ANNUAL REPORT 2010

adolphe merkle institute
excellence in pure and applied nanoscience

UNIVERSITY
OF FRIBOURG
SWITZERLAND

Summary

Message from the director

Christoph Weder
Director and Professor for Polymer Chemistry and Materials

«You really have a turbulent year behind you and a difficult one ahead», was how a member of our faculty opened a recent email to me. «No on both counts», I wrote back. Given that the public-private partnership on which our institute is built is a unique experience for Switzerland, I am overall very pleased about how things have developed this past year, and I certainly have all the reasons to be excited about the future!

Yes, the beginning of the last year, when my colleague, Peter Schurtenberger, resigned from his posts as AMI Director and head of the Soft Nanoscience department, was indeed quite turbulent. But the ensuing dialogue among our major stakeholders quickly afforded a new governance structure that was implemented in record time and is serving us well. AMI now has the formal status of an independent institute of the University of Fribourg, whose scientific, administrative, and strategic leadership rest with its directors. A new Institute Council, composed of representatives of the University of Fribourg and the Adolphe Merkle Foundation, provides oversight and serves as a platform in which our main stakeholders can dialogue. In addition, an independent external advisory board composed of scientists with outstanding international reputations advises the Institute Council and AMI directors in strategic and scientific questions. I am honored to be able to serve as AMI's new director and am grateful for the confidence and outstanding support that I have received since I took the helm.

Throughout the year, my team has worked relentlessly to keep AMI on its course to becoming a leading competence center for fundamental and applied interdisciplinary research in the field of soft nanomaterials, and I am proud of what we have achieved. We created a strategic plan that will help guide the development of our institute over the next few years. We started the hiring processes for two new chairs in the areas of Bio-Nanomaterials and Soft Matter Physics. This will add two new research departments to the institute and roughly double the size of our team within a year. Our support team has grown together so that our operations are almost on autopilot. Our group leaders have done an incredible job to keep existing research programs on track and to initiate new projects. Their hard work has resulted in a large number of outstanding scientific papers, several of which can already be classified as being of very high impact. Their efforts were also rewarded with an unexpectedly high level of new external funding. I am particularly proud of several highly competitive grants from National Research Programs of the Swiss National Science Foundation and am equally happy to point to a record number of new industrial research contracts. As these and many other achievements documented in this annual report are the result of great teamwork, I am optimistic that they not only reflect upon the past year, but are also a leading indicator for our institute's bright future!

At AMI, we all recognize the value of partnerships and are once again grateful for the interest, courtesy, and support that we receive from our partners. We will continue to work hard to be a valuable and reliable partner in the future, and to make relevant contributions to both science and society.

Professor Dr. Christoph Weder
Director

Implementation of AMIs strategic plan 2010–2015

Early last year, AMI put the final touches on its first strategic plan, which will guide the institute's development and activities over the next five years, and which provides the context for its core values: excellence and impact through teamwork, entrepreneurialism, and accountability. Its implementation is already well underway and every major new initiative and expenditure is critically reviewed in the light of the question, «Will it support the institute's strategic goals?»

Focus on soft nanomaterial science

The general field of nanoscience is vast and with its limited size, AMI can't be all things to all people. Therefore, the institute's activities are focused on a more narrowly defined field, soft nanoscience, in which it is likely to make a significant impact, achieve distinction, and exploit synergies through partnership with other units of the University of Fribourg. Indeed, the University has a strong track record in the area of soft matter that reaches back a long time, and the theme «Nanomaterials» has earned itself a prominent place in the University's strategic plan «Strategie 2020 der Universität Freiburg». But AMI's focus on soft nanomaterials also has other strategic reasons. This field is emerging as a scientific topic of significant interest, and spans across many disciplines and holds great technological relevance for many business sectors. As an actual (as opposed to virtual) competence center, AMI's focus on soft nanomaterials is unmatched in Switzerland, as well as in many other countries.

Mission: We conduct strategically oriented and programmatically focused scholarly research and develop new technologies. We study and apply nano-based and nano-structured materials. We focus on a soft nanotechnology approach that is based on bottom-up principles, self-assembly, and fab-less nano strategies.

Interdisciplinary collaborations are key

Uniting researchers from different disciplines, but with overlapping interests, and encouraging interdisciplinary collaborations both within the institute and with other research groups inside and outside the University are the most important strategies in support of AMI's vision and goals. The ongoing hiring processes for two new chairs in the areas of Bio-Nanomaterials and Soft Matter Physics are conducted with this notion, and provide a unique opportunity to build a cohesive research team that is greater than the sum of its parts.

Combination of fundamental and application-oriented research

Stimulated by the vision of the founder, Adolphe Merkle, AMI combines fundamental research with application-oriented research. The key idea of this rather unique proposition is to exploit synergies that arise through the dual role of «early-stage research», which makes it possible, to advance science and generate basic intellectual property at the same time. It allows AMI researchers to focus on what «researchers do well», and limits the risks arising from disconnect with markets. To support this approach, AMI has created its own technology transfer service, which differentiates itself from most of its peers in that its most important role is to actively foster partnerships with industrial partners that result in true win-win situations.

Ambitious budget model

In support of AMI's strategic plan, an ambitious budget model, which seeks to increase the limited funding from the Adolphe Merkle Foundation and the University to support a critical institute size of about 120 researchers and an appropriate support team, was established. The budget provides for a significant level of base funding for each research department, which must be complemented by a significant amount of external funding. Mechanisms that encourage an entrepreneurial mode of operation, calculated risk-taking, and alignment with the institute's vision and mission are under development.

Vision: AMI strives to be a leader in fundamental and applied interdisciplinary research in soft nanoscience. Our research stimulates innovation, fosters industrial competitiveness, and improves the quality of life.

By following its strategic plan, AMI will

- Build a world-class research program in soft nanomaterials science
- Establish international recognition as a top player in its field
- Stimulate innovation through generation and transfer of knowledge
- Become a preferred partner for academic peers and industry – locally and globally
- Become a desirable destination for graduate students and junior researchers
- Contribute to the development of the University of Fribourg, especially its faculty of sciences

Three years in the making, AMI is already on a great trajectory. The execution of this strategic plan will further foster the creation of an environment where collaboration serves as the basis for discovery and innovation.

A summary of the strategic plan can be found at: http://www.am-institute.ch/en/Communication/documents

Highlights 2010

In the year 2010, AMI witnessed further development of the institute, considerable growth of its research programs, and well-deserved recognition for research and researchers.

New Director

In March 2010, Prof. Christoph Weder was appointed as the new director of the Adolphe Merkle Institute.

Participation in National Research Programs 62 and 64

AMI researchers won three competitive grants to participate in new National Research Programs of the Swiss National Science Foundation. In the program NFP 62 «Smart Materials», Prof. Christoph Weder and Dr. Johan Foster work on «Bio-inspired mechanically adaptive nanocomposites» and Dr. Hervé Dietsch on «Magnetic elastomers for actuators» in collaboration with ETH Zürich. In the program NFP 64 «Opportunities and Risks of Nanomaterials», Prof. Christoph Weder and Dr. Johann Foster study «Cellulose-based nanocomposite building materials: solutions and toxicity» in collaboration with Dr. Martin Clift of the University of Bern.

Considerable external funding

AMI attracted new awards and industrial contracts in the amount of ca. CHF 2 Mio..

Distinguished awards for AMI researchers

Several of AMI's collaborators received prestigious grants from the Swiss National Science Foundation to continue their research careers: Dr. Ilja Voets (Ambizione), Dr. Najet Mahmoudi (Advanced Researchers Fellowship), and Vikash Malik (Postdoctoral Fellowship). Nicolas Dorsaz, who obtained his PhD degree from EPFL (École Polytechnique Fédérale de Lausanne) and worked closely with Dr. Anna Stradner's research group at AMI, received special recognition for his PhD thesis on «A colloidal approach to eye lens protein mixtures: relevance for cataract formation».

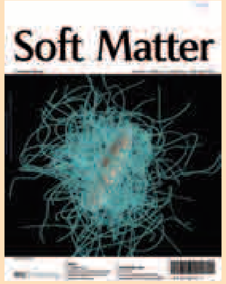
In early 2010, Dr. Julie Mendez, a former Post-Doc at AMI, was appointed assistant professor at McNeese State University, Lousiana, USA.

High impact research

An article on multiresponsive hybrid microgels combining thermo-responsiveness and optical and magnetic responses made the cover of the May issue of Soft Matter. This article, which was based on a collaboration between Prof. Peter Schurtenberger and Dr. Hervé Dietsch of AMI and Prof. Frank Scheffold and Dr. Camille Dagallier in the physics department of the University of Fribourg, was one of the top ten most-read articles from the online version of Soft Matter for several months.

An article on the restructuring of casein proteins in the yoghurt-making process was selected for the front cover of «Langmuir». The structure of yoghurt is formed by an aggregated network of milk proteins, the caseins. Thus far, it was assumed that casein undergoes internal restructuring upon acidification, although the exact mechanism was unclear. With a combination of light and x-ray scattering, Prof. Peter Schurtenberger, Dr. Christian

Impressions from the Micronarc Forum 2010, an event that was co-organized by the Nanotechnology Network.



Front cover of the Journal SoftMatter in May 2010 (courtesy of RCS Publishing).

Impression from the Fribourgissima conference 2010.

Moitzi, and Dr. Anna Stradner of the AMI research team, in collaboration with Dr. Andreas Menzel of the Paul Scherrer Institute, were able to separate the different processes and increase the understanding of one of the most important food proteins.

An article on stimuli-responsive, mechanically adaptive polymer nanocomposites, which highlights research results of Prof. Christoph Weder and collaborators from Case Western Reserve University, was among the most accessed articles from the 2010 issue of ACS journal Applied Materials & Interfaces.

Fribourgissima Congress

Under the title «Fribourg and the megatrends of the 21st century», the first congress of the association Fribourgissima took place on September 19th at the University of Fribourg. Approximately 300 participants from politics, economy, and academia attended this event. Prof. Christoph Weder had the opportunity to present the activities of the Adolphe Merkle Institute.

Impact of the Nanotechnology Network

Since the foundation of this regional network, which has the mission to facilitate industry access to profitable and responsible nanotechnology applications, the direct contact with more than 40 enterprises has been established, and in 2010, more than 110 people attended the different events and workshops of the network. The companies also made use of multiple services offered by the competence center that is grouped around AMI. These services included the conducting of technology assessments, allocation of expertise and infrastructure, organization of networking events, mediation of workgroups, and execution of preliminary studies and R&D projects.

Technology Transfer Office Fribourg

In May, the Adolphe Merkle Institute, the College of Engineering and Architecture Fribourg, and the University of Fribourg formalized their collaboration to form the association «Tech Transfer Fribourg». Tech Transfer Fribourg is the central contact point for all of the three partners' knowledge and technology transfer activities and provides services for the researchers and for external partners looking for collaborations.

COMBINING FUNDAMENTAL AND APPLICATION-ORIENTED RESEARCH

«If we knew what it was we were doing, it would not be called research, would it?» This famous quote by Albert Einstein pinpoints an important aspect of fundamental research: Sometimes, research is the search for and discovery of the unexpected. Many significant scientific breakthroughs are indeed related to the creation of groundbreaking knowledge. Having an open mind, being able to think outside the box, and the willingness to follow where research results lead are therefore important assets of successful researchers. This seems to contradict the needs of application-oriented research. But does it really?

Innovation means creating customer value

Nowadays, knowledge-based and research-driven innovation is viewed as the most important factor for the competitiveness of our western economy. However, the term «innovation» is not to be confused with «discovery» or «invention». To innovate means to create new customer value. It may therefore seem that innovation is much more goal-oriented than fundamental research. However, radical innovation has much in common with fundamental research, because it not only fulfills known customer needs, but also identifies new ways to provide customers with added value. For example, in 1908, Alan Archibald Campbell-Swinton described in 1908 how «distant electric vision» could be achieved by using a cathode ray tube as both a transmitting and receiving device. This invention clearly set the stage for the development of the television. At that time, his discovery was of little use, as it was not clear how such apparatuses could be mass-produced at a reasonable cost and, more importantly, how they could be useful to the general public and become the basis for a business. Consequently, it took many years until television became a successful commercial platform. The innovation involved engineers from several companies around the world who succeeded in developing technical solutions for viable products and broadcasting companies, and who put together the elements of programming and advertising to create a tangible benefit for viewers.

Aligning academic research with industrial needs …

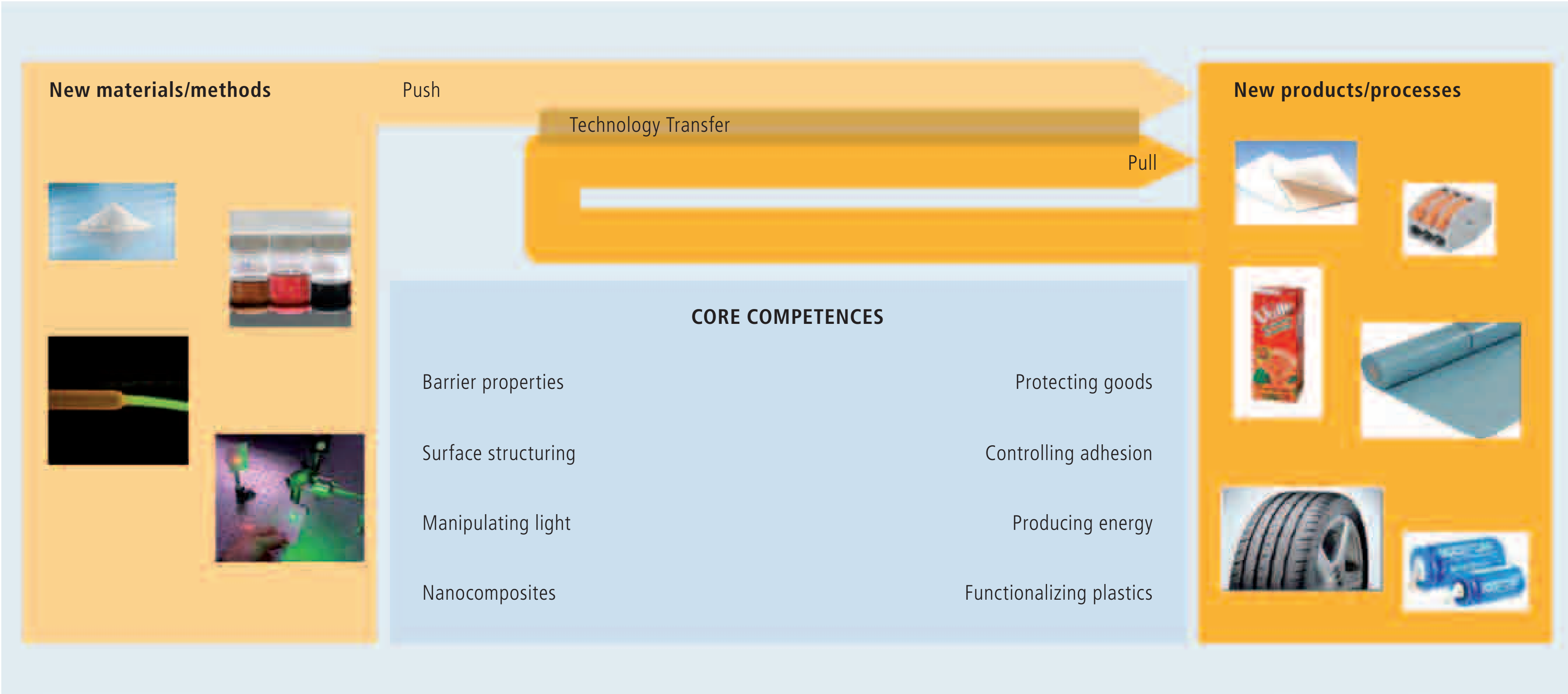
How can one strategically bring the rather distant worlds of fundamental research and business interests together to create maximum societal benefits, or in other words «customer value», on the basis of scientific and technological advancements? This question goes back to the roots of technology transfer in the 1940s, when U.S. President Franklin D. Roosevelt realized that academic research could play a key role to support the technological advancements that would improve society.

It was not until the 1960s that the U.S. implemented a policy on intellectual property, and inter-institutional patent agreements between federal funding agencies and a few universities that set the foundation for modern technology transfer. For the first time, universities were permitted to own the inventions they made under government-funded research. This ownership and the ability to grant exclusive licenses were instrumental in the willingness of private industries to license and develop university technology. The terms and provisions of the agreements led to the passage of Public Law 96 – 517, the Patent & Trademark Law Amendment Act (Bayh-Dole Act) in 1980.

In the 1980s, many universities in the US, and somewhat later also in Switzerland, started to formally exploit the knowledge generated in academic research by protecting the intellectual property generated by its researchers and transferring it to the industrial world, typically through licensing schemes. This form of technology transfer is often referred to as «technology push», since the university researchers are the main drivers who try to push their results into commercial exploitation. This approach has indeed resulted in the creation of many outstanding products and led to the birth of several highly successful companies, such as Cambridge Display Technologies, spun out of Cambridge University which develops flexible screens based on light emitting polymers. Another example is Prionics, a spin-off company from the University of Zurich that developed the first test for mad-cow disease and now is a world leader in farm animal diagnostics. Over time, and in parallel to the demise of industrial research labs that conducted fundamental or early-stage research, companies became more and more interested in university-based research. They intensified collaborations with academic researchers, provided support of their projects, and established endowed faculty positions at universities. Overall, they created a «technology pull» by directly or indirectly steering researchers to work on their

Invention New or improved process, machine, material, or service that claims to be both useful and not obvious to persons skilled in the particular field.

Innovation Invention that is replicable at an economical cost and satisfies a specific customer need.



Technology-push A technology push implies that a new invention is pushed onto the market by R&D, trying to identify or create a user need.

Market-pull An innovation based upon market pull has been developed by R&D in response to an identified market need.

unsolved problems. The now popular «open innovation» approach, in which companies actively solicit external ideas to advance their technologies, is a further expression of their intent to maximize the efficiency of their operations by drawing on the competences of outside partners.

…to create win-win situations

Is it the ultimate aim of the industry, then, to completely outsource research to universities? Is it the goal of universities to draw more and more research funding from industry while aligning their research programs with the sponsor's needs? The answer to both questions must be an emphatic «no». While it is a reality that industrial support of research programs at universities around the world has steadily increased over time, presumably because both partners benefit from this arrangement, it is likely that there is a point where the loss of independence and freedom negatively impacts the advantages on both sides. On the university's side, the creation of groundbreaking knowledge often depends on the availability of non-restricted funding that allows one to follow where research leads. On the flip side of the coin, industry needs to acquire and master the necessary core competences in house and must, at a certain point, be able to conduct the projects according to pure business considerations.

The question of how much industry funded or externally, programmatically directed research is acceptable without endangering the freedom of research, is a subject of controversial debates at universities around the world. In a recently published article in the December 2010 issue of Chemistry and Engineering, Professor Allen J. Bard of the University of Texas, a highly regarded capacity in his field, stated that «The culture of academic research has shifted over the past 50 years from research evaluation based on teaching, creativity, and productivity to one based simply on the amount of money (often now called «resources») raised». He adds «A more recent and potentially even more damaging trend is a growing expectation by universities that faculty should help fund operations not only through overhead from research grants, but also through the generation of intellectual property (IP)». Glenn D. Prestwich and Charles A. Wright, professors at the University of Utah, replied: «While the time consuming and often frustrating quest for research funding is a concern, the growing interest of universities in enterpreneurial activities is neither tragic nor greedy. Rather, it is a hopeful sign that universities have begun to recognize their true mission-to educate, motivate, and innovate. […] To this end, a new generation of faculty enterpreneurs has emerged: We identify and solve real-world problems, translate basic research into applied technology, and create products as well as publications. […] Rather than teaching only to the 5 % who will become professors and physicians, we provide real-world skills to the 95 % who will go on to become politicians, business owners, writers, and company scientists».

The AMI model

AMIs research strategy is based on the philosophy of exploiting synergies that arise through the dual role of «early-stage research», which allows one, if the research problems are cleverly selected, to advance fundamental science and generate results that are of value to industrial partners. To support this approach, AMI has created its own technology transfer service, which actively fosters partnerships with industrial sponsors. The key to success is to find a good compromise between the interests and competences of AMI researchers and the needs of the industrial partner, a process that often resembles the search for an appropriate public grant program. This approach is the basis for true win-win situations; the institute receives additional research funding and the involved companies gain a competitive advantage by exploiting the findings and know-how of the academicians. Another option is to leverage industrial funding with support from public sources, such as the Swiss Confederation's Commission for Technology and Innovation, or the Swiss National Science Foundation, which has recognized the value of this new form of public-private partnership. The fact that in 2010, approximately half of AMI's new third-party funding was attracted from industrial partners is, in combination with the institute's indicators that document a high level of fundamental scientific output, a clear indication for the success of this model.

AMI'S RESEARCH PROGRAMS 2010

Soft materials share the common characteristic of being easily deformable. Examples include liquids, colloids, gels, polymers, foams, and granular matter. Soft materials are the basis for many technological applications where they appear as plastics, rubbers, paints and adhesives, textiles, personal care products, cosmetics, foods, and many other forms.

From fundamental studies to advanced functional materials – an interdisciplinary approach

At AMI, scientists are combining bio-inspired self-assembly schemes with conventional chemical processes for the production of functional nanomaterials with well-defined properties. This approach represents an attractive and generally inexpensive route to nanostructured materials. The research ranges from the synthesis and in-depth characterization of nanoparticles to fundamental studies that aim to develop a predictive understanding of the interplay between nano-objects and their environment to the fabrication of nanocomposites and nanostructured materials. Complex architectures are created by directed self-assembly that incorporates features of bottom-up and top-down fabrication approaches, for example, template-assisted assembly processes or the use of external fields as a means to orient magnetic or charged nanoparticles. The knowledge generated in fundamental studies is applied to work on practical problems of high societal relevance.

In 2010, AMI's major research initiatives were:

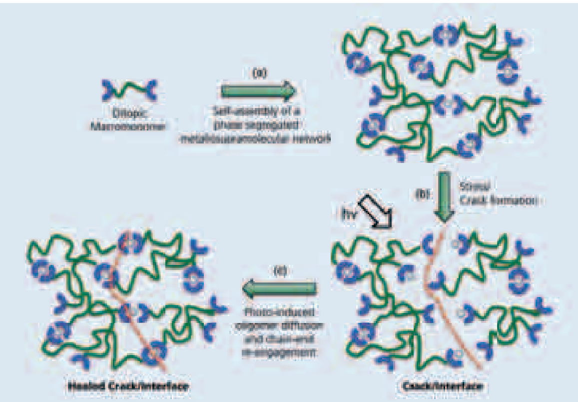
- **Fundamental condensed matter physics research with nanoparticles**
- **The exploration of analogies between soft matter physics and food science biology**
- **The investigation of protein aggregation**
- **The synthesis and use of functional nanoparticles**
- **The fabrication and study of bionanocomposites**
- **The preparation and investigation of mechanically adaptive materials**
- **The development and investigation of self-healing polymers**
- **The investigation of metal-containing materials with unusual optical properties**

Self-healing metallosupramolecular materials

Recently, AMI researchers and collaborators at Case Western Reserve University (USA) have developed a novel class of metallosupramolecular polymers, which can heal upon exposure to light.

Different approaches to create self-healing materials

Polymers that have the ability to repair themselves after sustaining damage are poised to improve the functionality and extend the lifetime of materials used in transportation, construction, packaging, and many other applications. Several approaches to the design of such materials have been proposed in the recent past, such as the incorporation of monomer-filled capsules, which release a liquid healing agent upon damage, into a polymer of interest. Alternatively, reversible chemical motifs can be used, such as moieties introduced by Diels-Alder reactions. Another approach is to liquefy the damaged polymer itself.

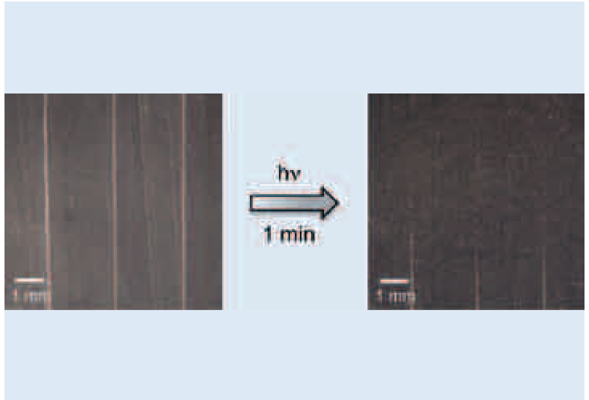


Schematic representation of the concept of healable materials based on light-responsive metallosupramolecular motifs.

Metallosupramolecular polymers – a new class of self-healing materials

The new family of self-healing materials introduced by AMI researchers and their collaborators are the first representatives of metallosupramolecular polymers in which mechanical damages are efficiently healed. This new class of organic-inorganic hybrid materials merges the structure of known polymer systems with the advantages of a dynamic (reversible) polymerization process. The materials were synthesized by the self-assembly polymerization of ditopic macromolecules via metal-ligand binding, allowing for access to materials that are otherwise difficult to process through conventional means. The resulting metal-coordinate linkages within the material are dynamic in nature. Taking advantage of the dynamic nature of the materials, light can be used to deliver heat locally, which facilitates the temporary disengagement of the metallosupramolecular motifs, concomitant with a reversible decrease in the molecular weight and viscosity of the polymer, thus leading to the healing of a damaged material. As a result, deliberately introduced defects heal quickly and with high efficiency upon exposure to ultraviolet light. Since light can be applied locally to the damage site, objects can be healed under load, and the dynamic binding scheme allows for repeated healing.

AMI researchers are continuing to explore this area further to develop a better understanding of the parameters that govern the mechanical properties, light responsiveness, and healing ability of metallosupramoleculear polymers.



Controlled photo-healing of a film of [Mebip2(Kraton)•Zn(NTf2)2]n with multiple scratches of different depth.

Contact: Dr. Gina Fiore

Water-acitvated shape-memory materials

With support from the Swiss National Science Foundation under the NFP 62 program «Smart Materials» and funding from several companies, AMI researchers pursue the creation of radically novel, mechanically adaptive materials, which respond to pre-determined stimuli with a pronounced change of their mechanical properties.

The mode of operation of a new shape-memory material

Last year, AMI researchers succeeded in developing a new type of material, which displays a shape-memory effect that can be triggered by exposure to water. Shape memory polymers (SMPs) are stimuli-responsive, or «smart», materials that have the ability to return from a temporarily deformed state to their original (permanent) shape when an external stimulus is applied. In the past, most researchers have worked on SMPs in which heat is used as a trigger. Such materials are first heated above a transition temperature, so that the shape can be changed from the original to a temporary shape, for example by stretching the material. This temporary shape can be «frozen» by cooling the material to below the transition temperature. When, at a later stage, the material is reheated above the transition temperature, it spontaneously contracts to regain its original shape. Such materials are useful for a diverse range of applications, such as cardiovascular stents that unfold upon implantation, or insulation foams used for building purposes that expand «on command» after put in place.

Artificial fishing lure, which starts to twitch once it is brought in contact with water.

Cellulose nanofibers do the trick

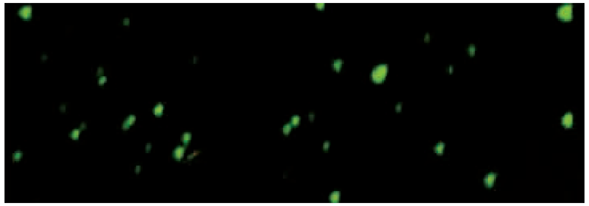
In particular, certain biomedical implants, but also other applications, would benefit from materials for which water could be used to trigger the transformation of an object from a temporary to a desired permanent shape. AMI researchers have now shown that this adaptive mechanical behavior can be achieved through a nanocomposite architecture, in which highly rigid cellulose nanofibers reinforce a soft, rubbery polymer matrix. The stiffness of the material is regulated by controlling the molecular interactions, and therewith the stress transfer, among adjacent nanofibers in the polymer. When the materials are dry, the nanofibers form a percolating network within the polymer matrix and are «glued together» by hydrogen bonding interactions. When the nanocomposite is exposed to water, the hydrogen bonds between the nanofibers are eliminated. This renders the material much softer, so that it can easily be deformed. The material is then dried in the deformed state, and newly reformed hydrogen bonds between the nanofibers fixate the «temporary» state. Subsequent exposure to water disrupts the hydrogen bonds once again, and the rubbery nature of the matrix polymer forces the material to relax to its original shape.

AMI researchers are currently exploring applications of such 'water-activated' shape memory polymers. A first example is an artificial fishing lure, which starts to twitch once it is brought in contact with water.

Contact: Dr. Johan Foster

Micro-sensors for the detection of volatile organic componds (VOCs)

Polymer beads capable of changing (fluorescence) color upon exposure to volatile organic compounds have been developed in collaboration between researchers at AMI and Case Western Reserve University (USA).



Fluorescence confocal microscopy image of dye-filled particles with an average particle size of 240 nm (picture width = 92 μm).

(Left) Picture of a glass slide covered with original sensor particles upon excitation with UV light.
(Right) Picture of the same sample after exposure to dimethylformamide vapors.

Color-changing dye at the core of a new sensor type

Exposure to volatile organic compounds (VOCs), of natural or artificial origin, can pose a significant risk to human and animal health. It can also pose a significant threat to non-living matter, ranging from electronic equipment to works of art. While the monitoring of VOCs is not a fundamental problem, low-cost «point-of-care» pollutant sensors and reader systems with responses correlated to pollutant and damage threshold values are desirable.

Simple, highly sensitive, irreversibly switching VOC sensors based on a novel approach were recently developed by AMI researchers. These sensors are comprised of a color-changing fluorescent dye that is dispersed in slightly cross-linked glassy polymer spheres with diameters of a few hundred nanometers. The materials are produced in a new manner that kinetically traps a thermodynamically unstable solution of molecularly dissolved dye molecules in the glassy polymer particles. In this state, the particles display the characteristic fluorescence color associated with well-individualized dye molecules. Since the polymer spheres employed are characterized by an exceedingly high surface area to volume ratio, they can rapidly absorb airborne organic compounds. This process offers some selectivity, because not all VOCs display the same solubility in different polymers. Upon swelling with VOCs, the polymer particles are plasticized and the increase in free volume and molecular mobility allows the dye molecules to aggregate. This causes dramatic changes of the (fluorescence) color, for example from green to red. Because the aggregation process is largely irreversible, the color change is permanent.

Paint-on sensor particles

AMI researchers have shown that this method can be used to detect the presence of high vapor pressure carcinogens such as chloroform in much less than a minute. Surprisingly, even VOCs with extremely low vapor pressure such as dimethylformamide can be detected. A distinct advantage of the new sensory materials is that they can be stored as highly stable aqueous particle dispersion in water, which can be applied to any surfaces through simple spraying techniques. Fluorescence confocal microscopy images of dye-filled particles show that the decoration of surfaces with well-spaced sensor particles is readily possible using this approach.

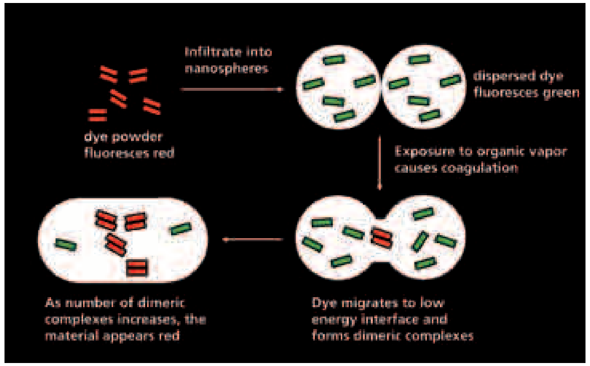


Diagram illustrating the operating mechanism for VOC-sensing nanospheres.

Initial studies suggest that confinement effects, related to the small dimensions of the particles, and changes of particle-particle interactions upon VOC exposure have a significant influence on the aggregation of dye molecules within the particles. AMI researchers are in the process of further probing these phenomena and of exploring the usefulness of the approach for specific applications.

Contact: Brian Makowski

Mechanochemistry in polymeric materials

Biological processes, such as cell-cell contacts, cell motility, or even haptic perception (touch), all rely on the conversion of mechanical stimuli into chemical energy. Building on their expertise in the field of mechano-responsive polymers, AMI researchers have recently launched a new research activity that aims to develop artificial materials that exhibit new functionalities through exploitation of chemo-mechanical transduction schemes.

Translating mechanical forces into chemical reactions

Despite the increasing number of smart materials, remarkably little effort has been put forth towards the elaboration of materials that convert mechanical stress into a useful response. The most prominent examples comprise materials whose absorption or emission change color with strain. In this context, AMI researchers have, in the past, introduced a pioneering approach that relies on the solubilization of dyes embedded in a polymer upon plastic deformation, resulting in pronounced color changes of the material. However, this strategy only offers access to mechanochromic responses. The now investigated approach of translating mechanical forces into chemical reactions has the potential to broaden the scope of mechanically responsive materials to a wide variety of previously unavailable functionalities, such as mechanically-controlled release of drug molecules, mechanical morphing, and cell growth.

Mechanoresponsive materials form the basis of an upcoming topical issue of the Journal of Materials Chemistry, which is guest-edited by AMI Professor Christoph Weder and scheduled to appear late spring 2011.

Weak polymer links – the key to success

As a first step to reach this ambitious goal, AMI researchers have taken on the challenge of conferring previously unknown mechanochemical properties to polymeric systems. Attaining this type of functionality is only possible through careful molecular design, i.e. the incorporation of judiciously placed «weak links» into polymer molecules. These «weak links» are designed to break upon mechanically deforming the material and are instrumental to bestow the desired properties upon the materials. In particular, strategies involving the incorporation of free radical generators, such as peroxides, have been chosen as a platform for this study. These radicals are then available for further reaction to generate a variety of responses. First proof-of-concept results have been successfully completed, demonstrating the feasibility of this general approach. AMI researchers will continue fundamental studies that seek to unravel the structure-property relationships at work behind this concept, while, at the same time, exploring the realization of previously unknown mechanically triggered responses.

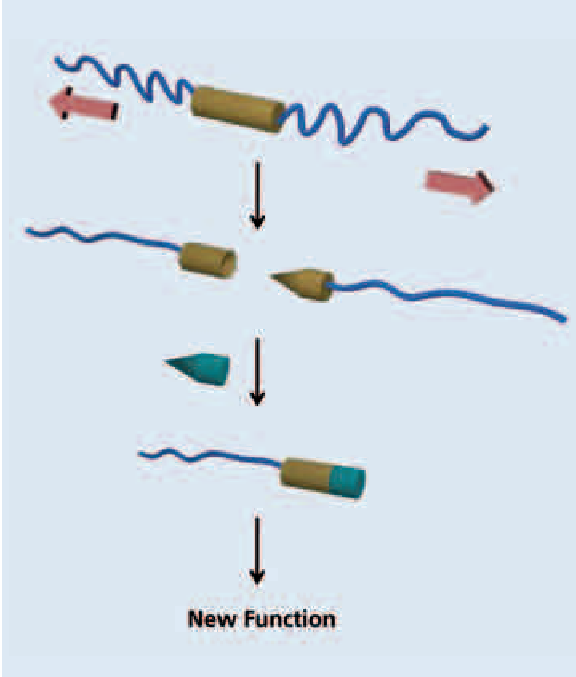


Diagram representing the operating principle of new mechanoresponsive polymers. Upon stretching a polymer chain, the «weak link» at its center breaks to form reactive species that can undergo subsequent chemical reactions with complementary reactants, resulting in new functions.

Contact: Dr. Yoan Simon

Research Programs | Polymer Cehmistry and Materials Department

Observing casein micelles on their way to yoghurt

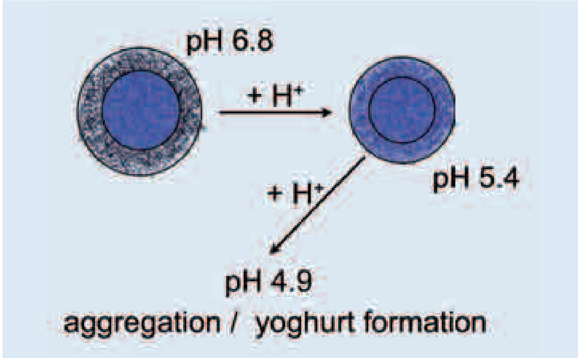
Skim milk seen with the eyes of a Soft Matter scientist is a colloidal suspension of so-called casein micelles. These are formed via self-assembly of casein proteins and calcium phosphate, which are dispersed in an aqueous solution of salts, sugar, and small proteins. This fascinating species – not only the main protein constituent of milk, but also one of the most investigated food colloids – exhibits a relatively broad size distribution around a mean radius of about 100 nm.

Separating the processes of self-assembly and aggregation

Its high stability stems from a surface brush of κ-caseins that prevent the casein micelles from aggregating. However, in various food processes, such as the production of yoghurt and cheese, it is essential that the caseins lose their colloidal stability and start to aggregate. In the yoghurt-making process, this is achieved by lowering the pH of the milk. Because of the shift in pH, the 'hairy' surface layer loses its stabilizing power and eventually collapses onto the surface of the micelle. For many years, numerous researchers have tried to understand the destabilization of casein micelles by making analogies to classical colloid models of aggregation and gelation. The biggest difficulty has always been the self-assembling nature of the casein micelles that respond in a highly complex way to variations of pH and salt. Using a combination of different scattering methods, AMI researchers have now been able to separate the processes of self-assembly and aggregation in the early stages of milk acidification for the first time. Specialized time-resolved measurements allowed them to clearly distinguish two parallel processes that describe the response of the casein micelles to a decreasing pH. The first process is the internal rearrangement of the casein micelles as a result of the pH shift. The driving forces for this are the dissolution of the calcium phosphate clusters that act as internal cross-links and the initial release and subsequent reassembly of some caseins during the acidification process. The continuous response of the casein micelles to the changing solvent conditions causes an immediate change of particle size, voluminosity, and aggregation number. The second process is the actual aggregation of multiple particles due to the collapse of the stabilizing electrosteric layer at a pH below 5.

For the first time, it is now possible to monitor the influence of the rate of acidification, the ionic strength, and the nature of the ions on micellar reassembly and intermicellar aggregation. The experiments conducted at AMI unambiguously demonstrate that both effects are virtually uncoupled and can be studied and understood independently.

References: [1] Christian Moitzi, Andreas Menzel, Peter Schurtenberger, Anna Stradner «The pH-Induced Sol-Gel Transition in Skim Milk Revisited – A Detailed Study Using Time-Resolved Light and X-Ray Scattering Experiments« Langmuir 2010, DOI: 10.1021/la102488g



Casein micelles on their way to yoghurt: During acidification, the casein micelles undergo drastic changes in respect to their size, mass, voluminosity, and internal structure. When the pH is below 5, they start to aggregate and form a space-filling gel – the yoghurt. [1]

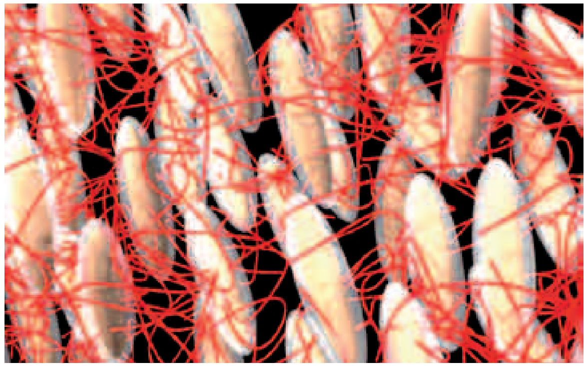
Contact: PD Dr. Anna Stradner

Nanoparticle based responsive materials

Inorganic-organic hybrid systems ideally combine the properties of nanoparticles and polymers. At AMI, a group of researchers is focusing on the design and creation of colloidal particles, the control of their surface chemistry, and their uses for fundamental (cf page 22) and applied research. The resulting nanomaterials are either hybrid nanocomposites, such as in bulk polymer materials, or hybrid colloidal particles, if the polymer is present as a small shell around the particles.

New memory-shape materials that respond to temperature, mechanical stress, and magnetic fields

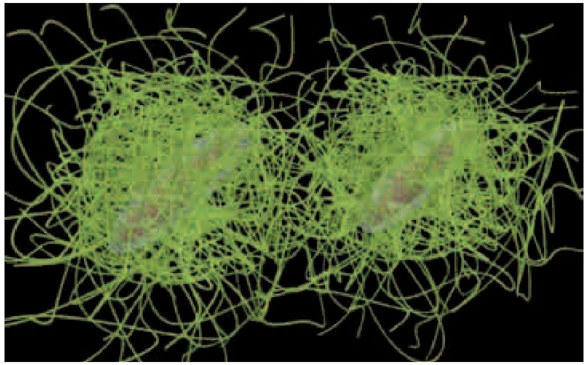
Micro- and nano-actuators are of high interest in the field of microdevice technology, e.g. in applications such as artificial muscles. In a project under the National Research Program NRP 62- «Smart Materials» of the Swiss National Science Foundation, the design of «smart» hybrid materials that are capable of responding to both temperature and magnetic external stimuli are created and studied at AMI. These hybrid materials constitute a new class of memory shape polymers, which can respond to external magnetic fields in a tunable manner. One big challenge in manufacturing these hybrid nanocomposites is the control of the integration of nanoparticles into polymer networks. In 2010, AMI researchers published two scientific articles concerning integration strategies of iron oxide nanoparticles in elastomeric matrices [1] and the resulting materials' properties [2], in a collaboration with a team at ETH Zürich. After the proof of a remarkably good well dispersity of the particles within the matrix, mechanical testing revealed that integration of only 1wt % of nanoparticles results in a 20 % enhancement of the elastic modulus of the resulting hybrid elastomers.



Schematic representation of silica coated hematite nanoparticles incorporated within an elastomeric matrix. The particles align their orientation due to the stretching of the elastomer [2].

Multiresponsive hybrid microgel particles

Dynamical arrest, i.e. glass or gel formation, can be studied using thermoresponsive microgels as ideal model systems. Interested in the arrest of rotational motion, AMI researchers designed novel hybrid microgel particles containing a magnetic spindle-shaped hematite core and investigated several aspects of dense microgel suspensions. It was possible to study the arrest of the rotational dynamics during the transition of the system into a glassy state in detail by taking advantage of the anisotropic magnetic cores. In an article that was published in Soft Matter and highlighted on the journal's front cover [3], a simple synthetic route to obtain these tunable particles was described, and a fundamental study on their rotational motion close to dynamical arrest was presented. These particles may have a considerable impact on fundamental investigations of the phase behavior of soft particles and as novel building blocks for responsive and switchable materials. This publication was the most downloaded paper of the journal in May and September 2010 and has also received positive reviews in the «Highlights» section of the journal «Chemical Science» in May 2010.



Cartoon illustrating the dual responsive thermal and magnetic hybrid particles.

References: [1] Sanchez-Ferrer, A.; Reufer, M.; Mezzenga, R.; Schurtenberger, P.; Dietsch, H. «Inorganic-Organic Elastomer Nanocomposites from Integrated Ellipsoidal Silica-Coated Hematite Nanoparticles as Crosslinking Agents». *Nanotechnology* **2010**, 21, 185603/185601-185603/185607.
[2] Sanchez-Ferrer, A.; Mezzenga, R.; Dietsch, H. «Orientational Behaviour of Ellipsoidal Silica-Coated Hematite Nanoparticles Integrated within an Elastomeric Matrix and its Mechanical Reinforcement» *Macromol. Chem. Phys.*, **2011,** DOI:10:1002/macp.201000720, **Front cover.**
[3] Dagallier, C.; Dietsch, H.; Schurtenberger, P.; Scheffold, F. «Thermoresponsive Hybrid Microgel Particles with Intrinsic Optical and Magnetic Anisotropy». *Soft Matter* **2010**, *6*, 2174-2177. **Front cover**

Contact: Dr. Hervé Dietsch

Structure-property relations of soft matter at interfaces

Interfaces play an essential role in technical processes, biological systems, and food products. Their importance increases further in the nano-world, as any material composed of nano-particles contains an exceedingly large internal interface area.

Soft matter at interfaces

Soft matter that is adsorbed to interfaces affects and determines interfacial properties, such as interface tension, softness, and response times to external perturbations. Of particular interest to AMI researchers in this context are polymers and surfactants, which can interact with macroscopic or microscopic interfaces encountered in colloidal particles. Soft matter structures on these particles prevent their aggregation in a solvent. This «colloidal stabilization» is the basis of any colloidal product, ranging from paints to sunscreen. The behavior of soft matter at interfaces thus strongly affects general material properties. For the design of materials beyond an empirical approach, AMI researchers seek to develop a physical understanding based on experimental access to interface structure and especially interfacial properties.

Investigation by optical techniques

The combination of several optical techniques allows for a comprehensive characterization of structure and properties.

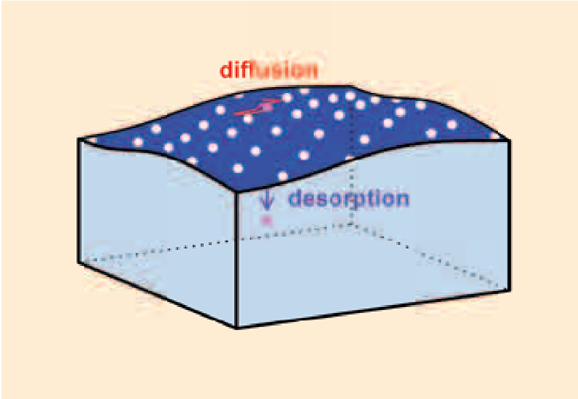


Figure 1: Schematic representation of the dynamics of charged colloidal particles adsorbed to a water/oil interface.

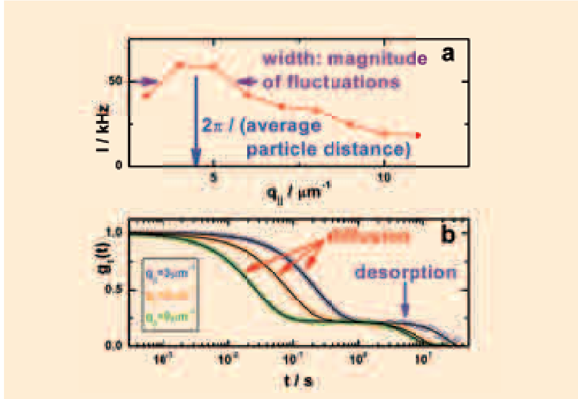


Figure 2: Structure (a) and dynamical properties (b) of an oil/water interface with adsorbed charged colloidal particles.

- Reflection techniques yield the thickness of interfacial structures. Ellipsometry is of special interest, as it has a high resolution in the nanometer range.
- Static interface light scattering provides the in-plane structure and the amplitude of its thermal fluctuations. The latter quantify the softness of the interfacial structures.
- Dynamic interface light scattering measures characteristic response times to perturbations within a broad time range.

As a combination of scattering measurements and ellipsometric detection, ellipsometric light scattering is able to detect layers on colloidal particles dispersed in water with nanometer resolution.

Optical techniques have a number of advantages: they are non-destructive, versatile, inexpensive, simple, and have a high sensitivity due to the large optical contrast.

Colloidal particles at an oil/water interface

Figures 1 and 2 illustrate how AMI scientists use optical techniques to investigate properties of soft matter at interfaces. Adsorption of colloidal particles is the basis of so-called Pickering emulsions, which provide a very long-lasting stabilization of unfavorable oil/water interfaces. Charged particles form a triangular lattice at the interface. The average particle distance and the extent of fluctuations can be determined by static interface light scattering. The in-plane mobility of particles via diffusion and the particle desorption are detected by dynamic interface light scattering. These dynamic properties determine the stability and response time of the interface.

Reference: [1] A. Stocco, T. Mokhtari, G. Haseloff, A. Erbe, R. Sigel «Evanescent Wave Dynamic Light Scattering at an Oil/Water Interface: Diffusion of Interface Adsorbed Colloids», Phys. Rev. E, DOI: 10.1103/PhysRevE.00.001600.

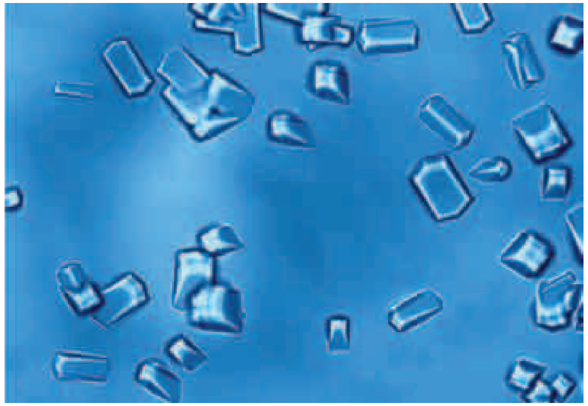
Contact: Dr. Reinhard Sigel

Routes to stability of concentrated protein mixtures

The stability of concentrated protein mixtures plays an important role in biology and in many fields of technology. With the use of physio-chemical methods, AMI researchers try to shed light on the factors that influence this stability.

Different types of phase transitions

Concentrated protein mixtures are ubiquitous in nature and widespread in many fields of technology. For example, living cells contain up to 300 mg ml-1 of thousands of different proteins in their intracellular fluid. An interesting new development in the food sciences concerns «high protein foods». These products contain large amounts of proteins and are thought to aid in the fight against obesitas and perhaps sarcopenia. While each organism or application may require a specific set of components and circumstances to function properly, perform optimally, or taste exquisitely, they certainly share one common requirement: stability. This is one of the biggest challenges in the field, as concentrated protein mixtures are prone to undergo many different types of phase transitions, such as crystallization, liquid-liquid phase separation, and complex coacervation.



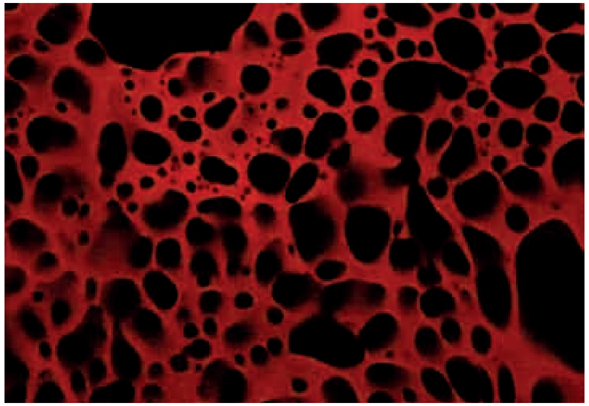
Lysozyme crystals grown from concentrated mixtures of lysozyme and α-lactalbumin visualized under a confocal laser scanning microscope.

The physico-chemical approach of studying phase behavior

AMI researchers use a combination of experimental methods including UV-Vis spectroscopy, confocal laser scanning microscopy, X-ray scattering, and optical microscopy to systematically investigate the phase behavior of several concentrated binary protein mixtures. Research experiments revealed that instabilities can be greatly suppressed by careful tuning of the salt concentration, pH, and protein composition. In the near future, the team hopes to connect these results to a theoretical framework to further enhance the understanding of the physics behind the rich and fascinating phase behavior of concentrated protein mixtures.

Into the future

In the long run, AMI researchers expect to use the lessons learned from these model systems to better understand why macroscopic phase transitions are rarely observed within the intracellular fluid of mammalian cells, the «cytosol». Its stability is remarkable, considering its contents: high concentrations of many thousands of different types of proteins and other macromolecules, differing in size, shape, mass, and charge.



Arrested associative phase separation in concentrated mixtures of lysozyme and α-lactalbumin visualized under a confocal laser scanning microscope.

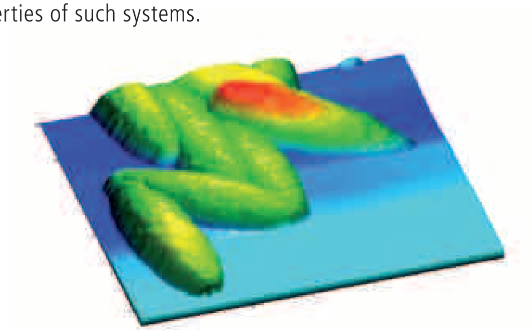
Contact: Dr. Ilja Voets

Anisotropic colloids

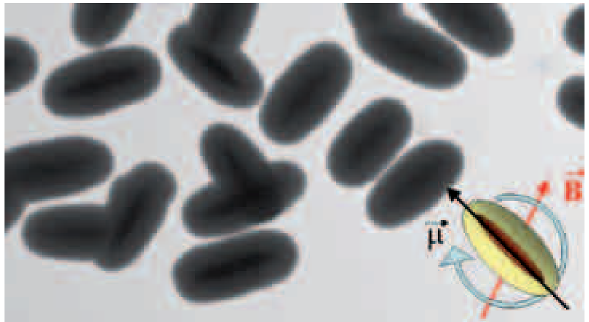
Colloidal particles are promising models for atomic or molecular systems. One can make them quite monodisperse and incorporate various features, such as tunable optical, mechanical, and magnetic properties. Their size shifts interesting physical processes and phenomena to time and length scales that are easily accessible with established methods from colloid physics. These investigations can therefore provide important insights into fundamental phenomena such as crystallization and glass formation.

A world of physical interactions in a single nanosystem

A comprehensive range of techniques, such as high-resolution electron microscopy, atomic force microscopy, or confocal laser scanning microscopy as well as light, neutron, or X-ray scattering and rheology, are available to study the characteristic properties of such systems.



Atomic force microscopy unveils the three-dimensional shape of the particles. They are, as recent light-scattering data shows, almost ideally monodisperse ellipsoids with rotational and translational dynamics allowing theoretical prediction with high precision.



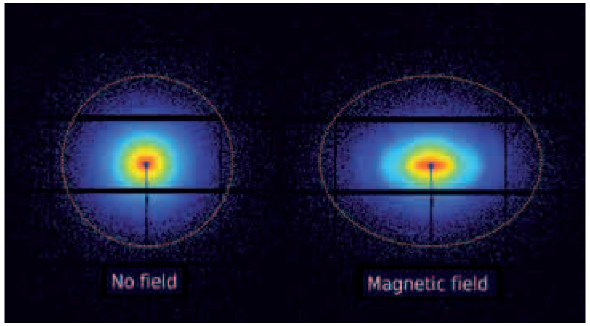
Hematite nanospindles are coated by porous amorphous silica. While the core provides magnetic anisotropy and establishes the initial morphology, the silica shell permits researchers to precisely tailor the size and shape.

AMI researchers from the Soft Nanoscience Department are working with several of such systems, ranging from magnetic colloidal hematite ellipsoids to hollow silica particles resembling egg shells, or even more complex systems incorporating several building blocks, each responsible for particular properties of the entire system.

Morphology, internal composition, shape anisotropy, and particle interactions of such colloids are tuned in a controlled way. It is now possible to successfully and quantitatively predict the physical behavior of such model particles using the theories established for «ideal» geometries.

Understanding the phase behavior of anisotropic colloids

Little systematic research has been done on the phase behavior of non-spherical colloids, partially due to the difficulties of tailoring their properties and finding a successful system combining low polydispersity and simultaneous control of shape and size. Progress made by AMI researchers in close cooperation with several groups, now primarily with Prof. Peter Schurtenberger's group at Lund University, provides a good foundation for reaching the long-term goal of better understanding the physics behind the ordering of highly concentrated colloids. With the accumulated results and experiences, experimental facilities, and the state-of-the-art experimental model systems, AMI scientists are uniquely positioned to tackle the study of the influence of interparticle interactions on structure and dynamics over a wide range of concentrations.



Small angle X-ray scattering provides insights into the form and structure of nanoscale systems. Without an applied magnetic field and under dilute conditions, particles are oriented randomly (left.) When a magnetic field is applied, the system may be ordered in a controlled way (right), as the magnetic response of the particles is established and tailored during the synthesis phase.

Contact: Ilya Martchenko

COLLABORATION BETWEEN AMI AND THE COLLEGE OF ENGINEERING AND ARCHITECTURE

One research group at AMI, namely that of Dr. Hervé Dietsch, studies different kinds of iron oxide nanoparticles and their incorporation in composite materials. After the first contacts with the professors and engineers at the Fribourg College of Engineering and Architecture (EIA-FR), it became obvious that both parties could benefit from the expertise of the other.

Synthesis of magnetic nanoparticles

After a semester project and two bachelor projects that sought to scale-up the synthesis of iron oxide nanoparticles developed at AMI in collaboration with the Fribourg College of Engineering and Architecture, an in-depth research program was launched. Thanks to funding from the Scientific Exchange Program SCIEX, a postdoctoral fellow from Poland, Dr. Izabela Bobowska, is now working on the control of the magnetic response of nanoparticles with fixed morphology in a joint project between the two institutions. Another recently initiated study is conducted in the form of a master thesis dedicated to the continuous production of nanoparticles in a flow-through microreactor.

Magnetic plastics

Another research project that is led by the EIA-FR researchers and funded by Fribourg's Reseau Plasturgie involves the incorporation of commercial magnetic microparticles in plastic injection molding processes. Such materials have lately gained a lot of interest from industry. Magnetic nanoparticles that were developed by AMI researchers promise significant advantages over current commercially available magnetic microparticles because they hold the promise that functional plastics with the desired properties could be made with a much lower particle content.

Dr. Hervé Dietsch, senior scientist at the Adolphe Merkle Institute, is convinced: «It is important to link fundamental research to products; the gap between both worlds is complex and involves quite a few factors like the economical viability and the up-scaling of the processes». As a research institute, AMI is able to create small quantities of new products based on a «bottom up» approach. The EIA-FR researchers take a much more practical approach by taking into account different key factors on the way to a commercial product, like cost reduction, improvement in synthesis yield, and scalability. Dr. Stefan Hengsberger, Physics Professor at the EIA-FR, who facilitated these collaborations, is excited about this development: «We started with rather modest collaborations, working a couple of days and then weeks together with AMI on semester or bachelor projects. The obtained preliminary results allowed us to understand where we can best create synergies».

Nanoparticles in microreactors

Another example involves Prof. Olivier Naef, head of the Chemistry Institute at the EIA-FR. His team acquired much knowledge in the development of continuous chemical reactions using low-cost micro-reactors. The original intent for these reactors was to use them to catalyze reactions by immobilized enzymes. In collaboration with AMI, the enzymes were grafted onto micro-sized silica beads, which significantly enhanced the catalytically active surface of the reactor.

It is foreseen to also use these micro-reactors for another purpose in the future, namely the synthesis of nanoparticles in continuous flow. Benoît Droz, a former student at the EIA-FR who also worked on some joint projects, comments, «Sometimes AMI members came to ask the engineers for help, sometimes it was the other way around. This is the base of a well working collaboration; AMI and EIA-FR are aware and understand what the other one does».

Microreactor developed with the HES-SO Call 2007 in collaboration with the HES-SO//Valais, the HE-Arc and the EIA-FR.

TEM image of silica micro-particles synthesized and characterized within the AMI and used as carriers for enzymes.

Contact: Dr. Hervé Dietsch

LIST OF RESEARCH PROJECTS

Projects financed by the Swiss National Science Foundation

Responsive colloids with soft and tunable potentials, 01.10.2009 – 30.09.2012, P. Schurtenberger, A. Stradner

This project concentrates on the use of an active control of the interaction potential between particles to reversibly cycle through different phase transitions and thus aims to explore not only the rich variety of structures that can form in these suspensions, but also to take advantage of this feature of responsive particles in order to create advanced materials with switchable functionality.

Interactions and phase behavior of colloid-polymer mixtures and the influence of charges, 01.04.2008 – 31.03.2011, A. Stradner

This project pursues the creation and characterization of a new aqueous model system with the objective to answer several of the open questions concerning the phase behavior of colloid-polymer mixtures, such as the influence of charges.

Fluctuations in colloidal coronas revealed by dynamic ellipsometric light scattering, 01.10.2009 – 30.09.2011, R. Sigel

This project aims to establish a new experimental technique to determine the softness and the rheological properties of polymers around colloidal particles. Such anchored polymers are used to stabilize colloidal materials against aggregation and precipitation. There is a high interest from industry for prediction tools for the long time stability of colloidal systems, since stability affects shelf lifetimes and concentration limits of products.

Antifreeze proteins in solution and at interfaces, 01.10.2010 – 30.09.2013, I. Voets

The goal of this project is to gain a deepened understanding of how antifreeze proteins function in vivo and to find links between functionality, solution, and adsorption behavior.

Bio-inspired mechanically responsive polymer nanocomposites, 01.01.2010 – 31.12.2012, C. Weder

This experimental research program targets the design, synthesis, processing, investigation, and application of a new family of bio-inspired polymer nanocomposites with stimuli-responsive mechanical properties. The program focuses on the fundamental aspects of cellulose nanowhisker-based mechanically adaptive composites, which are of interest for potential use for biomedical and other applications.

Smart Materials: magneto-responsive polymer nanocomposite actuators, 17.03.2010 – 30.11.2011, H. Dietsch

This project involves the development and integration of new iron oxide magnetic nanoparticles in a liquid-crystalline elastomeric matrix. This work is a collaborative effort between researchers at ETH Zürich and AMI, who are responsible for the liquid crystal monomer synthesis and the particle synthesis and integration strategy, respectively.

Cellulose-based nanocomposite building materials: solutions and toxicity, 01.12.2010 – 30.11.2013, C. Weder, J. Foster

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

Projects financed by the European Research Council

COST: Self-assembled photonic crystals from highly charged anisotropic core-shell particles, 01.02.2008 – 31.01.2011, P. Schurtenberger

The overall aim of this project is to develop a strategy for the synthesis of electrosterically stabilized, rod-like magnetic nanoparticles and to investigate their self-assembly into nanocomposites and highly ordered photonic crystals.

NanoModel: Multi-scale modeling of nano-structured polymeric materials: From chemistry to materials performance, 07.11.2008 – 31.12.2011, P. Schurtenberger, H. Dietsch
As part of this EU project, in which FIAT, Bosch and FZ Jülich participate as AMI's partners, AMI researchers develop strategies for the integration of silica and silica-coated nanoparticles synthesized by wet chemistry techniques, into a set of polymeric matrices using different approaches, such as in-situ and solvent integration.

Promix: Cluster, glass, and crystal formation in concentrated protein mixtures of opposite charges, 01.03.2009 – 28.02.2011, I. Voets
In this project, AMI researchers study cluster, glass, and crystal formation in concentrated protein mixtures of opposite charges. They examine similarities and differences between the phase behavior of these mixtures and single-component protein solutions and classical colloid model systems.

Projects financed by other public funding agencies

Photo-healable supramolecular polymers, US-Army, 01.07.2009 – 30.06.2012, C. Weder, G. Fiore
The goal of this project is the development and characterization of a novel class of metallosupramolecular polymeric materials which can be healed by exposure to light of an appropriate wavelength and intensity.

Projects financed by Industry

Get a grip, 07.01.2010 – 06.01.2013, C. Weder, J. Foster
This experimental research program focuses on the design, synthesis, processing, investigation, and application of novel bio-inspired, rubbery polymer nanocomposites with stimuli-responsive mechanical properties. The main objective of the program is to develop and investigate water-responsive rubbers that could form the basis for «smart» automotive (and other) tires with adaptive mechanical properties. These materials represent a possible advancement in tire technology.

Novel stereolithography materials for rapid prototyping, 01.10.2010 – 30.09.2011, C. Weder, J. Foster
This study elucidates if and how AMI's know-how can be used to improve the mechanical properties of the industrial partner's stereolithography resins for rapid prototyping.

Food physics, 01.02.2007 – 31.03.2010, A. Stradner, P. Schurtenberger
Analogies between well-defined model systems in colloid physics and much more complex food systems were drawn in order to advance our knowledge and understanding of colloidal food systems.

Epoxy resins with high thermal conductivity, 24.02.2010 – 30.09.2010, C. Weder
This experimental research program focused on the design, synthesis, processing, and investigation of heat-setting resins with high thermal conductivity.

Projects financed by the Adolphe Merkle Foundation

Dendronised polyelectrolytes, 01.12.2009 – 30.11.2010, P. Schurtenberger
Dendronised polyelectrolytes were analyzed with small angle scattering experiments to determine how the chain stiffness is influenced by the size and charge of the side chains that are attached to the polymer backbone.

Soft materials for light upconversion, 01.11.2009 – 30.11.2011, C. Weder, Y. Simon
This project targets the development of innovative polymeric materials that up-convert optical waves, or in other words, decrease the wavelength and increase the energy of the emitted light, with respect to the incident light. The possibility of creating materials capable of harnessing and manipulating light has major implications for a variety of technology domains ranging from harvesting solar energy and optical data storage to biomedical applications.

Mechano-chemistry, 15.02.2010 – 28.02.2013, C. Weder, Y. Simon

The proposed experimental research 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. These can be used to bestow polymers with unusual functionalities that were unavailable up until now, such as the mechanically-induced generation of light, heat, electricity, auto-lubricating behavior, the ability to release small molecules (e.g. drugs, fragrances, and antiseptics), or even the capability to cause self-degradation.

Photonic crystals from microgels with adjustable optical properties, 01.12.2009 – 31.12.2010, P. Schurtenberger

Optical properties of colloidal photonic crystals made with pure microgel particles or core-shell particles were investigated using spectroscopy experiments. The photonic bandgaps were characterized as a function of temperature or concentration of particles in order to cover a wide wavelength range.

Dynamic Photonic Crystals, 01.01.2010 – 31.12.2010 C. Weder, M. Geuss

Organic-semiconductor hybrid photonic crystals (PhCs) with well defined patterns of pores, individually filled with fluorescence or non-linear optical chromophores, are a highly interesting new class of switchable optical devices. This collaborative research project with ML University Halle-Wittenberg, University of Osnabrueck, and Karlsruhe Institute of Technology aimed to design chromophores with specific optical properties and to study and develop a predictive understanding of their (oriented) crystallization inside individual pores of a PhC, which represents an important step towards the creation of dynamic PhC.

Programs financed by the Adolphe Merkle Foundation

Structure, dynamics, and assembly of core-shell microgels, H. Dietsch

The synthesis of spherical colloidal core-shell microgels and their «nanoengineering» in novel ellipsoidal, hollow hemispheroidal, or facetted architectures, which are responsive to temperature, are being studied. In addition, the structure, dynamics, and supracolloidal assembly of this new class of materials are being explored.

Eye lens proteins and cataract formation, A Stradner

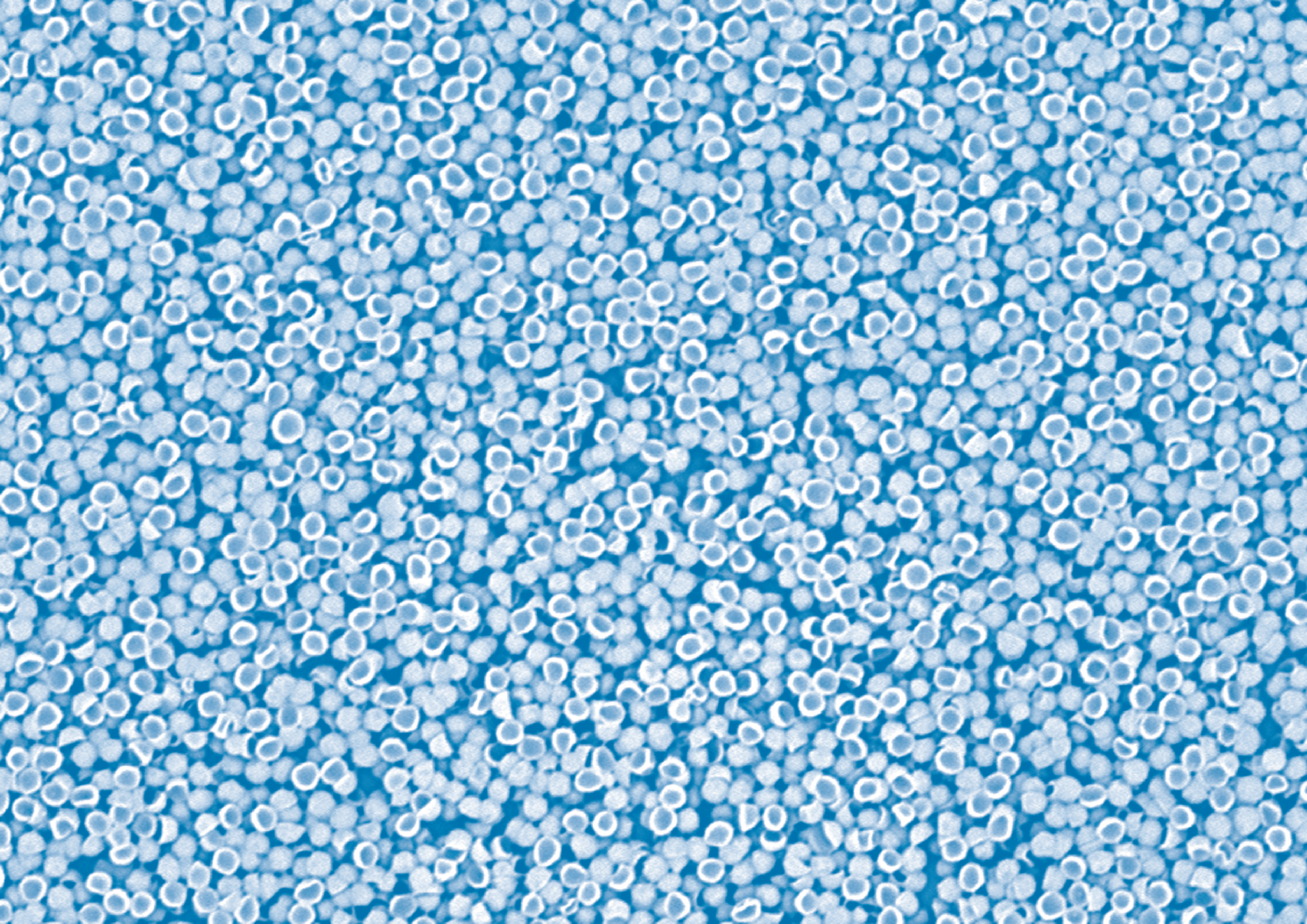
The goal of this project is to better understand eye lens transparency and cataract formation. AMI researchers are investigating the structural, dynamic, and viscoelastic properties of eye lens proteins up to concentrations corresponding to those found in the lens. Small-angle X-ray scattering experiments, light scattering experiments, and phase behavior studies are used in order to shed light on the behavior of eye lens crystallines as a function of various solvent parameters.

Effect of electrostatic interactions on the casein-poly (ethylene oxide) phase diagram in the colloid limit, A. Stradner

As most food systems contain food colloids with residual charges, such as caseins, the relevant interparticle interactions that drive phase separation and arrest are therefore not only dominated by hard core repulsion and a short range attraction, but also contain an additional contribution from a screened Coulomb repulsion that can also result in additional phenomena, such as the formation of equilibrium clusters. AMI researchers therefore work on the phase diagram of casein–poly (ethylene oxide) mixtures and the resulting equilibrium and non-equilibrium structures with a special emphasis on the effect of electrostatic interactions on phase separation and gelation using diffusing wave spectroscopy and confocal laser scanning microscopy.

Light scattering at interfaces, R. Sigel

Many processes in technical applications, biology, and everyday life involve aqueous interfaces. Soft matter, such as polymers, surfactants, or colloids adsorbed to such interfaces can improve their properties (e.g. for corrosion protection at metal/water interfaces). The combination of ellipsometry and static and dynamic light scattering at interfaces is used to study structure/property relations at the interface and allows a better understanding and tuning of soft matter at interfaces.



STIMULATE INNOVATION – TECHNOLOGY TRANSFER AND COLLABORATION WITH INDUSTRY

Nanotechnology is relevant to many different fields and industry sectors. This is reflected by the many contacts and resulting projects that AMI developed with interested industry partners in 2010. Their fields of application include fragrances, automotive applications, construction materials, medical care, and analytical and powder-handling equipment, just to name a few.

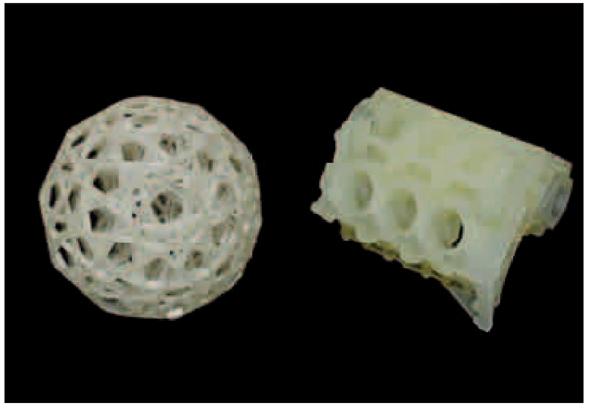
From virtual to real 3dimensional-objects

The incorporation of mechanically robust nanoscale fillers allows one to significantly improve the mechanical properties of polymers. One of AMI's research programs focuses on fundamental studies that aim to develop an understanding of the structure-property relationship of such materials, with a particular interest in cellulose nanofibers isolated from renewable sources as the filler. This expertise was the starting point of discussions with the Swiss branch of 3D Systems, a company that is a world leader in photo curable resins for rapid prototyping applications.

Dr. Bettina Steinmann (3D Systems) and Dr. Sandeep Kumar (AMI) in front of a rapid prototyping machine.

Founded in 1986 with the invention of the first stereolithography rapid prototyping system, 3D Systems has grown into a global company that delivers advanced solid imaging solutions to every major market worldwide. Their three-dimensional part-building systems and engineered materials reduce the time and cost of designing products by enabling the direct production of 3-dimensional physical parts from a digital input.

In a recently initiated research project that is co-financed by the Swiss Commission for Technology and Innovation (CTI), a team of AMI researchers and 3D Systems engineers collaborate to improve the mechanical properties of resins used in rapid prototyping by applying AMIs approaches to mechanical reinforcement with nanoparticles to resins developed by 3D Systems. This collaboration is a typical example of how findings of application-oriented fundamental research at AMI are translated into real-world applications.



Rapid prototyping is like 3D printing and enables the user to produce complex 3D-objects from digital input. Left: Complex geometrical object. Right: Part of an engine.

Creating new tools for the exploration of the nanoworld

Several research groups at AMI study structures and dynamic processes of nano-objects, such as artificial nanoparticles or natural proteins. Besides direct imaging methods, for example scanning electron and atomic force microscopy, scattering methods are important analytical tools used to provide structural information. Small angle X-ray scattering (SAXS) is one of these methods and allows one to study structural characteristics in the nanometer range.

AMI researchers assisted the US-based company Rigaku to launch a new type of SAXS instrument that is particularly well-suited for studying biological samples, such as proteins. The expertise of AMI researchers, who routinely use SAXS as a tool in a broad range of cutting-edge research projects, is a valuable asset in introducing the new Rigaku Bio-SAXS into the market. The first such instrument was recently delivered to AMI, where it has quickly become an important asset of the institute's first-class instrumental infrastructure.

Tech Transfer Fribourg

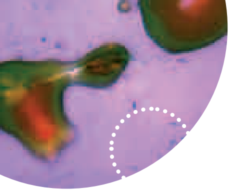
In May of this year, the Adolphe Merkle Institute, the College of Engineering and Architecture Fribourg, and the University of Fribourg created a common technology transfer office. The aim of Tech Transfer Fribourg is to act as THE drop-in center for all knowledge and technology transfer-related questions of the three partners. Towards the outside, its mission is to help companies that are searching for specific expertise to find the corresponding partners inside the institutions. Tech Transfer Fribourg also represents the three partners to other organizations that are active at this interface between academia and industry, and contributes to the development of a sustainable technology transfer process.

Although the partner institutions keep their independence and define their own policies regarding these processes, Tech Transfer Fribourg develops best practices and guarantees a transparent process for all implied partners, both internal and external. Another important mission of Tech Transfer Fribourg is to help the partner institutions establish a technology transfer culture and to help the researchers to best valorize their results.

The research background of the collaborators of Tech Transfer Fribourg coincides with the main strategic research directions of the partners, namely: engineering-, materials-, and life-science.

Picture of the new BioSAX instrument developed by Rigaku in collaboration with AMI.

Contact: Dr. Marc Pauchard, www.tt-fr.ch



PARTICIPATION IN THE EU-FUNDED SEVENTH FRAMEWORK PROGRAM (FP7)

The Adolphe Merkle Institute is already actively participating in European research programs and is steadily increasing its efforts to position itself and its researchers on the European level.

Enhancing the chances of getting highly competitive grants

Research funding by the European community through the Seventh Framework Program has an ever-increasing importance within the European research community. In addition to the traditional «cooperation» projects carried out by an international consortium for a chosen theme, the European Research Council was created to fund cutting-edge basic research, both for young «starters» and more mature «advanced» researchers. Due to the extremely competitive nature of these grants, in-house mentoring by an experienced researcher, Dr. David Tune, who gained EU research experience through participation in a FP6 nanotechnology cooperation project, is offered to AMI collaborators that qualify as candidates.

AMI welcomes ERC and Marie-Curie candidates with overlapping research interests in order to discuss whether AMI could act as their host institute.

SoftComp – SOFT MATTER COMPOSITES

Project Acronym:	SOFTCOMP
Contract Type:	Networks of Excellence Start
Start Date:	6.1.2004
Duration:	66 months
Project Cost:	6.2 million euros
Web site:	www.eu-sowftcomp.net
Participants:	29 organisations

NanoModel

Project Acronym:	NANOMODEL
Start date:	1.11.2008
Duration:	36 months
Contract Type:	Small or medium-scale focused research project
Project Funding:	3.48 million euros
Web site:	www.nanomodel.eu
Participants:	9 organisations

Current grants and projects

AMI members are already involved in several research projects within the 6th and 7th Frameworks funded by the European commission. Two examples are the projects SOFTCOMP and NANOMODEL.

One of AMI's FP7 funded Marie-Curie post doctoral fellows, Dr. Ilja Voets (project Promix), has received a special invitation to talk about her experience as a Marie-Curie fellow at the American Association for the Advancement of Science (AAAS) 2011 Annual Symposium.

AMI researchers have submitted several new FP7 proposals this year both within the ERC funded «Ideas» Programme and the «People» Programme of Marie Curie Actions funded by the Research Executive agency (REA). AMI intends to further increase its participation in FP7 and the forthcoming FP8 over the next few years.

The Adolphe Merkle Institute wishes to contribute its expertise to FP7 cooperation projects in its areas of interest and seeks new partnerships.

Contact: Dr. Dave-Earl Tune

AMI is reaching out to stakeholders and partners in order to communicate its activities and strengthen its network because good partnerships are fundamental to success.

Nanotech Report 2010

The Adolphe Merkle Institute was part of a team that published, for the first time, a comprehensive report on current nanotechnology developments within the economic and research location of Switzerland, the «Swiss Nanotech Report 2010». The report provides an insight into the excellent conditions regarding research and development and economic implementation, as well as the possibilities for financing in Switzerland. Nanotechnology is considered an industry of the future with huge economic potential.

Competence center for Nanotechnology in Fribourg

The close collaboration between AMI and the Fribourg College of Engineering and Architecture is the foundation of the Nanotechnology Network that was established in 2009. What started as a strategy to optimize synergies between an institute dedicated to fundamental and application-oriented research and an engineering school with a focus on applied research and development, grew into a competence center for nanotechnology in the Canton of Fribourg. Collaborations occur at many different levels and in many different disciplines. Examples include the postdoctoral fellow from the College who works in the AMI labs, the scale-up of the synthesis of magnetic nanoparticles originally developed at AMI at the College, and the coordinated acquisition of polymer processing equipment for the fabrication of high-value polymer nanocomposites.

Participants of the FriMat Day 2010.

The Fribourg Center for Nano-Materials (FriMat), which is an interdisciplinary research institute of the University of Fribourg's Faculty of Sciences that unites about a dozen research groups interested in Nano-Materials, also contributes to the expertise in the field of materials-oriented interdisciplinary research. Within FriMat, AMI collaborated closely with Prof. Frank Scheffold's physics group on thermoresponsive hybrid microgel particles, which led to a publication in the scientific journal «Soft Matter» that was broadly recognized within the community (see also p. 8 and 19)

Lab tour with a delegation of secretary generals and administrative directors of Swiss Universities at AMI in November.

Another study on the morphology, orientational behavior, and magnetic properties of silica-coated spindle type hematite particles benefitted from the collaboration with Prof. Christian Bernard's physics group and Prof. Bernard Grobety's geosciences group.

The first FriMat-Day, a one-day symposium that brought together the team members of all FriMat-research groups, took place on July 7th, 2010. Oral as well as poster presentations helped the researchers get to know each other better over some scientific exchange, and set the basis for future collaborations. As FriMat-members come from very different backgrounds, such events are essential to foster the interdisciplinary exchange.

Nanotechnology Network on the way to applications

The competence centers in Fribourg are slowly being recognized by the regional industry as the entry point for their questions around materials- and nanotechnology. In addition, the Nanotechnology Network is an outreach program to the industry, providing its members with an exchange platform to broaden their knowledge base and extend their network to experts in different fields. Currently, four academic and nine industrial partners span a broad range of expertise from materials development, and production processes (like liquid coating or hot melt extrusion) to characterization technologies and occupational health.

The Nanotechnology Network also strengthens its ties to other relevant organizations in the field, such as i-net Basel, INKA, KATZ, and the Polymer Division of the Swiss Chemical Society. As one of the main coordinators of this network, AMI plays an important role in bridging the gap between science and technology.

Micronarc Forum 2010

In 2010, the yearly Micronarc forum was organized in close collaboration between Micronarc and the Nanotechnology Network. The event took place at the Fribourg College of Engineering and Architecture on November 10th. The forum, titled «Aspects of nanomaterials: conception, characterization, and processing», attracted over 80 participants from about 50 different organizations, approximately half of them coming from industry. The presentations by the 5 invited speakers gave a coherent overview on how nanotechnology has been, and still is, used to improve existing products and processes, and the following round table discussion and exhibition was a good opportunity for personal exchange and networking. The presentation «How to teach polymers new tricks», by Prof. Weder, gave an insight into the world of smart polymer nanocomposites.

Technology watch

In some industry sectors, nanotechnology has been used for decades, in others companies discovered more recently what benefits this technology could bring to their products and processes. However, there are still many companies that analyze the potential of nanotechnology for their special application field. AMI supports these processes on a regular basis by giving overview presentations on nanotechnology and explaining the promises and limits of what can be done today. Examples of such events include presentations by AMI members at the general assembly of the Swiss Association for Horological Research (ASRH) in Neuchâtel, and at the general assembly of the Reseau Plasturgie (cluster for hot melt processing with over 70 members from all over Switzerland).

Meeting the next generation of young academics

AMI also regularly reaches out to help teachers spark the interest of their pupils in science. In this context, AMI opened its labs for a visit of students aged 15–16 from the Cycle d'Orientation de Marly that chose science as an elective course. In a comprehensive lab tour, they were offered an insight into the fascinating world of nano-science and -technology.

Impression of Lab work for the art project with the artist Edith Dekyndt.

The issue of Public-Private Partnerships (PPP) at Universities in Switzerland is a topic that is sometimes the subject of controversial discussions. The constitution of the Adolphe Merkle Institute, based on the support of the private Adolphe Merkle Foundation, is only one example of a PPP in Switzerland. Such PPPs are generally seen as an important contribution of the private sector to the development of the academic institutions, but some parties suspect the loss of independence and an inappropriate exertion of influence. The direction of AMI openly participates in such controversial discussions, such as its participation in a radio program on RadioFR in September 2010 to explain its viewpoint and contribute to a constructive discussion on this subject.

AMI also contributed to the LIMAT School 2010, which was organized by the Department of Physics for pupils interested in science to give them an insight into the research field of «Light and Matter».

Reaching out to a broader public

AMI also makes an effort to communicate its activities to a broader audience and give them an insight into AMI's activities. In two articles appearing in March 2010 in «Universitas», the University of Fribourg's scientific magazine, AMI collaborators talked about how the understanding of physical processes on the nanoscale can lead to a better understanding of food processing and finding new ways of making mayonnaise or gummy bears, for example. Another article in the December 2010 issue discussed the role of technology transfer at the University and its contribution to the creation of value in the society.

AMI also opened its doors for other interested groups that want to learn more about nanotechnology, such as the delegation of secretary generals and administrative directors of Swiss universities.

In our technology-driven world, science has become an important part of our society, and has many impacts on everyday life. This is the theme of the work of Edith Dekyndt, a Belgian artist. In collaboration with AMI, she attempted to visualize the link and controversy between nature (an apple) and technology (plastic) at the fundamental level of matter, the nanoscale. Anybody who is curious about the outcome can visit her exposition at FriART, the Fribourg center of contemporary art, from February to May 2011.

AMI inside

WELCOME TO THE TEAM

We are a very motivated team of researchers from many different countries. The mix of people with different cultural and professional backgrounds creates this inspiring atmosphere that we all appreciate. We feel privileged to be part of such a vibrant, diverse group of people, all of whom are fascinated by getting to the bottom of Nature's secrets and acquiring the knowledge needed to solve science's most interesting problems in the realm of soft nanomaterials. We are also driven by the wish to create added value to real life applications by combining our expertise with our partner's know-how from technical universities and industries. Here we can make things happen and set the start of an academic, industrial, or entrepreneurial career.

Portrait: Dr. Gina Fiore

Gina Fiore comes from a family that owns a paving business located at 4 Fiore Court (what a cool address!) in Oceanport New Jersey and is the first one from the clan who chose to become a scientist. «Choosing is maybe not the right word, because I normally don't follow a master plan, but rather stay open for new things and seize the opportunities when they appear», says Gina with one of her characteristic affectionate laughs. «When I was an undergraduate student at West Chester University in Pennsylvania, I wanted to become a physical therapist. Of all the classes I took, I found that chemistry was the hardest, so I decided to put my biggest effort into this. That's how I got hooked on chemistry». Since then, Gina has continued her trajectory; first she earned her Bachelor's degree in Molecular Biology and then got her PhD in Chemistry from the University of Virginia. She developed a strong fascination for metal-containing polymers and materials science, and developed her expertise in this field during her PhD with Prof. Cassandra L. Fraser, University of Virginia, and her post-doctoral research with Prof. Marc Hillmyer, University of Minnesota. «I never really planned to leave the United States, but when I was offered the position as a group leader in the group of Chris Weder, at AMI in Fribourg, I didn't hesitate! It's like a position of an assistant professor in the US, but you are integrated in a broader research field and can benefit from a lot of synergies and finally the expertise of a mentor». Her current research focuses on the synthesis and structure-property relationship of metallosupramolecular polymers. Due to the dynamic nature of the metal complexes, some of the materials can self-heal after being damaged. «Beyond this very interesting field of material science, I believe that these concepts are also playing an important role in biological materials. The role of metals in medicine is a very hot topic, where I would like to make my own contributions in the future». Working on important problems and training young researchers are two of the key incentives for her academic career. When asked about her hobbies, she mentions travelling, cooking, biking, outdoor sports, Danzan Ryu Jujitsu (Hawaiian style), and discovering new things. «I am always open to take on new challenges and to seize interesting opportunities, so we will see where I will stand 10 years from now».

Portrait: Dr. Najet Mahmoudi

«During my master-thesis in Nantes I was taken by the spirit of research and I decided to pursue a career in research rather than to work for a company, a much more classical path for someone who graduated as an engineer in Tunisia» states Najet Mahmoudi. «Although I miss my family and friends, who live on the Mediterranean coast in southern Tunisia, I wanted to move to Europe to continue my research career». She likes the hands-on part of her research very much. «I am a pragmatic experimentalist and like to contribute to new findings. In the lab is where I feel most comfortable». Like many other scientists, she is captivated by the physicochemical description of nature. Her postdoctoral work in Prof. Peter Schurtenberger's group at AMI was a great opportunity for her to continue in this area of research. Here, she used a Soft Matter Physics approach to look at the phase-behavior of protein-polymer mixtures. During her PhD defense at the University Of Nantes, France, she met Peter Schurtenberger, who was one of her external reviewers. «It was fascinating for me, having studied a broad mixture of biochemistry, microbiology, and a bit of physics, to listen to Peter describing proteins as hard spheres», Najet explains, when asked what drew her to the Adolphe Merkle Institute. «Besides the excellent scientific surrounding conditions, I very much liked the team spirit and the flat hierarchy». Najet has recently been awarded a fellowship for advanced researchers from the Swiss National Science Foundation to continue her research career. This will bring her to the University of Cambridge, where she will work with Professor Athene Donald on the phase behavior of hemoglobin concentrated solutions. Science is not the only thing that fascinates her. One book a week on average is what it takes to satisfy this avid reader; the books she reads range from biographies and books with political themes to best-sellers and thrillers. «I have always read a lot, but in Switzerland I learned to ski, something that I would have never done in Tunisia». Najet laughs. «I really like skiing and I really want to continue this». The future will show whether Cambridge is the right place for that. Anyway, for her wish to continue to work at a European University, her research stay in the UK will certainly be a valuable next step.

Portrait: Olivier Pravaz

«Already as a kid, I liked the objectivity of mathematics and the systematic approach of sciences to describe the world around us», says Olivier Pravaz, who is working on his PhD thesis at AMI. «Although we are not related, it fascinated me that a French physician named Charles-Gabriel Pravaz had developed the first practical metal syringe. So maybe this tipped the scale and led me into science». Olivier's scientific journey started at the University of Montpellier, France, where he graduated with a degree in Physics & Material Chemistry. After a short stay at the Ochanomizu University, Japan, he joined AMI, where he works in the framework of the European Research Council project Nanomodel. «It's fascinating to me that polymers reinforced with nanoscale particles show vastly modified and often improved properties. Yet, experimental evidence suggests that a simple extrapolation of the design paradigms of conventional composites cannot be used to predict the behavior of nanocomposites. It is our objective with this project to develop a better understanding of the structure-property relationship of these materials». Olivier likes working in an interdisciplinary team of experts from academia and industry on this important challenge. «It's the captivating subject, the people with different mindsets, and the opportunity to travel across Europe». Having the opportunity to work at AMI within this European project lets him combine the outstanding professional infrastructure with his personal interests: travelling and meeting people with different cultures and philosophies. By coincidence, Olivier became acquainted with the Belgian artist Edith Dekyndt, who planned to start an art project in Fribourg. Their interaction led to an installation that was presented at the art gallery Fri-Art in February 2011. «This was a very interesting experience and it was a challenge to open up our view on the nanoworld to a broader public by the means of art». Olivier likes Switzerland very much, and could imagine living here. «But also Italy or France would be nice places to live and work. So, we will see what the future brings».

Portrait: Bastien Schyrr

Born in Vevey, Bastien Schyrr grew up on the picturesque Swiss Riviera where he did most of his schooling. He went on to study Life Sciences at the École Polytechnique Fédérale de Lausanne and specialized in bioengineering and biotechnology. «For the longest time, I contemplated to become a medical doctor» he says before adding, «I enjoy studying life sciences because I feel we have a broad impact in people's everyday life». Under the supervision of Prof. Jeff Hubbel, he obtained his Master's degree studying functionalized nanoparticles for targeted vaccine delivery. Bastien started his PhD in August 2009 and focuses on the development of optical biosensors for wound monitoring. While he spends most of his time at the Centre Suisse d'Electronique et de Microtechnique (CSEM) in Neuchâtel, Bastien is also a PhD student of AMI's Polymer Chemistry and Materials Department, and is able to profit from the expertise of AMI members in the area of materials science and optically-responsive polymers. Bastien's status as a dual member of AMI and CSEM gives him the opportunity to border two very different domains, getting the best of both worlds. «I appreciate the dynamic interactions with people at AMI. I particularly like the diversity of backgrounds, both cultural and professional». Like a true Swiss native, Bastien enjoys spending his winters on the skislopes and taking advantage of the sunny summer days playing soccer.

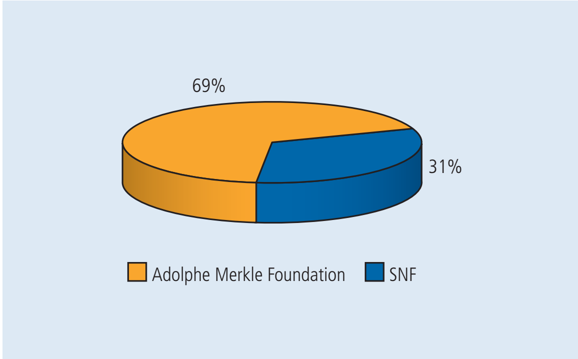
Facts & Figures

FINANCES

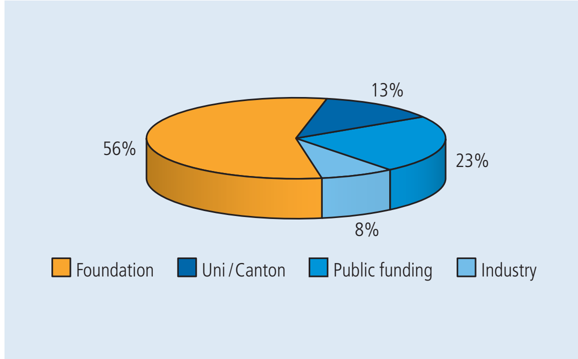
The institute's overall operating costs of CHF 4.8 Mio. and the CHF 0.7 Mio. of investments in research infrastructure in 2010 were financed by different sources including the Adolphe Merkle Foundation, the University of Fribourg, the Canton of Fribourg, Swiss and European public funds, and contributions from industry projects.

AMI was able to consolidate its financing strategy, which is based on a well-balanced mix of different funding sources. The total expenditures for research projects were increased by CHF 410'000 in comparison with 2009 to CHF 3.4 Mio. Industry-sponsored projects account for 12 % of the research expenditures. This reflects the successful implementation of the research strategy of working on fundamental and application-oriented nanoscience.

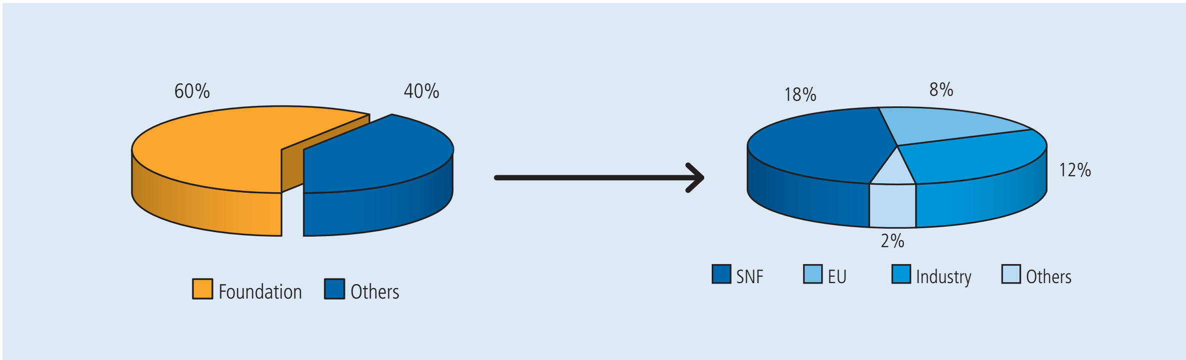
A considerable part of the investments in research infrastructure was co-financed by the Swiss National Science Foundation.



Sources of funding for investments in research infrastructure in 2010 (total investments of CHF 715'434)



Sources of funding for overall operating costs in 2010 (total operating costs of CHF 4'832'210)

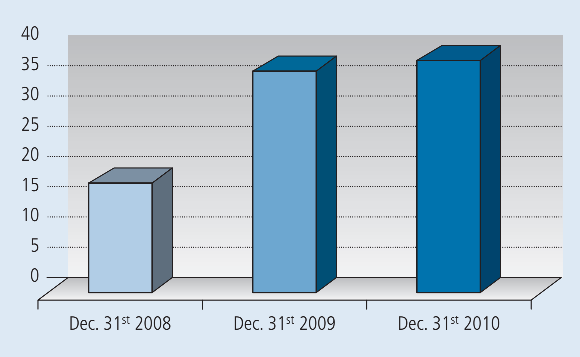


Sources of funding for research projects in 2010 (total research expenditures of CHF 3'411'029)

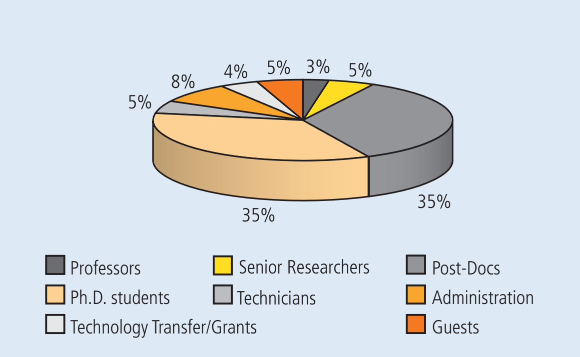
PERSONNEL

With the arrival of 18 new collaborators and the departure of 15 in 2010, it was again a very dynamic year. The rapid growth of the Polymer Chemistry and Materials department counterbalanced the departure of Prof. Schurtenberger and some of his team members, so that the total number of collaborators essentially remained the same.

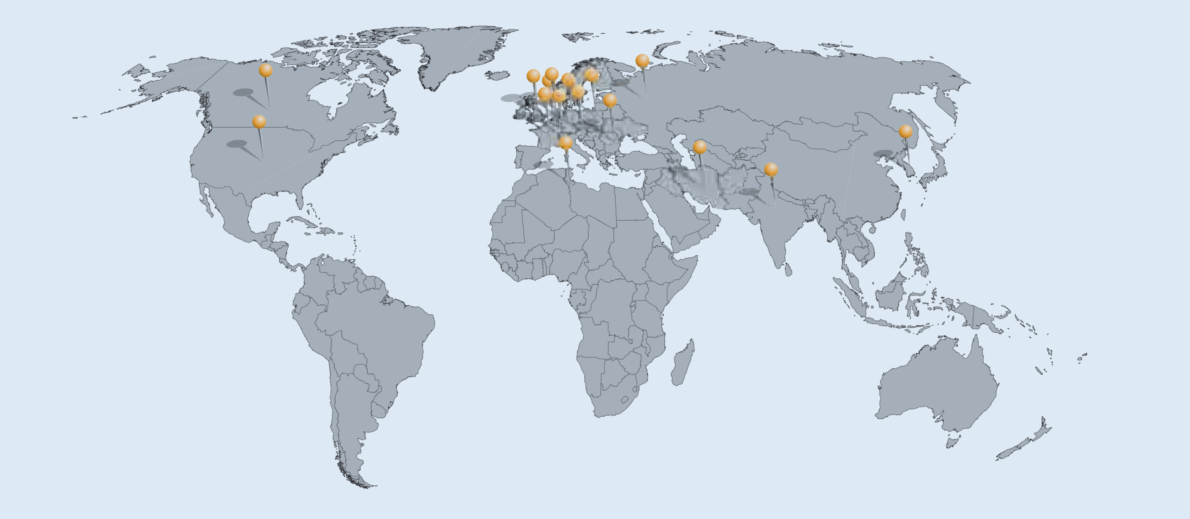
With further development of the Polymer department and the installation of two new chairs in the near future, an increased growth rate is expected for 2011. As of December 31, 2010, 43 people worked full- or part-time at AMI (corresponding to about 40 full-time equivalents). 88 % of them were active in research. The team is multinational and very young (16 different nationalities and an average age of 33 years). The most prominent nationality is Swiss, followed by French, Indian, and German. 42 % percent of the employees are women. The ratio of PhD students to Post-Docs increased in respect to 2009, which reflects the successful establishment of long-term research programs.



Development of personnel over the last three years, in full time equivalents.



Composition of personnel on December 31st, 2010.



Nationalities of researchers working at AMI in 2010.

GOVERNING BODIES OF AMI

Executive Board

Prof. Christoph Weder
(Director)

Dr. Marc Pauchard
(Associate Director)

Institute Council

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

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

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

Prof. Titus Jenny
Professor of Organic Chemistry at the Department of Chemistry, University of Fribourg,
Former Dean of the Faculty of Science, University of Fribourg

Scientific Advisory Board

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

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

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

Adolphe Merkle Foundation

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

Dr. Adolphe Merkle
Founder of the Adolphe Merkle Foundation,
Former Director and Owner of Vibrometer SA

Isabelle Chassot
State Councilor, Minister of Public Education, Culture, and Sport of the Canton of Fribourg, President of the Swiss Conference of Cantonal Ministers of Education

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

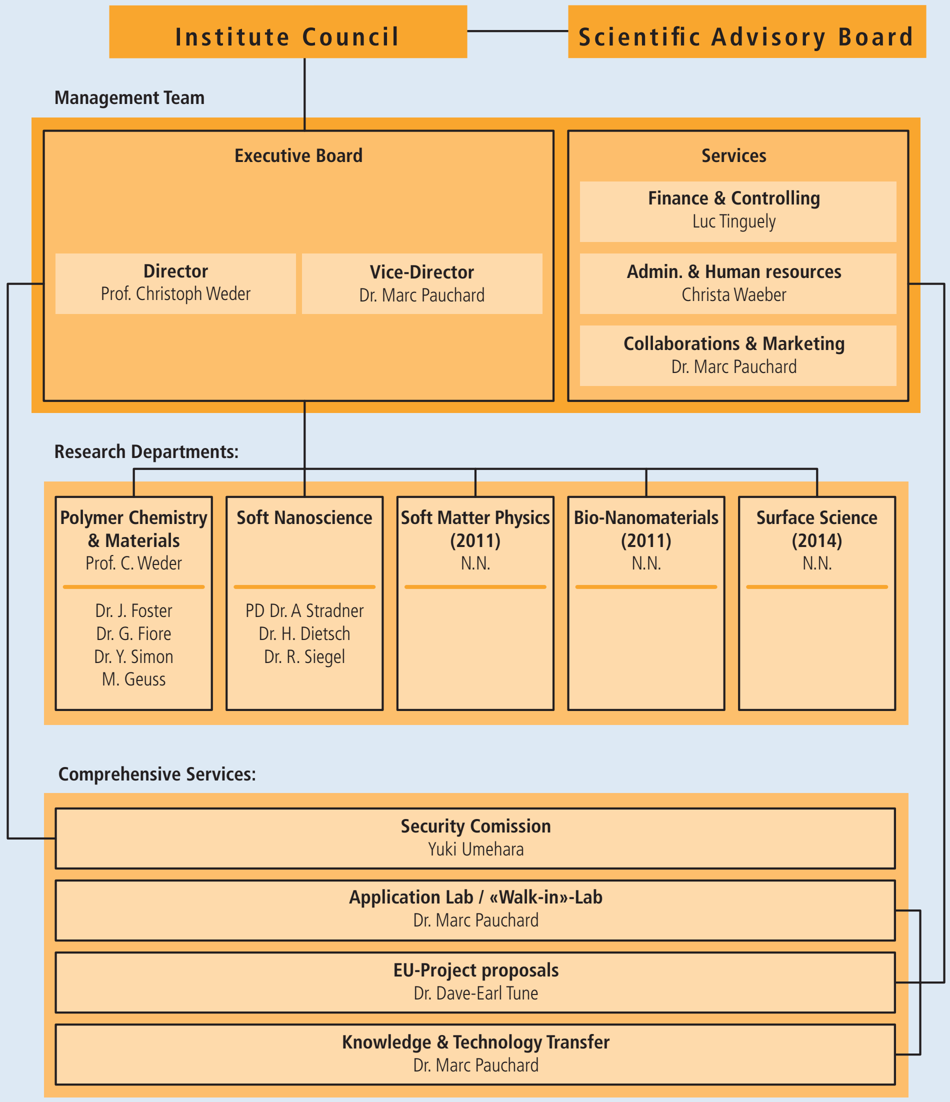
Dr. Hans Rudolf Zeller
Former Vice-President of Technology & Intellectual Property at ABB Semiconductors

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 directors. 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 directors in strategic and scientific questions.

AMI's research departments form the core of the institute. In 2010, AMI was comprised of two research departments, Polymer Chemistry & Materials and Soft Nanoscience. The current development plan foresees a continuous growth with two new departments to be installed in 2011. Average department sizes of about 30 researchers with 4 group leaders are envisioned. In addition to a small administrative team, several comprehensive services endorse the strategic activities of the institute:

- The security commission guarantees safe research operations.
- The application and walk-in labs facilitate external partners' access to the expertise and research infrastructure
- The professional support in EU project proposal writing guarantees an efficient participation of AMI in European research programs.
- A technology transfer service sets the basis for successful collaborations with industry.



Status January 2011

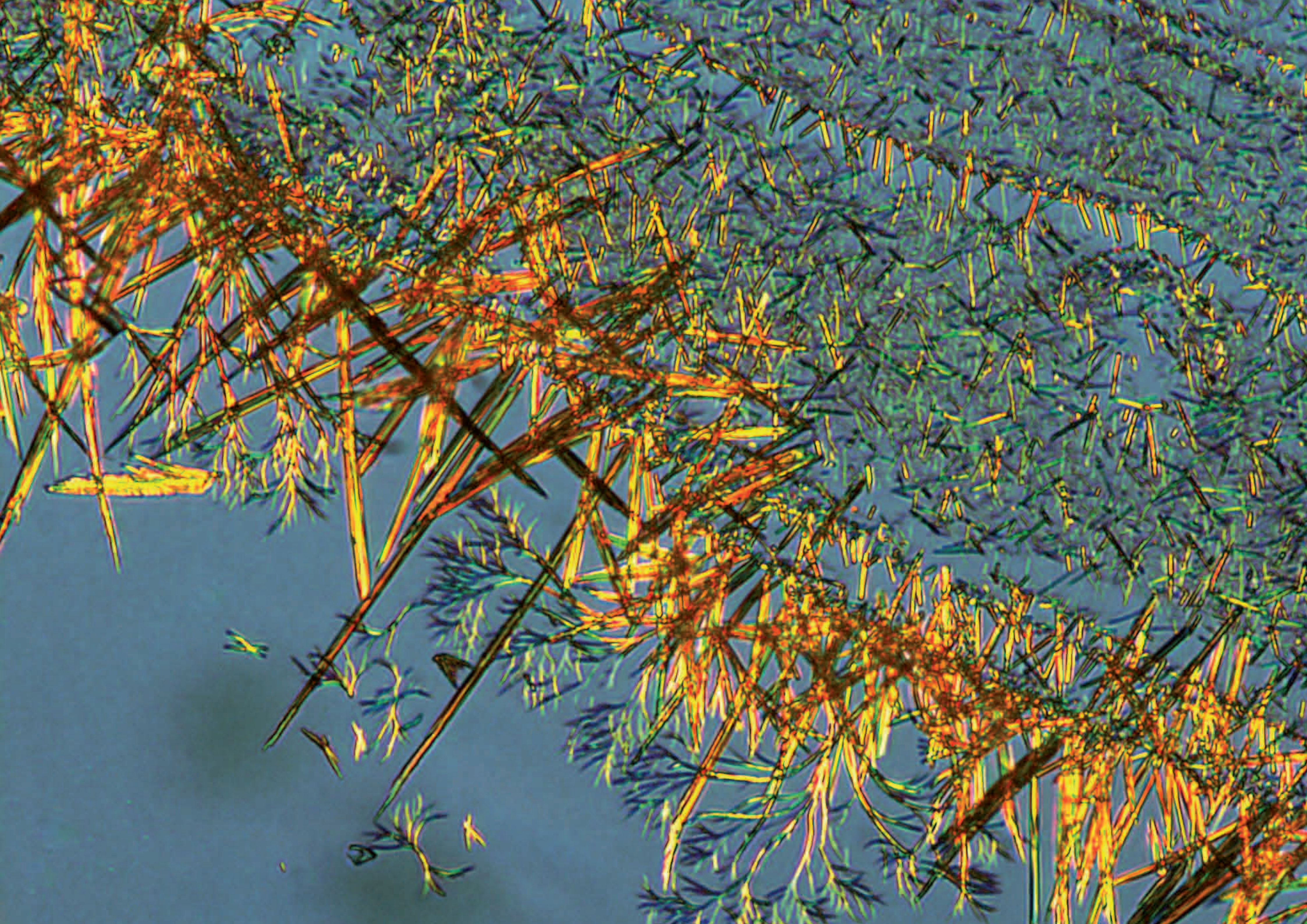
SCIENTIFIC OUTPUT

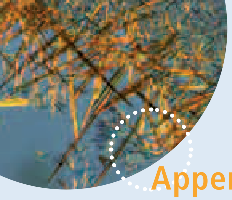
Researchers at AMI have published their recent findings in numerous high impact journals, such as Angewandte Chemie International Edition and Advanced Materials. Most notably, four publications from the groups of Prof. Peter Schurtenberger and Prof. Christoph Weder were selected for the cover of several journals, including Soft Matter, Macromolecular Chemical Physics, and Langmuir.

The scientific network of AMI researchers was expanded by participation in 30 international conferences. AMI researchers represented the institute and presented their latest results to the scientific community at conferences, such as the American Chemical Society National Meeting in San Francisco, California (USA), International Soft Matter Conference in Granada, Spain, and the IUPAC Polymer Conference in Glasgow, United Kingdom.

SCIENTIFIC OUTPUT

Publications in scientific journals:	
published	33
accepted	12
submitted	9
covers	4
Contributions at conferences and workshops:	
Invited talks	12
Talks	29
Posters	25
External presentations:	
Invited seminars	14





Appendix

Publications

1. Balog, S.; Gasser, U.; Mortensen, K.; Gubler, L.; Scherer, G. G.; Ben youcef, H. «Correlation between Morphology, Water Uptake, and Proton Conductivity in Radiation-Grafted Proton-Exchange Membranes» *Macromol. Chem. Phys.* **2010,** *211,* 635 – 643.

2. Burnworth, M.; Tang, L.; Kumpfer, J. R.; Duncan, A.; Bayer, F.; Fiore, G.; Rowan, S. J.; Weder, C. «Optically Healable Supramolecular Polymers». Submitted.

3. Cardinaux, F.; Zaccarelli, E.; Stradner, A.; Farago, B.; Egelhaaf, S.; Sciortino, F.; Schurtenberger, P. «Cluster-Driven Dynamical Arrest in Concentrated Lysozyme Solutions». Submitted.

4. Changsarn, S.; Mendez, J. D.; Weder, C.; Srikhirin, T. «Supaphol, P.; Electrospinning of Light-Emitting Fibers from a Tertiary Blend Solution of an Inert Polymer and Two Conjugated Polymers». *Chiang Mai J. Sci.* **2010,** In press.

5. Dagallier, C.; Dietsch, H.; Schurtenberger, P.; Scheffold, F. «Thermoresponsive Hybrid Microgel Particles with Intrinsic Optical and Magnetic Anisotropy». *Soft Matter* **2010,** *6,* 2174 – 2177. **Front cover**

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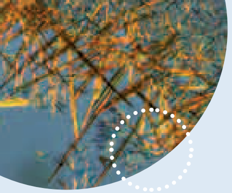

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Conference Contributions

1. AAAS Annual Meeting, Washington, USA
Invited Talk, «Cluster, Glass & Crystal Formation in Protein Mixtures of Opposite Charge», I. K. Voets, P. Schurtenberger

2. ACS 2010 Spring National Meeting, San Francisco, California USA
Poster, «Polymer Nanocomposites Reinforced with Cellulose Whiskers», J. Mendez, L. Tang, C. Weder
Poster, «Simple Routine for Rapid Growth of Organic Micro/nanorods with Anisotropic Fluorescence Emission», M. Guess, B. T. Makowski, P. Nolte, M. Steinhart, C. Weder
Talk, «Local and Reversible Polarization Switching in Textured Ferroelectric Polymer Nanofibers», M. Geuss, N. Shingne, T. Thurn-Albrecht, U. Goesele, M. Steinhart
Talk, «Cellulose Whiskers as Templates for Electrically (Semi)Conducting Polymer Nanofibers», J. D. Mendez, C. Weder
Talk, «Influence of Temperature on Low-Power Upconversion in Low Glass Transition Polymer Blends», J. Lott, T. Singh-Rachford, F. N. Castellano, C. Weder
Invited talk, «Bio-inspired Mechanically-Adaptive Nanocomposites», C. Weder, J. R. Capadona, K. Shanmuganathan, S. J. Rowan
Invited talk, «Cellulose Whisker Nanocomposites: From Bio-inspiration to Stimuli-Responsive Materials», S. J. Rowan, K. Shanmuganathan, J. R. Capadona, C. Weder
Invited keynote lecture, «Mixtures of like-charged colloids and polymers: Interactions and phase behavior», P. Schurtenberger

3. Annual Meeting of Swiss Chemical Society, Zurich, Switzerland
Poster, «Self-assembly of Globular Proteins in Mixed Solvents», I. K. Voets, C. Moitzi, E. P. G. Areas, P. Schurtenberger

4. BASF, Ludwigshafen, Germany
Invited talk, «Current Trends in Polymer-Based Nanomaterials», C. Weder

5. BiMaC Innovation, KTH Stockholm, Stockholm, Sweden
Invited talk, «Bio-inspired Mechanically-Adaptive Polymer/Cellulose Nanocomposites», C. Weder

6. Chulalongkorn University, Bangkok, Thailand
Invited talk, «Bio-Inspired Mechanically-Adaptive Nanocomposites», C. Weder

7. D43 COST Workshop. Genoa, Italy
Talk, «Characterization of Nanoparticle Formation from Nano-emulsions via Solvent Evaporation», M. Obiols-Rabasa, G. Calder, P. Schurtenberger, M. J. García-Celma, C. Solans

8. 3rd European Chemistry Congres (3rd EuCheMs), Nürnberg, Germany
Poster, «In-situ Polymerization as a Route Towards Polymer-Colloid Nanocomposites», O. Pravaz, B. Droz, P. Schurtenberger, H. Dietsch

9. European Colloid and Interface Science Conference, Prague, Czech Republic
Talk, «Solvent-Induced Self-assembly of Globular Proteins», I. K. Voets, C. Moitzi, E. P. G. Areas, P. Schurtenberger
Talk, «Photonic Crystals from Microgels with Adjustable Optical Properties», J.-F. Dechézelles, D. Paloli, P. S. Mohanty, J. Crassous, P. Schurtenberger
Poster, «Crystallization, Glass Formation and Aging in Soft Repulsive Microgels», P. Mohanty, J.-F. Dechézelles, H. Dietsch, P. Schurtenberger

10. 10th European Summer School on «Scattering methods applied to soft condensed matter», Bombannes
Talk, «Depletion Interactions in Colloid-Polymer Systems», M. Obiols-Rabasa, V. van Gruijthuijsen, N. Mahmoudi, A. Stradner, P. Schurtenberger

11. Firmenich, Geneva, Switzerland
Invited talk, «Current Trends in Polymer-Based Nanomaterials», C. Weder

12. Friburgissima, Fribourg, Switzerland
Invited talk, «Les Matériaux Intelligents du Futur», C. Weder

13. 1st FriMat Day, Fribourg, Switzerland
Talk, «Particles and Interfaces», R. Sigel, T. Mokhtari, D. Ross, A. Erbe, A. Stocco
Talk, «Stimuli Responsive Cellulose Nanowhiskers», E. J. Foster, C. Weder
Talk, «Thermoresponsive Hybrid Microgel Particles with Intrinsic Optical and Magnetic Anisotropy», C. Dagallier, F. Scheffold, P. Schurtenberger, H. Dietsch

Poster, «In-situ Polymerization as a Route Towards Polymer-Colloid Nanocomposites», O. Pravaz, B. Droz, P. Schurtenberger, H. Dietsch
Poster, «Low-Power Light Upconversion Schemes in Polymeric Matrices», J. Lott, M. Sing, Y. Simon, C. Weder
Poster, «Metallosupramolecular Polymers and Materials», M. Burnworth, L. Tang, G. L. Fiore, S. J. Rowan, C. Weder
Poster, «Switching Excimers On-off with UV Light and Shear forces: A Novel Class of «Photo»chromic & Piezochromic dyes», M. Geuss, B. T. Makowski, C. Weder

14. Gemeinsames Symposium der Deutschen Rheologischen Gesellschaft und der Kolloid-gesellschaft, Karlsruhe, Germany
Talk, «Structure and Dynamics from Hard to Soft Colloidal Systems», J. J. Crassous, M. Ballauff, M. Fuchs, P. Schurtenberger

15. Institute of Materials Seminar, Ecole Polytechnic Fédéral de Lausanne (EPFL) – Lausanne, Switzerland,
Invited talk, «Nanoparticles – from fundamentals to novel materials», P. Schurtenberger

16. International Conference on Intelligent Systems and Nanotechnology (IISN-2010), Klawad, Haryana, India
Talk, «Synthesis of Hybrid Superparamagnetic Magnetite@Silicondioxide Colloidal nanoparticles», V. Malik, S. Granville, B. Droz, K. van Gruijthuisen, P. Schurtenberger, H. Dietsch

17. Institute for Science and Technology Austria Seminar – Klosterneuburg, Austria
Invited talk, «From Soft Matter Physics to Functional Nanostructured Materials», P. Schurtenberger

18. International Soft Matter Conference 2010 (ISMC2010), Granada, Spain
Poster, «New Insight Into Gelation Through Arrested Spinodal Decomposition in Colloid-Polymer Mixtures», M. Obiols-Rabasa, K. van Gruijthuisen, N. Mahmoudi, A. Stradner, P. Schurtenberger
Poster, «Depletion Interactions in Aqueous, Charged Colloid/Polymer-Mixtures», K. van Gruijthuisen, R. Tuinier, M. Obiols-Rabasa, P. Schurtenberger, A. Stradner
Poster, «Phase-Separation and Gelation of Protein-Poly(ethylene oxide) Mixtures: Effect of Electrostatic Interactions», N. Mahmoudi, K. van Gruijthuisen, P. Schurtenberger, A. Stradner
Poster, «Self-assembly of Globular Proteins in Mixed Solvents», I. K. Voets, C. Moitzi, W. Cruz, E. T. G. Areas, P. Schurtenberger
Poster, «Hydrodynamic Properties of Core-Shell Nanoparticles with Tunable Shape Anisotropy», I. Martchenko, H. Dietsch, C. Moitzi, P. Schurtenberger
Poster, «Enhancement of Colloidal Stability of Silica Coated Hematite Particles with Polyelectrolyte», C. Rufier, M. Reufer, H. Dietsch, P. Schurtenberger
Poster, «Thermoresponsive Hybrid Microgel Particles: Probes for Rotational Diffusion», C. Dagallier, H. Dietsch, P. Schurtenberger, F. Scheffold

19. International Symposium on Stimuli-Responsive Materials, Hattiesburg, MS
Invited talk, «Stimuli-Responsive Nanomaterials through Integration of Dyes into Nanostructured Environments», C. Weder

20. Invited seminar, Leeds, UK
Invited Talk, «Structure and Viscoelastic Properties of Pectin GSels», R. Vincent

21. 43rd IUPAC Polymer Conference Macro 2010, Glasgow, UK
Poster, «Self-assembly of biopolymers in mixed solvents», I. K. Voets, E. P. G. Areas, P. Schurtenberger
Poster, «The influence of an anionic surfactant on the size of charged PNIPAM microgel», D. Paloli, P. S. Mohanty, H. Dietsch, P. Schurtenberger
Talk, «Interacting microgels with tuneable softness and charged density», P. Mohanty, H. Dietsch, U. Gasser, W. Richtering, P. Schurtenberger

22. Kantonsspital Fribourg, Fribourg, Switzerland
Invited talk, «Polymer Nanomaterials for Biomedical Applications», C. Weder

23. 1st Limat school 2010, Physics department
Talk, «Nanopartikel», H. Dietsch

24. 5th Materials Research Center Graduate Symposium (MRC10), Zurich, Switzerland
Talk, «Ellipsoidal Silica-Coated Hematite Nanoparticles for Inorganic-Organic Elastomer Nanocomposites», A. Sánchez-Ferrer, M. Reufer, R. Mezzenga, P. Schurtenberger, H. Dietsch

25. Micronarc Industrial Forum, Fribourg, Switzerland
Invited talk, «How to teach polymers new tricks», C. Weder

26. NanoEvent «NanoPolymers in Industry» organized by I-net Basel Nano during the SCS fall meeting, Basel, Switzerland
Talk, «Polymer-Particle NanoComposites within the new Nanotechnology Institute in Fribourg», O. Pravaz

27. NanoModel Project Meeting at Robert Bosch GmbH, Waiblingen, Germany
Talk, «Different surface treatments of nanoparticles, techniques for nanoparticles dispersion in polymers», O. Pravaz, P. Schurtenberger, H. Dietsch

28. NanoModel Project Meeting at University of Trieste, Trieste, Italy
Talk, «Fully dispersed surface-functinalized nanoparticles in monomer solvents and TEM & SAXS characterizations on the model systems», O. Pravaz, P. Schurtenberger, H. Dietsch

29. Neutrons and Food – Sydney, Australia
Poster, «Attraction versus repulsion: From proteins to model colloids – and back?», K. van Gruijthuijsen, R. Tuinier, P. Schurtenberger, A. Stradner

30. OMM annual meeting, University of Lund, Lund, Sweden
Invited talk, «Understanding protein interactions in complex mixtures», A. Stradner

31. Particles 2010, Orlando, USA
Poster, «Nanoengineering of Responsive Hybrid Anisotropic Particles», H. Dietsch, J. J. Crassous, C. Dagallier, A. M. Mihut, P. Schurtenberger

32. Passion for Soft Matter, San Sebastian, Spain, September 28th, 2010
Talk, «Solvent-induced self-assembly of globular proteins», I. K. Voets, E. P. G. Areas, P. Schurtenberger

33. Physics Colloquia, Università Degli Studi di Milano – Milan, Italy
Invited talk, «Food seen through the eyes of a condensed matter physicist», P. Schurtenberger

34. «Physics Meets Biology» conference, Oxford, UK
Talk, «How the pollen tube optimizes the mechanical properties of its wall», R. Vincent

35. School of Chemical Engineering and Analytical Science Seminar, University of Manchester – Manchester, UK
Invited talk, «Responsive colloids – from fundamentals to to novel materials», P. Schurtenberger

36. School of Physics Seminar, University of Edinburgh – Edinburgh, UK
Invited talk, «Protein condensation diseases – a soft matter physicists viewpoint», P. Schurtenberger

37. Seminar LCVN, Montpellier, France
Talk, «Thermoresponsive hybrid microgel particles with intrinsic optical and magnetic anisotropy», H. Dietsch

38. Sika, Switzerland
Invited talk, «New Functional Polymers», C. Weder

39. SoftComp Annual Meeting 2010, Terrasini, Italy
Talk, «Protein-polymer mixtures: depletion versus electrostatic interactions», N. Mahmoudi, P. Schurtenberger, A. Stradner
Talk, «Dendronized Polymers Investigated by Neutron Scattering», R. Sigel, S. Lages, Y.-C. Li, P. Schurtenberger, A. Zhang, Baozhang, D. Slüter

40. SPM & Optical Tweezers Symposium, Berlin
Invited talk, «Where are the domains in ferroelectric polymers? A PFM answer to an old question», M. Geuss

41. Swiss Chemical Society Fall Meeting – Lausanne, Switzerland
Talk, «Depletion interactions in aqueous, charged colloid/polymer-mixtures», K. van Gruijthuijsen, M. Obiols-Rabasa, R. Tuinier, P. Schurtenberger, A. Stradner

42. Swiss Plastics 2010, Luzern, Switzerland
Invited talk, «Funktionelle Polymere für Biomedizinische Anwendungen», C. Weder

43. 2nd Swiss Soft Day, Lausanne, Switzerland

Talk, «Solvent-induced denaturation, self-assembly, and gelation of globular proteins», I. K. Voets, C. Moitzi, E. P. G. Areas, P. Schurtenberger
Talk, «Nanoengineering of Responsive Hybrid Anisotropic Particles», H. Dietsch
Talk, «Inorganic-organic elastomer nanocomposites from nanoparticles as crosslinking agents», A. Sánchez-Ferrer, H. Dietsch, M. Reufer, R. Mezzenga, P. Schurtenberger
Poster, «Low-Power Light Upconversion Schemes in Polymeric Matrices», J. Lott, M. Sing, Y. Simon, C. Weder

44. 3rd Swiss Soft Day, Fribourg, Switzerland

Talk, «Depletion interactions in aqueous, charged colloid/polymer-mixtures», K. van Gruijthuijsen, R. Tuinier, P. Schurtenberger, A. Stradner
Poster, «In-situ polymerization as a route towards polymer-colloid nanocomposites», O. Pravaz, B. Droz, H. Dietsch
Poster, «Nanoengineering of Thermosensitive Core-Shell Particles», J. Crassous, H. Dietsch, A. M. Mihut, V. Malik, L. Ackermann, P. Schurtenberger
Poster, «Metallosupramolecular Polymers and Materials», M. Burnworth, L. Tang, G. L. Fiore, S. J. Rowan, C. Weder
Poster, «Where are the domains in ferroelectric polymers? A 2D piezoresponse force microscopy answer to an old question», M. Geuss, N. Shingne, T. Thurn-Albrecht, U. Goesele, M. Steinhart

45. Swiss Rheology Group Meeting - Zurich, Switzerland

Talk, «Origin of arrested phase-separation in protein/polysaccharide-mixtures», K. van Gruijthuijsen, V. Trappe, V. Herle, P. Schurtenberger, A. Stradner

46. University of Jena

Invited Talk, «Solution Properties of Functional Polymer Systems», R. Sigel

47. University of Lund, Faculty of Chemistry, Lund, Sweden

Invited seminar, «Understanding protein interactions in complex mixtures», A. Stradner

48. University of Lund, Institute of Physical Chemistry, Lund, Sweden

Invited seminar, «Protein condensation diseases seen with the eyes of a soft matter scientist», A. Stradner

49. Workshop on Complex Fluid - Fluid Interfaces, Institute of Physics London

Talk, «Adsorption and Dynamics of Charged Colloidal Particles at Alkane/Water Interfaces», R. Sigel, T. Mokhtari, A. Stocco, K. Tauer

50. Workshop: Modern Light Scattering Technologies - Düsseldorf, Germany

Invited lab session, «DWS and yoghurt», K. van Gruijthuijsen

Impressum

Publisher:
Adolphe Merkle Institute, Board of directors

Editor:
Adolphe Merkle Institute, Board of directors
and Marketing & Communications

Layout:
Grafikraum, Bern

Print:
Imprimerie St-Canisius, SA, Fribourg

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Fribourg, March 2011

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