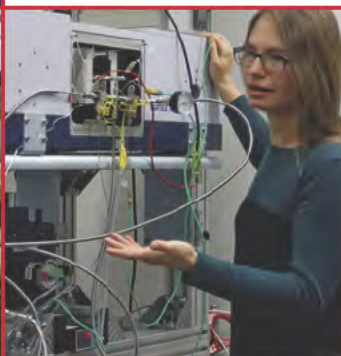


# Annual Activity Report 2014





# Annual Activity Report 2014

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# CCMX: Collaborate to Innovate, Invest for the



PHOTOS: MATHIE JONGEN, TONY KUENZ

## CCMX catalyses cross-disciplinary collaboration and competence

Over the past nine years, CCMX has fostered greater collaboration between Swiss research institutions and industry. The Public Private Partnership (PPP) model has become a proven alternative for funding pre-competitive materials science in a pragmatic and productive way. This unique approach permits multiple companies to cooperate in addressing scientific questions in the same topic area. It also enables a much broader scope of research to be realised with increased efficiency.

The PPP approach has been widely beneficial to the ETH Domain and industry partners—numerous offshoot projects have already brought a substantial return on investment, with funding from a broad range of Swiss and international sources.

Cross-disciplinary collaboration is a core value at every level of the Centre's activity—from funding to training to networking. Academic and industry partners acknowledge their interaction has become critical for innovation. Having established a framework that can address Swiss industry's scientific needs, CCMX has turned its focus on sustaining connections between industry and academia. The Centre continues implementing its tandem strategy for supporting materials research over the long-term by promoting negotiations for Materials Challenges and by co-funding new professor chairs.

Materials Challenges foster durable, innovative, and continuing collaboration between ETH Domain researchers and industry partners. Two Challenges were approved in 2014, a third one is close to finalisation, and others are in discussion.

An ongoing open Call for Proposals encourages proposals responding to these criteria:

- Focusing on scientific questions critical to industry in areas of durable interest currently lacking in adequately trained personnel
- Promoting interactions among CCMX's institutional partners
- Training activities for academic and industry partners
- Elaborating a strategy to ensure self-sustainability beyond CCMX's seed funding

So far, the Call has generated institutional and industry interest, with several inquiries from potential applicants. CCMX is optimistic that its intention of funding six Challenges will be realised.

The three professors appointed in 2013 saw significant progress in 2014. Having organised their respective research facilities, they are actively engaged in exciting and collaborative work. Their on-going contributions to CCMX networking and training events have been invaluable. The final CCMX co-funded professor will be selected by ETH Zurich in 2015.



# Future and Train for Life

PHOTOS TONY KUNZ



CCMX is a very wide platform and this expands your field of vision. When you look out to the sides, you can have interesting things showing up.

Olivier Martin, Professor, EPFL



Use of funding in 2014 (kCHF)	
Funding of research	3'579
Education activities, conferences, industrial liaison	112
Management & administration	362
Total	4'053

Three new projects supported by the CCMX Analytical Platform began in 2014 at ETH Zurich, Empa and PSI. They encompass substantial development of and installation of cutting-edge characterisation methods and analytical tools. These projects contribute to durable improvements in the ETH Domain's materials science-related analytical facilities, meeting these four criteria:

- Uniqueness and cutting-edge scientific value
- Accessibility
- Sustainability
- Leverage

A fourth proposal, approved in December 2013, to install a novel materials analytical tool will be funded once matching funds have been confirmed.

With the Materials Challenges research initiative, the co-funding of new professors, and a programme of well-attended training and outreach events, CCMX continues to advance materials science in Switzerland through productive and innovative partnerships between academia and industry.

# CCMX Education and Outreach Activities

What's important about CCMX courses is that people, from Doctoral students to people in industry, have an opportunity to complement the basic knowledge they have with more specialised, state-of-the-art expertise from a variety of domains.

Karen Scrivener, Professor, EPFL

Education is a key element of CCMX's mission. Since 2006, a variety of advanced training events have attracted nearly 1'200 participants. Combining state-of-the-art topics with hands-on experience, CCMX courses offer relevant skills and real-world application. Interdisciplinary interactions allow participants to benefit from shared experiences and differing perspectives. Courses are both intensive and comprehensive, enabling participants to put their new skills immediately to use.

CCMX's educational programme will be aligned with the Materials Challenges as they evolve, contributing to curriculum development and to opportunities for Master and PhD students to intensify their training through practical application.



PHOTOS: NATHALIE JONGEN, TONY KUNZ

## CCMX Education and Outreach Activities in 2014

2–7	February	Winter School, Surface Science and Coatings	Kandersteg
8	May	Annual Meeting	Kursaal, Bern
22	May	Metallurgy Day	Bern
2–4	June	Advanced Course, Powder Characterisation and Dispersion	EPFL, Lausanne
5	June	Technology Aperitif: New Perspectives on Magnetic Sensors Organised with new ETH Zurich professor Pietro Gambardella	ETH Zurich
1–3	September	Summer School, Atomistic Modelling of Materials	EPFL, Lausanne
2	October	Innovative Smart Materials Networking Conference Jointly organised with State Secretariat for Education, Research and Innovation (SERI)	EPFL, Lausanne
9	October	Technology Aperitif, How safe is safe enough? Translating Nanoscience to applications Organised with Materials Challenge NanoScreen	Empa, St. Gallen
3–7	November	Advanced Course, Combining Structural and Analytical Investigations of Matter at the Micro-, Nano and Atomic Scale	ETH Zurich
3	November	Technology Aperitif, Exploring Matter down to the Atomic Scale	ETH Zurich
26–28	November	Advanced Course, Advanced X-ray Diffraction Methods for Coatings: Strain, Defects and Deformation Analysis of Thin Films	Empa, Dübendorf

## CCMX creates an enduring network through training and outreach activities



### Events

CCMX Technology Aperitifs provide an informal networking environment that enables contacts for potential partnerships. These events feature concise presentations on current trends by academic researchers and associated companies. Discussions after the presentations, frequently initiate collaboration.

CCMX has organised eight annual meetings since 2007. These meetings feature presentations from industry and institutional partners, and regularly attract around 100 participants. The always lively and dynamic poster session allows industry participants to engage directly with CCMX project researchers.

Creating networking opportunities is an important component of CCMX's educational and outreach activities. Participants continually cite networking as a valuable feature. Designed to bring industry and academic researchers together in both structured and informal ways, the Centre's events introduce companies to research potential within the ETH Domain, while sensitising academic researchers to industry's current needs. To date, CCMX's outreach events have attracted more than 2'200 participants.

### Outreach

The monthly e-newsletter, distributed to 1'500 subscribers, is an effective and cost-efficient channel for promoting training and outreach activities, for sharing news and success stories from project researchers, for publishing profiles on researchers involved in current projects, and for publicising materials science-related activities at our partner institutions.

The website is also a means of publishing relevant news items, providing a more in-depth guide to research activities, explaining the structure of funding and performing research within the Public Private Partnership (PPP) framework, listing current projects with detailed descriptions available for download, and providing links to project research labs and facilities, as well as to partner institutions.



*"I really loved the interactions. You ask a question and suddenly everyone starts talking about it, and ideas are fusing and evolving from everywhere. The discussions were so dynamic and far-reaching."*

*Instructor, CCMX Winter School*

*"I really enjoyed talking with professors about my own work. This was possible thanks to the limited number of participants and contact with the speakers during lunch time, socialising events and the poster session."*

*Participant, CCMX Summer School*

*"It's not always easy to find interesting courses for PhD students. Some are either too specific or too superficial. More CCMX course offerings would be great because it's a bonus getting to know researchers from all over Switzerland!"*

*Participant, CCMX Advanced Course*

*"I really appreciated the broad selection of speakers from different branches of material science. The information they presented was from the cutting edge of their research—many of the speakers showed results from recently or soon-to-be published papers—while providing the big picture by embedding recent findings in the historical context."*

*Industry participant, CCMX Technology Aperitif*

*"What I most appreciated was the presence of both academia and industry. It is really fascinating to see how discoveries and developments from academia are implemented in products, or even better when they generate new products for new needs."*

*Participant, CCMX Technology Aperitif*



# CCMX Materials Challenges: Update

Public Private Partnerships (PPP) continue to be the cornerstone of CCMX's funding framework. Materials Challenges are designed to be a means of building on and extending past collaborations between academic groups and industrial sectors. Each Materials Challenge is a single research platform, involving one or more academic partners, that tackles underlying scientific questions critical to Swiss industry, addressing long-term research needs, while training future researchers for industry. CCMX matches funds from the private sector for five years—the ultimate goal is to ensure sustainability of the initiatives beyond 2016.

The open Call for Materials Challenge Proposals launched at the end of 2013 has brought good institutional and industry interest with many inquiries from potential applicants. This Call will remain open until funds for 2012–2016 have been allocated.

The first two Challenge proposals were approved for funding in 2014. The Nano-Screen Materials Challenge was launched in October 2014 and the Coating Centre will open in 2015. A thematic workshop in metallurgy was organised in May, bringing together interested academic and industry representatives. During the summer, significant progress was made in establishing a third Materials Challenge proposal in this field—which is currently completing a rigorous review process by panels of independent international experts.

A fourth proposal is expected to be submitted in spring 2015, having already successfully garnered industry commitment of over 650 kCHF.

CCMX is committed to assuring parity, transparency, and the highest level of scientific quality in implementing the Materials Challenges. The Centre is confident that it will reach its goal of launching at least six Materials Challenges during its final funding period. This initiative will foster durable, innovative, and continuing collaboration between ETH Domain researchers and industry partners.

## 54 Companies Involved Since 2006

ABB Turbo Systems (2)	KonMed	RMS Foundation
Alstom (2)	Kugler Bimetal	Rolex (2)
AO Foundation Davos	Lyncée Tec (3)	Rolic Technologies
Arrayon Biotechnology SA	Matter Aerosol	SCANCO Medical AG
Asulab	Métalor	Scientific Visual Sàrl
Attolight Sàrl	Meyer Burger Group	Sika
Ayanda Biosystems SA	Microsens SA	Stettler Sapphire AG
BASF (2)	Midatech	Straumann (2)
Biotronik AG	NanoScan AG	Sanofi-Pasteur
Bobst	Nanosys GmbH	Surface SolutionS
Bruker Optics GmbH	Nestec Ltd	swissnuclear
Cetics HT GmbH	Novartis (2)	Synthes GmbH (2)
Constellium (2)	Novelis	TSB GmbH
Crolles R&D	OC Oerlikon Balzers (2)	TSI GmbH
DECTRIS Ltd	Philips Semiconductors ZH	Varinor
HeiQ Materials AG	Plansee Powertech	Wessling GmbH
IG DHS	PreenTec AG	Zeiss
ION-TOF Technologies (2)		

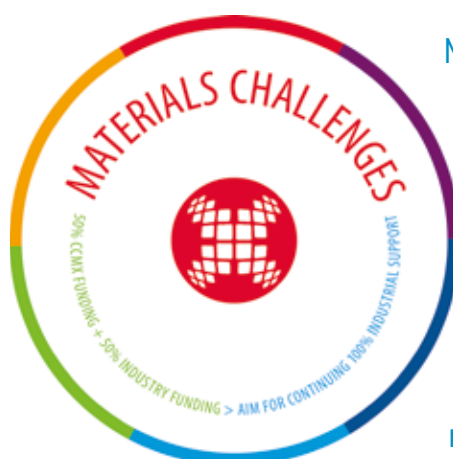
## 2 Federal Offices Involved Since 2006

Federal Office of Public Health (2)  
Federal Office for the Environment

## 3 HES and Universities Involved Since 2006

University Hospital Basel (3)  
University of Zurich (3)  
FHNW-Fachhochschule Nordwestschweiz

(2) signifies that a company has contributed twice to CCMX projects (3) signifies that the institution is involved in three CCMX projects



## Materials Challenges

tackle underlying scientific questions critical to Swiss industry, addressing long-term research needs while training future researchers for industry.

For more information, visit [www.ccmx.ch/research/call-for-proposals/materialschallenges0/](http://www.ccmx.ch/research/call-for-proposals/materialschallenges0/)



# NanoScreen Materials Challenge

## Consortium Targets Rapid Nanoparticle-Safety Assessment in five-year initiative

Eleven people from industry, academia and government got together in early October 2014 to kick off NanoScreen, the first research platform supported by CCMX's Materials Challenges programme. Bringing together partners from Empa, EPFL, Cetics Healthcare Technologies, Midatech and the Swiss Federal Office of Public Health, this consortium aims to develop a nanoparticle testing system that will quantitatively identify potential side-effects for human health *in vitro*.

"For me, this is a real bridging project," said Peter Wick, head of Empa's Laboratory for Materials-Biology Interactions. "Starting from basic science, we're delivering a robust and comparable methodology, closing the gap between the proof of concept to real nanotechnological applications."

Solid engineered nanoparticles are used in more and more products because they offer unique characteristics: they may feature high tensile strength, low weight, high thermal and electrical conductivity and unique optical properties. These properties offer benefits, but may also affect humans and the environment in unexpected ways. As use of these particles spreads, it becomes increasingly important to find out what effects they have on humans.

Although there are studies on the biological effects of engineered nanoparticles, there is little standardised testing—results are difficult to compare and can be inconclusive or even contradictory. The NanoScreen group wants to fill that gap by elaborating the fundamentals for a testing strategy that acts as a standardised tool that will allow partners in industry, regulation and academia to characterise engineered nanoparticles *in vitro* in a robust, reliable and comparable way.

"Sometimes industry comes to us asking for a solution and if we mention nanoparticles, they stop paying attention," said Heinrich Hofmann, head of the Powder Technology Laboratory at EPFL. "Very often people are not interested because they think these particles may be toxic. For us it's very important that we develop as fast as possible methods to

get a prediction of the behaviour of the particle. It will then be much easier to bring these products and nanoparticles with new properties to the market."

The two current industrial partners, Midatech and Cetics, share a similar aim. Midatech is a company that designs, synthesises and manufactures biocompatible gold nanoparticles. Though the company's core focus is on therapeutics for diabetes and cancer, they are also looking into the use of the nanoparticles in applications including vaccines, diagnostics and medical imaging. Justin Barry, Head of Gold Nanoparticle (GNP) Design & Manufacture at Midatech, says that it is absolutely vital to have clear guidance on the regulatory issues and to have testing that can show that the company's products are safe.

"In addition, from our company perspective, we're going to get a lot of essential information about our own nanoparticles because we're using them as part of the consortium's tools," he said. "This will give us direct feedback on our own portfolio as to what may or may not work."

German company Cetics Healthcare Technologies is providing the testing system for the consortium. Cetics' assay very rapidly demonstrates DNA strand breaks and DNA repairs, information that is highly relevant to toxicology. The assay is relatively new and taking part in the consortium gives the company a chance to gather more information about the test's capabilities.

"We want to have more and more applications for our test systems and to do that we need more data," said Marcel Pilartz, a product manager at Cetics. "In the end, we want to sell our systems."

Pilartz says a key feature of the consortium is the chance to see things from different points of view. Academics generally only talk with academics in their own fields and rarely have access to industry or regulators. "With this kind of consortium it's much easier to have these contacts," he said. "I think this is a good starting point."

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It is absolutely vital  
to have clear guidance  
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products are safe.

### Industry partner

The team nonetheless faces a challenge because nanoparticles are more difficult to test than bulk materials or classical chemicals. Because they are so reactive, they interact with proteins and other small molecules commonly used in testing—this interaction may ultimately result in false positive or false negative results.

The approach will involve correlating the physico-chemical properties of the engineered nanoparticles to biological effects and evaluating new biomarkers together with appropriate measurement technologies and integrating them into the testing strategy. The end result should be a reliable and robust testing strategy that is acceptable by regulatory bodies and, in turn, useful to Swiss industry.

"In regulation, risk assessment of nanomaterials is often done on a case by case basis," said Tobias Walser of the Swiss Federal Office of Public Health. "This is quite a lot of effort though and we need to streamline the risk assessment. This is really difficult if you don't have harmonised or standardised protocols available. Right now you can't get results that are done on a standardised basis and so it's really difficult for us to interpret the data we receive from both industry and research."

# CCMX Co-funded Professors: Update

Four professor chairs, two each at ETH Zurich and EPFL, are co-funded by CCMX for their first five years. Three new professors were appointed in 2013. The remaining professor will be selected by ETH Zurich in 2015.



**Magnetism is an old subject which continues to surprise us. The dream of a scientist in my position is to discover something fundamentally new, which can be put to use in real devices.** Pietro Gambardella, ETH Zurich

Pietro Gambardella became Full Professor of Magnetism and Interface Physics at ETH Zurich in January 2013. His work focuses on the synthesis and characterisation of magnetic systems with novel structural and electronic properties; this includes magnetic memories and sensors. Gambardella is particularly interested in how the interplay between structure, bonding and size effects determine their electrical properties, and, in controlling the spin, or magnetic orientation, of the materials. After transferring his group from Barcelona and installing lab equipment, his team has focused on experimenting with magnetic thin films, hiring additional collaborators and applying for funding.

In 2014, Gambardella's group of 12 researchers (including four PhD students) addressed diverse aspects, including studying spin torques in magnetic thin films for the realisation of an all electrical non-volatile memory. Another project involves materials properties optimisation by producing multi-layer films using molecular beam epitaxy and magnetron sputtering. Gambardella successfully organised a CCMX outreach event that was well attended. He also continued ongoing collaboration with a major supplier of sputter deposition equipment and settled a project agreement with a major company active in his field of research.



**Even though it takes time to build a laboratory that relies on unique fabrication methods, and to develop new contacts, I have already collaborated closely with several companies—yielding some results that I am confident will have a very strong scientific and technological impact.** Fabien Sorin, EPFL

Fabien Sorin has been leading the Laboratory of Photonic Materials and Fibre Devices since March 2013. EPFL appointed him as Tenure Track Assistant Professor in the Materials Science Institute. Sorin's expertise in multi-materials components and his unique experimental perspective attracted industry interest in the first year. His laboratory set-up has required building custom equipment, including a draw tower that produces multimaterials fibers.

During 2014, Sorin launched projects researching fiber devices, studying microstructured fibers, and investigating straightforward fabrication approaches for nanophotonic devices. He has continued long-standing industry collaboration for large area photonic systems on glass for light management applications. Sorin is also involved in one-to-one collaborations with several Swiss and foreign companies—for example focusing on optoelectronic fibres that can be sensitive to specific effects. All these research activities have expanded Sorin's group to three PhD students and two postdoctoral researchers. He hopes to settle more industry agreements in 2015.



**Machine learning enables us to take advantage of computers not only to simulate materials, but also to gain a deeper understanding of structure-properties relations.** Michele Ceriotti, EPFL

Michele Ceriotti has been Tenure Track Assistant Professor and head of the EPFL Laboratory of Computational Science and Modelling since November 2013. His first year has been dedicated to establishing his laboratory and launching research activities. Currently, his team of three PhD students and three postdoctoral researchers focuses on atomistic simulation of complex compounds and their applications in chemistry and materials science.

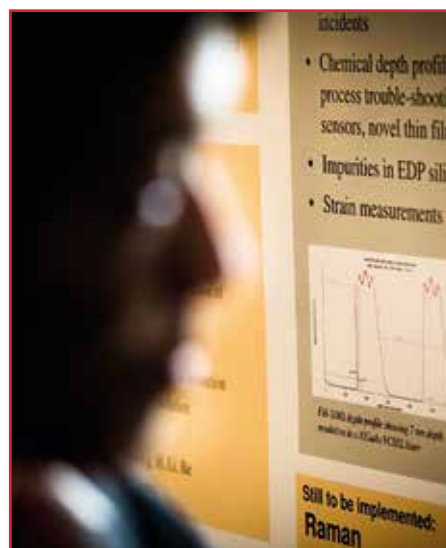
In the past year, Ceriotti investigated the development and application of methods used to model quantum nuclear effects in hydrogen-bonded materials—comprising the release of an open-source package to perform path-integral simulations. His work also focused on machine-learning algorithms to analyse and design structurally complex materials. Ceriotti has initiated a new line of research concerned with metal solidification from the melt. Collaborating with colleagues at EPFL, Empa and PSI, Ceriotti prepared and submitted a CCMX Materials Challenge to study the materials science of additive manufacturing. This proposal involves the participation of seven industrial partners and is currently under review. Ceriotti hopes this proposal will allow further collaborations with some of the participating industrial partners.

PHOTOS TONY KUNZ

# CCMX Research Activity: Projects



PHOTOS TONY KUNZ



In November and December 2014, CCMX Managing Director Nathalie Jongen and journalist Carey Sargent once again went on the road to gather stories and images for this year's annual activity report. They visited four running projects, meeting with project leaders and their various collaborators working in laboratories located in Basel, Dübendorf, Lausanne and Villigen. Sargent has also written some follow-up stories about recent achievements for selected projects that have been featured in previous reports.

Over the years of making these project visits, besides gathering information about ongoing research, what continues to touch Jongen and Sargent are the success stories and challenges along-side the research. The researchers reveal great enthusiasm and inspiration in developing new characterisation tools or materials exhibiting novel properties. Their generous collaboration in this year's report is gratefully acknowledged.

When asked what value CCMX has brought to their projects, researchers emphasised that not only many of their projects would not be supported by the other funding sources available in Switzerland but also that CCMX was able to offer a network beyond the barriers of their own research field, allowing them to expand their views and explore new avenues.

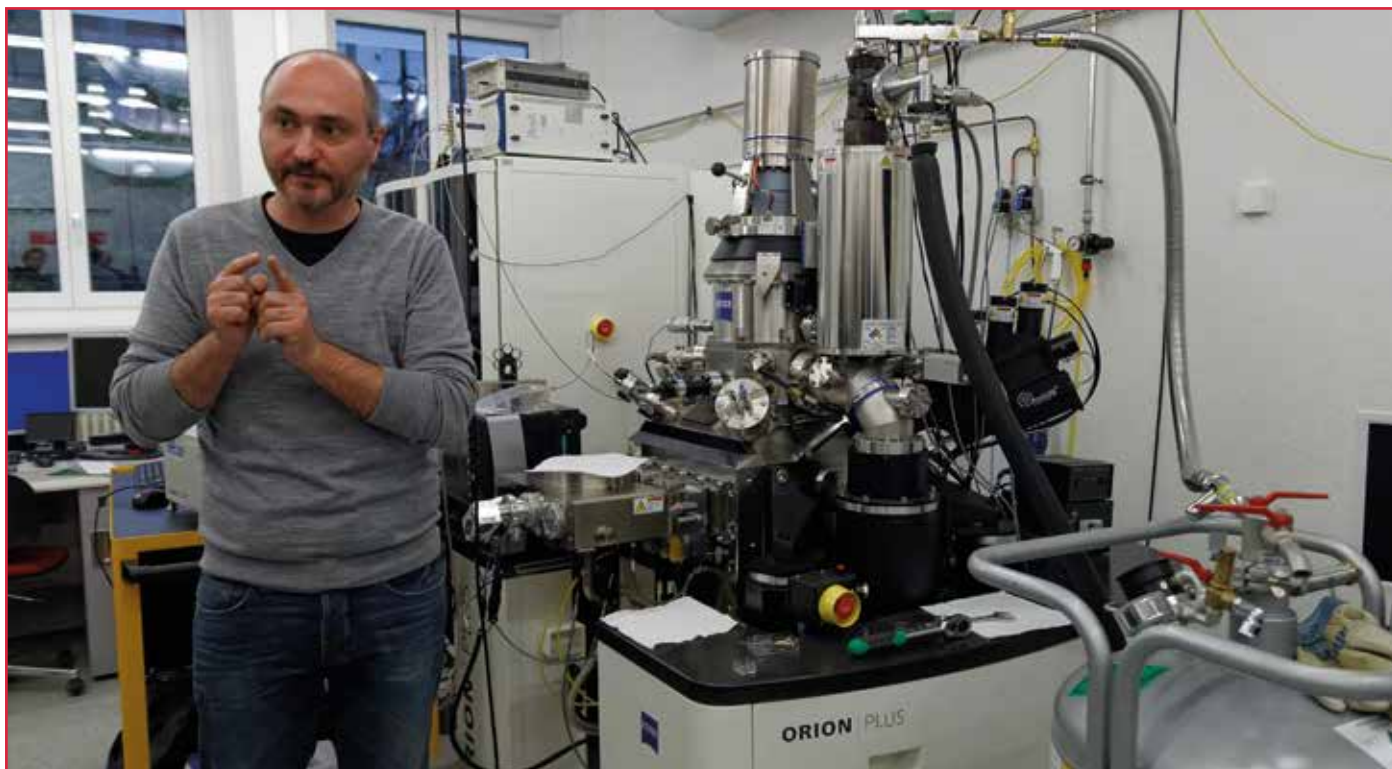
We hope the stories on the following eleven pages will be engaging to a wide audience, revealing interesting aspects of CCMX's multi-disciplinary projects.

Collaborating with  
the academic partners  
strengthened mutual  
relationships, deepening  
understanding of the  
partners' competencies  
and creating potential  
resources for other  
R&D activities.

Helmut Rudigier, OC Dierlikon Balzers



# New Tool to Tackle Scanning of Smallest Nano



PHOTOS NATHALIE JONGEN

F. La Mattina presents the new Helium Ion Beam Induced Charge scanning system based on an existing Focused Ion Beam microscope [all photos].

The main advantage of using helium ions is that the generated electron-hole cloud is smaller compared with other charged particle beams of similar energy.

The production of modern electronics is a complex multistep process where a lot can go wrong. Tiny imperfections in the substrate, alignment and patterning issues or even a microscopic dust particle can cause the whole chip to fail.

Tracking down the reason for a malfunction has never been easy. With more and more transistors being fit into smaller areas, the task is becoming very difficult indeed.

"If you have a billion transistors on a chip, it's really not easy to localise where the defect is in failure analysis," said Urs Sennhauser, head of the Reliability Science and Technology Laboratory at Empa. Sennhauser and colleague Fabio La Mattina are working with industrial partner Carl Zeiss AG on a new instrument that should make it easier.

"The trend is that everyone wants to have nano, but then you have to have tools to analyse this," La Mattina said.

The idea is to develop a technique known as ion luminescence for use in a machine that generates images of a given material by scanning it with a focused beam of helium

ions. While the focused ion beam (FIB) approach itself produces high-resolution images, its current set up does not offer much in the way of analytics. Introducing this additional element could, for example, help researchers generate information about the charge distribution profiles, data that is critical when trying to find failure points.

Ion luminescence involves spectral analysis of the light emitted by a sample after irradiation. In this case, luminescence is generated because bombarding the sample with high-energy ions results in the formation of electron holes, or other charge transferred mechanisms. When an electron and hole recombine, a photon can be emitted. The data contained in this light gives information about the material structure and potential defects. Another technique involves collecting the resulting cloud of electron charge to gather information about the profile of the electric field in heterostructures such as photovoltaic solar cells.

The size and distribution of the cloud of electron holes that forms is a critical element. The main advantage of using helium ions, which can be focused into a small probe size,





The big challenge is to go to higher resolution, and to go higher one must be ready to detect photons induced by only one ion. We are very close to being able to do that.

Fabio La Mattina, Scientist, Empa

is that the generated electron-hole cloud is smaller compared with other charged particle beams of similar energy. This should lead to higher resolution in all analytical techniques that use this technology.

So far, with the technique, the team has managed to demonstrate higher resolution with helium in terms of collecting the electron-hole pairs produced as beam-induced current. Concerning luminescence, they have produced results with a resolution that is comparable to what can be achieved by electron beam technology.

"So this still doesn't justify why you should use a helium FIB," La Mattina said. "You can already get this on an electron beam, standard technology that is cheaper. The challenge is then to go to a higher resolution."

The stumbling block is that the helium ions are producing some defects even at the low beam current. These defects compete with the electronic structure that produces the luminescence. The next approach is to try injecting only one or two ions per pixel to generate the needed photon.

"The big challenge is to go to higher resolution and to go higher one must be ready to detect photons induced by only one ion," La Mattina said. "We are very close to being able to do that."

Empa currently helps industrial partners with chip modification following redesign, and also with general failure analysis.

"Even large companies don't have the equipment to do this anymore," Sennhauser said. "We're in a unique position for micro-electronics and photonics analysis in Switzerland. We're also doing research along these lines and this project is a step forward in localisation and failure characterisation."

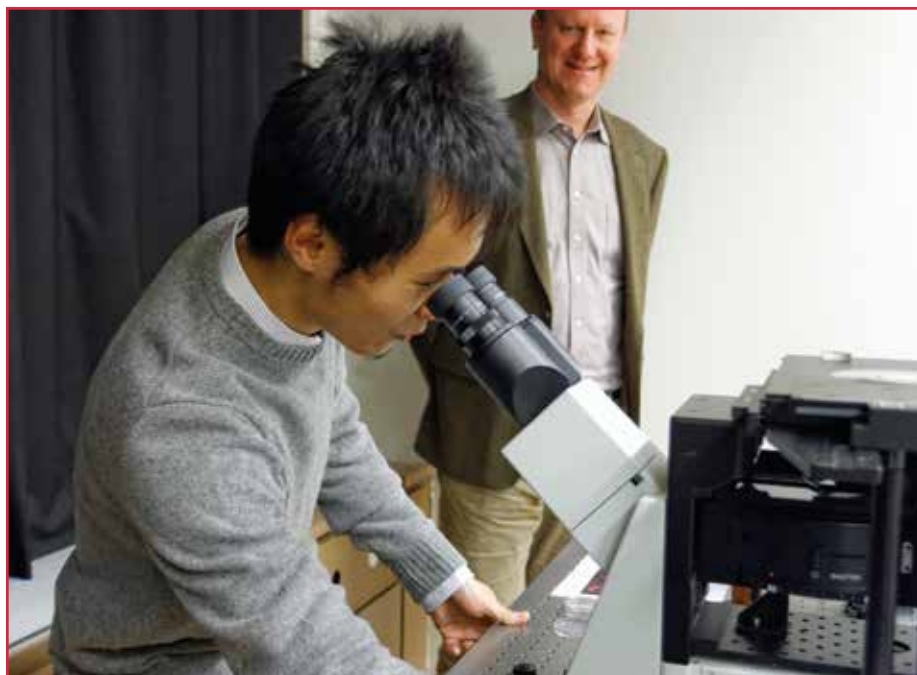
In addition to supporting existing services, the new techniques will also be suitable for use in new areas such as carbon nanotubes, graphene, bacteria and plasmonic structures.

"In high resolution imaging there is a lot of interest to get good contrast without damaging the materials," La Mattina said. "That's the future."

# Novel Optical Properties for Simple Sensing De

We want to develop materials that change information into an optical signal that anyone can understand. If the material changes colour, you know something has happened. That's the long-term vision.

Olivier Martin, Professor, EPFL



PHOTOS NATHALIE JONGEN

Although the aim of the project is to produce optical effects that can be observed with bare eye, the microscope is still very much needed to fine tune the metasurface under development by C. Yan.

Credit cards have featured security holograms for some time. The 3D pictures are meant to foil counterfeiters because they cannot easily be scanned or photocopied.

It turns out though that they are still not that difficult to reproduce. New materials with novel optical properties could make such features much more secure. A group of researchers—including Olivier Martin, head of the Nanophotonics and Metrology Laboratory at EPFL, his PhD student Chen Yan, CSEM's Marc Schnieper, section head of Integrated Sensing and Security, and Benjamin Gallinet—are working with industrial partner BASF on just such a thing.

"If we were to do the same with this new type of material, it would be much more difficult to counterfeit," Martin said. "The rainbow effect that you see on these holograms is neat, but doesn't provide much information. Having a surer sign that this is the real card, not a counterfeit, is the objective."

The team is working on metamaterials—materials made up of artificial atoms—that have specific optical properties. Merging

these nanostructures into crystal structures leads to materials that have properties that cannot otherwise be attained. These metamaterials can then be used, for example, to create sensors that transmit information in a way that is visible to the naked eye. This feature could be put to use in a number of applications. Take food safety, for example. Right now, there is no way to know whether a refrigerated carton of milk has previously been exposed to temperatures that promote the growth of bacteria. Sensors based on metamaterials could be printed on the carton and used to monitor and record ambient temperatures, changing colour when it has been exposed to too much heat and is likely to be spoiled.

"We want to develop materials that change information into an optical signal that anyone can understand," Martin said. "That is, if the material changes colour, you know something has happened. That's the long-term vision."

The group's work is based on Fano resonances, an optical interference phenomenon that can be seen in certain kinds of nanostructures. Martin explains it using an analogy to sound—striking a single tuning fork produces a

tone that corresponds to the peak in the wave produced. Striking a second tuning fork at the same time will result in two peaks and a modulation effect. Depending on the two resonances, the waves may strengthen or weaken each other. In terms of light, the observed effect is colour. That is, when a nanostructure is excited by white light, the scattered light corresponds to a single peak in the spectrum and therefore to a single colour. In materials that display Fano resonances, light is scattered so as to produce two peaks, or colours. This phenomenon is particularly sensitive to the environment, a characteristic that makes it ideal for use in sensors.

The first challenge was trying to understand exactly how Fano resonances work in these special materials. Since the team is focused on optical properties, they are working with coinage metals such as gold, silver and aluminium deposited on dielectric materials because they have a very strong interaction with light, creating strong optical effects.

Using samples to explore different Fano resonance regimes, they were able to confirm their theory that there is an optimum value,



PHOTOS NATHALIE JONGEN

Top left: Nickel grating replication master for wafer scale nanoimprinting. Bottom left: Hot-embossed subwavelength gratings including the CSEM logo. Right: M. Schnieper and F. Lütholf holding fano-resonant gold nanostructure fabricated with step-and-repeat UV molding (robot on the right-hand side).

the critical coupling, associated with a maximum intensity of light. Putting more energy in the system after this point leads to a decrease rather than an increase in light intensity. Using a special kind of spectroscopy, the researchers were able to reproduce the curve they had anticipated theoretically.

"In other terms, we have understood how these nanostructures work, have found a way of using them to design sensitive sensors," Martin said.

The team is using this knowledge to develop metamaterials with the properties they want. One goal is having a material that reflects a given colour in a specific direction. The material could, for example, reflect blue in one direction and red in another, a property that could be useful in anti-counterfeiting. Martin and Yan have developed one such material in which the effects can be seen with the naked eye. They have managed to fabricate their sample in the lab, but the next step is to produce these samples on a larger scale. Colleagues at CSEM are working on production processes to scale up to square centimetres.

"Our role here at CSEM is to produce on a bigger scale what has been developed at EPFL as a proof of concept," Schnieper said.

CSEM is using holography origination technology to pattern a large area at once and then using a replication process to produce on a larger surface. Their holographic set-up can go up to surfaces of 6 inches square, and, using the step and repeat process, up to A4 scale. The team also had a hand in developing the structures in collaboration with Martin's group—not everything that can be done with the small-scale technique of electron beam lithography can be done on the larger surfaces. CSEM has produced an A4 patterned demonstrator that shows the desired colour effect. The ultimate goal, Schnieper said, is to have a fully characterised sensor.

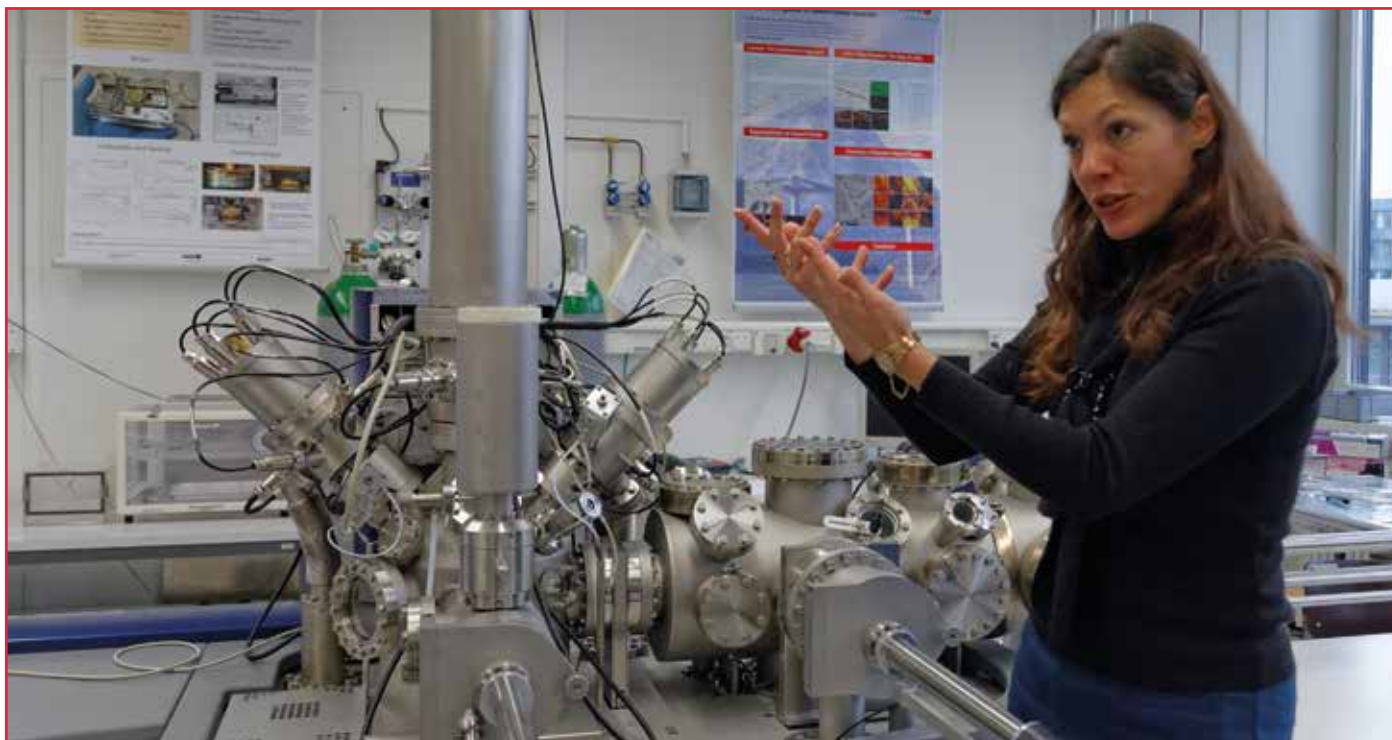
"There are a lot of different types of sensors in the world," he said. "Some are bulky, big and very expensive. Our goal is to have something that can be disposable, simple to use, with no need for batteries or energy, and easy to read."

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Marc Schnieper, Scientist, CSEM



# Argon Sputtering Helps Protect Delicate Organ



PHOTOS NATHALIE JONGEN

L. Bernard describes the principles of using a Time-of-Flight Secondary Ion Mass Spectrometer.

Researchers have focused on using clusters of argon atoms because the noble gas interacts chemically very little with the material.

Time-of-Flight Secondary Ion Mass Spectrometry is a method of analysis that involves bombarding a solid material with a focused beam of ions and investigating the surface ions ejected in the process. The approach uses spectroscopy to characterise the surface chemical composition, imaging to determine the distribution of species on the surface, and depth profiling to characterise the sample composition as a function of depth.

Though the whole process reveals a lot of information, the depth profiling has a significant drawback—the associated bombardment, or sputtering, alters the sample by creating defects and surface roughening.

“You implant ions, you break bonds, you displace things in the structure and create a surface roughness or topography,” said Laetitia Bernard, head of the ToF-SIMS group at the Nanoscale Materials Science Laboratory at Empa. “By sputtering, you disturb your initial material and so change your sample by the simple fact of measuring it.”

The problem is particularly pronounced in organic materials, which are made of large molecules that break very easily when bombarded with conventional sputtering

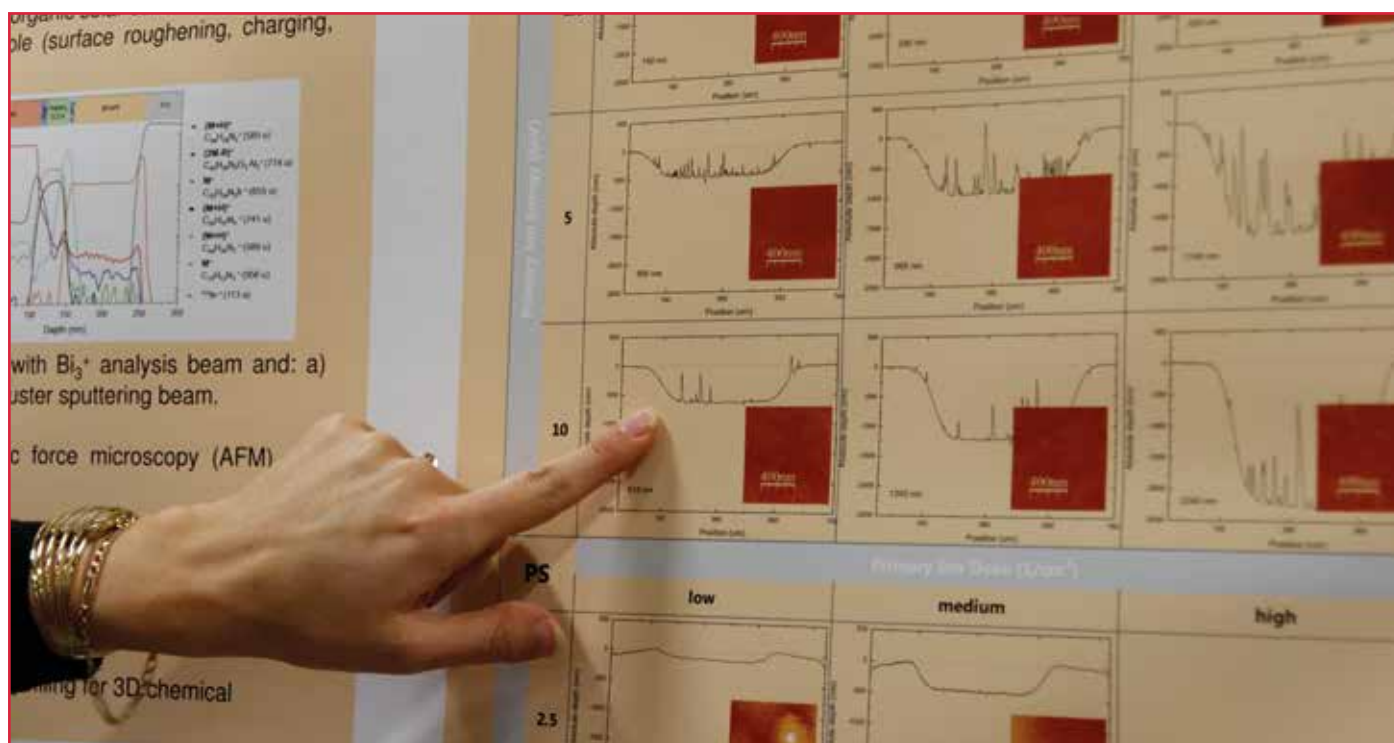
sources such as caesium and oxygen. With organic intelligent material and solar cells showing promise in a number of applications, finding a new source of sputtering that does not cause as many defects is critical. Researchers have focused on using clusters of argon atoms because the noble gas interacts chemically very little with the material. Using groups of 1'000 to 2'000 atoms makes the technique less destructive—the energy required to sputter is spread through all of the atoms rather than contained in a single one.

“When this big thing reaches the surface, single argon atoms each carry only a small part of this energy and so the damage is much less,” Bernard said. “This is important in organics because you want to keep the molecules intact, even after sputtering for a very long time, as is needed to investigate far into the depth.”

Though the argon approach is a big improvement on most soft materials, the sputtering beam still affects the surface. The extent depends not only on the chosen ion, but also on other factors such as the target material, the energy level chosen, the angle at which the particles are shot and the number of atoms in the ion.



# ic Samples



L. Bernard is demonstrating measurements carried out with the instrument under various conditions to get the best quality of analysis.

"Our objective is to take this one step further and find out what the best conditions are for given materials," Bernard said. "We want to establish recipes and standards with well characterised possibilities and limitations for each class of materials."

Specifically, they are looking at how to get the best quality of analysis, the lowest surface roughening, the most stable sputter yield and the best depth-resolution possible for given reference materials. Researchers at ION-TOF GmbH, the world-leader in ToF-SIMS equipment, are creating craters with argon clusters in various materials and with varying energies and doses of atoms. Bernard then investigates the ensuing depths, roughness and other variables.

So far, Bernard has seen that the argon cluster sputtering tends to generate only low surface roughening, as compared to caesium or oxygen sputtering—this is particularly important because increased topography decreases the depth resolution. It is also possible to penetrate deeper into the sample without increasing the roughness of the surface. The team is now focused on investigating crosslinking, a phenomenon that involves the creation of new bonds during the sputtering process.

"This is a problem with the conventional sources because you wind up analysing something that was not initially there," Bernard said.

Despite the advantages, there are some challenges associated with the method. While argon clusters are excellent for use in soft materials like organics, the sputter rate on metals is extremely low. At the moment, it is not possible to analyse metals in depth with argon clusters.

There may seem to be a simple solution—use argon clusters for organics and caesium for metals—but more and more materials are composites of the two. Organic electronics, for instance, have electrodes that contact a molecular part. The team may next try creating samples that feature both materials and see how the sputter rate evolves across the interface.

"Ultimately the idea is to address all these questions and end up with a kind of recipe booklet," she said. "That way we'd know what to expect from given parameters on a given type of material."

We want to establish recipes and standards with well characterised possibilities and limitations for each class of materials.

Laetitia Bernard, Scientist, Empa

# New Spectroscopic Cell Improves Testing of Fun



D. Ferri shows the new cell that combines different spectroscopic methods, and the mirrors used during the first experiment.

This new cell is also able to combine at least two radiations in a single experiment. We can run several spectroscopic methods, but the core of the experiment is always this cell.

Davide Ferri, Scientist, PSI

Diabetics are unable to produce the insulin required to deliver glucose to the cells that need it and without this source of fuel, the body burns fat for energy. The by-products of the process accumulate in the blood—elevated levels of chemicals such as acetone suggest the disease is not under control.

Monitoring these chemicals currently involves blood or urine testing, but a new generation of sensors could change that.

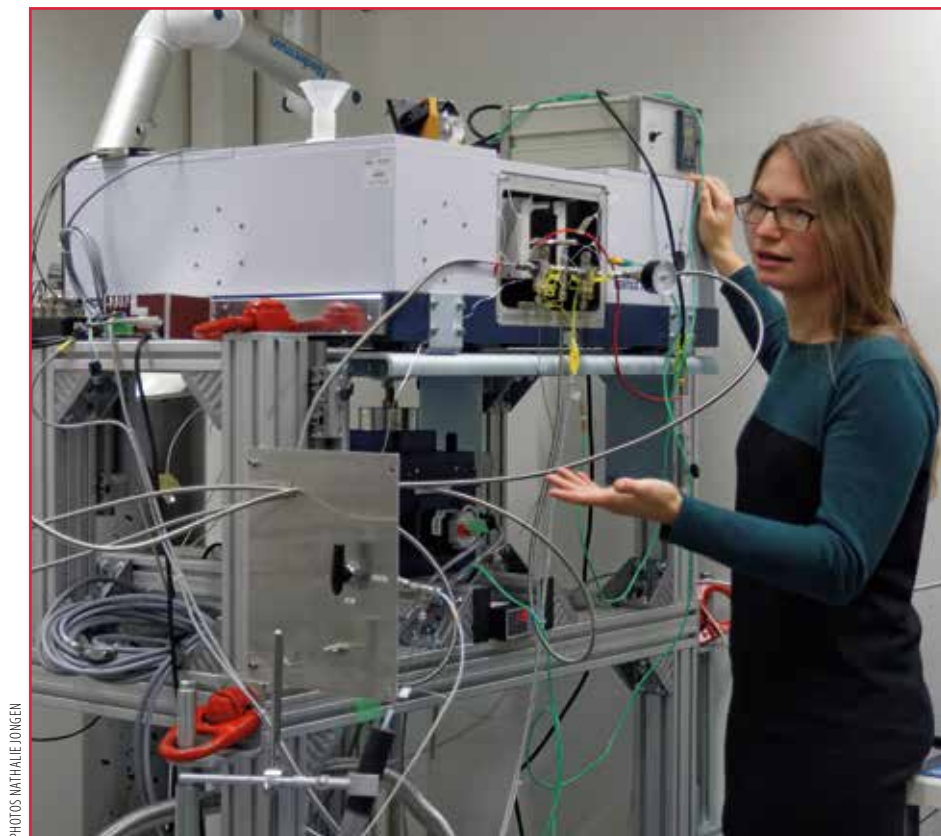
Based on tin and titanium oxide nanoparticles, the sensors simply detect the relevant gases in human breath. They are still being developed and improved—researchers are, for example, investigating the relationship between nanoparticles' structures as well as their biological activity.

The most critical information comes from analysing the materials under operating conditions. This involves flowing gases over the material, which is contained in a cell, and applying various spectroscopic methods to gather different sorts of information. X-ray absorption allows researchers to observe the

structure of the nanoparticles and infrared spectroscopy reveals the chemical species present on their surfaces. Similar work is used to investigate how catalysts work. Until now, the different spectroscopic methods have required specifically adapted cells. Different experiments required changing cells—this wastes time and money and can even change the chemistry of what's being examined.

"This is something you want to avoid," said Maarten Nachtegaal, group head of In situ X-Ray Spectroscopy at the Paul Scherrer Institute. "Having one reactor cell that does the job irrespective of the spectroscopic method helps you do this."

Nachtegaal and PSI colleagues Davide Ferri, a senior scientist in the Catalysis for Energy group, and PhD student Valentina Marchionni, have worked together to produce just that. Their new cell can be used for both infrared and x-ray absorption spectroscopy. They have also had success with x-ray diffraction and emission spectroscopy using the very same cell.



PHOTOS NATHALIE JONGEN

V. Marchionni with the infrared set-up where the new spectroscopic cell is used daily.

Until now, the different spectroscopic methods have required specifically adapted cells. Different experiments required changing cells—this wastes time and money and can even change the chemistry of what's being examined.

"We wanted to develop equipment that is able to use several spectroscopic methods to deliver different, complementary, information," Ferri said. "This new cell is also able to combine at least two radiations in a single experiment. We can run several spectroscopic methods, but the core of the experiment is always this cell."

The first application involved using an infrared spectrometer inside the beamline to carry out infrared and x-ray absorption experiments at the same time. This gives them the opportunity to study sensors or catalysts under operating conditions. Applying gas atmospheres and looking at how or if the structure is changing simultaneously allows them to correlate performance of the material using online mass spectrometry with structural change.

"This is very interesting for catalytic applications," Ferri said. "It can be a sensor, a catalyst or fuel cell material, it can be anything. What's important is being able to measure these two things at the same time. Structural aspects

can be investigated using various methods amenable to *in situ* conditions."

Marchionni is now using the cell in experiments to study the mechanisms and reactions linked to noble metal-supported catalysts for automotive and environmental applications. She builds the complexity of the reaction step by step, starting with the easier reactions and then adding another gas that can influence the reaction in every experiment. In the end, she has the real conditions of the reaction.

Infrared spectroscopy gives Marchionni data about what is going on on the surface of the catalyst. When she gets beam time, she is able to perform x-ray spectroscopy, which reveals information about the oxidation state and the structure of the noble metal.

"With the cell, I know I'm performing exactly the same experiment in exactly the same conditions," she said. "For me, it's a big advantage."

# CCMX Research Activity: Project Update

## Optimised Wear-Resistance, Improved Wetting in Alumina Bodies

Very hard materials like sapphire and diamond can be found in nature; so can plants with waxy, water-repellent leaves. Materials that are both very wear-resistant and liquid-repellent are not known to exist naturally. It turns out they are also quite hard to make.

"The fundamental idea of making a combination to improve both properties seems not to work," said Patrik Hoffmann, head of Empa's Laboratory for Advanced Materials Processing, which has been tackling the problem since November, 2011. "We have, however, found solutions for very good improvements over classical existing materials."

The team, which also includes PhD student Sriharitha Rowthu, is improving the wetting characteristics of alumina—a material that generally is wetted by water and most other liquids, that is, lyophilic—by manipulating the surface roughness and chemistry. They have made two key advances since the beginning of the project: optimising porosity to improve wear-resistance and improving wetting properties.

Hoffmann and Rowthu are working with mesoporous alumina bodies featuring open porous networks that can be filled with various kinds of liquids. An initial critical research step was to figure out the optimal density of the materials' open pores and which liquid to use to fill them. The best published results so far have come from bodies featuring densities of more than 90% and filled with fomblin oil, a lubricant. With this combination, the team has decreased the wear coefficient by an order of magnitude and cut the coefficient of friction by six times,



S. Rowthu showing her prize-winning poster at the CCMX Annual Meeting.

reaching a level that is very close to that of sapphire—a negligible rate of wear.

"Now we really know what the perfect porosity is in order to get dry lubrication," Hoffmann said. "The values are really fantastic and look like a world record to us, but we need to study more parameter variations."

The second success has been developing a novel, reproducible technique for adding surface microstructures—including one in the shape of Switzerland—to the tops of the alumina bodies. The ultimate goal of developing this technique was to tune the wetting properties of the alumina composite material. And here, there has been significant improvement in making the surfaces super-hydrophobic when the microstructured surfaces are coated with a waxy layer.

Right now, because the wear resistance decreases with the addition of the microstructures, the team faces a decision—they can either ensure that their wetting properties are the best possible or accept that they are less than ideal and target dramatically improved wear.

Another project partner, EPFL's Laboratory of Applied Mechanics and Reliability Analysis, headed by John Botsis, has developed simulations of fracture and deformation mechanics of the porous ceramic materials. Based on the size and distribution of the pores and grains, the simulations help researchers construct models for the fracture characterisation of such materials. At this point, additional input is needed about the material microstructure and properties, including the correct measurement of the 3D geometry of the mesoporous alumina samples.

This has proven challenging. The particles are too large for 3D imaging with transmission electron microscopy and too small for the other proposed methods. The group is now discussing the most appropriate tomography with the X-ray centre at Empa and is also in discussion with the Centre for Electron Microscopy at EPFL.

"This input is needed for making the model exactly describe our experimental products," Hoffmann said. "We want to get as close as possible to every researcher's dream of having the theoretical and experimental approaches meet and merge."

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We want to get as close as possible to every researcher's dream of having the theoretical and experimental approaches meet and merge.

Patrik Hoffmann, Professor, Empa



# CCMX Research Activity: Project Update

## Mechanical Innovations Turn PSI Beam Line into Unique Instrument



PHOTO COURTESY PSI

S. Van Petegem, T. Panzner and H. Van Swygenhoven with the new bi-axial deformation rig.

Demand for lighter and higher performance metals has resulted in alloys with complicated micro- and nanostructures. We know a lot about basic plasticity, but when it comes to understanding the interplay between mechanisms within one microstructure, there are many open questions.

Micromechanical modelling has therefore become much more important. These computational schemes incorporate equations that have to be “fed” with criteria and parameters that capture important operating mechanisms. A big problem though is that while materials usually experience multi-axial strains including strain path changes during synthesis or under service conditions, most of our detailed knowledge comes from uniaxial testing. Assessing the criteria that capture multi-axial treatments requires fundamental understanding and a systematic research approach.

*In situ* mechanical testing under neutron beam diffraction is an excellent way to follow the evolution of microstructures during deformation. It allows researchers to focus on micro-scale aspects such as intra- and inter-granular deformation phenomena and also provides information on load transfer in multiphase materials, generating data for predictive models.

A team of scientists led by Helena Van Swygenhoven, head of the group NXMM (Neutrons and X-rays for Mechanics of Materials) at the Paul Scherrer Institute, has developed a unique concept for a biaxial deformation rig to perform *in situ* mechanical tests of modern industrial alloys under more realistic working conditions.

The new equipment, inaugurated in October 2013, allows researchers to perform bi-axial non-proportional loadings on cruciform samples. One of the axes is also equipped to perform tension, compression, torsion and fatigue tests. The whole rig can fit on the sample stage of the Pulse Overlap Time-of-Flight Diffractometer (POLDI), which uses neutron scattering to determine the microstructure of the investigated sample *in situ*. The information generated by such mechanical tests can be used to optimise production processes or to determine the fundamental mechanical properties of new materials.

The machine, which was custom-built and developed in close collaboration with German company Zwick Roell Group can handle vertical tension/compression up to 100 kN, horizontal tension/compression up to 50 kN and torsion of the vertical axis of up to 200 Nm. It can also run low cycle fatigue tests up to 1,000 cycles. It has a 3D digital imaging correlation (DIC) system for non-contact macroscopic strain measurement. The tensile machine and the DIC system are integrated into the beam line software for

The unique rig should appeal to a wide variety of industrial and academic users.

Helena Van Swygenhoven, Professor, PSI

*in situ* measurements, so all three systems are synchronised. The rig is nearly 1.9 meters high and 2.7 meters wide and weighs 1.7 tons.

The PSI team involving scientists Steven Van Petegem and Tobias Panzner has run first model experiments on cruciform shaped stainless steel samples. They were deformed up to 50 kN with uniaxial and biaxial load ratios. The experiment found that under biaxial loading conditions, the values of the lattice strains in the elastic regime are about half as high compared to uniaxial loading. Deviation from linearity occurs at a similar applied force, though the nature of the deviation differs significantly between the two loading ratios. The nature and magnitude of the residual strain after unloading depend strongly on the loading conditions.

External users from internationally renowned research institutions used the machine in 2014 and others have applied to run experiments in 2015. “The unique rig should appeal to a wide variety of industrial and academic users,” PSI’s Van Swygenhoven said. It is likely to be useful for providing input parameters for constitutive equations in computational programs used in engineering, or to validate new computational methods that aim at more accurate descriptions of the relation between microstructure and mechanical behaviour.

# CCMX Research Activity: Project Updates

## Coatings Look Set to Extend Life of Joint Implants

Metal-on-metal friction in hip implants generates wear particles that can cause inflammation, pseudo-tumours, allergic reactions and pain—this means the devices sometimes need to be replaced using complicated, time-consuming surgery. Researchers at Empa and ETH Zurich have been developing new, corrosion-resistant, adhesion-promoting interlayer coatings to solve this problem.

The most promising is one made of amorphous Tantalum, which also contained a small amount of  $\alpha$ -Tantalum. The coating works independently from the substrate and so could be suitable for nearly every orthopaedic alloy. Empa has also developed tests for stress corrosion cracking and crevice corrosion to predict the lifetime of the implants in terms of these failure points.

Daniel Bernoulli, a former PhD student in Ralph Spolenak's Laboratory for Nanometallurgy at ETH Zurich, helped

improve the mechanical stability of the whole coating/implant system. Mechanical forces exerted on the implant either in the body or during movement of the joint can lead to crack formation and delaminated areas. Bernoulli set out to investigate how the coating fails by simulating contact damage with indentation, and mechanical stress with uniaxial loading. He also simulated stress distribution with finite element analysis and worked on interlayer characterisation.

During the course of his thesis, Bernoulli's approach included: quantitatively determining at which film thickness and at which strain the diamond-like carbon (DLC) film either cracked or delaminated; looking at damage in terms of contact load and DLC film thickness, including simulating such damage by finite element calculations to obtain quantitative values; and, finally, showing how damaging behaviour can be significantly improved when a ductile interlayer is used between the DLC and the substrate.

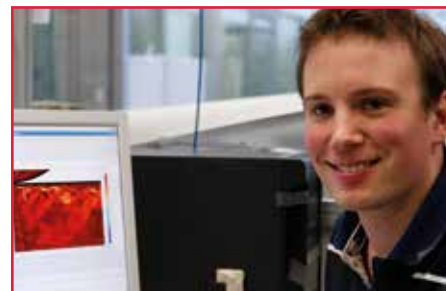


PHOTO NATHALIE JONGEN

D. Bernoulli performing finite element calculations.

The work gave the researchers insight into the processes that cause damage and how they can optimise the whole system. The finite element calculations and film thickness variations helped researchers develop a multilayer system that guarantees—independently from the medical alloy—high hardness, low friction, mechanical and corrosion stability. For softer alloys the risk of failure due to an imprint of the hard coating into the soft base material, the so-called eggshell effect, was clearly minimised.

## Investigating the Interplay When Arc Meets Metal

The contact materials used in the switches that carry current and extinguish arcs among electric transmission lines need to withstand charges of up to 1 million volts. Copper and tungsten alloys now used in such applications feature high thermal and electrical conductivity as well as heat resistance, but may be heavier than needed. The metal contacts can also be eroded by the temperatures they experience—if high enough, the copper evaporates and starts cooling the tungsten.

Ralph Spolenak at the Department of Materials at ETH Zurich, his PhD students Franz Vüllers, André Röthlisberger—also a student of Edoardo Mazza, head of Empa's Laboratory of Mechanics for Modelling and Simulation—and industrial partner Plansee Powertech AG, are looking to solve such problems with innovative contact coatings made from metal alloys. Understanding what happens when the arc meets the metal and how materials mechanically deform is, however, a critical first step to developing any new alloy. Over the past years the group has been investigating what really happens at the interplay between the arc and the material.

Röthlisberger has focused on using finite element modelling to produce numerical simulations of arc erosion, while Vüllers took on experimental investigation of the materials themselves. The research aims to determine the best length scale for making a material as resistant as possible to high local temperatures. Shorter diffusion distances improve thermal conductivity—but making things smaller and smaller eventually increases electrical resistivity with a corresponding drop in conductivity. Discovering the ideal scale may lead to designing circuit breaker components that are based on coatings that are just 100s or 10s of microns thick.

The focus has mostly been on looking at tungsten and copper on the smallest possible length scales, that is, examining the interpenetrating microstructures. Using a sputter process, the team deposited a solid solution of tungsten and copper quite far away from thermodynamic equilibrium, allowing them to phase separate tungsten and copper into an interpenetrating network and tune the length scales. The team was also able to create the same kind of interpenetrating

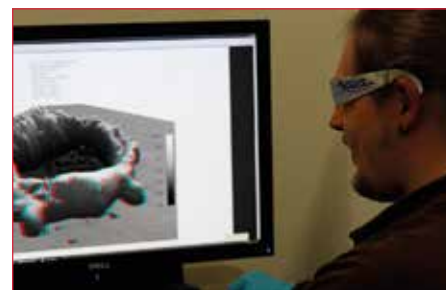


PHOTO NATHALIE JONGEN

F. Vüllers displays an image of an arcing crater reconstructed by Atomic Force Microscopy (AFM).

network on the bulk scale through a process they are developing with Northwestern University in the U.S. This means they have been able to make a bridge between the interpenetrating network on the nanoscale with the micro-scale and, finally, study the materials on all length scales.

They have also published a detailed study on how the simple microstructure of tungsten can be manipulated by sputtering parameters and used finite element modelling to mimic arc erosion, figuring out what temperatures and mechanical loads are generated during the processes.

# 2014 Peer Reviewed Publications

## MERU

M.S. Pham, S.R. Holdsworth; **Evolution of relationships between dislocation microstructures and internal stresses of AISI 316L during cyclic loading at 293K and 573K (20°C and 300°C)**, *Metallurgical and Materials Transactions A*, 45 (2014) 738-751.

M.A. Weisser, S. Van Petegem, A. Cervellino, H. Van Swygenhoven; **On the origin of cementite diffraction peak broadening during tensile deformation at ambient temperatures**, *International Journal of Plasticity*, 66 (2015) 138-144.

H. Meidani, A. Jacot, M. Rappaz; **Multiphase-Field Modeling of micropore formation in metallic alloys**, *Metallurgical and Materials Transactions A*, 46 (2014) 23-26.

A. Furrer, R. Spolenak; **Colors of thin films of binary and ternary gold- and platinum-based alloys**, *Acta Materialia*, 66 (2014) 241-250.

P. Schloth, J.N. Wagner, J.L. Fife, A. Menzel, J.-M. Drezet, H. Van Swygenhoven; **Early precipitation during cooling of an Al-Zn-Mg-Cu alloy revealed by *in situ* small angle X-ray scattering**, *Applied Physics Letters*, 105 (2014) 101908.

FT.N. Vüllers, R. Spolenak; **Alpha- vs. beta-W nanocrystalline thin films: A comprehensive study of sputter parameters and resulting materials' properties**, *Thin Solid Films*, 577 (2015) 26-34.

N. Chobaut; **Precipitation and modelling of residual stresses during quenching of thick heat treatable aluminium components in relation to their precipitation state**, *Thesis EPFL*, No. 6559 (2015).

## MatLife

M. Håkanson, E. Cukierman, M. Charnley; **Miniaturized pre-clinical cancer models as research and diagnostic tools**, *Advanced Drug Delivery Reviews*, 69-70 (2014) 52-66.

M. Rottmar, R. Mhanna, S. Guimond-Lischer, V. Vogel, M. Zenobi-Wong, K. Maniura-Weber; **Interference with the contractile machinery of the fibroblastic chondrocyte cytoskeleton induces re-expression of the cartilage phenotype through involvement of PI3K, PKC and MAPKs**, *Experimental Cell Research*, 320 (2014) 175-187.

D. Muff, R. Spolenak; **Mechanical properties of re-actively sputtered ceramic single and multilayer thin film structures for dental implants**, *DPG-Frühjahrstagung* (2014).

C.M. Pecnik, D. Muff, R. Spolenak, I. Sailer; **Color Evaluation of a Dielectric Mirror Coating Using Porcine Tissue and Prosthetic Gingival Material: A Comparison of Two Models**, *Clinical Oral Implants Research*, 00 (2015) 1-10.

C.M. Pecnik, M. Roos, D. Muff, R. Spolenak, I. Sailer; ***In vitro* color evaluation of esthetic coatings for metallic dental implants and implant prosthetic appliances**, *Clinical Oral Implants Research*, 00 (2014) 1-9.

D. Bernoulli, K. Häfliger, K. Thorwarth, G. Thorwarth, R. Hauert, R. Spolenak; **Cohesive and adhesive failure of hard and brittle films on ductile metallic**

**substrates: A film thickness size effect analysis with the model system hydrogenated diamond-like carbon (a-C:H) on Ti substrates**, *Acta Materialia*, 83 (2015) 29-36.

D. Bernoulli, A. Wyss, R. Raghavan, K. Thorwarth, R. Hauert, R. Spolenak; **Contact damage of hard and brittle thin films on ductile metallic substrates: an analysis of diamond-like carbon on titanium substrates**, *Journal of Materials Science*, 50 (2015) 2779-2787.

K. Thorwarth, G. Thorwarth, R. Figi, B. Weisse, M. Stiefel, R. Hauert; **On interlayer stability and high-cycle simulator performance of diamond-like carbon layers for articulating joint replacements**, *International Journal of Molecular Sciences*, 15 (2014) 10527-10540.

M. Mitsi, S. Handschin, I. Gerber, R. Schwartländer, E. Klotzsch, R. Wepf, V. Vogel; **The ultrastructure of fibronectin fibers pulled from a protein monolayer at the air-liquid interface and the mechanism of the sheet-to-fiber transition**, *Biomaterials*, 36 (2015) 66-79.

S. Früh, P. Spycher, M. Mitsi, M. Burkhardt, V. Vogel, I. Schön; **Functional Modification of Fibronectin by N-Terminal FXIIIa-Mediated Transamidation**, *ChemBioChem*, 15 (2014) 1481-1486.

B. Li, Z. Lin, M. Mitsi, Y. Zhang, V. Vogel; **Heparin-induced conformational changes of fibronectin within the extracellular matrix promote hMSC osteogenic differentiation**, *Biomaterials Science*, 3 (2015) 73-84.

G. Yalak, V. Vogel; **Ectokinases as novel cancer markers and drug targets in cancer therapy**, *Cancer Medicine*, 4 (2014) 404-414.

H. Zhao, E. Heusler, G. Jones, L. Li, V. Werner, O. Germershaus, J. Ritzer, T. Luehmann, L. Meinel; **Decoration of silk fibroin by click chemistry for biomedical application**, *Journal of Structural Biology*, 186 (2014) 420-430.

A.B. Faia-Torres, S. Guimond-Lischer, M. Rottmar, M. Charnley, T. Goren, K. Maniura-Weber, N.D. Spencer, R.L. Reis, M. Textor, N.M. Neves; **Differential regulation of osteogenic differentiation of stem cells on surface roughness gradients**, *Biomaterials*, 35 (2014) 9023-9032.

H.F. Krug; **Nanosafety Research: Are we on the right track?**, *Angewandte Chemie International Edition*, 53 (2014) 12304-12319.

M. Roesslein, J.T. Elliott, M.L. Salit, E.J. Petersen, C. Hirsch, H.F. Krug, P. Wick; **The use of cause-and-effect analysis to design a high quality nanocytotoxicology assay**, *Chemical Research in Toxicology*, 28 (2015) 21-30.

D. Bernoulli; **Cohesive and adhesive failure and contact damage of Diamond-Like Carbon (DLC) Coated Titanium Substrates**, *Dissertation ETH Zurich*, No. 22395 (2014).

D. Muff; **Development of mechanically robust esthetic coating systems for dental implants**, *Dissertation ETH Zurich*, No. 22348 (2014).

C. Pecnik; **Esthetics and reliability of thin films for dental implants**, *Dissertation ETH Zurich*, No. 22399 (2014).

## SPERU

M.P.H. Böttger, L. Braginsky, V. Shklover, E. Lewin, J. Patscheider, D.G. Cahill, M. Sobiech; **Hard wear-resistant coatings with anisotropic thermal conductivity**, *Journal of Applied Physics*, 116 (2014) 013507.

P. Michael, H. Böttger, A.V. Gusarov, V. Shklover, J. Patscheider, M. Sobiech; **Anisotropic layered media with microinclusions: Thermal properties of arc-evaporation multilayer metal nitrides**, *International Journal of Thermal Sciences*, 77 (2014) 75-83.

## Analytical Platform

C. Kottler, R. Longtin, S. Giudice, S. Jose-James, R. Niedermann, P.A. Neels, R. Kaufmann, J.R. Sanchez-Valencia, H.R. Elsener, O. Gröning, C. Leinenbach, P.A. Gröning, A. Dommann; **X-ray source down-scaling enabled by combining microfabricated electrodes with carbon nanotube cold electron emitters**, *Microelectronic Engineering*, 122 (2014) 13-19.

V. Achterberg, L. Buscemi, H. Diekmann, J. Smith-Clerc, H. Schwengler, H. Lenz, J.-J. Meister, H. Wenck, S. Gallinat, B. Hinz; **The nano-scale mechanical properties of the extracellular matrix regulate dermal fibroblast function**, *Journal of Investigative Dermatology*, 134 (2014) 1862-1872.

L. Bernard, J. Heier, W. Paul, H.J. Hug; **The SFM/ToF-SIMS combination for advanced chemically-resolved analysis at the nanoscale**, *Nuclear Instruments & Methods in Physics Research Section B-Beam Interactions with Materials and Atoms*, 339 (2014) 85-90.

S. dos Santos, M.N. Partl, L.D. Poulikakos; **Newly observed effects of water on the microstructures of bitumen surface**, *Construction and Building Materials*, 71 (2014) 618-627.

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Ch. Karageorgaki, D. Passerone, K.H. Ernst; **Chiral reconstruction of Cu(110) after adsorption of fumaric acid**, *Surface Science*, 629 (2014) 75-80.

J. Prinz, R. Gaspari, Q.S. Stöckl, P. Gille, M. Armbrüster, H. Brune, O. Gröning, C.A. Pignedoli, D. Passerone, R. Widmer; **Ensemble effect Evidenced by CO Adsorption on the 3-Fold PdGa Surfaces**, *The Journal of Physical Chemistry C*, 118 (2014) 12260-12265.

D. J. Adams, S. Chappellet, F. Lincker, M. Ibn-Elhaj, B. Watts, M. Iannuzzi, D. Šišak Jung, C. A. Pignedoli, D. Passerone; **Identifying Photoreaction Products**



# 2014 Peer Reviewed Publications [continued]

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## Pietro Gambardella

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## Fabien Sorin

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# Research Activities Ongoing in 2014

PROJECT	PRINCIPAL INVESTIGATOR (PI)	PI'S INSTITUTION	OTHER INSTITUTIONS	ERU/PLATFORM
Microtome4SIMS: Chemical tomography of biological material with 100 nm resolution	Beat Keller	Empa	Unispital Basel	NMMC
Colored ceramic surfaces for metallic dental implants and prosthetic appliances	Ralph Spolenak	ETH Zurich	Empa, UZH	MatLife
Structural evolution and rheological properties in gel carrier	Christopher Plummer	EPFL	ETH Zurich	MatLife
Low wear articulating implants employing DLC coatings on CoCrMo and TiAlNb with predictable, long-lasting coating adhesion lifetime	Roland Hauert	Empa	ETH Zurich	MatLife
Fibroblast Growth Factor 2 delivery for tissue repair: From Natural Concepts to Engineered Systems	Viola Vogel	ETH Zurich	PSI	MatLife
Liquid repellent wear resistant coatings (LIRE-WERE-CO)	Patrik Hoffmann	Empa	EPFL	SPERU
Serrulane-based antimicrobial surface platforms	Harm-Anton Klok	EPFL	ETH Zurich, Unispital Basel	MatLife
VIGO: A new evaluation tool for determination, description, and comparison of the biological effects of nanoparticles / nanomaterials	Harald Krug	Empa	EPFL	MatLife
Measurements and modelling of residual stresses in aluminium components in relation to their microstructure	Jean-Marie Drezet	EPFL	PSI	MERU
Arc erosion processes in contact materials: modelling and model experiments	Ralph Spolenak	ETH Zurich	Empa	MERU
Protective coatings with managed thermal conductivity for machining difficult-to-cut materials	Valery Shklover	ETH Zurich	Empa	SPERU
OMNY (tOMography, Nano, crYo stage)	Mirko Holler	PSI	CSEM (until 2012)	NMMC
Development of a He-Ion Beam Induced Charge scanning system (He-IBIC)	Urs Sennhauser	Empa	ETH Zurich	NMMC
Ultrasensitive sensing transducer based on Fano interferences in plasmonic metamaterials—FANONSENSE	Olivier Martin	EPFL	CSEM	NMMC
Gantry-based X-ray Phase Contrast Scanner for MicroCT Applications	Marco Stampanoni	PSI	ETH Zurich, CSEM	NMMC
NanoAir – Online coupling of a scanning mobility particle sizer SMPS to an inductively coupled plasma mass spectrometer ICP-MS for size fractionated, elemental analysis of nanoparticles in aerosols	Heinz Vonmont	Empa	EPFL, PSI, FHNW	NMMC
Argon-cluster as primary ion source in time-of-flight secondary ion mass spectrometry (ToF-SIMS)—method development by ToF-SIMS and Atomic Force Microscopy (AFM)	Laetitia Bernard	Empa		NMMC
QuadProbe FIB—an analytical FIBSEM microscope integrating ion, electron, X-ray, and laser beams for microanalysis in materials research	Johann Michler	Empa		NMMC
Neutron Microscope	Eberhard Lehmann	PSI		NMMC
Inductively coupled Plasma Focused Ion Beam (PFIB) system at ETH Zurich	Roger Wepf	ETH Zurich		NMMC
MATERIALS CHALLENGE	PRINCIPAL INVESTIGATOR (PI)	PI'S INSTITUTION	OTHER INSTITUTIONS	
NanoScreen: Reliable and rapid <i>in vitro</i> safety assessment of nanomaterials	Peter Wick	Empa	EPFL	



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