar organic solvents. The most popular controlled/living radical polymerization is referred to as atom transfer radical polymerization (ATRP), as it involves the transfer of halogen atoms between a transition metal catalyst and growing polymer chains. The catalysts required for ATRP, however, represent a drawback, since they can be toxic and environmentally problematic. Moreover, they are difficult to remove from the polymers and can consequently inhibit the application of the products as nano-sized drug carriers or biomaterials, and can render the polymers unsuitable for use in electronic materials.

A green chemistry approach to catalysis involves using enzymes for numerous reasons: enzymes are derived from renewable resources, function under very mild reaction conditions (i.e. in water and at room temperature) and often possess high catalytic efficiency and selectivity. Enzymes catalyze many polymerization reactions in nature, including polycondensations and radical polymerizations. The synthetic power of enzymes has also been extensively investigated for the preparation of synthetic macromolecules. However, until recently, it was not known that naturally occurring catalysts would be able to mediate controlled/living polymerizations.

Recently, the Macromolecular Chemistry group at AMI discovered that some metal-containing enzymes are indeed able to catalyze ATRP reactions. The heme proteins horseradish peroxidase and hemoglobin are enzymes which can initiate and control the polymerizations of acrylate-monomers. This novel function of these promiscuous proteins has been termed "ATRPase activity". Interestingly, in addition to such purified proteins, red blood cells can also be used to catalyze ATRP. As they are inexpensive byproducts of meat production, they are available in large quantities.

The resulting polymerizations exhibit all characteristics of a typical ATRP reaction. For example, the polymers carry a bromine atom at their chain end, which is a clear indication that the reaction mechanism involves halogen atom transfer between the initiator, the biocatalyst and the polymer.

Current work at AMI focuses on expanding the scope of biocatalytic ATRP to other monomers. Moreover, the reaction mechanism is being investigated in great detail in order to ascertain fundamental knowledge of the novel enzymatic activity. The goal is to determine and to understand the parameters that enable improvement of the catalytic performance of the enzymes. With this in mind, ATRPases could become green, non-toxic alternatives to traditional ATRP catalysts for the synthesis of macromolecules for nano-applications.

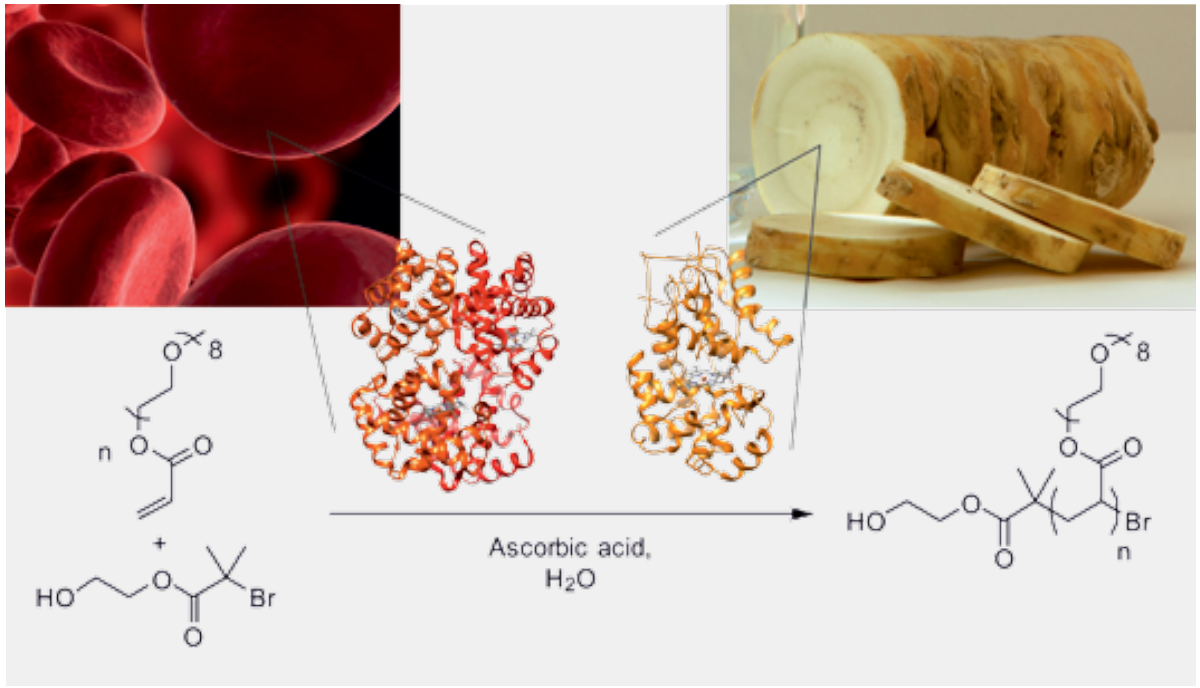


Figure 1: Schematic representation of an ATRP reaction catalyzed by the heme proteins hemoglobin and horseradish peroxidase.

References:

[1] Sigg SJ, Seidi F, Renggli K, Silva TB, Kali G, Bruns N. Horseradish Peroxidase as a Catalyst for Atom Transfer Radical Polymerization. Macromol Rapid Commun. 32(21):1710–5 (2011).

[2] Silva TB, Spulber M, Kocik MK, Seidi F, Charan H, Rother M, et al. Hemoglobin and Red Blood Cells Catalyze Atom Transfer Radical Polymerization. Biomacromolecules. 2013/08/12;14(8):2703–12 (2013).

[3] Kali G, Silva TB, Sigg SJ, Seidi F, Renggli K, Bruns N. ATRPases: Using Nature's Catalysts in Atom Transfer Radical Polymerizations. Progress in Controlled Radical Polymerization: Mechanisms and Techniques, ACS Symposium Series. ACS Symposium Series. 1100: American Chemical Society; p. 171–81 (2012).

[4] Renggli K, Spulber M, Pollard J, Rother M, Bruns N. Biocatalytic ATRP: Controlled Radical Polymerizations Mediated by Enzymes. ACS Symp Ser. (2013).

Contact: Prof. N. Bruns

GOLD: MORE THAN JUST JEWELRY

One of the best investigated nanosystems to date is gold. In the Bakerien Lecture of 1857, Michael Faraday described the experimental relations of gold to light [1], thereby initiating thousands of studies on colloidal gold. Gold nanoparticles are applied more and more often in nanomedicine and biotechnology due to their ease of fabrication, their fascinating size-dependent properties, their favorable surface chemistries and their biocompatibility .

While initial efforts were devoted to spherical gold, gold nanorods have been increasingly investigated over the past decade, as their anisotropy has stimulated extensive application-oriented research in the therapeutic and diagnostic field. As in the case of most nanoparticles, gold nanorods are rarely used in the state in which they are synthesized, but are generally surface functionalized. The ability to properly functionalize the nanorod surface significantly impacts the chances of success of many envisaged applications. AMI scientists have recently shown that in extreme cases, the stabilizing ligand present on the surface of gold nanorods solely dictates their toxicity and pro-inflammatory nature [2]. Complete detoxification of the gold nanorods was successfully accomplished in a recent complete and systematic study concentrating on the problem of surface ligand-exchange.

In addition to spheres and rods, gold nanoparticles can exist in many different forms, such as nanostars, nanohexapods, and nanocages. Current investigations focus on the role of shape in nanoparticle-cell interaction and the use of such highly anisotropic nanoparticles for the design of ultrasensitive biosensors.

In order to harness the unique properties of gold nanoparticles for novel clinical applications, precise knowledge of their interaction with cells is mandatory. The detection of these small particles at the single cell level requires cutting-edge techniques for visualization and quantification, which tend to be based on spectroscopy techniques or microscopy. Transmission electron microscopy is the method of choice for imaging the electron-dense gold nanoparticles at the highest resolution in subcellular structures. By combining this imaging technique with stereological approaches, it has been shown that the majority of the gold nanoparticles are localized in vesicular structures (Figure 2A), hinting to an active uptake, whereas no particles have been found in other compartments, such as the cell nucleus or mitochondria [3]. However, this method is rather labor-intensive. For this reason, the encoding of the particles with a fluorophore to enable their detection by fluorescence imaging techniques, such as laser scanning microscopy, has been offered as an attractive detection alternative (Figure 2B). This method also enables life-cell imaging, which indicated that the gold nanoparticles were taken up by cells within minutes [4]. Nevertheless, light microscopy is limited in its spatial resolution and individual nanoparticles cannot be resolved, therefore the combination of different techniques is crucial in order to gain a comprehensive understanding [5]. Gold nanomaterials possess huge potential for biomedical applications, not only because they can be manipulated by material engineers at the atomic level but also due to their fantastic properties. Additional fundamental studies are necessary to investigate the influence of size, shape and surface modification on the material properties, as well as on their interaction with living matter.

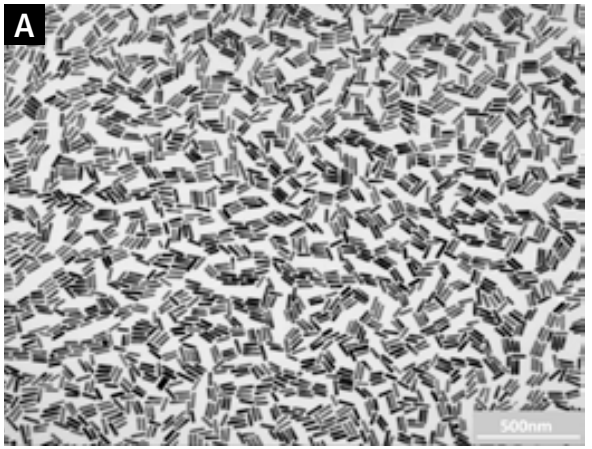


Figure 1A: Transmission electron micrograph of gold nanorods.

Figure 1B: Frontispiece, Angewandte Chemie.

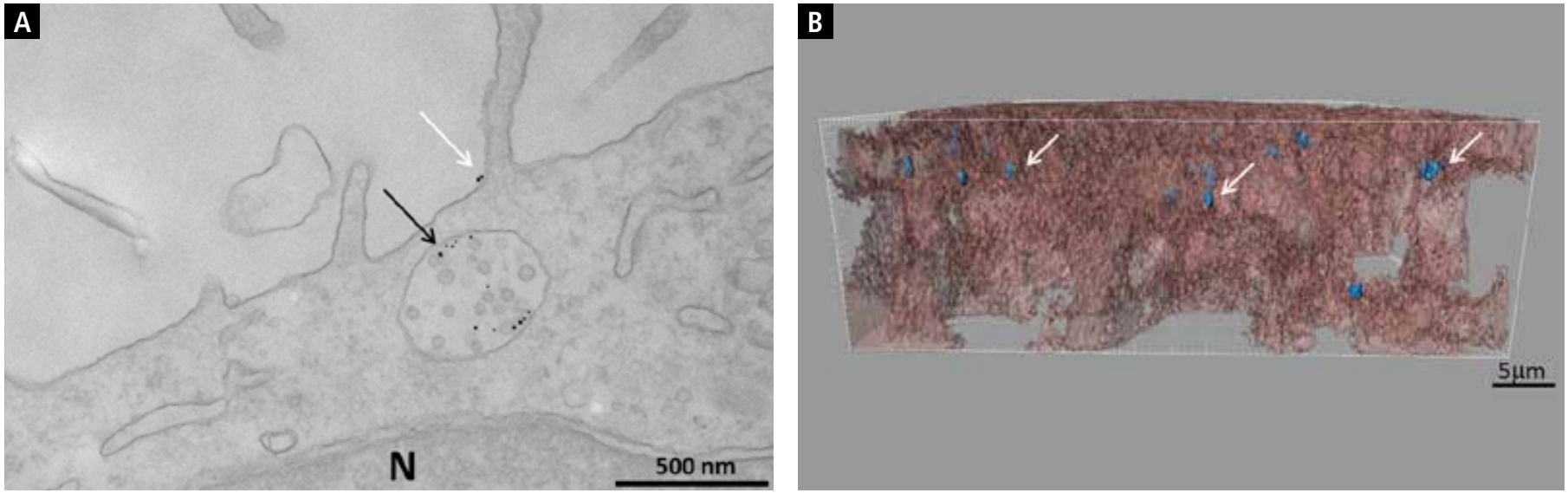


Figure 2: Visualization of fluorescently labeled polymer-coated gold nanoparticles interacting with epithelial cells.
(A) Transmission electron microscopy revealed gold nanoparticles that are outside the cell attached to the cell membrane (white arrow) as well as intracellularly in vesicles (black arrow). N: Nuclei.
(B) The fluorescence signal of the gold particles (blue) was detected by laser scanning microscopy. The F-Actin cytoskeleton of the epithelial cells is shown in red (transparent) and intracellular nanoparticles (white arrows) can nicely be demonstrated in the 3D rendering mode.

References:

[1] Faraday, M. The Bakerian Lecture: Experimental Relations of Gold (and Other Metals) to Light, 1857.
[2] C. Kinnear, H. Dietsch H, M.J.D. Clift, C. Endes, B. Rothen-Rutishauser, A. Petri-Fink A. Gold Nanorods – Controlling their Surface Chemistry and Complete Detoxification by a Two-Step Place Exchange, Angew Chem Int Ed, 52 (2013) 1934. The paper was selected to be highlighted in the frontispiece section of Angewandte Chemie. The paper was selected for a highlight in Chimia (issue 4, 2013).
[3] Brandenberger Ch, Mühlfeld Ch, Zulqurnain A, Lenz AG, Schmit O, Parak WJ, Gehr P, Rothen-Rutishauser B. Quantitative evaluation of cellular uptake and trafficking of gold nanoparticles with different surface coatings. Small, 6(15): 1669–78 (2010).
[4] Lehmann AD, Parak WJ, Zhang F, Zulqurnain A, Röcker C, Nienhaus GU, Gehr P, Rothen-Rutishauser B. Fluorescent-magnetic hybrid nanoparticles induce a dose-dependent increase of the pro-inflammatory response in lung cells in vitro correlated with intracellular localization. Small 6(6):753–62 (2010).
[5] Rothen-Ruthishauser B, Kuhn DA, Zulqurnain A, Gasser M, Faheem A, Parak WJ, Vanhecke D, Fink A, Gehr P, Brandenberger Ch. Quantification of gold nanoparticle cell uptake under controlled biological conditions and adequate resolution. Nanomedicine (2013).

Contact: Prof. B. Rothen-Rutishauser & Prof. A. Fink

A STRATEGY TO PREPARE ANISOTROPIC POLYMER NANOPARTICLES

Nanoparticles are one of the most promising materials platforms developed in recent years. Their potential range of application is vast, spanning fields such as biomedicine, material science, electronics and catalysis, just to name a few. A basic requirement for all these applications is that nanoparticle size and shape can be well controlled. However, creating polymer particles with a non-spherical shape and non-homogeneous functionality is challenging. The scope of research conducted by AMI's self-assembly group is to develop a flexible platform to create mondisperse polymeric nanoparticles which display anisotropy in both shape and functionality.

The prototype of a polymer nanoparticle is a homogeneous and isotropic sphere. While this is certainly the most common morphology, it is not necessarily the most useful if particles are to be used as building-blocks for the construction of structures via self-assembly. A comparison with molecules or proteins suggests that anisotropy and the possibility to create well-defined directional bonds are key nanoparticle features, in order for them to self-assemble into complex structures. However, considerable challenges are faced when preparing such particles. This research addresses these challenges, focusing on synthesizing well-defined and asymmetric polymer nanoparticles. The synthetic procedure involves several steps. A great advantage is that researchers begin with the most common type of existing polymer particles: polystyrene colloids. Polystyrene nanoparticles can be prepared in a very broad range of sizes and in large amounts, while maintaining excellent control over their size distribution.

The first step of the preparation procedure causes a swelling of the particles using a mixture of styrene, initiator and an acrylate monomer bearing a silane moiety. The hydrophilicity of this monomer leads to its accumulation on the surface of the particles upon polymerization. The particle surface is rendered vitreous by the silane groups. The second step of the process involves additional swelling using more monomer. The polymerization process leads to a phase separation within the particle due to its vitreous surface, and to the formation of a second lobe, resulting in a dumbbell structure. By varying the amount of monomer added, the morphology of the dumbbells can be controlled. A series of pictures of dumbbells of different sizes and aspect ratios is shown in Figure 1.

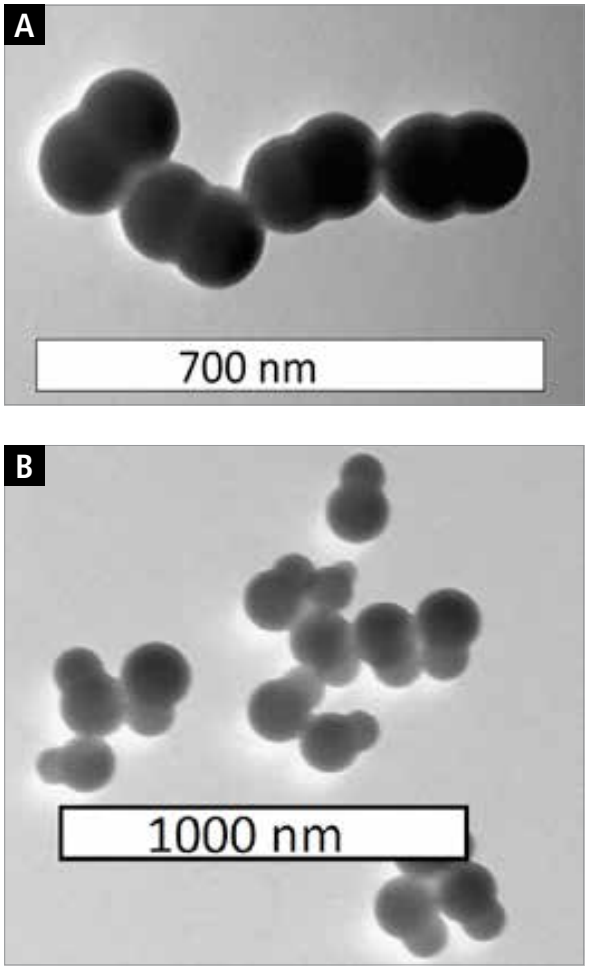


Figure 1: TEM pictures of polymer dumbbells of different sizes (A), and different size ratios (B).

The proposed approach offers several advantages. First of all, it yields monodisperse dumbbell particles in large amounts, possessing tunable morophologies, and of very different sizes, depending on the initial seed size. Secondly, the presence of silane groups, confined to the surface of the first lobe, offers the possibility to functionalize only one part of the surface of the dumbbells, by employing common silane chemistry.

In order to prove the concept, AMI scientists functionalized one of the lobes of the dumbbells with cationic groups. Since the second lobe only bears sulfate groups, this renders the dumbbell a dipolar structure. The dumbbells were then incubated with a large excess of small, negatively charged particles. The heteroaggregation of the small particle and the dumbbell will only occur on the positively charged lobe of the latter. Two types of nanoparticles have been used for this purpose: citric-acid functionalized magnetite nanoparticles and small SDS-protected polystyrene nanocolloids. Pictures of typical asymmetrically functionalized dumbbells are shown in Figure 2. The TEM micrographs clearly demonstrate that only one hemisphere of each dumbbell has been functionalized with the smaller nanoparticles.

These findings represent a major step forward in the preparation of particles with asymmetric functionalization, as well as asymmetric shape. Research continues with the aim of preparing particles possessing functionalities which are even more complex. Scientists are investigating the ability of these nanoparticles to self-assemble into novel structures.

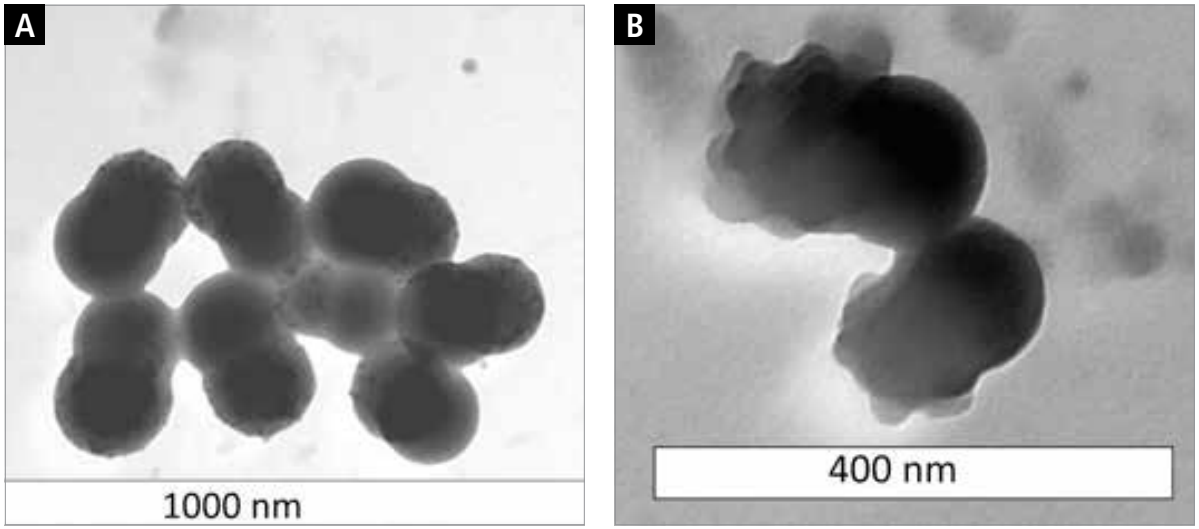


Figure 2: TEM pictures of asymmetrically functionalized dumbbell particles with magnetite nanocrystals (A) or polystyrene nanoparticles (B).

Reference:
[1] Guignard, F., Lattuada, M. Asymmetrically Functionalized Polymeric Dumbbells, Chimia (Polymer and Colloid Highlights), 67, 829 (2013).

Contact: Prof. M. Lattuada

HYDRODYNAMICS AND TRANSPORT OF HETEROGENEOUS NANOPARTICLES

Scientists at AMI aim to understand how natural and synthetic nanostructured soft materials interact with their environment, what governs their behavior, and how they respond to diverse stimuli. The understanding of such fundamental phenomena is then applied to engineer and tailor desired functionalities that relate to structure, size, and morphology on the nanoscale. Scattering techniques represent a unique toolbox to characterize these features on the relevant length scales.

Safe applications of nanotechnology require a profound understanding of the response of living cells to nanoparticles (NPs). Currently, *in vitro* cell culture assays focus on cellular uptake of NPs and possible cell responses. In order to understand dose-response relationships, an accurate and precise knowledge of the NPs that are deposited on the cell surface is of paramount importance.

Considering *in vitro* cell-culture assays, the dose of NPs that comes into direct contact with the cell surface is a function of time and is governed by three processes: (1) transport of NPs to the cell, (2) adsorption to the cell membrane, and (3) internalization. The transport of uniform NPs has already been modeled [1], however NPs are often heterogeneous in both shape and size (Figure 1). The influence of heterogeneity on transport and dose remains unexplored. The general equation describing the transport rate can only be solved analytically for a handful of simplified initial and boundary conditions, while the solutions that would be relevant for *in vitro* assays are not readily available, if at all, in closed form. Therefore, research at AMI has taken a novel approach, describing the motion of single particles on the mesoscopic level by building on elementary principles of nanoparticle hydrodynamics. Based on this route, an extended computational modeling platform has been developed over the past year [2]. This platform achieves more than simply reproducing the results of previous models. One of the most exciting developments of this approach is its unmatched versatility, as parameters defining NPs and the experimental conditions can be set as desired.

Figure 2 shows representative results where the influence of size-polydispersity (Figure 2A) the transport rate (Figure 2B) and on the dose at the surface of the outer cell membrane (Figure 2C) was calculated. This data shows that the dose-time relationship depends on the degree of NP polydispersity, even though the average size is kept constant. This feature should be taken into account when addressing biological responses.

In the future, more comprehensive elements will be included, such as the adherence of NPs to the cell and their subsequent internalization. In the long run, the new modeling platform will enhance the understanding of how diverse NPs are taken up by certain cells and where they are found in living systems, including the human body. Investigating properties which may be useful in applications dedicated to personalized therapeutics or which may be hazardous to living organisms and to the environment is one of the cornerstones of nanotechnology.

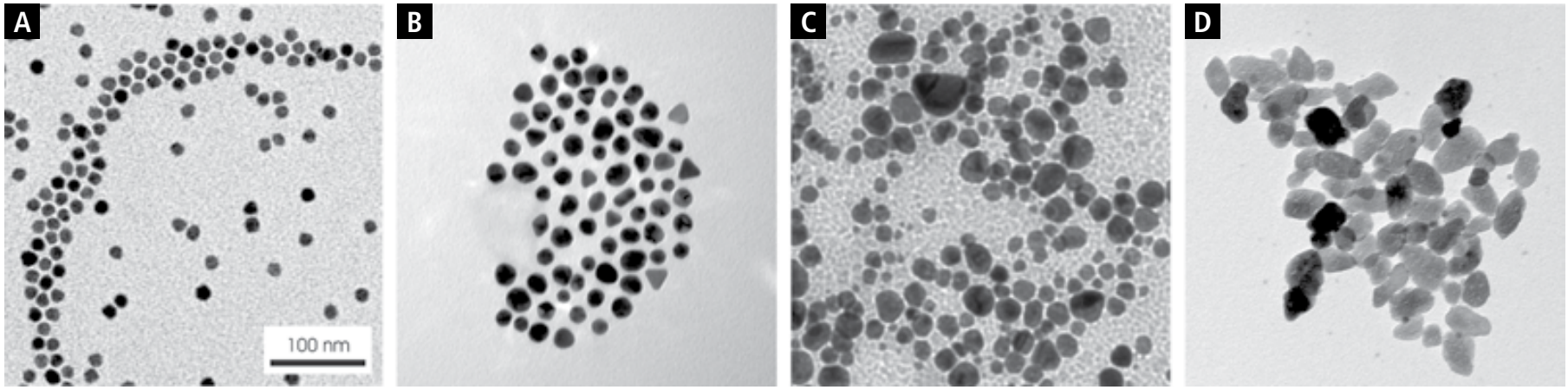


Figure 1: TEM image of (A) iron oxide, (B) gold, (C) silver, and (D) titanium dioxide nanoparticles. While the iron oxide particles are fairly uniform, the silver and titanium dioxide particles are highly heterogeneous.

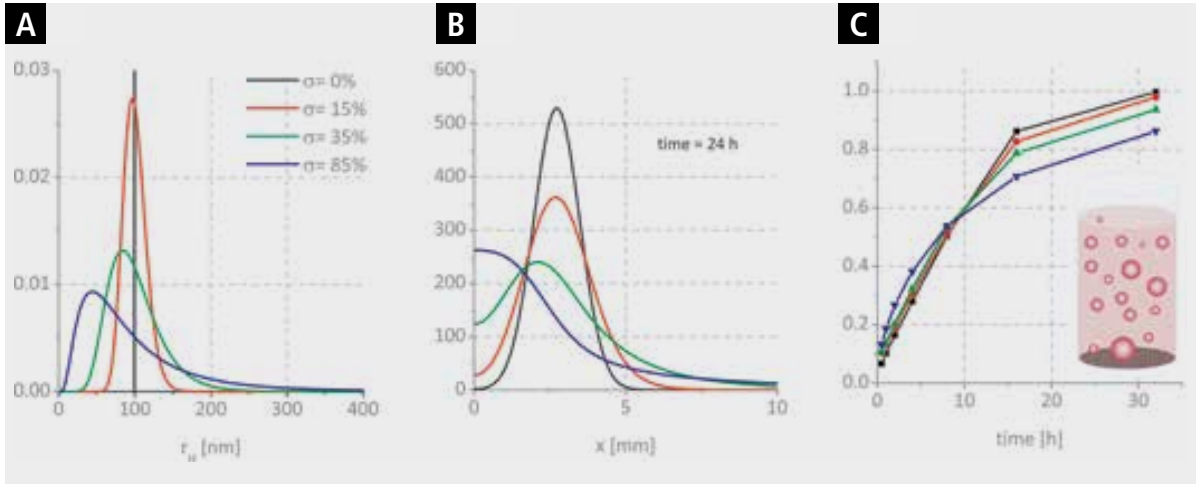


Figure 2: A) Lognormal distributions for nanoparticles possessing the same average hydrodynamic radius (r_H). The higher the polydispersity index (σ), the broader the distribution. B) The dispersion profiles of these nanoparticles in a dilute suspension. The transport is governed by sedimentation and diffusion. While the dispersion profile of uniform particles (σ=0w) is purely Gaussian, polydispersity results in convoluted profiles. C) Corresponding to the diverse dispersion profiles, the fraction of nanoparticles delivered to the cell in given time is a function of polydispersity.

References:
[1] Teeguarden et al. Toxicological sciences 95(2), 300–312 (2007), Hinderliter et al. Particle and Fibre Toxicology, 7:36, (2010)
[2] S. Balog et al., in preparation.

Contact: Dr. Sandor Balog

HEALABLE POLYMERS: STRONGER AND STIFFER

Polymers which can be repaired after being damaged are attractive materials, because this property can lead to an improvement in the reliability, functionality, and lifetime of products made from them. While many of the healable polymers studied to date display moderate strength and stiffness, AMI researchers have recently introduced an intriguing concept to merge good healing behavior with attractive mechanical properties.

One appealing approach to creating healable polymers exploits non-covalent, dynamic supramolecular motifs. These allow one to temporarily disassemble the constituent macromolecules as needed. The resulting increase in chain mobility and decrease in viscosity promote healing capability, before the equilibrium is shifted back and the polymer is reformed. AMI's initial studies in this area involved a novel class of optically healable supramolecular metallopolymers. These materials were assembled from telechelic building blocks, that is, molecules capable of entering into further reactions through their reactive end groups. In this case, they were terminated with ligands and metal salts that bind to these ligands, thereby promoting the formation of metallosupramolecular polymeric materials. Upon exposure to ultraviolet light, the metal-ligand motifs are excited and convert the absorbed energy into heat. This causes temporary dissociation of the metal-ligand motifs and transforms the polymers into low-viscosity liquids, which can easily fill small defects. When the light is switched off, the polymers and metal-ligand motifs re-assemble and the original properties of the materials are restored. Since light can be applied locally, objects can be healed under load. While this design imparts outstanding healability, it is also the reason for the materials' rather moderate strength and stiffness, a limitation that is common to many other types of polymers.

Reinforcing healable metallosupramolecular polymers with nanocellulose

AMI researchers have previously shown that soft polymers can be efficiently reinforced by introducing small amounts of rigid cellulose nanocrystals (CNCs). These bio-based and biodegradable nanoparticles can readily be isolated by hydrolysis of natural cellulose from various sources, such as wood pulp, cotton, or agricultural byproducts. In a pioneering study, it was shown that CNCs are also suitable for the reinforcement of metallosupramolecular polymers. If the CNC content is kept below a certain threshold, such nanocomposites remain optically healable and exhibit significantly higher strength and stiffness than the neat metallopolymers. The study also showed, however, that efficient repair of the material is associated with full dissociation of the reinforcing CNC network during the healing event, and, in compositions with high CNC content, improved mechanical properties result in reduced healability.

Hydrogen-bonded supramolecular nano-composites with outstanding healability and mechanical properties

In order to simultaneously maximize healability and mechanical properties, the newest generation of healable nanocomposites developed by AMI researchers involved a hydrogen-bonded supramolecular polymer and CNCs decorated with the same motif for supramolecular assembly. These materials display an intriguing combination of high stiffness, high strength, and rapid and efficient optical healing. These properties appear to be the result of the specific design, which leads to full integration of filler and matrix, to the extent that these components can no longer be distinguished from each other, thus permitting the temporary disengagement of all relevant supramolecular interactions during the healing process.

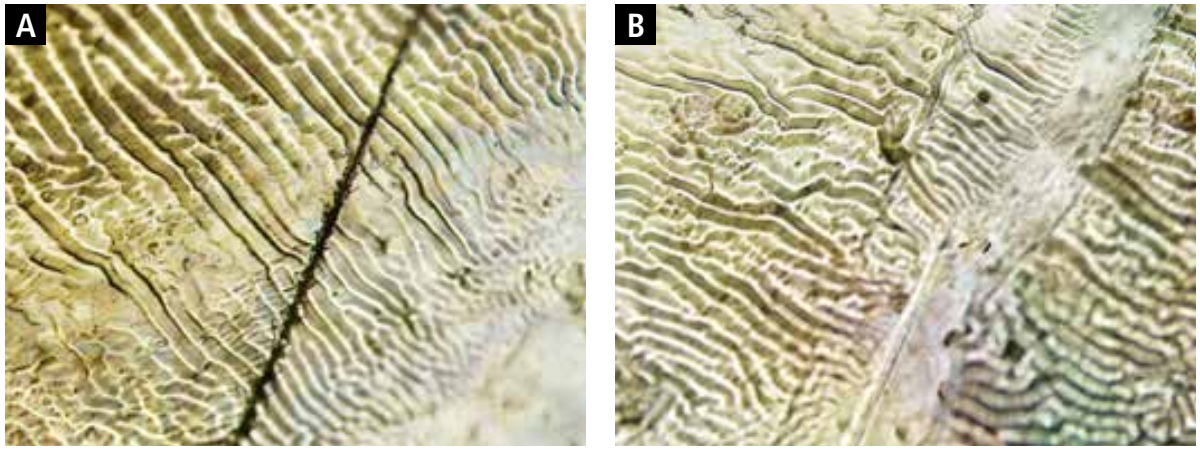


Figure 1: Optical microscopy images of a deliberately damaged film of a nanocomposite, consisting of a supramolecular metallopolymer and cellulose nanocrystals before (A) and after (B) healing by exposure to ultraviolet light.

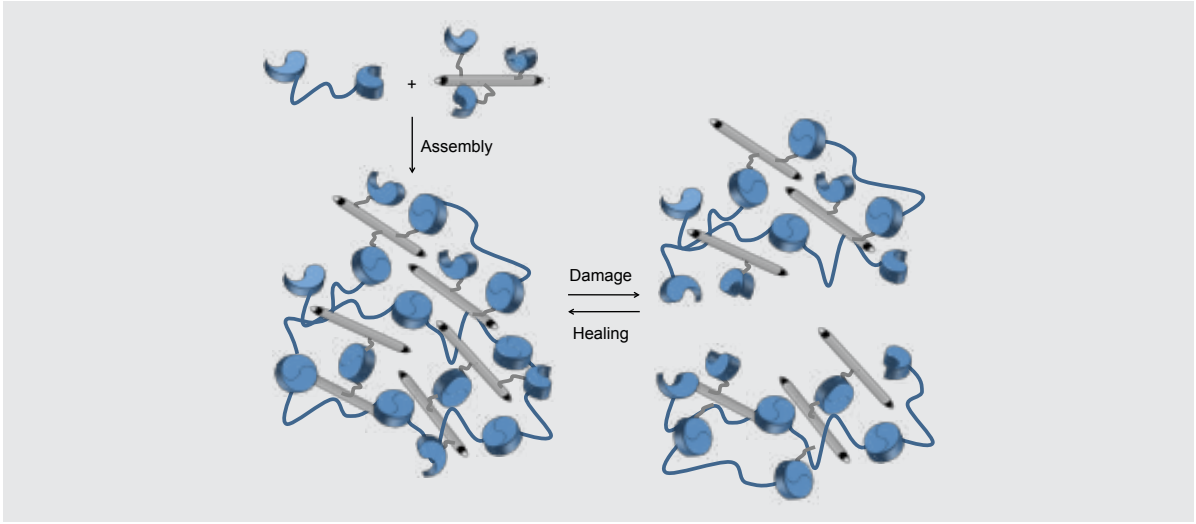


Figure 2: Schematic representation of the architecture of healable supramolecular nanocomposites based on telechelic building blocks terminated with hydrogen-bonding motifs and cellulose nanocrystals decorated with the same motif.

References:

[1] Coulibaly, S.; Roulin, A.; Balog, S.; Biyani, M.; Foster, E.J.; Rowan, S.J.; Fiore, G.L.; Weder, C.; Reinforcement of optically healable supramolecular polymers with cellulose nanocrystals; *Macromolecules*, 47, 152–160 (2014).

[2] Biyani, M.V.; Foster, E.J.; Weder, C.; Light-Healable Supramolecular Nanocomposites Based on Modified Cellulose Nanocrystals; *ACS Macro Letters*, 2, 236–240 (2013).

[3] Fiore, G.; Rowan, S.J.; Weder, C.; Optically Healable Polymers; *Chem. Soc. Rev.*, 42, 7278–7288 (2013).

Contact: Prof. C. Weder, Dr. G.L. Fiore, Dr. E.J. Foster.

List of research projects

PROJECTS FINANCED BY THE SWISS NATIONAL SCIENCE FOUNDATION

Bio-inspired mechanically responsive polymer nanocomposites
01.01.2010–31.12.2014
C. Weder

This experimental research program pursues 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 nanocrystals 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
01.12.2010–30.06.2014
C. Weder, J. Foster, M. Clift

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

Metal-containing polymers
01.04.2011–31.03.2014
C. Weder

This project focuses on the synthesis and characterization of metal-containing polymers, including metallosupramolecular polymers and metal-containing materials that display low-power optical upconversion.

Processing of polymer/cellulose nanofiber composites
01.08.2012–31.07.2015
C. Weder

This experimental research program 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.

Lanthanide supramolecular biomaterials
01.06.2012–31.05.2015
G. Fiore

This project targets the synthesis and investigation of a new class of lanthanide-containing polymers to explore their unique spectral properties and incorporation into solution assemblies for potential applications as delivery vectors and molecular probes.

Spatially resolved magneto-relaxation of *in vitro* magnetic nanoparticles using atomic magnetometry
01.09.2010–31.08.2013
A. Fink

This was an exploratory interdisciplinary project which aimed to develop a novel imaging method for specific *in vitro* biological entities, such as organs or tumor cells. These objects were tagged by attached or embodied magnetizable nanoparticles (MNP), whose spatial magnetic field distribution, recorded by arrays of atomic magnetometers, yields images of the biological entities.

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 for targeting selectively particular mammalian cells (e.g. cancer cells), these vesicles are designed to dock the cells or even merge with the cell membranes.

Advances in nanoparticle engineering with a focus on stability, surface, and particle-cell interaction
01.10.2009–30.09.2013
A. Fink

The project dealt with model particle synthesis, colloidal property investigations and protein profiling in environments of varying complexity. It seems that one possible and useful

classification of nanoparticles is according to the manner in which they interact with proteins, an approach that has not yet been studied by nanoscientists. This project sought to develop the fundamental knowledge required to address this significant limitation.

NCCR-Nanoscale science
01.06.2010–31.05.2013
B. Rothen-Rutishauser

The aim of this work was to correlate the different surface properties (functionalization, surfactant coating) of multi-walled carbon nanotubes (MWCNTs) to their potential adverse effects in lung cell cultures. Different surface functionalizations of the MWCNTs, for example with positively and negatively charged groups or biosurfactant coatings, were explored.

Biomedical nanoparticles as immune-modulators
01.09.2011–31.08.2015
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, together with PD Dr. Ch. von Garnier and Dr. F. Blank from the University Hospital in Bern, pursue the development and testing of specifically designed nanoparticles in order to investigate their immune-modulatory effects in the lung.

Realistic exposure scenarios to study nanoparticle-lung cell interactions
01.01.2012–31.12.2014
B. Rothen-Rutishauser, A. Fink, M. Clift

Increased efforts have been made towards the use of sophisticated, dose-controlled nanoparticle exposure devices in combination with lung cell cultures at the air-liquid interface. However, so far, such studies have only considered acute exposures (i.e. a single exposure of NPs). This project aims to optimize the 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 questions on 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 the research activity is the preparation of complex nanoparticles, understanding their self-assembly behavior and their utilization to prepare novel materials. The research activity is divided into three main projects. The first project will aim 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 which investigates the rheology of suspensions of colloidal particles undergoing self-assembly in the presence of flow fields.

Anisotropic self-assembly of nanoparticles
01.10.2010–30.09.2013
M. Lattuada

In this project, the behavior of particles subject to anisotropic interactions was investigated. Two different strategies were envisioned to achieve this goal. First of all, magnetic colloids were assembled in the presence of biaxial or triaxial magnetic fields. The second approach was based on the preparation, and then on the systematic investigation, of the properties of Janus-type asymmetrically functionalized colloids.

Controlled radical polymerization catalyzed by enzymes: From fundamentals to applications
01.10.2013–30.09.2017
N. Bruns

Controlled radical polymerizations allow synthesizing polymers with defined size and molecular architecture. Such polymers are essential building blocks for soft nanomaterials. The project investigates enzymes as environmentally friendly catalysts for atom transfer radical polymerizations (ATRP). The biocatalysts are an alternative to conventional toxic catalysts.

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.

NanoDiaRa
01.03.2010-28.02.2013
A. Fink

This project was part of a large-scale international, interdisciplinary program entitled "Nanosciences, Nanotechnologies, Materials and new Production Technologies", which involved a consortium of 15 partners. The main objective of this project was to develop modified superparamagnetic nanoparticles as a diagnostic tool for the detection of early stages of arthritis. In addition to research, the project considered the social, ethical and legal aspects of applying nanotechnology for medical purposes.

PROJECTS FINANCED BY OTHER PUBLIC FUNDING AGENCIES

Photo-healable supramolecular polymers, US-Army Research Office
01.07.2009–30.06.2013
C. Weder

The goal of this project was to develop and characterize a novel class of metallosupramolecular polymeric materials that can be healed by exposure to light of an appropriate wavelength and intensity.

Supramolecular polymers with multiple types of binding motifs: From fundamental studies to multi-functional materials, US Army Research Office
2012–2015
C. Weder

This project aims to advance the understanding of stimuli-responsive materials that incorporate multiple supramolecular binding motifs with orthogonal functionality.

Biological responses to nanoscale particles, Deutsche Forschungsgemeinschaft
01.01.2011–31.12.2013
B. Rothen-Rutishauser

This project aimed to advance the understanding of the interactions of nanoparticles with proteins, tissue, and cells of the respiratory tract. A special focus was on the interaction of proteins and other biomolecules of the body fluids with nanoparticles and the influence of these bindings on cell interaction – i.e. uptake and intracellular trafficking.

Assessing the toxicity of Ag nanoparticles at the air-liquid interface using a 3D model of the epithelial airway barrier in vitro, Bundesamt für Gesundheit
01.02.2010–31.12.2013
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 used the *in vitro* human epithelial airway model, combined with a valuable battery of experimental tests, to determine the different toxicological endpoints that might be involved in xenobiotic-induced toxicity, specifically in connection with silver nanoparticles.

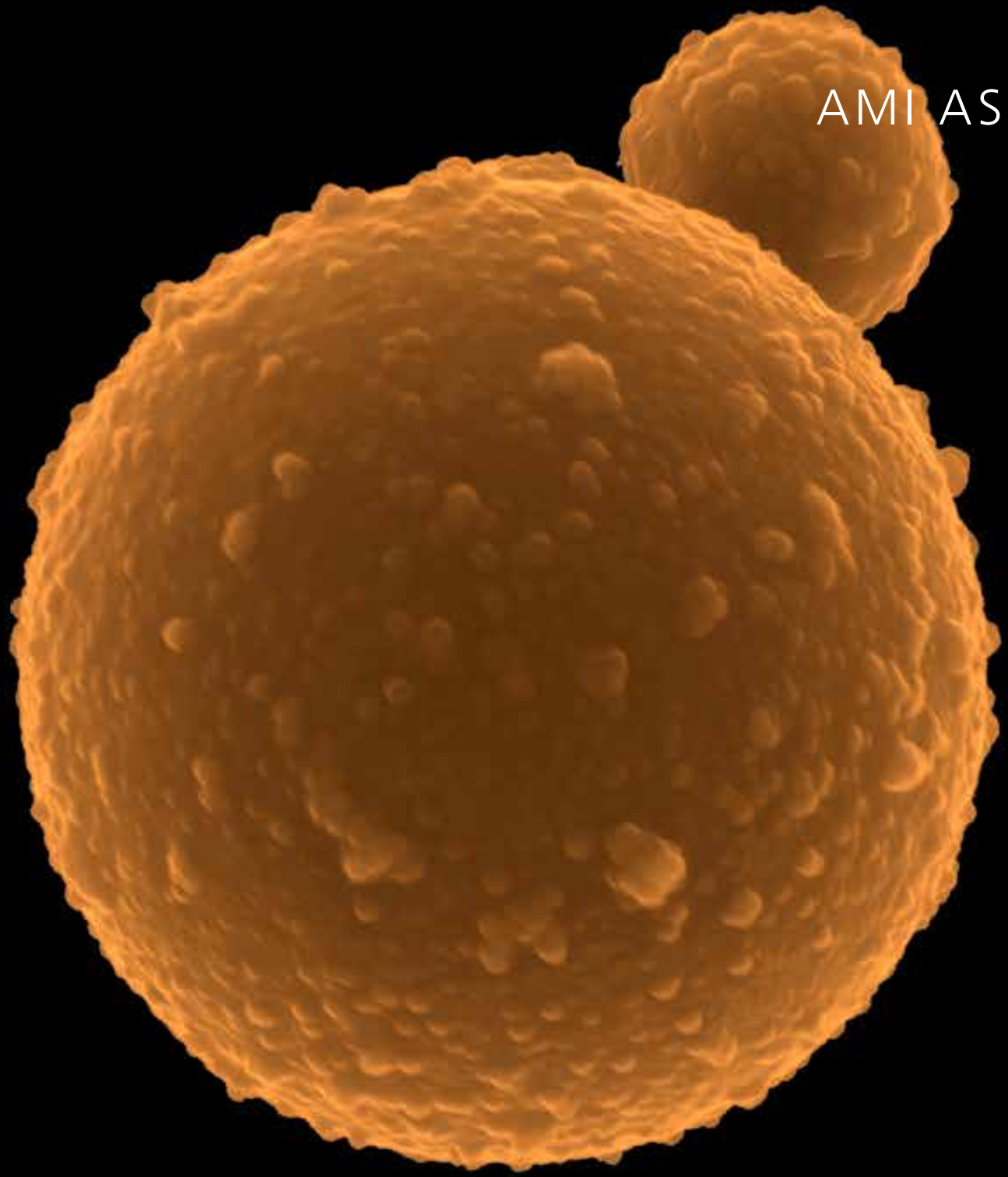
Surface-enhanced raman scattering (SERS)-based imaging and ultrasensitive-detection of biomarkers in biological samples, L'Oreal
01.08.2013–31.12.2014
L. Rodriguez Lorenzo
The main objective in this research project is the design and development of new protocols for routine diagnosis based SERS-imaging-ultra-detection methods. In other words, the project focuses on the fabrication of a sensor that can be utilized both imaging and sensing, allowing detection in the early stages of disease.

Bio-CRP: Biocatalytic controlled radical polymerizations of heterocyclic aromatic vinyl monomers, SCIEX
01.10.2013–30.09.2014
N. Bruns, C. Fodor
This project explores enzymes as catalysts for the atom transfer radical polymerization (ATRP) of vinyl imidazole and its derivatives. Poly(vinyl imidazoles) can be applied, for example, as membrane for water purification, as gene delivery vectors, and as proton conducting membranes in fuel cells. By using enzymes, the project aims to obtain metal-ion free polymers that are not achievable by conventional ATRP.

PROJECTS WITH INDUSTRY

In 2013, AMI collaborated with six companies from the medical devices, biomedical, pharmaceutical, adhesives, dental, and fragrances sectors on 7 different projects.

AMI AS A PARTNER



AMI as a partner

PARTICIPATION IN NATIONAL AND INTERNATIONAL INITIATIVES

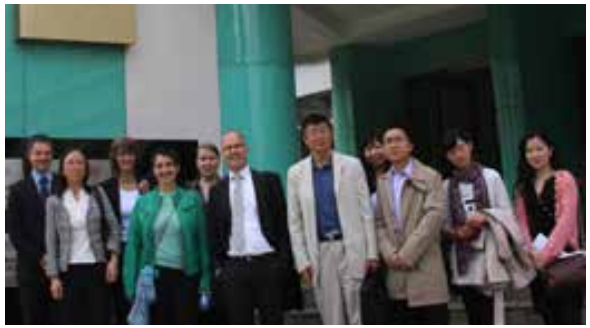
The large number of collaborations with researchers at institutions around the world is characteristic of AMI's multidisciplinary and international research approach. In 2013, AMI was active in the organization of several conferences, as well as the establishment of strategic collaborations with its partners internationally. In addition to this essential exchange among peers on an international level, the institute also participated in knowledge and technology transfer events on a local front.

In 2013, AMI became a contributor to the thematic platform "Micro- & Nanotechnology" of the Swiss Academy of Engineering Sciences (SATW), which provides expert guidance around the legislation and regulation of nanoproducts, the requirements regarding the declaration of the nanoparticulate content of such products as well as the public perception of nanotechnology.

Under the headline "Soft Materials for Advanced Products", AMI co-organized the 9th edition of the SATW Transfer Kolleg, which took place in Fribourg on June 6 and 7. Fourteen project teams, each comprizing an academic and an industry partner, met for this workshop. They presented common projects and were able to expand their network by engaging in discussions around how to progress to their innovative products during coaching sessions.

Strengthening partnerships on an international level

In order to take research and exchange opportunities to the next level, AMI sought to establish strategic partnerships with several select institutions in Asia and the USA. During visits to the State Key Laboratory of Metal Matrix Composites (SKLM-MC) at Shanghai Jiao Tong University (China), the Institute for Advanced Materials (IAM) at Case Western Reserve University (Cleveland OH, USA), and the Polymer program of the Petroleum and Petrochemical College (PPC) at Chulalongkorn University (Bangkok, Thailand), mutual research interests were identified.



AMI delegation with the representatives of Swissnex and the hosts of the State Key Laboratory of Metal Matrix Composites at Jiao Tong University, Shanghai.

As a result, a letter of intent governing student exchanges has already been signed with Case Western Reserve University's IAM and a memorandum of understanding was signed with PPC at Chulalongkorn University, Bangkok, Thailand. As a direct outcome of the latter, AMI Professors Alke Fink and Christoph Weder have been appointed to teach as part of the PPC Polymer Program and AMI has begun to recruit PhD candidates from this university.

PPC Dean, Asst. Prof. Pomthong Malaku and AMI director, Prof. Christoph Weder signing the memorandum of understanding.

Every year, AMI invites top Master students from around the globe to participate in a summer internship program, 2 to 4 months in duration. This year, the program attracted 6 outstanding and highly motivated students. As has been the case in previous years, several of these students are likely to return to AMI at a later stage in order to pursue higher degrees and to launch their academic careers.

From October 8 to 12, in commemoration of the 150th anniversary of diplomatic relations between Japan and Switzerland, the Swiss–Japanese Nanoscience Workshop, "Materials Phenomena at Small Scale", was held at the Namiki Site of NIMS in Tsukuba. The event brought together more than 40 prominent scientists and 20 young researchers and attracted an audience of over 200 members hailing from both countries. Prof. Weder and PhD student Fabian Herzog, inspired the audience with presentations on their research activities.

INDUSTRY COLLABORATIONS

The intent behind this year's industry-related activities was to consolidate relationships with current partners. One of the projects attracted particular attention.

In 2013, AMI collaborated with six companies from the medical devices, biomedical, pharmaceutical, adhesives, dental, and fragrances sectors on 7 different projects. Several multi-year joint research projects reached their second phase and some projects were extended. In addition to these ongoing projects, AMI discussed common interests and possible research projects with about 15 new companies, mainly based in Switzerland, Germany and the US.

AMI scientists with representatives from regenHu (from left to right): Raphael Wenger, Andreas Scheidegger, Lenke Horvath (AMI), Michael Kuster, Prof. Barbara Rothen-Rutishauser (AMI) and Marc Thurner.

A further highlight in 2013 was the launch of a research collaboration with the Swiss (Fribourg) start-up company, regenHu. regenHu is a pioneer in the field of 3D bio-printers and biomaterials, which serve its customers by creating tissue and organ models. Compared to other 3D printers which enable the printing of inanimate materials such as polymers, regenHu is a leader in the design and production of "biofactories", where different bio inks serve to print complex assemblies of living cells. The applications of this new technology are manifold, as are the challenges associated with it. In addition to adapting the printing technology, one needs to formulate the inks in such a way that the printed cells can then proliferate and form the desired structures. AMI collaborates closely with regenHu to develop inks and printing protocols which allow the creation of complex *in vitro* lung models to mimic the air-blood barrier in the human body.

Today, such models consisting of different cell types have to be prepared manually by very skilled technicians or researchers, which restrict their usage to a handful of highly specialized research labs. The aim of the project, which received a start-up funding from the Innovation Fund Fribourg, was to increase the impact of this tissue model by simplifying its production and increasing its reproducibility and throughput, thus making it available to other user groups. After some very promising initial results in printing single cell types, AMI researchers are now focusing on more complex structures.

NETWORKING & PUBLIC RELATIONS

AMI continuously seeks opportunities to engage the general public in order to promote interest in nanotechnology, as well as an understanding of its potential risks and benefits. Scientific audiences, both locally and internationally, also connect with AMI researchers on current research topics.

Outreach in 2013

One opportunity for public outreach was the ExpoNano, an exhibition which is is touring Switzerland in 2013 and 2014 and which made a stop at St Michel high school in Fribourg from November 18 to 22. Supported by various academic partners, federal agencies and NGOs, its aim is to provide information on everyday applications of nanotechnology in an interactive setting, and to weigh the advantanges and potential risks for the benefit of visitors. The exhibition features several contributions from AMI – a hands-on exhibit demonstrating cellulose-reinforced plastics, interactive information panels on smart capsules for drug delivery, as well as a video presentation on a novel approach to treat chronic asthma developed in collaboration with the University Hospital INSEL in Bern.

School students and members of the general public alike had the opportunity to take part in guided tours through the exhibition led by PhD students Carola Endes and Silvana Mueller:

"Several students asked pertinent questions around nano-enabled products which are readily available today", said Silvana Müller. *"I think this reflects a desire to know more about risks associated with nanotechnology, as well as its benefits. The ExpoNano is one way in which we can reach a diverse audience with this information."*

During its stop in Fribourg, a podium of experts representing sectors such as the consumer industry, green nanotechnology and academic research (AMI Director, Christoph Weder) fielded questions from members of the public, sparking lively debate around the future of nanotechnology and its potential impact.

AMI's interaction with local schools extends to the supervision of scientific research. The institute offers high school students placements for their capstone projects. AMI scientist, Dagmar Kuhn, was responsible for supervising the project of high school student, Séverin Yao, from Gymnasium Thun-Schadau.

The ExpoNano exhibition, featuring interactive exhibits which illustrate various research foci at AMI.

Séverin devised a project which investigated the influences of different sized nanoparticles on different cell types and carried out his lab work at AMI under Dagmar's supervision.

"It was inspiring to work with a young person possessing such an interest in nanotechnology", said Dagmar Kuhn. *"Supporting students with their final projects is a worthwhile cause. In providing expertise and resources, AMI is actively contributing to the nanotechnology talent pipeline."*

Further local outreach activities around the risks and benefits of nanotechnology were attended by Dagmar Kuhn and fellow PhD candidate, Christophe Monnier. The two scientists held a lecture and a question-and-answer session on October 23 at the Volkshochschule Langenthal for an audience of teachers, doctors, and pharmacists. Dagmar and Christophe related the content to their own basic and applied research in the field of bio-nanomaterials.

Local and International Exposure

AMI's research in the field of bio-inspired materials received international exposure at nano tech Japan, Tokyo (January 31 to February 1). Frequented by a large number of local exhibitors, the trade show was an opportunity for AMI to present its work and expertise.

Bio-inspiration was also a main topic at the kick-off of the National Thematic Network (NTN) for Innovative Surfaces. AMI is an institutional member of this CTI-sponsored network. The event, held on April 18 in Olten, was an opportunity for representatives from academia and industry to lend their expertise on the topic of knowledge and technology transfer in the field of advanced surface technologies, and the potential of this sector as an economic driver. As a member of the expert committee, Dr. Marc Pauchard from AMI was invited to present on the topic of "Bio-inspired innovative surfaces – mimicking successful concepts from nature."

Technology transfer by AMI

AMI was present on October 15 as representative of Tech-Transfer Fribourg, the technology transfer office of the local Universities founded in 2011, at Fribourg's Technology Park. Dr Marc Pauchard gave a presentation on technology transfer between academia and industry to an audience of representatives from both sectors as well as local politicians at this event, marking the launch of the Forum of the Swiss Integrative Centre for Human Health (SICHH). In supporting the SICHH Forum, AMI facilitates networking between partners and clients of the SICHH, which aims to equip scientists, companies, and clinicians with expertise in all areas related to human health. Dr. Pauchard once again confirmed AMI's commitment to facilitating successful technology transfer, in order to position Fribourg as a center of innovation in the field of new materials.

Dr. Pauchard (far right) from AMI participating in a round table discussion at the launch of the SICHH forum.

AMI INSIDE

Portraits of team members

MARTIN CLIFT

Martin joined the BioNanomaterials group at AMI in 2011. He has been living in Switzerland for over 5 years in Bern and its surrounding area. Martin originally comes from Scotland, where he completed his undergraduate and post-graduate education. He is a keen biologist, with a particular interest in toxicology and specifically the toxicology of nanomaterials. Martin is passionate about his research, with a view to pursuing an academic career where he may share his vehement outlook on the study of the biological interaction between nano-sized objects with other interested people. When not thinking about nanotoxicology, Martin spends his time with his wife, two daughters and beloved border collie (Sweep)! Martin especially likes to spend time outdoors, whether it be lighting up the BBQ in his garden when entertaining friends, or ascending the various mountain ranges, with their breath-taking views, that Switzerland has to offer. In addition to studying the many philosophical aspects of science and its origins, Martin also enjoys sports and can be found keeping up with all types, both as a spectator and as a player.

BERNADETTA GAJEWSKA

Bernadetta was born in Szczecin, Poland. She studied Chemical Technology at Warsaw University of Technology and was awarded her master's degree in the field of Polymer Technology. She began her PhD at AMI in 2013 as a member of Prof. Nico Bruns' in the field of enzyme-catalyzed Atomic Transfer Radical Polymerization (ATRPases).

Fribourg is the perfect location for Bernadetta because it provides her with the opportunity to realize all her dreams at once: to pursue a PhD in chemistry in macromolecular chemistry, to learn French, to improve her German and to ski in Winter and go hiking in the Summer. Quoting her organic chemistry teacher, she states that "chemistry is not so far from cooking and vice versa". She has also been inspired to broaden her cooking horizons and embrace molecular cuisine.

MAY NICHARAT

May (Apiradee) Nicharat was born in Bangkok, the capital city of Thailand. Chemistry has been her favorite subject since her primary school years. May completed both her bachelor's and master's degrees in Polymer Science at Chulalongkorn University in Bangkok, one of AMI's partner institutions. Her desire to find out more about polymers is driven by the fact that they are part of daily life and are continuing to grow in importance. As a member of the Polymer Chemistry and Materials group at AMI, she is currently working on new processes to produce composites of polymers and cellulose nanocrystals which are needed for the industrial application of such materials. May enjoys living in Switzerland, in a safe and quiet city which is surrounded by mountains. Once a member of Thailand's national swimming team, she still loves sports. When not in the laboratory, she likes to spend time outdoors; swimming, biking, and hiking, and is looking forward to learning to ski on the snowy slopes of the Swiss Alps.

MARCO LATTUADA

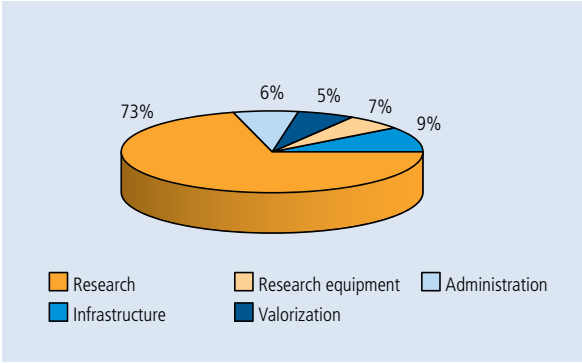
Marco Lattuada joined AMI in 2012 as an SNF Professor and established the Nanoparticles Self-Assembly Group. Fascinated by physics, mathematics and chemistry, Marco decided to study chemical engineering, the field in which he obtained his master's degree from Politecnico di Milano. He then left sunny Italy and crossed the Alps to reach Switzerland, where he completed his PhD in Chemical Engineering at ETH Zurich. After two years of post-doctoral work at the Massachusetts Institute of Technology in Cambridge (USA), he came back to Zurich to work as senior scientist at ETH. Marco enjoys working in international environments, such as AMI, together with young and enthusiastic people, each of whom bring their own personal cultural experiences. He is very passionate about his work and enjoys the academic world because of the challenges offered by the research activity, such as finding solutions to previously unresolved puzzles and creating new science and technology. In his spare time, Marco likes reading (mostly about science), watching documentaries and science fiction movies, visiting zoos and traveling. From time to time, he enjoys a vacation to some hot tropical destination, where he sits in the sunshine, relaxes and takes long swims in crystal clear waters surrounded by colorful fish.

FACTS & FIGURES

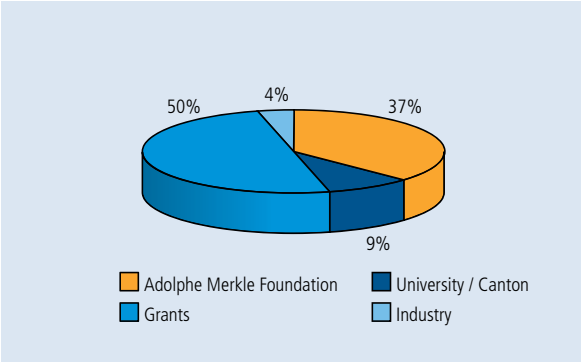
Facts & Figures

FINANCES

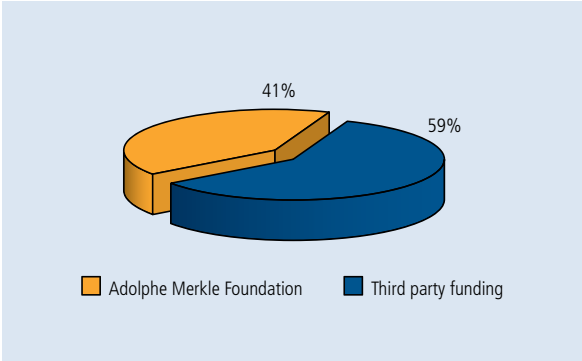
The institute's overall expenditures in 2013 grew to CHF 7.2 Mio. Over 70% of the expenses were spent on research and an additional 7% was invested in research equipment. About 5% of the budget supported valorization activities such as technology transfer and communication & marketing. About 9% was used for general infrastructure and 6% 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 last year, the third party funding of research projects increased by CHF 0.3 Mio. to CHF 3.1 Mio., covering close to 60% of all research expenditures. Here, the most important sources were the Swiss National Science Foundation (SNF), the European Union, industry partners, and the Swiss Commission for Technology and Innovation (CTI).



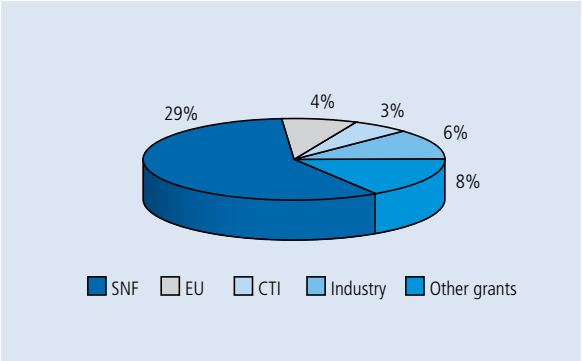
Overall expenses in 2013 by cost types.
Total expense of CHF 7.2 Mio.



Funding sources of overall expenses in 2013.



Funding sources of research projects in 2013.
Total research expenditures of CHF 5.2 Mio.

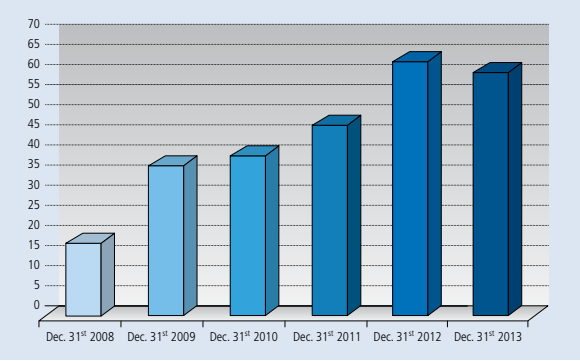


Sources of third party funding. Total of CHF 3.1 Mio.

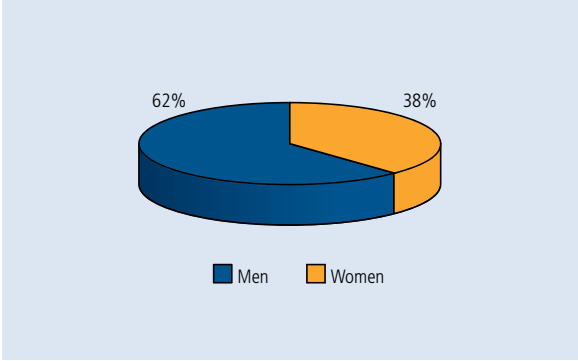
PERSONNEL

In 2013, 14 new collaborators joined AMI and 18 people left the Institute as a result of natural fluctuation. As of December 31, 2013, 60 full-time positions were occupied at AMI. 84% of all employees were active in research. More than half of the employees were PhD students and another 15% post-doctoral researchers, reflecting the educational and research mission of the institute.

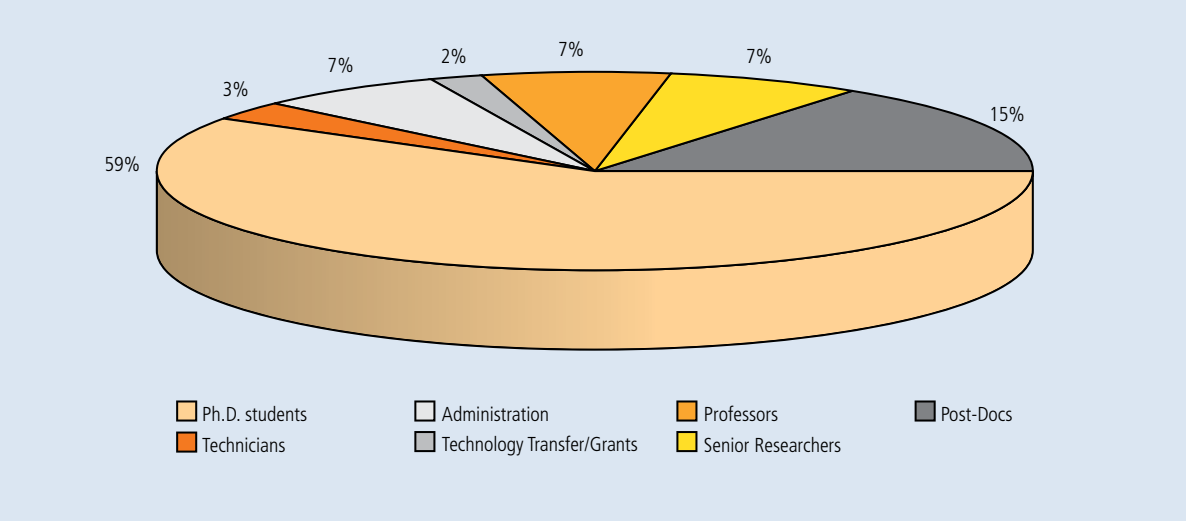
The AMI team is multinational, with 23 different nationalities represented. The average age of AMI employees is 33 years and, as was the case in 2012, 38% of employees are women.



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



Gender distribution at AMI on December 31, 2013.



Composition of personnel on December 31, 2013.

GOVERNING BODIES OF AMI

Executive Board

Prof. Christoph Weder
(Director)

Dr. Marc Pauchard
(Associate Director)

Prof. Alke Fink

Prof. Barbara Rothen-Rutishauser

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. Ulrich W. Suter
(President)
Professor Emeritus at the Department of Materials, ETH-Zürich, Switzerland

Prof. Giovanni Dietler
Head Laboratory of Physics of Living Matter at École Polytechnique Fédéral 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 Jülich, Germany

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

Prof. Hans Marcus Textor
Former Head of Biointerface Group at Department of Materials, ETH Zürich, Switzerland

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 State Councilor, 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, Hôpital Cantonal Fribourg, 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

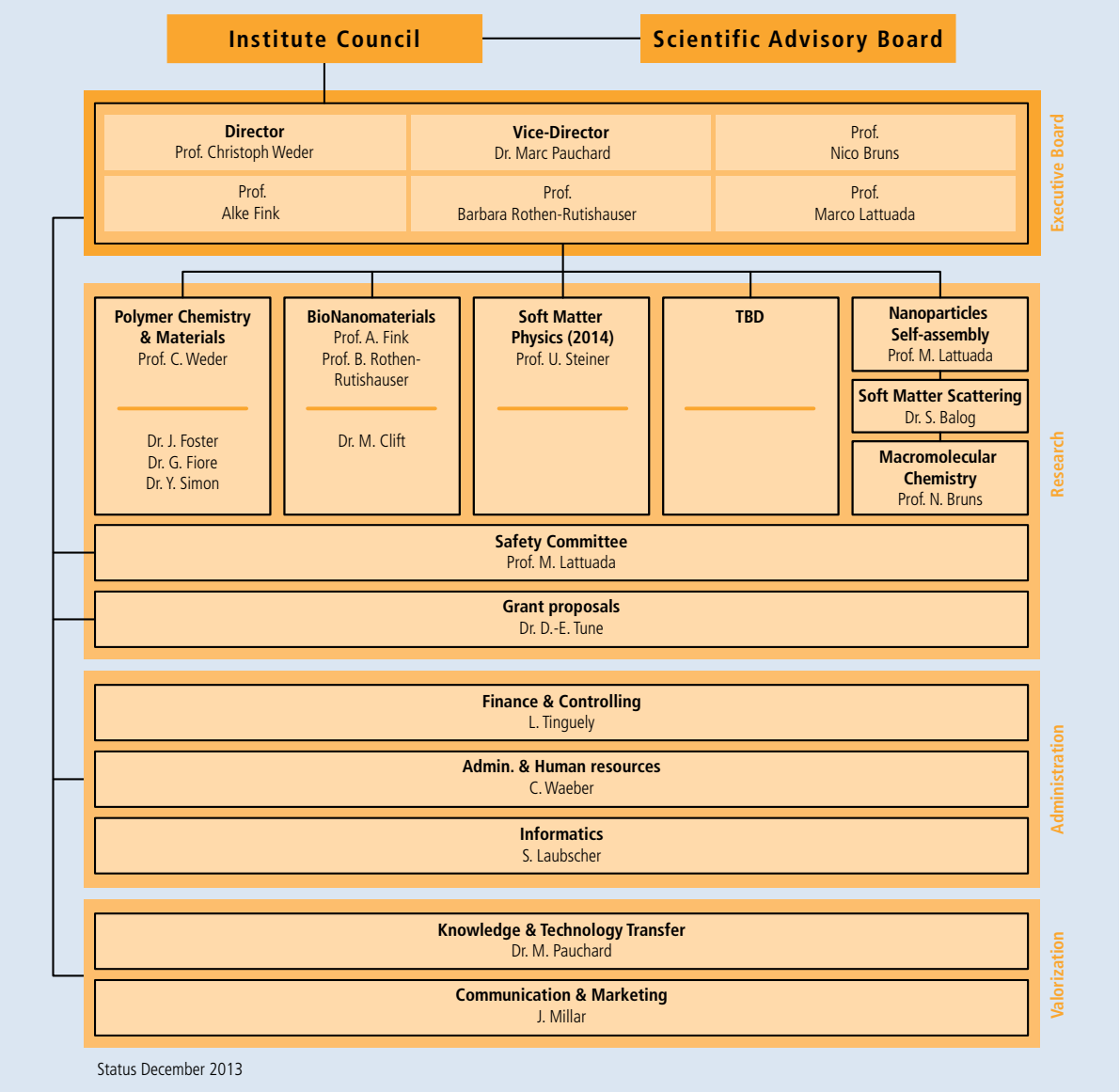
André Broye
(Managing Director)

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 2013, AMI comprised two research departments (Polymer Chemistry & Materials, BioNanomaterials) and three small research groups (Nanoparticles Self-Assembly, Macromolecular Chemistry and Soft Matter Scattering). The current development plan foresees continued growth, with one department to be installed in 2014 (Soft Matter Physics) and another one 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 2013

SCIENTIFIC OUTPUT

2013 has been another successful year for AMI researchers, yielding 64 publications in total. AMI researchers have published their findings in several high impact journals, including Small, Chemical Society Reviews, Nanomedicine, Nanotoxicology, Angewandte Chemie International Edition, Advanced Materials, and ACS Macro Letters.

In addition, AMI's scientific network continues to grow. AMI researchers have participated in 40 international conferences and 21 seminars, representing the institute at events hosted by network members such as the American Chemical Society, Swiss Chemical Society, FriMat, CLINAM, Nanotech, International Society of Aerosol Medicine, and the Swiss MNT Network.

SCIENTIFIC OUTPUT

Publications in scientific journals:	
Published:	37
Accepted:	11
Submitted:	9
Book Chapters:	7
Contributions at conferences and workshops:	
Invited Talks:	37
Talks:	43
Posters:	39
Keynote Lecture:	1
Invited Seminars:	21

APPENDIX

Appendix

PUBLICATIONS

Journal Articles:

1. Annamalai, P. K.; Dagnon, K. L.; Monemian, S.; Foster, E. J.; Rowan, S. J.; Weder, C. "Water-Responsive Mechanically Adaptive Nanocomposites Based on Styrene – Butadiene Rubber and Cellulose Nanocrystals – Processing Matters." *ACS Appl. Mater. Interfaces* **2013,** In press.

2. Bai, S.; Hua, Z.; Dietsch, H.; Simon, Y. C.; Weder, C. "Functional Iron Oxide Nanoparticles as Reversible Cross-Links for Magnetically Addressable Shape Memory Polymers." *Macromol. Chem. Phys.* **2013,** In press.

3. Balog, S.; Adamcik, J.; Mezzenga, R.; Cho, C. G. "Optimal Phase Segregation in Graft Copolymers." *Polymer* **2013,** *54,* 4629–4636.

4. Balog, S.; Gasser, U.; Jetsrisuparb, K.; Gubler, L. "Structure of the Hydrophilic Phase and Its Impact on the Conductivity of Graft Copolymer Ionomers at Low Hydration Level." *Polymer* **2013,** *54,* 4266–4275.

5. Balog, S.; Jetsrisuparb, K.; Gasser, U.; Scherer, G. G.; Gubler, L. "Structure of the Aqueous Phase and Its Impact on the Conductivity of Graft Copolymer Ionomers at Saturation." Submitted.

6. Behra, R.; Sigg, L.; Clift, M. J. D.; Herzog, F.; Minghetti, M.; Johnston, B.; Petri-Fink, A.; Rothen-Rutishauser, B. "Bioavailability of Silver-Nanoparticles and -Ions: From a Chemical and Biochemical Perspective." *J. R. Soc. Interface* **2013,** *10,* 20130396.

7. Biyani, M. V.; Foster, E. J.; Weder, C. "Light-Healable Supramolecular Nanocomposites Based on Modified Cellulose Nanocrystals." *ACS Macro Lett.* **2013,** *2,* 236–240.

8. Blank, F.; Stumbles, P.; Seydoux, E.; Holt, P.; Fink, A.; Rothen-Rutishauser, B.; Strickland, D.; Von Garnier, C. "Size Dependent Uptake of Particles by Respiratory Apc Populations and Trafficking to Regional Lymph Nodes." *Am. J. Respir. Cell Mol. Biol.* **2013,** *49,* 67–77.

9. Bruns, N.; Lörcher, S.; Makyla, K.; Pollard, J.; Renggli, K.; Spulber, M. "Combining Polymers with the Functionality of Proteins: New Concepts for Atom Transfer Radical Polymerization, Nanoreactors and Damage Self-Reporting Materials." *Chimia* **2013,** *11,* 777–781.

10. Camarero Espinosa, S.; Kuhnt, T.; Foster, E. J.; Weder, C. "Isolation of Thermally Stable Cellulose Nanocrystals by Phosphoric Acid Hydrolysis." *Biomacromolecules* **2013,** *14,* 1223–1230.

11. Carrillo-Carrion, C.; Nazarenus, M.; Paradinas, S. S.; Carregal-Romero, S.; Almendral, M. J.; Fuentes, M.; Pelaz, B.; Del Pino, P.; Hussain, I.; Clift, M. J. D.; Rothen-Rutishauser, B.; Liang, X.-J.; Parak, W. J. "Metal Ions in the Context of Nanoparticles Towards Biological Applications." *Curr. Opin. Chem. Eng.* **2013,** In press.

12. Chappuis, S.; Ripperger, J. A.; Schnell, A.; Rando, G.; Jud, C.; Wahli, W.; Albrecht, U. "Role of the Circadian Clock Gene Per2 in Adaptation to Cold Temperature." *Mol. Metab.* **2013,** In press.

13. Clift, M. J.; Rothen-Rutishauser, B. "Studying the Oxidative Stress Paradigm in Vitro: A Theoretical and Practical Perspective." *Methods Mol. Biol.* **2013,** *1028,* 115–133.

14. Clift, M. J. D.; Endes, C.; Vanhecke, D.; Wick, P.; Gehr, P.; R.P.F., S.; Petri-Fink, A.; Rothen-Rutishauser, B. "A Comparative Study of Different in Vitro Lung Cellculture Systems to Assess the Most Beneficial Tool for Screening the Potential Adverse Effects of Carbon Nanotubes." *Toxicol. Sci.* **2013,** *137,* 55–64.

15. Clift, M. J. D.; Endes, C.; Vanhecke, D.; Wick, P.; Schins, R. P. F.; Petri-Fink, A.; Rothen-Rutishauser, B. "Efficiency and Efficacy of Using a Sophisiticated 3d in Vitro System of the Human Epithelial Airway Barrier to Gain Insight into the Hazard Posed by Nanomaterials." *Toxicol. Lett.* **2013,** *200,* 146–147.

16. Clift, M. J. D.; Frey, S.; Endes, C.; Hirsch, V.; Kuhn, D. A.; B.D., J.; Wick, P.; Fink-Petri, A.; Rothen-Rutishauser, B. "Assessing the Impact of the Physical Properties of Industrially Produced Carbon Nanotubes Upon Their Interaction with Human Primary Macrophages in Vitro." *BioNanoMat* **2013,** *14,* 239–248.

17. Clift, M. J. D.; Raemy, D. O.; Endes, C.; Zulqurnain, A.; Lehmann, A. D.; Brandenberger, C.; Petri-Fink, A.; Wick, P.; Parak, W. J.; Gehr, P.; Schins, R. P. F.; Rothen-Rutishauser, B. "Can the Ames Test Provide an Insight into Nano-Object Mutagenicity? Investigating the Interaction between Nano-Objects and Bacteria." *Nanotoxicology* **2012,** *7,* 1373–1385.

18. Coulibaly, S.; Balkenende, D. W. R.; Balog, S.; Simon, Y. C.; Fiore, G. L.; Weder, C. "Mechanochemistry with Metallosupramolecular Poylmers." Submitted.

19. Coulibaly, S.; Roulin, A.; Balog, S.; Biyani, M. V.; Foster, E. J.; Rowan, S. J.; Fiore, G. L.; Weder, C. "Reinforcement of Optically Healable Supramolecular Polymers with Cellulose Nanocrystals." *Macromolecules* **2013,** In press.

20. Crowe, L. A.; Tobalem, F.; Gramoun, A.; Grosdemange, K.; Salaklang, J.; Redjem, A.; Petri-Fink, A.; Hofmann, H.; Vallée, J. P. "Improved Dynamic Response Assessment for Intra-Articular Injected Iron-Oxide Nanoparticles." *Magn. Reson. Med.* **2012,** In press.

21. Dechezelles, J. F.; Griffete, N.; Dietsch, H.; Scheffold, F. "A General Method to Label Metal Oxide Particles with Fluorescent Dyes Using Aryldiazonium Salts." Submitted.

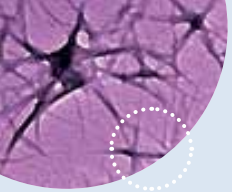
22. Diederich, V. E. G.; Studer, P.; Kern, A.; Lattuada, M.; Storti, G.; Sharma, R. I.; Snedeker, J. G.; Morbidelli, M. "Bioactive Polyacrylamide Hydrogels with Gradients in Mechanical Stiffness." *Biotechnol. Bioeng.* **2013,** *110,* 1508–1519.

23. Endes, C.; Mueller, S.; Schmid, O.; Vanhecke, D.; Foster, E. J.; Petri-Fink, A.; Rothen-Rutishauser, B.; Weder, C.; Clift, M. J. D. "Risk Assessment of Released Cellulose Nanocrystals-Mimicking Inhalatory Exposure." *J. Phys.: Conf. Ser.* **2013,** *429,* 012008.

24. Endes, C.; Schmid, O.; Kinnear, C.; Muller, S.; Camarero Espinosa, S.; Vanhecke, D.; Foster, E. J.; Petri-Fink, A.; Rothen-Rutishauser, B.; Weder, C.; Clift, M. J. D. "A Systematic in Vitro Approach Towards Mimicking the Inhalation of High Aspect Ratio Nanoparticles." Submitted.

25. Fiore, G. L.; Rowan, S. J.; Weder, C. "Optically Healable Poylmers." *Chem. Soc. Rev.* **2013,** *42,* 7878–7288.

26. Foderà, V.; Zaccone, A.; Lattuada, M.; Donald, A. M. "Electrostatics Controls the Formation of Amyloid Superstructures in Protein Aggregation." *Phys. Rev. Lett.* **2013,** *111,* 108105.



27. Griffete, N.; Clift, M. J. D.; Lamouri, A.; Digigow, R.G.; Mihut, A. M.; Fink, A.; Rothen-Rutishauser, B.; Dietsch, H. "Amino covalent binding approach on iron oxide nanoparticle surface: Toward biological applications." *Colloids and Surfaces A: Physicochemical and Engineering Aspects* 2012, *415,* 98–104.

28. Guignard, F.; Lattuada, M. "Asymmetrically Functionalized Polymeric Dumbbells." *Chimia* **2013,** *11,* 829–829.

29. Haberl, J.; Sanchez-Ferrer, A.; Mihut, A.; Dietsch, H.; Hirt, A.; Mezzenga, R. "Liquid-Crystalline Elastomer-Nanoparticle Hybrids with Reversible Switch of Magnetic Memory." *Adv. Materials* **2013,** *25,* 1787–1791.

30. Haberl, J. M.; Sanchez-Ferrer, A.; Mihut, A.; Dietsch, H.; Hirt, A. M.; Mezzenga, R. "Strain-Induced Macroscopic Magnetic Anisotropy from Smectic Liquid-Crystalline Elastomer-Maghemite Nanoparticle Hybrid Nanocomposites." *Nanoscale* **2013,** *5,* 5539–5548.

31. Haghpanah, J. S.; Tu, R.; Da Silva, S.; Yan, D.; Mueller, S.; Weder, C.; Foster, E. J.; Sacui, I.; Gilman, J. W.; Montclare, J. K. "Bionanocomposites: Differential Effects of Cellulose Nanocrystals on Protein Diblock Copolymers." *Biomacromolecules* **2013,** *14,* 4360–4367.

32. Harshe, Y. M.; Lattuada, M. "Breakup Dynamics of Colloidal Aggregates in Simple Shear Flow." Submitted.

33. Heinzmann, C.; Coulibaly, S.; Roulin, A.; Fiore, G. L.; Weder, C. "Light-Induced Bonding and Debonding with Supramolecular Adhesives." *ACS Appl. Mater. Interfaces* **2013,** In press.

34. Herzog, F.; Clift, M. J.; Piccapietra, F.; Behra, R.; Schmid, O.; Petri-Fink, A.; Rothen-Rutishauser, B. "Exposure of Silver-Nanoparticles and Silver-Ions to Lung Cells in Vitro at the Air-Liquid Interface." *Part. Fibre Toxicol.* **2013,** *10,* 11.

35. Hess-Dunning, A. E.; Hsu, L.; Capadona, J. R.; weder, C.; Rowand, S. J.; Tyler, D. J.; Zorman, C. A. "Mechanically-Adaptive Implantable Biosensors Using a Polymer Nanocomposite with Cotton-Derived Cellulose Nanocrystals." Submitted.

36. Heuking, S.; Rothen-Rutishauser, B.; Raemy, D. O.; Gehr, P.; Borchard, G. "Fate of Tlr-1/Tlr-2 Agonist Functionalised Pdna Nanoparticles Upon Deposition at the Human Bronchial Epithelium in Vitro." *J. Nanobiotechnol.* **2013,** *11,* 29.

37. Hirsch, V.; Kinnear, C.; Moniatte, M.; Rothen-Rutishauser, B.; Clift, M. J. D.; Petri-Fink, A. "Surface Charge Influences the Protein Absorption Kinetics, Colloidal Stability and Subsequent Cell Interaction of Polymer Coated Spions in Vitro." *Nanoscale* **2013,** *9,* 3723–3732.

38. Hirsch, V.; Salaklang, J.; Rothen-Rutishauser, B.; Petri-Fink, A. "Influence of Serum Supplemented Cell Culture Medium on Colloidal Stability of Polymer Coated Iron Oxide and Poystyrene Nanoparticles with Impact on Cell Interactions in Vitro." *IEEE Trans. Magn.* **2012,** *49,* 402–407.

39. Jorfi, M.; Roberts, M. N.; Foster, E. J.; Weder, C. "Physiologically Responsive, Mechanically Adaptive Bio-Nanocomposites for Biomedical Applications." *ACS Appl. Mater. Interfaces* **2013,** *5,* 1517–1526.

40. Jud, C.; Clift, M. J. D.; Petri-Fink, A.; Rothen-Rutishauser, B. "Nanomaterial and the Human Lung: What Is known and What Must Be Deciphered to Realise Their Potential Advantages?" *Swiss Medical Weekly* **2013,** 143:W13758.

41. Kinnear, C.; Dietsch, H.; Clift, M. J. D.; Endes, C.; Rothen-Rutishauser, B.; Petri-Fink, A. "Gold Nanorods - Controlling Their Surface Chemistry and Complete Detoxification by a Two-Step Place Exchange." *Angew. Chem., Int. Ed.* **2013,** *52,* 1934–1938.

42. Lattuada, M.; Del Gado, E.; Abete, T.; De Arcangelis, L.; Lazzari, S.; Diederich, V.; Storti, G.; Morbidelli, M. "Kinetics of Free-Radical Cross-Linking Polymerization: Comparative Experimental and Numerical Study." *Macromolecules* **2013,** *46,* 5831–5841.

43. Lee, S. H.; Lott, J. R.; Simon, Y. C.; Weder, C. "Melt-Processed Polymer Glasses for Low-Power Upconversion Via Sensitized Triplet–Triplet Annihilation." *J. Mater. Chem. C* **2013,** *1,* 5142–5148.

44. Lörcher, S.; Makyla, K.; Winkler, T.; Müller, C.; Eder, M.; Burgert, I.; Bruns, N. "Mechanical Unfolding of Fluorescent Protein Enables Self-Reporting of Damage in Carbon Fibre Reinforced Composites." Submitted.

45. Potter, K. A.; Jorfi, M.; Householder, K. T.; Foster, E. J.; Weder, C.; Capadona, J. R. "Curcumin-Releasing Mechanically Adaptive Intracortical Implants Improve Proximal Neuronal Density and Blood-Brain Barrier Stability." *Acta Biomater.* **2013,** In press.

46. Renggli, K.; Nussbaumer, M. G.; Urbani, R.; Pfohl, T.; Bruns, N. "A Chaperonin as Protein Nanoreactor for Atom Transfer Radical Polymerization." *Angew. Chem.* **2013,** *53,* 1443–1447.

47. Rodriguez-Lorenzo, L.; Fytianos, K.; Blank, F.; Von Garnier, C.; Rothen-Rutishauser, B.; Petri-Fink, A. "Fluorescence-Encoded Gold Nanoparticles: Library Design and Modulation of Cellular Uptake into Dendritic Cells." *Small* **2013,** In press.

48. Rothen-Rutishauser, B.; Kuhn, D.; Zulqurnain, A.; Gasser, M.; Faheem, A.; Parak, W.; Vanhecke, D.; Fink, A.; Gehr, P.; Brandenberger, C. "Quantification of Gold Nanoparticle Cell Uptake under Controlled Biological Conditions and Adequate Resolution." *Nanomedicine* **2013,** doi:10.2217/NNM.13.24.

49. Sacui, I. A.; Nieuwendaal, R.; Szmacinski, H.; Burnett, D.; Stranick, S.; Jorfi, M.; Weder, C.; Foster, E. J.; Olsson, R.; Gilman, J. W. "Nanocellulose Characterization." Submitted.

50. Saralegi, A.; Fernandes, S. C. M.; Alonso-Varona, A.; Palomares, T.; Foster, E. J.; Weder, C.; Eceiza, A.; Corcuera, M. A. "Shape-Memory Bionanocomposites Based on Chitin Nanocrystals and Thermoplastic Polyurethane with a Highly Crystalline Soft Segment." *Biomacromolecules* **2013,** *14,* 4475–4482.

51. Saralegi, A.; Foster, E. J.; Weder, C.; Eceiza, A.; Corcuera, M. "Thermoplastic Shape-Memory Polyurethanes Based on Natural Oils." *Smart Mater. Struct.* **2013,** In press.

52. Schulze, M.; Michen, B.; Petri-Fink, A.; Kilbinger, A. "Bis-Tegylated Poly(P-Benzamide)S: Combining Organo-Solubility with Shape-Persistence." *Macromolecules* **2013,** *46,* 5520–5530.

53. Steiner, S.; Czerwinski, J.; Compte, P.; Müller, L.; Heeb, N.; Mayer, A.; Fink, A.; Rothen-Rutishauser, B. "Reduction in (Pro-) Inflammatory Responses of Lung Cells Exposed in Vitro to Diesel Exhaust Treated with a Non-Catalyzed Diesel Particle Filter." *Atmos. Environ.* **2013,** 117–124.

54. Steiner, S.; Czerwinski, J.; Comte, P.; Müller, L.; Heeb, N.; Mayer, A.; Petri-Fink, A.; Rothen-Rutishauser, B. "A Low Oxidation Diesel Particle Filter Reduces (Pro-)Inflammatory Responses of Lung Cells to Diesel Exhaust Exposure in Vitro." Submitted.

55. Steiner, S.; Czerwinski, J.; Comte, P.; Popovicheva, O.; Kireeva, E.; Müller, L.; Heeb, N.; Mayer, A.; Fink, A.; Rothen-Rutishauser, B. "Comparison of the Toxicity of Diesel Exhaust Produced by Bio- and Fossil Diesel Combustion in Human Lung Cell in Vitro." *Atmos. Environ.* **2013,** *81,* 380–388.

56. Vadrucci, R.; Weder, C.; Simon, Y. C. "Low-Power Photon Upconversion in Organic Glasses." *J. Mater. Chem.* **2013,** In press.

57. Wu, H.; Lattuada, M.; Morbidelli, M. "Dependence of Fractal Dimension of Dlca Clusters on Size of Primary Particles." *Adv. Colloid Interface Sci.* **2013,** *195–196,* 41–49.

Book Chapters:

58. Biyani, M. V.; Jorfi, M.; Weder, C.; Foster, E. J. "Light-Responsive Cellulose-Based Materials." In *Production and Applications of Cellulose Nanomaterials;* Postek, M. T., Moon, R., Bilodeau, M., Rudie, A., Eds.; TAPPI Press: 2013, p 129.

59. Camarero Espinosa, S.; Kuhnt, T.; Weder, C.; Foster, E. J. "Thermally Stable Cellulose Nanocrystals Isolated by Phosphoric Acid Hydrolysis." In *Production and Applications of Cellulose Nanomaterials;* Postek, M. T., Moon, R., Bilodeau, M., Rudie, A., Eds.; TAPPI Press: 2013, p 13.

60. Greenland, B. W.; Fiore, G. L.; Rowan, S. J.; Weder, C. "Healable Supramolecular Polymeric Materials." *In Healable Polymer Systems;* Hayes, W., Greenland, B. W., Eds.; RSC Publishing: Oxford, UK, 2013, p 224.

61. Poland, C. A.; Clift, M. J. D. "Nanoparticle-Lung Interactions and Their Potential Consequences to Human Health." In *Bio-Nanotechnology: A Revolution in Food, Biomedical and Health Sciences;* Bagchi, D., Bagchi, M., Mariyama, H., Shahidi, F., Eds. 2013, p 820.

62. Rothen-Rutishauser, B.; Kuhn, D. A.; Vanhecke, D.; Herzog, F.; Petri-Fink, A.; Clift, M. J. D. "Cellular Uptake and Intracellular Trafficking of Nanoparticles." Submitted.

63. Sapkota, J.; Roberts, M. N.; Kumar, S.; Weder, C.; Foster, E. J. "Melt Processing of Pvac-Cellulose Nanocrystal Nanocomposites." In *Production and Applications of Cellulose Nanomaterials;* Postek, M. T., Moon, R., Bilodeau, M., Rudie, A., Eds.; TAPPI Press: 2013, p 111.

64. Zellner R, Blechinger J, Bräuchle C, Hilger I, Janshoff A, Lademann J, Mailänder V, Meinke MC, Nienhaus GU, Patzelt A, Rancan F, Rothen-Rutishauser B, Stauber RH, Torrano AA, Treuel L, Vogt A. "Biological Responses to Nanoparticles." In: *Safety aspects of engineered nanomaterials.* Eds: Luther W, Zweck A. Panford Stanford Publishing Pte. Ltd. (2013).

CONFERENCES AND SEMINARS

AICHE Meeting 2013, San Francisco, CA, USA, 6–7 November 2013
Talk, "Nacre-like composite materials produced via magnetically-controlled phase separation of sol-gel process", M. Furlan, M. Lattuada
Talk, "Asymmetric functionalization of shape-anisotropic polymer nanoparticles", F. Guignard, M. Lattuada
Talk, "Aggregation rate of colloidal particles under reaction-limited conditions at high concentrations", M. Lattuada

American Chemical Society National Meeting, New Orleans, Louisiana, USA, 7–11 April 2013
Talk, "Optically-Triggered Healing and Adhesive Properties of Metallosupramolecular Materials", G. L. Fiore
Invited Talk, "Mechanically Adaptive Nanocomposites", C. Weder
Invited Talk, "From Light-Polarizing Films and Semiconducting Polymer Networks to Mechano-Healable Polymers", C. Weder
Invited Talk, "Photo-responsive mechanically adaptive bio-nanocomposites", E. J. Foster
Talk, "Sensitized Upconversion in Polymeric Glasses", R. Vadrucci, S.-H. Lee, Y. C. Simon, C. Weder
Talk, "Mechanically-Adaptive Materials for Direct Neural Interfaces", M. Jorfi, M. Roberts, E. J. Foster, C. Weder

American Chemical Society National Meeting, Indianapolis, IN, USA, 8-12 September 2013
Talk, "Mechanochemistry of Europium-Containing Metallosupramolecular Materials", Y. C. Simon, S. Coulibaly, D. W. R. Balkenende, S. Balog, G. L. Fiore, C. Weder

American Chemical Society Polymer Composites and High Performance Materials, Santa Rosa, CA, USA, 24 July 2013
Invited Talk, "Photo-responsive mechanically adaptive bio-nanocomposites", E. J. Foster

5th Annual meeting of the Swiss Society for Anatomy, Histology, and Embryology (SSAHE/SGAHE), Fribourg, Switzerland, 6 September 2013
Poster, "Effects of silver nanoparticles on precision-cut slices from rat lungs and an in vitro model of the human epithelial airway barrier", F. Herzog, S. Hirn, J. Diendorf, N. Haberl, F. Krombach, M. Epple, W. G. Kreyling, A. Petri-Fink, B. Rothen-Rutishauser

Bioorganische Chemie, Münster, Germany, 23–25 September 2013
Invited Talk, "Mechanochemistry in Metallosupramolecular Materials", G. L. Fiore

48th Bürgenstock Conference, Brunnen, Switzerland, 2 May 2013
Invited Talk, "Stimuli-Responsive Polymers based on Noncovalent Interactions", C. Weder

CCMX EU FP7 Project 'NanoDiara' Winter School, Kanderstag, Switzerland, 13 January 2013
Invited Talk, "Investigating the Risk of Nano – 'Nanotoxicology'", M. J. D. Clift
Invited Talk, "Nanomaterials – Surfaces & Cells", A. Fink

Chulalongkorn University, Bangkok, Thailand, 20 May 2013
Invited Seminar, "Healing Polymers with Light and other Stimuli", C. Weder

6th CLINAM Conference, Basel, Switzerland, 24 June 2013
Invited Talk, "Novel Biomedical Nanocarriers for a Controlled Interaction with Cells", B. Rothen-Rutishauser

19th Congress of International Society of Aerosol Medicine (ISAM), Chapel Hill, NC, USA, 6–10 April 2013
Invited Talk, "Nanoparticle Exposure of in vitro Epithelial Co-culture Cell Systems for Risk Assessment", B. Rothen-Rutishauser
Poster, "Effects of silver nanoparticles on precision-cut slices from rat lungs and an in vitro model of the human epithelial airway barrier", F. Herzog, S. Hirn, J. Diendorf, N. Haberl, F. Krombach, M. Epple, W. G. Kreyling, A. Petri-Fink, B. Rothen-Rutishauser

COST Action FP 1003: Impact of renewable materials in packaging for sustainability - development of renewable fibre and bio-based materials for new packaging applications, Bratislava, Slovakia 21 March 2013
Invited Talk, "Stimuli-responsive mechanically adaptive bio-nanocomposites based on cellulose nanocrystals", E. J. Foster

COST Action FP1003 Meeting, Bologna, Italy, 10 October 2013
Talk, "Aerogels made from CNCs", S. Mueller, E. J. Foster, C. Weder

COST training school, Budapest, Hungary, 25-27 September 2013
Talk, "Melt-processing of Cellulose Based Nanocomposites", J. Sapkota
Talk, "Optically Responsive Nanocomposites Based on Cellulose Nanocrystals", M. V. Biyani

CPC Grand Rounds Seminars, Helmholtz Zentrum München, Deutschland, Germany, 27 May 2013
Invited Talk, "Going 3D with lung cell models – the next cell culture generation for risk assessment of inhaled xenobiotics", B. Rothen-Rutishauser

CTI MedTech, Bern, Switzerland, 27 August 2013
Poster, "Reversible Adhesives based on Supramolecular Chemistry", C. Heinzmann, G. L. Fiore, C. Weder

CTI Micro-Nano Event, Basel, Switzerland, 24 May 2013
Invited Talk, "Mechanically Adaptive Polymer Nanocomposites ", E. J. Foster

Cutting Edge Microscopy Lectures, Microscopy Imaging Center Bern, University of Bern, Bern, Switzerland, 18 December 2013
Talk, "Laser scanning microscopy", B. Rothen-Rutishauser

Department of Chemical and Environmental Engineering, Polytechnic School of Donostia-San Sebastián, San Sebastián, Spain, 10 December 2013
Invited Seminar, "Engineering of novel smart materials for biomedical implants", E. J. Foster

Department of Chemistry, University of Bern, Bern, Switzerland, 18 April 2013
Invited Seminar, "Light Upconversion and Other Optical Tricks in Polymers", Y. C. Simon

Department of Materials, Eidgenössische Technische Hochschule (ETH), Zürich, Switzerland, 19 November 2013
Invited Seminar, "Smart nanocomposites materials for stress transfer determination", E. J. Foster

ECIS 2013, Sofia, Bulgaria, 3–4 September 2013
Talk, "Asymmetric functionalization of shape-anisotropic polymer nanoparticles", F. Guignard, M. Lattuada
Poster, "Nacre-like composite materials produced via magnetically-controlled sol-gel phase separation", M. Furlan, M. Lattuada

École supérieure de physique et de chimie industrielles de la ville de Paris (ESPCI ParisTech), Paris, France, 28 November 2013
Invited Seminar, "Fluorescent Protein Senses and Reports Mechanical Damage in Fibre-reinforced Polymer Composites ", N. Bruns

European Polymer Federation (EPF) Conference, Pisa, Italy, 16–21 June 2013
Talk, "Mechanochemistry of Supramolecular Materials Containing Metal-Ligand Crosslinks and Built-In Optical Sensors", G. L. Fiore
Poster, "Reinforcement of optically healable supramolecular polymers with cellulose nanocrystals", S. Coulibaly, S. J. Rowan, G. L. Fiore, C. Weder
Poster, "Reversible Adhesives based on Supramolecular Chemistry", C. Heinzmann, G. L. Fiore, C. Weder
Talk, "Stimuli Responsive Materials Based on Cellulose Nanocrystals Containing Nanocomposites", E. J. Foster
Poster, "Optical upconversion via triplet-triplet annihilation in a glassy amorphous polymer matrix", S.-H. Lee, J. Lott, Y. C. Simon, C. Weder
Poster, "Low-power photon upconversion in metalloporphyrin-doped 9,10-diphenylanthracene-based molecular glasses", R. Vadrucci, Y. C. Simon, C. Weder
Poster, "Optically-Responsive, Healable Cellulose Nanocomposites", M. V. Biyani, E. J. Foster, C. Weder
Talk, "Physiologically-Responsive Polymer Bio-Nanocomposites for Intracortical Implants", M. Jorfi, E. J. Foster, C. Weder
Poster, "Isolation of thermally stable cellulose nanocrystals by phosphoric acid hydrolysis", S. Camarero Espinosa, T. Kuhnt, E. J. Foster, C. Weder

49th European Toxicology Conference (EUROTOX), Interlaken, Switzerland, 1–4 September 2013
Poster, "Efficiency and efficacy of using a sophisticated 3D in vitro system of the human epithelial airway barrier to gain insight into the hazard posed by nanomaterials", M. J. D. Clift, C. Endes, D. Vanhecke, P. Wick, P. Gehr, R. P. F. Schins, A. Petri-Fink, B. Rothen-Rutishauser

EMPA Seminar, EMPA, St. Gallen, Switzerland, 12 June 2013
Invited Seminar, "Cellulose nanocrystals versus cellulose microfibers", E. J. Foster

EMPA Seminar, EMPA, St. Gallen, Switzerland, 31 October 2013
Invited Seminar, "Combining Polymers with the Functionality of Proteins: New Concepts for Atom Transfer Radical Polymerization, Nanoreactor and Damage Self-Reporting Materials", N. Bruns

ESS Science Symposium – Neutrons for Future Energy Strategies, Paul Scherer Institute, Villigen, Switzerland, 28 May 2013
Talk, "Nanostructure of the aqueous phase and impact on proton transport in radiation-grafted fuel cell membranes", S. Balog, U. Gasser, K. Jetsrisuparb, L. Gubler, G.G. Scherer

Fachhochschule Nordwestschweiz – Hochschule für Life Science, Muttenz, Switzerland, 21 October 2013
Invited Talk, "A 3D model of the human lung to mimic risk and opportunities of new inhalable drugs", B. Rothen-Rutishauser

Fribourg Chemical Society, Fribourg, Switzerland, 18 June 2013
Invited Talk, "Materials Design from Nanoparticles Self-Assembly: Brick and Mortar at the Nanoscale", M. Lattuada

FriMat-DAY, Marly, Switzerland, 4 July 2013
Talk, "Stimuli-Responsive Behavior of PVAc/PEG Blends", K. Gries, G. L. Fiore, C. Weder
Invited Talk, "Nanoparticle-protein complexation as seen by photon correlation spectroscopy", S. Balog, B. Michen, L. Casal, P. Schurtenberger, A. Fink
Poster, "Reversible Adhesives based on Supramolecular Chemistry", C. Heinzmann, G. L. Fiore, C. Weder
Poster, "Nacre inspired composite materials produced via magnetically-controlled phase separation of sol-gel process", M. Furlan, M. Lattuada
Poster, "WORM-LIKE micelles as a template for polymerization", S. Rima, M. Lattuada
Poster, "Homopolymer blend nanoparticles and Super Paramagnetic Iron Oxide Nanoparticles confinement", F. Guignard, M. Lattuada
Talk, "Unbiased estimation of surface area and volume of single anisotropic gold nanostars", D. Vanhecke
Poster, "Cellulose nanocrystal aerosols: simulation of inhalation and interaction with lung cells in vitro", C. Endes, O. Schmid, C. Kinnear, S. Müller, S. Camarero Espinosa, D. Vanhecke, E. J. Foster, A. Petri-Fink, B. Rothen-Rutishauser, C. Weder, M. J. D. Clift
Poster, "Evaluation of inhibitors to investigate cell uptake mechanisms of nanoparticles", D. A. Kuhn, C. Jud, D. Vanhecke, M. J. D. Clift, A. Fink, B. Rothen-Rutishauser
Talk, "Optically-Responsive Nanocomposites via New Functionalized Cellulose Nanocrystals", M. V. Biyani

GDCh Seminar, University of Bayreuth, Bayreuth, Germany, 24 January 2013
Invited Seminar, "Exploiting Non-Covalent Interactions for the Design of Stimuli-Responsive Polymers", C. Weder

Gordon Research Conference, Self-Assembly & Supramolecular Chemistry, Les Diablerets, Switzerland, 5-9 May 2013
Poster, "Mechanochemistry in lanthanide-containing metallosupramolecular materials", Y. C. Simon, S. Couliabaly, D. W. R. Balkenende, S. Balog, G. L. Fiore, C. Weder

ICA Seminar, Salzburg Paris-Lodron University, Salzburg, Austria, February 2013
Invited Talk, "Nano-Genotoxicology: Deciperhing an enigma ", M. J. D. Clift

Inhaled Particles Conference XI, Nottingham, United Kingdom, 23-25 September 2013
Talk, "Impact of carbon nanotube physical properties upon their potential genotoxicity", M. J. D. Clift, C. Endes, D. Vanhecke, P. Wick, P. Gehr, R. P. F. Schins, A. Petri-Fink, B. Rothen-Rutishauser
Talk, "Hazard assessment of cellulose nanocrystal aerosols at the airliquid interface of lung cells in vitro", C. Endes, O. Schmid, C. Kinnear, S. Müller, S. Camarero Espinosa, D. Vanhecke, E. J. Foster, A. Petri-Fink, B. Rothen-Rutishauser, C. Weder, M. J. D. Clift

Institut de Science et d'Ingénierie Supramoléculaires, Strasbourg, France, 7 October 2013
Invited Seminar, "Mechanically Responsive and Optically Active Polymers", Y. C. Simon

10th International Conference on Nanosciences and Nanotechnologies, Thessaloniki, Greece, 9–12 July 2013
Talk, "Surface functionalization of gold nanoparticles influences cellular uptake but it has not effect in the functional properties of human dendritic cells", K. Fytianos, L. Rodriguez-Lorenzo, E. Seydoux, F. Blank, C. von Garnier, A. Petri-Fink, B. Rothen-Rutishauser

8th International Congress and Exhibition: Forum Life Science. Munich, Germany, 31–14 March 2013

Invited Talk, "Bio-Inspired Mechanically Responsive Polymer Nanocomposites for Medical Applications", E. J. Foster

10th International Particle Toxicology Conference, Düsseldorf, Germany, 4–7 June 2013

Talk, "Mimicking inhalation of cellulose nanocrystal aerosols: Investigation of their interaction with lung cells at the air-liquid interface in vitro", C. Endes, O. Schmid, C. Kinnear, S. Müller, S. Camarero Espinosa, D. Vanhecke, E. J. Foster, A. Petri-Fink, B. Rothen-Rutishauser, C. Weder, M. J. D. Clift

International Soft Matter Conference, Rome, Italy, 15–19 September 2013

Poster, "Mechanochemistry in Materials with Metal-Ligand Supramolecular Crosslinks", G. L. Fiore, S. Coulibaly, D. W. R. Balkenende, S. Balog, Y. C. Simon, C. Weder

International Symposium on Stimuli-Responsive Materials, Santa Rosa, CA USA, 20 October 2013

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

Institute of Food, Nutrition and Health, ETH, Zurich, Switzerland, 10 December 2013

Invited Seminar, "Nanomaterials and cells – pros and cons", B. Rothen-Rutishauser

Institute of Inorganic Chemistry, University of Zürich, Zürich, Switzerland, 1 November 2013

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

IRG44 annual meeting, Stockholm, Sweden, 16–20 June 2013

Poster, "Impregnation and distribution studies of model nanoparticles in wood", C. Geers, L. Rodríguez-Lorenzo, P. Brodard, B. Grobety, B. Rothen-Rutishauser, T. Volkmer, A. Fink

Jiao Tong University, Shanghai, China, 8 May 2013

Invited Seminar, "Stimuli-Responsive Polymers based on Noncovalent Interactions", C. Weder

Invited Seminar, "Design of safe nanomaterials – From concept to application!", B. Rothen-Rutishauser, A. Fink

Joint Annual Meeting of the Swiss Society of Allergology and Immunology and the Swiss Respiratory Society, Bern, Switzerland, 17–19 April 2013

Talk, "Functionalized gold nanoparticles to modulate the immune response in human lung dendritic cells", K. Fytianos, L. Rodriguez-Lorenzo, E. Seydoux, F. Blank, C. von Garnier, A. Petri-Fink, B. Rothen-Rutishauser

JUM@P'13 – Opportunities for Energy Research, Paul Scherer Institute, Villigen, Switzerland, 19 September 2013

Invited Talk, "Small-angle scattering studies of graft-copolymer electrolytes", S. Balog

Microscopy conference 2013, University of Regensburg, Regensburg, Germany, 25–30 August 2013

Poster, "Unbiased estimation of surface area of single gold nanostars", D. Vanhecke, B. Michen, B. Rothen-Rutishauser, A. Fink

Poster, "Preventing aggregation of nanoparticles during the drying procedure of TEM sample preparation", D. Vanhecke, L. Rodriguez-Lorenzo, C. Kinnear, B. Rothen-Rutishauser, A. Fink

MRC Graduate Symposium, ETH Zurich, Zurich, Switzerland, 13 June 2013

Poster, "WORM-LIKE micelles as a template for polymerization", S. Rima, M. Lattuada

MRS Spring Meeting 2013, San Francisco, CA, USA, 3 April 2013

Invited Talk, "Bio-Inspired, Stimuli-Responsive, Mechanically Adaptive Polymer Nanocomposites for Cortical Electrodes", C. Weder

MRS Fall Meeting 2013, Boston, MA, USA, 1–6 December 2013

Talk, "Physiologically-Responsive Drug-Releasing Materials For Neural Interfaces", M. Jorfi, K. A. Potter, K. T. Householder, E. J. Foster, J. R. Capadona, C. Weder

Nanosafe 2013, Saarbrücken, Germany, 21 November 2013

Invited Talk, "Detection of nanomaterials at the single cell level – do and don'ts", B. Rothen-Rutishauser

Nanotech 2013, Washington DC, USA, 15 May 2013

Talk, "Self-assembled Magnetic Silica Nano-rods and Micro-platelets as smart reinforcements for polymer-composites", M. Furlan, M. Lattuada

National Institute of Standards and Technology (NIST), Gaithersburg, MD, USA, 15 April 2013
Invited Seminar, "Stimuli Responsive Nanocomposites Based on Functionalized Cellulose Nanofibers", E. J. Foster

Net Nano Basel, Basel, Switzerland, 26 March 2013
Invited Talk, "Nanoparticles self-assembly and its Applications to the Design of Novel Materials", M. Lattuada

Nolax AG, Sempach, Switzerland, 14 January 2013
Invited Seminar, "Exploiting Non-Covalent Interactions for the Design of Stimuli-Responsive Polymers", C. Weder

Novartis, Basel, Switzerland, 9 September 2013
Invited Talk, "The Bio-nano-interface – towards a fundamental understanding on how tailor-made nanomaterials interact with (lung) cells", B. Rothen-Rutishauser, A. Fink

NRP62 kick-off meeting, Murten, Switzerland, 31 May 2013
Talk, "Smart vesicles for drug delivery", C. A. Monnier

NRP64 progress meeting, Lausanne, Switzerland, March 2013
Poster, "Mimicking the inhalatory exposure to cellulose nanocrystals", C. Endes, O. Schmid, C. Kinnear, S. Müller, S. Camarero Espinosa, D. Vanhecke, E. J. Foster, A. Petri-Fink, B. Rothen-Rutishauser, C. Weder, M. J. D. Clift
Talk, "Nanotechnology in the service of wood preservation", C. Geers

NRP 66 Resource Wood- Progress Meeting, Magglingen, Switzerland, 18 April 2013
Talk, "Melt processing of polymer/cellulose nanocrystal nanocomposites", J. Sapkota, A. Nicharet

PARTEC 2013, Nurnberg, Germany, 23–25 April 2013
Talk, "Facile Synthesis of Silica Micro- and Nano-rods", M. Furlan, M. Lattuada
Poster, "Encapsulation of magnetic silica rods in polymer matrices", M. Furlan, M. Lattuada

2nd Precision Polymer Materials (P2M) Conference, Ghent, Belgium, 27 August 2013
Invited Talk, "Stimuli-Responsive Supramolecular Polymers ", C. Weder

Polycoll, Basel, Switzerland, 7 July 2013
Invited Talk, "Fabrication of Anisotropic Porous Silica Monoliths by Means of Magnetically Controlled Phase Separation in Sol–Gel Processes", M. Furlan, M. Lattuada
Poster, "Mechanochemistry with Metallosupramolecular Polymers", S. Coulibaly, D. W. R. Balkenende, Y. C. Simon, G. L. Fiore, C. Weder
Invited Talk, "Janus Magnetic Liposomes", A. Fink, C. Monnier, C. Kinnear

Powder Technology Workshop, Leysin, Switzerland, June 2013
Invited Talk, "What nanoparticles can do with biological cells", A. Fink

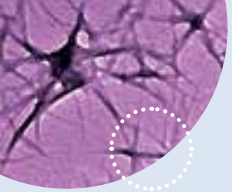
2nd QualityNano Conference, Prague, Czech Republic, 27 February – 1 March 2013
Talk, "Carbon Nanotube – Lung Cell Interactions In Vitro", M. J. D. Clift, C. Endes, D. Vanhecke, P. Wick, P. Gehr, R. P. F. Schins, A. Petri-Fink, B. Rothen-Rutishauser

SAOG meeting, Fribourg, Switzerland, January 2013
Talk, "Depolarized Dynamic Light Scattering (DDLS) to Investigate Nanoparticle-Protein Interactions", B. Michen, L. Casal, S. Balog, P. Schurtenberger, A. Fink

SoftComp Annual Meeting, Rimini, Italy, 27–30 May 2013
Talk, "Metallosupramolecular Polymers: From Self-Healing Materials to Reversible Adhesives and More", G. L. Fiore
Talk, "Nanoparticle-protein complexation as seen by photon correlation spectroscopy", S. Balog, B. Michen, L. Casal, P. Schurtenberger, A. Fink

SPP1313 Thematischer Workshop 7: Nanoparticle-cell interactions: Limitations, challenges and pitfalls, Adolphe Merkle Institute, Marly, Switzerland, 14 July 2013
Talk, "Nanoparticle-protein complexation as seen by photon correlation spectroscopy", S. Balog, B. Michen, L. Casal, P. Schurtenberger, A. Fink
Talk, "Colloidal engineering: Controlled nanoparticles synthesis, surface functionalization and design of hybrid nanoparticles", J.-F. Dechézelles
Talk, "Silver Nanoparticles at the air-liquid interface", F. Herzog
Talk, "Nanomaterials", A. Fink

Swiss Aerosol Group (SAG) 8th Meeting, Bern, Switzerland, 18 November 2013
Talk, "An innovative bio-printing platform to engineer lung tissue", L. Horvath



Swiss Chemical Society (Snow symposium), Saas-Fee, Switzerland, 11–13 January 2013
Talk, "Isolation of thermally stable cellulose nanocrystals by phosphoric acid hydrolysis", S. Camarero Espinosa, T. Kuhnt, E. J. Foster, C. Weder

Swiss Chemical Society Fall Meeting, EPFL Lausanne, Switzerland, 6 September 2013
Talk, "Nacre-like composite materials produced via magnetically-controlled phase separation of sol-gel process", M. Furlan, M. Lattuada
Poster, "Simulations of Breakage and Restructuring of Colloidal Aggregates in the Presence of Repulsive Interaction", Z. Ren, M. Lattuada
Poster, "Preparation of novel composite materials via CO-Coagulation of NPs", S. Rima, M. Lattuada
Poster, "Asymmetric functionalization of shape-anisotropic nanoparticles", F. Guignard, M. Lattuada
Poster, "Low-power photon upconversion in molecular glass materials", R. Vadrucci, Y. C. Simon, C. Weder

Swiss-Japanese Université de Montpellier, Institut Charles Gerhardt, Montpellier, France, 12 December 2013
Invited Seminar, "Mechanically Responsive and Optically Active Polymers", Y. C. Simon

Swiss MNT, Lugano, Switzerland, 26 September 2013
Invited Talk, "Materiali compositi a matrice polimerica ottenuti tramite co-aggregazione di nanoparticelle", M. Lattuada

Swiss Nano Convention, Basel, Switzerland, 23–24 May 2013
Poster, "Assessing the impact of the physical properties of industrially produced carbon nanotubes upon their interaction with lung cells in vitro", M. J. D. Clift, S. Frey, C. Endes, V. Hirsch, D. A. Kuhn, P. Wick, A. Petri-Fink, B. Rothen-Rutishauser

Swiss Soft Days, Paul Scherer Institute, Villigen, Switzerland, 4 March 2013
Poster, "Magnetic silica platelets produced in rotating magnetic field", M. Furlan, M. Lattuada
Poster, "WORM-LIKE micelles as a template for polymerization", S. Rima, M. Lattuada-
Poster, "Synthesis of Anisotropic Dumbbell Nanoparticles by Seeded Emulsion Polymerization", F. Guignard, M. Lattuada
Invited Talk, "Microstructure Manipulation in Porous Materials via Magnetically-controlled Phase Separation", M. Lattuada

Swiss Soft Days, University of Fribourg, Fribourg, Switzerland, 4 June 2013
Talk, "Functional iron oxide nanoparticles as reversible cross-links for magnetically addressable shape-memory polymers", Y. C. Simon

Swiss Soft Days, University of Bern, Bern, Switzerland, 12 September 2013
Poster, "Simulations of Breakage and Restructuring of Colloidal Aggregates in the Presence of Repulsive Interactions", Z. Ren, M. Lattuada
Poster, "Smart vesicles for drug delivery", C. A. Monnier, C. Bonnaud, D. Demurtas, D. Vanhecke, X. Montet, H. Vogel, A. Fink

Swiss Tropical and Public Health Institute, Basel, Switzerland, 28 February 2013
Invited Talk, "Risk assessment of inhaled (nano)particles using an advanced 3D model of the human lung", B. Rothen-Rutishauser

2013 TAPPI International Conference on Nanotechnology for Renewable Resources, Stockholm, Sweden, 23 June 2013
Invited Talk, "Thermally Stable Cellulose Composites", E. J. Foster

4th Technology Apéro NRP 62, Smart Materials in Electronics and Medicine, CSEM, Neuchâtel, Switzerland, 18 November 2013
Poster, "Smart vesicles for drug delivery", C. A. Monnier, C. Bonnaud, D. Demurtas, D. Vanhecke, X. Montet, H. Vogel, A. Fink

Technology Briefing: Intelligente Materialien – Unsere neuen Helfer im Alltag, EMPA, Dübendorf, Switzerland, 2 June 2013
Poster, "Smart vesicles for drug delivery", C. A. Monnier, C. Bonnaud, D. Demurtas, D. Vanhecke, X. Montet, H. Vogel, A. Fink

TEDD Workshop, St. Gallen, Switzerland, 14 March 2013
Invited Talk, "A 3D model of the human epithelial airway barrier – are we already done?", B. Rothen-Rutishauser

Tissue Engineering Practical Course, ARTORG, Universität Bern, Bern, Switzerland, 15 February 2013
Talk, "Lung regeneration – 3D models of the human epithelial airway and alveolar barrier", B. Rothen-Rutishauser

Trends in Micro Nano – Swiss MNT Network, Fribourg, Switzerland, 27 June 2013
Invited Talk, "Innovative Nanomaterialen – Risiken und Anwendungen", B. Rothen-Rutishauser

Universität Freiburg, Freiburg, Germany, 14 April 2013
Invited Seminar, "Sophisticated lung cell models combined with air-liquid exposures to (nano)particles – a new tool for the risk assessment of inhaled xenobiotics", B. Rothen-Rutishauser

University of Freiburg, Freiburg, Germany, 26 June 2013
Invited Seminar, "Exploiting Non-Covalent Interactions for the Design of Stimuli-Responsive Polymers", C. Weder

University of Mons, Mons, Belgium, 28 November 2013
Invited Seminar, "Stimuli-Responsive Metallosupramolecular Polymers ", C. Weder

Universität Salzburg, Salzburg, Austria, 14 January 2013
Invited Seminar, "Nano and the lung – good or bad?", B. Rothen-Rutishauser

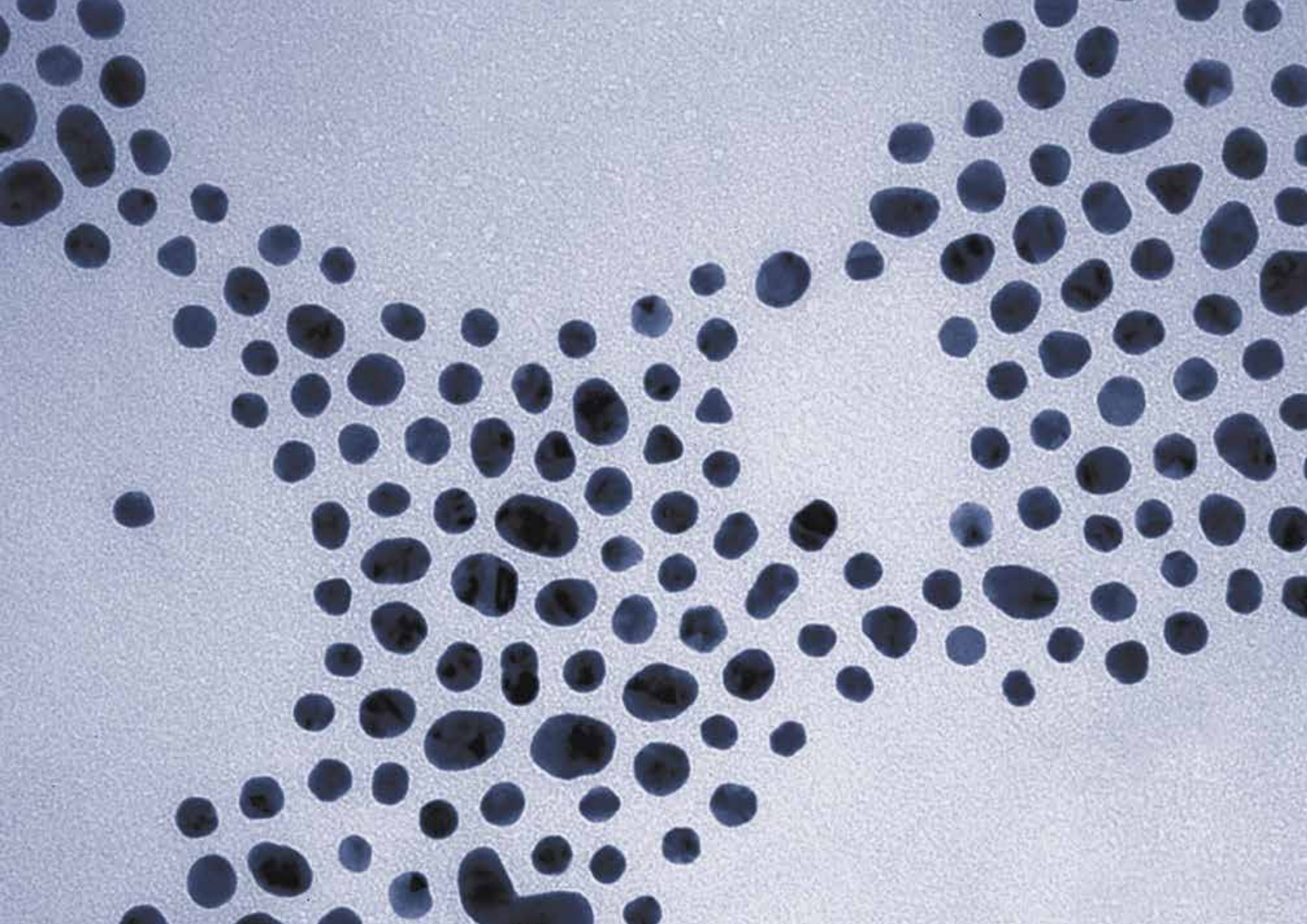
Université de Strasbourg, Institut Charles Sadron, Strasbourg, France, 8 October 2013
Invited Seminar, "Playing with Force, Magnets and Light", Y. C. Simon

Volksschule Oberaargau, Langenthal, Switzerland, 23 October 2013
Invited Talk, "Nanotechnologie: Chancen und Risiken", C. A. Monnier, D. A. Kuhn

2013 Winter Training School: Use of nanopolysaccharides in Biobased Packaging. Grenoble INP PAGORA, Grenoble, France, 11 December 2013
Invited Talk, "Smart materials based on cellulose nanocrystals: How to make a better plastic", E. J. Foster

Workshop on "NANOSCIENCE: Materials Phenomena at Small Scale", Tsukuba, Japan, 11 October 2013
Invited Talk, "Bio-Inspired, Stimuli-Responsive, Mechanically Adaptive Polymer Nanocomposites", C. Weder
Invited Talk, "Nanomaterials at the bio-interface: risk assessment of silver nanoparticles released into the environment", F. Herzog

World Immune Regulation Meeting VII, Davos, Switzerland, 13–16 March 2013
Poster, "Dendritic cells as a target for specifically designed gold nanoparticles – can we modulate the immune response?", K. Fytianos, L. Rodriguez-Lorenzo, E. Seydoux, F. Blank, C. von Garnier, A. Petri-Fink, B. Rothen-Rutishauser



Pictures

Front cover:
Christophe A. Monnier, Jean-François Dechézelles: Monolayer of silica particles pictured by atomic force microscopy (AFM).

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Christian Heinzmann: A thin film of a supramolecular polymer melted between two glass slides.

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Olivier Pravaz: TEM image of a network of surface functionalized silica nanoparticles and PMMA fibers (also known as Plexiglas). Some silica nanoparticles are also visible as individual or small chain arrangements.

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Christoph Geers: SEM micrograph of polystyrene beads covered with silica nanoparticles.

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Sandra Camarero: SEM image of mineralized poly (D,L) lactic acid / phosphated cellulose nanocrystals composites upon exposure to simulated body fluid.

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Yoan Simon: Optical micrograph of 9, 10-bis (phenylethynyl)anthracene crystals in the presence of surfactants.

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Mahesh Biyani: TEM image tof cotton cellulose nanocrystals (CNCs) functionalized with ureidopyrimidone.

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Calum Kinnear: Gold nanoparticles stabilized with a surface grafted polymer.

Photos of AMI staff and "Clinic Garcia" taken by Dr. Sandor Balog.

Impressum
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