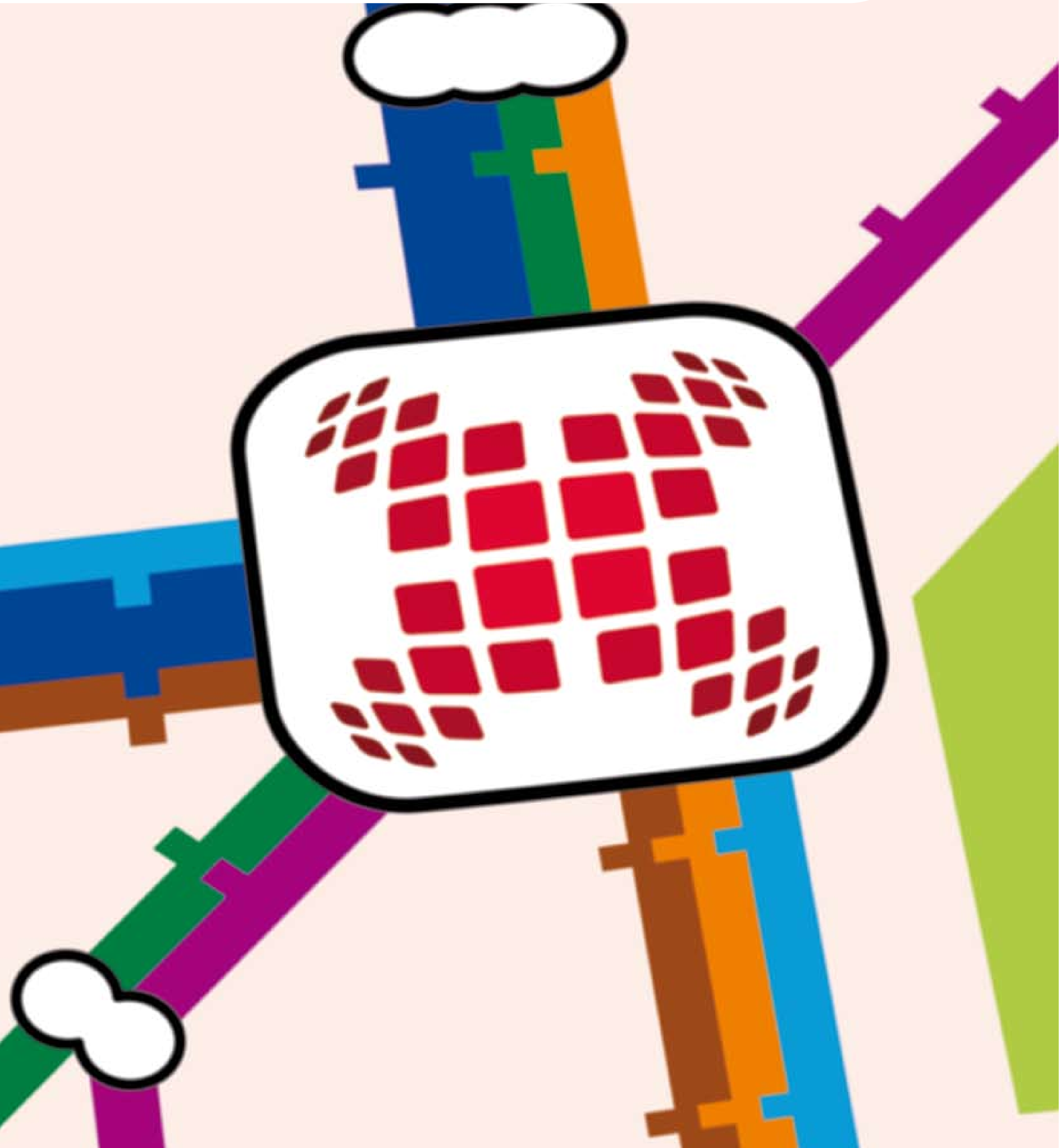
CCMX
Competence Centre for
Materials Science and Technology

ANNUAL REPORT 2007



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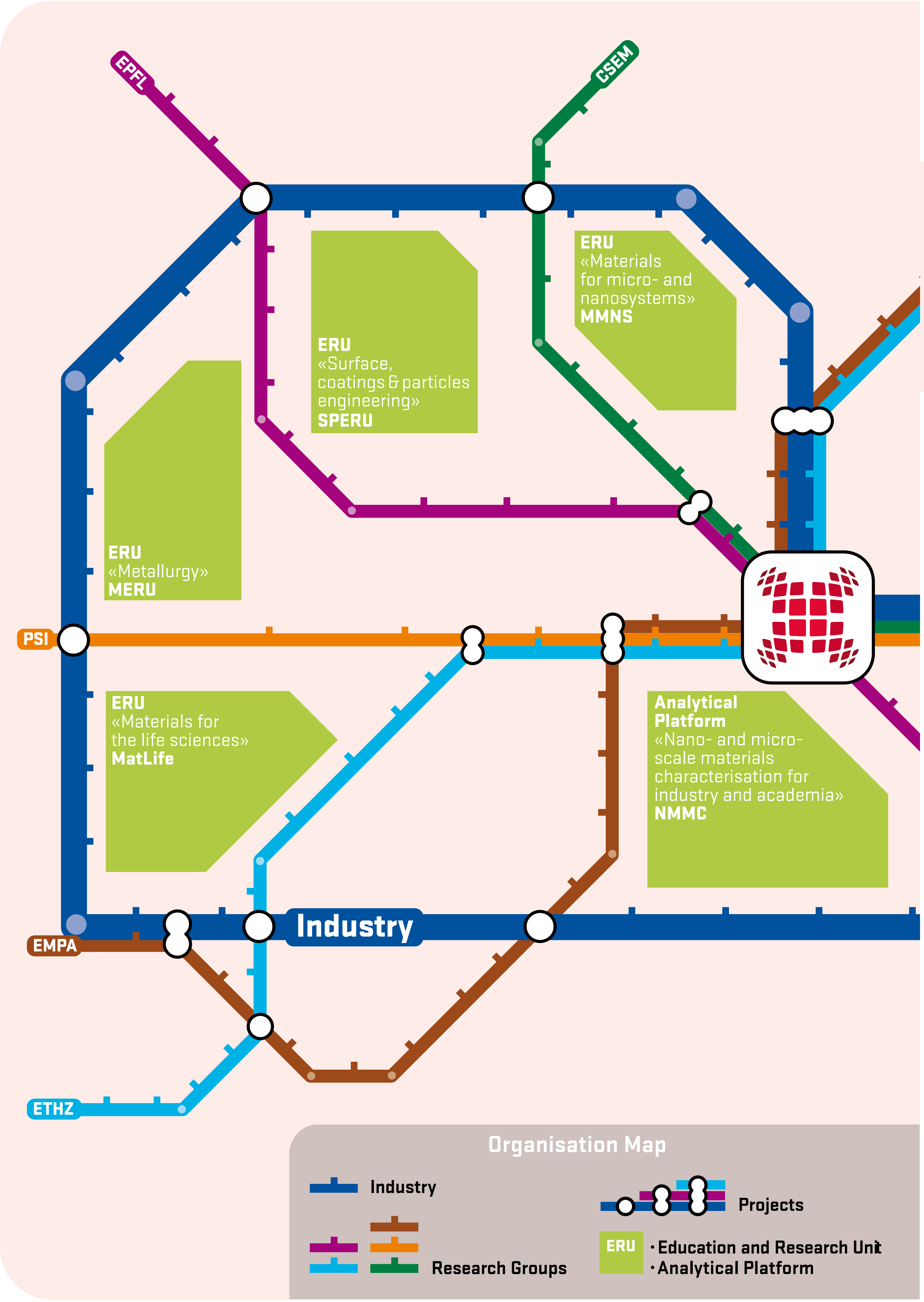

Welcome to the second annual report of CCMX

CCMX was created at the beginning of 2006 with the aim of linking the excellent academic research in the ETH domain to the needs of industry. Three Educational and Research Units (ERUs) were created in areas of key importance to the economy:

- Surface, coatings and particles engineering (SPERU);
- Materials for the life sciences (MatLife);
- Materials for micro- and nanosystems (MMNS);

An Analytical Platform (NNMC) was also created to develop and promote activities in nano- and microscale materials characterisation.

The first flagship projects started towards the end of 2006 and are already, after just over a year of work, starting to deliver important results. Highlights from these projects, involving 12 industrial partners and over 150 scientists and engineers from more than 60 laboratories, are shown in the pages of this report.

As a result of a detailed consultation with the industrial sector, a new ERU in metallurgy (MERU) was launched at the end of 2007.

The focus of the Centre is now on strengthening the role of industry in the research carried out by CCMX. The new call for proposals initiated at the end of 2007 is focussed on bridging the gap between the fundamental research supported by the Swiss National Science foundation and «near to market» research funded by the CTI. The new projects will be jointly funded by CCMX funds and pre-competitive consortia from the industry. Club CCMX has been set-up to offer companies another alternative to be involved in CCMX activities.

CCMX is growing fast. The exciting results of on-going projects, the level of the newly funded projects to start in 2008, and the growing network of industrial partners are all very promising. CCMX will be a strong force in materials research for Switzerland in the coming years.

Karen Scrivener

Chair CCMX

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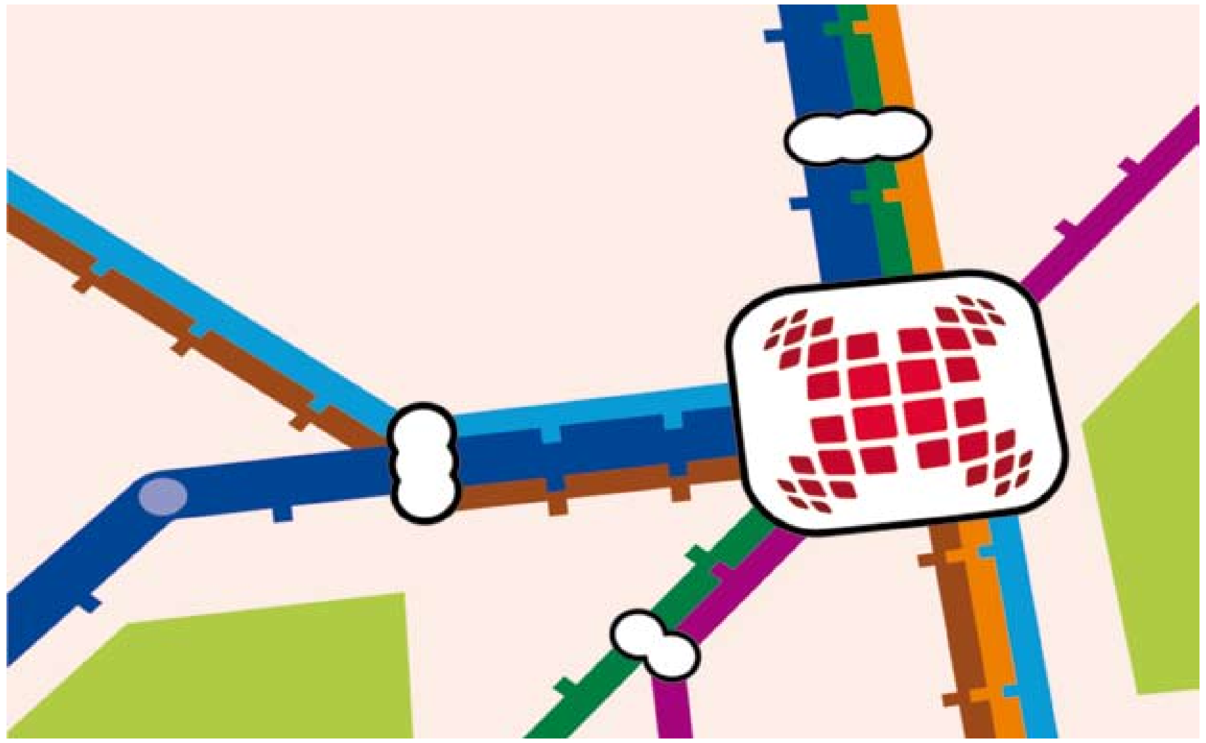
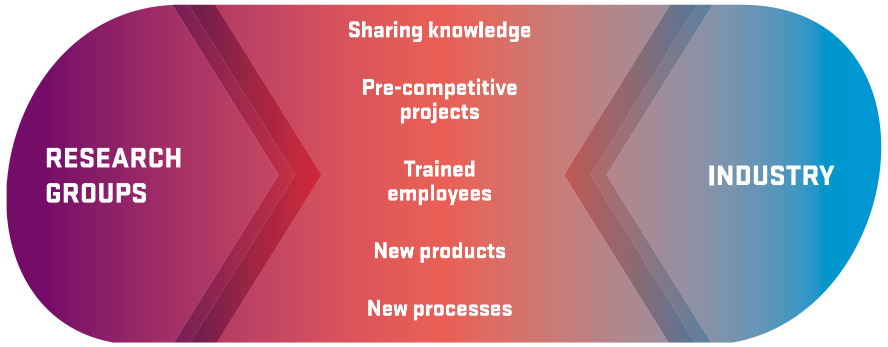


The **Competence Centre for Materials Science and Technology (CCMX)** is one of several centres of excellence initiated at the national level by the ETH Board in early 2006. It aims to serve the interests of Switzerland in the field of materials science in terms of research, education and technology transfer by reinforcing ties between academia, industry and the Swiss economy.

What is the Competence Centre for Materials Science and Technology?

NETWORKING WITHIN CCMX



Structure

CCMX federates the strengths of four ETH Domain institutions (EPFL, ETH Zurich, EMPA, PSI) and of CSEM, and involves the active participation of partners from industry, from industrial associations and from Swiss universities. The Centre is headed by a Steering Committee comprising members from EPFL (chair), ETH Zurich, PSI, Empa, CSEM and industry.

At the core of the Centre's activities are **ERUs – Education and Research Units** – and an **Analytical Platform**. The ERUs offer programmes of research and education, including technology transfer, in targeted fields of activity identified together with the Swiss industry:

- **surface, coatings and particles engineering (SPERU)**
- **materials for the life sciences (MatLife)**
- **materials for micro- and nanosystems (MMNS)**
- **metallurgy (MERU)**

Closely linked to these ERUs is an Analytical Platform developing and promoting activities in **nano- and microscale materials characterisation for industry and academia (NMMC)**.

Research

The Centre is currently funding 27 projects involving 12 industrial partners, over 150 scientists and engineers and more than 60 laboratories from 7 institutions (see the detailed list of projects on page 30). A call for new proposals is currently underway and will lead to the funding of new projects from spring 2008. CCMX concentrates on pre-competitive research and thus aims to strongly and positively influence this area in Switzerland.

Each CCMX funded project includes at least two institutions and very often one or more industrial partners. This multi-partner project approach brings together the best competencies from all over Switzerland in specific materials science related domains.

Education and training

A wide range of continuing education is on offer at CCMX. Courses, seminars and workshops are regularly organised by the ERUs and the platform (more details can be found on page 24). Topics are chosen based on the actual needs of the targeted audiences (PhD students, engineers, scientists from industry and/or academia).

These continuing education initiatives attracted more than 230 participants from industry and academia in 2007 and will continue in 2008. Some new modules such as short courses, summer schools and travelling lab workshops will be added to the offer in 2008.

Technology and knowledge transfer

The interactions that CCMX maintains with the industry are decisive in the process of technology and knowledge transfer. By involving several institutions and one or more industrial partner in each project, CCMX ensures access to fundamental and applied know-how.

The industrial liaison programme of CCMX is a means for both large and small companies to have access to the technology and the knowledge developed within the Centre. Companies have two options to be involved in CCMX. They can either purchase research tickets or become members of Club CCMX. For details please see the article «Perspectives 2008» on page 26.

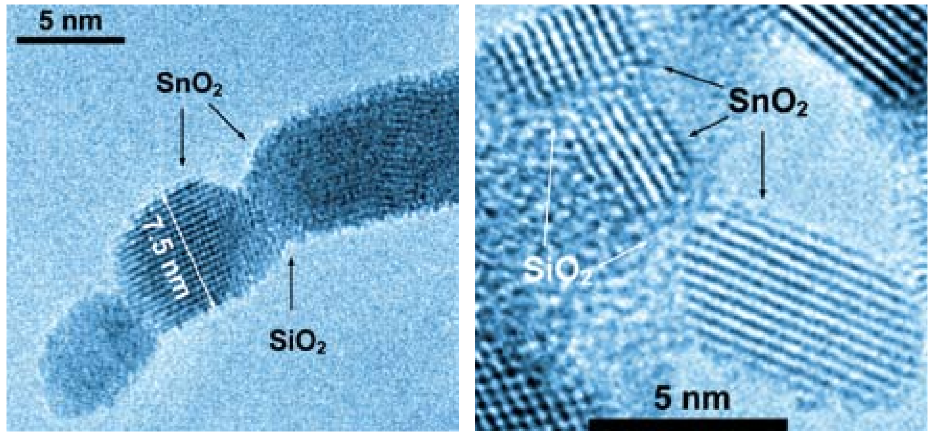
CCMX's outreach activities and industrial liaison programme are perfect opportunities for the industry to communicate its needs in terms of research and education.

Conclusion

CCMX aims to strongly and positively influence materials science in Switzerland by building a Swiss reservoir of expertise in the field of materials science. It builds bridges between the scientific and industrial communities and addresses targeted specific needs with particular emphasis on developments of interest for the applications of tomorrow.

The CCMX policy is to support pre-competitive research projects on noteworthy themes that will attract matching funding from industry. This positions CCMX in the "funding gap" between the funding strategies of SNSF - mostly centred on supporting fundamental research- and of CTI - focusing on applied developments to be brought quickly onto the marketplace.

The research we focus on



Morphology of two different SiO_2-doping level of SnO_2 nanostructures used for sensor applications. Low SiO_2 contents (left) lead to slightly aggregated nanostructures and small neck size/angle with high sensitivity; high SiO_2 contents (right) lead to isolated SnO_2 crystals with no sensitivity, due to the high resistance of SiO_2 between SnO_2 crystals (ETH Zurich, PSI & Empa).

The Education & Research Units and their research thematic areas

CCMX, through its four Education & Research Units (ERUs), currently focuses on the 9 thematic areas presented in detail in the coming pages. New pre-competitive research projects will be launched in 2008.

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

How industry can be involved in pre-competitive research in materials science

The active participation of industrial partners is considered as essential to CCMX's mission of linking academia and industry. To this end a common model for industrial liaison is being implemented. CCMX is establishing research consortia bringing together companies interested in the same thematic area.

With the purchase of research tickets in a chosen thematic area, industry consortia will share the costs of pre-competitive research with matching funds from the ETH domain and will have a direct say in the advancement of the projects within the chosen thematic area.

In addition to the development of technologies and know-how, the training of Ph.D. students in a field of direct interest to the companies adds significant value to this programme. The CCMX Research Programme offers direct access to the best Swiss expertise in selected thematic areas of materials science.

How will this work in practice?

Each time a research ticket of CHF 75'000 per year has been purchased, a matching fund of CHF 75'000 per year is provided by CCMX. One ticket may be split between a maximum of three companies. A commitment for 3 years is necessary to guarantee completion of a project (involving Ph.D. students). The company selects one thematic area to which the ticket is allocated. The companies involved participate in the regular meetings of the project and have voting rights (according to contribution) on subjects such as project start, continuation or discontinuation and re-orientation of the thematic area for upcoming projects. When there is a commitment to at least three tickets, new Calls for Proposals will be launched.

In the Analytical Platform (NMMC) matching funds from institutions are required as described in the article "Enabling solutions for materials analysis at the micro- and nanoscale".

Please contact the ERU/analytical platform directors or their industry liaison officers for more details. The contact details are to be found at the end of this report.

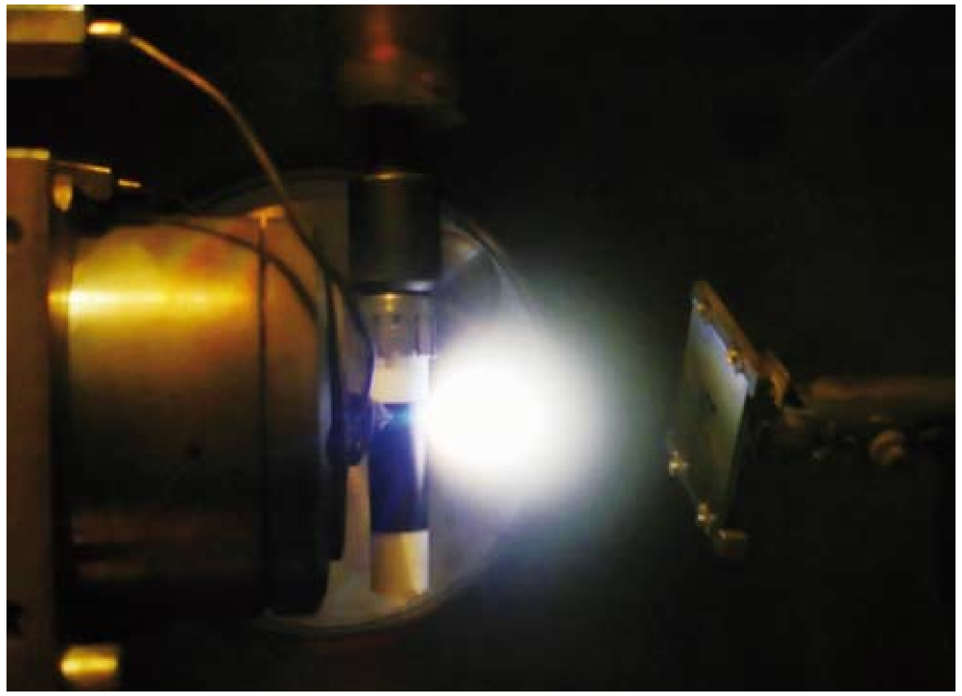
For smaller companies not able to fund research tickets, Club CCMX offers access to the networking and training activities of CCMX. More information is provided in the article entitled "Perspectives for 2008".

Besides fairly fundamental questions, novel cost effective processes for surface coating or structuring still have to overcome many challenges.

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 | RF sputtering metal-organic chemical vapour deposition | ceramic multi-layers | combustion chemical vapour deposition | nanoscale gratings | stability in layers | mechanisms of protection

Chemical or physical vapour deposition, spray pyrolysis, thermal spraying and laser assisted ablation are examples of essential technologies associated with particle processing. The creation of novel products exhibiting desirable optical, thermal, electrical, electrochemical or magnetic properties requires a better understanding of both the process parameters and the characteristics of materials. For instance, defining how the nature of the interface between the bulk material and the coating influences the device transport properties; or which surface treatment leads to adequate stress and strain level enabling production of crack-free or non delaminating coatings is essential.



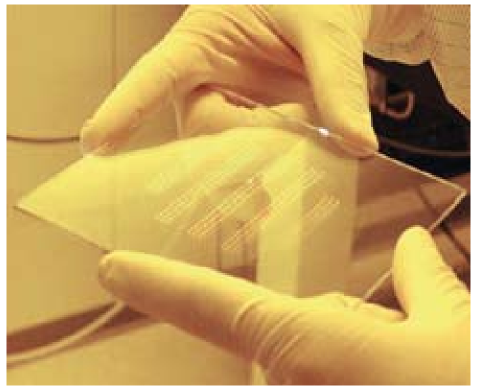
Pulsed Laser Deposition of ceramic thin films (PSI, ETH Zurich & EMPA).

Two projects initiated early 2007 are currently underway in this thematic area. The first one «Nanocrystalline ceramic thin film coating without sintering (NANCER)» 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). The thermal stability of nanocrystalline thin films integrated on silicon chip-sized devices is quantified in order to enable intermediate to high temperature applications such as with gas sensors and micro-solid oxide fuel cells.

Those high functionality films are manufactured through novel fabrication techniques without the need for traditional sintering treatment. Six deposition techniques – spray pyrolysis, pulsed laser deposition, direct aerosol deposition, metal-organic chemical vapour deposition, RF sputtering and combustion chemical vapour deposition – have been altered to enable the preparation of ceramic thin films with a range of selected thermal, electrical, electrochemical and magnetic properties. Yttria-stabilized zirconia thin films have been produced using all the above techniques and applied as electrolyte thin film for solid oxide fuel cells, providing for the first time indications on method-dependent properties, i.e. the relationship between microstructure and electrical conductivity.

Characterisation techniques for such films have been implemented including (1) the set-up of a new test platform for electrochemical properties enabling the discrimination between the ionic and electronic contributions to conductivity and (2) the set-up of a device for measuring electrical properties at high temperature. Macro- and micro- gas sensors were produced by direct aerosol deposition of thin layers of SnO_2 nanoparticles where small crystal size was preserved, therefore providing higher sensor performance.

Yttria-stabilized zirconia (YSZ) thin films electrolytes have been successfully integrated into the micro-solid oxide fuel cell for battery replacement in portable applications invented at ETH Zurich. Such an application is highly demanding on a wide range of characteristics, including thin film specific shape and temperature-time stability says NANCER's project coordinator Dr. Jennifer Rupp of ETH Zurich. Three micro-SOFCs have been deposited with these electrolyte thin films on one glass-ceramic chip and will soon be tested for their electrical performance. It is the first time that YSZ films were made by such a variety of deposition methods: a publication involving all the NANCER partners describing these thin films properties in relationship with the processes applied is in the 2008 agenda.



Fabrication process of Zero Order Diffraction structures (CSEM & PSI).

$La_{0.6}Sr_{0.4}Co_{0.2}Fe_{0.8}O_3$ (LSCF) thin films deposited on silicon nitride by cathode spray pyrolysis (ETH Zurich, PSI & Empa).

The second project in this thematic area 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. Those completely novel spectral characteristics are based on zero order diffraction - ZOD. The «Zero order nano optical pigments (ZONOP)» project is lead by Dr. A. Stuck at CSEM and involves PSI's Dr. R. Morf.

Theoretical simulations were performed to understand the effects of the shrinkage of the full structure length of a subwavelength on the reflection and transmission spectra. The first tests performed with structures of 10, 40, 80, and infinite number of periods are promising. The reflection peak is still present in structures of only 10 periods whereas the intensity decreases down by a factor of only 50 %. Those subwavelength structures do not lose their colour effect by reducing their size down to a few micrometers. As an example, a typical ZOD structure with a period of 360 nm exhibits a strong reflection (~100 %) in the green with an infinite number of periods. By reducing the size of the pigment down to 10 periods, which means to a pixel of 3.6 microns, the green reflection peak is still centred at the same wavelength but its intensity is decreased to 50 %. Such results were anticipated but never simulated before.

Trends

Vacuum-based thin-film technologies are vital for creating hard, resistant surfaces for electronics and tooling applications. Many of the underlying basic processes are still not yet elucidated and important production problems remain unsolved. In chemical vapour deposition coating performed at 800°C and above, residual tensile stress is built up caused by the different thermal expansion coefficients during cooling. Multi-layered and nanostructured 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.

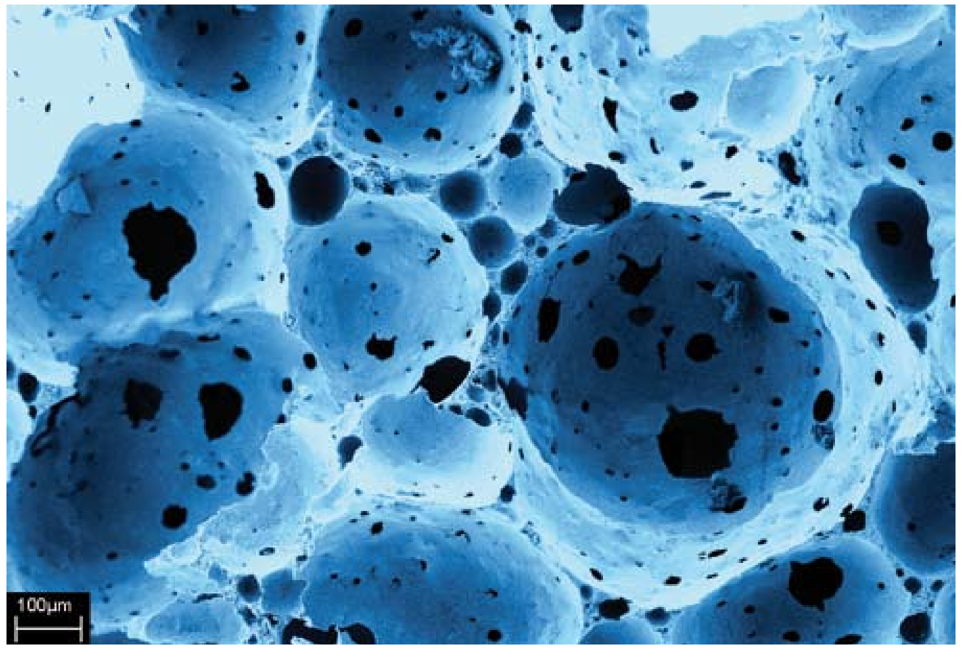
Exceptional gas-barrier performance is expected from artificially layered nanostructured materials. Interesting candidates for avoiding premature failure are hybrids based on metal-oxide layers combined with UV-curable organosilanes and hyperbranched polymer precursors, which substantially reduce in shrinkage stresses as a result of their particular network formation mechanisms. On the other hand, patterned electrodes with tailored conductivity can be made with a proven but expensive technology. Novel approaches should be explored and combined with the barrier function. In the field of organic electronics and thin films, solar cell devices with transparent electrodes compatible with continuous production are required.

Nanoscale gratings, with periods less than 500 nm combined with thin (less than 200 nm) dielectric layers also called zero-order diffraction (ZOD) devices act as highly effective colour filters at specific wavelengths. Strong colour and size effects are expected if the pigment size is of the order of a few grating periods or less, i.e. of about 1 micron. These effects are currently neither understood theoretically nor have they been verified experimentally.

Functional foams

biodegradable composite foams | light-weight foams from renewable resources
resorbable scaffolds and implants | smart metallic shape-memory foams

Solid foams find nowadays 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, 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.



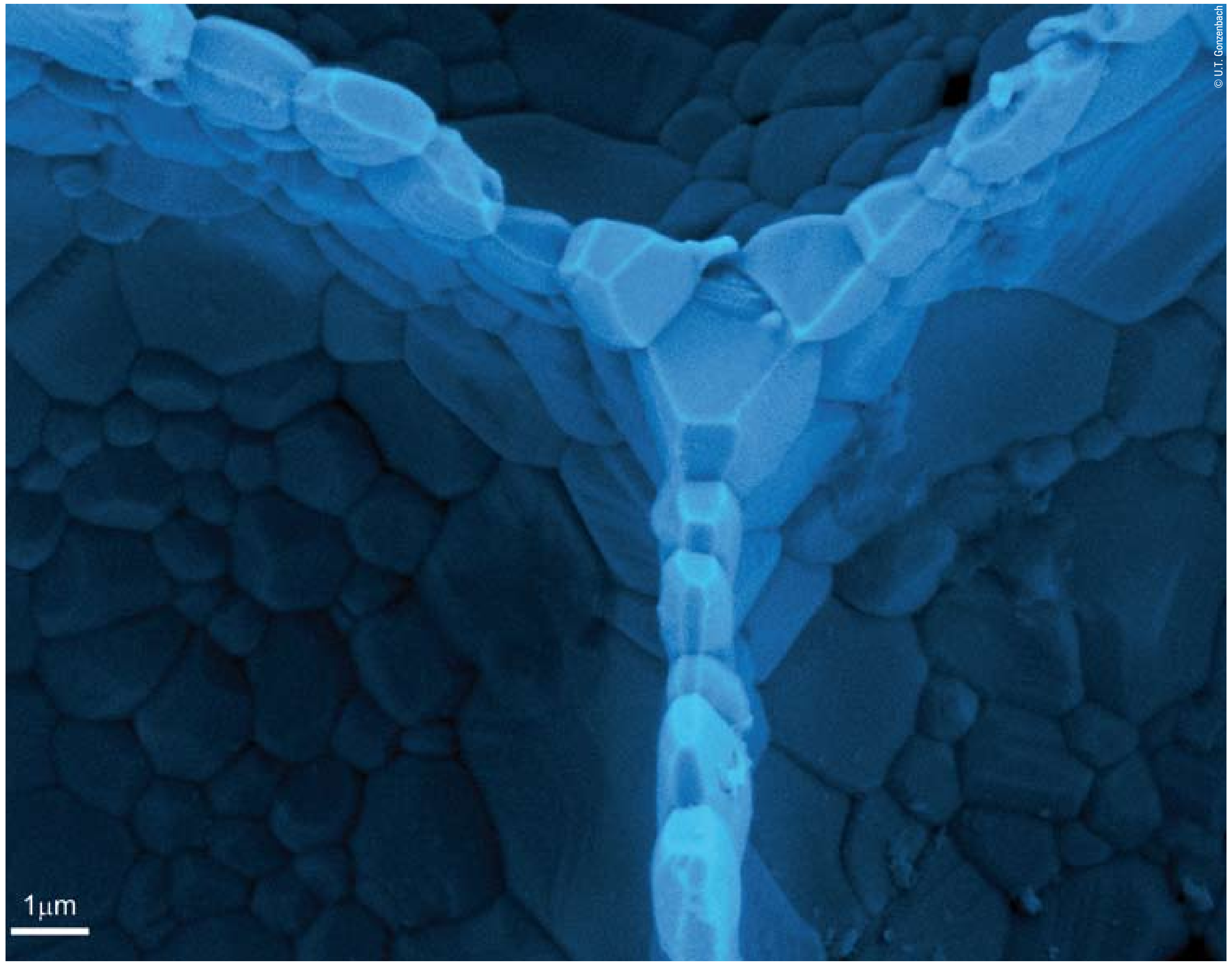
Open porous ceramic particle-stabilized foams (ETH Zurich & EPFL).

Porous materials with outstanding properties

Porous materials are important in numerous applications ranging from thermal insulation to bone graft materials. Within the CCMX initiative, a novel foaming method has been extended into the areas of ceramic, polymeric and metallic foams. «The achieved results demonstrate the universal nature of the method and the outstanding properties of the produced porous materials» stated Dr. Urs T. Gonzenbach (ETH Zurich) who is coordinating the «Smart Functional Foams» project. The large open pores in the ceramic foams make them a potential candidate for bone graft materials. Titanium foams can be produced with pore sizes below 50 μm, an interesting candidate for light-weight applications. Various polymer foams with high thermal stability and in some cases piezoelectric properties are fabricated as well. More exciting results are expected throughout 2008 and 2009.

One project entitled «Smart Functional Foams» and initiated early 2007 is currently underway 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 from EPFL (Prof. D. Pioletti).

Preparation of stable foams from all three classes of particulate materials – ceramic, metal or polymer – was achieved; this includes the challenge of manipulating highly inflammable metallic particles. A method for creating open pores larger than 100 μm in ceramic foams with controlled average pore size and pore openings was implemented. The growth of bone-growing cells for potential application as scaffold materials is currently under study. The whole processing chain for preparing dried foams from titanium and nickel/titanium nanoparticles was set-up in an oxygen free atmosphere. Oxide content as low as 2 mass-percent in the dry porous material and average pore sizes of less than 50 μm is quite promising. Polyvinylidene fluoride (PVDF) particles are used as starting materials for producing materials with a closed cell structure. To obtain a partially open-cell structure an emulsion-based process is used. Piezoelectric properties of both types of structures made of PVDF and other polymers are currently being tested.



Porous structure made from a ceramic particle-stabilized foam (ETH Zurich & EPFL).

Trends

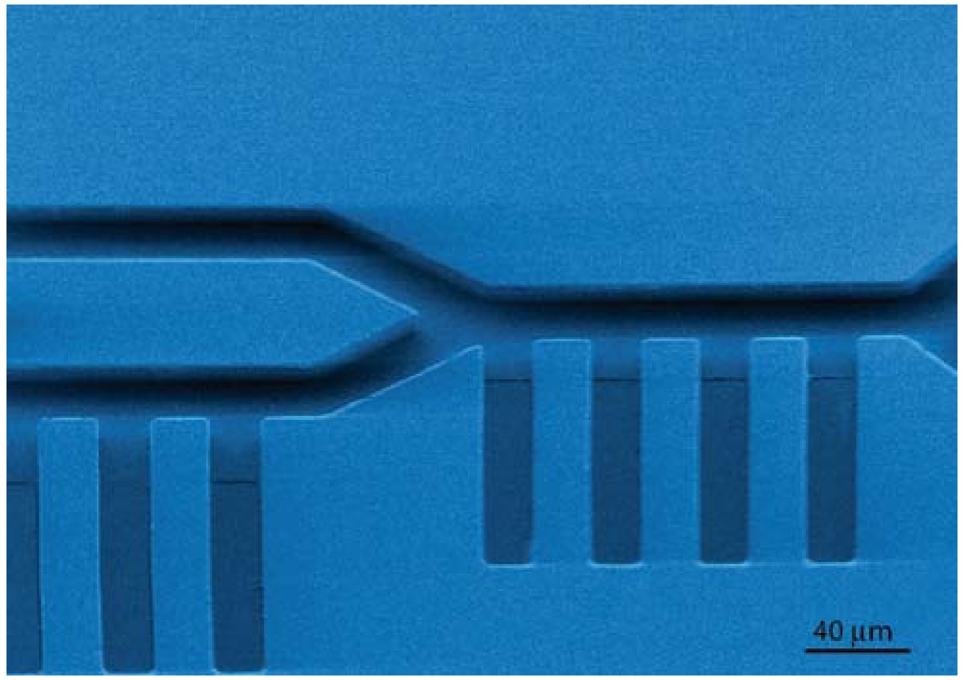
A major advantage of this novel foaming technique is the enhanced foam stability in the wet state, allowing for a better control of the foam microstructure. The method is very versatile and can be used to produce porous materials out of ceramics, metals, polymers and composites. A wide variety of foam products may therefore be foreseen. Porous scaffolds for hard tissue repair could be produced from inert biocompatible materials, biocompatible bioactive materials or from bioresorbable materials. Titanium- or magnesium-based foams have many potential applications due to their outstanding mechanical properties in combination with a low density and high chemical resistance. Superelastic foams could be created by using shape memory effect above transition temperature, i.e. using an alloy with the transition temperature below working temperature. Shape-memory foams could be designed by using shape memory effect below transition temperature, i.e. using an alloy with a transition temperature above working temperature. Electrically-charged polymeric foams represent promising piezoelectric transducers for monitoring/actuating soft matter. Carbon nanotube foam actuators represent the logical extension of proven two-dimensional actuators based on bucky papers to three-dimensional active structures.

Prime interests are to understand how cell processes may be influenced by nano-sized particles and to improve efficacy and safety of drug treatment and vaccination.

Functional particles in contact with biological fluids

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

Functional nanosized particles will have a major impact in several fields of bio-research, such as in systems biology which seeks to explain biological phenomenon not on a gene-by-gene basis, but through the interaction of all cellular and biochemical components in a cell or an organism. In order to penetrate step by step into this exciting field, functional nanoparticles systems will be first applied in the elucidation of how nanoparticles enter cells and may influence cell 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.



Flow-through particle processor for high yield and high quality functionalisation of particles (EPFL & CSEM).

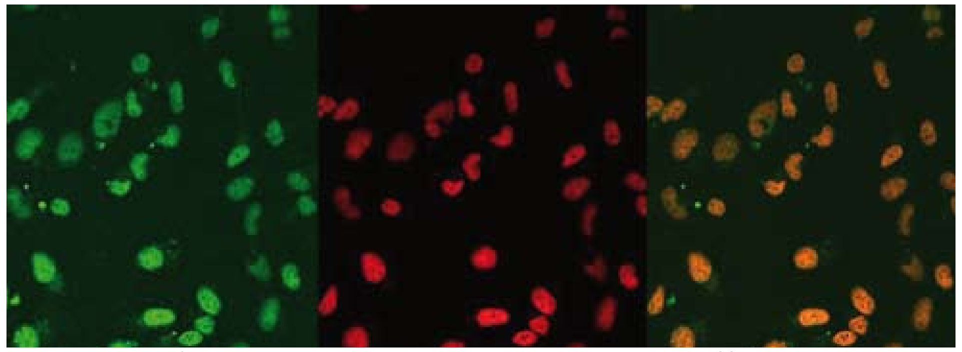
A novel vaccine and immunotherapy technology by designing materials exhibiting bio-functional and immuno-functional capabilities is being developed by a team led by EPFL (Prof. J. Hubbell). The team also involves other colleagues from EPFL (Prof. M. Swartz), from a Swiss company (SurfaceSolutionS AG) and consultants from another company. Specifically, polymer nanoparticle formulations, following intradermal injection, should target the draining lymph nodes. Furthermore a plug-and-play scheme to functionalise these nanoparticles with antigen will be set-up. The biophysical phenomenon of interstitial flow which can direct ultra-small antigen-bearing nanoparticles into the lymphatics and draining nodes, where dendritic cells reside in highest number, was demonstrated. Moreover materials surface biofunctionality can be exploited to activate complement *in situ* to generate a danger signal adjuvant. The achieved efforts span from the synthesis of the functionalised nanoparticles toward to the demonstration of strong and sustained antigen-specific cellular and humoral immunity in mice.

2007 «KPMG Tomorrow's Market Award» awarded to Ph.D. student Sai Reddy


© A. Herzog

Ph.D. student Sai Reddy of EPFL was awarded the "KPMG Tomorrow's Market Award" 2007 (Project "Immunofunctional Nanoparticles").

EPFL Institute of Bioengineering professors Melody Swartz and Jeffrey Hubbell and their team of researchers have developed and patented a type of nanoparticle that allows vaccines to be administered more efficiently, with fewer side effects, and at a fraction of the cost of current vaccine technologies. Antigen-bearing nanoparticle vaccines have been engineered with two novel features: lymph node-targeting and in situ complement activation. Those novel features may potentially be important strategies in vaccine design. In this system, fluid and macromolecules are constantly being drained from the interstitial space, this basic physiological phenomenon was exploited by using nanoparticles that are so small (25 nanometres) that they are convected by interstitial flow through the interstitial matrix into the draining lymphatic capillary bed. Ph.D. student Sai Reddy has been awarded the 2007 «*KPMG Tomorrow's Market Award*» worth CHF 50'000 for his contribution to this breakthrough. This work was published in *Nature Biotechnology*.


Nucleus targeting by functionalised superparamagnetic iron oxide nanoparticles (EPFL & CSEM).

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. H. Knapp). Nanosized superparamagnetic iron oxide particles (SPIONs) will be coated with 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.

Superparamagnetic nanoparticles were functionalised for molecular imaging and for protein separation inside living cells. Colloidal stability of dispersions of particles exhibiting different polymer coatings was evaluated with regard to cellular uptake by HeLa cells. Already minor modifications of the nanoparticles surface lead to an altered stability, uptake, and toxicity. The optimal cell culture medium should therefore be individually determined depending on the particle surface modification. The pathway of nanoparticles functionalised with organelle-targeting peptides was identified from the living cell membrane towards the nucleus. A first microfluidics device prototype enabling continuous multi-step functionalisation of particles has been tested. It is currently adapted to submicron and micron-sized particles but work is in progress for developing a device suitable for continuous functionnalisation of nanosized particles. The development of a device suited to classification of particles regarding their physical and chemical properties is also underway.

Trends

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. In the field of magnetic resonance imaging multifunctional particles are needed in the future. They will need to fulfil several requirements: chemical stability under physiological conditions and sufficient circulation time in vivo; low level of non-specific protein adsorption from blood plasma to prevent fast clearance from the blood stream; presentation of functional bioligands in order to actively target specific cells and tissue. 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.

Energy-related proteins are implicated in nanoparticles-organelle interactions within the cell nucleus

Particles functionalised simultaneously with several particular proteins are able to break through the cell membrane and specifically adsorb to organelles. These functionalised particles could for the first time be recovered from the cell and separated from the organelles. The proteins subsequently adsorbed at the surface of the particles after entering the cell could be detected. Interestingly, more than 90 % of these proteins are related to the uptake and the targeting process only. Energy-related proteins were also detected, confirming that the cells were still alive during the adsorption process. This exciting discovery has led to the filing of a patent application.

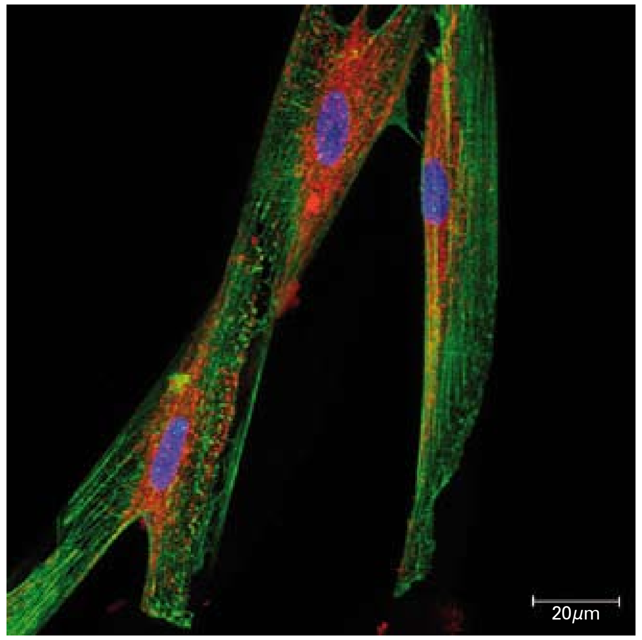
The development of a platform for the reproducible, multifunctional, and flexible surface derivatisation of nanoparticles suitable to investigate cell-nanoparticle interactions in living systems and biochemical interaction is another long-term goal of this thematic area. This platform should enable (a) 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. One of the most important questions for toxicologists is the quantification of nanoparticles that have been taken up by cells or organisms. This question has not been answered today.

Sophisticated applications of superparamagnetic particles will be tacked in a further step. They include magnetic enhanced transfection, treatment of tumours by hyperthermia, targeted drug delivery and target fishing for solving problems related to systems biology.

Medical device technology and inno vation

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

Implanted medical devices, despite their present important contribution to patients' quality of life, present longstanding challenges *in vivo*. Two key objectives in this field are the development of devices with improved clinical outcome based on molecularly designed materials that support the natural healing process *in vivo*, and biomedical systems that combine resorbable materials with controlled release of pharmaceutical drugs. Both strategies present great opportunities for breakthrough developments in the future, but can only be successfully addressed in consortia with expertise in materials science, biology, pharmacy and medicine.

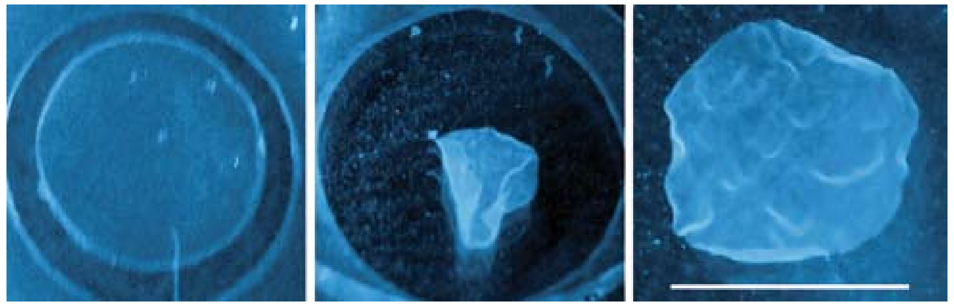


Model neuron system for studying onset of myelination. Three murine Schwann cells expressing fluorescently tagged nucleus (blue), myelin basic protein (red) and actin cytoskeleton (green) are cultured on poly(L-lysine) adsorbed poly(lactic-co-glycolic acid) fibers (white cylinders) for 20 days (CSEM & ETH Zurich).

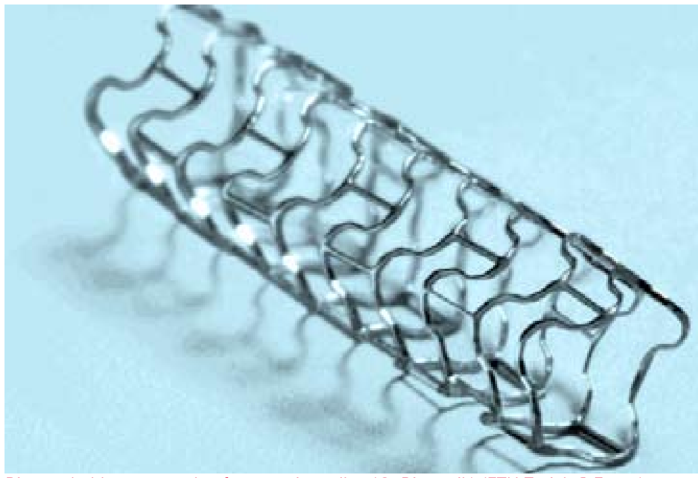
Three projects are currently underway in this thematic area. The first project deals with tissue replacement materials consisting of sheets of autologous cells and biodegradable polymer films. Researchers from ETH Zurich (Prof. J. Vörös), EPFL (Prof. J. A. Hubbell), and University Hospital Zurich (PD 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 will be validated *in vitro* and *in vivo*. The mechanism of electrochemical peeling of cell-sheets has been explored and optimised for different cell types. Polyelectrolyte carrier films have been developed that meet specific requirements for creation of sheets of human multipotent mesenchymal stromal cells. The methodology of using thin fibrin-like polyethylene glycol hydrogels has been established along with the functionalisation of these hydrogel films with cell-adhesive peptides. Moreover, a new method for the bottom-up design of hydrogels has been invented allowing the production of micropatterned thin film hydrogels promoting cell adhesion only at predefined locations.

Prof. Y. Akiyama (right) and O. Guillaume-Gentil at Tokyo's Women Medical University.

Cell sheet engineering is a pioneering discipline of tissue engineering that enables the replacement of thin tissues such as cornea and skin. Conventional methods are based on harvesting a layer of cultured cells of the patient from temperature responsive polymer dishes. This CCMX project focuses on establishing an alternative platform based on thin polymer hydrogels, stem cells, and bioelectronics. Ph.D. student Orane Guillaume-Gentil spent 9 months in Profs. T. Okano and M. Yamato's world leading tissue engineering laboratory at the Tokyo's Women Medical University. She explored the mechanism of the electrochemical peeling in detail. New peeling mechanisms have been discovered based on spontaneous mechanical detachment of cell sheets of various different cells types. These first results have just been published in a top materials research journal, *Advanced Materials*.



Electronically controlled cell sheet recovery: a confluent monolayer of fibroblasts grown on a polyelectrolyte coating (left) is detached once the substrate is subjected to an external potential (middle), allowing for the recovery of an intact cell sheet (right). Bar is 1 cm (ETH Zurich, EPFL & University Hospital Zurich).



Bioresorbable stent made of magnesium alloy (© Biotronik) (ETH Zurich & Empa).

The microstructure of this new bioresorbable magnesium alloy is characterised by a very fine grain size smaller than 10 microns. Such structures lead to very favourable deformation behaviour, resulting in a ductility of more than 30 % elongation to fracture. The alloying content of rare earth elements facilitates the formation of protective surface layers, producing the desired increase of the degradation resistance in physiological media. This close and trustful cooperation between the ETH Domain institutes and Biotronik AG is fruitful in several aspects: it closes the gap between fundamental research and practical application, it inspires the involved researchers and reveals new interesting scientific questions and opens the doors for the employment of ETH Domain Ph.D. students in various fields of medical-oriented industry.

Dr. S. Tosatti of ETH Zurich leads a project aiming to develop a novel class of nanostructured and biofunctionalised materials to be primarily used as implants in cardiovascular interventions. The materials should be completely bioresorbable after a period of around 3-6 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. The newly developed bioresorbable magnesium-based alloy shows exceptional plasticity together with slow and homogeneous degradation in simulated body fluid. The degradation mechanism differs in artificial plasma compared to simulated body fluid. *In vitro* cytotoxicity testing of the new magnesium alloy WZ21 reveals that hydrogen gas is a critical parameter influencing interfacial cell growth.

The third project in this thematic area deals with 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.

Proof of feasibility and optimisation of the electrospinning process for the polysaccharide-based photolinker polymer OptoDex have been shown. The creation of aligned fibres and adaptation of the photolinking protocol is underway. Necessary guidance cues were successfully produced recombinantly and neuronal guidance cues were covalently attached to polyethylene glycol and poly(L-lysine) linkers to improve the immobilisation efficiency on OptoDex surfaces. Using this strategy two different neuronal cues were attached to Optodex: their presence was found to increase the viability of neurones on the coated surfaces.

Trends

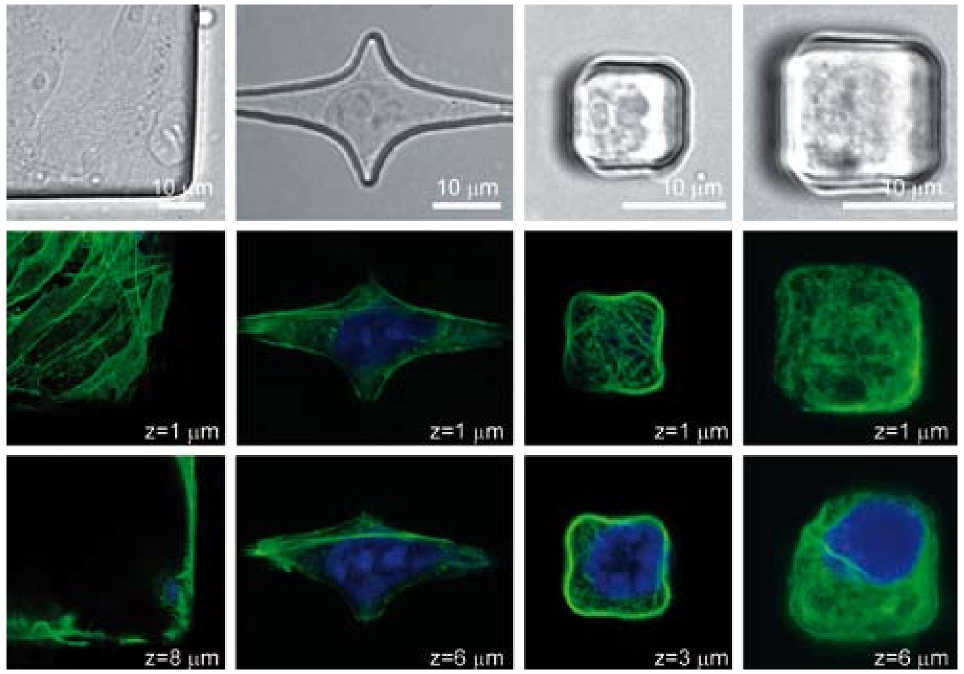
Although medical device technology permeates numerous areas including orthopaedics, dental implants, minimally-invasive surgical devices, cardiovascular surgery, wound healing applications and diagnostic devices, this field still suffers from many interfacial problems such as blood coagulation, infection, complement activation, foreign body reactions, and aseptic loosening. In response, surface modifications were explored to improve these devices with limited success.

This approach still holds promise in many device markets but is not a «one-size-fits-all» solution. The future points to combination devices, i.e. drug releasing components on board functional prosthetic implants, as an emerging clinical technology to improve performance of implant devices in several classes. Infection and sustained inflammatory responses are processes that often severely reduce the success rate of implantations and are the cause of very substantial health care costs. New antimicrobial and anti-inflammatory agents have recently shown promising effects but their effective combination with implants and surfaces requires further development and testing under clinically relevant conditions. New combination devices are most prominent. They consist of current orthopaedic and cardiovascular implants with new added capabilities on-board or directly associated drug delivery systems.

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 effort is directed worldwide towards the development of reliable methods for array fabrication. In particular, integrative engineering approaches are sought by combining enabling technologies and functional design to produce devices with improved performance, reliability, ease of handling and cost-effectiveness.



Live image of endothelial cells expressing fluorescently tagged actin skeleton (green) and nucleus (blue) in Micro-wells arrays (ETH Zurich, Empa, AO Davos and industry partners).

Prof. H. Vogel of EPFL leads 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).

The process enabling the fabrication of silicon chips comprising arrays and single nanopores using focused ion beam (FIB) technique was set-up. The formation of supported lipid bilayers on nanopore patterned substrates was demonstrated while the formation mechanism of supported lipid bilayers for complex and shell-protected liposomes has been explored. Finally poly(L-lysine)-graft-poly(ethylene glycol) selective functionalisation was demonstrated in view of directed liposome adsorption on nano- and microscale topographically structured samples.

Another project intends to prepare immobilised lectins and carbohydrate multivalent assemblies on surfaces using a comprehensive combinatorial approach. The quality and efficiency of glycosylated target binding to the protein receptors will be tested through quantitative and kinetic data. The project involves researchers from ETH Zurich (Prof. P. Seeberger and Dr. G. Coullerez) and Arrayon Biotechnology SA in Neuchâtel. Three terminal sugars of the human chorionic gonadotropin (hCG) protein were synthesised in a good yield and conjugated with a high quantum yield fluorescent marker.

Prof. V. Vogel of ETH Zurich leads the third project of this thematic area. Its ambition 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.

The fabrication of highly reproducible polydimethylsiloxane microwell platforms has been optimised. Endothelial cells could be stably entrapped within microwells and the cells were viable for several days although cell death was increased in very constrained microwells. The structural organisation of the cytoskeleton was studied as a function of the microwell size and of the ability of cells to assemble fibronectin matrix. Moreover immunohistochemical studies confirmed that bone progenitor cells undergo the process of osteogenesis in microwells. Promoter-based reporter constructs to be used as osteo-specific markers have been successfully cloned into constructs in which the expression of the green fluorescent protein (GFP) is now bone development-dependent.

Anne-Kathrin Born and Robert Mathys Jr (managing director of the Foundation).

Anne-Kathrin Born of Empa St. Gallen won the «Dr. Robert Mathys Foundation» poster prize at the European Cells & Materials (ECM) Meeting «Bone Tissue Engineering» in June 2007 for her poster «*Correlating cell architecture with osteogenesis: First steps towards live single cell monitoring*». This work co-authored with M. Rottmar, K. Maniura-Weber and A. Bruinink is part of the project «Studying single cells in engineered 3D microenvironments».

A novel platform is being developed for fabrication of protein arrays by applying a polyhydroxyalkanoates - extracellular PHA depolymerase system. Dr. Q. Ren of Empa coordinates this project. She collaborates with colleagues of PSI (Dr. H. Schift), ETH Zurich (Dr. H.-M. Fischer), Empa (Mr. M. Halbeisen), and with PreenTec AG of Fribourg. The biopolymer polyhydroxylkanoates (PHA) and the extracellular PHA depolymerase (ePhaZ) are explored respectively for protein immobilisation and as a capture ligand for selective immobilisation.

Different types of PHA were prepared from *Pseudomonas putida* GPo1 cells cultivated in bioreactors with different carbon sources. Spin-coating followed by UV initiation to cross-link PHA proves to be the best method for manufacturing PHA films, whereas oil-in-water emulsions provide PHA microbeads of the finest quality. The generation of ePhaZ-fusion proteins has been achieved and the study of the interaction between PHA films/microbeads and ePhaZ is currently underway.

The «Biochemical Nanofactory» project led by Prof. René Salathé of EPFL combines the individual competencies of the four other participating laboratories (Prof. H. Vogel, Prof. Y. Barrandon and Dr. J.-M. Fournier (EPFL) and Dr. H. Knapp (CSEM)) in laser trapping, micro-fluidics and macro/micro interfacing, as well as bio-analytics and smart functionalised surfaces for realising a micro-fluidic demonstrator system, compatible with a light microscope. It comprises several input and output ports for single cell/vesicle analysis within arrays created by multiple laser traps.

Laser tweezers offer the unique opportunity to maintain cells and native vesicles free from interactions with any substrate. The team has recently developed a novel concept for laser trapping in micro-fluidics based on micro-mirror arrays and demonstrated multi-array trapping of individual cells, cell fragments & vesicles in micro-fluidics. They have also demonstrated that individual cells, cell fragments & vesicles can be manipulated in microfluidics and addressed by chemicals thereby activating receptor-mediated cellular signaling reactions which was observed on-line in individual objects. The long-term objective of this project consists in building up the expertise for establishing a low-cost technology and platform allowing ultimate downscaling of chemical and biotechnological analysis (and production) for research and industrial applications.

Trends

Materials engineering for medical and diagnostic (microsensor and microarray) technologies faces a number of exciting challenges. While many materials exist to support cells and biosensing applications, they are often not optimised to allow for sophisticated screening applications, or to better support the vitality of cells or are unsatisfactory when it comes to long term performance as biomaterials, drug delivery systems or as devices with integrated sensory elements. For example, although deoxyribonucleic acid/ribonucleic acid (DNA/RNA) sensors are routinely used today, arrays of proteins and entire signalling complexes require much more sophisticated surface engineering and immobilisation strategies to preserve their biological activity. New technologies are thus being developed through the CCMX MatLife programme that will enable the presentation of large numbers of nucleic acids, peptides, proteins, carbohydrates as well as cells in novel ways. Applications include rapid and highly parallel read-out systems concerning gene expression or protein function. Protein, carbohydrate and cell-arrayed chips are expected to become future key elements in drug discovery/screening and in medical diagnostics.

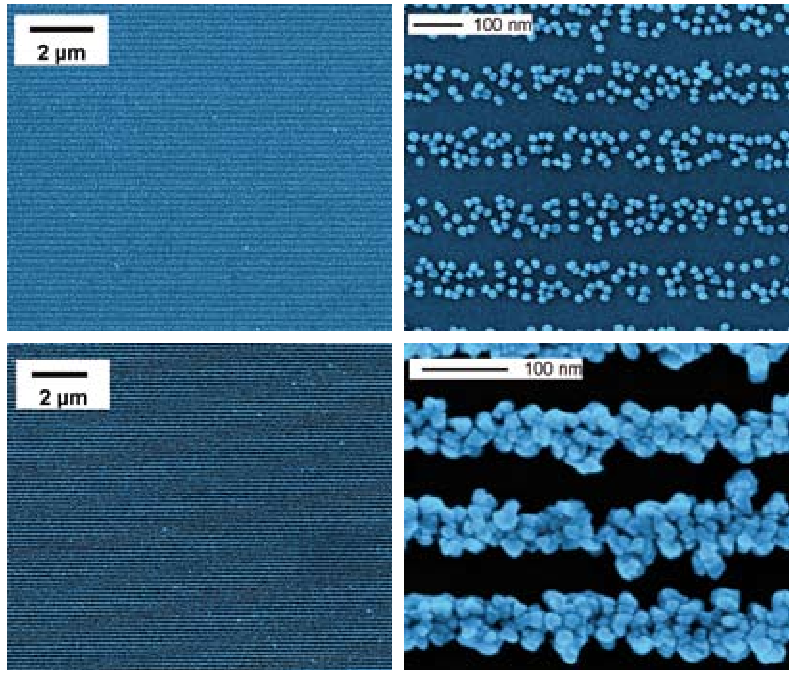
Integrative engineering approaches that combine enabling technologies (either existing or to be developed) and functional design to produce devices including improved performance, reliability, ease of handling and cost-effectiveness will drive future markets. Examples include biosensor systems for analysing proteins and protein-carbohydrate interactions, cell-based sensor platforms with cells in defined microenvironments and label-free sensing based on chip-based membrane proteins. 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.

A concerted effort is needed to explore new materials, fabrication technologies, and design methodologies so that very high-density nanosystems for data storage and computation can be addressed.

Materials technologies and design for micro- and nanosystems

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

The technological and economic feasibility of high-density, large-scale integration of nanoelectronic systems 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 to 15 years. However, we cannot expect to carry on 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.



Nanodot structures and nanolines (after gold enhancement) created with the Extreme UV interference lithography and the molecular assembly patterning by lift-off processes (ETH Zurich & PSI).

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 circuits and systems fully benefiting from 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 Dr. D. Atienza), ETH Zurich (Prof. C. Hierold) and CSEM (Prof. C. Piguet).

The team has witnessed very promising developments in the areas of ferro-electric polymer gate transistors, carbon nanotubes suspended gate devices and silicon-based gate-all-around (GAA) field effect transistors. The concept of a dense crossbar memory/Programmable Logic Array (PLA) which uses the new GAA transistors in address encoding was also developed. Test devices have been successfully manufactured and characterised. Results to be highlighted include the availability of a process flow for the fabrication of suspended single-walled carbon nanotubes structures and the synthesis of two kinds of piezoelectric nanowires ($KNbO_3$ and $Pb(Zr,Ti)O_3$) for sensing and actuation purposes. The ferroelectricity retention of monocrystalline $Pb(Zr,Ti)O_3$ nanowires was confirmed for the first time by temperature variable *in situ* Transmission Electron Microscopy. A high quality ferroelectric gate was integrated on the standard field-effect transistor (FET) structure and showed high and stable switching polarization. The tests carried out attest for good switching properties and long retention of the spontaneous polarization in the ferroelectric gate. Finally the fabrication of long arrays of parallel nanowires was made possible through a newly developed technology.

The project coordinated by Prof. J. Vörös of ETH Zurich and involving researchers from Prof. R. Spolenak's group (ETH Zurich) and Dr. 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 bio-electronics for sensing in microfluidic channels, and for interfacing neurons with artificial synapse mimics.

Efforts focussed on establishing the production of gold nanowires in large scale and selecting the suitable techniques for characterising their performance. A novel extreme UV interference lithography scheme enables the production of large scale gold nanowires with 12 nm line width – a current world record! The mechanical properties of gold nanowires have been measured on arrays created on polyimide providing unique insight into the scaling behaviour of metal nanostructures. Finally a novel platform allows the creation of self-assembled gold nanowires based on DNA-assisted positioning of gold nanoparticles.

Trends

Particular emphasis will be placed on: (i) patterning silicon and other materials to produce nano-scale devices for computation and storage, (ii) the design of, and materials for, integrated micro/nano peripherals that complement the computational/storage →

HRTEM image of the interface between [001] $SrTiO_3$ and substrate and $KNbO_3$ nanowires (EPFL, ETH Zurich & CSEM).

core of systems and provide the interface to its environment. In both cases, focus will be on the properties and processes of the materials to produce computational and sensing devices. The need to create new materials for interfacing the computational nano-environment to both traditional micro-systems and the environment will be emphasized. These technologies will be key to producing effective embedded systems that will become ubiquitously present. At the same time, it is becoming mandatory that such embedded systems be reliable and robust.

On the one hand systems are given control of critical functions (vehicular control, medical control). On the other hand we are confronted with both the downscaling of silicon technologies (beyond the 45 nm node) and the perspective of using new nano-devices that have intrinsically higher failure rates. 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 new techniques have to be compatible with existing constraints for system integration, such as low energy consumption, which were not present in the design of large fault-tolerant systems of the past.

Logic-On-Nanowire: From New Ideas to Reality Check

Ph.D. student Kirsten Moselund from the Micro/Nano-electronic Device Laboratory (LEG2) of EPFL contributed to the development of a versatile top-down silicon nanowire platform, which allows for the fabrication of various novel devices for future ultra-dense logic-on-wire. By combining the resources of technology and device research with the know-how of advanced circuit design from both EPFL Integrated Systems Laboratory and Microelectronics Systems Laboratory, innovative electronic building blocks have been created. They are the first steps towards logic-on-wire and addressing solutions for cross-bar architectures. An extraordinary result recently demonstrated concerns the enhanced (>100 %) electron mobility due to oxidation induced tensile strain in Gate-All-Around bended metal-oxide-semiconductor field-effect transistors (MOSFETs). In an effort to introduce a new candidate device in the research quest for the ideal switch, a punch-through impact-ionization device (PIMOS) on a body-tied W-gate MOS structure was introduced as an additional functionality. PIMOS devices show less-than-10 mV/dec abrupt switching combined with hysteresis in both ID(VDS) and ID(VGS). These outstanding results, all internationally recognised and even cited by the *Nikkei Microdevices Journal* in November 2007, have been obtained within one year.

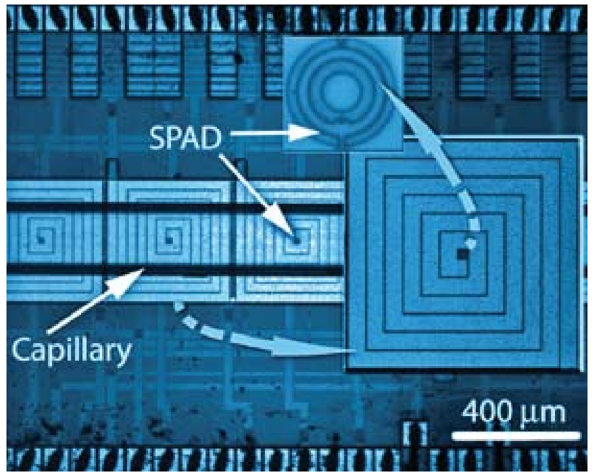
Although microarrays are already highly developed and widely used, they are still far from optimised.

MMNS

Laboratory-on-a-chip

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

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 biochemical 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.



Lab-on-a-chip for analysis and diagnostics (EPFL & CSEM).

Ulrike Lehmann getting her prize in Tokyo.

The poster entitled «Magnetic on-chip DNA extraction in a droplet-based microsystem» presented by Ph.D. student Ulrike Lehmann, and co-authored by C. Vandevyver, V. K. Parashar and M. Gijs won the best poster award at the 10th International Conference on Miniaturized Systems for Chemistry and Life Sciences, (microTAS 2006) held in Tokyo, Japan.

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. F. K. Gürkaynak, 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 complementary metal-oxide-semiconductor (CMOS) system enabling manipulation of magnetic microparticles through a magnetic field and *in situ* optical detection has been realised. Those microparticles have been grafted with polymer brushes with plasmodium lactate dehydrogenase (pLDH) antibodies for detection of the malaria virus. A magnetic transportation system for micro- and nanoparticles with integrated optical detection was also realised on a CMOS chip. Regarding the detection of antibiotics in milk, ppb-level optical detection has been demonstrated. Individual assays have been carried out on the wavelength interrogated optical system (WIOS) chip for various antibiotic families.

A multidetection assay has been successfully achieved for simultaneous detection of fluoroquinolone and sulfonamide. Test measurements «in the field» have been carried out in Nestlé lab facilities, comparing WIOS detection vs. conventional techniques. In the sub-project dedicated to environmental monitoring, a shear-mode acousto-gravimetric resonator based on aluminum nitride thin films and polymer brushes was succesfully processed on top of an acoustic reflector structure. The chemical or biological coupling to the water is mediated by a polymer brush layer that immobilises and accumulates the species to be measured, giving rise to a change in the oscillator frequency of the acoustic structure.

Trends

The development of gene and protein arrays has opened tremendous opportunities for measuring gene/protein expressions over repeated experiments. The scope of applicability of microarrays goes from medical diagnosis to bio-discovery. In particular microarray technology is fit to provide insight into gene regulatory mechanisms and support for fast diagnosis (e.g., infectious disease screening).

Although microarrays are already highly developed and widely used, they are still far from optimised. With respect to protein microarrays, for example, important challenges include the development of robust and generally applicable methods for the covalent immobilisation of proteins with retention of structure and function, and the design of new substrate materials that are not sensitive towards non-specific protein adsorption. In the area of microfluidics, important materials challenges lie in surface structuring and surface chemistry in order to better control and direct fluid flow.

Further research will involve the combination of hardware design using various materials technologies as well as software technologies for processing the measured data, and will link them to other diagnostic or ontological information. A variety of materials should be considered, with particular reference to their compatibility with integrated system technology and the living sample materials to be processed by the lab-on-a-chip.

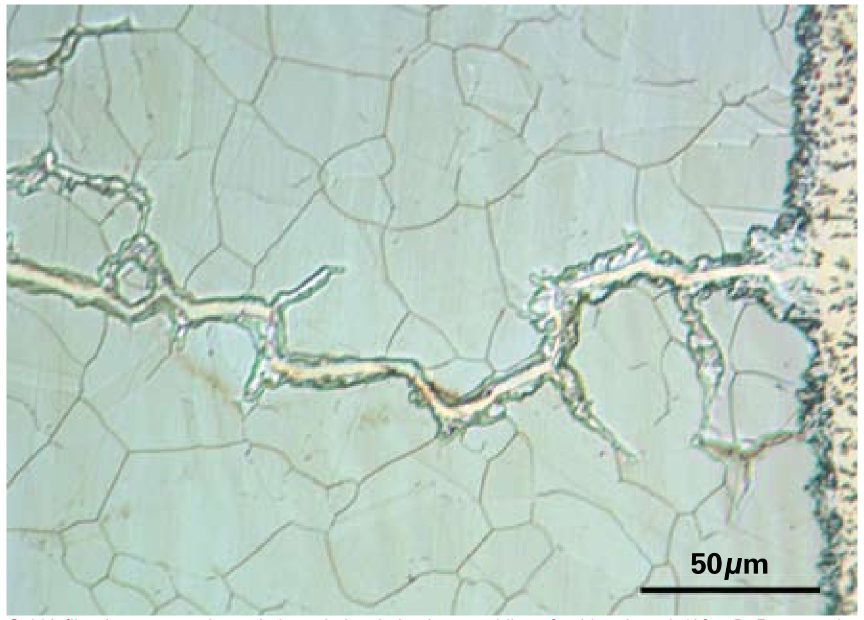
Metallurgy still represents a field of prime importance for the Swiss industry.

MERU

Towards cutting-edge metallurgy

multi-scale modelling | multi-component systems | neo-metallurgy

Although Swiss academia has always had a strong position in metallurgy, it has been somewhat eroded over recent years mainly as a result of a shift of funding and priorities towards new fields such as bio- and nano-materials. However, metallurgy still represents a field of prime importance for our industry.
An in-depth consultation by CCMX of its current and potential industrial partners resulted in a firm and widespread demand for a focussed activity in metallurgy. The Centre has therefore created a new Education and Research Unit (ERU) devoted to metallurgy. The «Metallurgy» ERU (MERU) will foster pre-competitive research projects in leading-edge metallurgy. It will be run in close collaboration with Swiss industrial partners and the research institutes of the ETH Domain.



Gold infiltration at austenite grain boundaries during laser welding of gold and steel. (After D. Favez et al., Intergranular penetration of liquid gold at stainless steel grain boundaries, French Soc. Metal., Paris (2008)).

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

One axis of the MERU proposal is the development of new alloys and processing routes for various applications and the improvement of characterising techniques. Alloy development 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., nano-indentation for mechanical properties or local optical or electrical measurements for functions. This raises then the question of up-scaling properties measured at a very local scale to those of more bulk materials, bringing sometimes fundamental questions when the characteristic length scales associated with the phenomena involved become comparable to that of the specimen or of the measurement technique.

New production or assemblage processes are also required for metallic alloys. For example, new metallic materials such as bulk metallic glasses (BMG) and metallic foams, metal matrix composites (MMC) offer new and quite unique mechanical properties.

Laser welding of dissimilar materials is of great interest for many industries in the watch or medical sectors, but also in the automotive and aeronautic sectors. While the metallurgy of materials A and B are well known, the assemblage of A and B by metallurgical bonds requires a deep understanding of both thermodynamics and processes.

Finally, novel characterising techniques such as *in situ* X-ray radiography or tomography, neutron scattering, orientation imaging using EBSD combined with EDX chemical analyses methods, nano-testing devices, etc, allow to characterise accurately and in depth metallic alloys down to very low scale.

Multi-scale, multi-phenomena modelling of metallic systems

At the same time new alloys are produced and analysed, computer simulation has really become an indispensable tool in metallurgy. For «traditional» metallurgy of standard composition alloys, the effort of researchers is directed towards integrated modelling in order to model, understand, calculate and optimise processing routes as a function of the final desired properties.

Along less traditional ways, multi-scale modelling requires the development of dedicated tools which can encompass nearly 10 orders of magnitude, from the atomistic to the process scale.

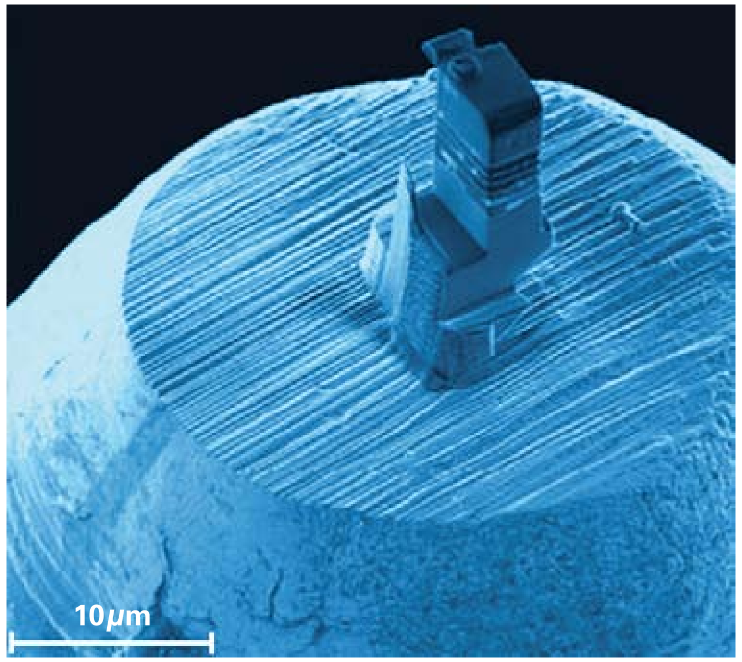
At the scale of a small population of atoms, *ab initio* calculations can be used to model the optical or electrical response of metallic systems, impurity-defect structures for use in Kinetic Monte Carlo and free energy cluster expansion methods. At the scale of a few million atoms, molecular dynamics 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 allow modelling the formation of microstructures and defects for multi-component and multi-phase systems. At a larger scale, granular approaches or cellular automata can take information from the microstructure scale level for the modelling at the scale of a large population of grains (macrostructures).

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

Enabling solutions for materials analysis at the micro- and nanoscale

dynamic mode atomic force microscope (AFM) at cryogenic temperature | scanning anode field emission microscope (SAFEM) | double passage scanning near-field optical microscope (SNOM) | Swiss Scanning Probe User Laboratory (SUL) | mechanical forces exerted at single molecule level | transmission electron microscopy (TEM) | focused ion beam (FIB) | Nano-X-ray absorption spectroscopy (Nano-XAS) | stress voiding and electromigration | SPM of Cytoskeletal Proteins | subattonewton force sensors for magnetic resonance force microscopy (MRFM).

Attention focuses on projects developing new tools for the analysis of physical, chemical or biological properties on the scale below 100 nm and on the use of existing methods for new application fields. The purchase of analytical equipment is supported, provided that the equipment will be made available to potential users of other laboratories within the ETH Domain institutions and CSEM. In addition several projects are supported by CCMX for carrying out series of exploratory experiments using existing equipment. Thanks to this extensive funding strategy, this platform caters for a wide range of demands concerning materials analysis at the nano- and microscale.



Etched fibre tip for the Focused Ion Beam instrument mounted on a Transmission Electron Microscope sample holder (Empa and ETH Zurich).

Characteristics of tuning fork based AFM probes can be now predicted

The numerical model developed during the first year offers lots of prospects in designing different types of tuning fork based AFM probes. Nanoworld AG and Nanosurf AG, respectively commercialising tuning fork based AFM probes and the associated instrumentation, consider this tool as of prime value.

A new generation Scanning Anode Field Emission Microscope replaces the former instrument located at EMPA Thun

This new Scanning Anode Field Emission Microscope allows in-depth analysis of planar field emission cathodes. Along with new hardware equipment, a new control and data analysis software enables novel users to perform effective measurement after only two days of training. In 2007 Dr. O. Gröning (EMPA) agreed to design and build a customised SAFEM for THALES LCR for the development of optically switched electron emitters. CCMX support has been crucial for the development of the SAFEM. Negotiations are currently underway with THALES for further development and use of the new SAFEM at Empa Thun.

The «Nano- and Microscale Materials Characterisation» analytical platform is directed by Prof. Hans Josef Hug. Chiara Corticelli is in charge of industrial liaison. The Management Board comprises Prof. Cécile Hébert (EPFL), Prof. Bruce Patterson (PSI), Prof. Marcus Textor (ETH Zurich), and includes the Management Team. An independent international board of referees advises the analytical platform for strategic decisions.

The projets funded through CCMX in this area are divided into three categories:

- Projects targeting the development of new analytical tools, methods or instrumentation for the analysis of physical, chemical, or biological properties on the scale below 100 nm;
- Projects involving the purchase of analytical instrumentation or components to complete the existing offer of the CCMX affiliated institutions. Matching funds from the home-institution should be provided and further development of the instrumentation should be envisioned after such a project, preferably with an industrial partner;
- 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 industry are preferred. Twelve projects have been funded in 2007, many of which have already led to exciting success stories as revealed in the coming pages.

Development of new Analytical Tools

The project «Development of Self-Sensing and -Actuating Probe for Dynamic Mode AFM at Cryogenic Temperature» led by Prof. N. de Rooij (EPFL) and involving Prof. K. Ensslin (ETH Zurich) focuses on two objectives: the development of a new type of tuning fork probe for the atomic force microscope (AFM) based on a novel probe concept invented in a previous project and the development of an easy interface for mounting the probe onto an AFM platform. The developed tuning fork AFM probe consists of a quartz tuning fork and a cantilever. The objective of the first year was reached as a model of this probe was developed based on two coupled spring-mass systems. The determining parameters are the mass and the spring constant of the cantilever. The behaviour of the quartz tuning fork due to the coupling from the cantilever could therefore be determined. A shift in the resonance frequency of the in-phase peak of the tuning fork occurs as the spring constant of the cantilever increases. This shift reaches a saturation state that should be avoided to achieve reasonable sensitivity in a frequency modulation scheme. The conducted experiments show that this model describes the qualitative behaviour of the system but further development will be required to achieve good quantitative predictions.

A new generation scanning anode field emission microscope (SAFEM) for the inspection of field emission properties of planar cold cathodes is being developed in a project carried out by Dr. O. Gröning (EMPA). The instrument will set new standards in the field of cold cathode characterisation with regard to spatial resolution (which in most measurement of planar field emission cathode is neglected). At this stage the main hardware design and bulk of the operation software has been developed and appropriate suppliers have been identified. The core of the SAFEM - the high precision UHV translation stages - is being manufactured by MICOS in Germany and will be delivered in the first semester of 2008. A key feature of the new SAFEM will be its userfriendliness making it possible for external research groups to carry out routine cold cathode characterisation.

Prof. U. Sennhauser (EMPA) and Prof. C. Hafner (ETH Zurich) are developing a new «double-passage» scanning near-field optical microscope (SNOM) that should show higher resolution than the «single-passage» SNOM thanks to a novel structuring of the tip cladding. A scanning probe microscope (SPM) set-up suitable for various SNOM configurations has been designed and built; it will soon be operational. The basic scanning functionality is effective and will be optimised. The possibilities to modify optical fibre SNOM tips with focused ion beam (FIB) have been investigated and simple structures on fibre tips have been produced. As commercial tips are not suitable, an etching process has already been set up but the obtained tip shape and surface quality will be further improved.

A novel type of scanning X-ray microscope is being developed by Dr. I. Schmid (Empa) who has teamed up with Dr. J. Raabe and Dr. C. Quitmann (PSI). This instrument will combine the chemical specificity of X-ray absorption spectroscopy with the spatial resolution (< 5nm) of a scanning force microscope. This instrument should significantly impact nanotechnology, material science and even industrial applications (i.e. semiconductor industry).

Beamtime allocated to Nano-X-ray Absorption Spectroscopy increases by a factor of 10

The on-going development of the Nano-X-ray absorption spectroscopy (Nano-XAS), thanks to a CCMX funding of 270 kCHF and substantial funding from PSI and Empa, has triggered the interest of industry and other academic institutions. This has fetched further funding (over 1 million CHF) for the installation of a beamline exclusively dedicated to this instrument. The beamtime allocated to the Nano-XAS has now increased by a factor of 10.

The conceptual design of the instrument was achieved already in March while the fabrication and assembly has been going on since August 2007.

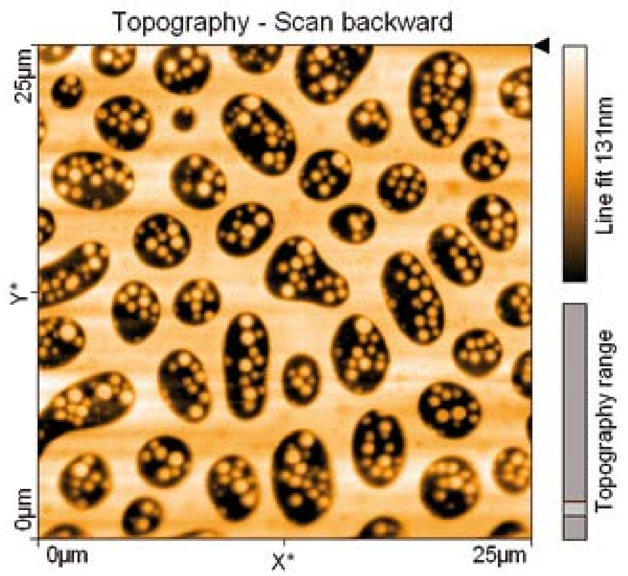
Providing new components to existing facilities

The five multi-purpose microscopes of the Swiss Scanning Probe User Laboratory (SUL) project led by Dr. R. Crockett (Empa) will be made available to industrial users →

Enabling solutions for materials analysis at the micro- and nanoscale

The Swiss Scanning Probe User Laboratory (SUL) has already helped solve crucial scientific questions

Several scientific projects already started during the establishment of the SUL. Access to the scanning force microscopy facilities has been critical for providing a better understanding of key scientific questions. Majority of these collaborations include laboratories of Empa, ETH Zurich and University of Basel.



AFM image of the phase morphology of a polythiophene/polystyrene mixture spin-coated from chlorobenzene after removal of polystyrene in hexane (Empa).

Empa and ETH Zurich extend their knowledge in preparation of TEM-specimens with minimised defects by focused ion beam

High resolution transmission electrron microscopy and electron energy loss spectroscopy (EELS) usually set very stringent requirements on the sample lamellae in terms of thickness and control of thickness, parallel sidewalls, and layer dammage. AMORTEM has allowed for an in-depth analysis of TEM lamellae fabrication using focused ion beam (FIB) and to quantify its advantages over other fabrication methods. Thanks to this project it is now possible to significantly reduce the thickness of the damaged or amorphous zones, even for very sensitive materials which cannot be prepared by other techniques but FIB. These results have been achieved through a fruitful collaboration between the laboratory for Electronics and Metrology and the laboratory for High Performance Ceramics of Empa and the Centre for Electron Microscopy at ETH Zurich. All involved groups could broaden their know-how and optimise their processes.

and to academic institutions for service measurements and for education and technical training courses. It is a unique facility in Switzerland. CCMX and Empa are joining forces to purchase three scanning force microscopes while another instrument is being constructed by the Empa Laboratory for Nanoscale Materials Science and NanoScan AG. This fourth instrument, a «physical property measurement system» scanning force microscope (PPMS-SFM), is expected to be operational by summer 2008.

Dr. B. Hinz (EPFL) investigates cytoskeletal proteins in living cells using scanning probe microscopy. These cells generate fibrosis of liver, heart, kidney and lung in response to mechanical stress. Targeting their molecular stress-detectors offers novel strategies to develop anti-fibrotic therapies. The aim of the project is to determine how mechanical forces, exerted on the single molecule level, control the development and function of contractile connective tissue cells. With CCMX support a life science atomic force microscope (AFM) could be acquired. This instrument significantly contributed to the disclosure that fibrogenic cells *de novo* form specialised contacts that intercellularly coordinate their destructive contractile activity. The mechanical stability of these contacts could be attributed to the high adhesion of specific transmembrane proteins on the single molecule level as inhibition of these proteins reduces contraction of tissue-like matrix. In a second publication, a novel mechanism of how fibrogenic cells activate growth factors from their surrounding extracellular matrix was described. These cells use specific cell-matrix receptors to literally pull on the biologically inactive growth factor. The mechanical force then liberates the active cytokine which feeds back on the cell to maintain its fibrogenic character. Again, by blocking the specific matrix receptor the vicious cycle leading to fibrosis could be interrupted.

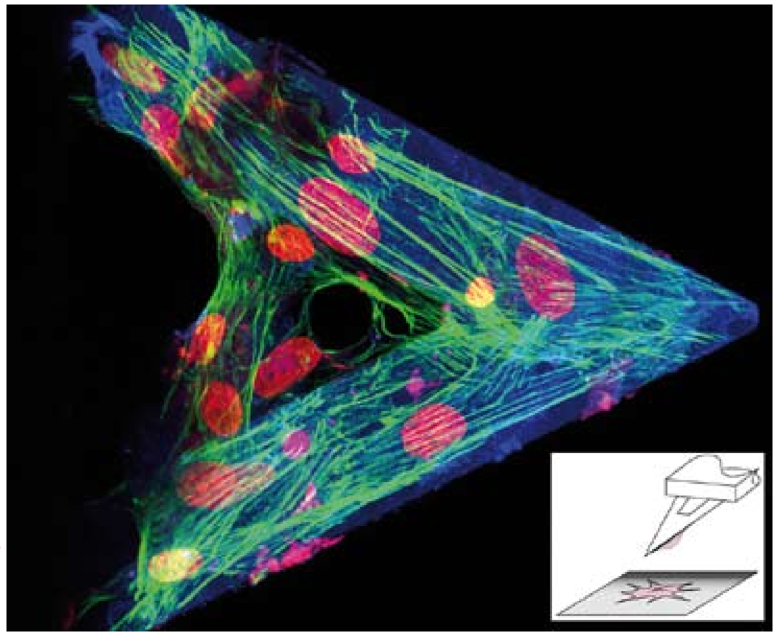
Using existing facilities to explore new analytical techniques

Dr. U. Sennhauser and Dr. S Liebert-Winter of Empa investigate weak mode failures in semiconductor devices using 3D transmission electron microscopy together with NXP Semiconductors Zurich. The TEM analysis of a sample which had failed during the electromigration stress test showed seven kinds of defects : (1) low k dielectric material with stress reliefs which are not caused by the TEM imaging, (2) porousity of the tantalum barrier, (3) migration of copper through the tantalum barrier down to the copper line below which caused an electric short, (4) accumulation of copper and (5) corresponding depletion area, (6) stress relief in the copper line below the stressed via and (7) cracks and/ or stress relief in the copper line above the stressed via. Before now no information about the thermal stress of copper lines and the low k dielectric material around the stressed via was available. Also the porosity of the tantalum barrier could be observed for the first time.

The project led by Dr. S. Rast (University of Basel) in collaboration with Dr. U. Sennhauser (Empa) aims to shrink the dimension of a micrometer sized magnetic particle attached to an ultrasensitive force sensor in order to achieve highest possible magnetic field gradient. The dimension of a micrometer sized hard magnetic tip, glued on a force sensor with attonewton sensitivity was shrinked to the nm regime with the focused ion beam (FIB). The magnetic and dissipative properties of individual hard magnetic particles were investigated with cantilever magnetometry. It turns out that the milling process with Ga+ ions does not significantly affect the magnetic properties of the tip, if the pristine tip has already excellent magnetic properties. The magnetocrystalline anisotropy energy and coercitive field of the nanometer sized particles are in good agreement with bulk values. Since the magnetic properties remain unchanged at small dimensions, far higher field gradients can be reached (10-100 G/nm). The dissipation of the magnet in the external magnetic field is comparable to the internal friction of the ultrasensitive cantilever. These values are exceeded by non-contact friction at tip sample separations below 10 nm.

The «AMORTEM» project aims to minimise the damage induced by focused ion beam (FIB) irradiation to sensitive materials for high resolution analysis by transmission electron microscopy (TEM). A reduction of the thickness of the amorphous layers on each side of the TEM lamellae allows for better quality high resolution TEM micrographs for material analysis. This project is carried out by Dr. U. Sennhauser (Empa) in collaboration with Dr. T. Graule (Empa) and Dr. E. Müller (ETH Zurich). Two methods were compared to each other and to reference TEM lamellae. The first method uses low energy (7 keV instead of the usual 30 keV) FIB irradiation while the other applies very low energy (<2 keV) broad ion beam irradiation in a separate machine. Both techniques enabled lower thickness of the damaged layers; however the best results were obtained using the broad ion beam milling machine evaluated and acquired during the AMORTEM project. Visibility of the crystalline structure is improved as showed by high resolution TEM microscopy.

Fibrotic cells grown on the force probe cantilever (blue) of an atomic force microscope (AFM) develop contractile fibers (green). Touching AFM- and glass-cultured cells (inset) induces formation of cell-to-cell contacts whose strength is measured with the AFM on the single molecule level (EPFL).



Wound healing cells unlock a growth factor via a purely mechanical process

The novel finding that cell-derived molecular forces directly activate a growth factor attracted the interest of Biologists and Clinicians. Pierre-Jean Wipff of the EPFL Laboratory of Cell Biophysics received the Young Investigators award of the European Society of Tissue Repair for the presentation of this work in September 2007. Its publication in the prestigious *Journal of Cell Biology* (December 17, 2007) was rated 'Exceptional' by the 'Faculty of 1000 medicine'. The critical matrix stiffness for mechanical growth factor activation and refined novel 'soft' polymer coatings for culture substrates were determined using the atomic force microscope. These coatings can be produced in any softness relevant for tissues of the human body and can be applied to all standard culture vessels. Cells grown on these coatings feel 'at home' and behave appropriately. A business idea to commercialise the substrates and named HelvaLab has just been awarded by Venture08 among 222 applicants. The life science atomic force microscope, acquired through support from CCMX, helped substantially to determine the polymer substrate stiffness on the cell-detection level.

Trends

One key task in the near future is to catalogue the analytical ressources available for characterising materials at the nano- and microscale within ETH Domain institutions and subsequently provide a single entry point to industry. The CCMX analytical platform will therefore emphasise the coordination of facilities currently on offer in the partner institutions. Educational training will be offered in specific areas of micro-/nanoscale analysis.
New analytical instrumentation will continue to be developed, with a clear accent on responding to the needs of CCMX researchers involved in pre-competitive research projects. Information exchange with the Education and Research Units will thus be strenghtened.

Funding of rapid analytical projects will be expanded. Such projects facilitate inter-institutional use of analytical equipment available within the ETH Domain or support the development of test experiments between an ETH Domain group and an industrial partner provided that a sufficient distinction from conventional service measurements is documented.

Education and training activities

Education initiatives are one of the fundamental priorities of the Centre. Initiatives on continuing education were started by the ERUs in 2007 and will continue in the coming years. These education initiatives have also proved to be good opportunities for the participants to network and to exchange with other persons from industry and academia.

SPERU Annual Course.

MMNS organised a **workshop** in relation to the CCMX funded project entitled «Materials, Devices and Design Technologies for Nano-electronic Systems Beyond Ultimately Scaled CMOS» in July at EPFL. It attracted 60 participants, 90% of whom were from academia. Five prominent scientists gave two back-to-back lectures; the first one was an overview of the subject, while the second one provided a more detailed insight. The aim of the workshop was to present the audience with the possible implications of emerging nanotechnologies and the exciting opportunities they may hold for academia and for the industry.

The MatLife **Tutorial Type Workshop** on high-priority areas of materials for the life sciences such as materials in biosensors, tissue engineering and carrier systems for targeted drug delivery was given by leaders of the field and held in combination with the BIOSURF VII conference in August. This workshop was specifically devoted to the science of functional interfaces directing biological response. The 128 participants consisting of engineers, chemists, biologists and clinicians working on interdisciplinary approaches originated both from academic institutions (85%) and industry (15%) from Switzerland, Europe and overseas.

The first SPERU **Annual Course** focussing on the processing and characterisation of particles and thin films was held over four days at the end of 2007 in Lucern. The course was given by experts from Empa, EPFL, ETH Zurich and CSEM who encouraged direct interactions with the participants. 37% of the 38 participants originated from the specialty chemicals, pharmaceuticals, sensors and watch industries. Constructive remarks were collected ensuring that the 2008 course can correspond even better to the audience's needs.

The pilot phase of a joint **EPFL/ETHZ Master Orientation on Molecular Bioengineering/ Biomaterials** was initiated in the 2007-2008 academic year. Student mobility is financed at the level of the Centre. If successful, the programme will be reinforced for the following academic year.

CCMX's **Master Support Programme** provided partial financial support to seven master students from abroad to support their master theses within CCMX funded projects, the programme will continue in 2008.

Outreach activities

A number of events took place in 2007. These outreach activities organised by the ERUs and the platform are supporting CCMX in its aim to reshape the landscape of Swiss materials science. In 2007, industry liaison activities focused on three priorities: formulate an attractive offer to industry for new pre-competitive projects; develop joint visions with contacts from Swiss industry and create focussed joint academia-industry activity groups.

CCMX Annual Meeting (left) and BIOSURF VII Conference (right).

Following the survey that was carried out by CCMX on «The demands of the Swiss industry in materials R&D : challenges and opportunities» a **workshop** was organised in Bern in January to present and discuss the results and the outcome of the survey. More than 25 people from industry attended together with the representatives of CCMX and its ERUs and platform. The creation of a new ERU on metallurgy (MERU) was the direct response to the needs that transpired from the survey and the workshop. SPERU organised its own workshop in April in Olten following discussions that had initiated at the Bern workshop. The main topic was to discuss and define SPERU's future thematic areas together with 12 participants from industry.

The first **Annual Meeting** of CCMX took place in Fribourg in March. This represented a good opportunity for the 250 participants from industry and academia to network and to be introduced to CCMX's activities. Ongoing projects were presented and possibilities for collaboration were discussed.

The first SPERU **Technology Aperitif** targeting the watch industry and held in July in Lausanne attracted more than 30 participants who learnt about the latest performances of materials of all classes from a panel of speakers from EPFL, ETH Zurich and CSEM.

MatLife participated in the European Science Foundation (ESF-EMBO) **Conference** on «Biological Surfaces and Interfaces» that was held in July in Spain. CCMX was presented overall and focus was given to MatLife activities. The conference programme was divided into 6 sessions with 25 invited speakers.

The BIOSURF VII **Conference** held in Zurich in August and organised by MatLife was a great success with 27 international speakers from academia and industry, 245 participants from 17 countries and 132 poster presentations.

In September, CCMX presented its activities on a $24\,m^2$ stand at the **NanoEurope fair** in St-Gallen. A total of approximately 3'500 visitors was recorded over the three days of trade show and conferences.

The MERU **Metallurgy Day** in September defined industrial needs in metallurgy R&D and provided an overview of the competencies and equipment available at institutions of the ETH Domain and CSEM. Attendance exceeded expectations, with 25 representatives from Swiss industry.

Perspectives for 2008

What to know about Club CCMX

Benefits included in Club CCMX comprise an invitation to the «Science & Networking Days» of the ERUs and platform, four person-days attendance to CCMX-wide educational activities, free attendance to all events (workshops and technology aperitifs, CCMX annual meeting).

The Science & Networking days organised by the ERU and the platform are a «one-stop» access to new knowledge in targeted fields of activity, the opportunity to establish personal contacts with young scientists and to network with researchers and potential customers.

For more information on Club CCMX, please see the separate brochure dedicated to the Club or contact CCMX directly.

Research

The CCMX steering committee agreed to continue funding 15 of the current flagship projects following the requests for continuation and the excellent results that were shown. These projects will be running into 2008 and 2009.

A new call for proposals was launched at the end of 2007. 22 outline proposals were received in October 2007 and 15 full proposals were finally submitted in January 2008. At the moment of the writing of this report the projects are being evaluated and the process will allow for new projects to be funded as of April 2008. These projects will be funded according to the new CCMX rule requiring matching funds from the industry.

The analytical platform (NMMC) will carry out a project entitled "Evaluation of the analytical instrumentation within the ETH Domain". The goal of this **survey** is to establish the situation of Analytical Instrumentation in the ETH Domain. It will lead to the creation of an analytical portal on the CCMX website.

Education and training

Education activities planned for 2008 include the SPERU **Annual Course** shaped for industry researchers which will take place end of October in Lucern.

The **MatLife Travelling Lab Workshop (TLab)** will provide academic and industrial participants hand-on experience with new functional materials and systems in a clinical and industrial perspective.

A **workshop** on Nanoanalytics organised by the platform (NMMC) will take place in June at Empa. The workshop will mainly target participants from the industry but will also be open to academic participants.

The MMNS **Summer School** on "Nano-electronic circuits and tools" will take place in July at EPFL, Lausanne. This mini-course targets essentially PhD students.

The **master thesis support programme** will be continued in 2008 and will encourage more undergraduate students from top foreign universities to obtain their master thesis within a CCMX funded project.

For a full list of education and training activities, please visit the CCMX website (www.ccmx.ch).

Industrial liaison and outreach activities

A common industrial liaison model will be applied as of 2008 by all ERUs. It addresses both large and small companies who can either purchase *"research"* tickets for participation in research projects and for playing a role in the decisions made in the selected thematic area, or join Club CCMX giving them access to education and networking activities (see «What to know about Club CCMX» above). Company contribution to research tickets may comprise an in-kind contribution together with a cash contribution. Matching funds will be provided by CCMX once research tickets are purchased by a company.

The industry outreach activities that are planned for 2008 include the ERUs and platform Science & Networking Days which will bring together industry researchers with the academic researchers involved in the ERU/platform projects. These events will be exclusively open to Club CCMX members and to industrial partners.

MatLife will be associated to several conferences including the Gordon Research Conference (GRC) on Biointerface Science that will take place in Aussois, France in September 2008 and the 3rd International Workshop on Single Cell Analysis taking place in September in Zurich

The ERUs and the platform will be organising several Technology Aperitifs. These 5-to-7 events aim at bringing the research activities closer to industry and thus generating creative ideas for new applications. The first SPERU/ MatLife joint Technological Aperitif is planned to take place in June in Basel to foster the contacts between the pharmaceutical and biotechnology industries and the academic institutions.

2007 Data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Use of funding in 2007 per ERU/platform, in kCHF

SPERU	MatLife	MMNS	NMMC	Centre	Total
1'412	1'670	1'811	556	336	**5'785**

Leverage of projects funded by CCMX in 2007

	SPERU	MatLife	MMNS	NMMC	Total
Number of projects funded	4	8	4	11	**27**
Personnel funded by CCMX (FTE)*	12.71	19.05	18.28	2.15	**52.2**
Personnel support provided by partners (FTE)*	3.4	4.31	3.4	1.6	**12.7**

* *FTE = full-time equivalent positions (status on 31st December 2007).*

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Projects funded in 2007

Title of project	Principal Investigator	PI's Institution	ERU/Platform
Development of novel methods for surface modification and investigation of cell-particles interaction for superparamagnetic nanoparticles (PAPAMOD)	Philippe Renaud	EPFL	SPERU
Nanocrystalline ceramic thin film coating without sintering (NANCER)	Jennifer Rupp	ETH Zurich	SPERU
Smart functional foams	Ludwig Gauckler	ETH Zurich	SPERU
Zero order nano optical pigments (ZONOP)	Alexander Stuck	CSEM	SPERU
Photochemically functionalizable scaffolds for Tissue Engineering and Nerve Regeneration	Christian Hinderling & Martha Liley	CSEM	MatLife
Immunofunctional Nanoparticles	Jeffrey Hubbell	EPFL	MatLife
Multivalent Lectin Array: A Combinatorial Approach	Peter Seeberger	ETH Zurich	MatLife
Bio-functionalized, biodegradable nanostructured magnesium implant for biomedical applications	Samuele Tosatti	ETH Zurich	MatLife
Three-Dimensionally Designed Cell Cultures Consisting of Microstructured Cell-Sheets and Polymer Layers for Tissue Engineering	Janos Vörös	ETH Zurich	MatLife
Platform for high-density parallel screening of membrane receptor function	Horst Vogel	EPFL	MatLife
Studying Single Cells in Engineered 3D Microenvironments	Viola Vogel	ETH Zurich	MatLife
Biopolymer PHA as surface material for micropatterning proteins on microarrays	Qun Ren	Empa	MatLife
Lab-on-a-chip for analysis and diagnostics	Martin Gijs	EPFL	MMNS
Materials, devices and design technologies for nanoelectronic systems beyond ultimately scaled CMOS	Yusuf Leblebici	EPFL	MMNS
Development and characterization of nanowires for applications in bio-electronics	Janos Vörös	ETH Zurich	MMNS
Biochemical nanofactory	René-Paul Salathé	EPFL	MMNS
Development of Self-Sensing and -Actuating Probe for Dynamic Mode AFM at Cryogenic Temperature	Nico De Rooij	EPFL	NMMC
New Generation Scanning Anode Field Emission Microscope at EMPA Thun	Oliver Gröning	Empa	NMMC
Nano-XAS	Iris Schmid	Empa	NMMC
Efficient double-passage SNOMs	Urs Sennhauser	Empa	NMMC
Correlated Energy Electron Loss and Cathodoluminescene spectrometry in SPTEM	Pierre Stadelmann	EPFL	NMMC
Scanning Probe Microscopy of Cytoskeletal Proteins in Living Cells	Boris Hinz	EPFL	NMMC
Swiss SPM User laboratory	Rowena Crockett	Empa	NMMC
Nanometric level investigations of Aluminum Nitride/Silicon Nitride hard coatings using High Resolution TEM and Energy Dispersive X-Ray analysis	Jörg Patscheider	Empa	NMMC
Subattonewton force sensors with hard magnetic tips for magnetic resonance force microscopy	Simon Rast	Uni. Basel	NMMC
Stress voiding and electromigration as reliability indicator in nanoscaled interconnects	Urs Sennhauser	Empa	NMMC
AMORTEM:FIB Preparation of TEM-Specimens with Minimized Defects	Urs Sennhauser	Empa	NMMC

Who is CCMX

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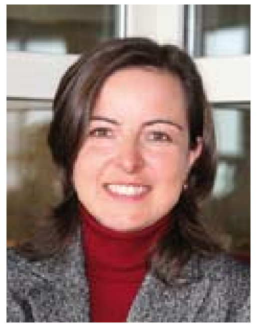

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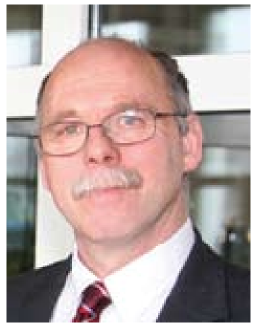
SPERU Surface, coatings and particles engineering



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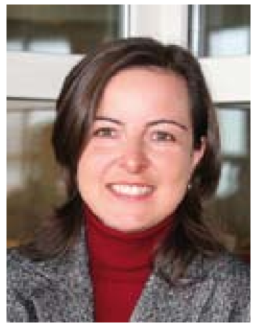

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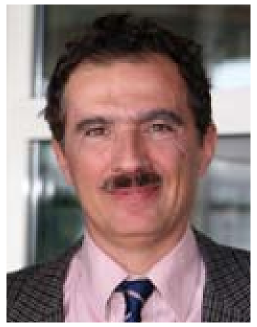
Who is CCMX

MMNS Materials for micro- and nanosystems



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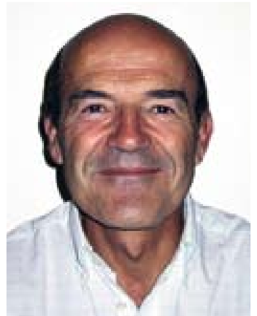
MERU Metallurgy



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NMMC Nano- and microscale materials characterisation for industry and academia

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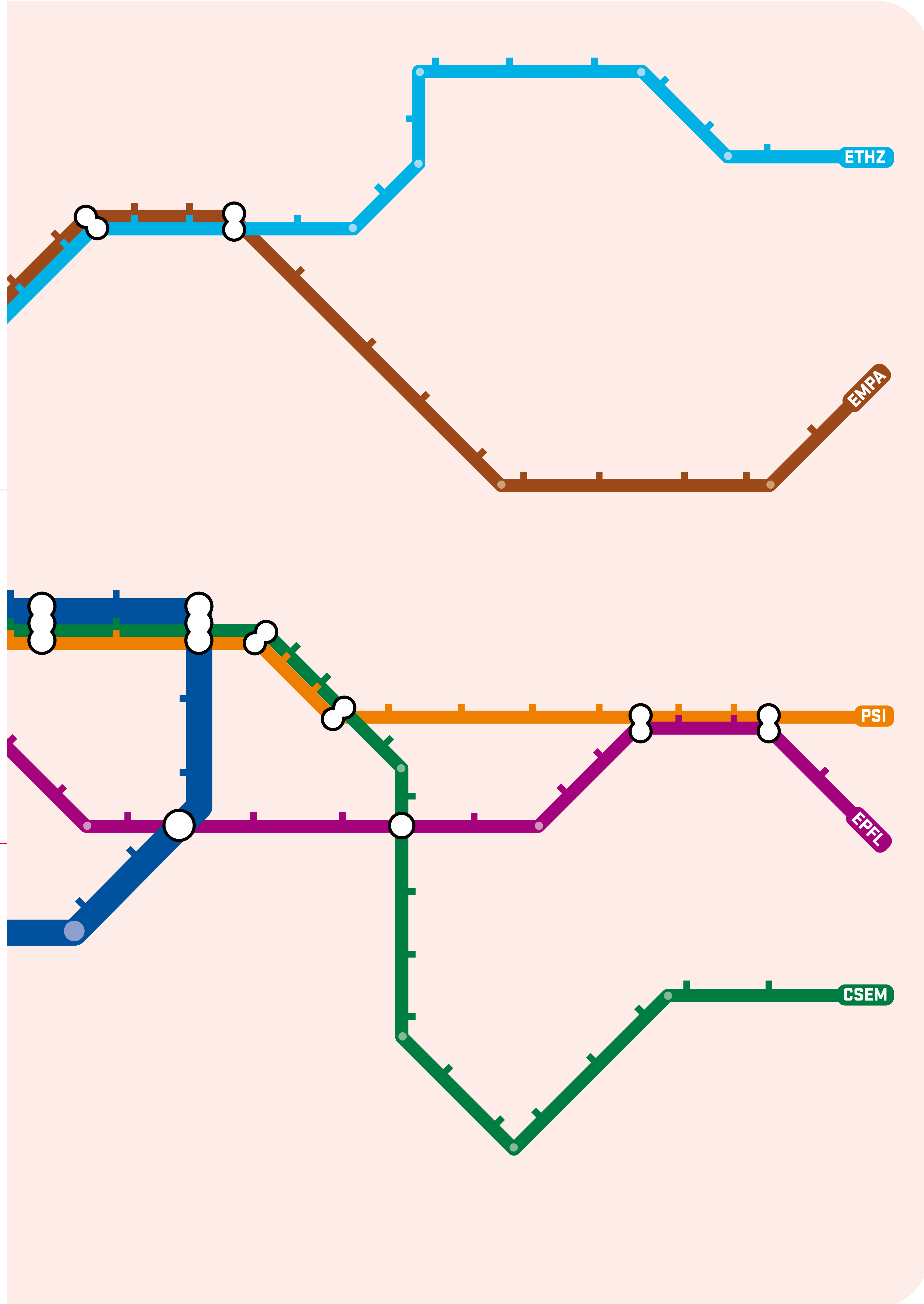

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