Performance Report 2012 | 2013 | 2014

Institute for Electron Microscopy and Nanoanalysis
Graz University of Technology

Graz Centre for Electron Microscopy
ACR Austrian Cooperative Research

TU Graz

ACR
AUSTRIAN COOPERATIVE RESEARCH
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FELMI-ZFE

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Cover Image

HR-STEM investigation of beryl (aquamarin) by
Christian Gspan
ASTEM with a 1Å probe at 300 kV
HAADF image viewed in [0001] direction
Specimen preparation by M. Paller: PIPS milling

Content

Statement from the Dean of Graz University of Technology

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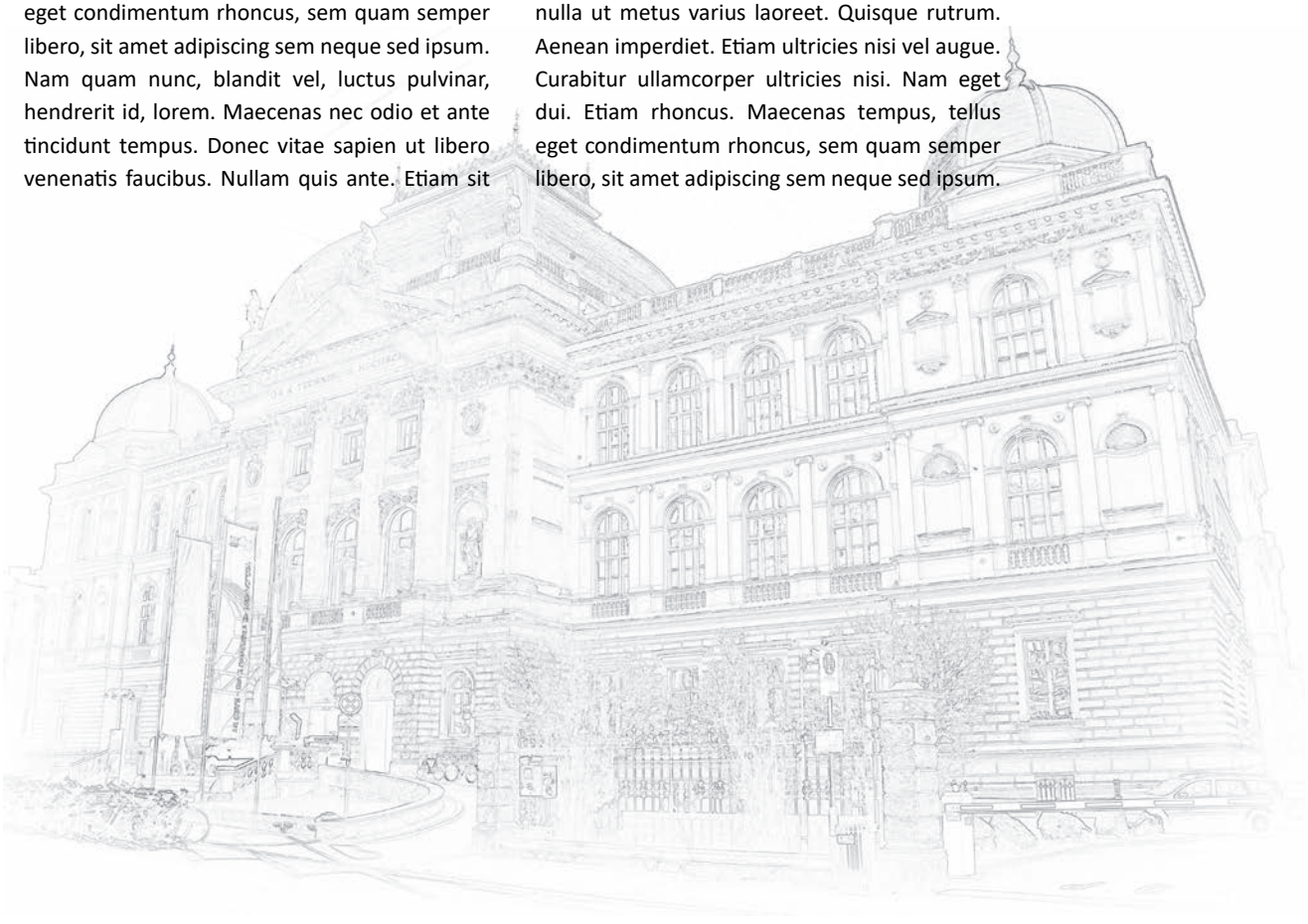


Making Progress – Step by Step

Ferdinand Hofer

The Institute looks back at three years of growth and success. Together (alongside) with a steadily growing number of bachelor, master and PhD students we could significantly increase the number and impact of our publications. Furthermore, international collaborations have also increased over the past three years.

A major step was the definition of four main research fields which rely on already existing scientific expertise and will be enforced in the years to come: *nanoanalysis of materials, functional nanofabrication, 3D and* in situ *characterisation, soft matter and biomicroscopy.*

These fields can only flourish if, as happened, the research infrastructure is also renewed and considerably improved. In 2011 we installed the Austrian Scanning Transmission Electron Microscope (ASTEM), one of the best microscopes in the world. However, it was necessary to complement the ASTEM with special specimen holders and improved specimen preparation facilities. Additionally, new scientific instruments have been installed such as an advanced infrared microscope and a leading-edge atomic force microscope (AFM).

The double task of research and teaching in world-class microscopy is an ambitious enterprise – impossible without research funding. Applications on a European scale (ESTEEM2 and Triple-S projects) have been successful as well as projects to be realised on a national level (in the NAWI faculty of the Graz Universities and with the University of Linz).

Instruments critical to materials research are becoming extremely expensive so that resources must be concentrated to manage them in midsize multiuser facilities (midsize facilities). Thanks to the close alliance of the FELMI with the ZFE, we are a typical example of a midsize facility with cutting-edge instrumentation, teaching, training and service. Thus the Institute plays a pivotal role fostering materials research in Central Europe.

I am very grateful to all who have contributed to these achievements, particularly to the hard-working colleagues at the Institute. I thank the Rector of the Graz University of Technology, Harald Kainz, as well as the Dean of the Faculty of Mathematics, Physics and Geodesy, Wolfgang Ernst, for their continuous support and last but not least Martin Leitl, president of the Austrian Cooperative Research (ACR), and the ACR managing director Johann Jäger.

A National Resource

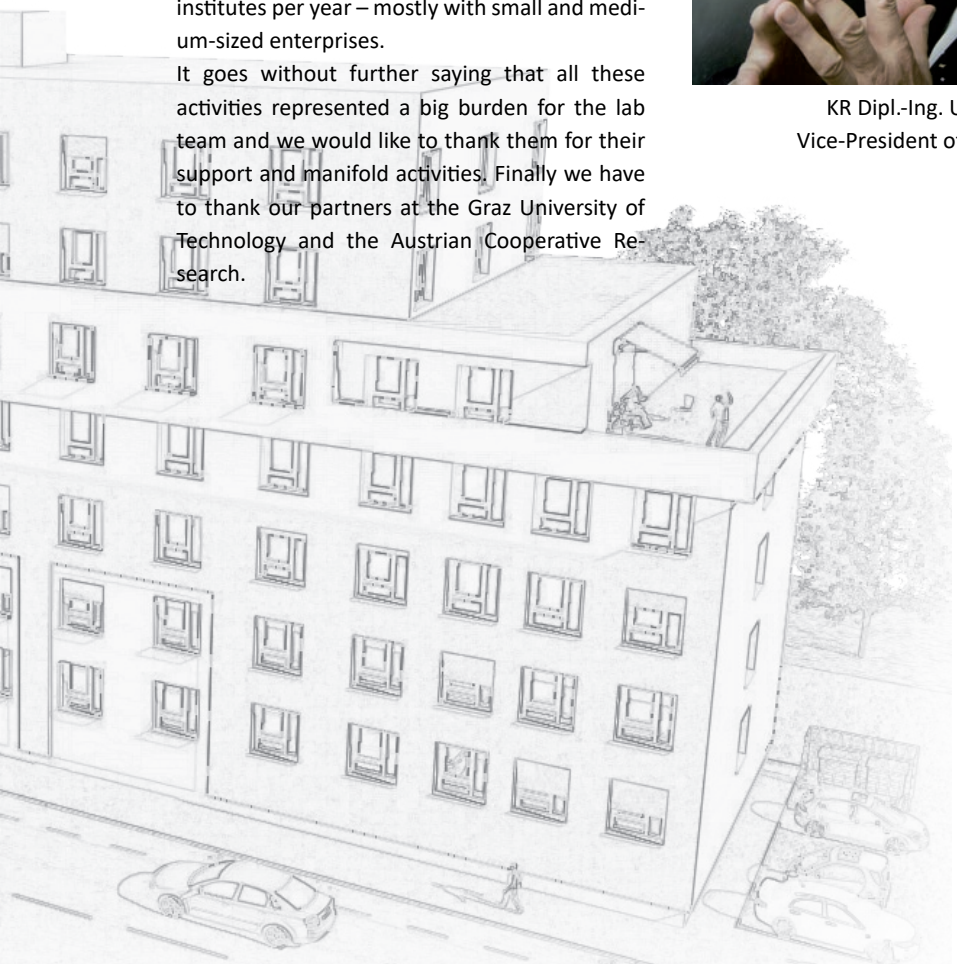
This performance report describes the transition period triggered by the installation of the ASTEM microscope – one of the most powerful electron microscopes in the world, a landmark in Austrian research. The realisation of this project was a major challenge; nevertheless it was absolutely necessary for the further development of the Institute within the European research area. In the meanwhile, the ASTEM serves as a main national resource for both: academic research and special industries in Austria. It plays a major role in the characterisation of advanced materials at the atomic scale; crucial research projects with semiconductor, ceramic, steel and automotive industries demonstrate its great impact.

With this step the Graz Centre for Electron Microscopy (ZFE) has become the leading research institution in the field of advanced materials microscopy in Austria. Collaborations with various industrial branches and the support of their needs are a main focus of the ZFE and therefore we proudly report that our experienced staff cooperates with more than 120 companies and institutes per year – mostly with small and medium-sized enterprises.

It goes without further saying that all these activities represented a big burden for the lab team and we would like to thank them for their support and manifold activities. Finally we have to thank our partners at the Graz University of Technology and the Austrian Cooperative Research.

Prof. Dipl.-Ing. Dr.-Ing.h.c. Helmut List
President of the Association

KR Dipl.-Ing. Ulrich Santner
Vice-President of the Association



The Institute

Our Institute

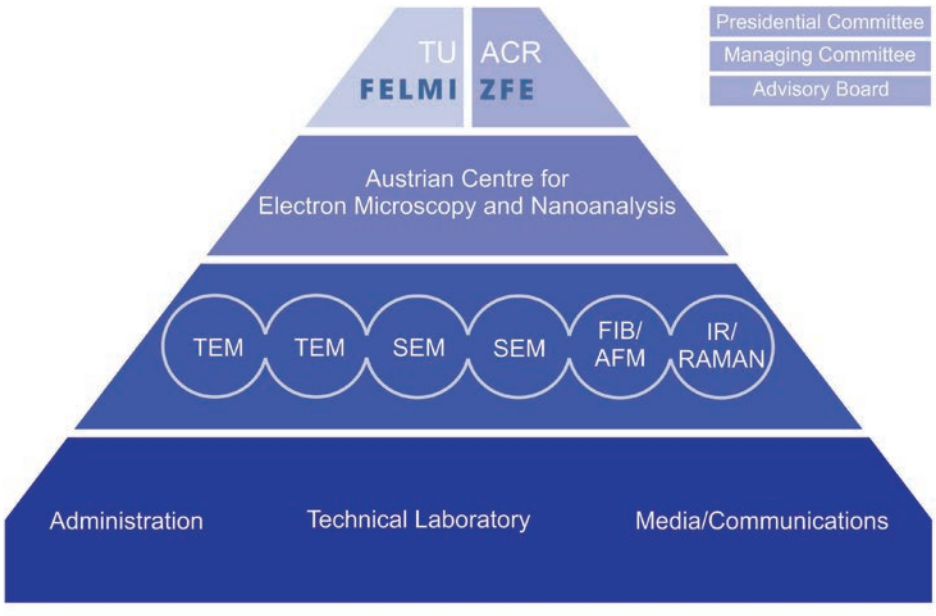
The Institute at a Glance

The Institute concentrates on research and teaching in the fields of physics, materials science, micro- and nanotechnology. Since the fifties of the last century, the Institute has been built on two main columns:

- the **Institute for Electron Microscopy and Nanoanalysis** (FELMI) at the Faculty of Mathematics, Physics and Geodesy.
- the **Graz Centre for Electron Microscopy** (ZFE), a member of Austrian Cooperative Research (ACR).

Having their own legal status and budget, both institutes work in close alliance to ensure efficient use of personnel and instrumental resources. The Institute is located in the heart of Graz, on the campus of the Graz University of Technology. It is organised in research groups focusing on crucial aspects of microscopy or significant materials classes.

The Institute in the building Steyrergasse 17 is located on the 2nd and 3rd floor.



Our Organisational Structure

Research Focus

We have wide-ranging, comprehensive and exciting research activities. Our research is carried out under a broad scope of challenging themes from fundamental to applied sciences and contractual projects with Austrian and European companies. Major areas of research are the micro- and nanoanalysis of materials, electronic devices and biomaterials.

Our Institute brings together

- well-accepted laboratory methods,
- cutting-edge instrumentation and
- advanced research skills.

We study fundamental scientific problems and transfer the acquired knowledge and capabilities into practical collaborations with other university institutes and special industries – with a clear focus on small and medium-sized enterprises. However, the spectacular developments of the Institute's research groups rely on an increasing number of high level research projects supported by European and Austrian funding organisations.

We specialise in research relevant to life. Our multi-disciplinary team of scientists aims to achieve the highest standards and conducts research in four main areas. Their projects are to be described in detail in chapter 2 of this report:

- Nanoanalysis of materials
- Functional nanofabrication
- 3D and *in situ* characterisation
- Soft matter and biomicroscopy

A History of Excellence

We support excellence in teaching and research for more than 50 years. Our unique position is based on our leading-edge equipment ranging from the latest light and electron microscopes to high performance computing hardware. This, combined with the ambition of our staff, makes us the Austrian powerhouse of electron microscopy.

On this basis we are endeavouring to develop new microscopy methods and to improve special preparation techniques, which are especially used for materials and life sciences to characterise all kinds of materials and to provide efficient answers and solutions to scientific and industrial problems.

We have established and strong links with research partners and special industries which is reflected by the fact that development of personnel is increasingly influenced by funded research projects and contractual research.

Collaborations

Each year we have been collaborating on average with around 30 university institutes and more than 120 companies – mainly from Austria, but increasingly also from other European countries. Two main directions are being followed during recent years:
Firstly, collaborations within the *ACR group* which are developing well and secondly, the incorporation into important European research networks such as the *STREP project "CopPeR",* the *ENIAC initiative* or the *ESTEEM2 project*.

Being an interdisciplinary research institute we are constantly creating new knowledge and methods. We believe that it is not only our responsibility to support knowledge creation but also to share generated know-how and expertise with others: each year we welcome some 300 visitors from other research groups and companies. During the last three years 133 master and PhD students from other institutions have benefited from our scientific and technical support.

Europe

Belgium
University of Antwerp, Antwerp
France
Université Paris Sud, Orsay
CEMES-CNRS, Toulouse
Germany
Martin-Luther-University, Halle-Wittenberg
Goethe University, Frankfurt a. M.
Jülich Research Centre, Jülich
Fritz-Haber-Institute (MPG), Berlin
Hungary
Academy of Sciences, Budapest
Italy
Politecnico di Milano, Milano
Poland
AGH University of Science and Technology, Kraków
Slovenia
University of Maribor, Maribor
Institute Jožef Stefan, Ljubljana
Spain
Insituto de Cienca de Materiales, Sevilla
Sweden
Chalmers University of Technology, Gothenburg
Switzerland
EMPA, Dübendorf
École Polytechnique Fédérale de Lausanne, Lausanne
The Netherlands
Delft University of Technology, Delft
Turkey
Sabancy University, Istanbul
United Kingdom
University of Oxford, Oxford

America

USA
Gatan Inc., Pleasanton
Lehigh University, Bethlehem
The University of Tennessee, Knoxville

Asia

Japan
Okinawa Institute of Technology, Okinawa
United Arab Emirates
The Petroleum Institute, Abu Dhabi

Australia

University of Melbourne, Melbourne
ESEM Research Laboratory, North Bondi

Research Expert for Austrian SMEs

For around sixty years the Institute has supported Austrian companies in their innovation process. We have made a considerable contribution to the competitiveness of the Austrian economy thanks to numerous projects and temporary activities.

The strengths of the Institute is our research and development competence with excellent links to the academic and business world, strong and flexible research groups in close contact with SMEs and expert knowledge of the national and international funding landscape. Please find a list of our company members of the association on the next page!

MITGLIEDER
DES VEREINS ZUR FÖRDERUNG DER ELEKTRONENMIKROSKOPIE UND FEINSTUKTURFORSCHUNG

- Alicona Imaging GmbH, Grambach
- Allnex, Graz
- ams AG, Unterpremstätten
- AT&S AG, Leoben
- AVL List GmbH, Graz
- BÖHLER Edelstahl GmbH & Co KG, Kapfenberg
- Borealis Polyolefine GmbH, Linz
- Brigl & Bergmeister GmbH, Niklasdorf
- CERATIZIT Austria GmbH, Reutte
- Chemson Polymer Additive AG, Arnoldstein
- Constantia Teich GmbH, Weinburg
- Durst Phototechnik Digital Technology GmbH, Lienz
- EPCOS OHG, Deutschlandsberg
- Fresenius Kabi Austria, Graz
- Gatan GmbH, München, Deutschland
- IBIDEN Porzellanfabrik Frauenthal GmbH, Frauenthal
- Industriellenvereinigung Steiermark, Graz
- Infineon Technologies Austria AG, Villach
- Ingenieurbüro für Kunststofftechnik, Spielberg
- Joanneum Research GmbH, Graz
- Karl Franzens Universität Graz
- LAM Research AG, Villach
- Montanuniversität, Leoben
- MSG Mechatronic Systems GmbH, Wies
- Omya Development AG, Oftringen, Schweiz
- Omya GmbH, Gummern
- Papierfabrik Wattens GmbH, Wattens
- Plansee SE, Reutte
- Plasmait IT GmbH, Lebring
- Semperit TP GmbH & Co KG, Wimpassing
- Technische Universität Graz
- Treibacher Industrie GmbH, Treibach
- Vishay BCcomponents Austria GmbH, Klagenfurt
- Voith Paper Rolls GmbH & Co KG, Wimpassing
- Wirtschaftskammer Steiermark, Sparte Industrie, Graz

FELMI-ZFE

Stand Juni 2014

Austrian Cooperative Research (ACR)

Mihaela Albu received the ACR Woman Award 2014. Being expert in analytical electron microscopy of materials, she analysis high-tech steels and magnesium and/or aluminum-silicon alloys to be used in domestic, military, automotive, and aerospace components. She is focusing on the improvement of mecanical properties; in the concequence of her efforts a number of different chromium rich steels and aluminum based alloys have already been upgraded.

In cooperation with Vivamed **Harald Plank** and his team developed a new class of high-strength allogenic screws fully absorbable by the bone material of the receiving patient. The screws are prepared from human femur corticalis in a special screw design after an optimised selection process for fixation purposes in clinical applications. This achievement has been honored with the ACR Cooperation Award 2012.

The ZFE Graz is a member of the "Austrian Cooperative Research" (ACR) organisation. For more than 60 years ACR has been supporting Austrian SMEs in their innovation process offering specialized research and technology expertise. ACR stimulates and enables innovation within trade and industry thus improving the competitiveness of the Austrian economy.

The strengths of ACR-members:

- Applied research, development and innovation
- Technology and know-how transfer
- Project management for R&D projects
- Efficient funding advice
- High-grade testing and measuring accredited at EU level
- Certification and audits
- Training courses, expert seminars, company events

Currently, ACR has 19 full members. In 2014 the full members with a total of more than 700 employees generated a turnover of EUR 58.8 million. The network performed 75% of their services for SMEs.

The ZFE Graz cooperates with the following ACR institutes:

Austrian Foundry Institute (ÖGI), Leoben
Austrian Research Institute for Chemistry and Technology (OFI), Vienna
Austrian Institute of Material Science and Welding Technology (SZA), Vienna
Holzforschung Austria (HFA), Vienna
V-Research, Dornbirn

AUSTRIAN COOPERATIVE RESEARCH
KOOPERATION MIT KOMPETENZ

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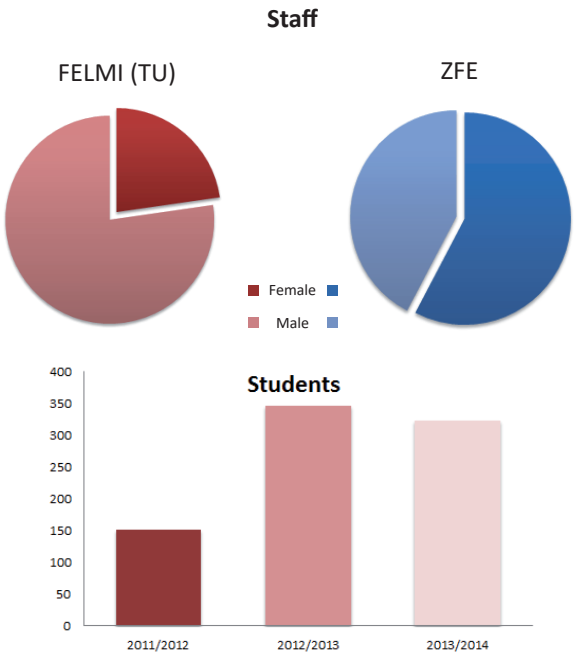
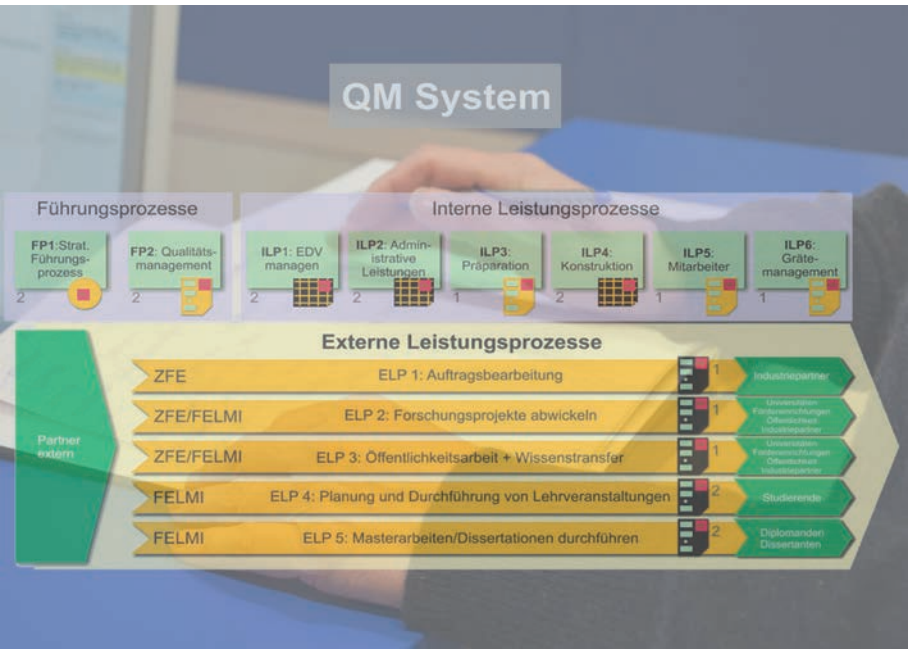


The Institute in Figures

We seek to foster and sustain a creative and supportive working environment based upon an ethos of respect and rigorous scientific enquiry. We value the diversity of our staff and student population and want to promote equality as an essential element.

The number of scientists has increased, a factor which is helping to expand the expertise into new research areas, e.g. cryo-microscopy and atomic resolution microscopy. Since we are also hosting more and more master students the space pressure we are facing remains very tight.



Quality Assurance

The Institute works under an advanced quality management system according to the rules of EN ISO 900. The aim is to maintain the outstanding quality of our work and analysis results and to improve continuously our organisation and management structures. Following the successful audits performed by TÜV Austria, the Institute was awarded the EN ISO 9001 certificate which is valid until May 2015.

TÜV AUSTRIA
MANAGEMENTSYSTEM ZERTIFIZIERT
TÜV AUSTRIA CERT GMBH

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ikat Nr. 20 100 4200
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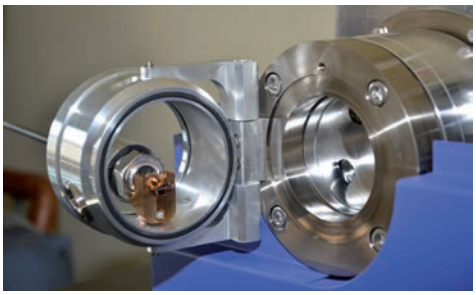
New Laboratory Facilities

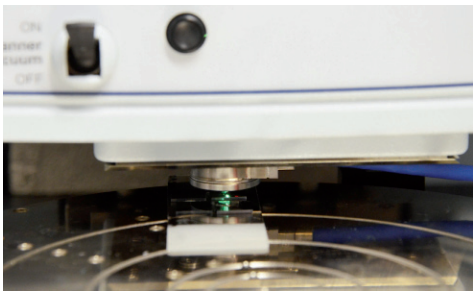
NanoMill

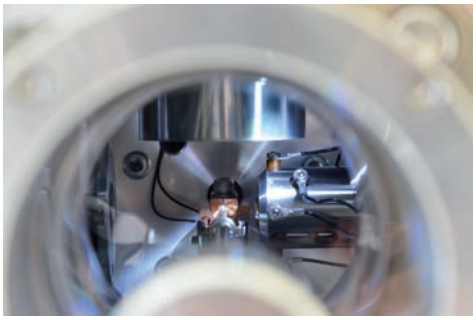
The NanoMill TEM specimen preparation system is our new tool for creating high-quality thin specimens needed for advanced transmission electron microscopy imaging and analysis. It is ideally suited for both post-FIB processing and the enhancement of conventionally prepared specimens. The NanoMill allows specimens to be prepared without amorphization, implantation or redeposition.

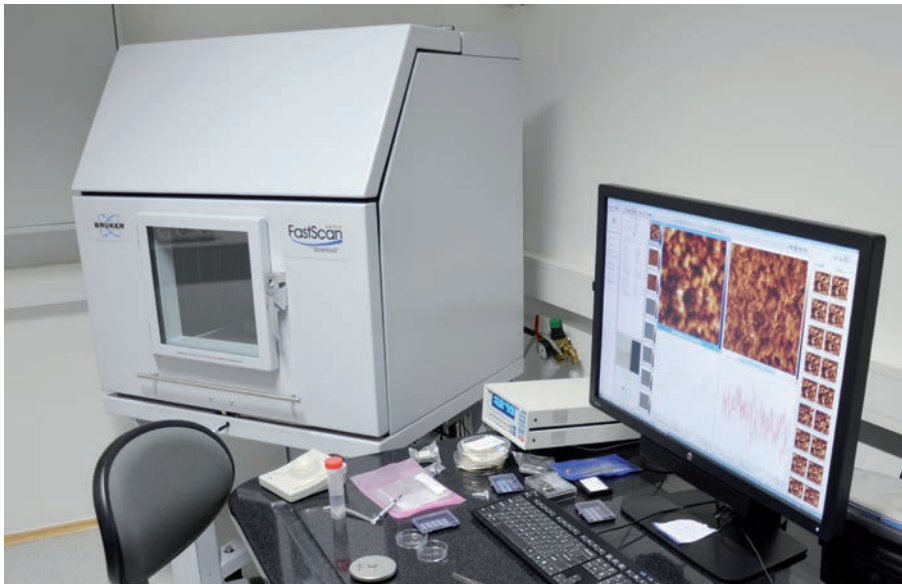
Bio-AFM

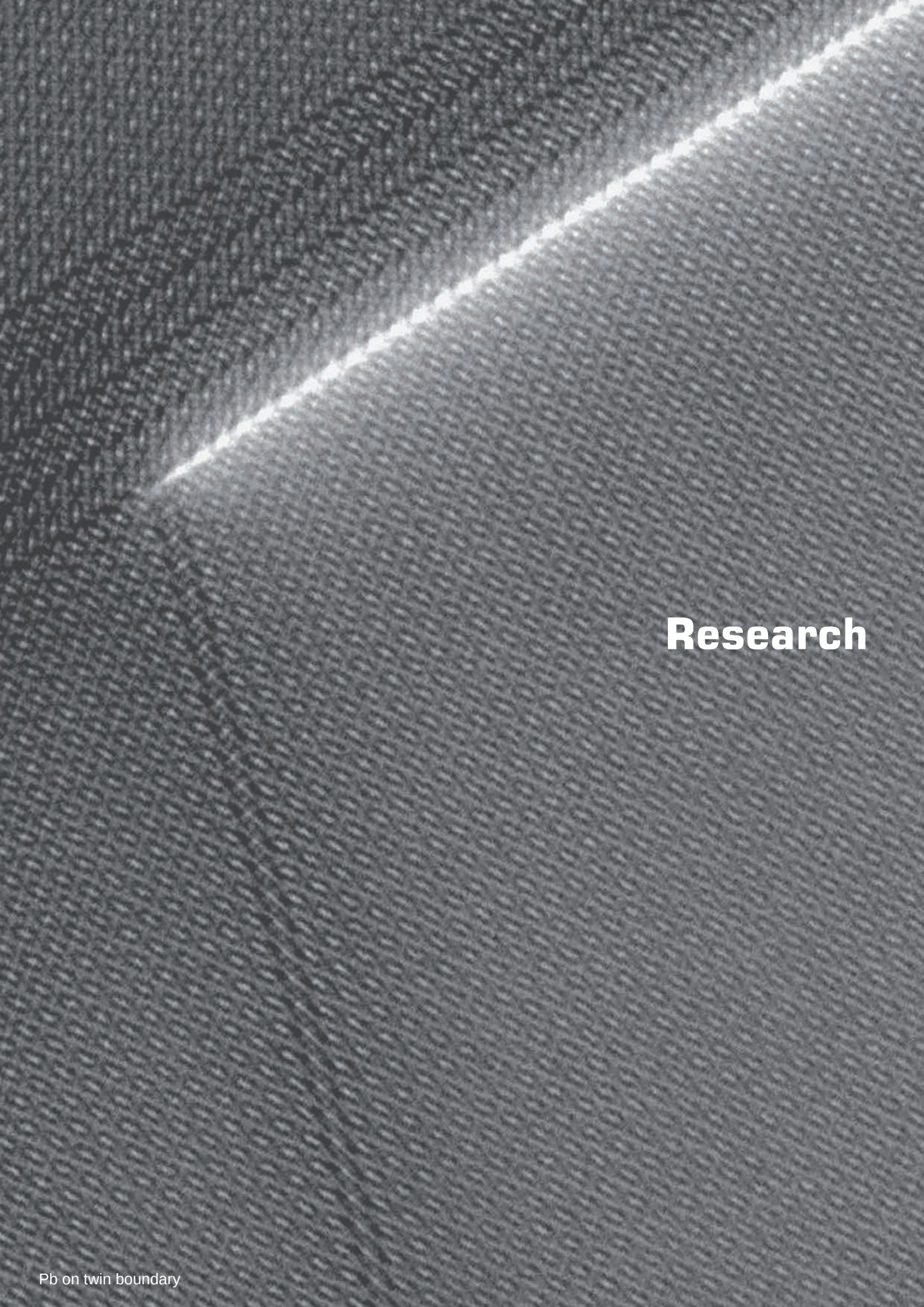
The Dimension FastScan Bio™ Atomic Force Microscope provides routine high-resolution research of biological dynamics, with temporal resolution up to 3 frames per second for live sample observations. Thanks to these high scan rates we are able to observe and study the mechanisms of biological functions in natural environments. The observation of molecules, proteins, DNA, RNA, living cell membranes, and tissues, and many other dynamics studies are possible. (Supported by the Faculty of Technical Chemistry, Chemical & Process Engineering and Biotechnology)











Research

Pb on twin boundary

Research Highlights

As already mentioned in chapter 1 our six research groups concentrate their activities on four main fields. Please find on the following pages some general introduction followed by selected research highlights of the past three years and presentations of the groups.

1. Nanoanalysis of Materials

The ability of modern transmission electron microscopes to investigate solids at atomic resolution has led to a tremendous progress in materials science. With the basis of a monochromated transmission electron microscope (TEM) and an atomic resolution STEM (ASTEM), the groups of Werner Grogger, Gerald Kothleitner and Ferdinand Hofer concentrate on the development of nanoanalytical methods using EELS and EDXS. These advanced methods are used to explore the structure of materials and devices as diverse as transistors, turbine blades and biomaterials.

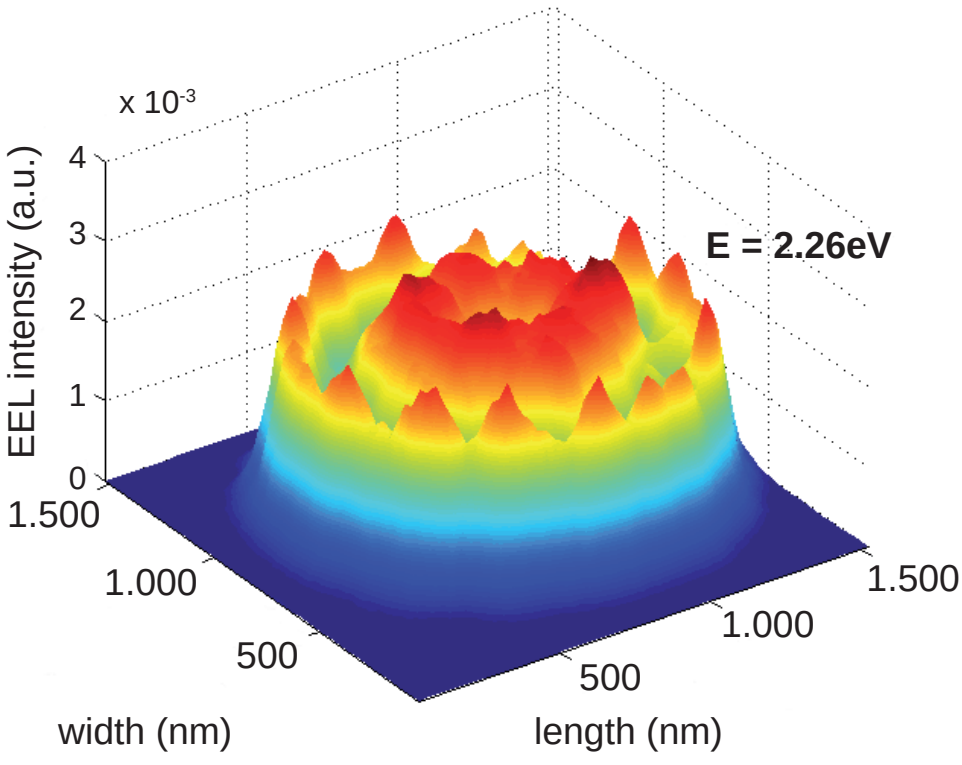


Figure Localized surface plasmon of a 30 nm thick silver nanodisk with a diameter of 500 nm. The disk was prepared by electron beam lithography and the plasmon signal was resolved by electron energy loss spectroscopy in a monochromated transmission electron microscope.

Quantitative EDXS Analysis of Organic Materials using the ζ-factor Method

S. Fladischer, W. Grogger

Ultramicroscopy
136C, (2014), 26–36

Energy dispersive X-ray spectrometry (EDXS) is a very important analytical technique in transmission electron microscopy (TEM). Although this technique is fairly easy to use and quantitative analysis seems simple it might be a challenging task to obtain reliable, accurate quantitative results. Since 40 years the Cliff-Lorimer method is well-established and widely used for the quantification of EDX spectra of thin samples. However, the quantitative analysis of light elements is still challenging due to low X-ray generation rates and absorption effects of low energetic X-rays.
In this work we use the ζ-factor method with its built in X-ray absorption correction for quantitative analyses of specimens containing light elements. We describe in detail the process of determining sensitivity factors (ζ-factors) using a single standard specimen and the involved parameter optimisation for the estimation of ζ-factors for elements not contained in the standard. The ζ-factor method is then successfully applied to the quantitative analysis of organic semiconducting materials frequently used in organic electronics, which – to the best of our knowledge – has not been done before. The accuracy of the quantitative analysis and the good performance of the ζ-factor method could be confirmed. Based on this work we established the ζ-factor method as the standard quantitative tool in our TEM lab for determining the chemical composition of a sample on a nanometer length scale.

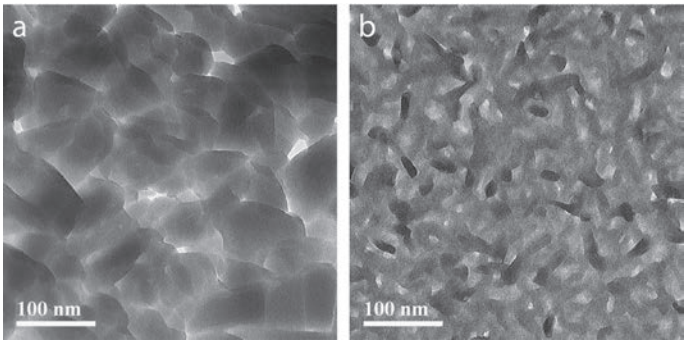


Figure 1 TEM Bright-field images(zero-loss filtered) of (a)CuPcand(b)PTCBi.

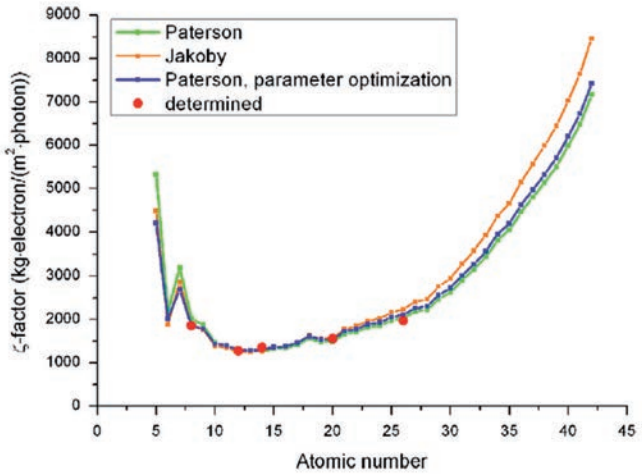


Figure 2 Estimated ζ-factors of K lines plotted against the atomic number for different ionization cross-sections (Paterson (green line), Jakoby (orange line)), with parameter optimization (Paterson (blue line)) and the directly determined ζ-factors (red dots).

Quantitative Elemental Mapping at Atomic Resolution Using X-Ray Spectroscopy

Physical Review Letters 112 (2014), 085501

G. Kothleitner, M. J. Neish, N. R. Lugg, S. D. Findlay, W. Grogger, F. Hofer, L. J. Allen

Elemental mapping using energy-dispersive x-ray spectroscopy in scanning transmission electron microscopy is a well-established technique for precision elemental concentration analysis at submicron resolution. In 2010 it was first demonstrated at atomic resolution. However, to date atomic resolution elemental maps have only been interpreted qualitatively. On the one hand the elastic and thermal scattering of the electron probe confounds quantitative analysis, on the other hand, the procedures for an accurate elemental quantification on an atomic scale were non-existent. Accounting for this scattering, and using novel quantification schemes, this paper describes absolute scale quantitative comparisons between experiment and quantum mechanical calculations for both energy dispersive x-ray and electron energy-loss spectroscopy.

The test vehicle was a single crystal $SrTiO_3$ specimen, viewed in the [001] orientation. Since the structure of $SrTiO_3$ is known, the proportionality factors between the true atomic number density and the measured signals could be determined and a quantitative analysis was performed. It was shown that over the full image, scattering effects and delocalisation of the particular ionisation edge have produced apparent number densities either larger or smaller than the nominal values. Contributions from the vicinity of the Sr columns, Ti/O columns, and O columns were also analysed, using the masks whose size was guided by simulations. The spatial concentration variation was also rather revealing since there was a substantial contribution to all signals from atomic columns which did not contain the element in question.

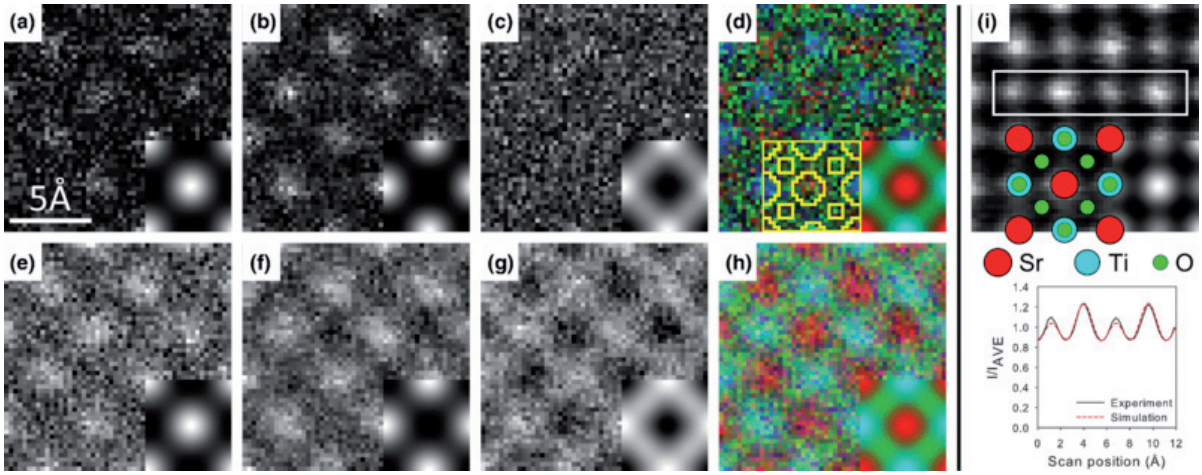
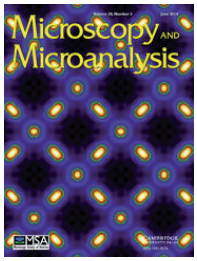


Figure Experimental atomic resolution EDX elemental maps for the [**001**] direction in **$SrTiO_3$** for the (a) Sr ***K*** shell, (b) Ti ***K*** shell, (c) O ***K*** shell, and (d) color composite (Sr red, Ti blue, O green). Overlaid on (d) are the mask areas over which the signal will be integrated. Simultaneously acquired EELS maps for the (e) Sr $L_{2,3}$ edge, (f) Ti $L_{2,3}$ edge, (g) O K edge, and (h) color composite. (i) Simultaneously acquired HAADF image, with the projected averaged linescan over the boxed region shown below. Simulations, assuming a Gaussian incoherent effective source with a HWHM of 0.8 Å, are inset in each figure.

Linking TEM Analytical Spectroscopies for an Assumptionless Compositional Analysis

G. Kothleitner, W. Grogger, M. Dienstleder, F. Hofer



Microscopy and Microanalysis 20 (2014), 678

The classical implementation to put quantitative figures on maps in order to reveal elemental compositions in transmission electron microscopy is by analytical methods like X-ray and energy-loss spectroscopy. Typically, the technique in use often depends on whether lighter or heavier elements are present and more practically which calibrations are available or witch sample-related properties are known. A framework linking electron energy-loss spectroscopy (EELS) and energy-dispersive X-ray (EDX) signals such that absolute volumetric concentrations can be derived without assumptions made *a priori* about the unknown sample, is largely missing. In order to combine both techniques and harness their respective potentials for a light and heavy element analysis, we have set up a powerful hardware configuration and implemented an experimental approach, which reduces the need for estimates on many parameters needed for quantitative work such as densities, absolute thicknesses, theoretical ionisation cross-sections, etc. Calibrations on specimens with known geometry allow the measurement of inelastic mean free paths. As a consequence, mass-thicknesses obtained from the EDX ζ-factor approach can be broken up and quantities like concentrations and partial energy-differential ionisation cross-sections become accessible. ζ-factors can then be used for conversion into EELS cross-sections that are hard to determine otherwise, or conversely, connecting EDXS and EELS in a quantitative manner quite effectively.

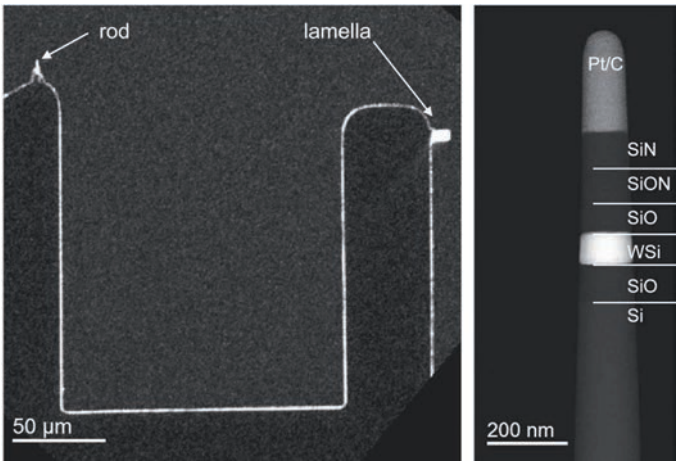


Figure 1 (left): Focused ion beam preparation of a conically shaped transmission electron microscope (TEM) specimen rod for thickness calibrations; (right): On the right side of the TEM grid the lamella is visible that was used for subsequent quantitative analysis. The milled cone has a thickness of < 150 nm and shows different binary phases also containing light elements.

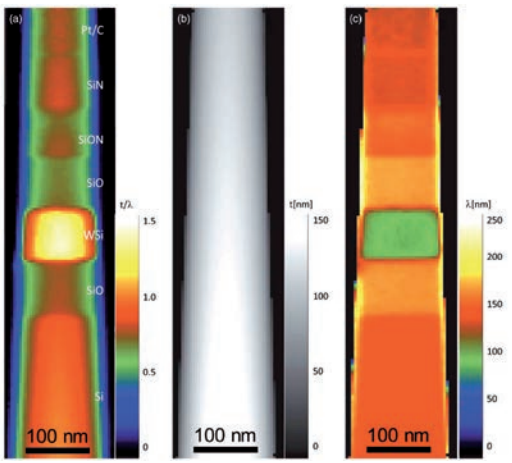


Figure 2 Relative thickness map (t/λ) (a), and model of the thickness of the focused ion beam milled cone (b). The inverse of (a) multiplied by (b) yields a map displaying the inelastic mean free paths λ of the sample, used for further thickness calibrations (c).

Three Dimensional Quantitative Characterization of Magnetite Nanoparticles Embedded in Mesoporous Silicon

Nanoscale 5 (2013), 11944

T. Uusimäki, G. Margaris, K. Trohidou, P. Granitzer, K. Rumpf, M. Sezen, G. Kothleitner

Porous silicon (pSi), a versatile material achieved by nano-structuring of a silicon wafer, is employed in various fields such as in sensors, photovoltaics, energetic materials, and biomedicine. Due to the tunable size and the growth mechanism of the pores, as well as their quasi-regular arrangement, pSi is often used as a template for the deposition of molecules or nano-particles. In the case of magnetite nanoparticle infiltration into the pores, the resulting material constitutes an interesting system, as magnetic properties can be tuned by the particle-size and their distance between each other. In this work we have shown that electron tomography has the power to reveal three dimensional quantitative, magnetic information on the nanoparticle assemblies. In particular we were able to calculate the demagnetizing factors and the direction of the shape anisotropy easy axis for every particle. The demagnetizing factors, along with the knowledge of spatial and volume distribution of the superparamagnetic nanoparticles, were used as a model for magnetic Monte Carlo simulations, yielding zero field cooling/field cooling and magnetic hysteresis curves, which were compared to the measured ones. Additionally, the local curvature of the magnetite particles' docking site within the mesoporous silicon's surface could be obtained, giving a comprehensive picture of the spatial and magnetic circumstances of this material.

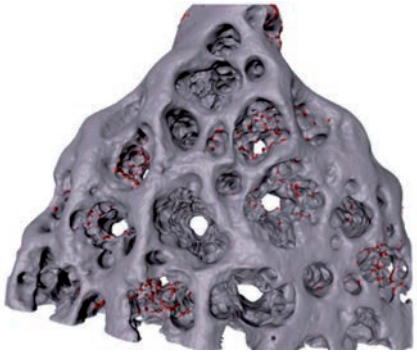


Figure 1 Triangulated surface of the whole reconstruction (red: Fe_3O_4, grey: Si).

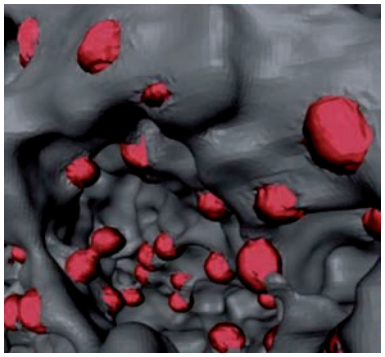


Figure 2 Triangulated mesh of the magnetite particles (red) in one pore. (pSi: grey).

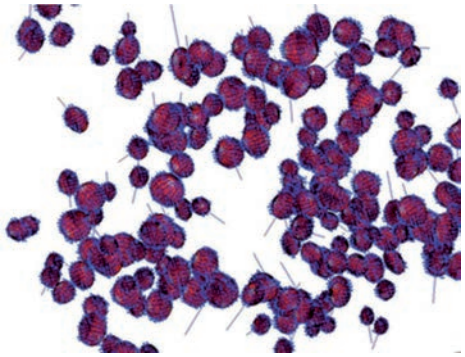
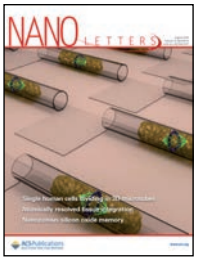


Figure 3 Fitted ellipsoids (red). Blue points are from the mesh of the generated surface of the particles and the lines are the directions of the shape anisotropy easy axis. The length of the line is the inverse of DF.

Morphing a Plasmonic Nanodisk into a Nanotriangle

F. Schmidt, H. Dittlbacher, F. Hofer, J.R. Krenn, U. Hohenester



Nano Letter 14(8)
(2014), 4810–4815

Metallic nanostructures and their extraordinary optical properties have become of great interest in the last two decades. Their ability to concentrate light into areas much smaller than its wavelength and to increase strongly the electric field intensities led to an immense motivation for scientific research. In addition, it promises new and exciting technological applications, ranging from novel light sources, innovations in photovoltaics, improved optical communication and storage to new sensor devices. The interesting properties of metal nanostructures are linked to optical excitations on their surfaces, so-called surface plasmons (SPs), i.e, resonant collective electron oscillations coupled to an evanescent light field.

Scanning transmission electron microscopy (STEM) in combination with electron energy loss spectroscopy (EELS) is a powerful technique to study optical excitations at (sub)nanometer resolution. In this work SPs are investigated, taking advantage of the high spatial resolution of fast electrons in a TEM. A monochromator, available at the microscope used in this work (FEI Tecnai F20) enables an energy resolution as good as 100 meV to measure optical excitations with subwavelength resolution.

Starting with a single silver nanodisk, a series of nanoparticles is produced with electron beam lithography. The nanodisk is stepwise morphed into a nanotriangle and the evolution of disk and edge modes during morphing is studied. With the support of simulations, realized within the boundary element method approach to solve Maxwell's equations, a new theoretical concept, which describes plasmon modes of arbitrary shape as linear combination of fundamental disk eigenmodes is introduced. This allows an intuitive ordering scheme of plasmonic eigenmodes as film and edge modes.

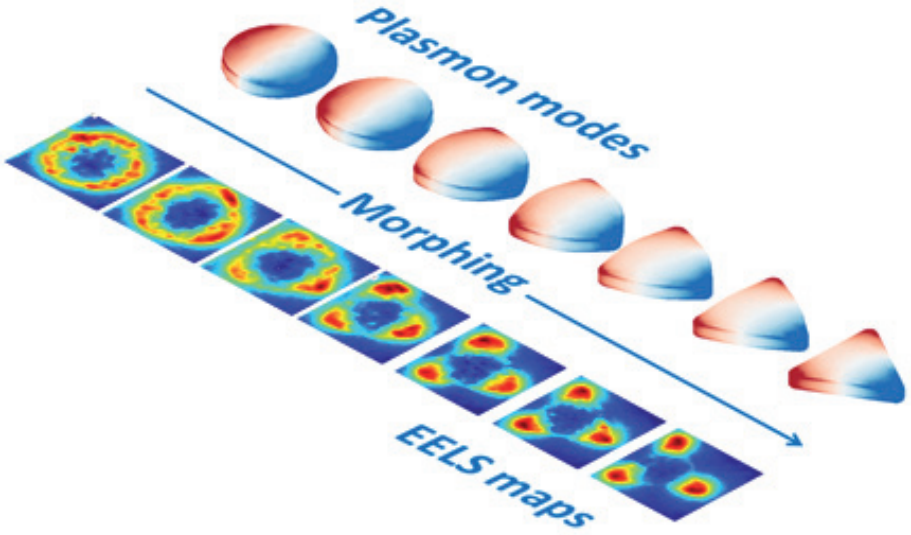
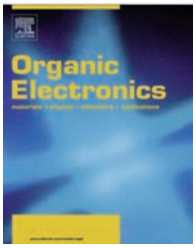


Figure Morphing a nanodisk into a nanotriangle: experimental EEL-maps of the dipolar disk mode, starting with a disk which is stepwise morphed into a nanotriangle (bottom) and the according surface charges (up).

Channel Length Variation in Self-aligned, Nanoimprint Lithography Structured OTFTs



Organic Electronics 15 (2014), 3274–3281

T. Rothländer, A. Fian, J. Kraxner, W. Grogger, H. Gold, A. Haase, B. Stadlober

The transistor is the key element of any logic circuit. It is a perfect device to study basic influences of used materials, methods and processes. Especially in the field of organic electronics, which is still a young field of research and therefore under constant development, the transistor (namely the organic thin film transistor OTFT) is a prominent device under investigation. The OTFT is used to study the influence of materials, device configurations and manufacturing process steps on the device performance. As far as the performance of OTFTs is concerned a decreased channel length is always desired because in theory it leads to an increased performance, such as an increase of source-drain current and an improved switching speed. Nevertheless the theoretical improvements are compromised due to several other effects which come into play with a decreased channel length; short channel effects due to contact resistance and geometrical difficulties of an adequate downscaling. Therefore, it is important to identify an optimum channel length for a given device setup. In this work OTFTs are fabricated following a self-aligned approach using nanoimprint lithography (NIL). The channel length is varied from 25 µm to 0.8 µm and its influence on the on-current, the subthreshold swing and the onset voltage is studied. The transmission electron microscope provides cross section insight in such devices. Information on the quality of the manufacturing process as well as important device parameters can be gained. Device parameters like the dielectric layer thickness in the channel region as well as the source/drain and gate electrode overlap can be measured and the gained information contributes to the understanding of the electrical performance of the device. In our study we indicate that for the given device setup a channel length of 5 µm shows the best results regarding the on-current and the subthreshold swing. Furthermore it is also reported that copper could be used as gate electrode. Due to the availability of copper inks this is a step closer towards our goal of fabricating self-aligned NIL OTFTs consisting only of printable materials.

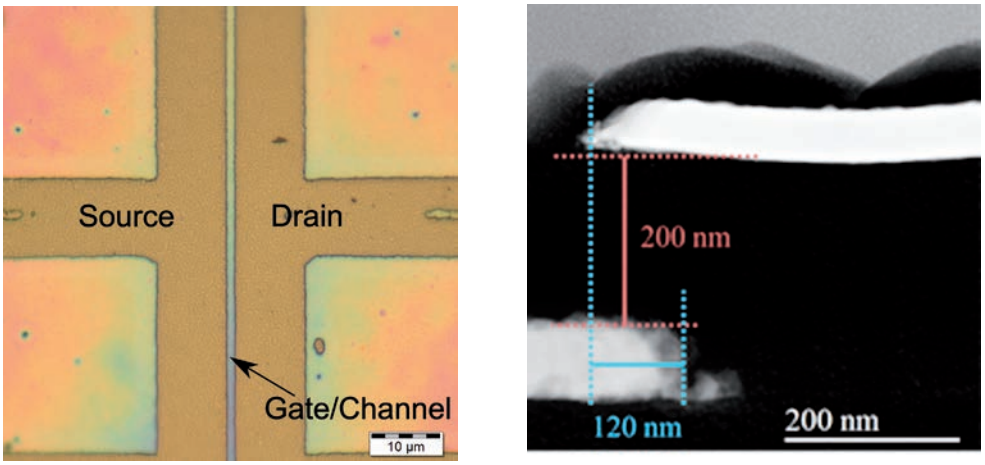


Figure (left): Optical micrograph of an OTFT with a channel length of 1.2 µm. (right): STEM HAADF image of the cross section region showing the source to gate overlap as well as the dielectric layer thickness.

2. Functional Nanofabrication

During the last decade the fabrication of functional nanostructures has become increasingly important for the development of new applications for advanced microscopy. Such developments are based on a fundamental understanding of the physical and chemical properties of materials. Within the diverse range of fabrication methods, maskless direct-write techniques enable rapid-prototyping with superb spatial resolution down to the lower nanoscale. At FELMI-ZFE, our activities in this field are based mainly on two techniques: focused electron beam induced processing (FEBIP) and focused ion beam processing (FIB). Both provide unique fabrication and analysis capabilities. Our main interest is a fundamental understanding of fabrication processes, related material properties and the development of new application concepts.

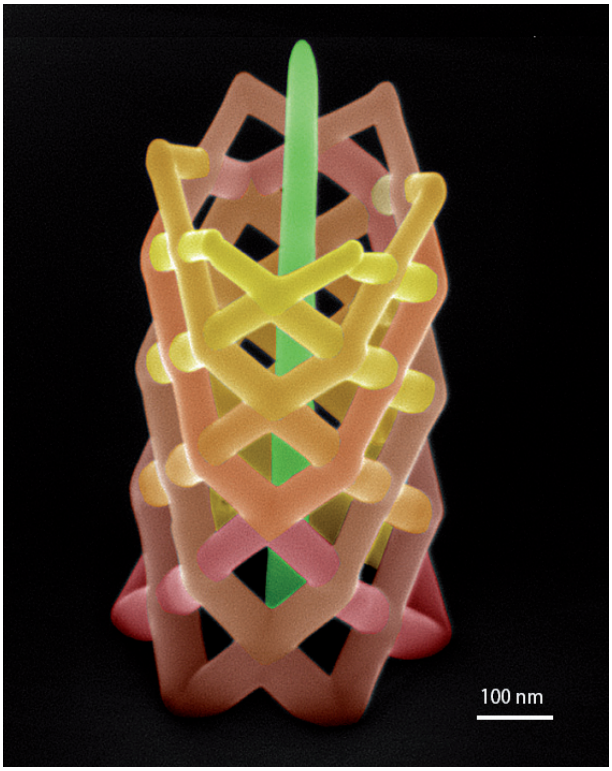
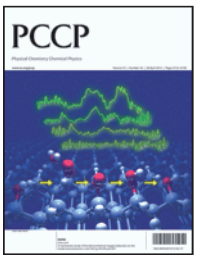


Figure Shielded nano-resonator, central pillar 50 nm.

Chemical Degradation and Morphological Instabilities during Focused Ion Beam Prototyping of Polymers



Physical Chemistry Chemical Physics, PCCP 16 (2013), 1658

A. Orthacker, R. Schmied, B. Chernev, J.E. Fröch, J. Hobisch, G. Trimmel, H. Plank

During the last decade focused ion beam (FIB) processing has become a unique tool for the site specific fabrication of ultrathin lamellas suitable for transmission electron microscopy. Due to its versatile functionalities, this method has also attracted increasing attention as a rapid prototyping tool for surface modification and 3D surface structuring with spatial resolutions down to the nanometer range. However, when combined with soft matter, such as polymers or biological materials, morphological instabilities and severe chemical damage are often observed results. In 2012, FELMI's workgroup S3 revealed that the often observed damage is not primarily related to individual ion-matter interactions but strongly governed by the typically used patterning processes. Based on these findings, extensive research activities were carried out on different classes of polymers and advanced FIB patterning strategies. In this study we could successfully correlate morphological and chemical damage during FIB processing with chemical polymer peculiarities explaining the often observed but barely discussed resulting disruptions. Based on these finding we introduced an alternative patterning approach which minimizes technically related influences and allows processing capabilities which have been considered impossible in the past. The sole implementation of the alternative patterning process enables strongly improved FIB processing of soft matter and might open new possibilities for material modification or device applications.

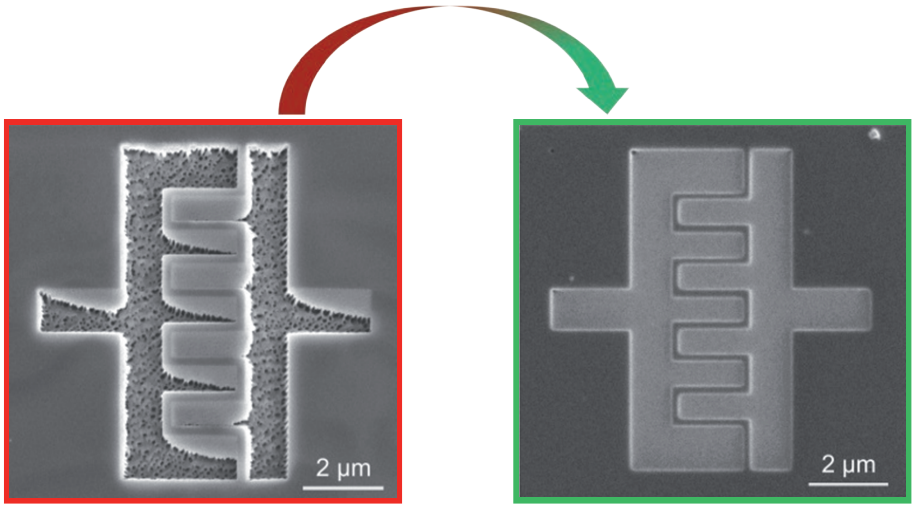


Figure (left): Direct comparison of FIB processed polymer surfaces using standard conditions; (right): advanced patterning for identical process times and beam conditions.

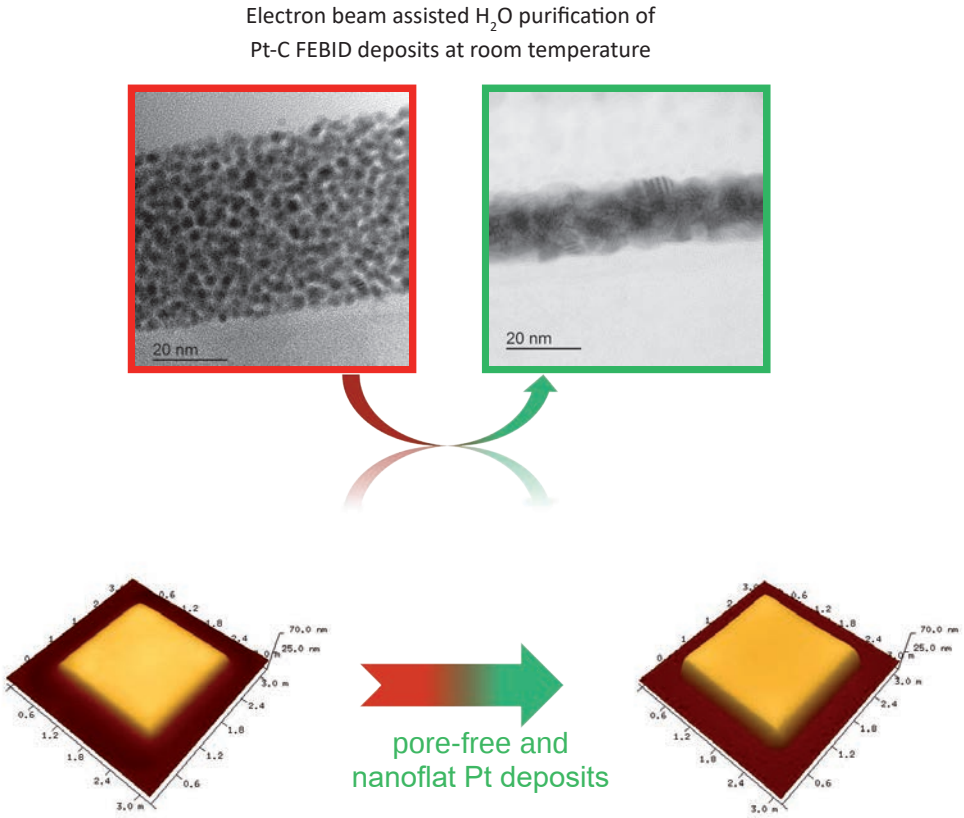
Rapid and Highly Compact Purification for Focused Electron Beam Induced Deposits: a Low Temperature Approach Using Electron Stimulated H_2O Reactions

Journal of Physical Chemistry C 118, 25 (2014), 14009

B. Geier, C. Gspan, R. Winkler, R. Schmied, J. D. Fowlkes, H. Fitzek, S. Rauch, J. Rattenberger, P. D. Rack, H. Plank

During the last decade, focused electron beam induced deposition (FEBID) has made significant progress with respect to potential applications ranging from passive devices, such as plasmonic gratings, towards active concepts like mechanical, magnetic or chemical sensing. Besides the undoubted advantages of FEBID as direct -write tool with spatial nanometer resolution the limitations due to low material purity still remain. Previous attempts of purifying metal containing deposits were based on *in situ* and/ or post-growth purification processes including fabrication on hot substrates, synchronized laser assisted FEBID, co-flow with reactive gases or other combined processes. Although some approaches were successful in terms of chemistry, the deposit surfaces revealed strongly disrupted morphologies which ultimately limit the applications on the lower nanoscale due to the unstable morphologies.

In 2014 a new approach was introduced by FELMI's workgroup S3 which allows entire carbon removal via electron beam assisted purification in H_2O vapor atmospheres at room temperatures. The main advantages of this new strategy are entirely pore / crack free high-fidelity deposits with a minimal lateral shrink of less than 4 % while 3D surface features are qualitatively maintained. Together with FEBIDs unique direct-write capabilities including real 3D fabrication, this enables entirely new applications (e.g. plasmonics), where pure metallic nanostructures are not optional but absolutely needed.



3. 3D and in situ Characterisation

Research and development in highest-performance materials requires increasingly sophisticated investigation methods. Dynamic experiments both in scanning and transmission electron microscopy enable the investigation of the progress of physical processes and chemical reactions at the micro- and nanoscale. Correlations between the microstructure of a material, its composition and its behaviour under various stresses (mechanical, thermal, …) can be deduced. Another advantage of *in situ* experiments is the fact that materials can be investigated under conditions they experience in their practical applications.

Subsequent 3D reconstructions of the bulk of the material will provide additional information about the material's properties and behaviour. Correlation of the results is gained from both the dynamic experiments and the 3D reconstructions which will facilitate the design and development of new materials.

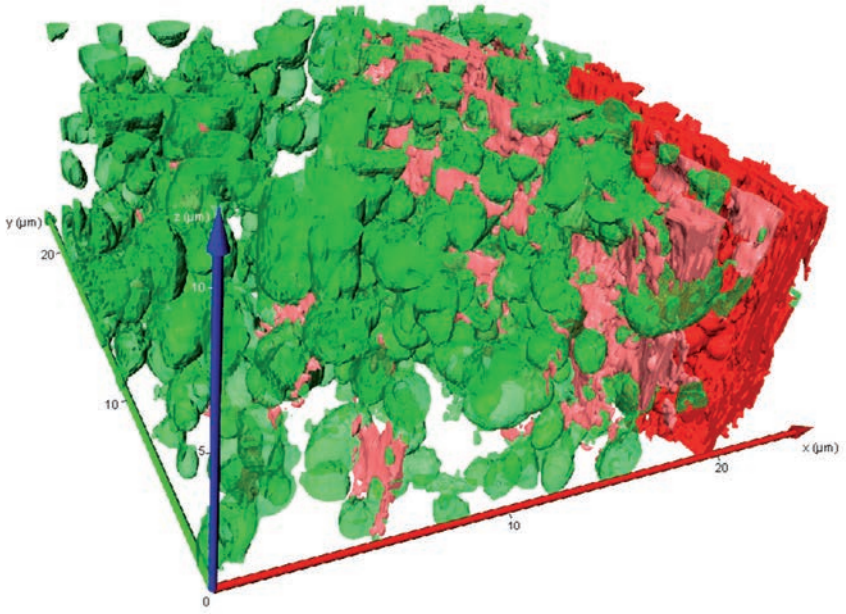


Figure 3D reconstruction of cracks (red) in a polypropylene sample, modified with ethylene propylene rubber particles (green). The sample underwent a tensile test which was stopped at a predefined force. Serial block-face scanning electron microscopy was used to obtain the respective image stack (volume: 20 x 20 x 10 µm³, voxel size: 10 x 10 x100 nm³).

In situ Mechanical Compression of Polycrystalline $BaTiO_3$ in the ESEM

A. Reichmann, S. Mitsche, A. Zankel, P. Poelt, K. Reichmann

Journal of the European Ceramic Society 34 (2014), 2211

A domain structure within a single crystal, polycrystalline ceramics or thin films is a commonly observed feature of ferroic materials (ferroelectrics, ferromagnetics and ferroelastics) below a typical transition temperature usually referred to as Curie point. The formation of domains is a result of the minimisation of electric or magnetic stray field energy and/or elastic energy. Ferroelectric materials like $BaTiO_3$ respond to mechanical stress with a polarization. This polarization consists of an intrinsic part due to compression of the unit cell and an extrinsic part due to domain wall motion. The mechanical behaviour is called ferroelastic effect. The direct observation of domain wall motion under mechanical stress provides a tool for evaluating the extrinsic contribution to the materials polarization with respect to reversible and irreversible contributions. Ferroelectric $BaTiO_3$ was mechanically compressed *in situ*, in an environmental scanning electron microscope (ESEM) equipped with a compression stage. Domain wall motion was recorded using orientation contrast imaging, a very useful method to investigate the microstructure of ceramic materials. Before and after the experiment the sample was characterised by electron backscatter diffraction (EBSD) in order to determine the misorientation between single domains which was 90° in every case. Under compressive stress the domain structure, at least at the surface, changed from a banded twin structure to lamellar twinning, and these structures remained after stress release.

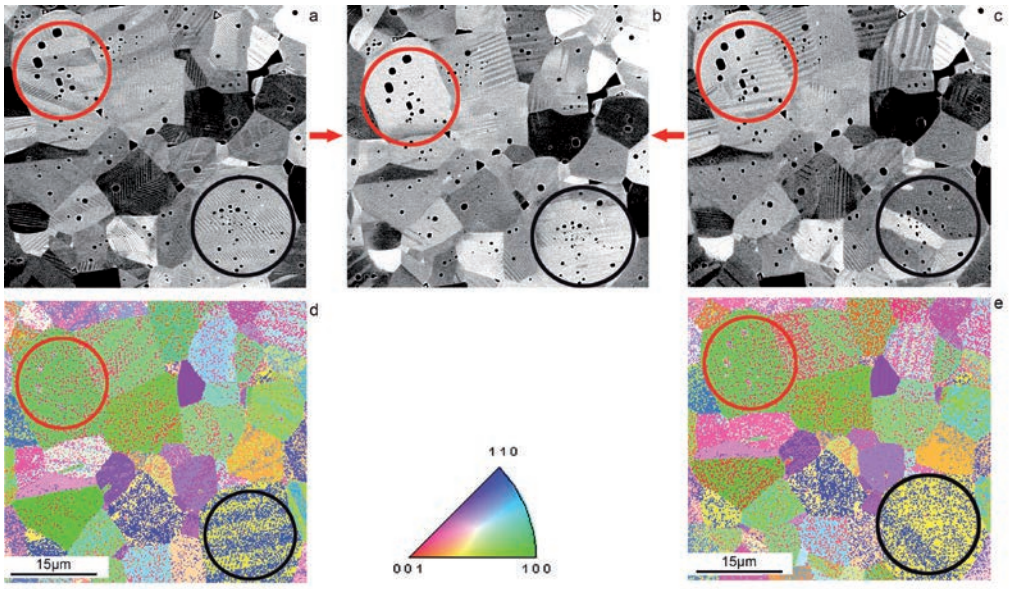


Figure Orientation contrast image of the ceramic before (a) during (b) and after compression (c), EBSD IPF maps of ceramic before (d) and after (e) compression. The red circle indicates a grain with a domain pattern that disappears during application of compressive stress and exhibits changes compared to the initial state after compression. The changes of the domain pattern in this grain are hardly seen in the EBSD IPF map, but differences in the domain pattern of the grain marked with the black circle are clearly visible with this technique. The length of the scale bar is 15 µm.

A New in situ Method for the Characterization of Membranes in a Wet State in the Environmental Scanning Electron Microscope

H. Reingruber, A. Zankel, C. Mayrhofer, P. Poelt

Journal of Membrane Science 86 (2012), 399

In the environmental scanning electron microscope (ESEM) wet samples can be investigated, e.g. the wetting and drying of microfiltration membranes used for waste water treatment. Especially the drying process of porous media, e.g. membranes, is strongly dependent on their pore size distribution, the connectivity of the pores, the wettability of the material and thus the specific surface area. Investigations of wet cooled membranes in the ESEM provide on the one hand information about the drying of the membrane surface, even of individual pores. For example the number of dry pores and the respective pore size distribution as a function of time can be determined.

On the other hand, by recording of the temperature changes during the drying-cycles one can obtain information about both the interior structure of the membrane and the progress of the drying process in the bulk of the membrane. The wetting and drying of the membrane can be controlled by variation of the pressure in the specimen chamber. The respective temperature – time characteristics give qualitative information about the asymmetry of the membrane structure, but also the mean pore size and the pore size distribution in the membrane. Fouling of the membrane or a change in the surface properties of the membrane material, e.g. from hydrophilic to hydrophobic, cause a change in the progress of the characteristics, thus enabling the detection of such phenomena and also their attribution to a specific membrane layer.

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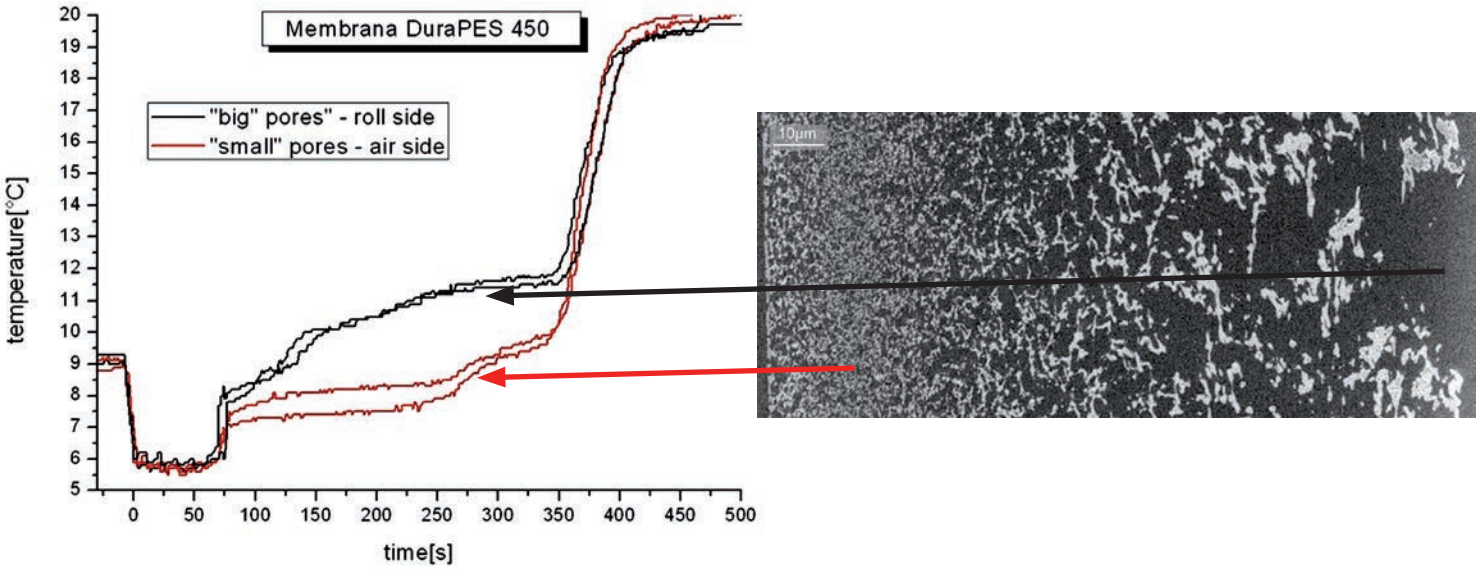


Figure (left): Drying of a microfiltration membrane; temperature-time characteristics for the drying of a wetted membrane (two tests), mounted at a cooled specimen holder in the ESEM. The thermocouples for measuring the temperatures were mounted at the opposite surfaces. (Right): Cross section of the membrane (image width: 140 µm). The asymmetry, pore size distribution, but also the interaction membrane-water is clearly mirrored in the temperature characteristics.

Direct Observation of Ferroelectric Domain formation by Environmental Scanning Electron Microscopy

A. Reichmann, A. Zankel, H. Reingruber, P. Pölt, K. Reichmann

Journal of the European Ceramic Society 31 (2011), 2939

Crystal orientation contrast caused by orientation anisotropy of backscattered electrons can generate images in which grains of different orientations in a polycrystalline material have different grey levels. If a well-collimated electron beam is directed at a polycrystalline ceramic, the density of atoms that the beam encounters will vary with the crystal orientation. Along certain directions, paths of very low atomic density are found, the so-called “channels”, which permit at least a fraction of the beam electrons to penetrate more deeply into the crystal before they begin to scatter (dark signal). For another crystal orientation, a denser atom packing is found, and the beam electrons begin to scatter immediately (bright signal). With this technique the grain size and domain structure of ferroic materials can easily be observed and it is possible to study domain switching phenomena. As a model material we chose donor-doped barium calcium titanate with a phase transformation from tetragonal to cubic structure at the Curie temperature (Tc) of around 130°C. The experiment was carried out in an Environmental Scanning Electron Microscope (ESEM) equipped with a heating stage using low vacuum mode with water vapour as imaging gas. Starting from room temperature, the domains become blurred and disappear gradually when approaching Tc. Cooling from Tc causes a recurrence of the domains in a very similar pattern as observed before heating, thus confirming that the mechanical stresses predetermine the domain structure.

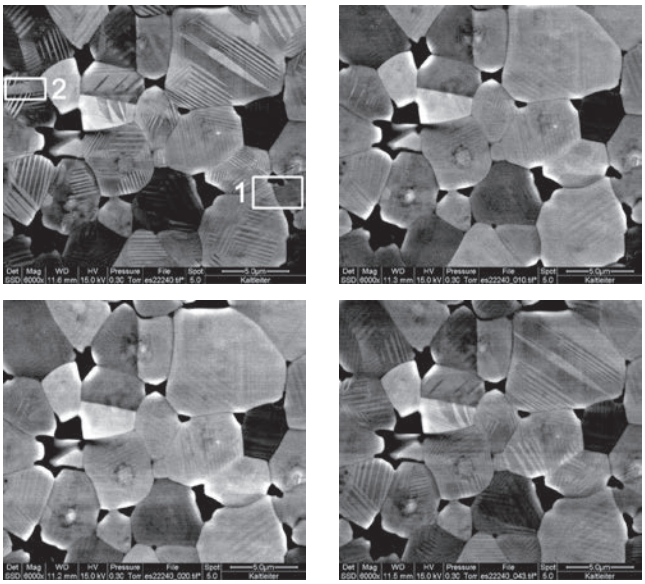


Figure2 Orientation contrast images of the polished ceramic sample at different temperatures. (a) 40 ◦C, (c) 115 ◦C, (d) 124 ◦C, (f) 118 ◦C, (i) 40 ◦C.

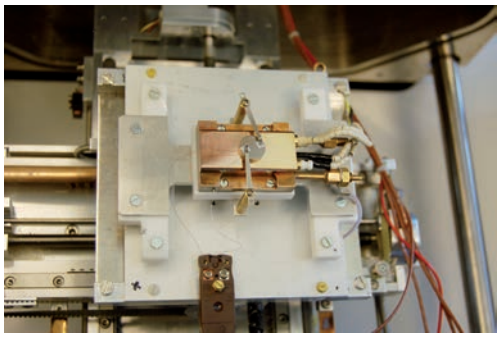


Figure1 Sample stage with the sample clamped to the heating block.

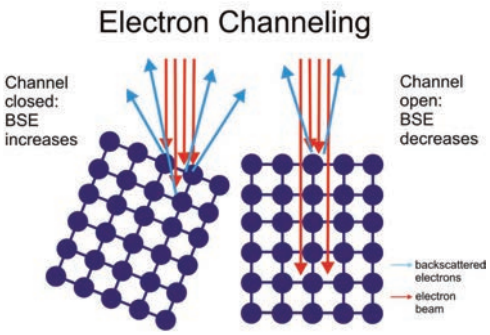
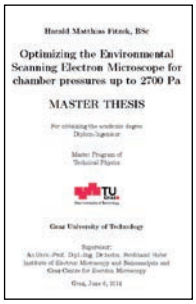


Figure3 Channeling contrast **(left)** high atomic density, bright signal **(right)** low atomic density, dark signal.


Harald Matthias Fitzek, BSc

Optimizing the Environmental Scanning Electron Microscope for chamber pressures up to 2700 Pa

MASTER THESIS

Graz University of Technology

Master Thesis:
Optimizing the Environmental Scanning Electron Microscope for chamber pressures up to 2700 Pa

Harald Fitzek

Environmental scanning electron microscopy enables the opportunity to investigate electrically insulting, wet and biological samples in its natural state without sample preparation. Unfortunately the applications are limited by poor image quality. The scattering of the primary electron beam strongly increases and the secondary electron amplification decreases with pressure and thus the image quality vanishes [2,3].
The key to high image quality at high pressures is making primary beam scattering as small as possible while maintaining ideal operation conditions for the secondary electron detector.

A new aperture holder is presented that significantly reduces the primary beam scattering and a new blade shaped SE-detector yielding better image quality as usual flat SE-detectors [1].
The electrode of the new SE detector is positioned on the sample table, which allows the SE-detector to operate at ideal conditions and to use simultaneously the backscatter detector. The overall improvements of the new design can (detector plus aperture holder) can be seen in Figure 1. All images were acquired by using the same microscope parameters (tin spheres on carbon, 1500 Pa water vapor as imaging gas, 5 keV electron energy, 30 µs dwell time / pixel).

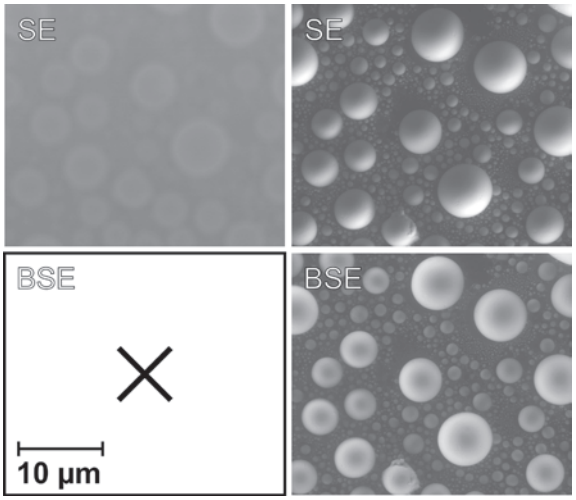


Figure 1 Overall improvements: (left): original design (no BSE imaging possible), (right): by FELMI-ZFE optimised design.

[1] Fitzek, H. (2014) Optimizing the Environmental Scanning Electron Microscope for chamber pressures up to 2700 Pa, Master Thesis, Institute for Electron Microscopy and Nanoanalysis (FELMI), Graz University of Technology.

[2] Danilatos, G.D (1988) Foundations of environmental scanning electron microscopy. Advances in Electronics and Electron Physics Vol. 71, 109–250.

[3] Danilatos, G.D., Rattenberger, J., Dracopoulos, V. (2011) Beam transfer characteristics of a commercial environmental SEM and a low vacuum SEM. Journal of Microscopy Vol. 242, 166–180.

4. Soft matter and Biomicroscopy

FELMI-ZFE has a long tradition of cutting-edge research in the field of real-time and *in situ* characterisation of bio-degradable and bio-compatible materials. During the past decades these materials have gained more and more importance due to environmental protection and medical sciences issues. Current core activities are 3D investigations of neuronal networks, microfiltration membranes and crack propagation in polymers. *In situ* characterisation of enzymatic cellulose degradation in real-time as well as *in situ* testing of membranes and polymers have become major research areas. 3D sectioning / imaging / reconstruction aspects under static, dynamic and even cryogenic conditions allow us to get a comprehensive insight into material properties at the micro- and nanoscale. Against this challenging background we are driven by the desire to move beyond current limitations.

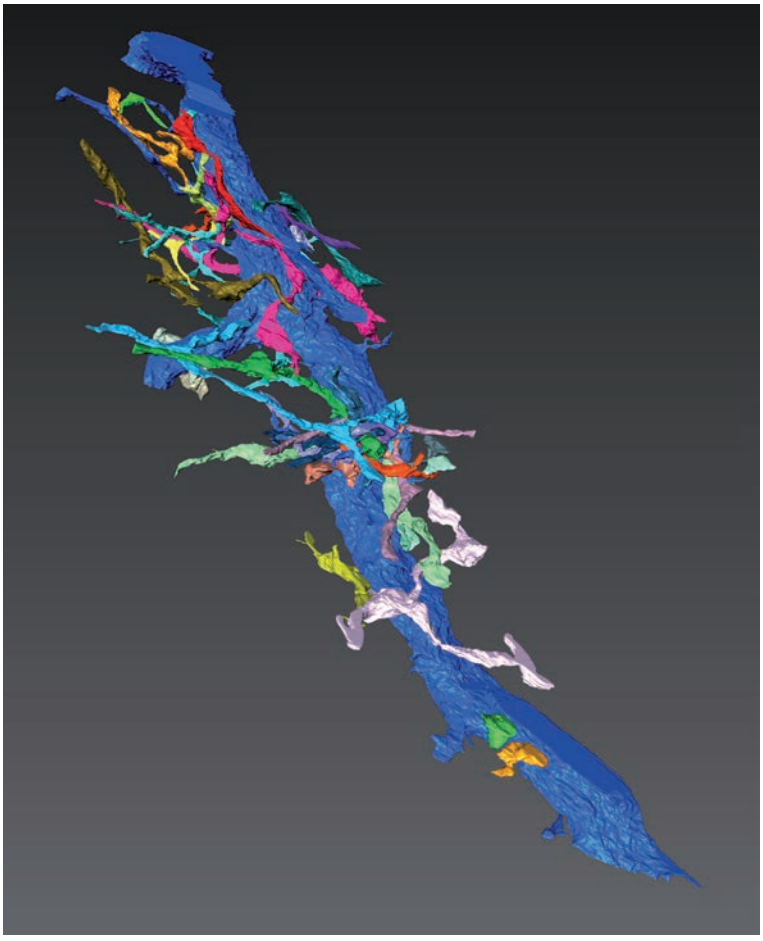


Figure 3D reconstruction (scale bar: 5 µm) of part of a neuron of the neural network active in the processing of signals from a locust eye using serial blockface scanning electron microscopy (SBEM) and showing the distribution of the afferent synaptic connections (yellow). [Cooperation with the Medical University of Graz]

Side Effects in the Application of Polyamide 6 Barrier Materials for Fuel Tanks

Journal of applied polymer science 127, 1 (2012), 230-236

Boril S. Chernev, Gabriele C. Eder

Vibrational spectroscopy was found to be a suitable method to determine the degree of cross-linking of ethylene vinyl acetate (EVA) polymers. Spectral changes in the Raman spectra of EVA with increasing lamination time (which equals increasing degree of cross-linking) were mainly detected in the CH vibrational regions, namely, in the relative intensities of the characteristic CH_3 and CH_2 band. These spectral regions were chosen for a chemometric evaluation where a calibration was performed with the Raman spectra of reference EVA samples and the results obtained from corresponding thermal analysis (differential scanning calorimetry) and Soxhlet extraction data. These datasets were subsequently used to non-destructively determine the progress of cross-linking in EVA foils, embedded in various mini-modules by Raman microscopy. Thus, we could show that Raman spectroscopy is a highly interesting method for quality control in the production of photovoltaic (PV) modules. However, this approach is valid only for a given grade of EVA, meaning a demand for a new calibration when changing the supplier or the type of EVA used. In addition, the applicability of infrared spectroscopy for the determination of the degree of cross-linking was tested. A good correlation of the decrease in intensity of the characteristic cross-linker infrared bands with increasing progress of the cross-linking was found, as determined by reference methods. However, this analytical method requires taking samples of the EVA foils and is, thus, unsuitable for the non-destructive determination of the degree of cross-linking of the EVA encapsulated within a PV module.

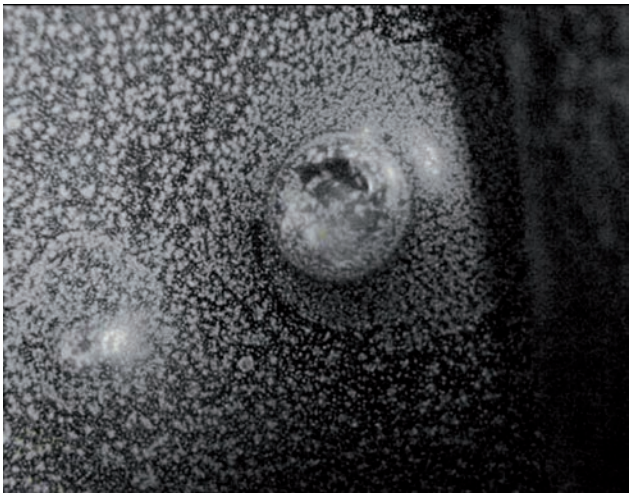


Fig.1

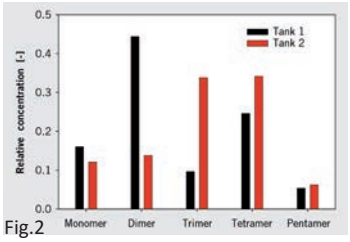


Fig.2

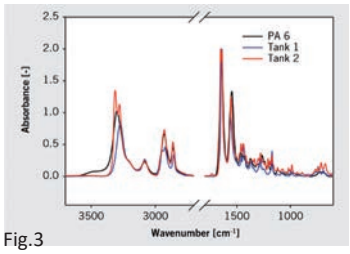


Fig.3

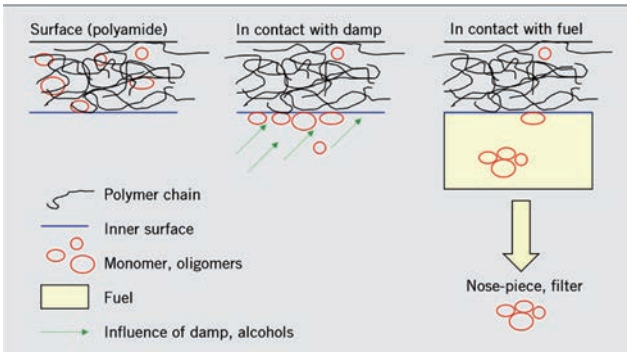
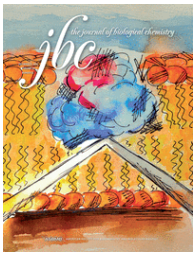


Fig.4

Figure 1 Crystalline deposits on the inner surface of the tank.
Figure 2 Relative amounts of the individual cyclic oligomers in the deposits of tank 1 (black) and tank 2 (red).
Figure 3 Infrared-spectra of the precipitates of tank 1 (blue), tank 2 (red) and the reference spectrum of the base material PA 6 (black).
Figure 4 Schematic representation of the formation process of the crystalline deposits and their distribution in the tank system.

Dissecting and Reconstructing Synergism: in situ Visualization of Cooperativity among Cellulases

T. Ganner, P. Bubner, M. Eibinger, C. Mayrhofer, H. Plank, B. Nidetzky



Journal of Biological Chemistry 287 (2012), 43215

Cellulose is the most abundant biopolymer and a major reservoir of fixed carbon on earth. Comprehending the elusive mechanism of its enzymatic degradation is a fundamental problem at the interface of biology, biotechnology and materials science. The interdependence of cellulose disintegration and hydrolysis as well as the synergistic interplay among cellulases is yet poorly understood. This is due to a lack of appropriate methods which allow direct observation at high resolutions in natural liquid environments. With the advent of high-speed Atomic Force Microscopy (AFM) in liquid conditions imaging of enzymatic decomposition of cellulose is now accessible. However, substrates emulating natural cellulose sources with a mixed crystalline and amorphous morphology are yet barely available. During recent years, FELMI's workgroup S3 focused on the development of appropriate cellulose substrates for high-resolution AFM imaging and succeeded in the fabrication of flat and pure multiphasic cellulose substrate denoted as mixed amorphous crystalline cellulose substrate (MACS). In this study, MACS was used to reveal synergistic effects of a well-studied enzyme system of the fungus Trichoderma reesei. In detail, results show that synergism is significantly influenced by the morphological distribution of small crystalline fibers in the amorphous matrix yielding a dichotomous form of cooperativity between cellulases CBH1 (cellobiohydrolase 1), CBH2 (cellobiohydrolase 2) and EG1 (endoglucanse 1). Specialization of the individual cellulases species triggers amorphous cellulose disintegration to be dominated by CBH2 and EG1, whereas crystalline features are mainly removed by CBH1. The resulting stepwise degradation is only visible through direct evidence on small time scales by liquid AFM and allows further optimization of known cellulose conversion models which are highly relevant for the fabrication of second generation biofuels.

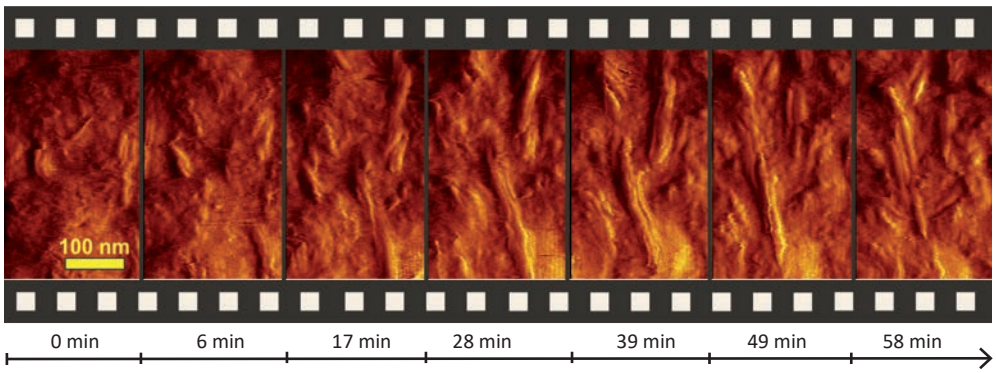


Figure Degradation by Trichoderma reesei fungal enzyme system on MACS visualized by AFM imaging in liquid. Super-high resolution imaging reveals a dichotomous form of degradation where fibres are first uncovered from amorphous cellulose material (0–39 min) and then quickly removed (39–58 min) by the enzymes.

Research Groups

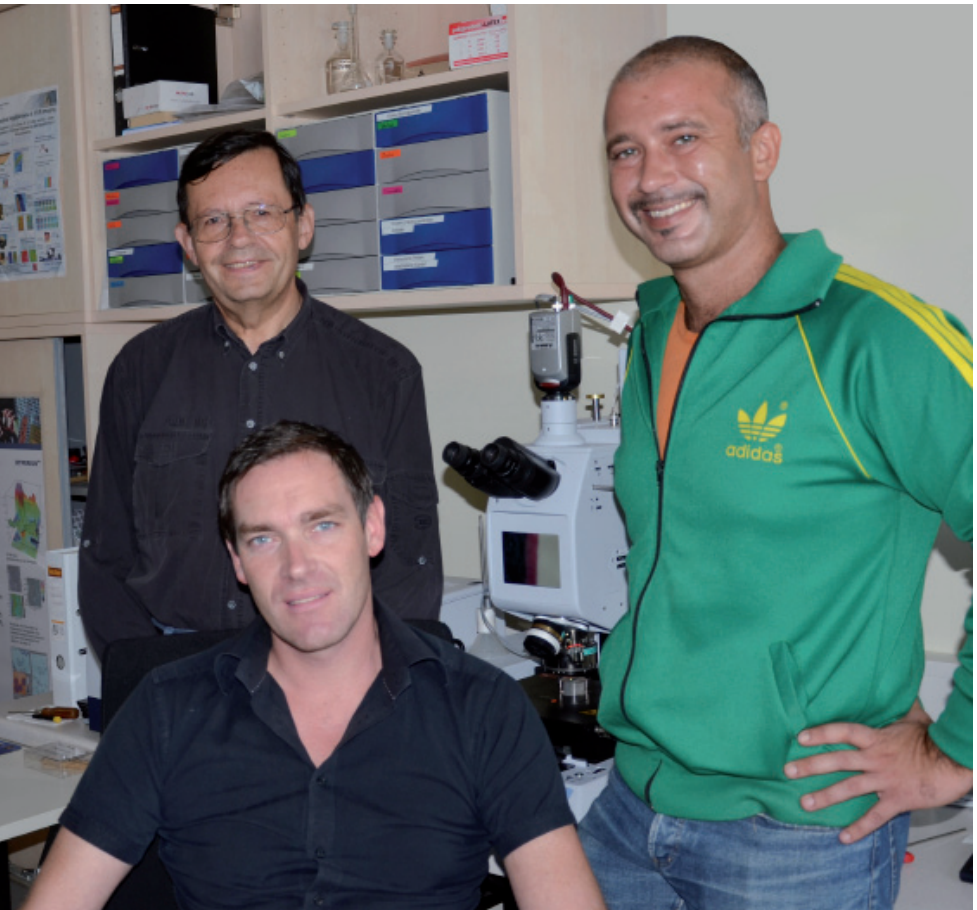
Dr. Boril Chernev

finished his master in Sofia (Bulgaria) and earned his PhD at the University of Graz. His research interests include quality control and failure analysis with a focus on soft matter which has a direct impact on industrial collaborations.

IR and Raman Microscopy

Class Leading Technology for Molecular Microscopy

Confocal Raman imaging is a well-established imaging method, combining the resolution power of a conventional optical microscope with the chemical information at each point of the image, as this may be obtained from the Raman and IR spectra [1]. While there is a fundamental difference between how the images are recorded in the IR-microscope with focal plane array detector (FPA), where all spectra from the field of view will be recorded simultaneously, and how they are recorded in the Raman microscope (sequentially, point by point), the results yield the vibrational spectrum at each pixel of the image, thus giving the opportunity to carry out analyses of multiple analytes with only one recorded image. Moreover, especially with FPA detectors these measurements are aperture-less, which leaves the achievable spatial resolution solely as a result of the sampling technique and/or integration range [1]. Furthermore, with transparent samples it is also possible to collect XZ- or YZ-scans (without the need to embed and microtome the sample) or even collect Raman XYZ-Maps, and thus, to carry out 3D reconstructions from these data. The main research interests of the group consist of soft matter research and basic research, mainly but not exclusively with respect to polymers and their accelerated ageing or changes during manufacturing and/or everyday use (1–6), where multiple analytical questions especially with respect to the chemistry of the sample may be answered with aid of IR and/or Raman imaging microscopy.



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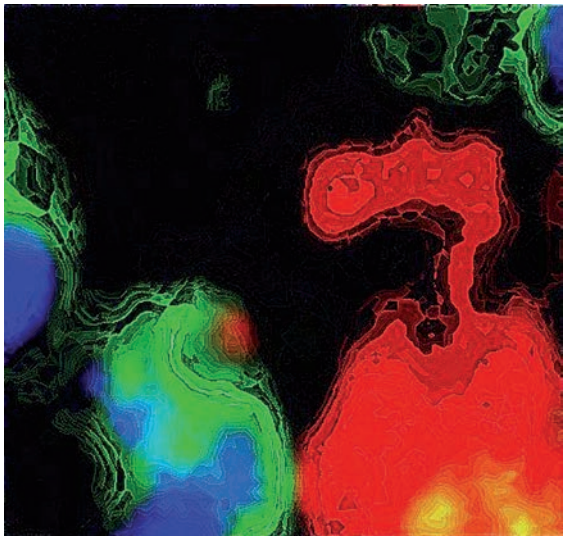

Figure 1

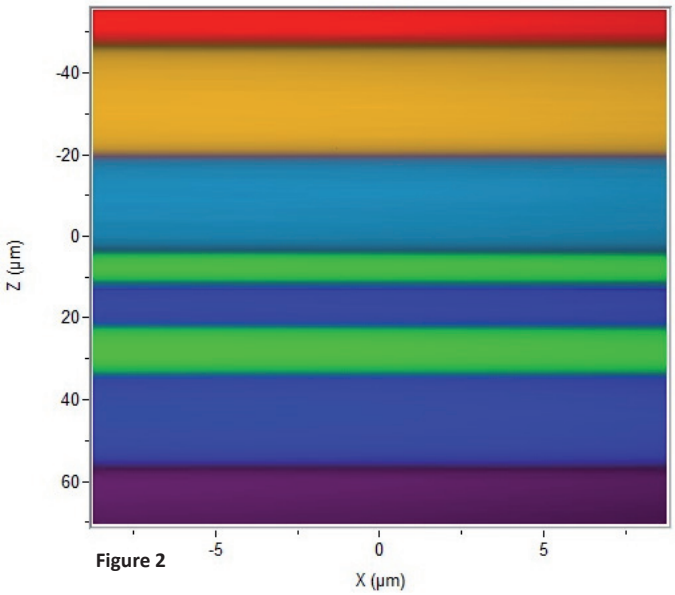

Figure 2

Imaging MIR and NIR Microscopy in one Microscope

Imaging MIR and NIR microscopy are well established techniques to study the material's chemistry on a molecular level at µm-resolution. These methods may also be driven in averaging modes, especially in attenuated total reflection (ATR) mode where a macro accessory, as well one for imaging (images up to 600 x 600 µm² with a technical pixel resolution of down to 0.5 µm/px) and one for averaged signal are available as options for the new Bruker Hyperion 3000 IR microscope with Tensor 27 IR spectrometer. This makes the new Hyperion 3000 with its high speed, high performance last generation FPA detector with superior signal-to-noise ratio a most flexible and powerful system, aiding the group, the Institute and the Technical University of Graz in the area of the fundamental research in general, and our industrial partner in particular with small, custom-made solutions for the specific problems during the manufacturing of various industrial products – from pharmaceuticals to steel and concrete, from ceramics to microelectronics, and also in the research and development of the same. Moreover, both MCT detectors offer also sensitivity for NIR. A dedicated NIR-light source is already built in.

Figure 1 LiMi and IR image of effervescent tablet
Figure 2 Multilayered foil; from up to down: immersion oil (red), polypropylen (dark yellow), acrylatglue (light blue), polystyrene (green), PMMA (blue), PET (violet)

References:

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[3] Chernev, B. S.; Hirschl, C.; Eder, G.: Non-Destructive Determination of Ethylene Vinyl Acetate Cross- Linking in Photovoltaic (PV) Modules by Raman Spectroscopy. In: Applied spectroscopy 67 (2013), 1296–1301.

Analytical Cryo High-Resolution Simulation TEM Group

Dr. Prof. Werner Grogger

holds a PhD in Physics and defended his habilitation in 2004. He is head of the research group for high-resolution analytical transmission electron microscopy. In the course of his scientific career he carried out research at the National Center for Electron Microscopy, Berkeley.

Cool (and also low temperature) experiments, accurate elemental and structural analysis, and supporting image simulations.

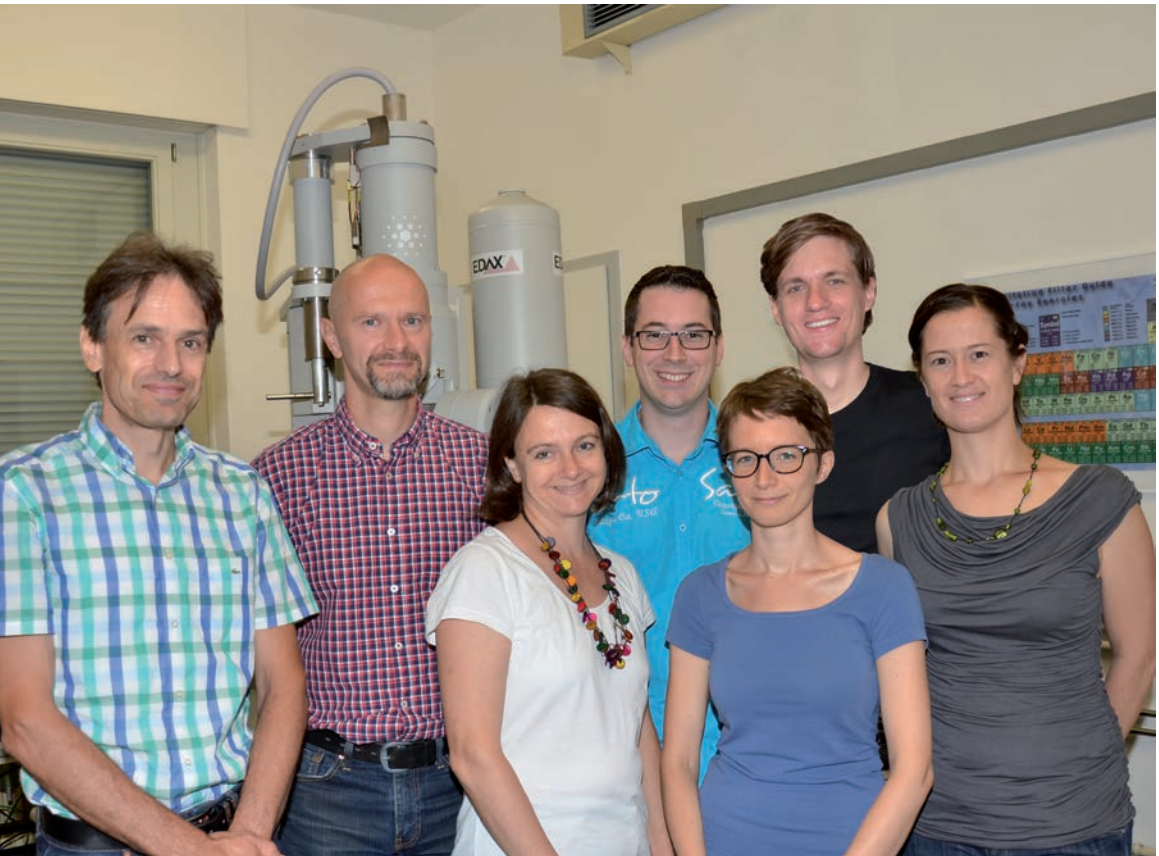
The group of Prof. Grogger works in the field of analytical transmission electron microscopy (TEM). The methods we use mainly focus on quantitative elemental analysis using X-ray spectrometry (EDXS) [1], cryo-TEM, high resolution STEM, and image simulation. These techniques are applied to different materials ranging from hard coatings, perovskites and nanoparticles to organic materials and pharmaceuticals.

Cryo-TEM of an Amphiphilic Designer Peptide

Short peptides recently raised attention as biocompatible nanostructured materials for totally new purposes in medicine and technology. Amphiphilic designer peptides spontaneously self-assemble above a critical aggregation concentration into highly ordered nanostructures. Consequently, these peptides are now exploited as building blocks for the design of (biocompatible) nanostructured materials in medicine and material sciences. We successfully used Cryo-TEM to investigate the different morphologies of nanostructures derived from varying concentrations of an amphiphilic designer peptide. SAXS measurements complemented the Cryo-TEM results which allow a direct visualisation of the peptide assemblies.

Imaging of Surface Plasmons

Metallic nanostructures and their extraordinary optical properties have become of great interest in the last two decades. Their ability to concentrate light into areas much smaller than its wavelength and to increase strongly the electric field intensities led to an immense motivation for scientific research. In addition, it promises new and exciting technological applications, ranging from novel light sources, innovations in photovoltaics, improved optical communication and storage to new sensor devices. The interesting properties of metal nanostructures are linked to optical



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excitations on their surfaces, so-called surface plasmons (SPs), i.e, resonant collective electron oscillations coupled to an evanescent light field. We used scanning transmission electron microscopy (STEM) in combination with electron energy loss spectroscopy (EELS) and an electron monochromator to study optical excitations (i.e. surface plasmons) with (sub)nanometer resolution.

Organic Electronics

Organic electronics is a field of research with growing interest during the last years. Many applications are already entering industrial commercialisation, but the search for new materials and the improvement of the used processes are still in progress. With regard to the optimisation of organic electronic devices, transmission electron microscopy provides an excellent method to systematically study the various device manufacturing steps. Moreover, it contributes to the interpretation of the electrical characterisation output by giving cross section insight into the device. This TEM characterisation is continuously challenged by the on-going transition to all organic materials, due to the lack of distinguishable features between the materials. In addition a special, very gentle approach was used when preparing the thin TEM specimen by the FIB. By taking care of the sensitive nature of the specimen and applying optimized imaging methods we could successfully distinguish between the different polymer materials in the devices.

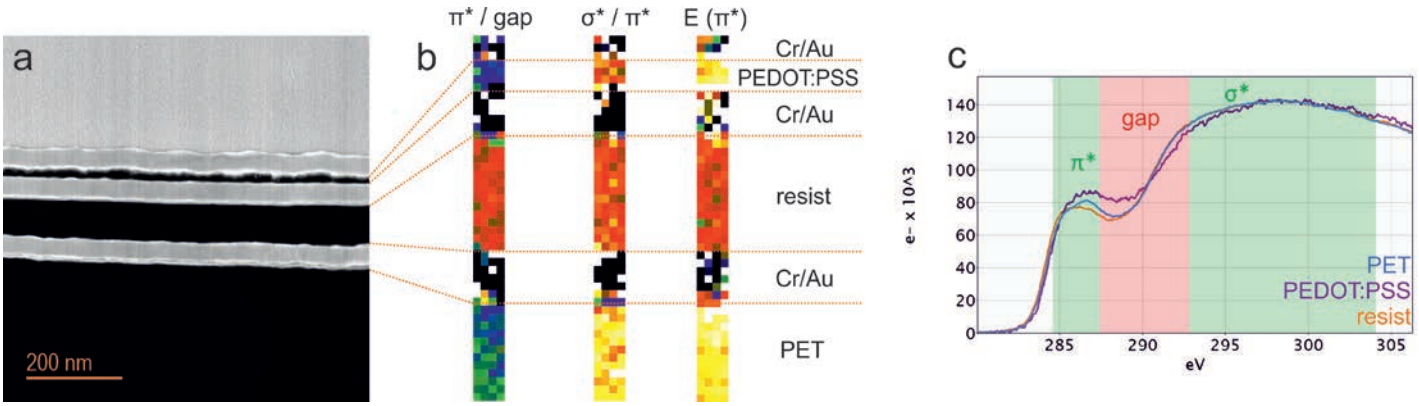

Figure (a) HAADF image of a polymer layer stack. (b) extracted C-K edge signal for different layers with the definition of integral regions for ratios in (c). (b) π*/gap and σ*/π* ratio maps and onset energy map of the π* peak (E(π*)).

References

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Analytical Electron Microscopy

Prof. Dr. Gerald Kothleitner

earned his PhD in Chemistry, worked abroad as an international product manager for analytical instruments in electron microscopy and received his habilitation in Physical Chemistry. His focus is on analytical techniques and methodical developments for materials characterisation.

Counting Atoms and Resolving the TEM Projection Issue

In the past couple of years the AEM group at the FELMI has undertaken big efforts to extend and fully harness the experimental capabilities of the ASTEM microscope. These includes the possibility to count atomic species with picometer resolution and to perform electron tomography on materials science specimens.

Analytics in the ASTEM

Spherical-aberration (CS) correction of electron probes as used in the Austrian scanning transmission electron microscope (ASTEM) has enabled numerous applications, such as atomic resolution analysis on interesting materials science samples. This progress in STEM imaging remained unaccompanied by equivalent improvements in the equipment needed to augment such measurements with analytical EELS (electron energy loss spectroscopy) and EDXS (energy dispersive x-ray spectroscopy) data. In order to combine both techniques and harness their respective potentials for light- and heavy-element quantitative atomic resolution analysis, we have teamed up with the key analytical suppliers (Gatan / Bruker / FEI) and have set up a powerful and unique hard- and software configuration (GIF Quantum, Bruker / FEI Super-X detector, CS-probe corrected Titan, operated under 64bit DigitalMicrograph and driven by DigiScan) enabling unprecedented analytical investigations at the atomic scale.

Atomic Resolution Quantification

Putting quantitative figures on atomic resolution maps, revealing elemental compositions, requires detailed theoretical simulations ensuring the observed analytical intensities are not disconnected from the projected atomic positions. For this we have ongoing collaborations with the theory group in Melbourne (Australia) around Prof. Les Allen, who is able to calculate multiple dynamic electron scattering processes in solid state materials. The product of this team-work is the first atomic resolution EDX and EELS quantification published in Physical Review Letters 2014 [1].

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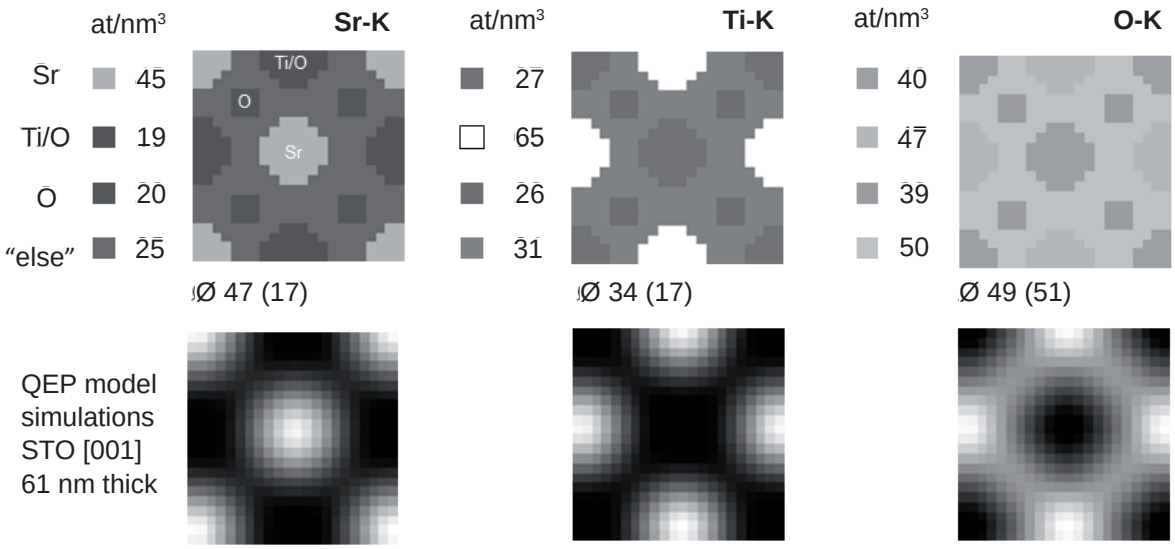

New Analysis Concept

Even on a lower scale no overlapping framework existed that links EELS and EDX analytical signals such that absolute volumetric concentrations could be derived without any assumptions made *a priori* about the bulk. A new mathematical framework was therefore developed that reduced the need for estimates on most of the parameters needed for quantification. With a smart preparation approach on the samples, the relevant quantities like concentrations, partial ionization cross-sections, densities and thicknesses can now be explicitly determined [2].

Electron Tomography

Nanospatial factors often hold the key to a deeper understanding of the properties of matter at the nanoscale level. At FELMI tomographic investigations can be carried out in the TEM, enabling the investigation of materials in all three dimensions. One research focus of the group is the development and implementation of new alignment, segmentation, reconstruction, and analysis routines for tomograms, with the goal to access some of the relevant parameters like shape, size, distribution, and elemental composition amongst others.

Recently magnetite nanoparticles embedded within the pores of a mesoporous silicon template have been characterised using electron tomography. It was possible to calculate the demagnetising factors and the direction of the shape anisotropy easy axis for every particle. Together with Monte Carlo simulations, zero field cooling/field cooling and magnetic hysteresis curves have been derived. This work was published in Nanoscale 2013 [3].

Figure
Absolute volumetric concentrations from X-ray data (upper row) together with QEP (Quantum Excitation of Phonons) simulations (below) from a 61 nm thick strontiumtitanate crystal, imaged along [001] zone axis.

References:
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[3] T. Uusimäki, G. Margaris, K. Trohidou, P. Granitzer, K. Rumpf, M. Sezen and G. Kothleitner, Nanoscale 5 (2013), 11944.

Workgroup S3
Scanning Electrons, Ions and Probes

DI Dr. Harald Plank

earned his PhD in Technical Sciences. Since 2010 he has been coordinating the work group S3 for Focused Ion Beams (FIB) and Atomic Force Microscopy (AFM). In the course of his research activities he spent several months in the USA, South Corea, France, and Turkey.

From Functional Nanofabrication towards Bioapplications

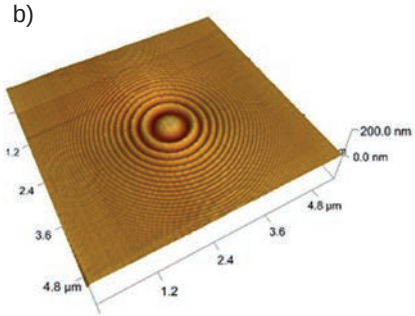
Focused Electron Beam Induced Processing (FEBID)

FEBID is a maskless, direct-write method for the additive fabrication of functional nanostructures with spatial nanometer resolution allows and enables real-3D nano-architectures barely possible via other techniques (Fig.1a). The technique is based on the local decomposition and immobilization of functional precursor molecules by a scanning electron beam. The scientific main focus of FELMI's workgroup S3 is the fundamental understanding of the deposition process in dependency on the preparation parameters and patterning strategies. The gained knowledge is used to tune the chemistry and internal structure on the atomic level while specifically controlling the deposit shapes with respect to highest spatial resolution on the lower nanoscale. This approach led to the development of a solution for the long lasting problem of chemical impurities in FEBID structures. They typically exhibit a metal-matrix composition of metallic nanoparticles (~ 2 – 5 nm) which are homogeneously embedded in a carbon matrix of up to 90 at.%. As this high degree of impurities may lead to reduced or even masked functionalities, we have demonstrated the first approach to purify these structures without pore / crack formation or lateral deposit shrinkage. Being successful in this direction, strong emphasis is still put on the development of new sensor concepts based on the original metal-matrix structure. In 2013 the workgroup demonstrated the first FEBID based gas sensor which uses the carbon matrix as intrinsic transducer to detect polar molecules on its surface. These concepts are currently further expanded towards selective gas sensing, chemical detection of biological analytes in liquids and advanced AFM tip modification towards electric and thermal nano-probing. By that the scientific activities in the field of FEBID span the bow from fundamentals towards applications which can be seen as S3's main focus in this scientific field (Fig.1b–c) [1].

a)

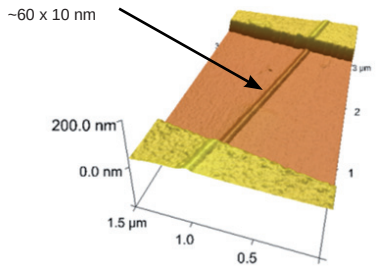
free-standing 3D architecture

b)

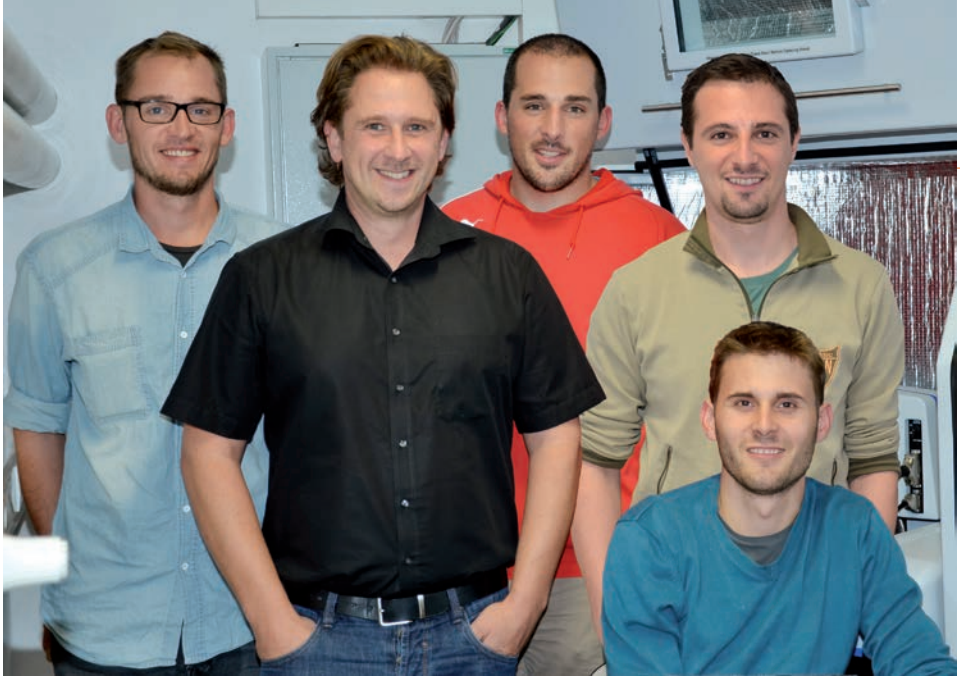


30 nm thick 3D lens

c)



PtC nanowire device



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DI Robert Winkler (FEBID)

Technical Assistant:
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Enzymatic Cellulose Degradation

Based on a strong collaboration with the Institute for Biotechnology (TU Graz) the work group S3 is focusing on the fundamental understanding of enzymatic cellulose degradation as key element for the production of 2nd generation biofuels. This is mainly done by atomic force microscopy (AFM) in liquid environments for direct observation of enzymatic dynamics down to the molecular scale. As the reliability of such investigations strongly depends on the cellulose substrates, increasing efforts have been made in order to develop appropriate specimens. This led to so-called mixed amorphous-crystalline-cellulose-substrates (MACS), enabling specific control about their internal structure while exhibiting nano-flat surfaces for high-resolution AFM investigations. These MACS are currently used to gain deeper insight into fundamental processes during enzymatic and synergistic hydrolysis on multiphasic cellulose systems as presented in nature [2].

Focused Ion Beam Processing

Focused ion beam (FIB) processing has become an integrative part in science and technology with particular attention on the site-specific preparation of ultra-thin lamellas for transmission electron microscopy investigations. However, in combination with low melting materials such as polymers or biological specimens, FIB procedures mostly led to chemical and morphological degradation which led to the status of “practically incompatible”. S3 focused on the origins of these degradation and was able to demonstrate that the patterning strategy itself leads to additional heating effects beyond the acceptable limit for low melting materials. Based on a combined approach between experiments and simulations we introduced an alternative patterning approach which minimizes these technically induced heating effects. This opened the door for FIB processing of low melting materials which had been considered as impossible in the past [3].

Figure (a) – (c): Examples of FEBID’s direct-write capabilities by means of free-standing 3D nanoarchitecture (a); sine-modulated Gabor lens for passive focusing applications (b); and nano-granular PtC nanowire for active (sensing) applications (c).

References:

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From Static to Dynamic

Dr. Peter Pölt

works at the Institute since 1980. He holds the *Venia docendi* since 2008. Being group leader in the field of scanning electron microscopy, his current research concentrates on materials characterisation including *in situ* experiments in the ESEM and electron backscatter diffraction.

The Environmental Scanning Electron Microscope as a laboratory

Dynamic experiments in the environmental scanning electron microscope enable the investigation of the progress of physical processes and chemical reactions at the micro- and nanoscale. They open new possibilities for both, a fundamental understanding of materials and the design of new materials with tailored properties.

Basics

In general microscopy is linked to the recording of images of the surface morphology of a specimen and the analysis of its chemical composition and its crystallographic structure. The state of the material itself does not change during the investigation; in fact it should not change because this is commonly regarded as undesirable specimen damage.

But actually microscopes are increasingly used for *in situ* experiments. The specimen chamber of an e.g. electron microscope acts as a laboratory, in which physical and chemical experiments can be performed. The progress of the experiments can be observed at high magnification and with great depth of focus and can also be documented by video recordings. Thereby, additionally to the information gained about macroscopic changes modifications and transformations of the material at the micro- / nanoscale can be tracked and the basic mechanisms elucidated.

Wetting and Drying of Microfiltration Membranes

Polymeric microfiltration membranes consist generally of several different layers and are used in a great variety of applications such as waste water treatment or filtration of colloids and particles in the beverage industry. The wetting and drying of cooled membranes can be controlled by variation of the pressure in the specimen chamber of the ESEM. The simultaneous recording of images at one membrane surface and the temperature changes at both membrane surfaces provides on the one hand information about the membrane structure, on the other hand about the interaction between the pore walls and the water [1]. Thus changes in the surface properties of the membrane, e.g. its hydrophilicity, can be detected and also the membrane layer, in which the change has predominantly taken place, can be located.

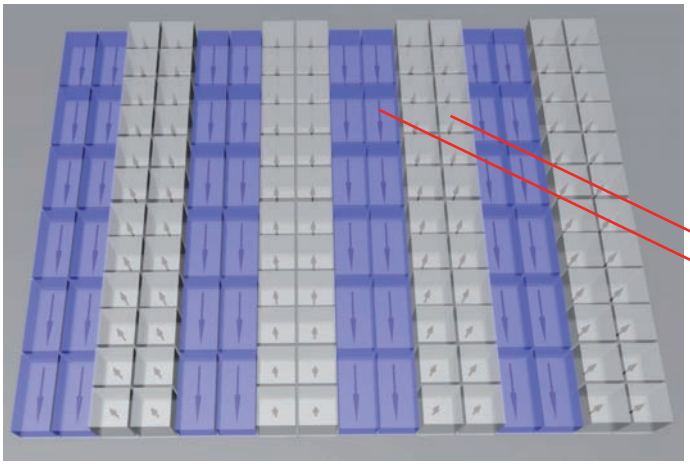


Figure 1

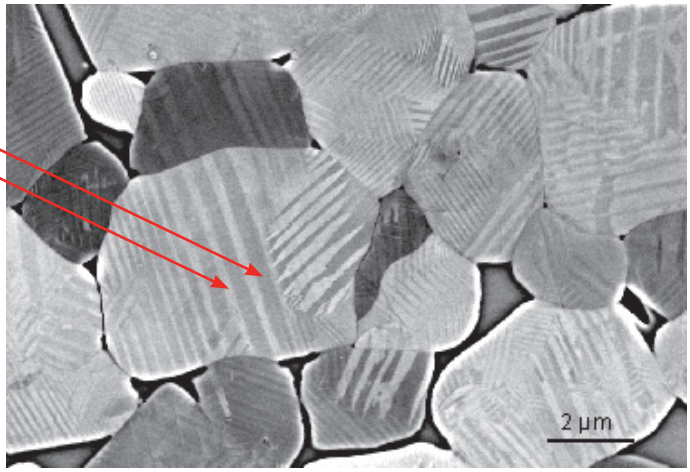
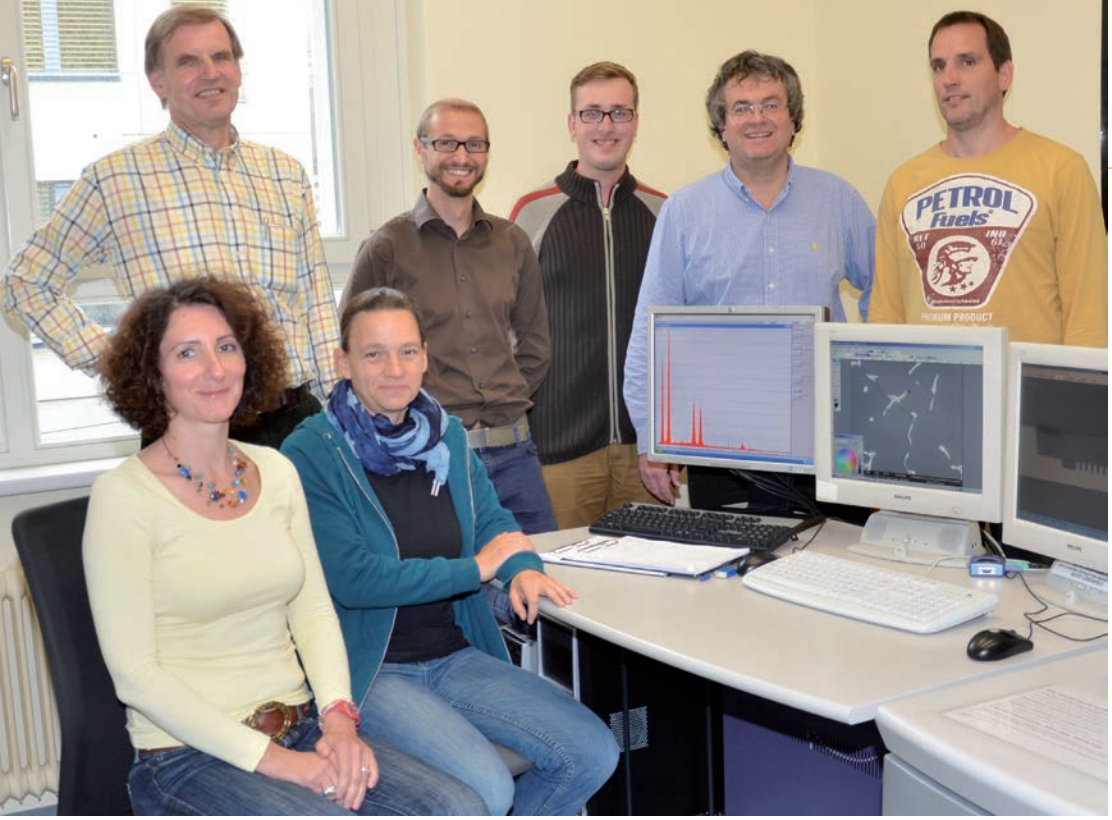


Figure 2



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Sanja Ximi

The Environmental Scanning Electron Microscope (ESEM)

In the specimen chamber of an ESEM, contrary to the conventional scanning electron microscope, the use of gases in a pressure range from 0.1 to 20 torr is also possible. Thus in case of water vapour as gas wet samples can be investigated and the relative humidity can be controlled. Moreover, materials can be heated up and the onset of corrosion and the growth of the scales can be directly observed. Also many types of mechanical tests, e.g. tensile tests, can be performed and the evolution of the microstructures developing at the crack tip or at the surface can be recorded.

Ferroelectric Ceramics

By use of a heating stage the evolution of domain patterns in ferroelectric ceramics (during both: heating and cooling across the Curie transition temperature TC) are investigated. It is easily visible whether domains become blurred and whether they disappear spontaneously or gradually when approaching TC. Changes in the domain pattern of individual grains during heating and cooling may indicate local changes in elastic energy conditions [2].
Similarly in the ESEM domain wall motion can be continuously recorded during mechanical compression with a compression stage [3]. An example can be found at the page. It is the great advantage of these methods that changes at every single grain can be observed.

Figure 1 Schematic of a grain consisting of 90° domains, which can be seen in the microscope.
Figure 2 The domain orientations are perpendicular to each other, so-called 90° domains. One domain itself consists of many unit cells with the same polarization direction.

References:
[1] H. Reingruber, A. Zankel, C. Mayrhofer, P. Poelt, J. Membr. Sci. 399–400 (2012), 86–94.
[2] A. Reichmann, A. Zankel, H. Reingruber, P. Poelt, K. Reichmann, J. Eur. Ceram. Soc. 31 (2011), 2939.
[3] A. Reichman, S. Mitsche, A. Zankel, P. Poelt, K. Reichmann, J. Eur. Ceram. Soc. 34 (2014), 2211.

Surface & Materials Characterisation from A to Z

From Automotive to Pharmaceutical Engineering

Ing.
Harmuth Schröttner

Work at the Institute since 1991. Being group leader (since 2005) in the field of scanning electron microscopy his focus is on the development of preparation techniques and methods in microanalysis. His expertise is directly incorporated into industrial collaborations and applications.

The work group is focusing on the interface between development and optimisation of (environmental) scanning electron microscopy techniques and preparation methods and relevant industrial applications to provide a sustainable creation of value and know-how for our cooperation partners.

Fundamental Research

Fundamental Research driven by self-initiative of the Austrian Centre for Electron Microscopy and Nanoanalysis leads to a contemporary fundamental grasp of modern and future low energy and low vacuum scanning electron microscopy techniques. A perfect understatement of image and contrast formation is the foundation for all up-to-date applications. A project driven by DI Dr. Johannes Rattenberger is focused on the "Optimisation of the Environmental Scanning Electron Microscope for chamber pressures up to 2700 Pascal" [1]. The key to high image quality at high pressures is making primary beam scattering as small as possible while maintaining ideal operation conditions for the secondary electron detector [2].
Top quality electron microscopical investigations on a high end level close to the physical limitations depends on artifact-free and perfectly adapted sample preparation methods. Another project this time as a Master-thesis in collaboration with an industrial partner (LEICA Microsystems) – took aim in the optimisation of "Magnetron Sputtered Thin Films for High Resolution Scanning Electron Microscopy".

Research Partner for Industry & University

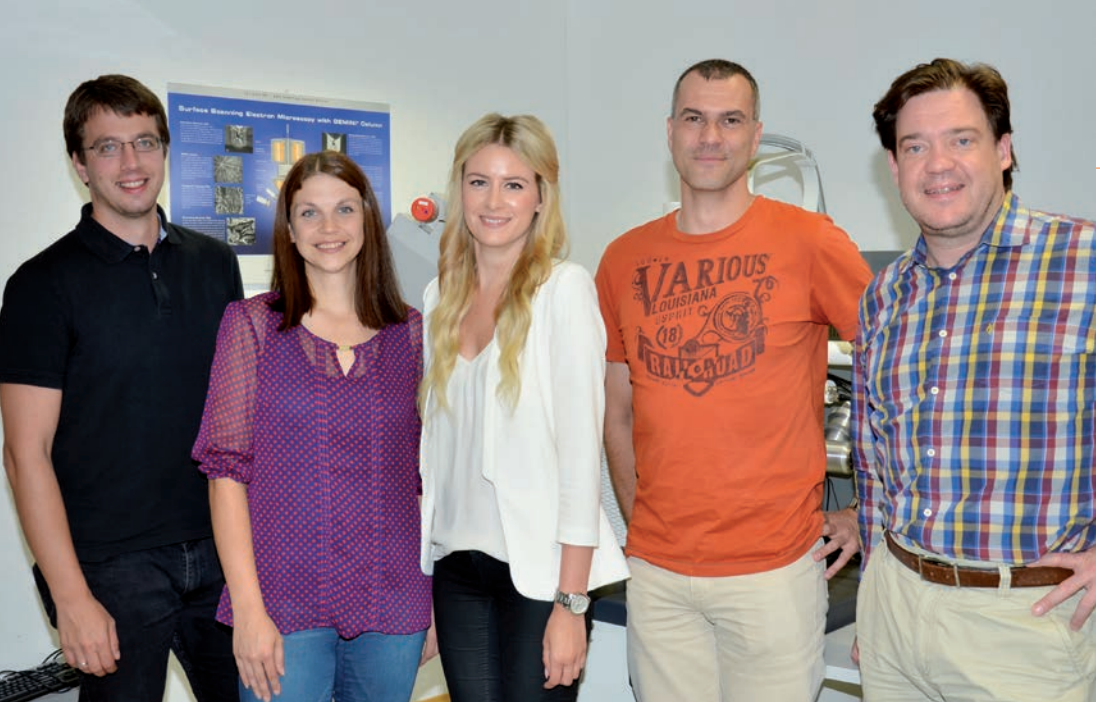
In the past couple of years the work group with its experience could position itself as a capable and reliable cooperation partner in a lot of different R&D projects. For example inside the Austrian Cooperative Research and its Competence-Platform-Projects "Multi-Material-Compounds" and "Materials-Characterisation".
Two FFG-COIN-projects "Optimatstruct" [3] and "AMCC" are focused on generating knowledge of modern light-weight-alloys and transfer this know-how and expertise into industrial applications. Currently there are many more different projects running – from perennial projects with different industrial collaboration partners to small projects (for example "Innovationsscheck") with SME partners. Such an entry project has been distinguished with the ACR-SME-Cooperation-Award together with our innovative partner Bionic Surface Technologies in 2011. Further research projects are aligned on pharmaceutical engineering and soft material characterisation.

Industrial Applications for Materials Characterisation

The methodical and material knowledge elaborated in our fundamental-projects is then transferred into industrial applications and investigations as customer service on a widespread field of different materials (metals, cast alloys, hard metals, ceramics, soft materials, polymers, materials compounds). Our know-how is also transferred within different conferences, expert seminars, workshops, or LLL-Courses.

Your Solution Provider

Thanks to our long time experience, materials know-how and good networking we can act as a solution provider for your problems (e.g. failure analysis). We offer a Multi-Scale-Analysis of surfaces and materials with a wide variety of methods from the mm to nm range for your current and upcoming developments (quality assurance, product optimisation) on the base of confidential disclosure agreements.
"MeetUS2Talk!"



Group Leader:
Ing. Hartmuth Schröttner

Senior Researchers:
Dr. Julian Wagner
Dr. Johannes Rattenberger

Technical Assistants:
Sabrina Mertschnig
Anita Rossmann

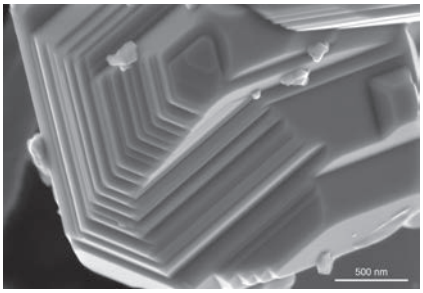


Figure 1

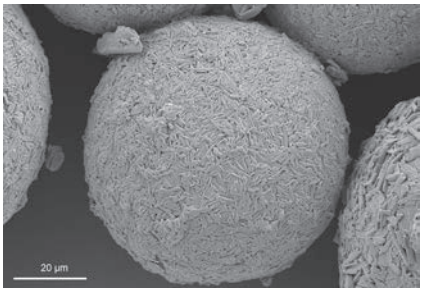


Figure 2

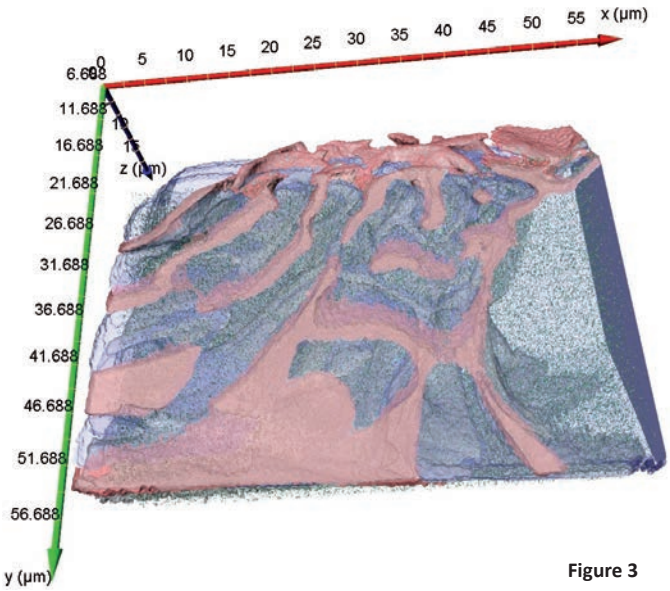


Figure 3

Figure 1 FESEM SE-image of initial NbO, Valeeva, A. A.; Schröttner, H.; Rempel, A. A.: NbO Disintegration by Surfactant-Assisted High-Energy Ball Milling. In: Inorganic materials 50 (2014), 398–403.

Figure 2 FESEM SE-image of spray dryed mannitol, Littringer, E. M.; Mescher, A.; Eckhard, S.; Schröttner, H.; Langes, C.; Fries, M.; Grieser, U.; Walzel, P.; Urbanetz, N. A.: Spray drying of mannitol as a drug carrier – The impact of process parameters on the product properties. In: Drying technology 30 (2012) 1, 114–124.

Figure 3 3D reconstruction based on FIB Slice & View techniques of an ECO-MgAZ91 alloy. Grey stands for aluminium, transparent blue for magnesium, pink for calcium, Wagner, J.; Schröttner, H.; Rattenberger,J.; Mitsche,S.; Panzirsch,B.: Comparison of the 3D Calcium and Aluminium distribution in standard and ECO-Mg alloys. In: Microscopy for Global Challenges (2014), MS-4 - P-3413 International Microscopy Congress; 18.

References:

[1] Fitzek, H. (2014) Optimizing the Environmental Scanning Electron Microscope for chamber pressures up to 2700 Pa, Master Thesis, Institute for Electron Microscopy and Nanoanalysis (FELMI), Graz University of Technology.

[2] Danilatos, G.D., Rattenberger, J., Dracopoulos, V. (2011) Beam transfer characteristics of a commercial environmental SEM and a low vacuum SEM. Journal of Microscopy Vol. 242, 166–180.

[3] Schröttner, H.; Panzirsch, B.; Albu, M.; Mitsche, S.; Mertschnigg, S.; Gspan, C.; Rattenberger, J.; Wagner, J.; Hofer, F.: Multi-Scale-Analysis of Modern Aluminium-Alloys. In: Microscopy for Global Challenges (2014), MS-4 - P-2525 International Microscopy Congress; 18.

Research Grants

Peer-reviewed research grants acquired or active in 2012, 2013 and 2014

FELMI projects

ESTEEM2
Leader: Ferdinand Hofer
Coordinator: CEMES-CRNS, Toulouse
EC-FP/ Infrastructures, Brussels, 10/2012–9/2016

Cellulose
Leader: Harald Plank
Coordinator:
FWF 2013–2015

AMOREE
Leader: Stefan Mitsche
Coordinator:
COMET 2014–2017

TEM-Probenhalter
Leader: Ferdinand Hofer
Coordinator:
HSRM-Project 2014–2017

Mapping Surface Plasmons of Designed Metal Nanostructures with an Electron Beam
Leader: Ferdinand Hofer
Coordinator: Karl-Franzens-University of Graz
Austrian Science Fund (FWF), Vienna, 10/2010–7/2014

Integrated Organic Sensor and Optoelectronic Technologies (ISOTEC)
Leader: Werner Grogger
Coordinator: Nanotec Center Weiz
FFG, Vienna, 1/2005–4/2012

Nanoprobe – Analytics on Nanosized Objects
Leader: Gerald Kothleitner
Coordinator: Johannes-Kepler-University of Linz
FFG, Vienna 3/2009–2/2012

CD Laboratory for Nanocomposite Solar Cells
Leader: Ferdinand Hofer
Coordinator: Institute for Chemistry and Technology of Materials, TU Graz
Christian Doppler Research Society, Vienna

ZFE projects

Austrian Scanning Transmission Electron Microscope (ASTEM)
Leader: Ferdinand Hofer, Gerald Kothleitner, Werner Grogger
Austrian Research Promotion Agency (FFG), Vienna, 10/2009–9/2014

Electronic Circuits for Hot-embossed Organic Devices (NILecho)
Leader: Werner Grogger
Coordinator: Joanneum Research, Graz
Austrian Research Promotion Agency (FFG), Vienna, 4/2008–3/2014

ESIP 2
Leader, Ferdinand Hofer, Werner Grogger
Coordinator: Infineon, Regensburg
ENIAC & Austrian Research Promotion Agency (FFG), Vienna
5/2010–6/2013

Soft Matter Processing via Focused Ion Beams
Leader: Harald Plank
Austrian Research Promotion Agency (FFG), Vienna, 1/2010–3/2013

Microscopical Analysis of Composites for Automotive Applications
Leader: Hartmuth Schröttner
Coordinator: Austrian Foundry Research Institute (ÖGI), Leoben
Federal Ministry of Economy, Family and Youth (BMWFJ), Vienna, 7/2009–6/2012

COIN OPTIMATSTRUCT
Leader: Hartmuth Schröttner
Coin-Aufbau 2013–2015

ESEM-Optimierung
Leader: Johannes Rattenberger
FFG-Basis 2013–2015

IR-Mikroskop
Leader: Peter Wilhelm
ACR-Infrastructur 2013

Nanomill
Leader: Ferdinand Hofer
ACR-Infrastructur 2014

Triple-S
Leader: Harald Plank
FP7 EUROSTARS 2013–2016

Sandvik
Leader: Gerald Kothleitner
Sandvik, 2013–2016

AMCC
Leader: Ferdinand Hofer
COIN-FFG ÖGI 2014–2017

AFM-neu
Leader: Ferdinand Hofer, Harald Plank
SFG 2014–2015

Pastenprojekt
Leader: Hartmuth Schröttner
RCPE 2013

ChemPro
Leader: Boril Chernev
FFG 2013–2014

RCPE
Leader: Hartmuth Schröttner
RCPE-Subauftrag 2013–2015

COIN "OPTIMATSTRUCT"

Multi-Scale-Analysis of Modern Aluminium Alloys

Continuous research and steady developments in materials science result in a lot of new lightweight-alloys for automotive and aerospace applications. The Austrian Cooperative Research (ACR) and its Competence-Platform-Project "OPTIMATSRUCT" combines the know-how and competence of four institutes (ÖGI, OFI, SZA, ZFE). The project is concerned with ECO-Magnesium and modern cast-aluminium alloys. The aim is the creation of a modern all-inclusive knowledge of these alloys. From the manufacturing process, its mechanical properties, adapted joining techniques, its redox reactions, the structure investigations with classical metallographical methods down to the micro- and nano-characterisation at an atomic scale. The gathered information and expertise is finally transfered into industrial applications for small and midsized enterprises as well as for the industry.

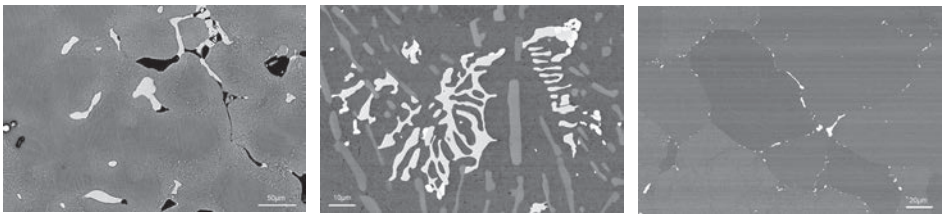


Figure 1 (left): Backscattered-Electrons-(BSE)-image of an AZ91 magnesium alloy of a cross section prepared with Broad Ion Beam Milling [1]. (middle): BSE-image of a cross section of an AlSi12Ni alloy for phase-characterisation [2]. (right): BSE-image of an AlCu4Ti alloy preliminary to thermal treatment [2].

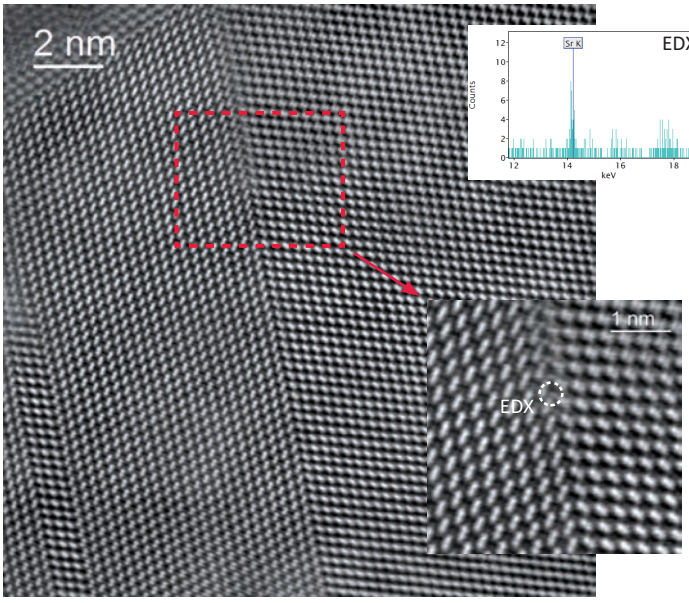


Figure 2

[1] Wagner, J.; Schröttner, H.; Rattenberger, J.; Mitsche, S.; Panzirsch, B.: Comparison of the 3D Calcium and Aluminium distribution in standard and ECO-Mg alloys. - in: Microscopy for Global Challenges (2014), S. MS-4 -P-3413 International Microscopy Congress ; 18

[2] Schröttner, H.; Panzirsch, B.; Albu, M.; Mitsche, S.; Mertschnigg, S.; Gspan, C.; Rattenberger, J.; Wagner, J.; Hofer, F.: Multi-Scale-Analysis of Modern Aluminium-Alloys. - in: Microscopy for Global Challenges (2014), S. MS-4 - P-2525 International Microscopy Congress ; 18

[3] Albu, M.; Li, J.; Kothleitner, G.; Schumacher, P.; Hofer, F., "Atomic resolution scanning transmission electron microscopy analysis of Sr and Yb addition in Al-Si alloys". - in: Magnesium; Aluminium; Titanum Science and Technology (2013), S. 162 International Congress on Light Materials.

Access

Access

Services to Industry and Research Institutes

We are committed to keeping up to date with materials research and to provide the best service to our industrial/research partners. We also promote and work in collaborative Research&Development Projects (R&D); we facilitate procedures (planning, training, data acquisition etc.) and have access to other facilities as well as networks within the research community that could be of benefit to our clients.

- Grant-aided Partnerships

We work in collaborative long term research projects which are granted by Austrian and European funding organisations.

- Contract Research

Industrial partners fund the costs of research (instrument fees, consumables and salaries for staff or scholarships).

- Testing and Consultancy

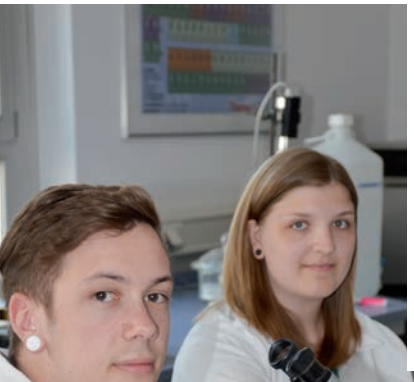
We assist the client to make well-informed decisions – be it failure analysis, materials testing, identification of contaminants or quality assurance.

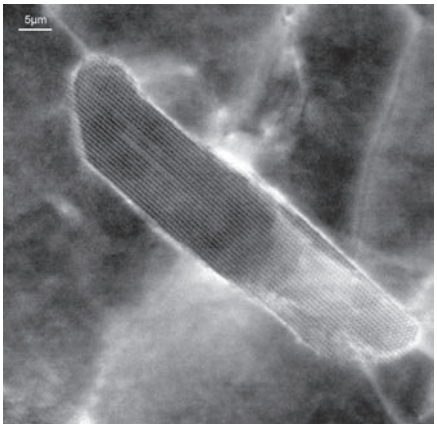
- Training Courses

We provide training on in-house instruments for SMEs who wish to purchase certain microscopes or use these instruments on a regularly basis and see the need to upskill their staff to become self-sufficient with their analyses.

- Know how Transfer

We offer apprenticeships and work experience to young people who are interested in finding out more about work in different sectors of our institute, from physical and chemical laboratories to public relations and media engineering.





Events and Workshops

Lange Nacht der Forschung 2012 & 2014

International Impact

Being an (inter)national resource of expertise our skills are in high demand. Since international collaboration, discussions and exchange of ideas are creating a productive and sustainable environment to develop new approaches – and subsequently projects – we are engaging in two different areas: European research programmes (FP7) such as ESTEEM2 in Infrastructures or S3 in Eurostars on the on hand; and world-wide collaborations focussing on specialized research tasks on the other hand.

ACR-Workshop

"Zoom bis in die Atome", Organized by ZFE Graz and ÖGI Leoben, 20 Nov 2013, TU Graz

SFG Workshop Fast Forward for You

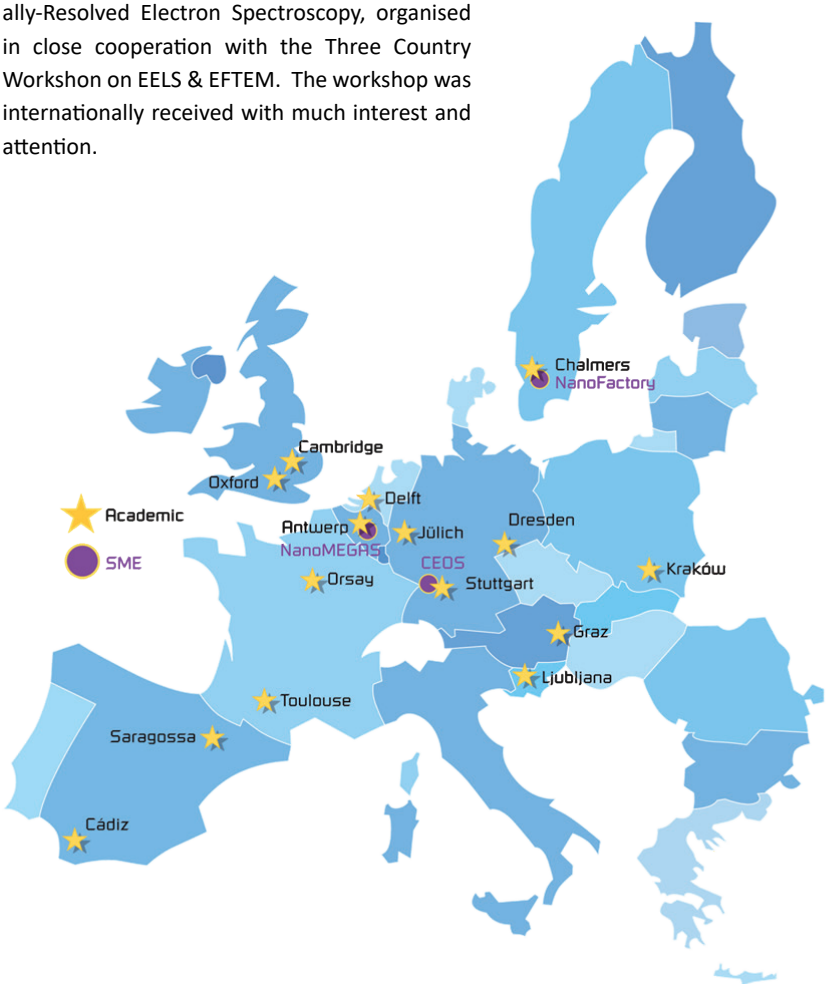
"Mikroskopie von Polymeren und Verbundstoffen", 2 Feb 2012, TU Graz

ESTEEM2

ESTEEM2 is a European Integrated Infrastructure of electron microscopy facilities providing access for the academic and industrial research community in the physical sciences to the most powerful TEM installations in Europe (amongst them the ASTEM at Graz) and to some of the best characterisation techniques available at the nanoscale. ESTEEM2 will benefit from European Union support until September 2016.

FELMI-ZFE concentrates on nanoanalytical characterisation techniques such as EELS and EDX as well as studies of surface plasmons of nanostructures.

In April 2014 it was the great pleasure of FELMI-ZFE to run the European Workshop on Spatially-Resolved Electron Spectroscopy, organised in close cooperation with the Three Country Workshon on EELS & EFTEM. The workshop was internationally received with much interest and attention.



Academic Education

LLL Courses

Problem Solving with Scanning Electron Microscopy and X-ray Microanalysis

(S. Mitsche, P. Pölt, A. Reichmann, H. Schröttner)

Once a year, scientists, engineers as well as technicians profit from this course to solve their analytical problems. Our qualified staff takes interested participants step-by-step through the use of advanced scanning electron microscopes during an intense three days hands-on workshop so that they gain deep insight into essential principles and methods in the field of scanning electron microscopy and x-ray microanalysis of materials.

We are using the latest equipment and know-how to assure that the participants take successfully top quality images, spectra and elemental maps. The techniques are applicable to fields ranging from materials research (steel, ceramics, semiconductors, polymers, etc.) to biological research. Participants are very welcome to bring their own samples to analyse them with our professional help.

GIF-School in Cooperation with Gatan, USA

(T. Haber, G. Kothleitner, W. Grogger)

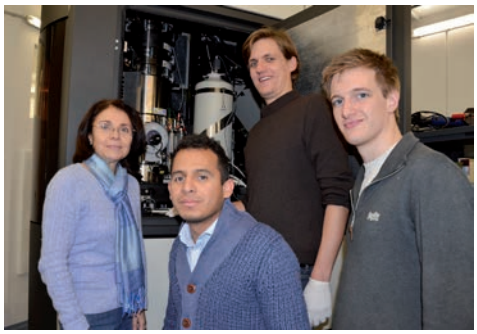
The joint FELMI/GATAN GIF-School is an intense four days hands-on laboratory workshop taking participants step-by-step through the use of an integrated FEI energy-filtering / EELS system (CM20/GIF, TF20/HR-GIF and TITAN/GIF Quantum).

Our qualified staff familiarizes participants with the latest EELS & EFTEM equipment as well as with fundamental principles and methods which are crucial to take top quality EELS spectra and energy-filtered images or elemental maps. Participants learn to apply practical techniques, how to use hardware and software systems as well as advanced EELS and EFTEM applications in a very efficient manner. The techniques are applicable to fields ranging from biological to materials research. Prior experience with transmission electron microscopy is beneficial, in the conventional and in the scanning (STEM) mode; a basic familiarity with EELS and EFTEM is an advantage.

The lectures are highly informative filled with detailed discussions with experts in the field and hands-on experience with various techniques. By the end of the course participants have the know-how to optimize the performance of their GIF as well as their EELS and EFTEM experimental setups in order to capture and extract the maximum amount of information from TEM samples.

Presentations and Lab Tours

Presentations at and tours through the Institute including lectures and demonstrations have been organised for groups of physics and chemistry teachers and for students of the TU Graz, schools and local universities. Around 250 pupils, teachers and students from other institutions visited the Institute during the period 2012–2014.



2012

27 Jan. 2012, Chemie-Ingenieurschule, Graz (Letofsky-Papst)
9 Feb. 2012, Grammar School BG/BORG (HIB), Graz Liebenau (Zankel)
13 Feb. 2012, ASTEM-Tour (Hofer)
23 Apr. 2012, Grammar School BG/BRG Pestalozzi, Graz (Zankel)
27 Apr. 2012, Lange Nacht der Forschung 2012: Wie sehen Atome aus? (Zankel)
3 May 2012, Prasentation of the Institute: Conference of Experimental Physics, Dr. Pottlacher (Zankel)
7 May 2012, Grammar School Keplergymnasium, Graz (Zankel)
31 May 2012, University of California, Berkeley USA, Prof. Peter Hosemann (Hofer)
19 Jul. 2012 FIT-Frauen in die Technik (Reichmann)
14 Aug. 2012 Holiday interns TU Graz (Zankel)
5 Nov. 2012, Chemie-Ingenieurschule, Graz (Letofsky-Papst)
7 Nov. 2012, Introduction day TU Graz, Walter Blass (Zankel)
8 Nov. 2012, Presentation of the Insitute, Faculty of Mathematics, Physics and Geodesy (Hofer)
1 Dec. 2012, Students of Bionik/Biomimetics in Energy Systems, Carinthia University of Applied Sciences (Pölt)

2013

18 Apr. 2013, Texas Christian University, Department of Chemistry, Prof. Jeffrey L. Coffer (Pölt)
16 May 2013, Physics Teacher, Grammar School BRG Petersgasse, Graz (Mayrhofer)
25 Jun. 2013, Grammar School Ursulinen, Graz (Letofsky-Papst)
7 Aug. 2013, Rotary Club, Graz (Hofer)
9 Aug. 2013, AVL Graz, Dr. Michael Paulweber, Alexander Bergmann (Hofer)
21 Oct. 2013, Chemie-Ingenieurschule, Graz (Letofsky-Papst)

2014

8 Jan. 2014, Introduction day for new employees, TU Graz: Walter Blass (Mitsche)
31 Jan. 2014, President Eichler, ASTEM-Tour (Hofer)
25 Mar. 2014, University Leoben, University Paderborn (Wewerka)
4 Apr. 2014, LANGE Nacht der Forschung, “Zoom bis in die Atome” (Zankel)
15 Mai 2014, ASTEM-Tour, Controller group of the Austrian Universities (Kothleitner)
3 Jun. 2014, AMAG, Braunau-Ranshofen (Mitsche)
5 Jun. 2014, Joanneum Research, Waldhauser Wolfgang; Institutsbesichtigung im Rahmen der CBC 2014 (Grogger)
4 Aug. 2014, Mitsubishi Heavy Industries, Ltd., Nagasaki R&D Center (Albu)
19 Aug. 2014 Holiday interns TU Graz, FIT-Frauen in die Technik (Wewerka)
21 Oct. 2014, Chemieingenieurschule, Graz (Reichmann)

Guest Speakers at the Institute

Knut Urban,
Research Centre Jülich

2012

10 Feb. 2012, Klaus PASTL
AKH Linz, Austria, "Entwicklung und Einsatz von Knochenschrauben aus humaner Corticalis"
24 Feb. 2012, Harald THOMMESEN
TU Graz, Austria, "Bestimmung der Korngrößenverteilung und Domänenstruktur von NTC-Keramiken"
11 May 2012, Marc WILLINGER
Fritz-Haber-Institut (MPG), Berlin, Germany, "Observation of dynamic processes on the surface of metallic systems by environmental SEM"
1 Jun. 2012, Ulrich HOHENESTER
Institute of Physics, University of Graz, Austria, "The promise of plasmonics"
22 Jun. 2012, Christian MITTERER
University of Leoben, Austria, "Multifunctional hard coatings"
25 Jun. 2012, Philip D. RACK
The University of Tennessee, Knoxville, USA, "Focused electron beam induced processing: experiments, simulations, and applications"
13 Jul. 2012, Ramona KÖPPL
TU Graz, Austria, "Morphologische Untersuchung von Papier- und cellulosischen Faserproben mittels Rasterelektronenmikroskopie"
16 Oct. 2012, Stanislav GORB
University of Kiel, Germany, "Biologically-Inspired reversible Adhesives: Where Are We Now?"
23 Nov. 2012, Christian RANACHER
TU Graz, Austria, "Evaluierung von leitfähigen Inkjet Tintensystemen und Sintermethoden für Anwendungen im Bereich der gedruckten Elektronik"

2013

8 Jan. 2013, Knut URBAN
Peter Gruenberg Institute, Research Centre Jülich, Germany, "Pikometer Elektronenmikroskopie – Auf der Spur der Atome an den Grenzen der Optik"
19 Mar. 2013, Eva OLSSON
Chalmers University of Technology, Gothenburg, Sweden, "Correlating transport properties to local nanostructure using *in situ* microscopy"
19 Apr. 2013, René de KLOE
EDAX, Tilburg, Netherland, "High resolution EBSD mapping: data collection and orientation accuracy considerations"
23 Apr. 2013, Peter SCHATTSCHNEIDER
Vienna University of Technology, Vienna, Austria, "Electrons with topological charge"
14 Jun. 2013, Heinz WANZENBÖCK
Vienna University of Technology, Vienna, Austria, "FEBID of Fe based precursors: toward direct write CNT templating"

2014

7 Jan. 2014, Quentin RAMASSE
SuperSTEM, STFC Daresbury Laboratories Warrington, UK, "Applications of low voltage STEM-EELS: from fingerprinting single atom dopants to full structure determination"
13 Mai 2014, Nicola HÜSIG
Universität Salzburg, Austria, "Porous and High Surface Area Nanoarchitectures: Synthesis and Application in Lithium Ion Batteries"
21 Nov. 2014, Ing. Mag. Georg RAGGL
(JEOL Germany GmbH); "Neuigkeiten im Bereich der Elektronenmikroskopie von JEOL-2"
2 Dec 2014, Joachim MAYER
RWTH Aachen, Germany, "PICO – The next generation of Aberration Corrected TEMs"

Master & Doctoral Theses at the Institute

Finished PhD Theses

REINGRUBER Herbert (2012), New microscopic methods for the characterization of microfiltration membranes.
FLADISCHER Stefanie (2013), Application of new EDXS quantification schemes in TEM to organic semiconducting devices.
HAAS Wernfried (2013), Morphology control of high-performance polymer solar cells.
SCHMIDT Franz (2014), Mapping surface plasmons of designed nanostructures with an electron beam.
SCHMIED Roland, Focused ion beam structuring of low melting polymers.

PhD Theses in Progress

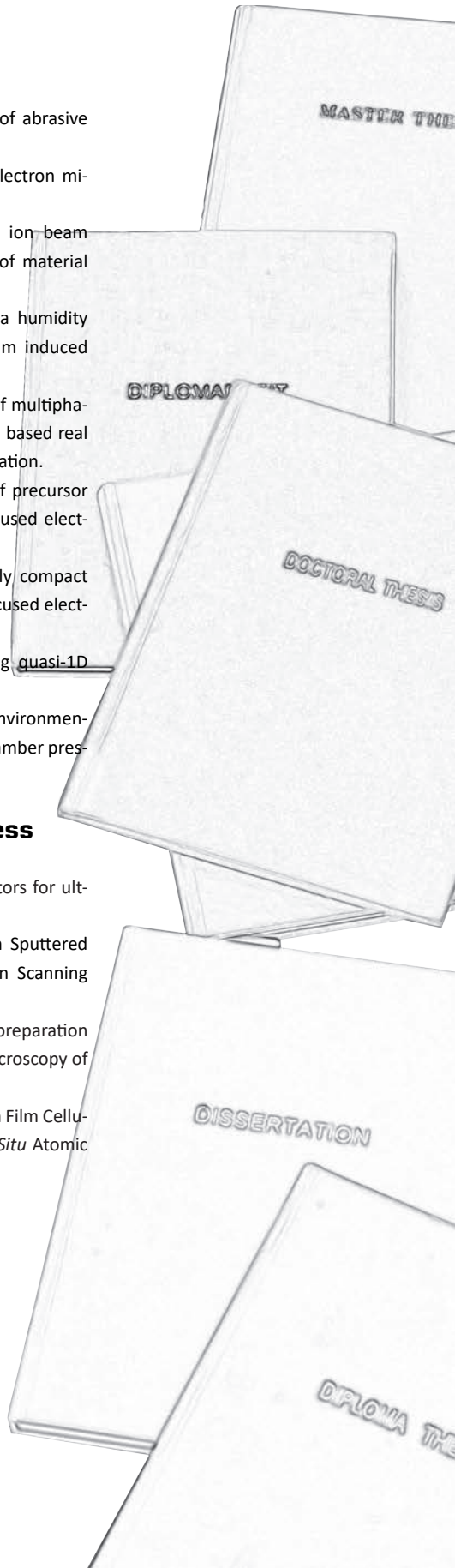
GANNER Thomas, Enzymatic cellulose degradation visualized by *in situ* high resolution Atomic Force Microscopy.
KNEZ Daniel, High resolution STEM of nanoparticles and nanoalloys.
KONRAD Lukas, EEL and EDX spectroscopy for the quantitative Analysis of Hard Metals.
KRAXNER Johanna, Quantitative Analyse von organischen Materialien mit TEM.
MEINGAST Arno, STEM investigations of GaN-based semiconductors.
NACHTNEBEL Manfred, *In situ* Experimente mit soft materials im ESEM.
ORTHACKER Angelina, Focused Ion Beam Processing of Polymers: The Influence of Material Properties.
WINKLER Robert, Fabrication of functional, freestanding 3D nano-architectures via focused electron beam induced deposition.
UUSIMÄKI Toni, Nanotomography in the transmission electron microscope.

Finished Master Theses

ASCHL Timothy (2012), Tunable artificial cellulose substrates for *in situ* AFM investigation of enzymatic degradation.
GANNER Thomas (2012), Enzymatic cellulose degradation via atomic force microscopy in liquid environments.
KNITEL Serafin (2013), Defect analysis of abrasive wear of cutting inserts.
KNEZ Daniel (2013), Preparation and electron microscopy of graphene.
ORTHACKER Angelina (2013), Focused ion beam processing of polymers: the influence of material properties.
KOLB Florian (2013), Development of a humidity sensor based on focused electron beam induced PtC deposition.
ROSKER Stephanie (2014), Fabrication of multiphase artificial cellulose substrates for AFM based real time investigations of enzymatic degradation.
WINKLER Robert (2014), Implications of precursor dynamics on nanostructures during focused electron beam induced deposition.
GEIER Barbara (2014), Rapid and highly compact purification at room temperature for focused electron beam induced Pt-C deposits.
STERMITZ Martin (2014), Free standing quasi-1D resonators for sensing applications.
FITZEK Harald(2014), Optimizing the environmental scanning electron microscope for chamber pressures up to 2700 Pa.

Master Theses in Progress

ARNOLD Georg, Quasi-1D nano-resonators for ultrasensitive gas sensing applications.
MELISCHNIG Alexander, DC Magnetron Sputtered Metallic Thin Films for High Resolution Scanning Electron Microscopy.
PLATZER Julia, Optimization of sample preparation techniques for transmission electron microscopy of Al-Cu and Eco Mg alloys.
SATTELKOW Jürgen, Semicrystalline Thin Film Cellulose: Close-to Nature Substrates for *In Situ* Atomic Force Microscopy.



Master and Doctoral Students from other University Institutes

With its advanced microscopy competence the Institute supports Master and PhD students from other institutes of the TU Graz and even other Universities and reserch organizations. These activities range from short term service to enduring scientific collaborations.

Graz University of Technology

Institute of Inorganic Chemical

Luciana VIEIRA, PhD thesis

Institute of Chemistry and Technology of Materials

Dominik GENSER, PhD Thesis
Elisabeth ZIEGLER, PhD Thesis
Haimo BUCHER, PhD Thesis
Clemens EBNER, PhD Thesis
Gabriel SCHROTTER, Master Thesis
Florian PREISHUBER-PFLÜGL, PhD Thesis
Patrik PERTL, Master Thesis
Lisa Dreier, Master Thesis
Michaela SCHARFEGGER, PhD Thesis

Institute of Chemical Engineering and Environmental Technology

Stefan WEINBERGER, Master Thesis
Astrid STADLHOFER, PhD Thesis
Christoph GRIMMER, PhD Thesis
Stephan NESTL, PhD Thesis

Institute of Environmental Biotechnology

Veronika PERZ, PhD Thesis
Karin GREIMEL, PhD Thesis

Institute of Biotechnologie and Biochemical Engineering

Manuel EIBINGER, PhD Thesis

Institute of Experimental Physics

Alexander VOLK, PhD Thesis
Philip THALLER, PhD Thesis
Matteo LUISI, Master Thesis
David FUCHS, Master Thesis
Johannes STEURER, Master Thesis

Institute of Solid State Physics

Johann Wolfgang FISCHER, PhD Thesis
Michael ZAWODZKI, Master Thesis

Institute of Materials Physics

Eva-Maria STEEYSKAL, Master Thesis
Stefan TOPOLOVEC, PhD Thesis
Peter PARZ, PhD Thesis

Institute of Applied Geoscience

Daniel HÖLLEN, PhD Thesis
Artur DEDITIUS, PhD Thesis
Andre BALDERMANN, PhD Thesis
Bettina BURGSTALLER, PhD Thesis

Institute of High Voltage Engineering and System Management

Jürgen FABIAN, PhD Thesis
Norasage PATTANADECH, PhD Thesis

Institute of Materials Science and Welding

Rene RADIC, Forschung
Rudolf JESSE, Master Thesis
Kemal MUCIC, Master Thesis
Asmir KUDERZOVIC, PhD Thesis
Ernst PLESIUTSCHNIG, PhD Thesis
Alexander TIMOSHENKOV, PhD Thesis
Mizanur RACHMAN, PhD Thesis
Deao Yadau SURAY, Master Thesis
Monika SCHULER, PhD Thesis
Thomas SPRENGER, Master Thesis
Romain BUREAU, PhD Thesis

Institute of International Combustion Engines and Thermodynamics

Andrej GOLUBKOV, PhD Thesis
Claus MATZER, Master Thesis

Tools & Forming, Member of Frank Stronach Institute

Marina KOFLER, PhD Thesis

University of Graz

Institute of Chemistry

Tibor MÜLLER, PhD Thesis

Institute of Physics

Kashif NADEEM, PhD Thesis
David FUCHS, Master Thesis
Johannes STEURER, Master Thesis
Christian GRUBER, PhD Thesis
Markus KRUG, Master Thesis
Judith DOHR, Master Thesis

Institute of Earth Science

Barbara PUHR, PhD Thesis

Institute of Pharmaceutical Sciences

Romana BAUMGARTNER, PhD Thesis

Medical University of Graz

Institute of Cell Biology, Histology and Embryology

Stefan WERNITZNIG, PhD Thesis

University of Leoben

Departement Physical Metallurgy and Materials Testing

Christian SARINGER, Master Thesis
Nina SCHALK, PhD Thesis
Michael TKADLETZ, PhD thesis
Thomas WEIRATHER, PhD Thesis

Department of General, Analytical and Physical Chemistry

Andreas EGGER, PhD Thesis

MCL Materials Center Leoben

Marina GRUBER, PhD Thesis

Departement Metallurgy

Jiehua LI, Habilitation Thesis

Vienna University of Technology

Institute of Solid State Electronics

Stefan STEINHAUER, PhD Thesis

University of Vienna

Physics of Nanostructured Materials

Stefan NOISTERNIG, Master Thesis

University of Maribor, Slovenia

Faculty of Mechanical Engineering

Peter GSELMANN, PhD Thesis
Matej STEINACHER, PhD Thesis

Jozef Stefan Institute, Ljubljana, Slovenia

Department of Nanostructured Materials

Sandra DREV, PhD Thesis

University of Groningen, The Netherlands

Zernike Institute for Advanced Materials

Gopi KRISHNAN, PhD Thesis

University of Madrid, Spain, Sevilla

Instituto de Ciencia de Materiales

Carlos GARCIA-NEGRETE, PhD Thesis

University of Zagreb, Croatia

Faculty of Pharmacy and Biochemistry

Jablan JASNA, PhD Thesis

Bilkent University Ankara, Turkey

Advanced Research Laboratories

Emel Sungur OZEN, PhD Thesis

Ecole polytechnique fédérale de Lausanne, Switzerland

Nuclear Materials at Paul Scherrer Institute

Christiane VIEH, PhD Thesis

University of Tübingen, Germany

Center for Applied Geoscience–Geomicrobiology

Nikolaus HAGEMANN, PhD Thesis

Ben-Gurion University, Israel

Departement of Materials Engineering

Eran AMSELLEM, PhD Thesis

Polish Acadamy of Sciences

Institute of Low Temperature and Structure research

Katarzyna BARANOWSKA, PhD Thesis

Christian Doppler Laboratory for localized corrosion

Manuela PROHASKA, PhD Thesis
Roland LACKNER, PhD Thesis

Outreach

Outreach


GEWINNERIN

BESTE TIPPS FÜR SEKRETÄRINNEN

„Das ‚Secretary Success'-Forum war eine tolle Gelegenheit zum Erfahrungsaustausch mit KollegInnen und um effizientere Arbeitstechniken kennenzulernen", schwärmt Silke Winkler (l.) über ihren Gewinn eines **zweitägigen Workshops für Assistentinnen.** Im Balance Hotel Stegersbach widmete sich ein Top-Expertenteam rund um Gastgeberin und Initiatorin Anna Zambelli (r.) im Rahmen von 17 parallel laufenden Workshops den Herausforderungen von Sekretärinnen. *Infos: secretary-academy.at*

The Institute in the News

News 2012

DIE PRESSE/WISSEN, 15 Jan. 2012, "Sicher verbunden"
TU GRAZ PEOPLE, 21 Jan. 2012, "Spezialkurs für Nanoanalytik an der TU Graz"
ACR NEWSLETTER, 12 Feb. 2012, "ACR Pilotprojekt: Gemeinsame Forschungsinfrastruktur"
TU GRAZ PEOPLE, 15 Mar. 2012, "Very Good News"
WIENER ZEITUNG, 7 Apr. 2012, "Deutliche Signale"
WOMAN, 8 Jun. 2012, "Silke Winkler: Gewinnerin Secretary Success 2012"
FACTORY, 1 Jul. 2012, "ACR-Pilotprojekt Forschungsinfrastruktur"
TOP OF AUTOMOTIVE 2012, 10 Oct. 2012, "Weniger Material, weniger Energie"
KLEINE ZEITUNG, 14 Oct. 2012, "Erklär mir das Elektronenmikroskop"
TU GRAZ NEWS & STORIES, 16 Oct. 2012, "Der Unsichtbarkeit auf der Spur: Physiker untersuchen Elektronenwolken"
DIEPRESSE.COM, 20 Oct. 2012, "Eine Schraube, die sich nach getaner Arbeit auflöst"
DIE PRESSE am Sonntag, 21 Oct. 2012, "Eine Schraube, die sich nach getaner Arbeit auflöst"
KURIER, 24 Oct. 2012, "Verbesserung der Lebensqualität"
DER STANDARD, 27 Oct. 2012, "Mit der dunklen, atmenden Mode der Unsichtbarkeit auf der Spur"
MEDICAL TRIBUNE, 31 Oct. 2012, "Kooperationspreise vergeben – Desinfektion und Schrauben"
SALZBURGER WIRTSCHAFT, 2 Nov. 2012, "Innovative Medizintechnik"
DIE PRESSE/WISSEN, 25 Nov. 2012, "Größe, Form, Chemie: Partikel auf einen Blick"
NEW BUSINESS, Dec. 2012, "Werkstoffprüfung bis in die Atome"
UNI.ON, 11 Dec. 2012, "Kleine Teile, große Forschung"

News 2013

TUGRAZ RESEARCH, Feb. 2013, "Elektronenmikroskop der Superlative an der TU Graz"
TU GRAZ PEOPLE, Mar. 2013, "e-mail from Granada"
ACR NEWSLETTER, Mar. 2013, "Weltpremiere in Graz: Atomare Auflösung mit 1000 Spektren pro Sekunde"
ATZonline, Jun. 2013, "Polyamid in Tanksystemen"
DER STANDARD, 24 Aug. 2013, "Neuartiger Nano-Sensor für Luftanalysen der Zukunft"
FORUM SCIENCE, Sep. 2013, "Investitionen in die Innovationskraft"
FACTORY, Sep. 2013, "Durchbruch in der Sensorik"
KRONENZEITUNG, 10 Nov. 2013, "Das Super-Mikroskop"
KLEINE ZEITUNG, 13 Nov. 2013, "Der Herr des Nebels"
JAHRESBERICHT TUGraz 2013, "Forschungsthemen"

News 2014

TUGRAZ RESEARCH 12, 1 Jan. 2014, "Forschungsverbund für atomare Auflösung Research Association for Atomic Resolution"
KLEINE ZEITUNG, 2 Jan. 2014, "Forschung begleitet das neue Jahr"
PEOPLE TUGRAZ, Feb. 2014, "Kontinuität und Erneuerung"
UNIZEIT, Feb. 2014, "Wolkentanz"
UNIZEIT, Feb. 2014, "alumni UNI Graz"
STEIRISCHE BERICHTE, Mar. 2014, "Tanz der Elektronenwolken"
PRESSE.TUGRAZ.at, 3 Apr. 2014, "Atome exakt zählen: TU Graz entwickelt Quantifizierungsmethode mittels Elektronenmikroskopie"
ACR NEWSLETTER, Apr. 2014, "Verbessert: Nanofabrikation mit Elektronen"
DER STANDARD.at, 19 Mai 2014, "Grazer Forscher finden Schlüssel zum Verhalten von Plasmonen"
ACR NEWSLETTER, Mai 2014, "EELS und EDS unter dem Mikroskop"
PEOPLE TUGRAZ, Jul. 2014, "Kontinuität und Erneuerung"
ACR INOVATIONSRADAR, 30 Sep. 2014, "Ich lebe für den Aha-Effekt"
DER STANDARD, 10 Okt. 2014, "Rivalitäten um

Forschungsgeräte beseitigen”
KLEINE ZEITUNG.at, 13 Okt. 2014, “Mihaela Albu erhält ACR Woman Award 2014”
DER STANDARD.at, 16 Okt. 2014, “In der Küche der Elemente”
APA Austria Presse Agentur eG, 16 Okt. 2014, “Mihaela Albu erhält ACR Woman Award 2014”
LOGISTIK EXPRESS, 16 Okt. 2014, “ACR Kooperationspreis 2014: Leistungsschau der innovativen KMU”
KLEINE ZEITUNG, 16 Okt. 2014, “Frau des Jahres”
WKO.TV, 17 Okt. 2014, “Kernphysikerin Mihaela Albu erhält ACR Woman Award 2014”
DER GRAZER, 19 Okt. 2014, “Mihaela Albu, Kernphysikerin”
INDUSTRIE MAGAZIN, 20 Okt. 2014, “ACR Woman Award 2014 geht an die Kernphysikerin Mihaela Albu”
ÖSTERREICHS ERSTES WIRTSCHAFTSMAGAZIN FÜR FRAUEN, 20 Okt. 2014, “ACR Woman Award 2014”
ACR NEWSLETTER, 20 Okt. 2014, “Eine entschlossene Wissenschaftlerin: Kernphysikerin Mihaela Albu”
WWW.NEWSWALK.info, 20 Okt. 2014, “In der Küche der Elemente”
BMWFW, 20 Okt. 2014, “ACR Kooperationspreis und ACR Woman Award 2014”
DIE PRESSE.com, 20 Okt. 2014, “Eine Bühne für die Forschung”
GATAN NEW.com, 3 Nov. 2014, “Spectral Voxels Reconstructed from Simultaneous EELS and EDS Spectrum Image Tomography”
ACR NEWSLETTER, 9 Dec. 2014, “EELS und EDS unter dem Mikroskop”
DER STANDARD, 31 Dec. 2014, “Blick in die Materie mit Pioniergeist”


12 WISSEN

Very Good News

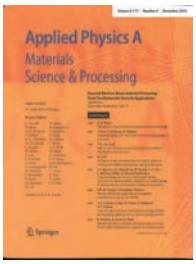
Elektronenmikroskopie an der TU Graz in europäische Spitzenliga aufgenommen: Ab 1. Oktober 2012 können Forschende aus ganz Europa auf die Elektronenmikroskopie-Einrichtungen der TU Graz zugreifen. Das Elektronenmikroskopielabor FELMI fand Aufnahme in das ESTEEM-2-Konsortium. Im Infrastrukturnetzwerk ESTEEM sind die 14 führenden Elektronenmikroskopielabors Europas vereint. Das Programm läuft bis August 2016.

Publications

Publications

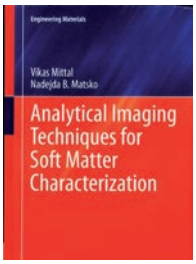
Editor in Applied Physics A

Last year Harald Plank edited the special edition “Focused Electron Beam Induced Processing: From Fundamentals Towards Applications” of the international journal “Applied Physics A”. The articles have been written by 14 key scientists doing research in the Americas, Europe and Australia.



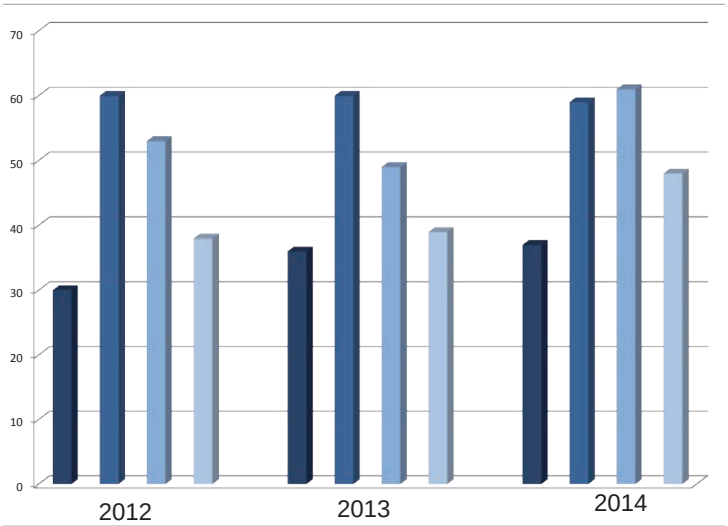
Analytical Imaging Techniques for Soft Matter Characterization

Nadejda Matsko and Vikas Mittal present new advances in different microscopy techniques such as AFM, SEM and TEM. The chapters are not based on describing materials systems, but rather on answering the problems or questions arising in their characterisation. Qualitative and quantitative analyses are discussed, polymers as well as biologiacal matter are included.



FELMI-ZFE is facing a number of different tasks due to the fact that we are not only a research institute but also devoted to teaching activities as well as industry services. Still we have reached a satisfactory number of peer reviewed publications which is steadily rising.

Articles written by our scientists are published in high ranking journals, such as ACS Nano, Chem.Commun. Angewandte Chemie, Ultramicroscopy, Advanced Materials, Soft Matter etc.



Development of poster and oral presentations (conferences, workshops, etc.) of FELMI-ZFE staff and of non peer-reviewed publications of the institute.

Peer Reviewed Publications 2012

Albu, M.; Mayr, P.; Hofer, F.; Kothleitner, G.: "Comprehensive analysis of precipitates in rich Cr steels by means of electron energy loss spectrometry spectrum imaging" in: *Metallurgical analysis = Yejin-fenxi, 32* (2012) 12, 8–14.

Arar, M.; Pein, A.; Haas, W.; Hofer, F.; Norrman, K.; Krebs, F. C.; Rath, T.; Trimmel, G.: "Comprehensive Investigation of Silver Nanoparticle/Aluminum Electrodes for Copper Indium Sulfide/Polymer Hybrid Solar Cells" in: *The Journal of Physical Chemistry* C 116 (2012) 36, 19191–19196.

Bubner, P.; Dohr, J.; Plank, H.; Mayrhofer, C.; Nidetzky, B.: "Cellulases dig deep: *in situ* observation of the mesoscopic structural dynamics of enzymatic cellulose degradation" in: *The journal of Biological Chemistry* 287 (2012) 4, 2759–2765.

Eder, G.C.; Spoljaric-Lukacic, L.; Chernev, B.S.: "Visualisation and characterisation of ageing induced changes of polymeric surfaces by spectroscopic imaging methods" in: *Analytical and Bioanalytical Chemistry 403* (2012) 3, 683–695.

Djuric, T.; Ules, T.; Gusenleitner, S.; Kayunkid, N.; Plank, H.; Hlawacek, G.; Teichert, C.; Brinkmann, M.; Ramsey, M.; Resel, R.: "Substrate selected polymorphism of epitaxially aligned tetraphenyl-porphyrin thin films" in: *Physical Chemistry Chemical Physics* 14 (2012) 1, 262–272.

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Fladischer, S.; Neuhold, A.; Kraker, E.; Haber, T.; Lamprecht, B.; Salzmann, I.; Resel, R.; Grogger, W.: "Diffusion of Ag into Organic Semiconducting Materials: A Combined Analytical Study Using Transmission Electron Microscopy and X- ray Reflectivity" in: *ACS Applied Materials & Interfaces* 4 (2012) 10, 5608–5612.

Ganner, T.; Bubner, P.; Eibinger, M.; Mayrhofer, C.; Plank, H.; Nidetzky, B.: "Dissecting and Reconstructing Synergism - *IN SITU* VISUALIZATION OF COOPERATIVITY AMONG CELLULASES" in: *Journal of Biological Chemistry* 287 (2012) 52, 43215–43222.

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Rumpf, K.; Granitzer, P.; Hilscher, G.; Albu, M.; Poelt, P.: "Magnetically interacting low dimensional Ni-nanostructures within porous silicon" in: *Microelectronic Engineering* 90 (2012), 83–87.

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Brunet, E.; Maier, T.; Mutinati, G.C.; Steinhauer, S.; Köck, A.; Gspan, C.; Grogger, W.: "Comparison of the gas sensing performance of SnO^2 thin film and SnO_2 nanowire sensors" in: *Sensors and Actuators* B 165 (2012), 110–118.

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Valeeva, A.A.; Schroettner, H.; Rempel, A.A.: "NbO Disintegration by Surfactant-Assisted High-Energy Ball Milling" in: *Inorganic Materials* 50 (2014), 398–403.

Zellnitz, S.; Schröttner, H.; Urbanetz, N.A.: "Surface modified glass beads as model carriers in dry powder inhalers- Influence of drug load on the fine particle fraction" in: *Powder Technology* 268 (2014), 377–386.

Thaler, P.; Volk, A.; Lackner, F.; Steurer, J.; Knez, D.; Grogger, W.; Hofer, F.; Ernst, W.E.: "Formation of biometallic core-shell nanowires along vortices in superfluid He nanodroplets" in: *Physical Review* B 90 (2014), 155442-1–155442-5.

Timoshenkov, A.; Warczok, P.; Albu, M.; Klarner, J.; Kozeschnik, E.; Gruber, G.; Sommitsch, C.: "Influence of Deformation on Phase Transformation and Precipitation of Steels for Oil Country Tubular Goods" in: *steel research international* 85 (2014) 6, 954–967.

Winkler, R.; Geier, B.; Plank, H.: "Spatial chemistry evolution during focused electron beam-induced deposition: origins and workarounds" in: *Applied Physics* A 117(2014), 1675–1688.

Winkler, R.; Fowlkes, J.; Szkudlarek, A.; Utke, I.; Rack, P.D.; Plank, H.: "The Nanoscale Implications of a Molecular Gas Beam during Electron Beam Induced Deposition" in: *ACS Applied Materials & Interfaces* 6 (2014), 2987–2995.

Wohlmuth, D.; Epp, V.; Bottke, P.; Hanzu, I.; Bitschnau, B.; Letofsky-Papst, I.; Kriechbaum, M.; Amenitsch, H.; Hofer, F.; Wilkening, M.: "Order vs. disorder — a huge increase in ionic conductivity of nanocrystalline $LiAlO_2$ embedded in an amorphous-like matrix of lithium aluminate" in: *Journal of Materials Chemistry* A 2 (2014) 47, 20295–20306.

Demmel, L.; Schmidt, K.; Lucast, L.; Havlicek, K.; Zankel, A.; Koestler, T.; Reithofer, V.; de Camilli, P.; Warren, G.: "The endocytic activity of the flagellar pocket in *Trypanosoma brucei* is regulated by an adjacent phosphatidylinositol phosphate kinase" in: *Journal of Cell science* 127 (2014), 2351–2364.

Müllner, T.; Zankel, A.; Svec, F.; Tallarek, U.: "Finite-size effects in the 3D reconstruction and morphological analysis of porous polymers" in: *Materials Today* 17 (2014) 8, 404–411.

Zankel, A.; Wagner, J.; Poelt, P.: "Serial sectioning methods for 3D investigations in materials science" in: *Micron* 62 (2014), 66–78.

Lectures 2012

Hofer, F.; "Analytical electron microscopy of complex nanostructured materials", Graduate School BuildMoNa, Universität Leipzig, 11 Mar. 2012, **invited.**

Hofer, F.: "Advanced microscopy of complex nanostructured materials", SCANDEM Congress, Bergen, 14 Jun. 2012, **invited.**

Kothleitner, G.: "Analytical Transmission Electron Microscopy", Symposium on Nanostructured Surfaces and Interfaces, 13 Apr. 2012, **invited.**

Plank, H.: "Passive Erzeugung von Luftionen durch funktionale Beschichtungen", Innenraumtagung, Wien, 05 Nov. 2012, **invited.**

Zankel, A.: "*In situ* ultramicrotomy in the ESEM a 3D view into technical and biological materials", Newcastle University, Institute of Neuroscience, Newcastle, 25 Sep. 2012, **invited.**

Dienstleder, M.; Gspan, C.; Grogger, W.: "30M Progress Report in ESiP", ESiP Meeting, London, 08 Nov. 2012.

Fladischer, S.; Neuhold, A.; Haber, T.; Resel, R.; Grogger, W.; Kraker, E.; Lamprecht, B.: "Characterization of Ag diffusion into organic materials using Transmission Electron Microscopy and X-ray reflectivity", International Conference on Organic Electronics. Tarragona, 25 Jun. 2012

Fladischer, S.; Neuhold, A.; Resel, R.; Haber, T.; Grogger, W.; Kraker, E.; Lamprecht, B.: "Ag Diffusion into Organic Semiconductors: A Transmission Electron Microscopy and X-ray Reflectivity study",

ASEM-Workshop. Salzburg, 26 Apr. 2012.
Grogger, W.; Fladischer, S.: "Erste Ergebnisse mit integriertem EDS (ChemiSTEM) am ASTEM", Bruker EDS-Kolloquium. Berlin, 23 May 2012.

Haber, T.; Rothländer, T.; Auner, C.; Palfinger, U.; Stadlober, B.; Grogger, W.: "Analytical TEM cross-section investigations for organic electronic devices", International Conference on Organic Electronics, Tarragona, 25 Jun. 2012.

Hofer, F.; "Analytical electron microscopy of energy storage materials", 2nd International Symposium on Advanced Electron Microscopy for Catalysts and Energy Storage Materials. Fritz-Haber-Institut Berlin, 27 Feb. 2012.

Hofer, F.; Grogger, W.; Kothleitner, G.; Fisslthaler, E.; Haas, W.; Haber, T.; Schmidt, F.: "Towards atomic resolution STEM of energy-related materials", 14th annual conference YUCOMAT 2012, Herceg Novi, 03 Sep. 2012.

Hofer, F.: "New Trends in Materials Microscopy", Werkstoffkongress, Leoben, 28 Mar. 2012.

Hofer, F.: "Analytical electron microscopy of energy storage materials", EM-CAT2, Fritz-Haber-Institut, Berlin, 05 Feb. 2012.

Kothleitner, G.; Fladischer, S.; Grogger, W.; Haber, T.; Meingast, A.; Hofer, F.: "Synergies between EDX and EELS Chemical Analysis on a Probe Corrected STEM", European Microscopy Congress, Manchester, 16 Sep. 2012.

Kothleitner, G.: "Optimizing EM Sample Preparation", ESTEEM2-NA3 kick-off meeting, Stuttgart, 03 Dec. 2012.

Matsko, N.: "How cryo-microscopy can solve your problems", Fast Forward for you „Mikroskopie von Polymeren und Verbundstoffen", Graz, 02 Feb. 2012.

Meingast, A.; Bonanni, A.; Kothleitner, G.: "Quantitative (S)TEM-Investigations of an Iron-doped GaN Semiconductor", ASEM-Workshop, Salzburg, 26 Apr. 2012.

Orthacker, A.; Schmied, R.; Chernev, B.S.; Plank, H.: "Advanced Soft Matter Processing via Focused Ion Beam", International Conference of Physics Students 2012, Utrecht, 04 Aug. 2012.

Plank, H.: "Advanced FIB / FEB Dual Beam Prototyping", Solid State Physics Seminars–EMPA, Thun, 28 Aug. 2012.

Plank, H.; "Exploiting the full potential of Focused Electron Beam Induced Deposition", Guest Lecture, 18 Oct. 2012.

Plank, H.; Schmied, R.; Kolb, F.; Gspan, C.; Haber, T.; Smith, D.A.; Rack, P.D.; Jason D., F.; Kothleitner, G.; Hofer, F.: "Minimization of unwanted proximity deposition during electron beam induced Pt deposition", FEBIP 2012, Zaragoza, 18 Jun. 2012.

Plank, H.; Schmied, R.; Kolb, F.; Gspan, C.; Haber, T.; Smith, D.A.; Fowlkes, J.; Rack, P.D.; Kothleitner, G.; Hofer, F.: "Improving functionality and resolution capabilities for electron beam induced Pt deposition processes", FIB Arbeitskreismeeting, Dresden, 25 Jun. 2012.

Plank, H.: "Advanced Dual Beam Prototyping & Real Time AFM in Biology", Seminar Festkörperphysik, Graz, 13 Jul. 2012.

Pölt, P.: "Von statisch zu dynamisch: *In situ* Experimente im ESEM", Fast Forward for you "Mikroskopie von Polymeren und Verbundstoffen", Graz, 02 Feb. 2012.

Rattenberger, J.; Schröttner, H.; Wagner, J.; Hofer, F.: "Beam transfer characteristics of a low vacuum SEM", Scandem 2012, Bergen, 12 Jun. 2012.

Reichmann, K.; Kirstein, K.; Mitsche, S.: "Grain Boundaries: Still Active in Electronic Ceramics", E-MRS 2012 Spring Meeting, Strassbourg, 17 May 2012.

Reingruber, H.; Zankel, A.; Pölt, P.: "New microscopic methods for characterizing micro filtration membranes", World Filtration Congress WFC11, Graz, 16 Apr. 2012.

Reingruber, H.; Pölt, P.: "New advanced microscopic methods for detailed analysis of strong asymmetric microfiltration membranes", ÖPG Tagung, Technische Universität Graz, 20 Sep. 2012.

Schmidt, F.; Ditlbacher, H.; Hohenester, U.; Hofer, F.; Krenn, J.: "Plasmonics–Using fast electrons to analyze surface plasmons", ASEM-Workshop, Salzburg, 26 Apr. 2012.

Schmidt, F.: "Mapping surface plasmons on metal nanoparticles from breathing modes to edge plasmons", Meeting on Optical Response of Extended Systems (MORE 2012), Vienna, 14 Nov. 2012.

Schmidt, F.; Ditlbacher, H.; Hohenester, U.; Hofer, F.; Krenn, J.R.: "Full characterization of localized surface plasmons on a silver nanodisc", European Microscopy Congress, Manchester, 16 Sep. 2012.

Schmied, R.; Chernev, B. S.; Trimmel, G.; Plank, H.: "New possibilities for soft matter applications: Eliminating technically induced thermal stress during FIB processing", ASEM-Workshop, Salzburg, 26 Apr. 2012.

Schröttner, H.: "Präsentation der Untersuchungsergebnisse aus dem 2. ACR-Automotive-Plattformprojekt", Fachkolloquium Mikro- und Nanoanalytik, Technische Universität Graz, 22 Jun. 2012.

Schröttner, H.: "Materialcharakterisierung mitteles elektronenmikroskopischer Methoden und ergänzenden Verfahren–Methodenkombinationen und in-situ-Untersuchungsmöglichkeiten", Vorstellung der Untersuchungsmöglichkeiten am FELMI-ZFE-Graz, INFINEON Villach, 18 Jun. 2012.

Schröttner, H.: "Funktionelle Materialverbunde (AP5 und AP6)", ACR Automotive Plattform Workshop, Zentrum für Elektonenmikroskopie Graz, 22 Mar. 2012.

Schwaiger, N.; Witek, V.; Feiner, R.; Pucher, H.; Zahel, K.; Pieber, A.; Pucher, P.; Ahn, E.; Chernev, B.S.; Schröttner, H.; Siebenhofer, M.: "Formation of Liquid and Solid Products of Liquid Phase Pyrolysis", 19th International Symposium on Analytical and Applied Pyrolysis, Linz, 21 May 2012.

Uusimäki, T.; Margaris, G.; Trohidou, K.; Granitzer, P.; Rumpf, K.; Morales, M.; Sezen, M.; Kothleitner, G.: "Quantitative electron tomography of magnetite nanoparticles embedded in mesoporous silicon", European Microscopy Congress, Manchester, 16 Sep. 2012.

Wewerka, K.: "TEM-Präparation von Polymeren und Verbundstoffen", Fast Forward for you „Mikroskopie von Polymeren und Verbundstoffen", Graz, 02 Feb. 2012.

Wilhelm, P.: "Ein Bild sagt mehr als 1000 Spektren: bildgebende IR - und Ramanmikroskopie", Fast Forward for you „Mikroskopie von Polymeren und Verbundstoffen", Graz, 02 Feb. 2012.

Zankel, A.; Reingruber, H.: "3D characterization of asymmetric microfiltration membranes", Aviso User Group meeting, Bordeaux, 30 May 2012.

Zankel, A.: "Institutsvorstellung: FELMI-ZFE", Elektronenmikroskopie Core Facilities Meeting 2012, Innsbruck, 04 Jul. 2012.

Lectures 2013

Hofer, F.: "Scanning transmission electron microscopy at atomic resolution", DPG Spring Meeting 2013, Regensburg, 10 Mar. 2013, **invited.**

Hofer, F.: "Electron energy loss near edge fine structures", QEM Quantitative Electron Microscopy 2013, St. Aygulf, 13 May 2013, **invited.**

Hofer, F.: "Scanning transmission electron microscopy of complex nanomaterials", Symposium „Atomic resolution scanning transmission electron microscope", Ljubljana, 19 Sep. 2013, **invited.**

Hofer, F.: "Electron energy-loss spectrometry at high energy resolution", NorTEMnet Conference, 27 Mar. 2013, **invited.**

Hofer, F.: "Towards quantitative elemental mapping at atomic resolution", Annual Users' Meeting, Berkeley, 04 Nov. 2013, **invited.**

Hofer, F.: "Analytische Elektronenmikroskopie von Legierungen und Stählen", Towards Advanced High-Strength Steels: Microstructures, Linz, 09 Oct. 2013, **invited.**

Hofer, F.: "Analytical transmission electron microscopy", EMAT School on Transmission Electron Microscopy, University of Antwerpen, 14 Jun. 2013, **invited.**

Hofer, F.; Kothleitner, G.; Grogger, W.; Albu, M.; Gspan, C.; Fisslthaler, E.: "Rastertransmissionselektronenmikroskopie mit atomarer Auflösung", Festkörperanalytik 2013, Chemnitz, 01 Jul. 2013, **invited.**

Matsko, N.; Mittal, V.: "Low temperature thermotropical dynamical processes in multiphase polymer systems by cryo AFM", MC 2013, Regensburg, 25 Aug. 2013, **invited.**

Matsko, N.: "Novel analytical imaging techniques for soft matter characterization", Bio Nano Imaging, Vienna, 21 May 2013, **invited.**

Plank, H.: "Advanced FIB / FEB Dual Beam Prototyping", Nano and Photonics, Mauterndorf, 19 Mar. 2013, **invited.**

Plank, H.: "Focused electron beam induced creation of functional nanostructures", LASERION, Tegernsee, 03 Jul. 2013, **invited.**

Schmied, R.; Orthacker, A.; Chernev, B.S.; Trimmel, G.; Plank, H.: "Focused ion beam processing of low melting polymers: new perspectives due to optimized patterning strategies", MC2013, Regensburg, 25 Aug. 2013, **invited.**

Schmied, R.: "FIB Processing of Soft Matter: Towards TEM Lamella Preparation", Ultramikrotomie und ergänzende Verfahren in der Materialforschung, Halle, 08 Oct. 2013, **invited.**

Wagner, J.; Zankel, A.; Reingruber, H.; Mayrhofer, C.; Schröttner, H.: "Diamond knife versus Gallium ions", MC 2013, Regensburg, 25 Aug. 2013, **invited.**

Zankel, A.: "Update bzgl. Institutsaktivitäten, Elektronenmikroskopie in der studentischen Ausbildung", Core Facility Meeting, Vienna, 04 Jul. 2013, **invited.**

Albu, M.; Li, J.; Schumacher, P.; Kothleitner, G.; Hofer, F.: "Atomic resolution scanning transmission electron microscopy analysis of Sr and Yb addition in Al-Si alloys", International Congress on Light Materials, Bremen, 03 Sep. 2013.

Chernev, B.S.: "Probenpräparation für die Polymeranalytik", PE Workshop, Oberwaltersdorf, 16 May 2013.

Chernev, B.S.; Eder, G.C.; Voronko, Y.: "Spectroscopic investigations on thin adhesive layers in multimaterial laminates", 19th European Symposium on Polymer Spectroscopy, Prague, 07 Jul. 2013.

Chernev, B.S.; Eder, G.C.: "Non-destructive determination of EVA crosslinking in PV modules by Raman-Spectroscopy", ASPM 2013, Bled, 03 Apr. 2013.

Dienstleder, M.: "FIB introduction", European School on Advanced TEM Sample Preparation, Stuttgart, 01 Dec. 2013.

Ganner, T.; Eibinger, M.; Mayrhofer, C.; Bubner, P.; Nidetzky, B.; Plank, H.: "Synergistic Effects Among Cellulases during Enzymatic Cellulose Degradation, Visualized by *In situ* Atomic Force Microscopy", MRS Spring Meeting 2013, San Francisco, 31 Mar. 2013.

Ganner, T.; Bubner, P.; Eibinger, M.; Mayrhofer, C.; Plank, H.; Ni-

detzky, B.: “Synergistic Effects Among Cellulases during Enzymatic Cellulose Degradation, Visualized by *In situ* Atomic Force Microscopy”, MC2013, Regensburg, 25 Aug. 2013.

Hofer, F.; Kothleitner, G.; Grogger, W.: “Towards quantitative elemental mapping at atomic resolution”, Frontiers of Electron Microscopy in Materials Science, Lorne, 09 Sep. 2013.

Knez, D.; Fisslthaler, E.; Hofer, F.: “Preparation and Electron Microscopy of Graphene”, 3rd ASEM-Workshop, Vienna, 25 Apr. 2013.

Kolb, F.; Schmoltner, K.; Huth, M.; Hohenau, A.; Krenn, J.; Klug, A.; List-Kratochvil, E.; Plank, H.: “Variable tunneling probabilities in granular metals as key element for new sensor concepts”, E-MRS Spring Meeting, Strasbourg, 26 May, 2013.

Kothleitner, G.; Fladischer, S.; Grogger, W.; Meingast, A.: “Linking EDX and EELS for an assumption-free quantitative STEM compositional analysis”, Enhanced Data Generated by Electrons (EDGE), Sainte Maxime, 26 May 2013.

Kraxner, J.; Rothländer, T.; Hütter, P.; Grogger, W.: “Characterization of the production process of nanoimprinted organic devices by TEM”, ASEM workshop 2013, Vienna, 25 Apr. 2013.

Orthacker, A.; Schmied, R.; Chernev, B.S.; Trimmel, G.; Plank, H.: “Improved morphological and chemical stability during FIB soft matter processing”, ASEM Workshop, Vienna, 25 Apr. 2013.

Orthacker, A.; Schmied, R.; Chernev, B.S.; Trimmel, G.; Plank, H.: “Improved morphological and chemical stability during FIB soft matter processing”, E-MRS Spring Meeting, Strasbourg, 26 May 2013.

Plank, H.; Kolb, F.; Schmoltner, K.; Huth, M.; Hohenau, A.; Krenn, J.; Klug, A.; List, E.: “Variable tunneling probabilities in granular metals as key element for new sensor concepts”, MRS Spring Meeting 2013, San Francisco, 31 Mar. 2013.

Pölt, P.; Mitsche, S.: “Analysis based on WDS: applications, problems, solutions”, EDAX WDS Workshop, Wiesbaden, 04 Nov. 2013.

Schmidt, F.; Ditlbacher, H.; Hohenau, A.; Hohenester, U.; Krenn, J. R.; Hofer, F.: “Morphing nanodisks to triangles–A plasmonic EELS”, Microscopy Conference 2013, Regensburg, 25 Aug. 2013.

Schmied, R.; Orthacker, A.; Chernev, B.S.; Trimmel, G.; Plank, H.: “Temperature Evolution During Focused Ion Beam Processing of Low Melting Materials”, EMRS 2013 Spring Meeting, Strasbourg, 27 May 2013.

Schröttner, H.: “Advanced Electron Microscopy in Materials Science”, Workshop „Electron Microscopy“, Izmir Institute of Technology, Izmir, Turkey, 18 Apr. 2013.

Schröttner, H.: “Versatile Methods for the Characterization of Polymers at FELMI-ZFE-Graz”, Workshop „Polymer-Characterization“. Akdeniz Kimya, Izmir, 19 Apr. 2013

Wilhelm, P.; Chernev, B.S.; Mayrhofer, C.; Dienstleder, M.: “Probing deep polymer layers–preparing for a dive”, 19th European Symposium on Polymer Spectroscopy (ESOPS19), Prague, 07 Jul. 2013.

Zankel, A.: “Review of 3View: Practical Experiences with *in situ* Ultramicrotomy in the ESEM”, Symposium „Ultramikrotomie und ergänzende Verfahren in der Materialforschung“, Halle, 07 Oct. 2013.

Lectures 2014

Chernev, B.S.; Eder, G.C.: “POLYAMID IN TANKSYSTEMEN: UNERWÜNSCHTE PHÄNOMENE”, Tank- und kraftstoffführende Systeme, Stuttgart, 02 Jul. 2014, **invited.**

Hofer, F.: “Electron energy-loss spectrometry: basics”, Autumn School on Materials Science and Electron Microscopy, Humbolt University, Berlin, 08 Oct. 2014, **invited.**

Hofer, F.; Kothleitner, G.; Schmidt, F.; Grogger, W.: “Scanning Transmission Electron Microscopy at Atomic Resolution”, Hungarian Microscopy Meeting 2014, Siofolk, 29 Mai 2014, **invited.**

Hofer, F.; Grogger, W.; Albu, M.; Gspan, C.; Findlay, S.; Lugg, N.; Allen, L.; Radmilovic, V.: “Scanning transmission electron microscopy at atomic resolution”, 3rd European Conference on NanoFilms. Sevilla, 07 Jul. 2014, **invited.**

Ganner, T.; Rosker, S.; Eibinger, M.; Chernev, B.S.; Kraxner, J.; Mayrhofer, C.; Aschl, T.; Zahel, T.; Bubner, P.; Nidetzky, B.; Plank, H.: “Tunable close-to-nature cellulose for enzymatic degradation studies via dynamic high resolution AFM”, ASEM 2014 . Wien, 08 Mai 2014, **invited.**

Zankel, A.; Mayrhofer, C.; Nachtnebel, M.: “Ultramicrotomy in the ESEM, a versatile method for materials and life sciences”, 3View Users Group Meeting and Symposium, Ghent, 09 Mar. 2014, **invited.**

Zankel, A.; Nachtnebel, M.; Mayrhofer, C.; Wewerka, K.: “Characterization of polymers in the scanning electron microscope – from low voltage surface imaging to the 3D reconstruction of specimens”, Polymertec 2014, Merseburg, 26 Jun. 2014, **invited.**

Albu, M.; Schmidt, F.; Gspan, C.; Paller, M.; Grogger, W.; Kothleitner, G.: “Sub Angstrom investigation of high tech materials”, 1st International Conference on Functional Integrated Nano Systems. Graz, 03 Dec. 2014.

Ganner, T.; Rosker, S.; Eibinger, M.; Chernev, B.S.; Kraxner, J.; Mayrhofer, C.; Aschl, T.; Zahel, T.; Bubner, P.; Nidetzky, B.; Plank, H.: “Tunable close-to-nature cellulose for enzymatic degradation studies via dynamic high resolution AFM”, 18th IMC 2014, Prag, 07 Sep. 2014.

Grogger, W.; Fladischer, S.; Kraxner, J.; Paller, M.; Kothleitner, G.; Hofer, F.: “Quantitative EDXS in STEM: Super-X, detector geometry

and other topics", ASTEM Workshop 2014. Piran, 30 Sep.2014.

Grogger, W.; Fladischer, S.; Kraxner, J.; Paller, M.; Kothleitner, G.: "Quantitative EDXS: Influence of Detector Geometry", Super X user meeting 2014, Lausanne, 12 Feb. 2014.

Geier, B.; Gspan, C.; Orthacker, A.; Kothleitner, G.; Fowlkes, J.; Rack, P.; Plank, H.: "Rapid and highly compact purification for focused electron beam induced deposits: a room temperature approach using electron stimulated H_2O reactions", FEBIP 2014, Frankfurt, 22 Jul. 2014.

Haber, T.; Gspan, C.: "Evaluation of TEM-lamella oxidation", ISTFA 2014, Housten, Texas , 09 Nov. 2014.

Haberfehlner, G.; Albu, M.; Orthacker, A.; Kothleitner, G.: "Four-dimensional simultaneous EELS & EDX tomography of an Al-Si based alloy", 18th International Microscopy Congress, Prague, 07 Sep. 2014.

Knez, D.; Thaler, P.; Volk, A.; Grogger, W.; Ernst, W.; Hofer, F.: "HR-STEM investigations of metallic nanoparticles grown with superfluid He-droplets", Tagungen der Österreichischen Physikalischen Gesellschaft, Pöllau, 24 Sep. 2014.

Knez, D.; Volk, A.; Thaler, P.; Fisslthaler, E.; Grogger, W.; Ernst, W.; Hofer, F.: "HR-STEM investigations of metallic nanoparticles grown with superfluid He-droplets", 4th ASEM Workshop, Wien, 08 Mai 2014.

Knez, D.; Volk, A.; Thaler, P.; Fisslthaler, E.; Grogger, W.; Ernst, W.; Hofer, F.: "HR-STEM investigations of metallic nanoparticles grown with superfluid He-droplets", IMC 2014, Prague, 07 Sep. 2014.

Kothleitner, G.; Neish, M.; Lugg, N.; Findlay, S.; Grogger, W.; Hofer, F.; Allen, L.: "Quantitative EDX and EELS Elemental Mapping at Atomic Resolution", Microscopy and Microanalysis 2014, Hartford, Connecticut, 04 Aug. 2014.

Kraxner, J.; Schmied, R.; Rothländer, T.; Grogger, W.; Stadlober, B.: "Analytical TEM: a powerful technique in the field of organic electronics research", 4th ASEM Workshop, Wien, 08 Mai 2014.

Nachtnebel, M.; Pölt, P.: "Characterisation of Microfiltration Membranes by Wetting Investigations in the ESEM", ÖGP Jahrestagung, Pöllau, 27 Sep. 2014.

Nachtnebel, M.; Pölt, P.: "Characterisation of Microfiltration Membranes by Wetting Investigations in the ESEM", ASEM Workshop 2014, Wien, 08 Mai 2014.

Nachtnebel, M.; Zankel, A.; Mayrhofer, C.; Gahleitner, M.; Pölt, P.: "3D–reconstruction of cracks in polymers – New insight into the fracture behaviour?", PolyMerTec 2014, Merseburg, 25 Jun. 2014.

Arnold, G.; Schmied, R.; Timilsina, R.; Fowlkes, J.; Orthacker, A.; Kothleitner, G.; Rack, P.; Plank, H.: "Fundamental resolution limits during focused electron beam induced deposition on bulk substrates", FEBIP 2014, Frankfurt, 22 Jul. 2014.

Orthacker, A.; Haberfehlner, G.; Tändl, J.; Poletti, M. C.; Kothleitner, G.: "Experimental and Computational Aspects of Analytical Electron Tomography and its Application to Nanomaterials", 64. Jahrestagung der ÖPG. Pöllau, 24.09.2014.

Orthacker, A.; Haberfehlner, G.; Poletti, M.C.; Tändl, J.; Kothleitner, G.: "Tomography in Analytical Transmission Electron Microscopy of Nanomaterials", ASEM Workshop 2014, Wien, 08 Mai 2014.

Plank, H.: "Advanced FIB / FEB Dual Beam Prototyping & Real Time AFM in Biology", Halbleiter Seminar - Montanuniversität Leoben, 02 Dec. 2014.
Plank, H.: "FEBID based sensing concepts: impurities as advantage", FEBIP 2014. Frankfurt, 22 Jul. 2014.

Pölt, P.; Nachtnebel, M.; Zankel, A.: "*In situ* testing of soft materials in the Environmental Scanning Electron Microscope", International Conference on Electron Microscopy (EMSI-2014), Dehli, 09 Jul. 2014.

Pölt, P.; Nachtnebel, M.; Zankel, A.: "*In situ* characterization of polymers in the ESEM", 18th International Microscopy Congress, Prague, 07 Sep. 2014.

Schmidt, F.; Ditlbacher, H.; Hohenester, U.; Hohenau, A.; Hofer, F.; Krenn, J.: "Universal scaling of surface plasmons modes", Microscopy and Microanalysis 2014. Hartford, Connecticut, 02 Aug. 2014.

Schmidt, F.; Kothleitner, G.: "Plasmonik", NAWI Graz Alumni Kick-off, University of Graz, 13 Mar. 2014.

Schmidt, F.; Ditlbacher, H.; Hohenau, A.; Hohenester, U.; Hofer, F.; Krenn, J.R.: "Universal scaling of surface plasmon modes", 4th ASEM Workshop, Wien, 08 Mai 2014.

Schmied, R.; Arnold, G.; Timilsina, R.; Fowlkes, J.; Orthacker, A.; Kothleitner, G.; Rack, P.; Plank, H.: "Fundamental resolution limits during focused electron beam induced deposition on bulk substrates", FEBIP 2014. Frankfurt, 21 Jul. 2014.

Schmied, R.; Fröch, J.; Orthacker, A.; Kraxner, J.; Hobisch, J.; Trimmel, G.; Plank, H.: "Focused Ion Beam Processing of Soft Matter: From Fundamental Effects towards TEM Lamella Preparation", IMC 2014, Prague, 07 Sep. 2014.

Schmied, R.; Orthacker, A.; Kraxner, J.; Fröch, J.; Chernev, B.S.; Dienstleder, M.; Plank, H.: "Temperature Evolution during Focused Ion Beam Processing of Soft Matter: From Fundamentals towards TEM Lamella Preparation", 4. ASEM Workshop, Vienna, 08 Mai 2014.

Schröttner, H.: "Mikroskopische Analysemethoden für Oberflächen und Grenzflächen von Polymeren", Klebkaschieren von PVC-Fenster-Profilen, Würzburg, 05 Nov. 2014.

Schröttner, H.; Mertschnigg, S.; Roßmann, A.: “Probleme bei der Präparation weicher Metalle”, Fachkolloquium „Mikro- und Nanoanalytik“, 11 Apr. 2014.

Stüger, H.; Haas, M.; Rauch, S.; Gspan, C.; Plank, H.: “Towards optically active nanostructures using focused electron beam induced nano-synthesis of Si-Ge precursor”, Materials Day, Graz, 29 Nov. 2014.

Tändl, J.; Hütter, A.; Orthacker, A.; Kothleitner, G.; Poletti, M.C.: “Subjecting a novel AlMgScZr alloy to electron beam and friction stir processing”, IIW IX-NF intermediate Meeting, Berlin, 05 Apr. 2014.

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Wagner, J.; Schröttner, H.; Rattenberger, J.; Mitsche, S.; Panzirsch, B.: “Comparison of the 3D Calcium and Aluminium distribution in standard and ECO-Mg alloys”, IMC Prag, 07 Sep. 2014.

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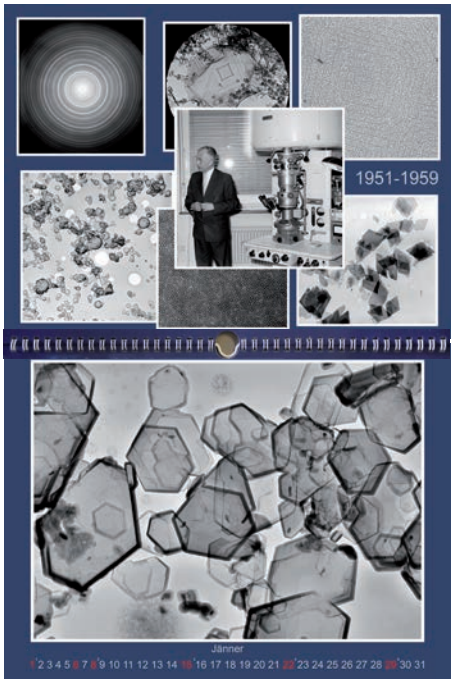
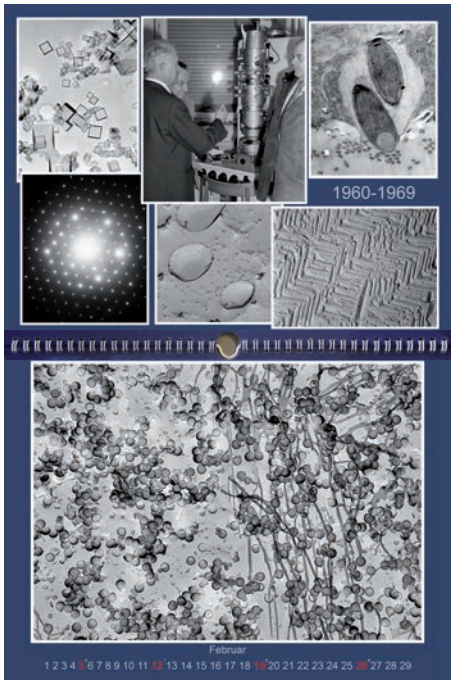
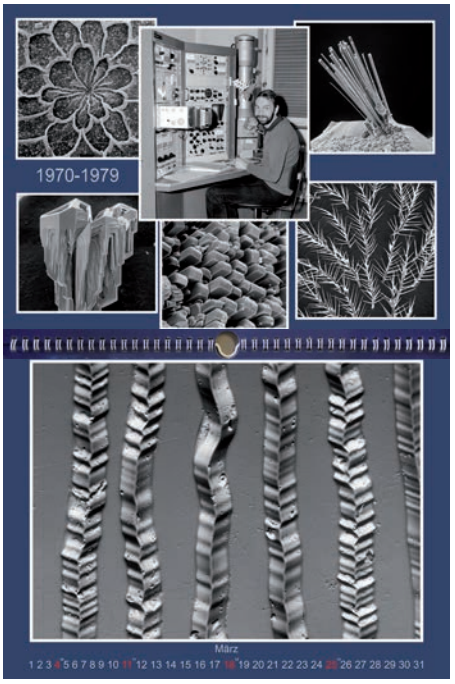
What else ?

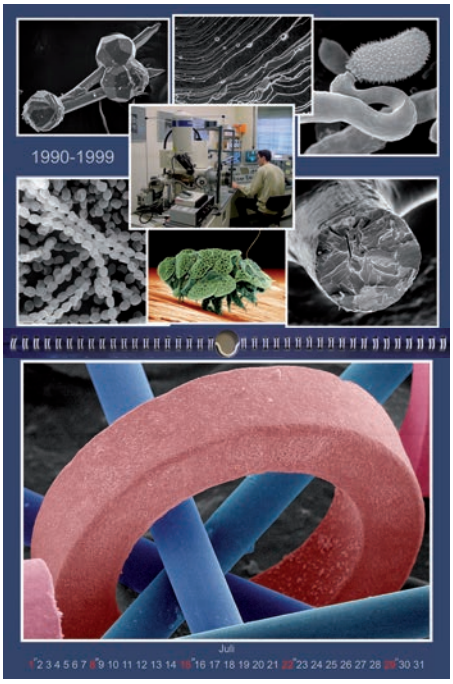
FELMI-ZFE Calendar 2012

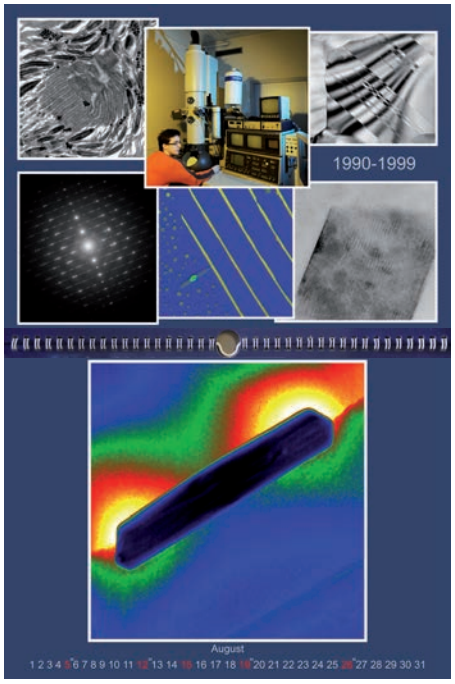
A pool of fascinating micrographes is generated via an internal image competition; the best micrographs are chosen once a year shortly before Christmas. The most interesting images are usually combined under a general theme and published in our biannual calendar. However, in 2012 we decided to celebrate our 60th birthday with a calendar showing milestones and achievements we have reached so far.

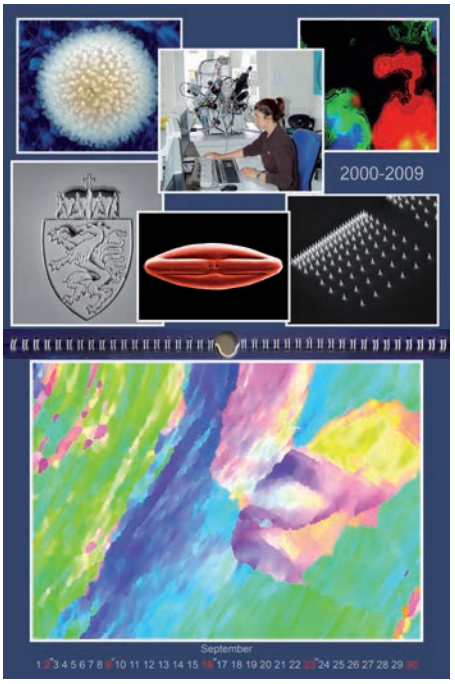













Titelbild
Seit 1951
Institut für Elektronenmikroskopie und Feinstrukturforschung
Zentrum für Elektronenmikroskopie Graz
Jänner
Februar
März
April
Mai
Juni
Juli
August
September
Oktober
November
Dezember


1950-1959
1960-1969
1970-1979 REM
1970-1979 TEM
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1990-1999 REM
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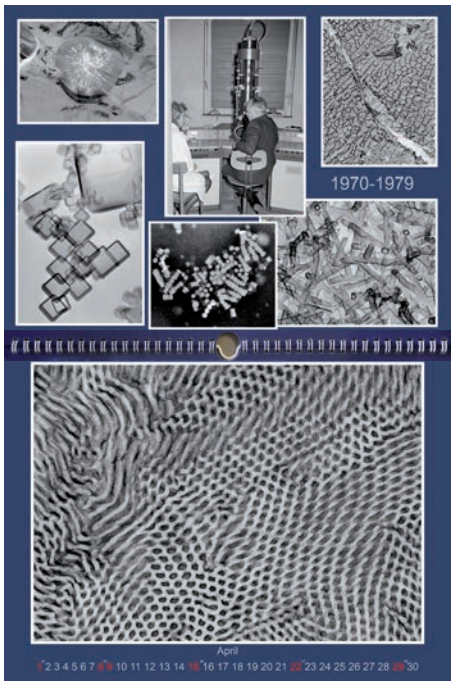
2000-2009 REM
2000-2009 TEM
2010 - REM
2010 - TEM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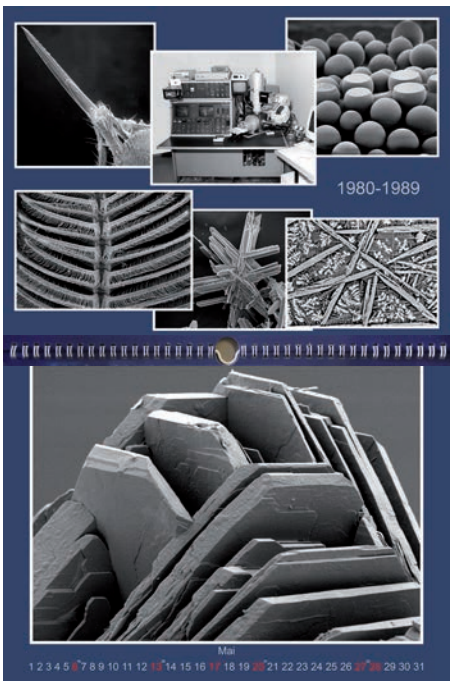
April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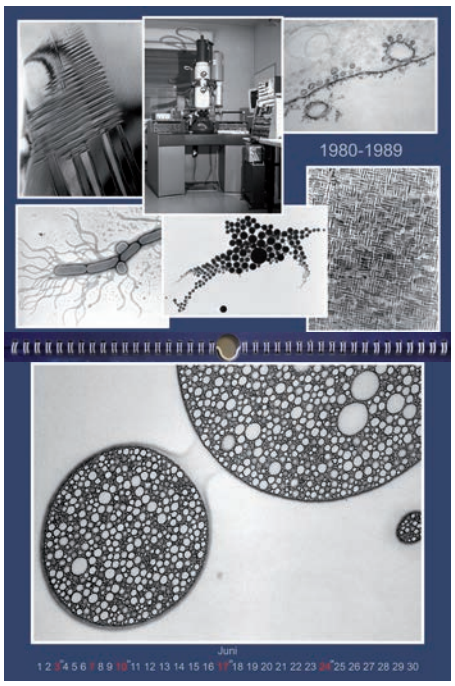
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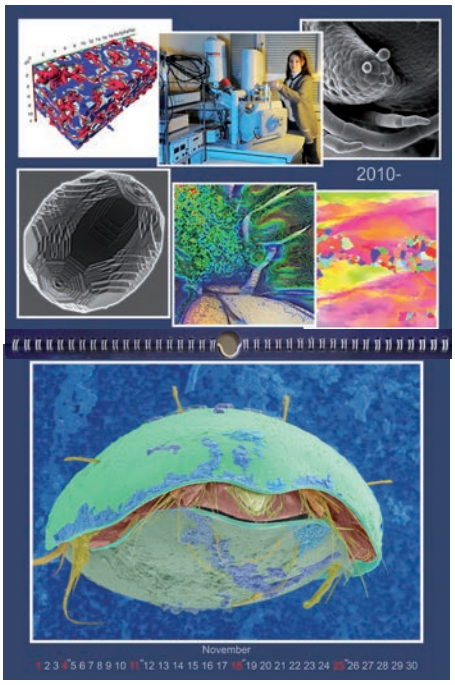
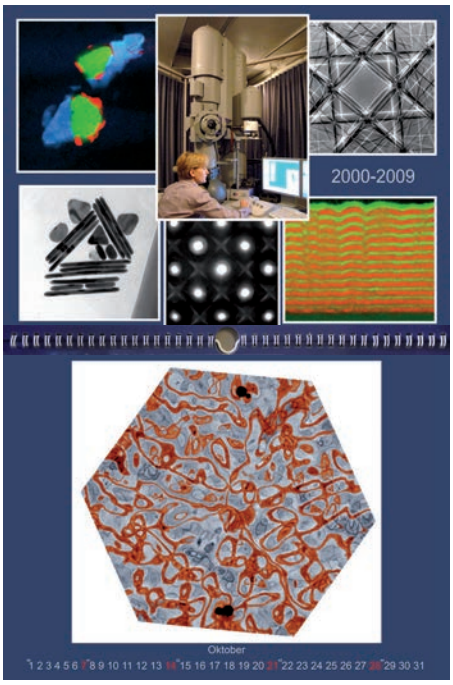

2010-
November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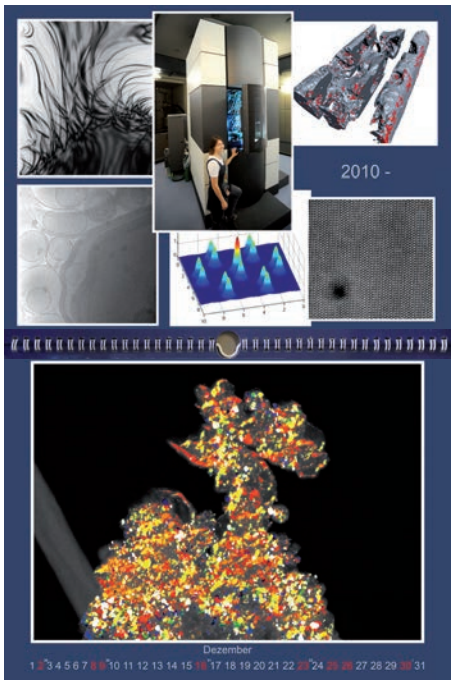
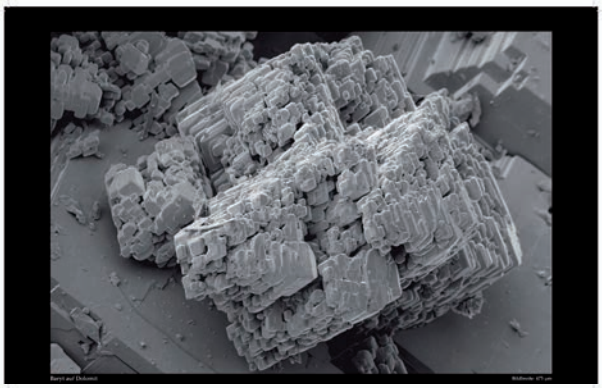
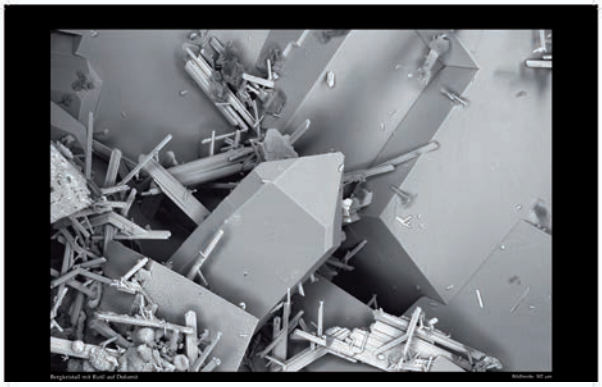
Oktober

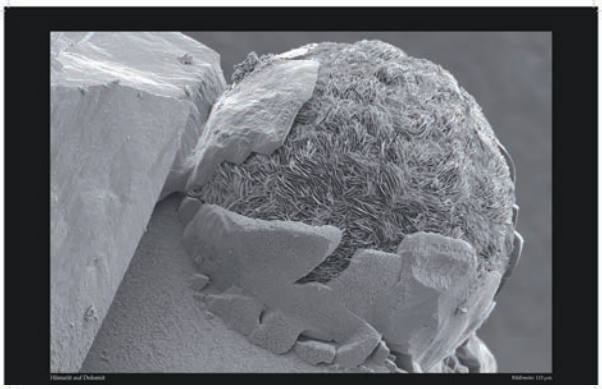

2010 -
Dezember

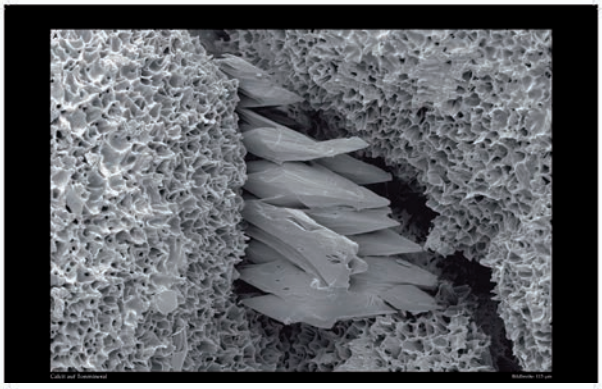
FELMI-ZFE Calendar 2014

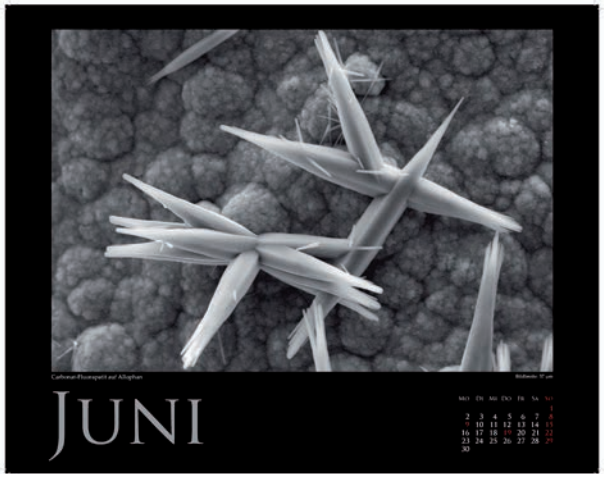
In cooperation with Josef Taucher, the local expert in mineralogy, the Calendar 2014 has been realised. The spotlight was put on minerals to be found in Styria.

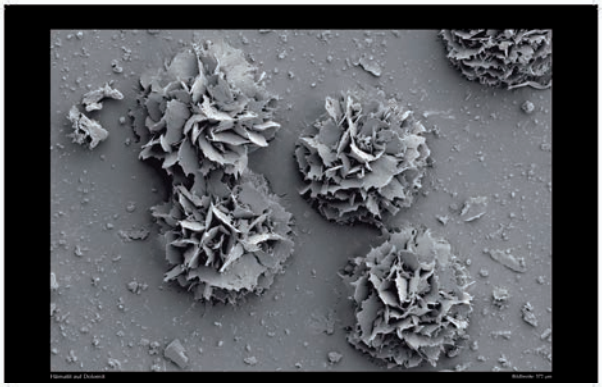


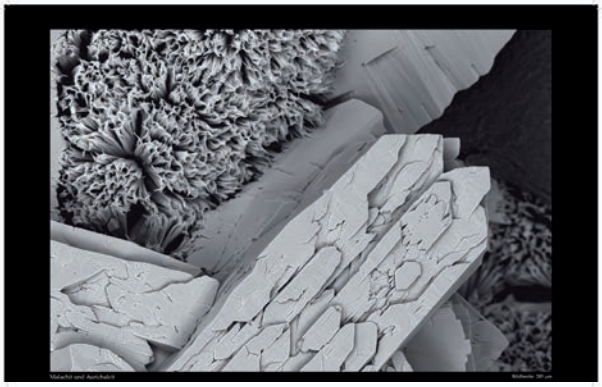


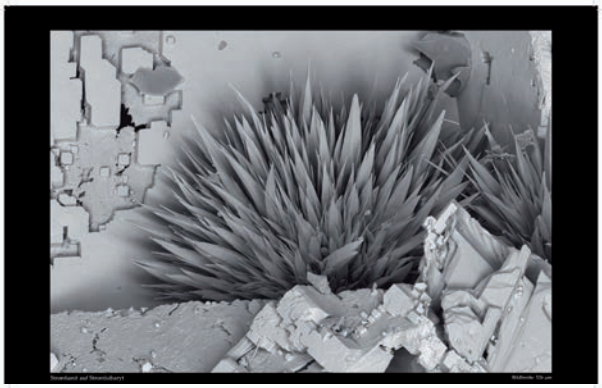




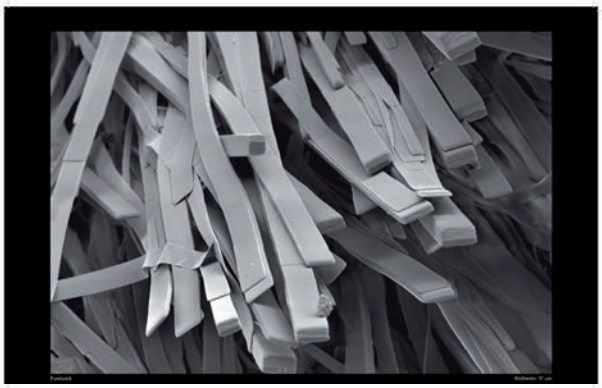









DEZEMBER




OKTOBER


MINERALIEN AUS DER STEIERMARK
Abbildungen im Rasterelektronenmikroskop
Jänner
Februar
März
April
Mai
Juni
Juli
August
September
Oktober
November
Dezember
Institut für Elektronenmikroskopie und Nanoanalytik, Technische Universität Graz, Zentrum für Elektronenmikroskopie Graz
Steyrergasse 17, A-8010 Graz

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Administration

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Austrian Centre for Electron Microscopy and Nanoanalysis

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Verein zur Förderung der Elektronenmikroskopie u. Feinstrukturforschung

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- Selina Haingartner

Techn. Laboratory

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Head: DI Ulrich Santner
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Peter Wilhelm
Retired Nov. 2014

Status: December 2014

Out of Office

2012

Life in the Institute is not only about industrial needs, microscopes, students, or articles. To be creative and foster a productive work environment one sometimes needs a change in time and place to break out of the daily routine and see problems with a fresh eye.

Over the years solid traditions have been established: winter meets a funny end when students and researchers dress in all sorts of costumes to celebrate carnival with *würstel* and *krapfen* (1). In 2012 the company outing started with a degustation of all sorts of delicious vinegars and oils (2) and ended in a "typically Austrian manner" at the magnificent garden terrace of a *Buschenschank* (wine tavern) (3).

To be continued in 2013: in autumn a trip lead to the beautiful wine region in the south of Styria to enjoy young wine (4). A running competion for teams is always organised by the sports' centre of the University of Graz. Of course, we've sent our winning teams! (5) Time travelling was the agenda of last year's company


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2013

outing: we were dining like knights (6) and admiring vintage cars (7). The last highlight of the year is usually the Christmas Party (8, 9) which gives Mr. Hofer the opportunity to sum up what progress has been made in the past months and to honour the achievements of his staff, e.g. handing over the jubilee coin for 35 years at the institute (10).

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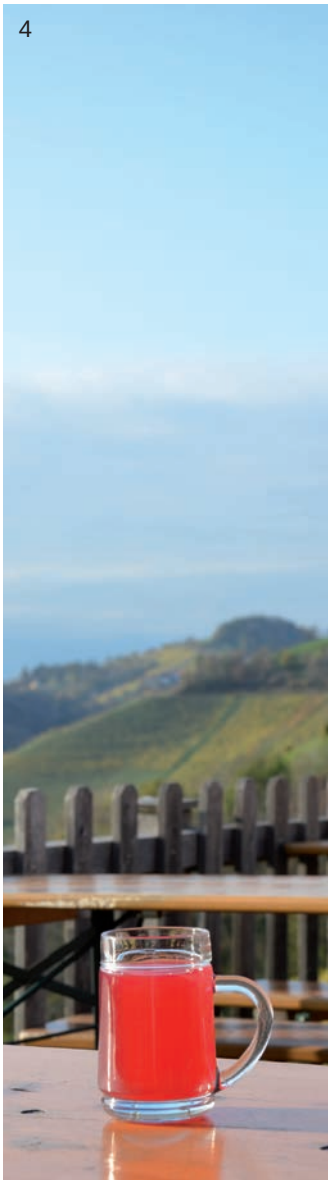
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2014

In 2014 we have been to the zoo Herberstein (1) – the animals were adorable (2), the weather was splendid (3) and the food wonderful (4). On a cloudy day a group visited the radar station “Hilmwarte” and got insight into the highly stable microwave radiometer system (5). Every winner of our internal competitions (best publication, best image, best industrial cooperation) is awarded during the Christmas Party (6).


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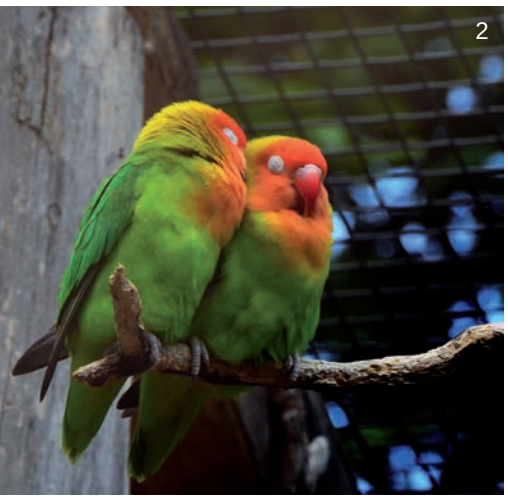
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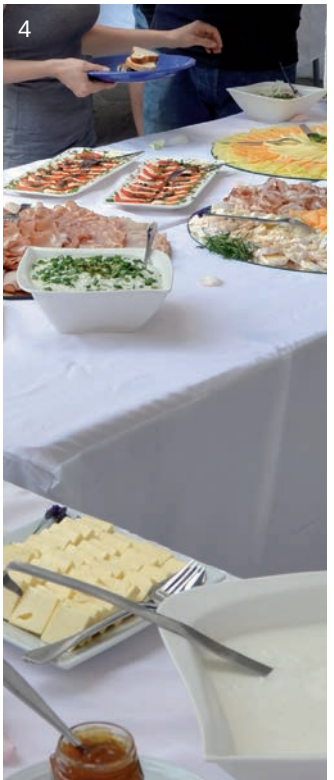
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As time goes by...

As time goes by we have seen the retirement of valuable members of our staff.
Elisabeth Ingolic (1) and Peter Wilhelm (2) have been group leaders for many years. Gerhard Windisch (3) laid the basis of our technical infrastructure and Angela Freund (4) assured a clean environment for our highly sensible instrumentation.