We honour the memory of an innovative entrepreneur, generous patron and cofounder of our institute and will continue to implement his vision of a leading-edge research institute in the field of nanotechnology and materials science here in Fribourg. Dr. Adolphe Merkle has set a new impetus by his foresight and commitment that reaches far beyond the borders of Fribourg. His initiative has sparked a spirit of optimism that is clearly evident in his institute. The Adolphe Merkle Institute is increasingly becoming a magnet for people who wish to participate in this exciting project and we believe that Dr. Adolphe Merkle’s vision is just the beginning. We deeply regret that our distinguished patron can no longer accompany us on this path but his dedication stays with us and will continue to light the way ahead.

IN MEMORIAM
Dr. Dr. h. c. ADOLPHE MERKLE
(1924 – 2012)
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Multidisciplinarity is indeed becoming a virtue of our institute. I trust that the developments and achievements documented in this annual report support our institute’s position on the importance of multidisciplinary research. Hopefully, they also reflect the creativity, compassion, motivation, and professionalism of our team members, who have worked relentlessly to keep AMI on its course to realize Adolphe Merkle’s vision of becoming a leading competence center for fundamental and applied interdisciplinary research in the field of soft nanomaterials.

At AMI, we recognize the value of partnerships and are once again grateful for the interest, courtesy, and support that we have received throughout the year. We will continue to work hard to be a valuable and reliable partner and to make relevant contributions to science and to society.

Christoph Weder
AMI Director and Professor for Polymer Chemistry and Materials
After three years of existence, all indicators show that AMI is still continuing to grow rapidly. The institute’s development is following its strategic plan for the years 2010–2015, which seeks to position AMI as a leading interdisciplinary research center for soft nanomaterials science and technology.

New chair for bio-nanomaterials
The scope of AMI’s research activities broadened considerably with the appointment of Professors Barbara Rothen-Rutishauser and Alke Fink. Since July 2011, the two share the position as chair for bio-nanomaterials and lead AMI’s new department for bio-nanomaterials.

Prof. Barbara Rothen-Rutishauser joined AMI from the University of Fribourg’s chemistry department, where she had directed the advanced particle research group as a Swiss National Science Foundation Professor since 2009. The chemist was trained at the University of Wales in Sydney (AU). Her research focuses on the synthesis and expertise are nanoparticle-cell interactions, particularly in relation to the lung. Her research seeks to utilize the knowledge generated in fundamental studies to promote the safe use of engineered nanomaterials by considering possible health risks, and for the creation of new drug delivery systems.

Professor Alke Fink joined AMI from the University of Fribourg’s Department of Anatomy of the University of Bern, where she had held the positions of group leader and independent research group leader from 2002 to 2010. The cell biologist was trained at ETH Zürich and also has worked as a researcher at the Center for Health and Environment of Nanyang University in Singapore (SG). Professor Rothen-Rutishauser’s main interests and expertise are nanoparticle-cell interactions, particularly in relation to the lungs of children. Her research seeks to utilize the knowledge generated in fundamental studies to promote the safe use of engineered nanomaterials by considering possible health risks, and for the creation of new drug delivery systems.

The joint chair for bio-nanomaterials builds on the previous efforts of the two researchers and allows them to further merge Professor Fink’s expertise in materials science with Professor Rothen-Rutishauser’s biological competences. The joint chair for bio-nanomaterials broadened considerably with the appointment of Professors Barbara Rothen-Rutishauser and Alke Fink in 2011, the two share the position as chair for bio-nanomaterials and lead AMI’s new department for bio-nanomaterials.

Polymer Chemistry & Materials Physics
Bio-Nanomaterials (Profs. Fink/Rothen)
Soft Matter Physics
Interface Physics
Assembly & Materials
Polymer Chemistry
Interfaces
Physics
Materials (2012)
Adolphe Merkle Institute

Am I in 2011

Fostering multidisciplinary interactions
With the expansion of the institute, a range of mechanisms that actively encourage multidisciplinary research projects between departments and groups have been implemented. The topics of the AMI Seminar Series, which featured in 2011 over 12 external speakers from institutions as far as the Institute Charles Gerhardt Montpellier (F) and the University of North Carolina (USA), were broadened to meet the interests of the new audience. Brainstorming workshops, joint grant proposals, and a scientific retreat are just some examples of how interactions between researchers are stimulated to establish a culture of multidisciplinary at AMI.

New building takes shape
The planning of AMI’s future home on the faculty campus, which is located in the heart of the University of Fribourg’s campus where the natural science faculty of the University of Fribourg is located, has been completed. The start of construction when this annual report was printed, after the parlia-
New Bio-Nanomaterials group

(Professor Alke Fink (chemist) and Barbara Rothen-Rutishauser (biologist) joined AMI in July 2011 to build and co-chair a new research department that focuses on the study of biological materials. The new bio-nano team rapidly started to activities and has already grown to over twenty scientists.

High impact research

AMI researchers and partners at Case Western Reserve University (USA) and the US Army Research Laboratory at Aberdeen Proving Ground (both USA) developed a polymer-based material that can heal itself when placed under ultraviolet light. These findings were published in the prestigious scientific journal ACS Nano. The healing film displays the same mechanical properties as the original while the technology is still in a “proof-of-concept” phase, the new approach is to be useful for the development of automotive paints, varnishes for floors and furniture, and many other applications where being able to fix damages easily would be of great use.

Other applications where being able to fix damages easily would be of great use. Papes by Hervé Dietsch and co-workers on upconverting nanoparticles were selected to be featured on the covers of the journals Journal of Physical Chemistry and the Journal of Materials Chemistry on Mechanoresponsive Materials. Professor Alke Fink was elected as co-president of the Fribourg Chemical Society, and Professor Barbara Rothen-Rutishauser as board member of the International Society of Aerosol Medicine.

Continued success in attracting external research funding

AMI researchers received new research funding of a total of over 6.5 Mio CHF from European and Swiss government agencies, as well as from industry, surpassing expectations by far. After achieving two competitive goals from the Swiss National Science Foundation’s National Research Program Resource Wood (NRP 44) to research the processing of nanocellulose composites and nanoparticle-based wood treatments, AMI now hosts eleven research projects that are part of National Research Programs.

Recognition for AMI researchers

Professor Christoph Weder was elected to serve as Associate Editor of the new polymer journal ACS Applied Materials. He also served as guest editor of a special issue of the Journal of Materials Chemistry on Materials for Medicinal Applications. Professor Alke Fink was elected as co-president of the Fribourg Chemical Society, and Professor Barbara Rothen-Rutishauser as board member of the International Society of Aerosol Medicine. Sandro Steiner received an award for highly skilled individuals of the year. The polymer department’s work on smart material was also the subject of a feature story broadcasted by the Swiss National Science Foundation. The work entitled “future tense” in local radio and TV stations Radio Fribourg and La Télé, as well as national newspapers such as 20 Minutes, SRF, La Télé, Le Temps, and Le Matin.

National and international press coverage for AMI

AMI’s research programs received significant attention from both national and international media. The polymer department’s breakthrough on self-healing polymers was featured in well over a hundred stories that appeared in newspapers such as the Washington Post and the Irish Independent, German and Swiss public radio stations SRF2 and SWR2, respectively, and TV stations such as ATV TV in Germany. The polymer department’s work on smart material was also the subject of a feature story broadcasted by the Swiss National Science Foundation. The polymer department’s work on smart material was also the subject of a feature story broadcasted by the Swiss National Science Foundation. The polymer department’s work on smart material was also the subject of a feature story broadcasted by the Swiss National Science Foundation.

In addition, AMI’s governance structure, its role in the creation of the institute, its view on public-private partnerships, its research strategy, the dynamic growth, and the progress of the institute’s new home were the subjects of articles in newspapers and magazines that included 20 Minuten, Le Temps, La Liberté, and the Swiss national newspaper Die Welt. AMI’s governance structure, its role in the creation of the institute, its view on public-private partnerships, its research strategy, the dynamic growth, and the progress of the institute’s new home were the subjects of articles in newspapers and magazines that included 20 Minuten, Le Temps, La Liberté, and the Swiss national newspaper Die Welt.

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Bio-nanotechnology is a young and rapidly evolving research field at the crossroads of biotechnology and nanoscience, two interdisciplinary areas that combine advances in both science and engineering. This technology has the potential to provide specifically designed nanomaterials for numerous applications in biology, medicine, and life science. However, to safely and efficiently translate bio-nanotechnology into life science applications, it is crucial to gain a thorough understanding of the interaction between nanomaterials and living matter.

The strength of the interdisciplinary nature within the Bio-nanomaterials research department, including (bio)chemistry, biology, chemical and biological engineering, and material science brings a unique holistic approach to exploring bio-nanotechnology. From the Bio-Nanomaterials department's research vision, all undertaken projects have the aim to address the question: «What does a particle look like?»

Nanomaterial-cell interaction: A comprehensive laboratory-wide effort to understand the interactions between nanomaterials and living systems.

Preparation of nanomaterials: Highly reproducible, monodisperse, colloidally stable, and easy to manipulate.

Fig. 1: Overview of the BioNanomaterials department's research vision. All undertaken projects have the aim to address the question: «What does a particle look like?»

Preparation of nanomaterials

Nanomaterials and living systems:

- Development of the novel cell-inherent cellular uptake assay for cell response i.e. cell death, oxidative stress, immune response
- Monodisperse, colloidally stable
- Reproducible

Preparation of nanomaterials

Fig. 2: Preparation of dendritic cell-derived superparamagnetic iron oxide nanoparticles (SPIONS) that can be used for T cell stimulation.


References:

Contact: Prof. A. Fink and Prof. B. Rothen-Rutishauser
Funding received from the recent Swiss National Science Foundation National Research Programmes 64, “Opportunities and Risks of Nanomaterials”, has provided AMI with the ability to undertake an interdisciplinary landmark project in which the interactions of cellulosic nanomaterials with the human lung are studied in vitro and in vivo and new nanomaterials are developed.

Intersecting early results in a collaborative project between the Bio-nanomaterials and Polymer Chemistry & Materials departments at AMI, a new investigation was launched that utilizes the core expertise of the Polymer Chemistry & Materials departments at AMI, a new interdisciplinary research project in which the interactions of nanomaterials with the human lung are studied in vitro and in vivo and new nanomaterials are developed.

New promising research areas
The Switzerlan National Foundation (SNF) is currently funding five PhD students who are seeking to gain answers to such questions. The results of this project will provide essential information on the potential use and opportunities of nanomaterials in the context of possible applications by developing an understanding of the structure-property relationships of new nanomaterials and which characteristics limit adverse biological responses.

Cell culture model of the human airway barrier
Every day, new products containing nanoparticles (NPs) come on the market and influence our daily life. The distinct physiochemical characteristics of nanoparticles have, for example, been used to develop new inhalable NPs for local drug targeting. However, the effects of many NPs on living organisms is still poorly understood and needs to be further investigated. To understand the effects brought forth by NPs in the human lung, the group of Prof. Robin Rothen-Rutishauser and Prof. Patrice Ettlin started to study whether NPs can reach the alveolar region where they can induce the formation of reactive oxygen species and inflammation.

The smaller the particles are, the deeper they can penetrate within a human blood derived macrophage. (Fig. 1). The conventional inserts, which are used in the existing epithelial-endothelial co-culture system including two types of immune cells (i.e. macrophages and dendritic cells). This group’s present study is to refine this existing model to also include endothelial cells. Moreover, the new cell culture model will take advantage of novel air-permeable porous membranes, which are developed as the CSEM ultra-thin membranes.

The new cell culture model of the human airway barrier consists of macrophages and dendritic cells by using a newly developed ultrathin porous membrane. This project is being done in collaboration with Dr. Silvia Angeloni and Dr. Martha Liley from CSem* and with Dr. Silvia Angeloni and Dr. Martha Liley from CSem*. Researchers’ first results show that both epithelial cells, which are seeded on the upper side of the membrane, and endothelial cells, which are seeded on the lower side, can be cultured on the new ultrathin membrane, and that both cells form a tight epithelial layer by using a newly developed ultrathin porous membrane. This project is being done in collaboration with Dr. Silvia Angeloni and Dr. Martha Liley from CSem*.

REFERENCES

Contact: Dr. M.J.D. Clift and Dr. E.J. Foster

**Research programs in Neuchâtel and Zurich (Switzerland) funded by the Swiss National Science Foundation (SNSF)

Fig. 1: A 3D reconstructed image of an electron tomogram showing a cellulose nanofiber derived from cotton (orange/red) inside a vesicular body (yellow). (Color figure available online)

The results of this project will provide essential information as to the potential use and opportunities of nanomaterials in the context of possible applications by developing an understanding of the structure-property relationships of new nanomaterials and which characteristics limit adverse biological responses.

Development of a novel human air-blood barrier model using an ultrathin porous membrane

Every day, new products containing nanoparticles (NPs) come on the market and influence our daily life. The distinct physiochemical characteristics of nanoparticles have, for example, been used to develop new inhalable NPs for local drug targeting. However, the effects of many NPs on living organisms is still poorly understood and needs to be further investigated. To understand the effects brought forth by NPs in the human lung, the group of Prof. Robin Rothen-Rutishauser and Prof. Patrice Ettlin started to study whether NPs can reach the alveolar region where they can induce the formation of reactive oxygen species and inflammation.

Cell culture model of the human airway barrier
Currently, the possible effects of inhaled NPs are mainly being investigated using invasive animal tests. Over the last few years, Prof. Robin Rothen-Rutishauser’s group has established and evaluated a 3D cell culture model of the human airway barrier consisting of macrophages and dendritic cells. The goal of this group’s present study is to refine this existing model to also include endothelial cells. Moreover, the new cell culture model will take advantage of novel air-permeable porous membranes, which are developed as the CSEM ultra-thin membranes.

Researchers’ first results show that both epithelial cells, which are seeded on the upper side of the membrane, and endothelial cells, which are seeded on the lower side, can be cultured on the new ultrathin membrane, and that both cells form a tight epithelial layer by using a newly developed ultrathin porous membrane. This project is being done in collaboration with Dr. Silvia Angeloni and Dr. Martha Liley from CSem*.

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Fig. 1: A 3D reconstructed image of an electron tomogram showing a cellulose nanofiber derived from cotton (orange/red) inside a vesicular body (yellow). (Color figure available online)
Fig. 2: Human epithelial cells stained for actin filaments (red), cell nuclei (blue), and E-cadherin (green) under a confocal laser scanning microscope.

Fig. 3: The passage of blue dextran from the upper to the lower chamber is used to assess epithelial-endothelial bilayer integrity.

In vivo mechanical switching. Implantation of cortical substrates into the brain model reduced the storage modulus from stiff (easily implantable materials – left) to soft (tissue-matching materials – right) by using water as a chemical switch.

Contact: Dr. C. Jud

1 CSEM: Swiss Center for Electronics and Microtechnology
2 «Lunge Zürich» is a Swiss non-profit organization active in the field of lungs, air, and respiration.

SMART BRAIN IMPLANTS

As part of the Swiss National Science Foundation’s National Research Program 62, «NanoMaterials», AMI researchers are developing mechanically-adaptable materials for biomedical applications.

Mechanically adaptive materials for biomedical applications

Materials whose properties change in response to an external stimulus in a desirable manner are often referred to as «smart» or «intelligent». AMI researchers are investigating several types of stimuli-responsive nanomaterials that change their mechanical properties on demand. One international, interdisciplinary collaboration pursues the development of such mechanically adaptive materials for use as a crucial structural component in intracortical microelectrodes. These biomedical devices serve to record neural signals and/or provide neural stimulation and are potentially useful in clinical applications that require bio-compatibility between the brain and the outside world. For example, they could be used for the treatment of Parkinson’s disease, strokes, and spinal cord injuries.

Unfortunately, broad clinical implementation of neural interface technology is delayed by the fact that current electrodes don’t normally permit long-term recording of neural activity. It has been suggested that the mechanical mismatch between these devices, which are traditionally made from stiff materials such as tungsten, silicon, and stainless steel, and the soft cortical tissue is a significant contributor to the progressive decrease in neuron density around the electrodes. To alleviate this problem, AMI researchers, inspired by the architecture of the sea cucumber dermis, were able to engineer a new class of mechanically adaptive materials as substrates for «smart» intracortical electrodes. These original rigid polymer nanocomposites soften considerably upon exposure to certain physiological conditions. The adaptive nature of these materials makes them useful as a basis for electrodes which are stiff enough to penetrate the brain tissue, but whose stiffness can be adjusted after implantation to more closely match the stiffness of the tissue. This reduces the mechanical mismatch between the brain and the outside world.

The first generation of smart implants based on the new materials was recently possible to create the first generation of smart implants based on the new materials. Initial histological evaluations conducted in collaboration with partners at Case Western Reserve University (USA) showed through in-vivo studies with rodents that mechanically adap-
Magnetic shape memory polymers

Materials that are capable of changing their mechanical properties and shape under the application of an external stimulus are highly suitable for many applications, such as actuators and valves. Relying on the combined expertise of researchers at AMI, a collaborative project was initiated with the objective of fabricating organic as well as inorganic hybrid polymers whose shapes can be remotely controlled by an oscillating magnetic field.

Shape-memory materials are capable of switching between two or more predefined mechanical states and shapes in response to external stimuli, such as heat, electrical current, light, chemicals, or other commands. Shape memory polymers can be classified according to the thermal transition that is exploited (glass transition or melting) and the nature of the cross-links imparting elasticity (covalent or physical cross-linking).

The AMI team utilizes superparamagnetic iron oxide nanoparticles as the active component that will respond to an external trigger and integrates them into an elastic polymer matrix. By applying a high-frequency oscillating magnetic field, the nanoparticles act as “hot spots” that locally heat the material above the transition temperature of the polymeric matrix.

Tough challenges, big opportunities

A number of challenges had to be overcome to create these smart materials. For example, one of the critical aspects lies in carefully controlling the surface chemistry of the nanoparticles, which is important for the distribution and dispersion of these “nanomagnets” within the polymer. A classical method to ensure good compatibilization relies on the post-treatment of the particles with organic or polymeric solubilizing agents. AMI researchers used this and other approaches to integrate the nanoparticles into the polymer. A wide variety of polymeric matrices can be used such that the thermal transition temperature can be tailored at will.

This approach to shape-memory materials opens up new avenues for smart materials that can be triggered remotely by an external magnetic field. Furthermore, this project aims to answer some more fundamental questions such as those regarding heat transfer at the nanoscale and the influence of the detailed architecture on internal heat generation and the therewith magnetically-triggered response. These materials are anticipated to be useful for a wide range of purposes, such as panel unfolding in satellites and magnetically mendable vehicle parts that can be repaired after a minor fender-bender.

Contact: Dr. E.J. Foster and Prof. C. Weder

Shape-memory of a polymer nanocomposite strip upon application of an oscillating magnetic field.
Response colloids with soft and tunable potentials, 01.06.2010  – 31.05.2013, B. Rothen-Rutishauser
This project focuses on the synthesis and characterization of novel model particles with tuning of stability, surface, and particle-cell interaction purposes. In addition to research, the project will consider the social, ethical, and legal aspects of applying nanotechnology for medical purposes.

NanoDia research programs

01.03.2010  – 28.02.2011, A. Fink
This project is part of a large-scale international, interdisciplinary program aiming to develop nanostructured materials and new Production Technologies, which involves a consortium of 15 partners. The main objective of this project is to develop multifunctional superparamagnetic nanoparticles as a diagnostic tool for the detection of early stages of arthritis. In addition to research, the project will consider the social, ethical, and legal aspects of applying nanotechnology for medical purposes.

Biomedical nanoparticles as immune-modulators
01.09.2011  – 31.08.2014, B. Rothlisberger
In order to harness the unique properties of nanoparticles for novel clinical applications in the treatment of allergic respiratory diseases, AMI researchers propose developing and testing specifically designed nanoparticles in order to investigate the immune-modulatory effects in the lung.

C. Weder, J. Foster, M. Clift
Scientists at ETH Zürich and AMI, who are responsible for the separation and purification of silica and silica-coated carbon nanotubes (MWCNTs) to their potential adverse effects on stability, surface, and particle-cell interaction purposes.

Cellulose-based nanocomposite building materials:
01.12.2010  – 30.11.2013, C. Weder
The overall aim of this project is to develop double-walled nanocontainers, in-called vesicles, whose outer wall mimics cell membranes. Equipped with functionalized surface features for targeting selectively particular mammalian cells (e.g., cancer cells), these vesicles are designed to dock the cells or even merge with the cell membranes.

Advances in nanotechnology with a focus on stability, surface, and cell-particle interaction
01.04.2009  – 30.06.2010, A. Fink
This project deals with model particle synthesis, colloidal property investigations, and particle testing in environments of various scales in order to achieve the optimal characterization of metal-containing particles, namely metallo-supramolecular polymers with photo-healable properties and metal-containing macromolecules that undergo low-power upconversion.

Spatially resolved magnetic relaxation in ultra-nano magnetic nanoparticles using atomic magnetometers,
01.05.2010  – 30.06.2012, A. Fink
This project aimed to establish a new experimental technique to determine the structure and the rheological properties of polymers around colloidal particles. Polymers bonded to the surface are continuously used to stabilize colloidal materials and to protect them from aggregation and precipitation. There is a high interest from industry for prediction tools for the long-term stability of colloidal systems, since stability affects lifetime and conservation limits of products.

Interactions and phase behavior of colloid-polymer mixtures: such as the influence of charges.
This project pursued the creation and characterization of a new experimental technique in order to improve the understanding of the open questions concerning the phase behavior of colloidal systems as well as the influence of changes.

Smart vesicles for drug delivery
This project aims to develop double-walled nanocontainers, in-called vesicles, whose outer wall mimics cell membranes. Equipped with functionalized surface features for targeting selectively particular mammalian cells (e.g., cancer cells), these vesicles are designed to dock the cells or even merge with the cell membranes.

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Projects financed by adolphe merkle foundation

Mechano-chemistry, Adolphe Merkle Foundation, C. Weder, Y. Simon

This proposed experimental research program targets the design, synthesis, processing, 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 develop polymers with unusual functionalities that allow for unique properties, such as mechanical-induced generation of light, heat, and electricity, self-assembling behavior, the ability to release small molecules (e.g., drugs, fragrances, and antioxidants), or even the capability to cause self-degradation.

Structure, dynamics, and assembly of core-shell microgels, Adolphe Merkle Foundation, B. Rothen-Rutishauser

Spherical colloidal core-shell microgels, such as novel ellipsoidal, hollow hemispheroidal, and facetted analogues, which are responsive to temperature, are being studied. In addition, the structure, dynamics, and supramolecular assembly of this new class of materials are explored.

Eye lens proteins and cataract formation, Adolphe Merkle Foundation, B. Rothen-Rutishauser

The goal of this project is to better understand the physical properties of eye lens proteins at concentrations corresponding to those found in the lens. Small-angle X-ray scattering experiments, light scattering experiments, and phase behavior studies are being used by researchers in order to study the behavior of eye lens crystalline as a function of various solvent parameters. The significance of the project will be to correlate the well-defined physical properties of eye lens proteins with the purpose of implying it for the improvement of data quality in toxicological studies. The significance of this project will be to correlate the well-defined physical and chemical properties of eye lens proteins with the purpose of implying it for the improvement of data quality in toxicological studies.

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Structure, dynamics, and assembly of core-shell microgels, Adolphe Merkle Foundation, B. Rothen-Rutishauser

Spherical colloidal core-shell microgels, such as novel ellipsoidal, hollow hemispheroidal, and facetted analogues, which are responsive to temperature, are being studied. In addition, the structure, dynamics, and supramolecular assembly of this new class of materials are explored.

Eye lens proteins and cataract formation, Adolphe Merkle Foundation, B. Rothen-Rutishauser

The goal of this project is to better understand the physical properties of eye lens proteins at concentrations corresponding to those found in the lens. Small-angle X-ray scattering experiments, light scattering experiments, and phase behavior studies are being used by researchers in order to study the behavior of eye lens crystalline as a function of various solvent parameters. The significance of this project will be to correlate the well-defined physical properties of eye lens proteins with the purpose of implying it for the improvement of data quality in toxicological studies.
Predicting the impact that fundamental research results may have on our daily lives is usually very difficult. However, the significant interest from innovative companies in working with AMI suggests that the research conducted at the institute is indeed relevant for future practical applications.

Competitive advantage through open innovation

The exchange of ideas, observations, and experimental results between researchers is the basis for scientific and technological progress. Based on this paradigm, AMI researchers constantly seek to create synergies between different research projects, leverage the complementary expertise of the different research departments, and develop new ideas based on interactions with external scientists. The resulting knowledge and expertise are the basis of AMI’s emerging technology platforms (see figure on the right), which are beginning to attract significant interest from industrial partners around the world.

Based on the idea of “open innovation”, many technology-based companies rely on collaborations with academic partners. Merging fundamental with application-oriented research, AMI has quickly established itself as a valuable partner for innovative companies. In 2011, the institute continued to expand its interactions with industry to several independent research projects. The figure on the right gives an overview of the connection between AMI’s technology platforms and possible application areas in various industry sectors.

### Controlled fragrance release

One illustrative example of such an open innovation project is the partnership with Firmenich, a leading company in the flavor and fragrance industry. The interaction of fragrances with cellulose materials significantly influences their performance in laundry applications.

Firmenich was founded in 1895 in Geneva, Switzerland. Today, it is the world’s largest privately owned company in the fragrance and flavor industry. Its clients are the world’s leading multinational manufacturers of beauty, household, and fabric care products, as well as pharmaceuticals, food, and beverages.

The concept of open innovations involves the use of internal and external ideas to innovate and secure a competitive advantage. Originally implemented by large companies, the concept is now also being used by Small and Medium Enterprises (SMEs).
Interdisciplinary collaborations within the institute and with research groups inside and outside the university are two of AMI’s most important strategies to conduct cutting-edge research.

To further develop its own capabilities, in 2011, AMI participated in joint research projects with scientists from various institutions including:

- Case Western Reserve University (Cleveland, USA)
- Chulalongkorn University (Bangkok, Thailand)
- EMPA (Dübendorf, CH)
- Lucerne University (Horw, CH)
- Purdue University (West Lafayette, USA)
- University of Essex (Essex, UK)
- University of Marburg (Marburg, Germany)
- US Army Research Laboratory (Aberdeen Proving Ground, USA)
- US Forest Service (Madison, USA)
- University of Applied Sciences (Bern, CH)
- German Research Center for Environmental Health (Munich, D)
- Helmholtz-Institute for Pharmaceutical Research Saarland (Saarbrücken, D)
- ETH (Lausanne and Zurich, CH)
- University of Edinburgh (Edinburgh, GB)
- Lund University (Lund, S)

This event was organized in collaboration with i-net Basel Nano and the Fribourg Nanotechnologie Netzwerk. The Innovation Circle seeks to bring together participants that want to benefit from a direct access to current information and findings on a specific subject.

Swiss aerosol group (SAG) annual meeting

In November, more than 150 members of the SAG attended the annual meeting, which was hosted by Professor Barbara Rothen-Rutishauser from AMI and Professor Wendelin Stark from ETH Zurich in Bern. Participants from universities, industry, and public authorities exchanged scientific concepts and discussed collaborations.

«Open house for interested collaboration partners»

In November about 60 participants from industry and academic institutions met at AMI for the kick-off meeting of a new Innovation Circle on the topic of «Nanopolymers and Surfaces».

This event was organized in collaboration with Swiss Aerosol Technology (SwissSAT) and the Fribourg Nanotechnologie Netzwerk. The Innovation Circle seeks to bring together participants that want to benefit from a direct access to current information and findings on a specific subject.

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Yoan Simon

An engineer at heart, Yoan considered going into aircraft or car manufacturing. However inspired by a passionate chemistry professor, he decided to pursue an academic career in nanotechnology. After obtaining a PhD in the Department of Polymer Science and Engineering at the University of Massachusetts in Amherst (one of the top polymer centers in North America), he obtained a PhD in the Department of Polymer Science and Applied Chemistry at the University of Fribourg, where he also teaches on the bachelor and master levels. Yoan now works on the use of biomaterials for photodynamic therapy, although he has many more potential applications in areas such as drug delivery, photodynamic therapy, and waste treatment. Other projects revolve around the optimization of nanoparticles, which is currently under investigation for cancer therapy using photodynamic therapy.

Yoan travelled extensively during his studies at the Ecole Nationale Supérieure de Chimie de Montpellier (France), native therefore decided to carry on with his desire to solve more fundamental problems. This science where he could combine his application-oriented mind set with his scientific career, from Italy to Spain, and then to the US industry, Yoan decided to pursue an academic career in nanotechnology. However inspired by a passionate chemistry professor, he decided to return to Europe and the EPFL. During his many travels, Yoan has learned to speak many languages, including both English and French. Although his work is currently under investigation for the aerogels I am currently working on.»

Alke Fink

Alike Finn, a statistician by training, has a thirst for travelling and experiencing the many cultures of the world, which has contributed to the person and scientist she is today. Alke received her PhD in biogeochemistry, in Germany, and subsequently travelled to Sydney, where she first got in contact with materials science. Next, her desire to travel led her to the United States, where she received her PhD in California and then moved to France, where she worked at AMI part-time, she spends the other half of her working life with Barbara Rothen-Rutishauser. She is currently working on several fundamental and applied projects. Since she only works at AMI part-time, she spends the other half of her working life as an SNF professor in the department of Chemistry at the University of Zurich, where she teaches on the bachelor and master levels.
The institute's overall expenditures in 2011 amounted to CHF 6.3 Mio. About 60% of the expenses were spent on research and 18% on investments for research equipment. About 4% of the budget supported valorization activities such as technology transfer and communication & marketing. About 18% were used to support the general infrastructure and administration. The main sources of income were the Adolphe Merkle Foundation, the University and the canton of Fribourg, as well as research funds from funding agencies and industry.

In absolute terms, the third party funding of research projects grew considerably from the last year, covering about half of all research expenditures and making up 34% of the total budget. Here the most important sources were the Swiss National Science Foundation (SNF) and industrial partners.

In 2011, 23 new collaborators joined AMI and 15 people left the institute due to natural fluctuation. Most of the new collaborators joined the Bio-Nanomaterials department that was created this year, further increasing the total number of collaborators. As of December 31, 2011, 52 people worked full- or part-time at AMI, which corresponds to about 47 full-time employees. 86% of them were active in research, a percentage that has remained stable through the years.

The AMI team is multinational with 16 different nationalities and very young with an average age of 33 years. The majority of AMI employees are Swiss. The next most prominent nationalities are French, German, and Indian. 38% of employees are women. The ratio of PhD students to Post-Docs more than doubled in 2011, which is in line with AMI’s educational mission.

Sources of funding for overall expenses in 2011.

Sources of funding for research projects in 2011 (total research expenditures of CHF 3.7 Mio.)

Distribution of overall expenses 2011 by cost types (total cost of CHF 6.3 Mio.).

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

Gender distribution at AMI on December 31st, 2011.

Composition of personnel on December 31st, 2011.
AMII has the formal status of 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 to 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 on strategic and scientific questions.

AMI’s research departments form the core of the institute. In 2011, AMI was comprised of two research departments (Polymer Chemistry & Materials, Bio-Nanomaterials) and two small research groups. The current development plan foresees a continuous growth with two new departments to be installed in the coming years. Average department sizes of about 30 researchers with 4 group leaders are envisioned. In addition to a small executive board, several comprehensive services endorse the strategic activities of the institute: Knowledge & Technology Transfer services sets the basis for successful research programs. The professional support in EU project proposal writing guarantees an efficient participation of AMI in European operations.

OBERORATOREN UND IHRE AKTIVITÄTEN

- The security commission guarantees safe research operations.
- The professional support in EU project proposal writing guarantees an efficient participation of AMF in European research programs.
- A technology transfer officer acts as the basis for successful collaborations with industry.

The results were disseminated in almost 100 presentations, including 27 international conferences. AMI researchers represented the institute and presented their latest research results to the scientific community at conferences such as the American Chemical Society National Meeting in Anaheim, California (USA), the International Soft Matter Conference in Crete, Greece, and the Congress of International Society for Aerosols in Medicine in the Netherlands.

**Scientific Output**

Publications in scientific journals:
- Published: 39
- Accepted: 11
- Submitted: 8
- Covers: 3

Contributions at conferences and workshops:
- Invited talks: 27
- Talks: 33
- Posters: 28
- Keynote Lecture: 2

External presentations:
- Invited seminars: 14


Nanocomposites Workshop 2011, SoftComp, University of Montpellier 2, Montpellier, France, 16 – 17 June 2011

NanoModel meeting, BASF SE, Speyer, Germany, 6 – 7 October 2011

Poster: "In-situ polymerization as a route towards polymer-colloid nanocomposites", O. Pravaz, P. Schurtenberger, H. Dietsch


Poster: "In-situ polymerization as a route towards polymer-colloid nanocomposites", O. Pravaz, P. Schurtenberger, H. Dietsch

The 8th Liquid Matter Conference, Wien, Austria, 7 – 9 September 2011

Poster: "Towards a better understanding of eye lens transparency and cataract formation", C. Jud, J. Holzmann, T. Ursula, A. Stradner, P. Schurtenberger

M. J. D. Clift, B. Rothen-Rutishauser, C. Weder

Research on 'Microscopic and macroscopic interactions in soft materials' (via and inverse scattering techniques)

30th TAPPI International Conference on Nanotechnology for Renewable Resources, Washington, D.C., USA, 8 – 11 June 2011

Poster: "Towards a better understanding of eye lens transparency and cataract formation", C. Jud, J. Holzmann, T. Ursula, A. Stradner, P. Schurtenberger

M. J. D. Clift, B. Rothen-Rutishauser, C. Weder

Research on 'Microscopic and macroscopic interactions in soft materials' (via and inverse scattering techniques)
36. Seminar at the Departments of Chemistry and Materials Science, University of New Hampshire, Durham, New Hampshire, USA, 23 May 2011
Invited Seminar, Alpha-Innoveiro Inhibitory Polymer Nanocomposites and Toxicology, C. Weder
37. UK National Mission in Switzerland, Lausanne, Switzerland 24th June 2011
Talk, Alpha-Innoveiro Inhibitory Polymer Nanocomposites for Medicines, M. J. D. Clift, C. Weder
38. Swiss NanoConVA, Baden, Switzerland, 18 – 20 May 2011
Poster, citrate-responsive dendrimer nanoparticles, M. Bigay, E. J. Foster, C. Weder
39. PSI/FR, Basel nanotechnology, Nanotechnology Network, Murten, Switzerland, 17 May 2011
Talks, learning from nature. How cellulose nanfibers can be used to reinforce plastics; E. J. Foster, M. J. D. Clift, C. Weder
40. NNP-DIPA-Kolloquium, Rottweil, Switzerland, 3 – 4 March 2011
Talks, citrate-based core-outer polymer building materials: solutions and strategy; E. J. Foster, M. J. D. Clift, C. Weder
41. Smart Cylinder 2011, Symposiuma, Orlando, Florida, USA, 23 – 25 February 2011
Invited Talk, Core-outer Polymer Nanocomposites; C. Weder
42. 18th Congress of International Society for Aerosol Medicine, The Netherlands, 18 – 22 June 2011
Invited Talk, X-ray radiopaque particles of particles into lung culture surfase. A new study to standard particle-cell interactions; B. Rothstein-Rutishauser, C. Weder
43. 37th Nanoconvergence Celebration Workshop Nano-remote-interactions, Stockholm, Sweden, 17 June 2011
Invited Talk, Co-culture of remye and lung cells for in vitro assessment of nanoparticle toxicity, B. Rothstein-Rutishauser
44. Allegheny Epiphysis Sanction, Organized by the Fachschaft Chemie - Biology, Briss, Switzerland, 30 August 2011
Invited Talk, Nanotechnology – Nature and Risiken, B. Rothstein-Rutishauser
45. Jahrestagung Silag, Zürcherische Arbeitsgemeinschaft zur Erforschung und Bekämpfung der Staublungen in der Schweiz, Adolphe Merkle Institute, Marly, Switzerland, 4 October 2011
Invited Talk, Nanoparticle-Lung-Interactions: Risiken and Chancen, B. Rothstein-Rutishauser
46. Seminar in Molecular Toxicology, Molecular and Systems Toxicology, Department of Pharmaceutical Sciences, University of Basel, Basel, Switzerland, 21 November 2011
Invited Talk, Alpha assessment of nanotoxicity – Do we need to worry?, B. Rothstein-Rutishauser
47. 19th ETH Conference on Combustion Generated Nanoparticles, ETH Zentrum, Zurich, Switzerland, 26th – 29 June 2011
Poster, studying nanoparticles mutagenicity: Can nanoparticles-bacterial interactions provide access into the unknown?, B. Rothstein-Rutishauser
48. Eastern Scientific Congress, Fribourg, Switzerland, Talk, Cellulose fibers, A. Fink
50. IADT Swiss, Bern, Switzerland, Invited Talk, New innovative nanomaterials to life science – an interdisciplinary approach, A. Fink
51. Workshop on Magnetic Nanoparticles, Sollburg, Austria, Workshop, @MNP for in vitro applications, A. Pajenk
52. NPF2 Project Meeting, Fribourg, Switzerland, Poster, Research on bacteriostatic superparamagnetic iron oxide nanoparticles, A. Bardas
53. Invited Talk, Towards design of magnetic nanoparticles, C. Weder
54. Poster, stencil seed for drug delivery, Cryo EM study to elucidate particle/bacterial interactions, C. Bonnaud
55. Poster, Towards better control of superparamagnetic iron oxide nanoparticles, A. J. Foster, M. J. D. Clift, C. Weder
56. Poster, Pathways to design magnetic nanoparticles, C. Bonnaud
57. Poster, stencil seed for drug delivery, Cryo EM study to elucidate particle/membrane interactions, C. Bonnaud
58. 8th Swiss Aerosol Group Meeting, Bern, Switzerland, Invited Talks, Comparing the interaction of silver and gold nanoparticles using a 3D in vitro model of the epithelial airway barrier; C. Weder
59. Poster, Air-liquid exposures of particles onto lung culture surfaces: A new approach?, M. J. D. Clift
60. 15th ETH Conference on Combustion Generated Nanoparticles, ETH Zentrum, Zurich, Switzerland, Poster, Comparing the interaction of cellulose nanofibre derived from cotton, jute and ramie and asbestos fibers with a sophisticated 3D human lung cell co-culture, M. J. D. Clift
61. Invited Talk, Effect of bacterial loading on lung cells in vitro, C. Weder
62. 5th Nanoscience & Nanotechnology (5NN) of the United Kingdom Annual Meeting, Liverpool, United Kingdom, Poster, Investigating the nanoparticle-cell interaction in vitro: an advantageous ‘alternative’ approach?, M. J. D. Clift
63. In the Year Toxicological Society (ITY) of the United Kingdom Annual Meeting, Liverpool, United Kingdom, Poster, Investigating the nanoparticle-cell interaction in vitro: an advantageous ‘alternative’ approach?, M. J. D. Clift
64. DISchool2011 Workshop entitled ‘Biological Responses to Nanoparticles’, Volos, Greece, 2011
Invited Talk, Studying nanoparticles-cell interactions in vitro: an advantageous ‘alternative’ approach?, M. J. D. Clift
65. Swiss Chemical Society Annual Meeting, Lausanne, Switzerland, Poster, stencil seed for drug delivery, C. Bonnaud
66. Poster, @MNP for in vitro applications, Y. Richon
67. Swiss Chemical Society Annual Meeting, Lausanne, Switzerland, Poster, Searching the surface influence on charge superparamagnetic cellular interaction of polymer coated SPIONs in vitro, E. Hirsch
68. Poster, Evaluating the potential for a variety of nanomaterials to develop cardiotoxicity in the lung using a 3D in vitro model of the human epithelial airway barrier, M. J. D. Clift, C. Weder
69. Swiss Chemical Society Annual Meeting, Lausanne, Switzerland, Poster, stencil seed for drug delivery, C. Bonnaud
70. Poster, Alpha-Innoveiro Inhibitory Polymer Nanocomposites and Toxicology, C. Weder
71. 6th Swiss Aerosol Group Meeting, Bern, Switzerland, Invited Talks, Towards better control of superparamagnetic iron oxide nanoparticles, C. Bonnaud
73. Invited Seminar, Towards design magnetic nanoparticles, C. Bonnaud
74. Invited Seminar, Stencil seed for drug delivery, Cryo EM study to elucidate particle/membrane interactions, C. Bonnaud
75. Malta Aerosol Research Group Meeting, Valletta, Malta, Poster, Alpha-Innoveiro Inhibitory Polymer Nanocomposites and Toxicology, C. Weder
76. Invited Talk, Towards better control of superparamagnetic iron oxide nanoparticles, C. Bonnaud
77. Invited Talk, Stencil seed for drug delivery, Cryo EM study to elucidate particle/membrane interactions, C. Bonnaud
78. Invited Seminar, Towards better control of superparamagnetic iron oxide nanoparticles, C. Bonnaud
79. Invited Seminar, Stencil seed for drug delivery, Cryo EM study to elucidate particle/membrane interactions, C. Bonnaud
80. Invited Seminar, Towards better control of superparamagnetic iron oxide nanoparticles, C. Bonnaud
81. Invited Seminar, Stencil seed for drug delivery, Cryo EM study to elucidate particle/membrane interactions, C. Bonnaud
82. Invited Seminar, Towards better control of superparamagnetic iron oxide nanoparticles, C. Bonnaud
83. Invited Seminar, Stencil seed for drug delivery, Cryo EM study to elucidate particle/membrane interactions, C. Bonnaud
84. Invited Seminar, Towards better control of superparamagnetic iron oxide nanoparticles, C. Bonnaud
85. Invited Seminar, Stencil seed for drug delivery, Cryo EM study to elucidate particle/membrane interactions, C. Bonnaud

66. Jahrestagung Ehemaliger Chemie- und Biochemiestudenten, Fribourg, Switzerland, 7 May 2011
Invited Seminar, «Exploiting Supramolecular Interactions for the Design of Smart Polymers», C. Weder


68. Swiss Engineering, Technikgruppe Kunststofftechnik, Seminar Funktionale Kunststoffe, Fribourg, Switzerland, 23 March 2011
Invited Talk, «Functionale Polymere und Nanocomposites», C. Weder

69. Makromolekulares Kolloquium Freiburg, Freiburg, Germany, 24–26 February 2011
Invited Talk, «Bio-inspired, mechanically adaptive polymer nanocomposites», C. Weder

70. 7th Swedish Neutron Scattering Society Meeting (SNSS-15), Gothenburg, Sweden, 25 August 2011
Invited Talk, «Escaping the squeeze: Soft particles at high effective volume fractions», P. Mohanty

71. Department of Physics and Phys. Oceanography Memorial University of Newfoundland, St. John’s, Canada, 4 March 2011
Invited Seminar, «Structural ordering and phase behavior in responsive microgels», P. Mohanty

72. Condensed matter division, Institute of Physics, Bhubaneswar, India, 8 July 2011
Invited Seminar, «Interacting soft microgel colloids», P. Mohanty

73. Department of Physics, University of Vienna, Vienna, Austria, 12 September 2011
Invited Seminar, «Escaping the squeeze: Soft particles at high effective volume fractions», P. Mohanty


75. Euroconf, Montpellier, France, 12–15 September 2011
Talk, «State Power Sensitive Upconverting Nanoparticles», Y. C. Simon

76. 6th International Conference on Microtechnologies in Medicine and Biology, Lucerne, Switzerland, 4–6 May 2011
Martin Clift & Dimitri Vanhecke. A 3D reconstructed image from an electron tomogram showing a cellulose nanofiber derived from cotton (orange) inside a vesicular body (yellow) within a human monocyte derived macrophage. For more details see the NRP64 project «Cellulose-based nanocomposite building materials: solutions and toxicity» by C. Weder, J. Foster, and M. Clift as well as Clift et al. Biomacromolecules 2011.

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