CCMX
Competence Centre for
Materials Science and Technology

ANNUAL ACTIVITY REPORT 2008

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Message from the Chair

As we come to the end of 2008 and reflect on the accomplishments over the past three years, we realize that CCMX is a unique network that brings together Swiss research institutions, researchers and industries in a way that has never been done before. The main aim is to build academic/industrial partnerships to explore areas of pre-competitive research and provide educational and networking opportunities. The funding and leadership provided by CCMX has enabled its members to share resources, to exchange expertise and to establish critical mass - this has already led to significant advances in several areas. In addition, industry increasingly sees the value of partnering with Swiss research institutions on both small and large scale research projects thus fostering productive collaboration. Much of this good work is due to members embracing an unprecedented level of cooperation.

Following a rigorous and successful 3 year review, held in Bern on 2-4 December 2008, I am pleased to say that CCMX's future looks positive and I am confident that we can continue to build on the solid foundation that has been established in CCMX's first three years. A very special thank you goes out to the evaluation panel for their dedication and contribution to this important initiative. In addition, many thanks to the excellent work of the ERU directors, the scientific and industrial liaison officers, the Steering Committee and the CCMX management team.

Over the next year, we will continue to expand the existing collaboration between the research community and industry through the Research Ticket Programme. With greater industry participation, we plan to launch research in new and existing thematic areas relevant to the long term needs of the sector.

Sincerely,

Professor Karen Scrivener
Chair CCMX

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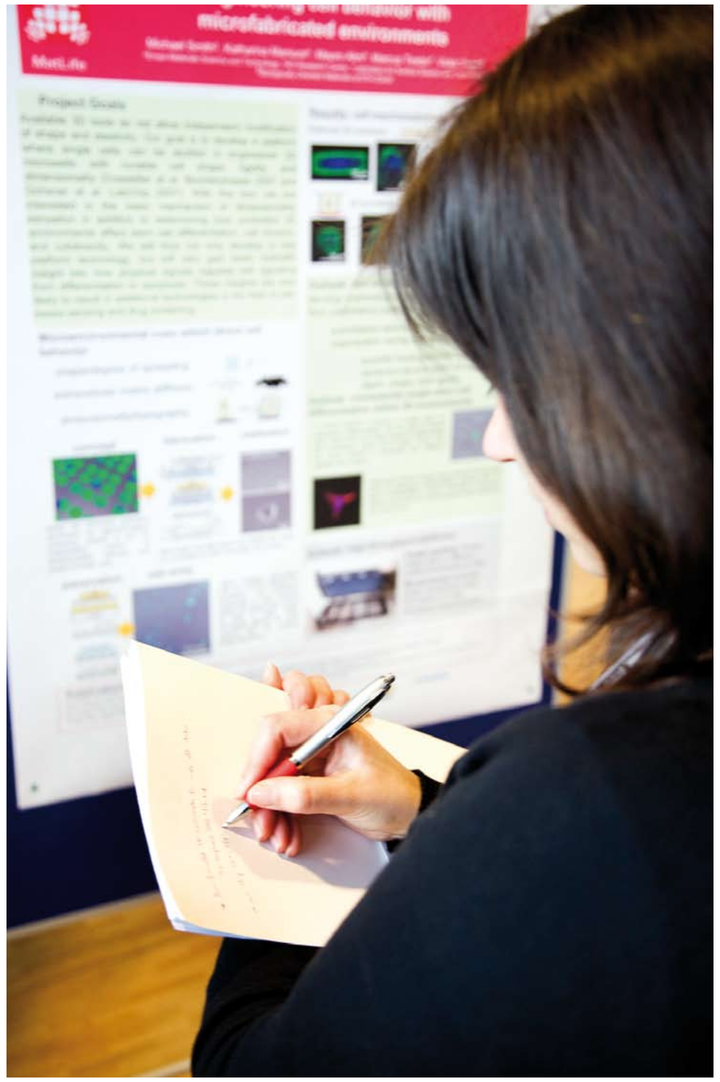
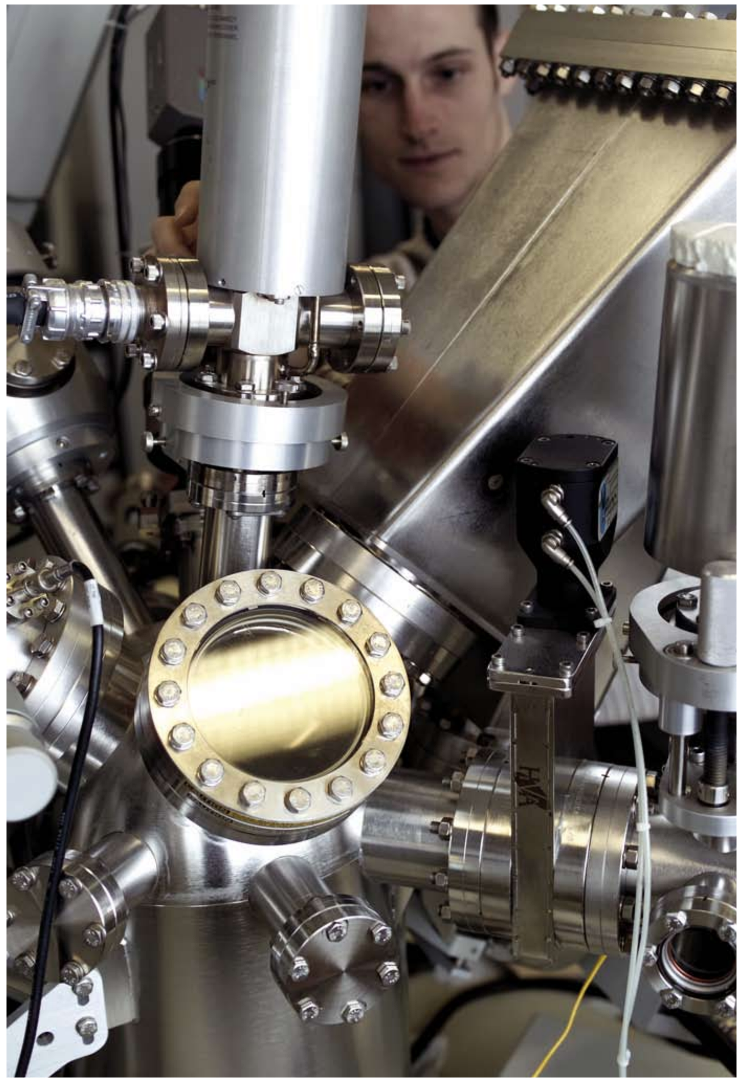
How to be involved with CCMX ?

The main mission of CCMX is to link the needs of industry with academic research. To achieve this mission, CCMX has established several entry points for its target clients in order to both understand and fulfil their needs.





X-ray photoelectron spectroscopy (XPS) (ETH Zurich).

Education & training
CCMX aims to fulfil the expectations of actors across the Swiss materials science network by offering a wide range of courses, seminars and workshops. The topics are chosen based on the needs of the target audience (scientists from industry and/or academia, engineers, PhD students). These events are not only an opportunity to learn, but have also proven to be an ideal networking occasion.

Please see page 6 for more details on education and training.

Outreach & networking activities
The outreach activities of CCMX have two main goals. The first is to ensure knowledge transfer and the second is to stimulate networking. CCMX strongly believes that promoting informal exchanges between industry and academia facilitates the germination of new ideas, and fosters long-term collaborations.
An example is the "Technology Aperitifs" organized on a regular basis. These early evening events bring research activities closer to the industry and aim to generate creative ideas for new applications.

For more information and details on outreach and networking activities please see page 8.

Research
CCMX concentrates on pre-competitive research. This enables companies from the same domain to be involved together in research activities at an affordable cost. CCMX has established its "Research Ticket Programme" allowing small and large companies to "buy into" research in chosen thematic areas. Thematic research areas are selected based on the medium and long term needs identified by the companies.
The thematic research areas and more details on the research carried out within CCMX can be found from page 10 to page 35.

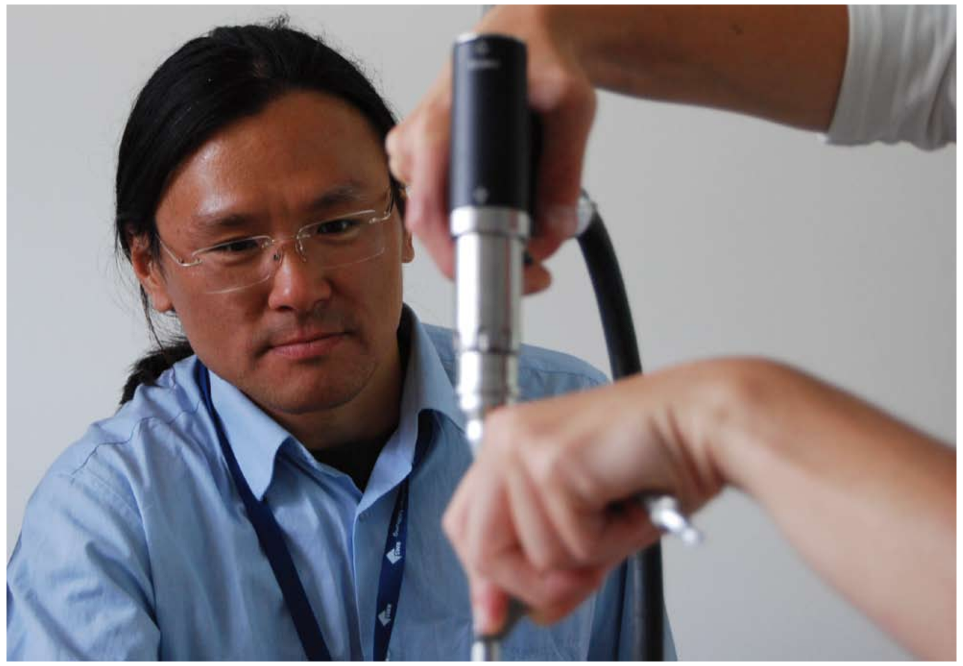
More information and details on these subjects are available on the CCMX homepage (www.ccmx.ch), including all the upcoming training courses and events.

Companies involved in CCMX in the framework of research projects

2006-2007: 8 companies	5 SMEs
	3 large companies
2008: 24 companies	12 SMEs
	12 large companies

Learning with CCMX

More than 160 people participated in the different training activities organised by CCMX in 2008. The strong programme of education in materials science offered by CCMX is designed for PhD students, engineers and scientists from both industry and academia. CCMX aims at proposing a varied approach to learning, thus trying to suit everybody's needs.



CCMX Training activities in 2008

Date	Training offer
July 2008	Summer School on Nanoelectronic Circuits and Tools[1]
August 2008	Travelling Lab Workshop on « Needs and perspectives of materials science and technology in industry and clinics »
September 2008	Workshop on Single-Cell Analysis
October 2008	Workshop on Nanoanalyses
October 2008	Annual Course «Colloidal Chemistry for Materials Science»

[1] *In partnership with the Integrated Circuits Centre of EPFL.*

New teaching concept
A new concept was created by CCMX in 2008 with the « Travelling Lab Workshop ». Twenty young researchers went on a 5-day tour around Switzerland visiting different labs from EPFL, CSEM, the Robert Mathys Foundation and University Hospital in Zurich. This « hands-on » approach was strategically linked to lectures, case studies and the understanding of collaboration with industry.

In order to offer an extensive view of a given subject, the CCMX network of lecturers was regularly joined by national and international experts and professors, such as Prof. H.S. Philip Wong from Stanford University and Prof. Shunri Oda from the Tokyo Institute of Technology who both gave talks at the Summer School on Nanoelectronic Circuits and Tools, or Prof. Peter Schurtenberger from University of Fribourg who lectured at the Annual Course on « Colloidal Chemistry for Materials Science ».

The CCMX « Master Support Programme » provided partial financial support to two master students, one from France and one from Sweden. They carried out their master thesis project at ETH Zurich within the thematic area of materials for the life science.

Positive feed-back
The overall feedback received by the participants of the training activities was positive. The questionnaires showed a high satisfaction rate and constructive comments were received. Another positive aspect that was raised was the personal contacts made between participants from different research institutes that led to new collaborations.

« We were all very satisfied with our learning success each day, but also a bit exhausted. After the avalanche of versatile scientific presentations and lab tours, social contacts were tied for the future. Not only was this week a very well organised and highly informative event, it also led to long lasting contacts and the build-up of a professional network for all participants. »

Petra Gunde, Hanja Haenzi, Bruno Zberg, Michael Schinhammer and Christoph Mayer (PhD students at ETHZ-DMATL) - Participants of the Travelling Lab Workshop

What participants said about CCMX courses:
- **A good way to get academia, industry and also different fields of sciences together.**
- **Nice overview of different research fields from different institutes within Switzerland.**
- **An opportunity to meet people involved in materials characterisation.**
- **Excellent balance between theory and the examples used to illustrate it.**

Focus
Understanding the needs of its target audiences is one of the main focus points for CCMX in terms of education. The feedback collected from the participants of the courses is precious and is always analysed in detail. CCMX intends to continuously adapt its offer in accordance to the expectations of the participants.

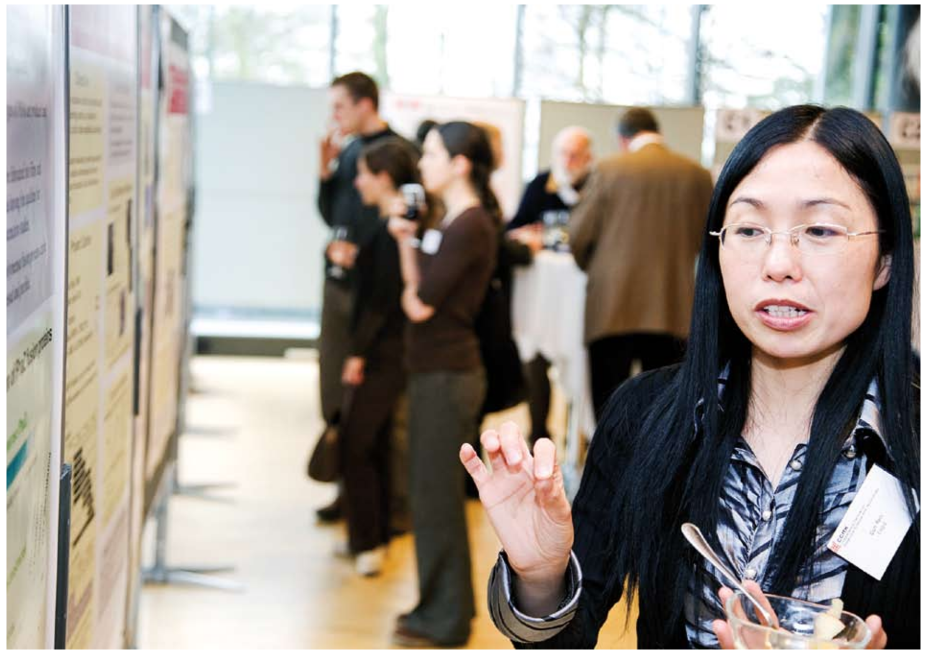
The theory/practice balance found in CCMX courses is important, whether ex-cathedra courses or hands-on experiences in a lab, the aim is to find the best way to pass on the knowledge.

CCMX will continue encouraging networking as a solid base for future collaborations and would like to help put on the market, via its education activities, a supply of talented engineers that will help drive development and innovation in the Swiss manufacturing sector.

Outreach and networking activities

Staying in touch with the various actors of the Swiss materials science scene is central to the working of CCMX, which should act as a plaform allowing these people to meet to exchange ideas and information.

The 2008 CCMX Annual Meeting was organised in April in Bern. This day was dedicated to presenting the evolution of CCMX, the results of its on-going projects and of course to give the opportunity to the more than 210 participants (more than 50% from industry) to network.



Industrial liaison activities
It is essential for CCMX to know and to understand the needs and expectations of the industry to be able to adapt its offer accordingly. CCMX regularly organizes sessions with representatives from both industry and academia to discuss these issues.

The Metallurgy Day took place in September and brought together industry and academia to discuss the scientific issues related to the Metallurgy Education and Research Unit. The status of current projects, ideas for new projects and industrial concerns were discussed between the 11 industrial and the 14 academic representatives that were present.

The Science & Networking Day organised in November by the Surface, Coatings and Particles Engineering Education & Research Unit gathered all the researchers involved in the running projects and was open to industry. Results of the on-going projects were shared and discussed.

A fruitful discussion organized by the Materials for the Life Sciences Education and Research Unit took place in December between the Swiss Med-Tech industries, the ETH institutions and selected partners from university hospitals. Industries and clinics were invited to formulate their needs and visions for future R&D activities in the field of interfaces between engineered biomaterials and soft/hard tissues in accordance with clinical needs. The conclusions and recommendations that emanated from this discussion will serve as a basis for a future call for project proposals in this field.

Current and potential industrial partners were questioned by an external consultant on their perception of CCMX at the end of 2008. The goal of this exercise was to determine how CCMX is seen from the outside and how it can adapt to the needs of industry.

Benefiting from associations
As often as possible, CCMX likes to benefit from partnerships with professional associations thus ensuring to target as many people as possible in the right field and to ensure larger audiences and better coverage.

The Technology Aperitif "Materials for Pharmaceutical Applications" was organized in partnership with BioValley Basel (a network of life sciences companies present in the Basel area) and attracted more than 75 researchers and marketing people from industry and academia.

The materials-oriented organizations of Switzerland such as the SVMT (Swiss Association for Materials Science and Technology), SGO-SST (Swiss Society of Surface Treatment) and SAOG (Swiss User Group Surfaces and Interfaces) were involved in the other Technology Aperitifs.

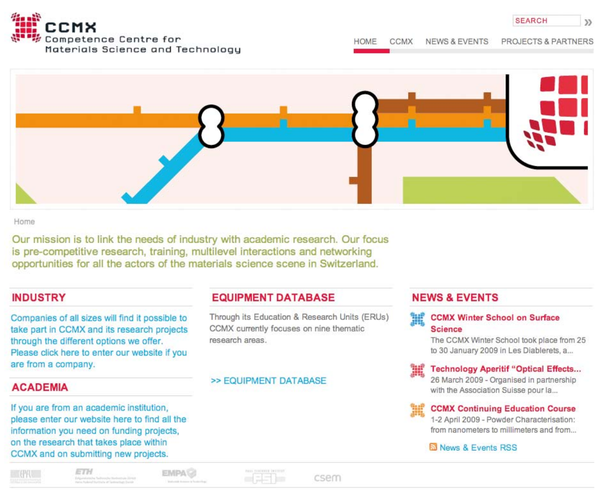
CCMX Outreach and networking activities in 2008

Date	Outreach & networking activities
February 2008	Technology Aperitif « Coating materials - processes and properties »
April 2008	CCMX Annual Meeting
April 2008	Workshop on creating a « Packaging Consortium »
August 2008	Technology Aperitif « Materials for pharmaceutical applications »
September 2008	Metallurgy Day
October 2008	Re-launch of the newly designed CCMX website
November 2008	Science and Networking Day
December 2008	Technology Aperitif « Modelling of Materials »

Participation
In 2008, more than 120 industry representatives participated in CCMX outreach and networking activities with a good proportion coming from SMEs.
100% of respondents to a survey that was carried out stated that they would attend future events again.

Sharing of resources
Following a request made from industry, a database detailing and identifying modes to access micro- and nanoscale analytical instrumentation available to industry within the ETH Domain is being created. This database will be directly accessible from the CCMX webpage (as of April 2009) as a free service to industry and to academia. Please go to page 27 for more information on this database.

A new website

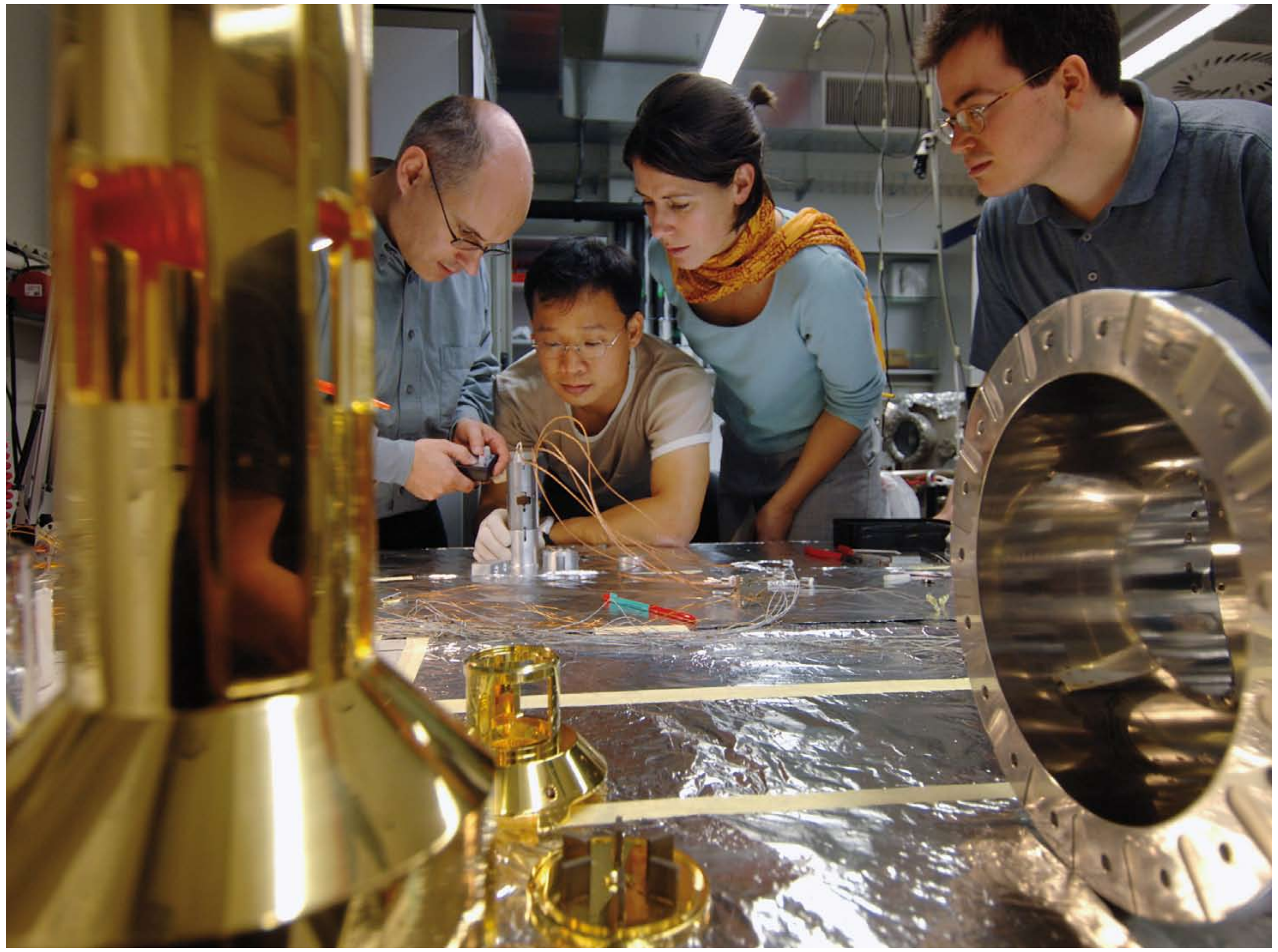


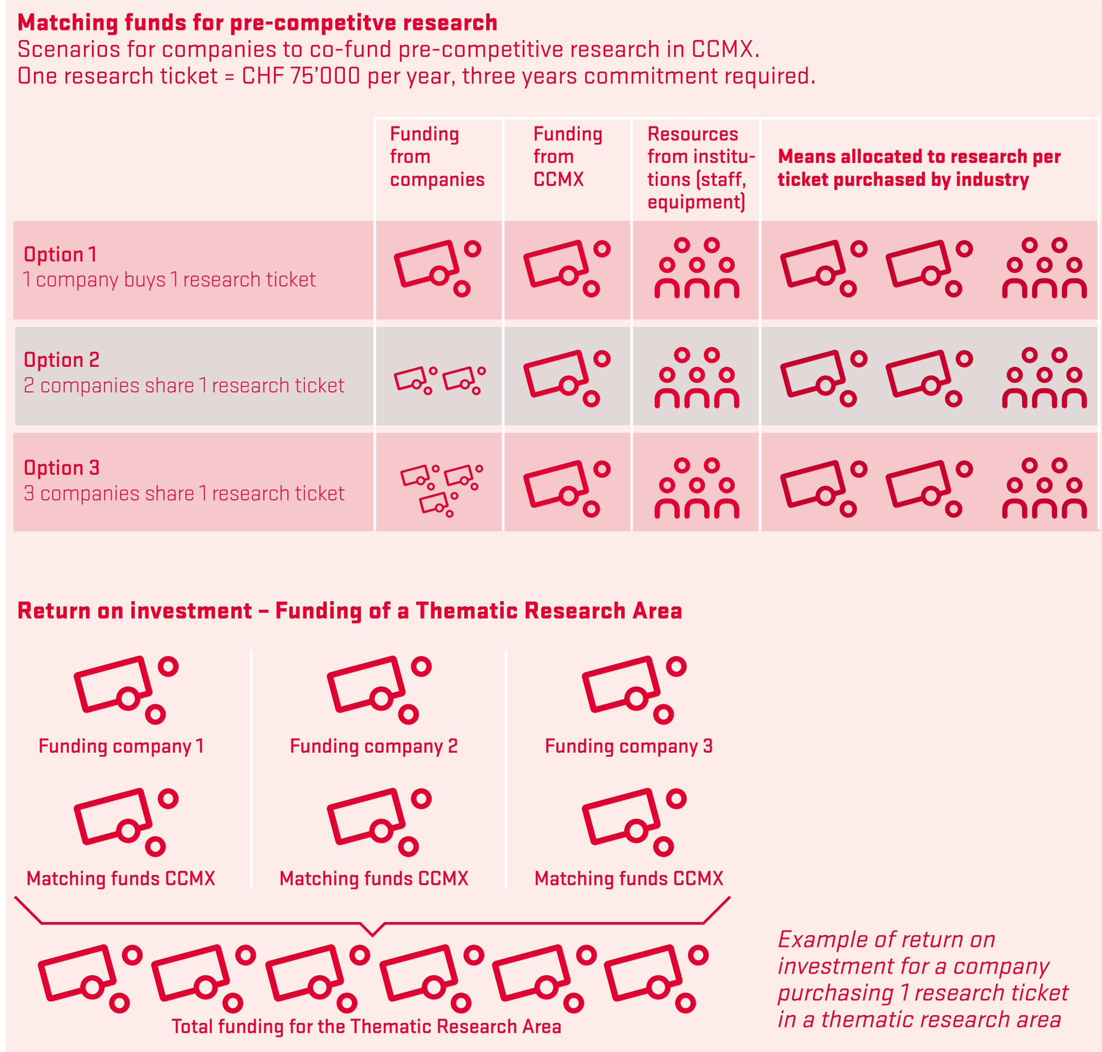
The new CCMX website was launched in the Autumn of 2008 providing a more user-friendly and interactive communication tool.

Outside perception of CCMX*
- CCMX creates synergy between the various competences available within the Swiss research institutions.
- Networking, continuous education and interdisciplinary projects give multiple opportunities to improve mutual academic-industrial understanding of research.
- A new cohort of interdisciplinary trained young researchers with soft skills will provide great advantage for the industry/workplace.
- Personal contacts attract industry to join initiatives.
- This new initiative needs time to bear fruit.

** Survey carried out in 2008 by an external consultant to determine how CCMX is perceived from the outside.*

The research we focus on





There is strong agreement between industry and academia that the creation of multilateral partnerships for medium term pre-competitive research is mutually beneficial and is a good way to bridge the funding gap between the fundamental research supported by SNSF and the applied, "close to market" projects supported by CTI.

The new collaborative model (Research Ticket Programme) put in place by CCMX replies to this demand. Instead of engaging in research on a project-by-project basis as it has been in the past, industrial partners collaborate with academic groups in a consortium focusing on a selected "Thematic Research Area". In addition to this research programme, CCMX's Analytical Platform covers all aspects linked to analytical methods and resources.

A new form of partnership in materials science

The Research Ticket Programme, which started at the end of 2007, is designed to foster public-private partnerships in materials science in order to ensure the longevity of the interactions between industry and the CCMX institutions. With this programme, funding from industry is matched one for one by funds from CCMX thus giving companies a very high return on investment. To ensure that the research being carried out is at the pre-competitive level, two or more companies must be involved in each thematic area, each of which includes several projects.

The Analytical Platform – keeping materials characterisation in the loop

The Analytical Platform aims at bringing together expertise in the development of analytical methods and broad analytical resources from different institutions within the ETH domain, industrial partners and other universities.

On one hand the analytical platform funds projects aimed at the development of new analytical tools, methods or instrumentation for the analysis of physical, biological or chemical properties on the scale below 100µm. On the other hand, the projects funded concern the exploitation of existing analytical techniques for nanoscale analysis in new fields of application. Co-funding from industrial partners and/or other institutions is a fundamental aspect of these projects.

In addition to funding projects, the analytical platform is setting-up a free web-based database detailing and identifying modes to access micro- and nanoscale analytical instrumentation available to industry within the ETH Domain. This database will be available on the CCMX website as of April 2009. Please see page 27 for more detailed information on this database.

Current Thematic Research Areas in 2008

- Neo-metallurgy: new alloys, new processes and new investigation techniques
- Multi-scale, multi-phenomena modeling of metallic systems
- Surface modification by coating and structuring
- Functional foams
- Functional particles in contact with biological fluids
- Medical device technology and innovation
- Biosensing and diagnostic strategies
- Materials technologies and design for micro- and nanosystems
- Laboratory-on-a-chip

Future Thematic Research Areas

- Modern packaging
- Engineered biomaterial-tissue interfaces

Companies are in the driver's seat

Companies take a lead in identifying the priority research topics and may influence the choice of research projects to be carried out within a thematic research area. Not only is research funding more than doubled since funding comes from both CCMX and two or more industrial partners, but companies also share the risk of funding long term strategic research.

CCMX will continue to significantly increase the involvement of industrial stakeholders in 2009 and beyond. The Research Ticket Programme allows flexibility for companies of different sizes to participate in the research activities of the Centre.

Main benefits of participating in the Research Ticket Programme

- Increased expertise in topics relevant to industry
- Access to hiring well-trained scientists
- Access to new knowledge, data and tools
- Directing research on industry's medium and long term needs
- Option to negotiate IP Rights
- Vote on allowing other companies to join.

Neo-metallurgy: New alloys, new processes and new investigation techniques

metallurgy | new alloys | new processes | characterisation techniques | combinatory experiments | compositional gradients | up-scaling properties | measurements at the nanoscale | structure-property relationships

MERU

Characterising metallic alloys in depth down to very low scale nurtures the development of innovative alloys and new processing routes.

This thematic area focuses on characterising the structure - property relationships of new metallic alloys, and in doing so, developing new techniques for materials characterisation. Increasing the efficiency of alloy and process development will lead to the development of structural and functional materials with improved properties.

Two projects were initiated in this new thematic area in 2008. The first project, led by Dr. S. R. Holdsworth (Empa) and involving Dr. C. Solenthaler (ETH Zurich) and Dr. K. Janssens (PSI), studies the evolution of microstructure and mechanical response due to cyclic deformation at elevated temperatures. The aim is to determine the variation in dislocation, sub-grain and glide band conditions due to cyclic deformation at elevated temperatures in two steels, one which cyclic softens (2CrMoNiWV) and one which cyclic hardens (17Cr12Ni2Mo) during transient loading. These variations will be quantified as a function of temperature, cyclic strain and strain rate to provide the basis for the formulation of evolutionary equations for the internal variables that determine the history dependence of material cyclic deformation behaviour. For the industrial partners, the expected outcome is the availability of advanced high temperature cyclic deformation constitutive equations for the selected steels which are based on physical observation of microstructural changes at the sub-grain level and which have been verified by the results of service-cycle thermo-mechanical fatigue benchmark tests. Since the beginning of the project, in October 2008, a preliminary evaluation of the microstructural characteristics of both steels was performed in order to examine the long term behaviour of critical components at elevated temperatures.

The "In situ mechanical testing" project, led by Prof. H. Van Swygenhoven-Moens (PSI) and in collaboration with Dr. S Holdsworth and Dr. E. Mazza (Empa), is an opportunity to conduct innovative experiments on the fundamental mechanisms of deformation as it relates to residual stresses in finished components. The project aims to determine the microstructure - mechanical property relationships of polycrystalline materials and Ni-base single crystal superalloys through in situ mechanical testing using diffraction methods. These relationships will then be used to correlate fundamental deformation mechanisms with the residual stresses present in industrially important components. The extended testing facilities and the knowledge gained through this project will not only provide in-depth understanding of these alloys, but also demonstrate the power of these in situ methods to the industry. Two PhD students started working on this project in October 2008. Initial experiments have been conducted using neutron and synchrotron diffraction to characterise both the residual stresses present in finished components of copper-based alloys and their respective response to in situ tensile loading. Micro-diffraction experiments using synchrotron X-ray radiation on single crystal Ni-base superalloy material has also been performed.

Industry partners in this thematic area:
ABB, ALSTOM, Swiss Nuclear.

Trends

Efficient development of new metallic alloys for structural or functional applications relies on the possibility of making combinatory experiments in a fast and efficient way. One way is to produce materials with composition gradients, with testing made afterwards at a very local scale (e.g. nanoindentation for mechanical properties, or local optical/electrical measurements for functional properties). In order to industrially produce these new alloys, new processing routes are required. For example, new materials such as bulk metallic glasses, metallic foams, and metal matrix composites offers new and quite unique mechanical properties that are difficult to fabricate in bulk. Laser welding of dissimilar materials is also of great interest for many industries from the watch or medical sectors to the automotive and aeronautic sectors. While the metallurgy of base elements within an alloy may be well known, the combination of elements by metallurgical bonds requires a deep understanding of both thermodynamics and processing. Finally, novel characterising techniques such as in situ X-ray radiography or tomography, neutron scattering, orientation imaging using EBSD combined with chemical analyses, nano-testing devices, etc., allow one to characterise accurately and in-depth metallic alloys down to a very low scale. While some of these techniques are relatively mature, others still require considerable effort to achieve a single result. In all cases, improvements in speed, accuracy, and resolution of these techniques will aid in developing new alloys and new processing routes.

CCMX aims to develop this thematic area over the next two years by obtaining further industrial commitment and by launching additional projects.

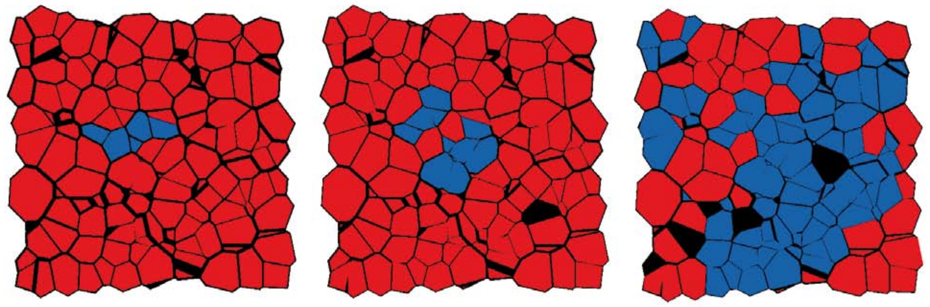
Setup of the in situ tensile deformation stage at the Material Science beamline of the Swiss Light Source (PSI & Empa).

Multi-scale, multi-phenomena modelling of metallic systems

computer simulation | optimised processing routes | defect reduction | multi-scale modelling | ab initio calculations | molecular dynamics | phase-field methods | granular approaches | cellular automata | finite elements

MERU

A single model to combine effects at lengths scales between the atomistic and the process level.



Simulation of different stages during solidification using a granular approach: black represents the liquid, red represents individual grains, and blue represents a single grain cluster (EPFL & PSI).

For traditional metallurgy, a key area of research is the optimization of processing routes in order to enhance structural or functional properties. Computer simulation has become a crucial tool in this regard, since the right model allows one to efficiently investigate processing and compositional variables over a large parameter space. Multi-scale models allow researchers to combine the effects at length scales between the atomistic and the process level in one model. However, this type of modelling requires the development of dedicated tools which can encompass nearly ten orders of magnitude.

Two projects were initiated in this new thematic area in 2008. The first project, led by Prof. M. Rappaz and Dr. A. Jacot (EPFL) and involving Prof. H. Van Swygenhoven-Moens (PSI), aims to model defect formation in solidification processes using granular dynamics and phase field approaches. Porosity and hot tearing are the two major defects formed during solidification of metallic alloys. Control of such defects is a key aspect to most companies involved in the production and usage of metals. While several modelling tools exist on the market, two key phenomena are treated in this project: the contribution of curvature to porosity formation and the coalescence of grains in hot tearing. Three PhD students started working towards the end of 2008 on three features: 1) modelling of porosity formation using a phase field method; 2) modelling of hot tearing formation using a granular dynamics approach; 3) characterisation of porosity and hot tears, in particular through X-ray tomography experiments at the Swiss Light Source of PSI. Initial-stage phase field and granular models have already been developed with the former adapted to the case of a compressible phase while the latter adapted to predict the evolution of the solid morphology during solidification. Two X-ray tomographic sessions also took place in 2008 to characterise porosity and hot tears in specimens both created in the laboratory and provided by industrial partners.

The second project, led by Prof. R. Spolenak (ETH Zurich) and involving Prof. H. Van Swygenhoven-Moens and Dr. P. Derlet (PSI), combines thin-film experiments with modelling to investigate the optical properties of gold alloys. The principal aims are twofold: to develop an ab initio model which predicts the colours of gold-based alloys; and to fabricate complex gold alloys which exhibit both new colours and sufficient ductility for industrial usage. This project is being carried out in close collaboration with industrial partners in the watch and jewellery sectors. Recent work has included the fabrication of thin-film samples of Au-Ag, Au-Cu-Ag and Au-Al alloys with a compositional gradient. These samples are now being tested. On the modelling side, two ab initio packages, namely VASP and Wien2k are currently being evaluated for the calculation of optical properties. The first results indicate that the modelling predictions compare well to the experimental results.

Industry partners in this thematic area:
Alcan, Asulab, Kugler Bimetal, Metalor, Rolex.

Trends

Modelling metallic systems can take many forms. At the scale of a small population of atoms, ab initio calculations can be used to model the optical or electrical response of metallic systems. At the scale of a few million atoms, molecular dynamics can help in the understanding and calculation of mechanical properties of nanoparticles, the structure and property of diffuse solid-liquid interfaces or the interactions between metallic systems and radiation. Numerical simulation methods such as pseudo-front tracking and phase field methods are used to model the formation of microstructure and defects in multi-component and multiphase systems. At larger scales, granular approaches or cellular automata can be used to model interactions of macrostructures, i.e. at the scale of a large population of grains, while still incorporating grain boundary interaction. Finally, models can be developed using, for example, finite elements or computational fluid dynamics, to simulate entire industrial processes at the macro scale.

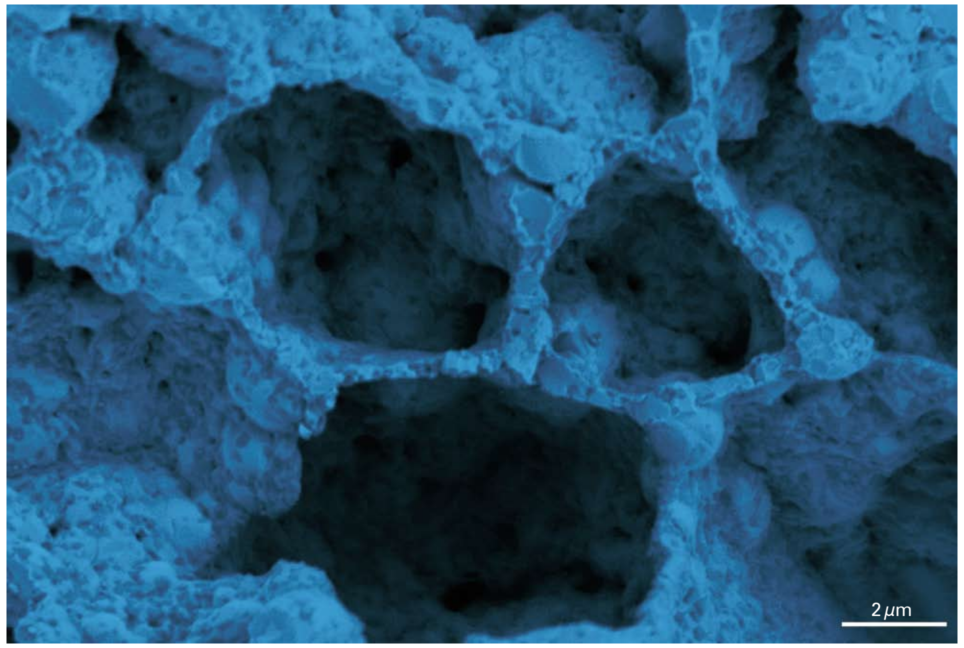
CCMX aims to develop this thematic area over the next two years by obtaining further industrial commitment and by launching additional projects.

Functional foams

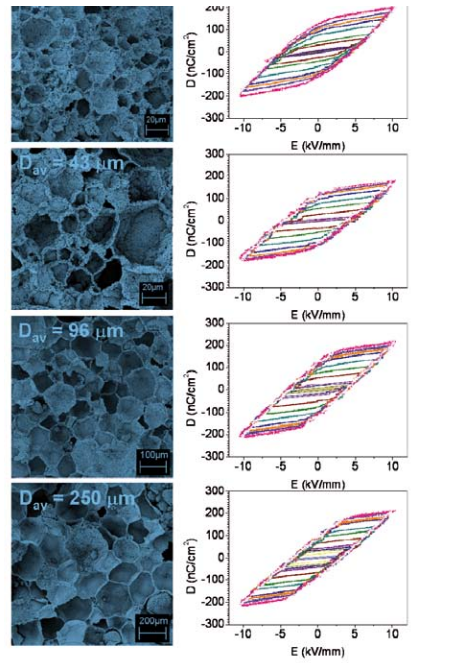
Biodegradable composite foams | light-weight foams from renewable resources | foams as resorbable scaffolds and implants | tissue engineering | smart metallic shape-memory foams

SPERU

Foams and emulsions stabilized by colloidal particles can lead to new materials with unique structures and properties.



Scanning electron microscopy image of a sintered nickel-titanium foam produced via a water/octane emulsion and exhibiting a porosity of about 67% (ETH Zurich & EPFL).



Charge hysteresis loops for sintered poly(vinylidene difluoride)(PVDF) foams with varying microstructures (ETH Zurich & EPFL).

Today solid foams find many applications both in every-day life and in important technological processes such as polymeric foams for packaging, aluminium lightweight structures for buildings and airplanes and porous ceramics for molten metal filtration. In addition, foams can also be beneficial to the fabrication of smart functional materials, including for example bio-scaffolds for tissue engineering, electrodes for solid oxide fuel cells, smart and light-weight structural components or soft actuators and sensors.

The project entitled "Smart Functional Foams" was initiated in early 2007 and is currently in progress in this thematic area. A direct foaming method is applied for producing foams with tailored porosity, pore size distribution and pore connectivity, using modified colloidal particles as foam stabilizers.
The project gathers four research groups, originating from ETH Zurich (Prof. L. Gauckler, Prof. P. Ermanni & Prof. J. Löffler) and EPFL (Prof. D. Pioletti).

Being able to adjust the microstructure of the wet foams is essential for the development of porous structures with defined and unique properties. Solid ceramic, metallic and polymer foams have already been produced and some of their key properties measured. The microstructure of the ceramic foams can be tailored in a wide range. The researchers prepared foams with porosities between 30 and 95% and average pore sizes between 50 μm and 1 mm while also adjusting their permeability. This makes these foams a definitively interesting candidate for new type of bone graft materials. For metallic foams, the system was adapted to water-octane in order to reduce the oxygen concentration and the surface oxidation of the metallic nanopowders. The optimal experimental parameters were systematically studied and it was found that very stable emulsions can be produced. These emulsions were dried and sintered and even first mechanical tests were performed. Mechanical testing of miniaturized porous titanium samples in compression indicate an elastic modulus of ~2 GPa, a yield strength of 12 MPa and strains of more than 10%. The method has been extended to several polymeric particles. For poly(vinylidene difluoride) (PVDF), wet foams with varying microstructures were produced and further processed by drying and partial sintering. First measurements show that these foams can be poled and a remanent charge can be induced. The charge hysteresis loops strongly depend on the microstructure of the porous PVDF. The hysteresis loops grow wider with decreasing pore diameters

Trends

The deliberate control over the foam microstructure opens opportunities to apply these foams in many different applications ranging from thermal insulation where closed pores are advantageous to certain filter applications where open pores are needed. Foamed materials are characterised by good heat insulation and damping as well as high energy absorption and a high specific stiffness. Combinations of these properties allow for new future-oriented applications. New porous materials with metallic matrix are continuously gaining importance. Metal foams are characterised by a higher specific stiffness as well as higher chemical and thermal resistance compared to their polymer based equivalents and enable the design of a new group of advanced structural lightweight components. Electrically-charged polymeric foams represent promising piezoelectric transducers for monitoring/actuating soft matter. Foam materials produced from inert biocompatible materials, biocompatible bioactive materials or from bioresorbable materials show an interesting potential for producing artificial implants or scaffolds for drug delivery and tissue engineering.

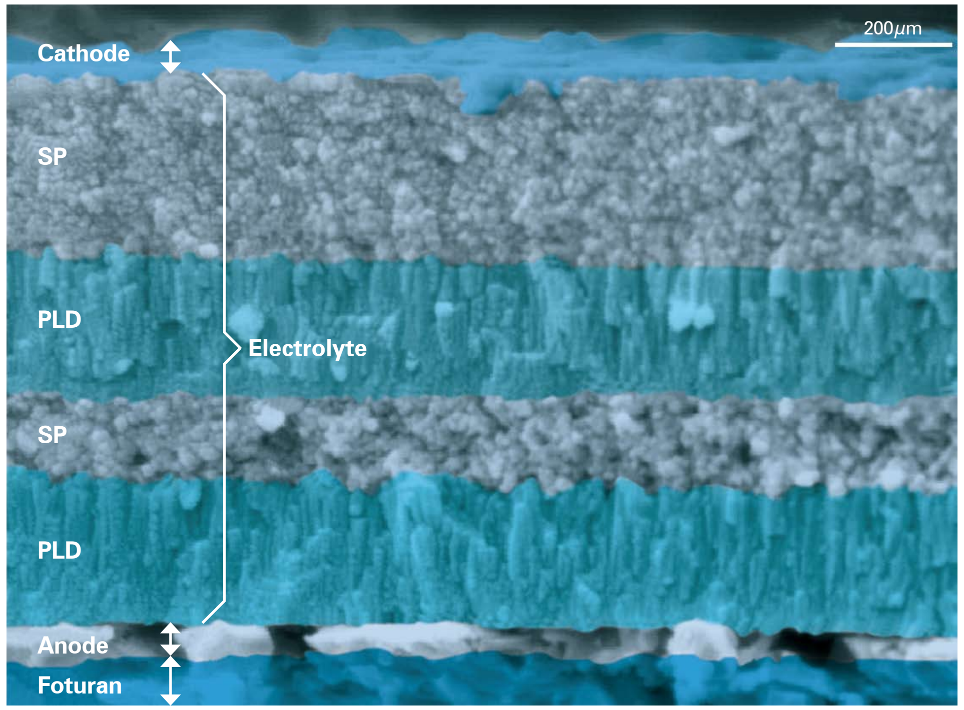
Surface modification by coating and structuring

Roll-to-roll coating processes | barrier coatings | metal oxide coatings on metals and polymers | spray pyrolysis | pulsed laser deposition | direct aerosol deposition | metal-organic chemical vapour deposition | RF sputtering, combustion chemical vapour deposition | ceramic multi-layers | transparent electrodes | nanoscale gratings | mechanisms of protection | stability in layers

SPERU

New process diagnostic and characterisation methods are required to fundamentally understand the physics beyond thin film processes and the influence of process parameters on the coating structure and properties.

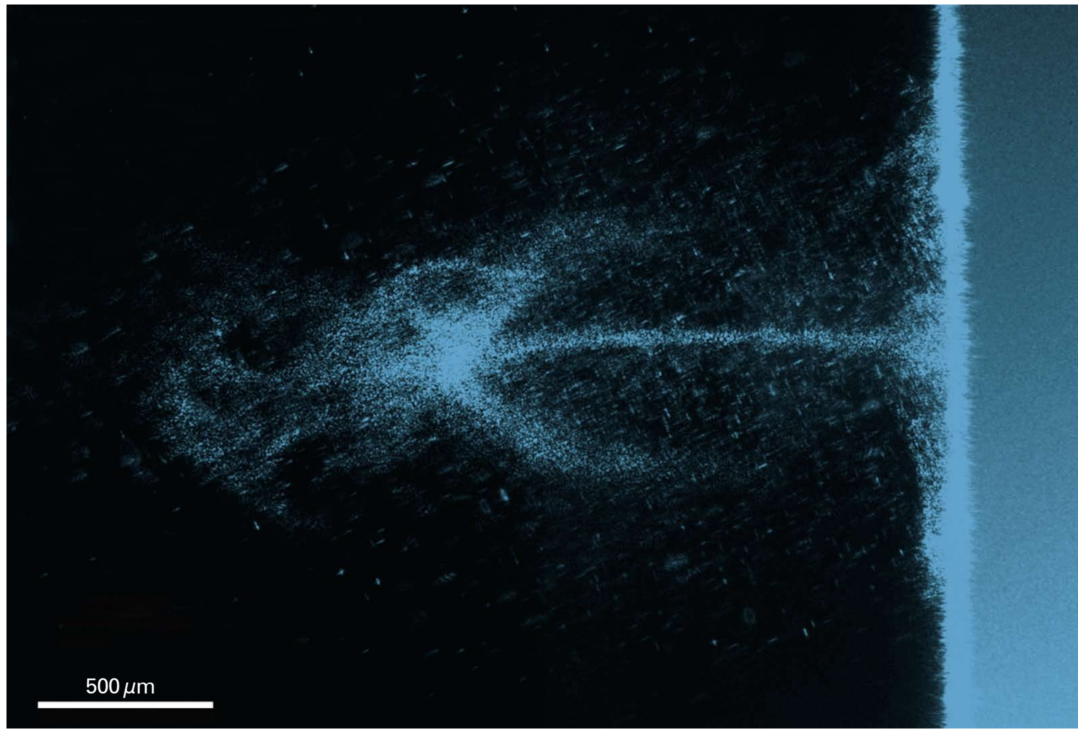
Surface and coating technology is one of the enabling technologies for innovative engineering solutions. It is a cross-functional technology, not only in relation to the applications but also to the involved materials, from metals, metal alloys and ceramics to plastics as well as the combination thereof. Surface structuring can be developed to extend the performance of the coated material and apply additional functionality. The creation of novel products exhibiting desirable optical, thermal, electrical, electrochemical or magnetic properties requires a better understanding of the relations between the process parameters, resulting microstructure and the characteristics of materials.



Fuel cell component consisting of a quadrilayer of 8YZ electrolyte made by alternating pulsed laser deposition (PLD) and spray pyrolysis (SP) and positioned between the sputtered platinum anode and the cathode (ETH Zurich, Empa & PSI).

Two projects are currently underway in this thematic area. The first one "Nanocrystalline ceramic thin film coating without sintering (NANCER)" started in 2007 and involves five research groups from ETH Zurich (Prof. L. Gauckler & Prof. S. Pratsinis), EMPA (Dr. T. Graule) and PSI (Dr. T. Lippert & Dr. K. Conder). High functionality films are manufactured through novel fabrication techniques combining five deposition techniques without the need for additional consolidation steps. In 2008 the research team focused on the comparison of the properties of electroceramic thin films deposited via different methods and on the integration of those films into micro-solid oxide fuel cells and gas sensors. Processing of amorphous to nanocrystalline zirconia, ceria and tin oxide-based thin films by up to five different thin film methods was successful. The microstructure evolution with respect to temperature and time was fundamentally investigated and first quantitative relationships established. Micro-machined silicium-based test platforms were produced to simultaneously study properties such as in-plane conductivity, cross-plane conductivity or catalytic activity. First results on the interplay of microstructure and electric properties were collected. Furthermore integration of the electrolyte thin films produced by the research partners into micro-solid oxide fuel cells was a success, as well as the processing of new micro-gas sensors with tin oxide and ceria-based films. High performance electroceramic micro-devices could be engineered on Silicium or Foturan chips thanks to the knowledge gained earlier in the project.

The "Zero order nano optical pigments (ZONOP)" project deals with novel physical colours made-up through the unique arrangement of non-spherical nanosized particles in an inorganic or organic matrix for applications in safety or decorative surfaces. These completely novel spectral characteristics are based on zero order diffraction -ZOD. The project is lead by Dr. A. Stuck at CSEM. Prof. O. Martin (EPFL) has been involved since the end of 2008 and his group will perform theoretical simulations to understand the effects on the reflection and transmission spectra when shrinking the full structure length of a sub-wavelength. CSEM will then take care of the fabrication of pigments exhibiting the desired zero order structure based on the simulation results.



Visualization of submicrometer particle ejection from an Yttrium-stabilized Zircona target upon femtosecond laser irradiation in a scattering experiment (ETH Zurich, Empa & PSI).

Trends

Thin-film technologies are vital for creating novel multifunctional surfaces. Besides the well-known technologies based on physical and chemical vapour deposition (PVD, CVD) or thermal spraying (plasma or flame), new methods were developed in the last 15 to 20 years in academia as well as in industry. Interesting aspects are the combination of these technologies with nanosized particles which enables the formation of nanostructrued porous or dense coatings with combination of properties based on the nanosized crystals (quantum effects) and the microstructure of the coating. However, many of the underlying basic processes are not yet elucidated and important production problems remain unsolved. In CVD coating performed at 800 °C and above, residual tensile stress is built up caused by the different thermal expansion coefficients during cooling. Multilayered and nano-structured coatings with a built-in high compressive stress may be an answer. Thin, transparent, inorganic coatings on polymers are alternatives to heavy, brittle and rigid glass for food and pharmaceutical packaging. These thin-film composites are inherently flexible and, moreover, enable cost-effective roll-to-roll production. Exceptional gas-barrier performance is expected from artificially layered nano-structured materials. Interesting candidates for avoiding premature failure are hybrids based on metal-oxide layers combined with UV-curable organosilanes and hyperbranched polymer precursors, which substantially reduce in shrinkage stresses as a result of their particular network formation mechanisms.

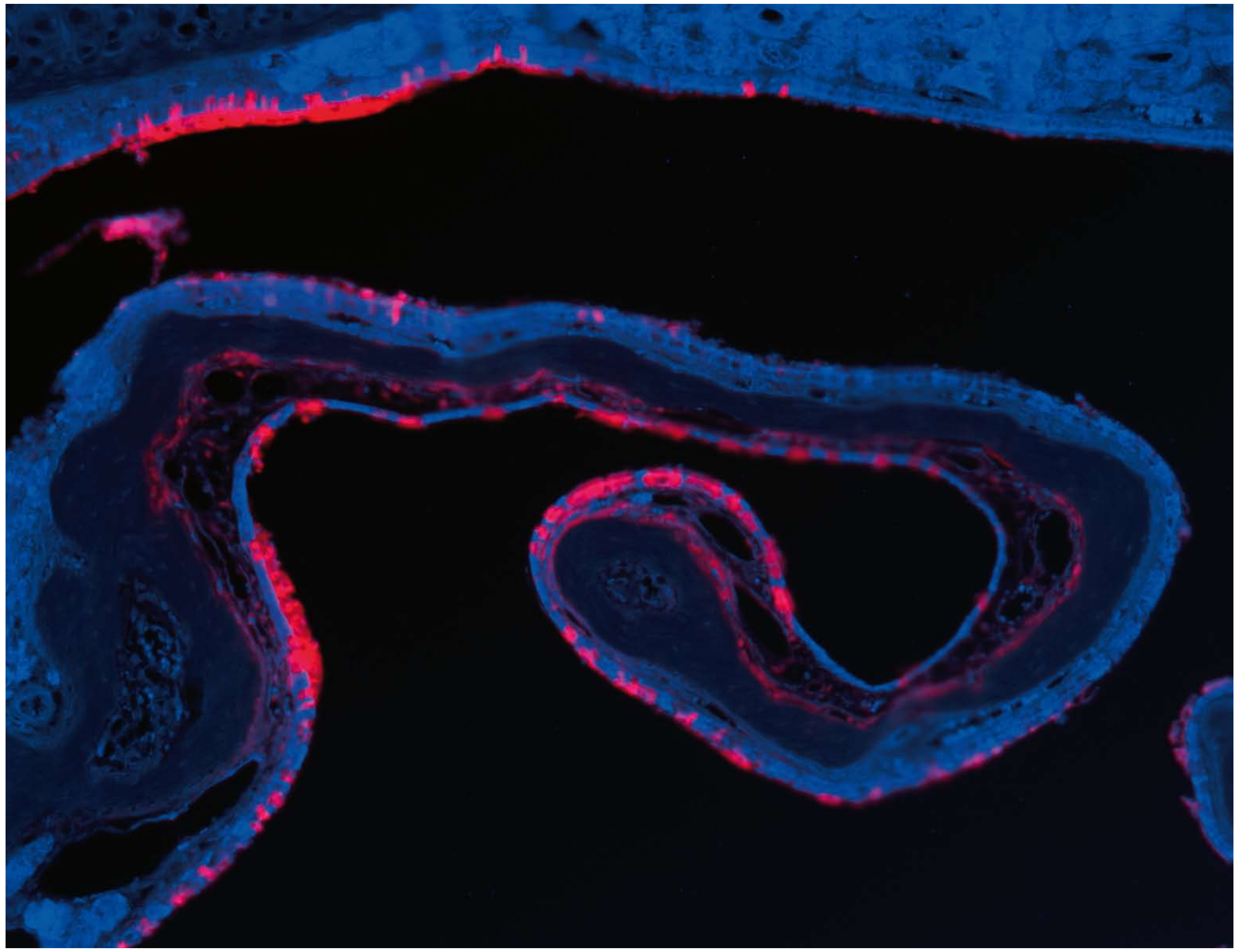
A study featuring crystallization and grain growth kinetics of electroceramic thin films provides critical information for engineering high performance electroceramic micro-devices. The relationship between the microstructure and the electric conductivity of 8 mol % yttria doped zirconia (8YSZ) thin films was investigated in depth. The thin films were deposited using spray pyrolysis, pulsed laser deposition (PLD) or RF sputtering. Amorphous, biphasic amorphous-crystalline or fully nanocrystalline ceramic thin films were deposited depending on the processing method and processing parameters. The researchers could study the crystallization and grain growth kinetics of 8YSZ during post-annealing as a function of the various processing methods initially used. This new knowledge is of key value for engineering and for integrating these thin films into devices such as micro-Solid Oxide Fuel Cells (micro-SOFCs). This study has already been validated in fully functional micro-SOFCs in which thin films produced by PLD and spray pyrolysis were integrated for the first time. Those fuel cells delivered 209 mW/cm² at 550°C (with a one-micron thick and a 200-micron wide single membrane).

Functional particles in contact with biological fluids

Particle functionalization and encoding | fluid handling | colloidal properties | target fishing with surface-modified nanoparticles | improved tissue targeting | biocompatibility and toxicity assay development | *in vivo* and *in vitro* screening of particle-cell interaction | targeted tissue loading and solubilisation | enhanced bioavailability/ enhanced delivery | combination imaging/delivery | delivery and imaging

MatLife / SPERU

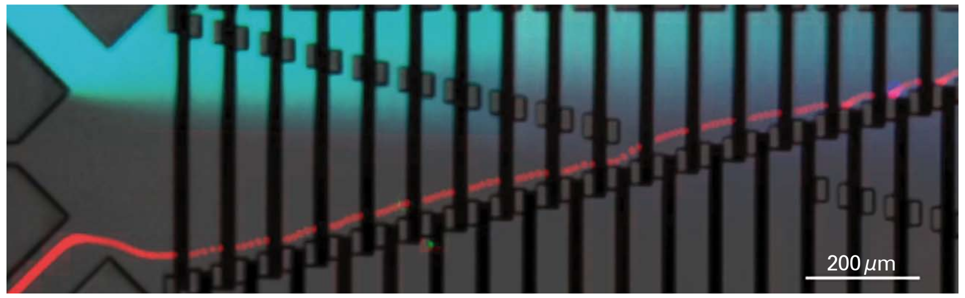
Functional nanosized particles may significantly impact several fields of biological research.



Ultrasmall polymer nanoparticles (in red) developed to penetrate deeply into the mucosa (nuclei in blue), where they can induce a high immune response in the nasal sinus cavities of the mouse. Vaccine contained in fluid sprays can be administered to the nasal sinus surfaces inexpensively and without the need for needles. The nanoparticles are delivered extremely effectively, due to their size and surface nature (EPFL, SurfaceSolutionS AG & Sanofi-Pasteur).

Prime interests lie in improving efficacy and safety of drug treatment and vaccination using nanoparticles and in understanding how cellular processes may be influenced by nanosized particles. Systems biology seeks to explain biological phenomena through the interaction of all cellular and biochemical components in a cell or a living organism. Functionalized and well characterised nanoparticle systems are a valuable tool to elucidate how nanoparticles enter cells and may influence cellular processes. Novel technologies in the discovery of new therapeutic or immunogenic moieties based on low molecular weight and biomacromolecular pharmaceuticals have led to an increasing demand for delivery systems capable of protecting, transporting, and selectively depositing those therapeutic agents at their sites of action.

A novel vaccine and immunotherapy technology relying on materials with bio-functional and immuno-functional capabilities is being developed by a team led by EPFL (Prof. J. Hubbell) and involving other colleagues of EPFL (Prof. M. Swartz), SurfaceSolutionS AG (Dübendorf) and Sanofi-Pasteur. Specifically, polymer nanoparticle formulations should target the draining lymph node(s). Furthermore a plug-and-play scheme to functionalise these nanoparticles with antigen will be set-up. The polymer nanoparticle family originally developed in the project in 2007 has been extended. Early results demonstrated a strong dependence of behaviour on size distribution: nanoparticles smaller than 30 nm very efficiently enter the lymphatic capillaries and traffic to the draining lymph node. Self-assembly of another polymer material (Poly(ethylene glycol)/ Poly(propylene sulfide) block copolymers) results in nanoparticles very narrowly distributed around a 15nm diameter. Such particles accumulate very efficiently in the lymph node where they can activate dendritic cells and initiate an adaptive immune response.



Trajectory of a 10µm latex particle in the wide channel Particle Exchanger (EPFL & CSEM).

PAPAMOD seeds a new EU project involving three CCMX partners
The FP7 European project "Development of novel nanotechnology based diagnostic systems for Rheumatoid Arthritis and Osteoarthritis" worth €9.2 Mio over 4 years was granted in November 2008 based on innovative results originating from the "PAPAMOD" Flagship project. The six Swiss partners (including three CCMX partners) will receive €4.5 Mio for carrying out their tasks.

CCMX sows seeds for new vaccine technology projects
The nanoparticle-based vaccine platform developed thanks to CCMX funding attracted substantial interest in the vaccine community in 2008. The Engineering Foundation International conference on Vaccine Technology, in Albufiera, Portugal awarded their meeting prize to this project in June. The data collected in the project successfully competed for substantial additional research funding: an award on HIV vaccines from a Swiss company (CHF 150k per year for 2 years), an award on cancer vaccines from a German company (CHF 300k per year for 3 years) and a European Commission Advanced Grant to Prof. J. A. Hubbell on hepatitis B and influenza vaccine technology (€ 0.5 Mio per year for 5 years) were recently granted.

The PAPAMOD project led by Prof. P. Renaud (EPFL) aims to develop novel methods for surface modification and investigation of cell-particles interaction for superparamagnetic nanoparticles. The project further involves researchers from EPFL (Prof. J. Hubbell, Dr. A. Petri-Fink) and CSEM (Dr. Knapp). Nanosized superparamagnetic iron oxide particles (SPIONs) will be coated with interesting biological molecules and classified regarding their physical and chemical properties using a novel technique based on microfluidics. The particles should help evaluate the uptake mechanisms used by cells from the membrane toward the nucleus.

The EPFL researchers improved the microfluidic device enabling continuous multistep functionalization of magnetic particles with respect to diffusion and washing efficiency. Unexpectedly this tool could also be used to study the interaction of cells with a set of nanoparticles suspended in a buffer solution. This new method allows the assessment of the number of nanoparticles effectively interacting with a cell's membrane based on the duration of the contact and the particle concentration. Meanwhile CSEM's team developed a 'High Gradient Magnetic Filtration' demonstrator device which sorts out superparamagnetic microbeads based on their size. However the possibility of sorting out smaller magnetic particles (i.e. SPIONs) by size with this tool showed to be limited by the small magnetic volume and the Brownian motion of these nanoparticles. Alternatively, a microfluidic filter was developed; it very efficiently collects, retains and elutes SPIONs from a solution while maintaining the original particle size distribution. This microfluidic filter represents a valuable tool both for the analysis of cellular uptake of SPIONs and for testing new SPION functionalization protocols.

Trends

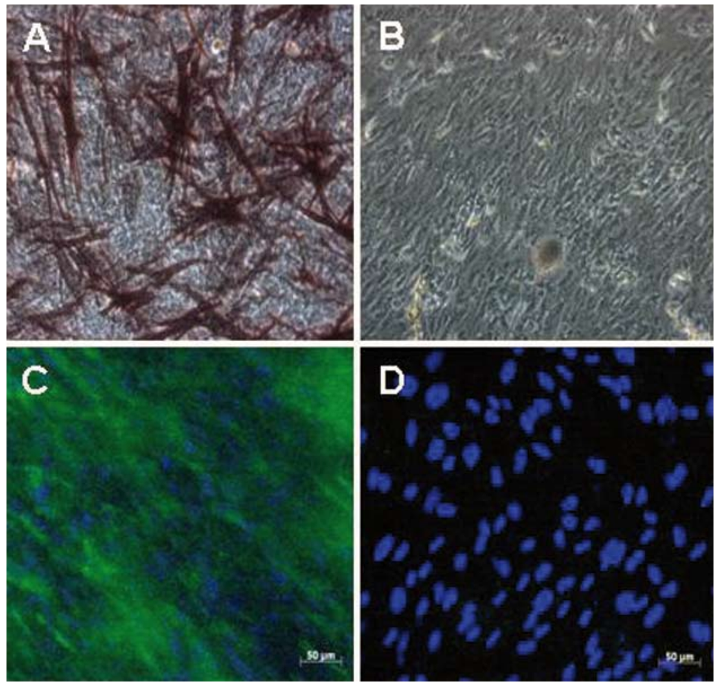
One of the most important questions for toxicologists is the quantification of nanoparticles that have been taken up by cells or organisms. This question remains unanswered today. The development of a platform for the reproducible, multifunctional, and flexible surface derivatisation of nanoparticles suitable to investigate cell-nanoparticle-interactions in living systems and biochemical interaction is a long term goal of this thematic area. Such a platform should enable (a) the reproducible and straightforward surface derivatisation of magnetic particles, (b) the creation of a particle library, (c) the principal understanding of the properties of complex nanoparticles in a physiological environment, (d) the correlation of material properties to their biological effects, and (e) the proof of principle for the identification of the interaction partners. Both, industry and academia will gain from the availability of such a device for systems biology and from the investigation of cell-nanoparticle interactions.

Demand for novel therapeutic or immunogenic functional groups or molecules designed for low molecular weight and biomacromolecular pharmaceuticals is increasing. They should act as delivery systems capable of protecting, transporting, and selectively depositing those therapeutic agents at their sites of action. Of particular interest is the combination of imaging with the targeted delivery of therapeutic agents, thus increasing the safety and efficiency of medical treatment protocols. Such approaches are still at the research stage, but show high potential for major breakthroughs in medicine. Examples include the development of composite particles that contain both drug and contrast agents and allow for site-specific release of therapeutics upon activation.

Medical device technology and innovation

Tissue engineering | cell-based therapies | minimally invasive technology | integrated healing | combination devices | implant-centred infection | microbial proliferation

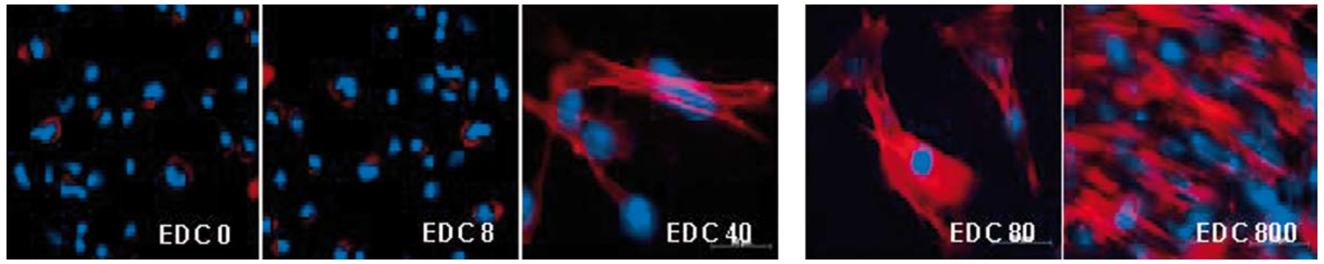
Implanted medical devices still present longstanding challenges *in vivo*.



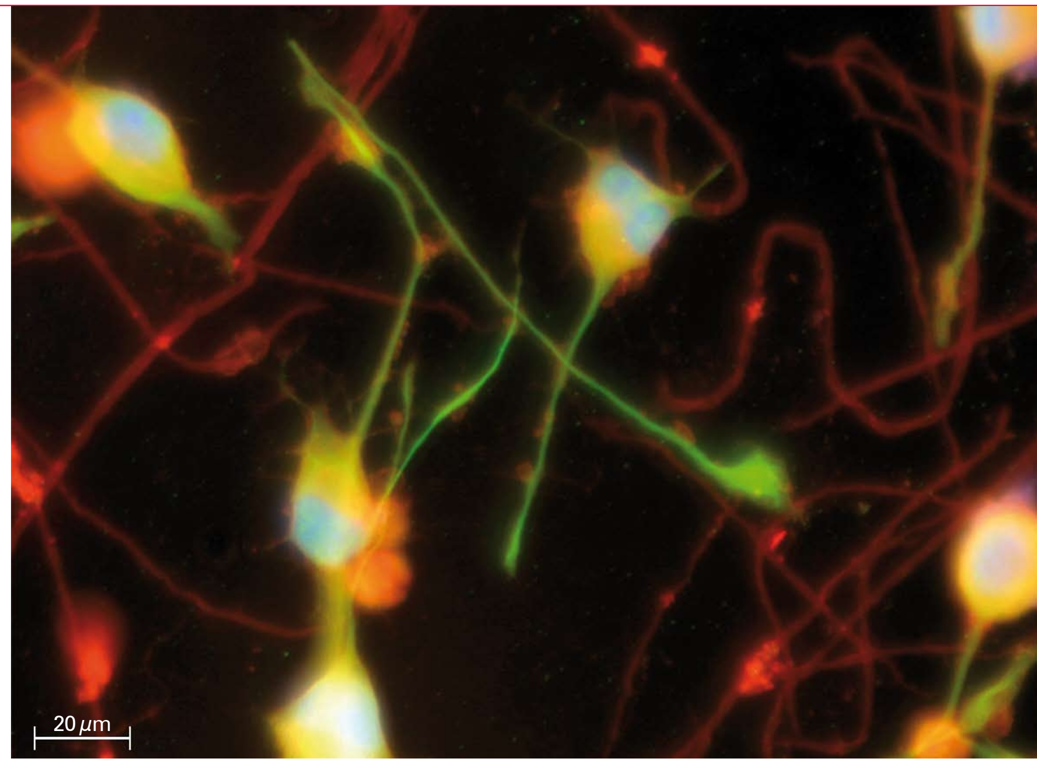
Human mesenchymal stem cells grown on covalently cross-linked, fibronectin-terminated polymer multilayers maintain their ability to differentiate into osteocytes and chondrocytes when exposed to soluble induction factors. (A) Staining for osteocytic marker (brown color). (C) Staining for chondrocyte marker (green color). Counter-stain (blue) marks all cells. (B, D) Control cultures without induction. (ETH Zurich, EPFL & University Hospital Zurich).

Biomaterials have been of critical importance in the development and marketing of medical devices. Despite notable contributions for patients' quality of life, implanted medical devices still present long-standing challenges *in vivo*. Metals represent an important class of biomaterials but they are not biodegradable in the human body and can cause long term issues such as infections. However, new biodegradable metallic implants, dissolving in biological environment after a certain time of functional use, are a promising alternative but they should exhibit both biocompatibility and suitable mechanical properties. Tissue engineering has been successfully applied to various tissue reconstructions although the use of cell sheets so far has been limited to structures as thin as five cells due to a lack of sufficient oxygen and nutrient supply to the cells located inside thicker engineered tissues. An ideal tissue scaffold is a good mimic of the structure and function of the native extracellular matrix - a meshwork of collagen and elastin fibers. In addition to providing mechanical support for cells, the extracellular matrix also serves as a substrate to display specific ligands and factors controlling cell adhesion, migration and regulating cell proliferation and function. Such challenges can only be fruitfully tackled by consortia demonstrating expertise in materials science, chemistry, biology and medicine.

Three projects were initiated in 2006 in this thematic area. One project deals with tissue replacement materials consisting of sheets of autologous cells and biodegradable polymer films. Researchers from ETH Zurich (Prof. J. Vörös), EPFL (Prof. J. A. Hubbell), and University Hospital Zurich (PD Dr. A. Zisch and Prof. F. Weber) have teamed up to establish a platform for cell-sheet engineering. Cells are organised in a well-defined, multilayered 3D environment of designed polymer substrates presenting specific -and variable- cues for cell growth. The approach is to be validated *in vitro* and *in vivo*. The research team successfully established the conditions enabling stable adhesion of mesenchymal stem cell on polymer multilayer film. These cells maintain their highly proliferative capacity and form confluent monolayers as desired for cell sheet transplantation. Such cellular monolayers are subsequently capable of differentiating into osteocytes and chondrocytes. Cell sheets once combined with thin fibrin-like hydrogels layers form building blocks of 250µm thickness. Cell differentiation and tissue regeneration are now to be evaluated in vivo using larger tri-dimensional constructs made up from these building blocks.



Fluorescence micrographs show mesenchymal stem cells on polymer multilayer substrates cross-linked with increasing concentrations of carbodiimide (EDC 8 to EDC 800). Red: phalloidin stained actin cytoskeleton. Blue: counter-stain of all cell nuclei. Stem cells were unable to spread on soft multilayers. (ETH Zurich, EPFL & University Hospital Zurich).



ND7/23 cells (yellow/green/blue) after two days culture on L1Ig6-modified OptoDex fibers (red). Cells differentiated and extended neurites (green) (CSEM, ETH Zurich & arrayon biotechnology SA).

Stable adhesion of mesenchymal stem cells requires stiff surfaces
The native polymer multilayer films were too soft for the mesenchymal stem cells, to anchor on their surface. Stiffness was increased using a cross-linking polymer to support the stable adhesion of mesenchymal stem cells essential to the preparation of viable cell sheets. Furthermore the successful grafting of fibronectin, an adhesive blood glycoprotein, onto the polymer film was another key element ensuring the differentiation of the stem cells into bone- or cartilage-forming cells. Such polyelectrolyte multilayers offer biotechnological platforms for intelligent cell cultures and harvesting of viable cell sheets to be used in future surgical procedures.

Dr S. Tosatti of ETH Zurich is leading a project aiming to develop a novel class of nanostructured and biofunctionalised materials to be primarily used as stent implants in cardiovascular interventions. The materials should be completely bioresorbable after a period of around three to six months. The research partners comprise several teams from ETH Zurich (Prof. N. D. Spencer, Prof. J. F. Löffler, Prof. P. Uggowitzer and Dr. I. Gerber) and from Empa (Dr. P. Schmutz) as well as the company Biotronik AG. Heat treatments were applied to the newly developed magnesium-based alloy, leading to the formation of a thermal oxide layer to slow down degradation of the materials. Such oxide layers protect the metal underneath to a certain extent, even if they contain cracks that may form during implantation in the body, and perform better than their polished counterparts. Cellular adhesion onto surface modified alloys was improved in comparison to bare materials. The stent forming ability of the alloy has been assessed and the manufacture of a prototype for biological assays is now in progress.

The third project covers photochemically functionalisable scaffolds for tissue engineering and drug screening. The research team involving CSEM (Dr. C. Hinderling & Dr. M. Liley), ETH Zurich (PD Dr. H. Hall-Bozic & Prof. P. Seeberger) and arrayon biotechnology SA aims to generate a novel nanofibrous material. It will be used as three-dimensional scaffolds for the directed growth of cells, e. g. in nerve regeneration and nerve guiding. The material is shaped as a non-woven mat of nanofibers produced by electrospinning. The OptoDex nanofibres could efficiently be aligned into denser layers using a novel alignment technique. The availability at the surface of the fibers of a neuronal guidance cue, incorporated during processing, was demonstrated. Additionally in vitro studies using neuronal cells revealed the non-toxicity of the Optodex fibers. Those cells differentiated and extended neuritis, but fibers thicker than 200-500nm should be used in order to significantly enhance cell growth along the fibrous structure.

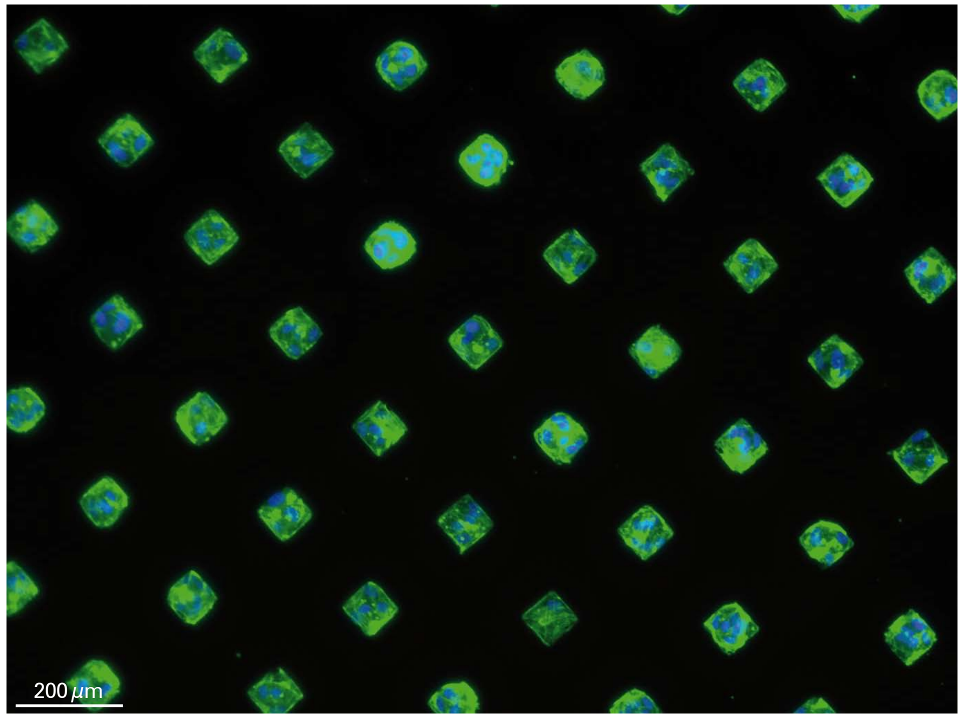
Trends

Although medical device technology permeates numerous areas from orthopaedics and dental implants to wound healing applications and diagnostic devices/biosensors, the field still suffers from many interfacial problems such as blood coagulation, infection, complement activation, foreign body reactions, and aseptic loosening. In response to these issues, research efforts have explored surface modifications, such as coatings, to improve these devices with limited success. While this approach is still promising, it is not a "one-size-fits-all" solution. The future points to combination devices, those comprising drug releasing components on board of functional prosthetic implants, as an emerging clinical technology.

Biosensing and diagnostic strategies

Direct sample-to-assay | rapid assay | high through-put field portable | closed-loop feedback sensors | cell multiplexed assay | label-free | public safety | global health | food screening | microarray | protein | carbohydrate

Substantial efforts concentrate on development of reliable methods for array fabrication.



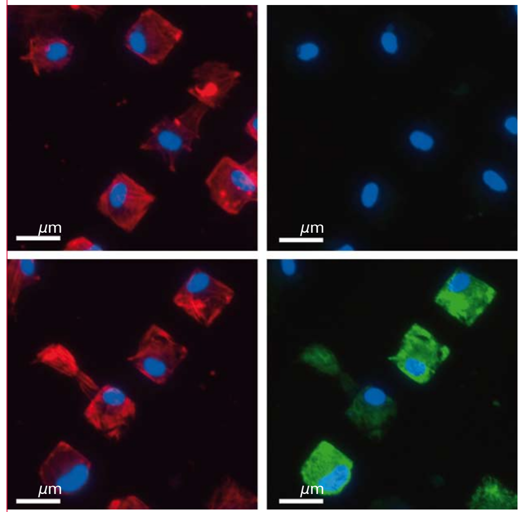
3D microwell arrays designed for studying the influence of physical parameters in the differentiation of stem cells (ETH Zurich, Empa & AO Foundation).

Protein, carbohydrate and cell-arrayed chips are expected to be key elements in future drug discovery, drug screening and medical diagnostics. In particular, integrative engineering approaches are required, combining enabling technologies and functional design to produce devices with improved performance, reliability, ease of handling and cost-effectiveness.

The objective of the project led by Prof. V. Vogel of ETH Zurich is to develop a platform technology where single cells can be studied in engineered quasi three-dimensional microwells. Partners from ETH Zurich (Dr. M. Grandin, Prof. M. Textor & Dr. M. Smith), Empa St. Gallen (Dr. K. Maniura), AO Davos and partners from the pharmaceutical industry are involved. The physical aspects of the cellular environments will be further tuned to learn how cell shape and rigidity of the microwell walls differentially regulate diverse cell functions. In addition, the relationship between the efficiency of drugs and the state of single cells will be determined.

In 2008, the researchers developed a microwell coating protocol that allows longer term cell culture. Stem cells have been seeded on the microwell platform and have remained confined to the microwells for up to 10 days. The shape of the microwells has been found to regulate the tri-dimensional organisation of the cytoskeleton and the ability of endothelial cells to assemble extracellular matrix. Whether stretching and unfolding of fibronectin fibers co-regulates stem cell differentiation is now being addressed. While improving the passivation of the microwell array as well as seeding conditions for different cell types, conventional markers for stem cell differentiation were selected and tested.

Significant technology transfer and several awards for the "Studying Single Cells in Engineered Three-Dimensional Microenvironments" project



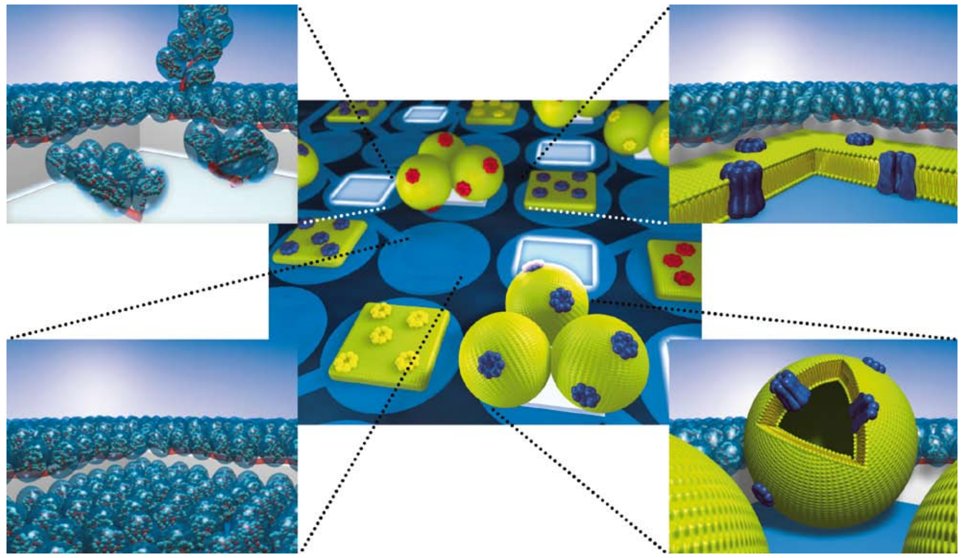
Osteogenic differentiation of mesenchymal stem cells in square shaped microwells. Stained for bone specific alkaline phosphatase (green), actin (red) and nuclei (blue) after 7 days in (upper row) proliferation medium or in (lower row) differentiation medium. (Scale bar 30µm). (ETH Zurich, Empa & AO Foundation).

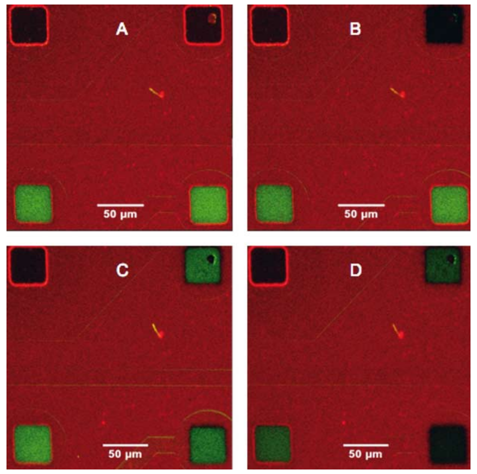
Considerable technology transfer has occurred between the three laboratories involved, ranging from the fabrication and handling of the microwell platforms to the management of conventional and optical live-cell markers.

Dr. Michael L. Smith (ETH Zurich), a leading postdoctoral scientist in this project, was granted an Assistant Professor position at the Department of Biomedical Engineering of Boston University.

Professor Viola Vogel (ETH Zurich) was awarded an Advanced Investigator Award from the European Research Council.

PhD student Miriam Pleskova (Empa) was awarded a prize for her poster "3D microenvironments and live monitoring of osteogenesis in single cells" at the International Bone-Tissue-Engineering Congress (Hannover) in November.





Schematic view of microelectrode arrays with each individual electrode exhibiting a different membrane functionality (top). Snapshot of the as-produced array : the green squares are labelled membranes on bottom electrodes, activated electrodes on top electrodes (left). (EPFL, ETH Zurich, CSEM and Ayanda Biosystems SA).

Prof. H. Vogel of EPFL is leading a project aiming to develop a versatile platform for screening membrane-protein-mediated cellular signalling pathways. The platform will allow for probing the function of membrane proteins by simultaneous electrical and fluorescence measurements. It will consist of arrays of nanopores machined into silicon-chips. Each chip will be individually addressable via micro-fluidic channels and via electrodes. The project partners are located at ETH Zurich (Dr. E. Reimhult & Prof. M. Textor), at CSEM Neuchâtel (Dr. H. Heinzelmann & Dr. C.Santschi) and in Lausanne (Ayanda Biosystems SA).

Cellular membrane receptor function screening can take place using a range of on-chip tools. A chip suitable for electrochemical sensing and exhibiting nanopores was manufactured from a silicon nitride window and integrated into a fluidics electrochemistry cell. Such nanopores are fabricated either in large numbers using particle lithography or in single pore versions using focused ion beam milling. Self-assembly of suspended membranes on the nanoporous supports was investigated either using liposomes adapted to the pore size or by breaking live cells. G protein-coupled receptors, a protein component of cell membranes that sense molecules outside the cell to activate inside signal transduction pathways and ultimately cellular responses, were trapped at the pores and could directly be probed. Furthermore a tool for dynamically creating membrane arrays using embedded indium tin oxide electrodes was created.

Trends

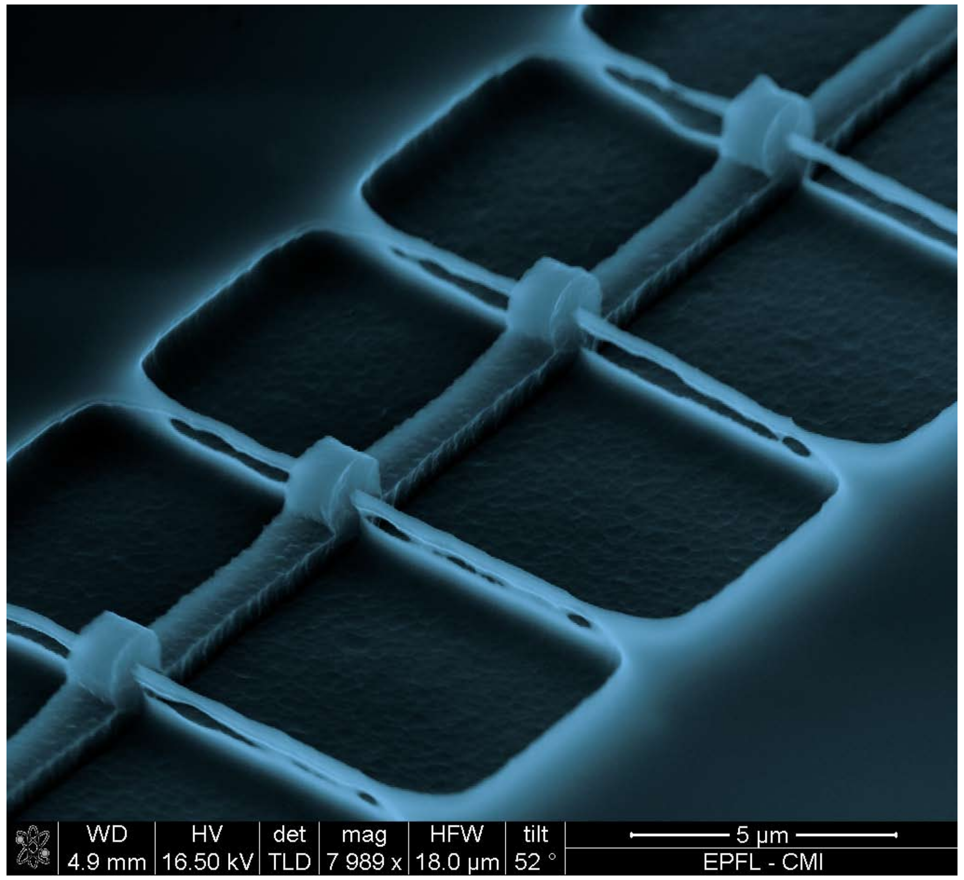
While deoxyribonucleic acid/ribonucleic acid (DNA/RNA) sensors are routinely used today, protein arrays, in particular membrane protein chips, require much more sophisticated surface engineering and immobilization strategies to preserve their biological activity. Despite this challenge, protein, carbohydrate and cell-arrayed chips are expected to become key elements in drug discovery/screening and in medical diagnostics. Integrative engineering approaches that combine enabling technologies (either existing or to be developed) and functional design to produce devices including improved performance, reliability, ease of handling and cost-effectiveness will drive future markets. Future success heavily relies on the ability to combine biological surface modification, quantitative sensing of biomolecules, micro/nanofluidics for efficient handling of solutions and intelligent integration within dependable devices.

Materials technologies and design for micro- and nanosystems

Nanoengineering | nanotechnology | process | fabrication | CMOS | nanowires | molecular electronics | carbon nanotubes | DNA scaffolding | self-assembly | electron beam lithography | nanomaterials

MMNS

Radical action is needed to ensure continuity in the nanoelectronic systems integration paradigm.



Four parallel suspended silicon nanowire devices with one common gate electrode (EPFL, ETH Zurich & CSEM).

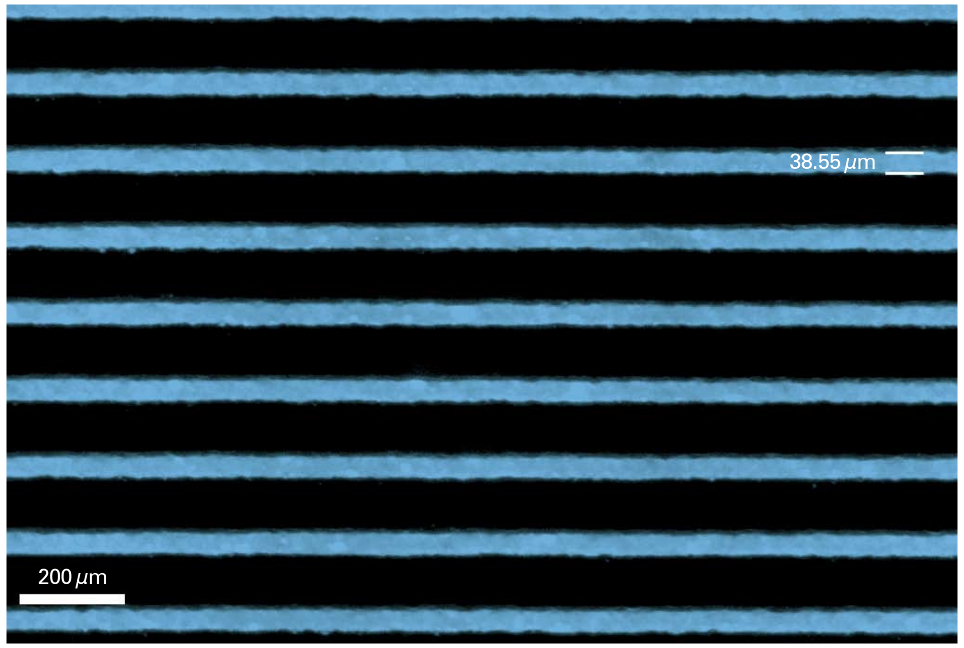
The technological and economic feasibility of high-density, large-scale nanoelectronic systems integration is still being driven - to this day - by classical complementary metal oxide semiconductor (CMOS) technology, for which there is no apparent substitute in the next 10-15 years. However, we cannot expect to continue the lithography scaling of classical devices and circuits indefinitely, due to fundamental physical limitations such as process variability, excessive leakage, process costs as well as very high power densities. This observation calls for radical action on several fronts in order to ensure the continuity of the nanoelectronic systems integration paradigm until one or more feasible alternative technologies emerge. A concerted effort is needed to explore new materials, fabrication technologies and design methodologies to address very high-density nanosystems for data storage and computation.

The new book "Nanosystems: design and technologies" brings Swiss-made research to a worldwide audience

The two projects of this thematic research area have been running for less than 3 years and have produced such significant and varied outcomes that they will be the subject of a new book entitled "Nanosystems: design and technologies" to be published by Springer in 2009. This publication brings successful "Swiss-made" research to the attention of a wider international audience.

Two projects are currently running in this thematic area. Despite the endless upwards spiral of modern ultra-large-scale integration (ULSI) technology, many experts are predicting a red brick wall for CMOS by about 2020. Little is known or practically demonstrated today about how to design complete circuit and systems that take full benefits of devices integrated on nanowires. In this context, the project led by Prof. Y. Leblebici of EPFL targets the identification of possible solutions enabling the continuation of the scaling paradigm. The project involves groups from EPFL (Prof. A. Ionescu, Prof. L. Forró, Prof. C. Piguet, Prof. N. Setter and Prof. D. Atienza), ETH Zurich (Prof. C. Hierold) and CSEM (Prof. C. Piguet).

The researchers integrated for the first time a vinylidene fluoride-trifluoroethylene copolymer into the gate stack of a standard Metal Oxide Semiconductor Field Effect Transistor (MOSFET) structure and demonstrated a fully operational 1T non-volatile memory cell. Its measured performances make this 1T Fe-FET memory cell suitable for any non-volatile memory application requiring storing time of some days, with an associated low cost. The research team also addressed the issue of strain induced mobility enhancement in silicon nanowires. By bending the wire as a result of one or more sacrificial oxidation steps, a bended MOSFET with tensile strain on the order of 1-3% and a mobility improvement of up to 100% was demonstrated. Moreover a punch-through impact ionization device (PIMOS) was also developed. It is based on a low-doped MOSFET structure operated in subthreshold under punch-through conditions. Abrupt switching transients of less than 10mV/decade are obtained with this device, due to the impact ionization mechanism. Furthermore different design approaches for regular arrays based on silicon nanowires were investigated so that fault-tolerant design methodologies could be developed for nanowire arrays. Finally the researchers devised and demonstrated a new circuit design technique to dramatically reduce the leakage power dissipation and variability in nanometer-scale CMOS technologies.



38µm wide gold nanowires obtained with the new lift-off process. Note the extremely smooth line edges. The pitch is 150nm (ETH Zurich & PSI).

The development of a new silicon nanowire platform was selected for publication in a special issue of IEEE Transactions in Nanotechnology

The top-down silicon nanowire platform reported in Vincent Pott's and Kirsten Moselund's PhD theses was published in the November 2008 Special Issue of IEEE Transactions in Nanotechnology dedicated to nanowires and featuring 20 selected research papers on this topic. The article is entitled: "Fabrication and Characterization of Gate-All-Around Silicon Nanowires on Bulk Silicon". This published work was sponsored by CCMX (K. Moselund) and by the FP6 Nanosil Network of Excellence (V. Pott).

The project coordinated by Prof. J. Vörös of ETH Zurich and involving researchers from Prof. R. Spolenak's group (ETH Zurich) and Dr. H. H. Solak's group (PSI) deals with the development and the characterisation of nanowires for applications in (bio-) electronics. The project targets the creation of large scale, high-quality nanowire arrays of different conducting materials in which nanowires present controlled electronic and mechanical properties. In another aspect, bio-functionalised nanowires should be applied in bioelectronics for sensing in microfluidic channels, and for interfacing neurons with artificial synapse mimics.

A new Extreme UV interference lithography scheme enabling the production of large scale gold nanowires with extremely smooth edges has been developed. The researchers gained new insights in the mechanical properties of the gold nanowires, after testing at different temperatures and strain rates. Diffusion effects seem to be important even at room temperature. In addition, due to strain gradient plasticity, nanowires are much stronger in bending rather than uniaxial load. New processes have been created for the reliable and stable self-assembly of particles (Ag, Au) to form nanowires down to 20nm, which has enabled not only the electrical characterization, but also the optical characterization of the large-scale nanowires arrays and the design of a first functional nanowire biosensor.

First successful biosensing measurements using novel gold nanowire arrays

The project team led by Prof. Vörös actually discovered unexpected optical properties while testing their new nanowire arrays. First successful biosensing measurements were carried out exploiting the phenomena of localized surface plasmon resonance (LSPR). The team's ability to control the deposition of even smaller nanoparticles (5nm) explains some of this exciting achievement. The particles in those nanowire arrays are in fact so stable that they survive plasma treatments, many steps of photolithographic exposure and development, as well as mechanical bending (i.e. on flexible substrates). The researchers are fully aware that they have only begun to discover the advantages of their bioelectronic system over conventional nanowire systems. They would like to highlight that all has been possible thanks to the motivation and skills of all the project members. Their responsive, efficient and enjoyable interaction has accelerated and will continue producing results as the project moves forward in 2009.

Trends

Research must address the combination of new device-level error-prone technologies within systems that must deliver to the user a high level of dependability. The need to create new materials for interfacing the computational nano-environment to both traditional microsystems and the environment will be emphasized. These technologies will be essential elements in the production of effective embedded systems. Moreover such embedded systems should be reliable and robust as they should control critical functions such as vehicular control or medical control. We are however confronted with both the downscaling of silicon technologies (beyond the 45nm node) and the perspective of using new nano-devices that have intrinsically higher failure rates. The new technologies should be compatible with existing restrictions for system integration, such as low energy consumption, lacking in the design of large fault-tolerant systems of the past.

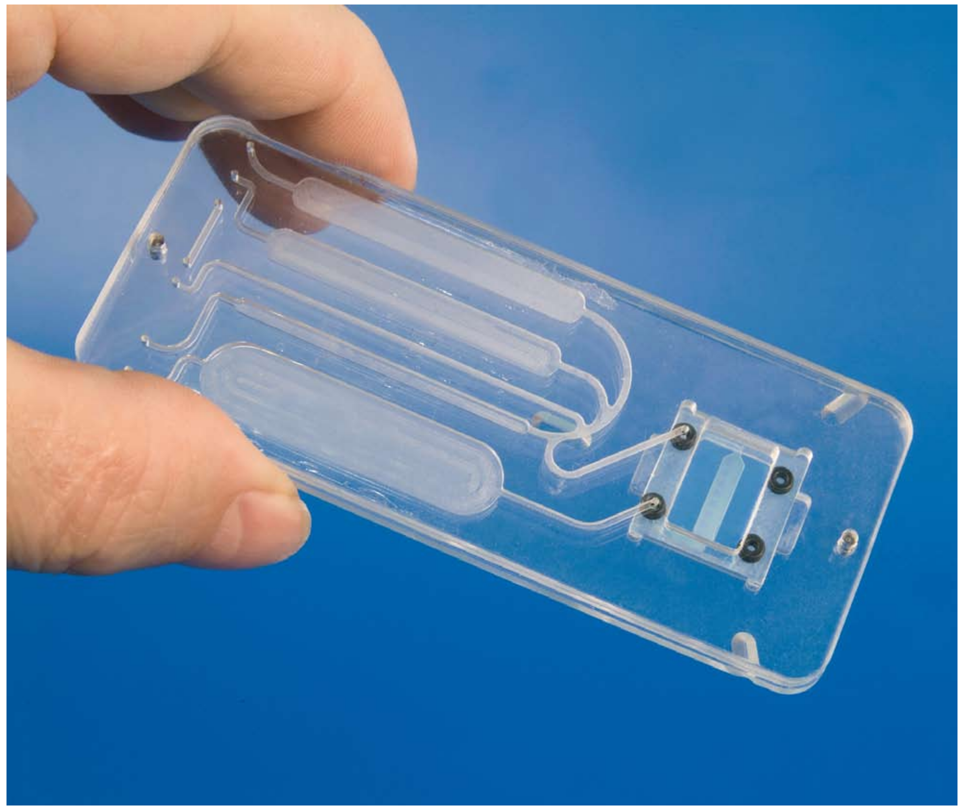
Laboratory-on-a-Chip

Microchip technology | microfluidics | DNA | protein | antibody | high throughput biology | assays | immunoassays | microarrays

MMNS

Minute sample quantities and fast reaction times,

two major advantages of the Lab-on-a-Chip approach.



Lab-on-a-Chip for the detection of antibiotics in milk (EPFL & CSEM).

Microtechnology and miniaturisation of devices have opened a vast domain of research due to the exceptional performance of microfabricated systems. Pharmaceutical and food industries, doped by the expansion of biotechnology, pushed the development of new devices into the bio-chemical analytical field. Focus is on materials, design, microfabrication and experimentation of novel types of miniaturised analysis systems for developing Lab-on-a-Chip devices. Applications of interest include in vitro diagnostics, food analysis and monitoring of the environment. A strong synergy needs to be achieved between the different applications through similar material and microfabrication solutions.

The project "Lab-on-a-Chip for analysis and diagnostics" led by Prof. M. Gijs of EPFL and involving other research groups from EPFL (Prof. E. Charbon, Prof. Y. Leblebici, Prof. P. Muralt, Prof. H.-A. Klok, Dr. Y. Leterrier), CSEM (Dr. G. Voirin) and the company Microsens, aims to develop Lab-on-a-Chip devices suited for the detection of malaria, the detection of antibiotics in milk and the detection of pH and ionic strength in environmental water.

A fully integrated and automated detection system has been developed that allows multi-antibiotic detection in raw milk samples. The design and fabrication of a plastic microfluidic cartridge containing both the assay reagents and the sensor chip make the test disposable, cheap, fast and easy to perform. The detection system has been validated for the simultaneous detection of three antibiotics belonging to different families: sulfapyridine, ciprofloxacin and ampicillin.

The basis for obtaining a working micro-acoustic device was established. The researchers managed to prove, by finite element modelling as well as by experiment, that the device produces the desired shear mode excitation. A further important result is the experimental verification that the brush layer works as sensor for pH measurement, and even more, shows a high sensitivity when detecting the pH change through the frequency change of a quartz micro balance.

The resulting output signal of the single photon avalanche diode clearly shows a dependence on the concentration of the target malaria antibody in the solution, indicating the possibility of differentiating between different antibody concentrations. Sensitivity for antibody detection better than 1ng/ml was demonstrated. These results indicate the potential of the approach undertaken by the research team for innovative, automatised techniques for on-chip immunoassays.

Best Poster Award for CSEM and EPFL at the EUROSENSORS 2008 conference
The poster entitled "Automated label-free optical sensor for multi-antibiotics detection in milk" by G. Suárez *et al.* won the Best Poster Award at the Eurosensors XXII conference, the only European forum to cover the entire field of Sensors, Actuators and Microsystems and gathering more than 500 experts every year.

Trends

The Lab-on-a-Chip concept has gained ever increasing attention in worldwide research activities. Microfluidics has provided attractive solutions for many problems in chemical and biological analysis and especially for on-field analysis and point-of-care testing. Three of the most important advantages of using fluidic systems of reduced dimension for analytical applications are (i) the possibility of using minute quantities of sample and reagents (down to picoliters), as issues of fluidic connectors with large dead volumes can be avoided for an integrated Lab-on-a-Chip, (ii) relatively fast reaction times, when molecular diffusion lengths are of the order of the microchannel dimension, and (iii) a large surface-to-volume ratio offering an intrinsic compatibility between the use of microfluidic systems and surface-based assays.

Enabling solutions for materials analysis at the micro- and nanoscale

Development of new analytical tools | new analytical methods | investigations at the nanoscale | inter-institutional collaborations | research driven by CCMX education and research units

Analytical Platform

CCMX aims to facilitate access to the extensive analytical resources of its academic network.

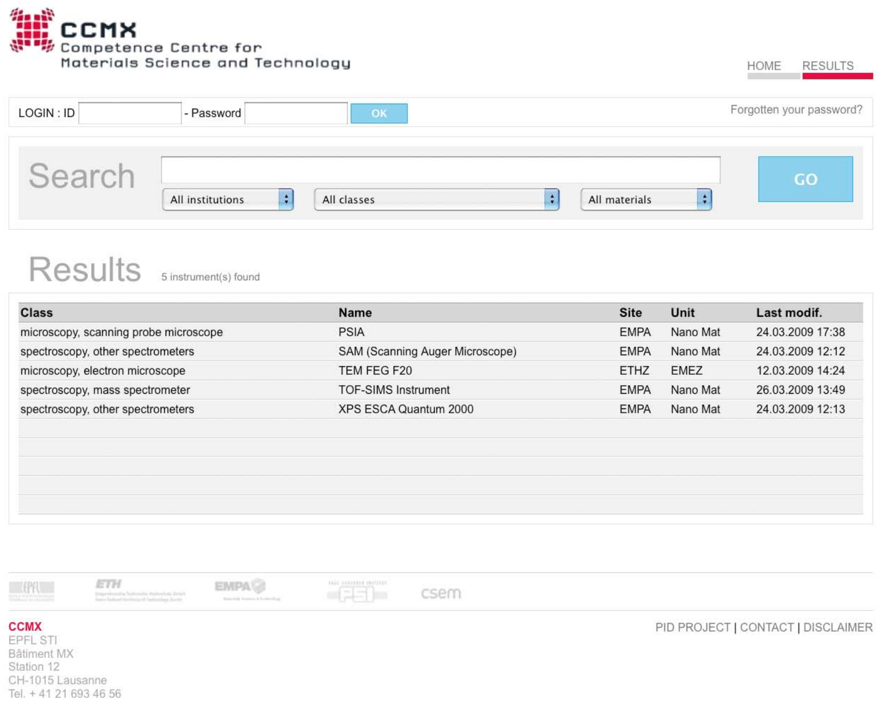
The focus of the Analytical Platform is on projects developing new tools for the analysis of physical, chemical or biological properties at the scale below 100nm and on the use of existing analytical methods for new application fields. A few projects are additionally supported by CCMX for carrying out exploratory experiments using existing equipment. In order to better match the needs of the various research groups within the ETH Domain and those of the industry, the project "Evaluation of the analytical instrumentation within the ETH Domain" was launched in 2008. The database compiling (micro- and nanoscale) analytical instrumentation will be accessible from the CCMX webpage in 2009.

The projects funded in 2008 are:

- Projects targeting the development of new analytical tools, methods or instrumentation for the analysis of physical, chemical, or biological properties on the scale below 100nm.
- Rapid analytical projects using existing instrumentation for single experiments with a well defined duration or multiple experiments, possibly on different instruments, or to carry on test experiments for feasibility studies at the nanoscale.

In general, projects bringing a positive impact on other CCMX ongoing research activities or that are of interest to several ETH domain laboratories and/or to industry are preferred. Nine new projects were launched in 2008.

Need a special analysis or a specialist to solve a tricky characterisation problem? Search the analytical equipment database!



Following a request from the industry a database detailing and identifying modes to access analytical instrumentation available to industry within the ETH Domain is being created. This database will be directly accessible from the CCMX webpage (as of April 2009) as a free service to industry and to academia. The project is led by the Analytical Platform (NMMC).

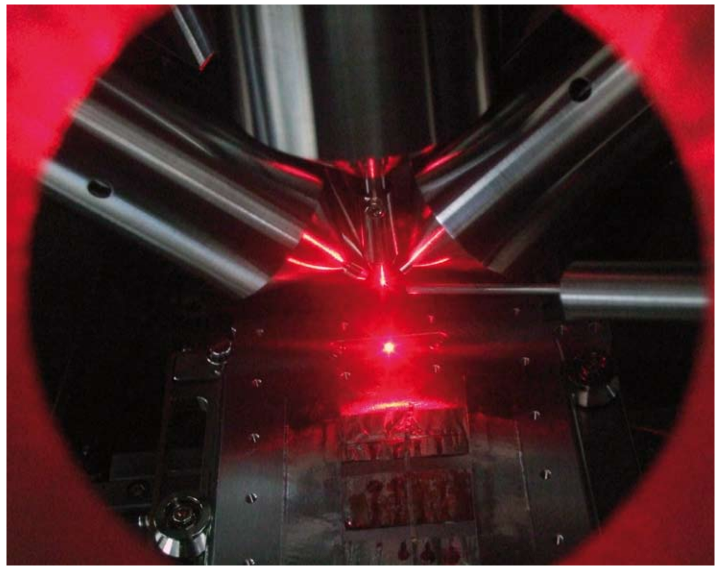
The primary goal of the database is to allow people to find the location of specific equipment and the right contact person. In addition the information contained in the database will help to determine the adequate instrument for solving specific characterisation problems. Application examples will be given for each instrument including properties that can be measured and materials that can be analysed.

Academic partners will also be interested in such a tool to help them find instruments in other labs. Whether looking for another expert or to conclude shared maintenance contracts with manufacturers; when planning to purchase equipment or when equipment is out of order; this database can be useful in many situations.

To ensure accuracy, the data will be managed directly by the persons responsible for the instruments. A web based platform with an administrative interface and a form for data collection (also useful for updating) has been created for this purpose. The database has two entry points: one for the public and another one for academic partners. Each lab chooses the target audience for its instruments.

The search tool incorporated in the database will allow the users to contact highly qualified research teams. At the moment of writing this report, the database is starting to be filled in by the partners. During the year 2009, approximately 150 professors and heads of labs will be contacted to be involved in the project.

Enabling solutions for materials analysis at the micro- and nanoscale



Chamber of a Time-of-Flight Secondary Ion Mass Spectrometer (ToF-SIMS) with ion guns, sample holder and the laser used for alignment (instrument located at Empa).

Development of new Analytical Tools
Seven projects aim to develop new analytical tools, new methods or new instrumentation:

1. Label-free Imaging of Molecular Adsorption on in situ Surface-Functional Patterns
Principal investigator: Prof. N. D. Spencer (ETH Zurich)
Partners: ETH Zurich & Empa

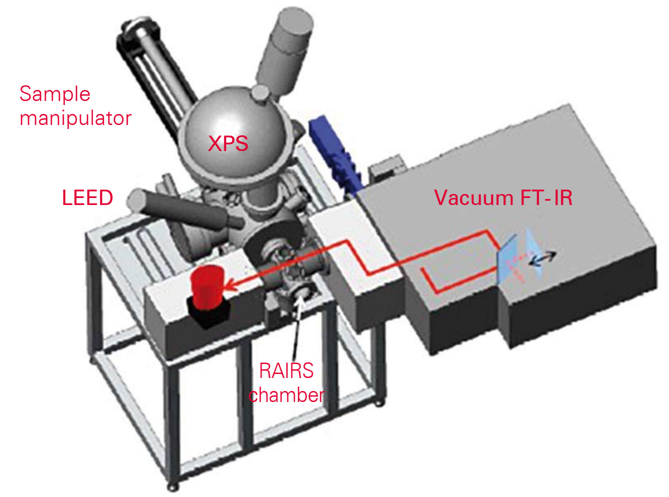
The project aims to develop a novel Imaging Adsorption Sensor (IAS) for the label-free detection of molecular interactions at surfaces in real-time. The new sensor will be integrated into an existing microscope set-up to be used as an add-on component and will be combined with a microfluidic system to enable one-dimensional and two-dimensional multiplexing.

2. Study of complex interfacial properties with nanoscale resolution optical microscopy
Principal investigator: Prof. C. Depeursinge (EPFL)
Partners: EPFL, CSEM & Lyncée Tec SA

Optical interferometric techniques, and more particularly Digital Holographic Microscopy (DHM), offer attractive performances for surface and interface characterisation in terms of speed, accuracy and measuring range. These techniques are expected to play a key role in the future for industrial quality control and R&D activities in fields where new non-destructive and non-invasive investigation tools are needed. The project aims to improve and further develop Digital Holographic Microscopy to evaluate complex surfaces and interfaces, in particular for protein deposition on substrates for biosensor and biocompability applications and for cellular adhesion and growth on selected substrates.

3. Vibrational spectroscopy of nanostructured surface systems
Principal investigator: Dr. D. Ferri (Empa)
Partners: Empa & ETH Zurich

The researchers will set-up an ultra-high vacuum (UHV) reflection-absorption infrared spectroscopy (RAIRS) system, including the polarization modulation option for high-pressure studies. The instrument will allow reflection-absorption infrared spectroscopic measurements on model thin films for application ranging from heterogeneous catalysis to chirality and self-assembled monolayers. This instrument will be the first UHV-RAIRS system in Switzerland.



Scheme of the future ultra-high vacuum (UHV) reflection-absorption infrared spectroscopy (RAIRS) system (Empa & ETH Zurich).

Building the first ultra-high vacuum (UHV) reflection-absorption infrared spectroscopy (RAIRS) in Switzerland
Intense collaboration between Empa, ETH Zurich and Prof. H.-J. Freund (Fritz-Haber-Institute Berlin), one of the key players in heterogeneous catalysis, started thanks to the CCMX project "Vibrational spectroscopy of nanostructured surface systems". The Swiss team has received substantial know-how support from Berlin for the set-up of the instrument. It is planned to continue interacting closely in the future by, for instance, exchanging students.

4. Time-Resolved Cathodoluminescence
Principal investigator: Dr. J.-D. Ganière (EPFL)
Partners: EPFL, Attolight Sàrl & Delong Instruments

A new compact measurement tool for semiconductor nanostructures that combines both high spatial and high temporal resolution (10nm and 10ps respectively) will be developed. An electron beam is focused onto a specimen and information on the structural and optical properties can be obtained using respectively secondary electrons or cathodoluminescence signal. The proposed design is a cost effective solution based on an electrostatic/magnetostatic Scanning Electron Microscope column equipped with an optically driven electron source.

High performance Scanning Electron Microscope equiped with Focused Ion Beam (FIB) for micromachining and gas-assisted etching or deposition (Interdisciplinary Centre for Electron Microscopy - EPFL).

5. Microtome4SIMS: Chemical Tomography of Biological Material with 100 µm Resolution
Principal investigator: Dr. B. Keller (Empa)
Partners: Empa, University Hospital Basel & IonTof GmbH

This project proposes to design, build and implement an in vacuo label free Microtome4SIMS for use in a commercial Time-of-Flight Secondary Ion Mass Spectrometer (ToF-SIMS) apparatus. TOF-SIMS is an analytical technique allowing the identification, localization and depth profiling of atoms, molecular fragments and isotopes with excellent spatial resolution. The principle is based on material slicing and analysis of freshly exposed surfaces on a modified standard sample holder. It opens the possibility to reconstruct three-dimensional molecular distribution maps from stacks of quasi non-destructively analyzed surfaces. This instrument will for the first time produce true high resolution three-dimensional chemical distribution maps of biological samples with high lateral precision.

An intense and fruitful collaboration between the Electron Microscopy Center of the ETH Zurich and a diamond-knife manufacturer was initiated in the framework of the Microtome4SIMS project. This could lead to future projects to apply cryo-microtome in Scanning Electron Microscopy/Transmission Electron Microscopy. This project led IonTof and Nanoscan to initiate an intense collaboration for future manufacturing and commercialization of piezomotor driven microtomes.

6. Adaptation of the Nano-X-Ray Absorption Spectroscopy (NanoXAS) Instrument to a dedicated Beamline at the Swiss Light Source
Principal investigator: Dr. I. Schmid (PSI)
Partners: PSI, Empa & semiconductor manufacturer

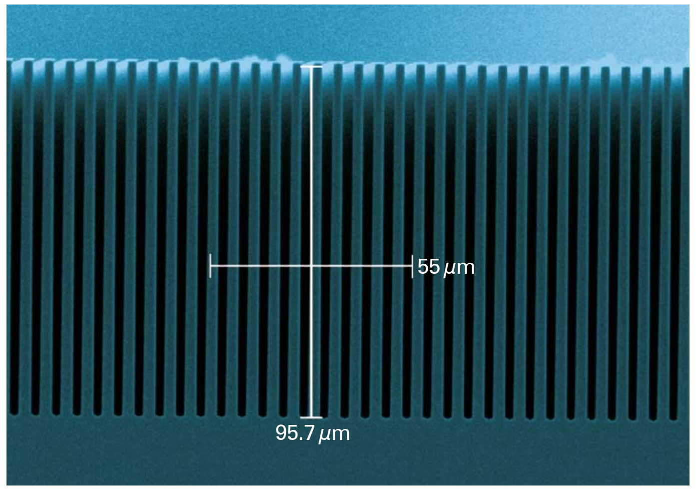
This project aims to set up the new NanoXAS instrument (previously funded by CCMX, Empa and PSI) at a new dedicated beamline of the Swiss Light Source. Operating at this new location will increase the available beamtime by at least a factor of five, allowing access by a broader community. Using the higher X-ray energies provided by the new beamline up to Al-1s absorption edge will allow the analysis of several absorption edges of element (Ga, Ge, As, Al) relevant to the semiconductor industry.

Christian Kottler working at the development of an X-ray phase contrast instrument at CSEM Zurich (CSEM & Empa).

A dedicated Nano-X-ray Absorption Spectroscopy beam line is now being setup at the Swiss Light Source at PSI. Software development within the project gave rise to intense collaboration with Nanoscan and Semafor mainly financed by resources gained from an undisclosed industrial partner and has been a great example of how making use of industrial competence can generate work in high tech industry.

7. Development of an X-ray phase contrast instrument for the characterization of materials with low atomic mass
Principal investigator: Dr. C. Urban (CSEM)
Partners: CSEM & Empa

The newly developed technology of phase-contrast X-ray imaging will be used to enable X-ray inspection technology to materials of low atomic weight, like for example fibre reinforced plastics. A dedicated phase-contrast X-ray instrument will be constructed integrating new developments that allow for X-ray energies up to 80 keV and for dual energy operation. First measurements are expected to occur early in 2009.



New silicon-made diffraction grating to be used in an X-ray phase contrast instrument dedicated to the characterisation of materials with low atomic mass (CSEM & Empa).

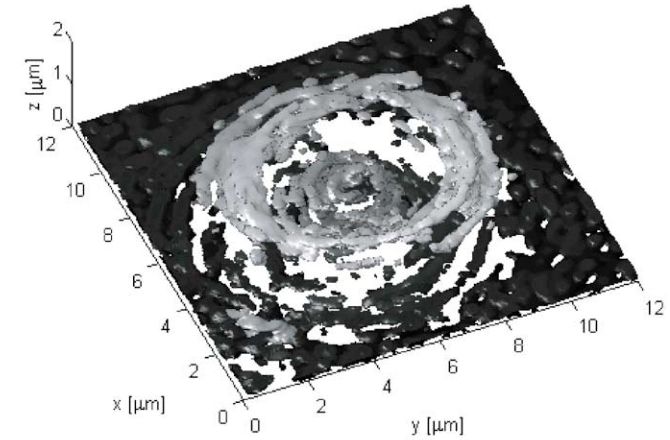
Manufacturing a 90µm deep diffraction grating with a pitch of 5.5µm already suitable for energies of 70 keV is the first achievement while building this new X-ray phase contrast instrument
The research team building the new X-ray phase contrast instrument for the characterization of materials with low atomic mass first developed simulation tools for X-ray diffraction taking into account fabrication tolerances and experimental non-idealities. Based on these findings detailed specifications for the instrument were worked out. Different production technologies and processes for the X-ray diffraction- and absorption-gratings, needed for phase contrast X-ray imaging, were investigated theoretically and experimentally. A major technical success was the achievement of a 90µm deep diffraction grating with a pitch of 5.5µm. Such diffraction gratings are already suitable for energies of about 70keV, which is already close to the goal (80keV) of the project.

Using existing facilities to explore new analytical techniques
Two rapid analytical projects were devoted to using existing instrumentation or existing facilities to explore new analytical techniques:

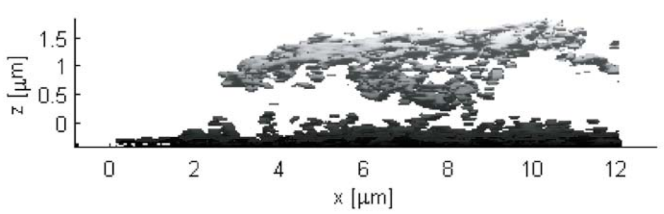
1. Focused Ion Beam (FIB) investigation of Ge-Si heterojunction photo diodes
Principal investigator: Dr. R. Kaufmann (CSEM)

Germanium is an ideal material for near infrared light detection. This rapid analytical project aimed at investigating the microscopic structure of Ge-Si heterojunction photo-diodes, which were monolithically grown on a pre-processed complementary metal oxide semiconductor (CMOS) image sensor. Focussed Ion Beam (FIB) analysis equipment of Empa Dübendorf was used for this experiment. Two different chips with Ge-Si heterojunction photodiodes were analysed to find out more about their etching borders, oxide coverage for isolation and contacting. Germanium photodiodes are an extension of an existing CMOS process and for their manufacture additional processing steps are necessary in the process-flow. Thanks to process simulations and extensive discussions, a new process flow was established. The predicted device geometry and functionality could be confirmed using FIB measurements.

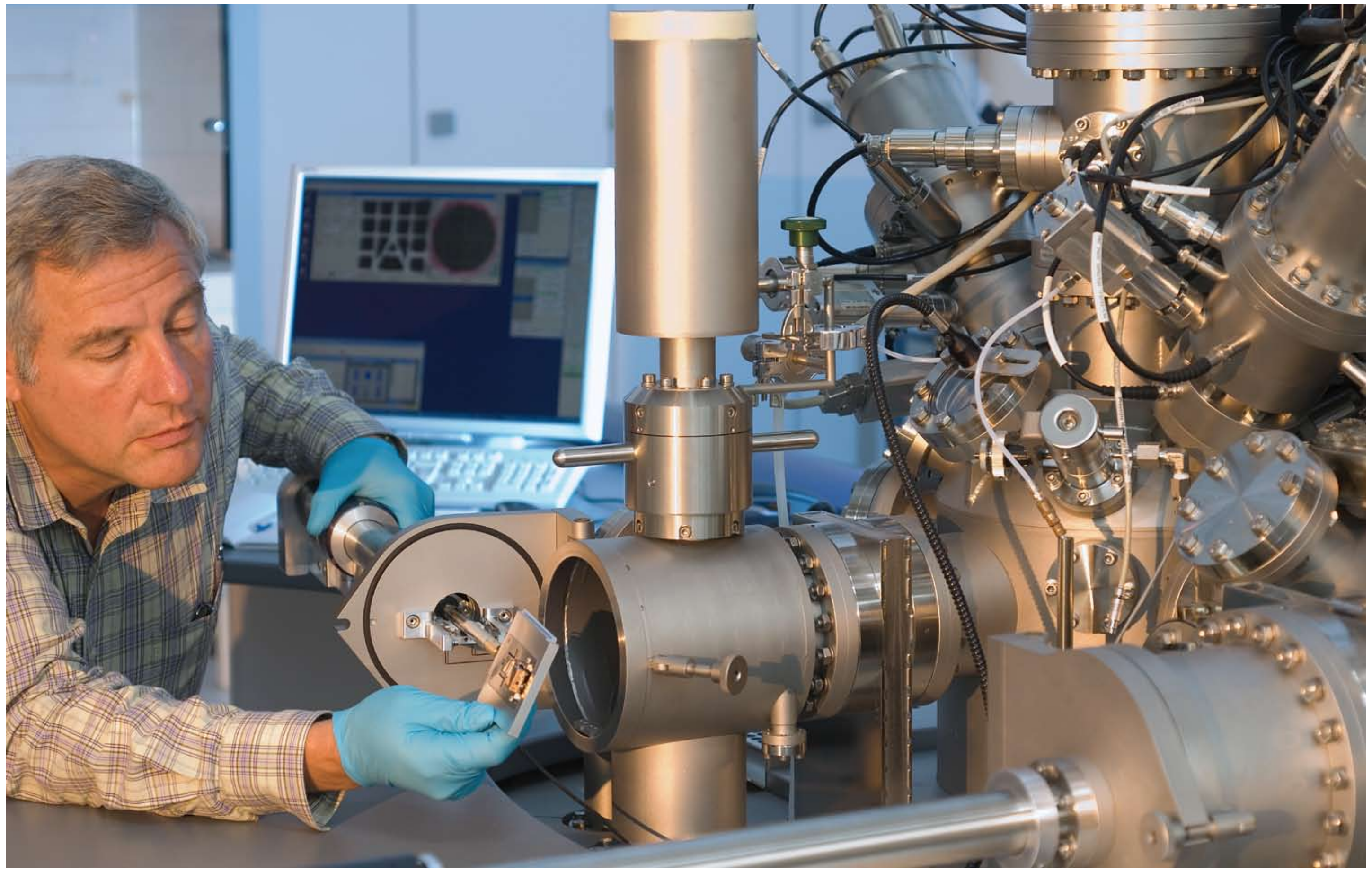
a)



b)



Three-dimensional image made using Digital Holographic Microscopy and characterising the contour of a red blood cell adhering to a substrate (EPFL, CSEM & Lyncee Tec SA).



Time-of-Flight Secondary Ion Mass Spectrometer (ToF-SIMS) (located at Empa).

2. Protein labelling for Time-of-Flight Secondary Ion Mass Spectrometer (ToF-SIMS) imaging of hydrophobicity gradients
Principal investigator: Dr. R. Crockett (Empa)

The project develops a method for labelling proteins to image them on surfaces using ToF-SIMS in an analogous way to fluorescence microscopy. A number of possible labels have been investigated to date. The most promising ones were dibromobenzoic acid and difluorobenzoic acid as both could be attached to the protein without disturbing the structure. However, both those acids feature weak peaks in the ToF-SIMS making them unsatisfactory for imaging. A contrast could be achieved between the presence and absence of protein but differences in concentration should rather be detected in order to fulfil the goals of the project. Larger carboxylic acids are presently being investigated as possible alternatives.

Future
Interlinking the research activities of the Analytical Platform with the Education and Research Units will be emphasized. New analytical instrumentation will continue to be developed in 2009 and beyond with a clear accent on responding to the needs of CCMX researchers involved in pre-competitive research projects. Such projects will require the expertise and collaboration of minimum two ETH Domain institutions. A maximum funding of 350 KCHF per project will be provided by CCMX. Co-funding by institutions and industry partners should at least amount to 50% of the total budget.

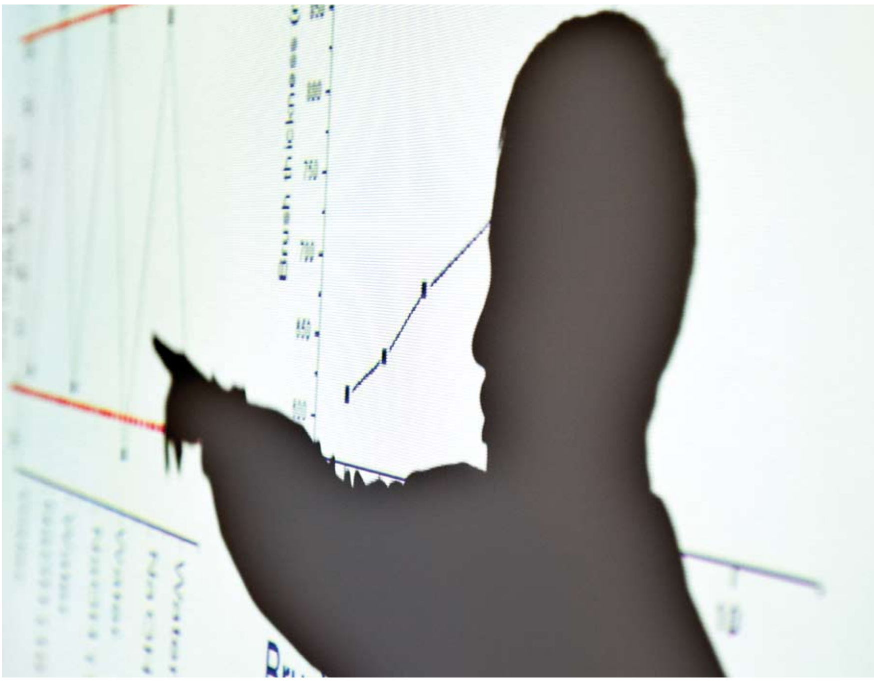
The exploitation of existing techniques in new fields will be funded in the future provided they are of industrial relevance or interlinked with another CCMX project. Projects with industrial partners will be preferred. Such projects will also require the expertise and collaboration of minimum two ETH Domain institutions. A maximum funding of 150 KCHF per project will be provided by CCMX and co-funding by the institutions should amount at least to 50% of the total budget. Higher funding than provided in the framework of the rapid analytical projects will allow more ambitious research to be carried out in this area.

Thanks to the new analytical equipment database, CCMX's Analytical Platform will emphasise the coordination of facilities currently on offer in the partner institutions. Educational training will continue to be offered in specific areas of micro-/nanoscale analysis.

2008 Data

Use of funding in 2008 (KCHF)	
Funding of projects	3'996
Education activities, conferences	220
Industrial liaison	275
Management & administration	509
Total	5'000

Metrics for 2008
28 Running projects
46 Professors involved in projects
17.8 Senior scientists (FTE)
19.2 Post docs paid by CCMX (FTE)
10.5 Post docs not paid by CCMX (FTE)
34.4 PhD students paid by CCMX (FTE)
4.8 PhD students not paid by CCMX (FTE)
33 Publications (peer reviewed)
3 Invention disclosures
1 Patent (Low as research is pre-competitive)



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Projects funded in 2008

Title of project	Principal Investigator (PI)	PI's Institution	Others Institutions	ERU/ Platform
Development of novel methods for surface modification and investigation of cell-particles interaction for superparamagnetic nanoparticles (PAPAMOD)	P. Renaud	EPFL	EPFL (2), PSI	SPERU
Nanocrystalline ceramic thin film coating without sintering (NANCER)	J. Rupp	ETH Zurich	ETH Zurich, Empa, PSI (2)	SPERU
Smart functional foams	L. Gauckler	ETH Zurich	EPFL, ETH Zurich (2)	SPERU
Zero order nano optical pigments (ZONOP)	A. Stuck	CSEM	EPFL	SPERU
Photochemically functionalizable scaffolds for Tissue Engineering and Nerve Regeneration	C. Hinderling & M. Liley	CSEM	ETH Zurich (2)	MatLife
Immunofunctional Nanoparticles	J. Hubbell	EPFL	EPFL, ETH Zurich	MatLife
Multivalent Lectin Array: A Combinatorial Approach	P. Seeberger	ETH Zurich	ETH Zurich	MatLife
Bio-functionalized, biodegradable nanostructured magnesium implant for biomedical applications	S. Tosatti	ETH Zurich	ETH Zurich (4), Empa	MatLife
Three-Dimensionally Designed Cell Cultures Consisting of Microstructured Cell-Sheets and Polymer Layers for Tissue Engineering	J. Vörös	ETH Zurich	EPFL, Unispital Zurich	MatLife
Platform for high-density parallel screening of membrane receptor function	H. Vogel	EPFL	ETH Zurich (2), CSEM	MatLife
Studying Single Cells in Engineered 3D Microenvironments	V. Vogel	ETH Zurich	ETH Zurich, Empa	MatLife
Lab-on-a-chip for analysis and diagnostics	M. Gijs	EPFL	EPFL (6), CSEM	MMNS
Materials, devices and design technologies for nanoelectronic systems beyond ultimately scaled CMOS	Y. Leblebici	EPFL	EPFL (4), CSEM, ETH Zurich	MMNS
Development and characterization of nanowires for applications in bio-electronics	J. Vörös	ETH Zurich	ETH Zurich, PSI	MMNS
Evolution of microstructure and mechanical response due to cyclic deformation at elevated temperatures	S. Holdsworth	Empa	ETH Zurich, PSI	MERU
In-situ mechanical testing	H. Van Swygenhoven	PSI	Empa (2)	MERU
Modelling of defect formation in solidification processes using granular dynamics and phase field approaches	M. Rappaz & A. Jacot	EPFL	Empa, PSI	MERU
Combinatorial study and modeling of optical properties of gold alloys	R. Spolenak	ETH Zurich	PSI	MERU
Label free imaging of molecular adsorption on in-situ surface-functional patterns	N. Spencer/Balmer	ETH Zurich	Empa	NNMC
Nanoscale resolution optical microscopy for material imaging and spectroscopy	C. Depeursinge	EPFL	EPFL, CSEM	NNMC
Vibrational spectroscopy of nanostructured surface systems	D. Ferri	Empa	ETH Zurich, Empa	NNMC
Time-resolved cathodoluminescence (TRCL)	J.-D. Ganière	EPFL	ETH Zurich	NNMC
Microtome4SIMS: Chemical Tomography of Biological Material with 100 nm Resolution	B. Keller	Empa	UniSpital Basel	NNMC
Nano-Xas	I. Schmid	Empa	PSI	NNMC
Development of a X-ray phase contrast instrument for the characterization of materials with low atomic mass	K. Urban	CSEM	Empa	NNMC
Development of a database detailing modes to access micro- and nanoscale analytical instrumentation available to industry within the ETH Domain	S. Meuwly	Empa	–	NNMC
Rapid Analytical Project (RAP): "FIB investigation of Ge-Si heterojunction photo diodes"	R. Kaufmann	CSEM	–	NNMC
Rapid Analytical Project (RAP):"Protein labelling for TOF-SIMS imaging of hydrophobicity gradients	R. Crockett	Empa	–	NNMC

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