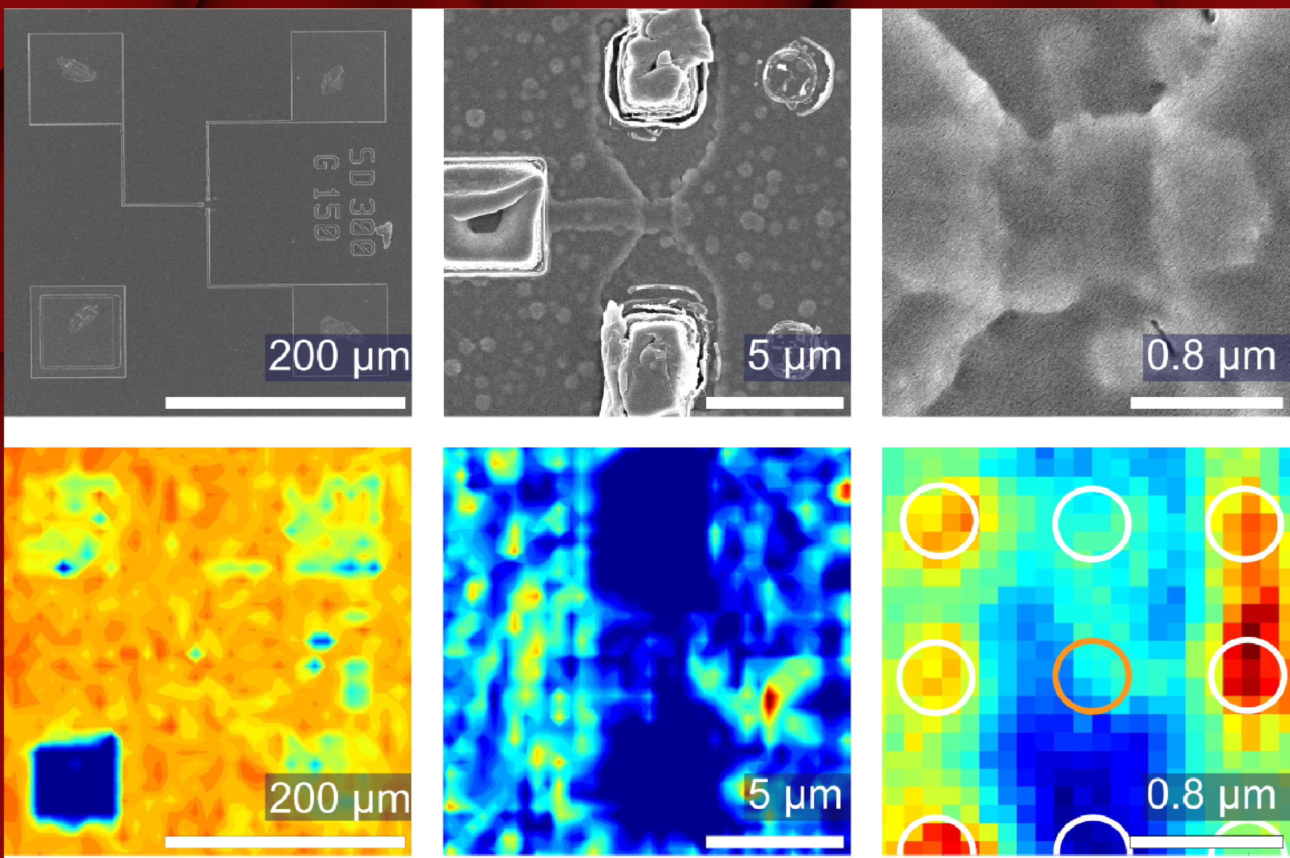
Synchrotron Radiation Research in Austria

with particular consideration of the European Synchrotron Radiation Facility ESRF



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Images: Caption and Origin

Cover: Field Effect Transistor device based on a single SiGe nano-island: the upper row shows Scanning Electron Microscope images at increasing magnifications (from left to right) and the lower row shows the corresponding images obtained by scanning X-ray diffraction at the ESRF. The diffraction signal can be directly related to the local crystalline properties of SiGe. Individual nano-island positions are marked by circles; from Hrauda N., Zhang J. , Wintersberger E., Etzelstorfer T., Mandl B., Stangl J., et al., **Nano Letters 11, 2875-2880 (2011)**.

Page 5: Crystals of the molecule pentacene grown on a polymer surface: a reciprocal space map measured by grazing incidence x-ray diffraction together with the thin film morphology obtained by atomic force microscopy, from A. Moser; H.G. Flesch, A. Neuhold; M. Marchl; S.J. Ausserlechner; M. Edler; T. Griesser; A. Haase; D.M. Smilgies; J. Jakabovič; R. Resel, **Synthetic Metals in print (2011)**

Back-cover: Experimental hall and storage ring building of the ESRF (Courtesy: P.Ginter/ESRF).

Background (Cover and Back-cover): Artistical representation of the content of Fig. 3c from M. Leitner, B. Sepiol L.M. Stadler, B. Pfau, G. Vogl, **Nature Materials 8, 717 (2009)**.

Preface

Austrian synchrotron radiation research has a long tradition and a remarkable international scientific visibility in many fields, like material science, physics, chemistry, biosciences, medicine, geology, palaeontology, fine arts, and others; although the country has never succeeded to build its own national synchrotron source.

Currently, Austria is an associated member at the European Synchrotron Radiation Facility (ESRF) in Grenoble (with a 1% financial contribution to the total expenses), and finances and operates the Austrian small-angle X-ray scattering (SAXS) beamline at the ELETTRA storage ring in Trieste. Adding to this, many Austrian groups get and use beamtime at national European sources such as BESSY II at the Helmholtz-Zentrum Berlin, HASYLAB in Hamburg, ANKA in Karlsruhe, MAXLab in Lund, SOLEIL near Paris, DIAMOND in Didcot, SLS in Villigen, and others. For most of these sources, access was regulated in the past via European Transnational Access (TNA) programs. The TNA program ELISA in FP7 and preceding programs provided also support for travel costs in particular for scientists from countries without own facilities. Occasionally, Austrian scientists perform experiments even overseas at synchrotron sources in the USA and in Japan.

Among all these activities, the beamtime at the ESRF has the biggest share of more than 40%. This is certainly the consequence of the large beamline portfolio of the ESRF (more than 40 beamlines are currently in operation), and the fact that the beam properties in the hard X-ray regime are only met by sources outside Europe (SPring8 in Japan and APS in the USA). Comparable (PETRA III in Hamburg and MAX IV in Lund) or even much superior (European X-ray Free Electron Laser in Hamburg) sources in Europe are not yet equipped with the full beamline portfolio, or are still under construction.

On the national level, the Austrian community is organized within NESY (Neutrons and Synchrotron Radiation), a technical committee of the Austrian Physical Society (ÖPG). The major event among the NESY activities is the biannual "NESY Winterschool Planneralm", a young academics educational program taking place already since 1999. NESY is also represented in the European Synchrotron User Organization (ESUO), coordinating synchrotron issues on the European level.

Beamtime at synchrotron facilities worldwide is granted based on scientific proposals, which are evaluated by international review committees. Austrian groups have been very successful in their applications, receiving typically significantly more beamtime than the average success rate of proposals. For instance, in 2009 and 2010 Austrian groups have used 1.67% and 1.43% of ESRF beamtime, respectively, which has to be compared to the 1% budget contribution (until the end of 2010). Another example is the beamtime allocation rate of more than 87% of Austrian proposals at BESSY II in the years 2008-2009, as compared to a 65% average allocation rate in the same time frame.

As a matter of fact, the current financial situation for basic research in general and for the use of expensive large-scale infrastructure in particular becomes more and more competitive. This is seen for instance by the fact that the TNA continuation proposal for ELISA, CECILIA, was rejected by the EC few months ago. Moreover, recent reductions of the financial contributions to the ESRF by Great Britain and Italy had a profound influence on the ESRF upgrade program, and have led to a much more rigorous handling of the financial compensation for beamtime over-use also for associate members of the ESRF. The consequence of this ESRF council decision for Austria is the following: for the first time also financial criteria and not exclusively the scientific quality and merit of beam time proposals are applied to Austrian ESRF proposals since the beginning of 2011. Since these adjustments are applied based on three year averages, i.e., retroactively, Austrian scientists would effectively have lost more than half of their beamtime from 2011 onwards. Fortunately, the Austrian Bundesministerium für Wissenschaft und Forschung (BMWF) has agreed to cover expenses for beam time over-use up to a limit of 1.3%. The acceptance rate for Austrian proposals at the ESRF in the last few years was, however, in the order of 1.5% or even higher.

Thus clearly a gap is opening between the need of the Austrian scientific community and the achievable share of synchrotron beamtime. If the resubmitted European TNA proposal CECILIA would fail again, the situation would become even more troublesome. Then, restricted access to- and missing travel support for the other European synchrotron sources would probably further increase the request for ESRF beamtime (where the full refunding of travel costs is included in the associate membership). It is hence the declared goal of the Austrian synchrotron user community to ensure a financial contribution to the ESRF for a beamtime use of at least 1.5% in order to maintain the current scientific output. A mid-term goal is the creation of a consortium with two or three partner countries, aiming at a total contribution of 4%, which is the condition to achieve full ESRF member status to take part in board decisions.

To reach these goals, it is of vital importance that the Austrian synchrotron user community makes itself and its scientific achievements more visible to the public and to the policy-making units in the government, in the Austrian Academy of Sciences and within the Austrian Universities. This brochure presents some important facts and figures, and gives a brief overview of the most active research fields covered by Austrian scientists using synchrotron radiation at the ESRF and elsewhere. We have also tried to compile the contact email addresses of the actually active research group leaders or responsible scientists. However, although comprehensive, it is probably far from being complete, and we express our apologies to all those active synchrotron scientists who do not find their valuable contributions mentioned.

This brochure accompanies the second Austrian synchrotron users meeting organized by the BMWF on October 18th 2011 in Vienna. Certainly this activity can only be a first step on the way to permit Austria full participation in the brilliant future as envisioned by the ESRF upgrade program and by the X-FEL in Hamburg.

October 2011 Oskar Paris Julian Stangl Günther Bauer

Synchrotron Radiation Research in Austria

The Austrian research activities based on the use of international large scale synchrotron radiation facilities are a story of success. Mainly European facilities, offering unique experimental opportunities for different research fields (including Physics, Medicine, Chemistry, Material Science and Engineering, etc.), have enabled frontier research of Austrian scientists. This can be exemplified by the scientific output from the last four years (2008-2011):

- **Publications (2008-2011)**[1]

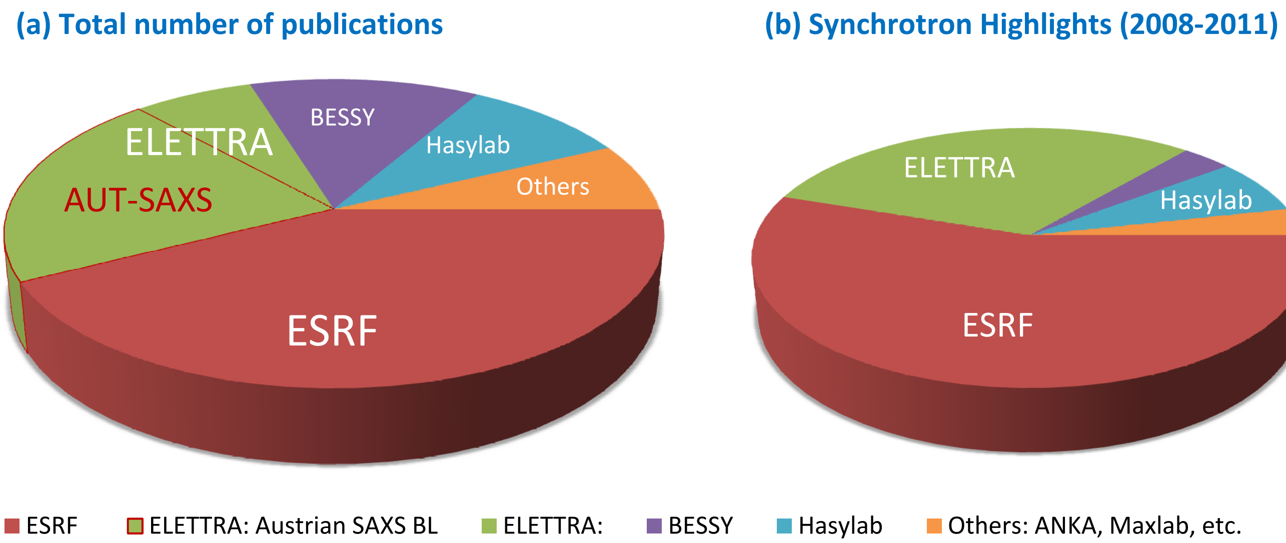


Fig. 1: 449 publications (a) and **29 scientific highlights (b)** with at least one Austrian co-author are the result of synchrotron research from 2008-2011. Others are: ANKA, MAXLab, SLS, DIAMOND, Soleil (Europe), SSRL, Chess (USA), LNLS (Brazil).

In total **449 publications** (papers, conference proceedings, PhD theses) result from the activities of Austrian groups at synchrotron sources. More than 40% of them are from work at the ESRF, and roughly one fifth from the Austrian SAXS beamline at ELETTRA. The rest distributes quite evenly between ELETTRA, BESSY, HASYLAB and "Others". **29 papers** were selected to appear in the annual *Scientific Highlight* journals published by the respective synchrotron organizations. **Seven articles** from ESRF work appeared in the ***Nature* family** of journals, several others in high impact journals such as in the *Proceedings of the National Academy of Sciences USA, Nanoletters, Physical Review Letters*, and others, underlining the worldwide relevance of Austria's synchrotron based research.

- **Education**

Beside the importance for the research activities, the access to synchrotron beamtimes is massively used for training and educating under-graduate and graduate students, resulting in **10 master-** and **19 PhD-theses** in the years 2008-2011.
The **habilitation thesis** of G. Requena (TU Wien, 2010) is to a large extent based on research at the ESRF.

[1] Though comprehensive, the data inquiry is certainly not complete. ESRF publications were taken from the ESRF data base (www.esrf.eu/UsersAndScience/Publications), the others were obtained from an inquiry among the Austrian user community, from the Web of Science, and additional information was provided from the data bases of other facilities (ELETTRA, BESSY, HASYLAB). Effective date for the data inquiry was August/September 2011.

Austria's Associate Membership at the ESRF

Austria joined the ESRF in 2002, and is Scientific Associate since 2003 with 1% financial contribution to the total ESRF budget. The continuous increase of the Austrian publication output originating from ESRF beamtime is shown in Fig. 2. The high scientific relevance of the proposed experiments is also proved by the percentage of granted beamtime which exceeds substantially the 1% mark (see Fig. 3). Interesting to see is that the Austrian request for beamtime was in the order of 1.2% until 2008, but then increased considerably to more than 1.8% in 2010 and about 1.7% in 2011. While the acceptance rate was always higher or at a similar level as the requested beamtime, it is noted that the acceptance rate in 2011 is the lowest rate ever. This is a direct consequence of the 1.3% cutoff as agreed between ESRF and the Austrian Ministry (BMWF) in 2011 following the new rules regulating the compensation for beamtime over-use from associated members.

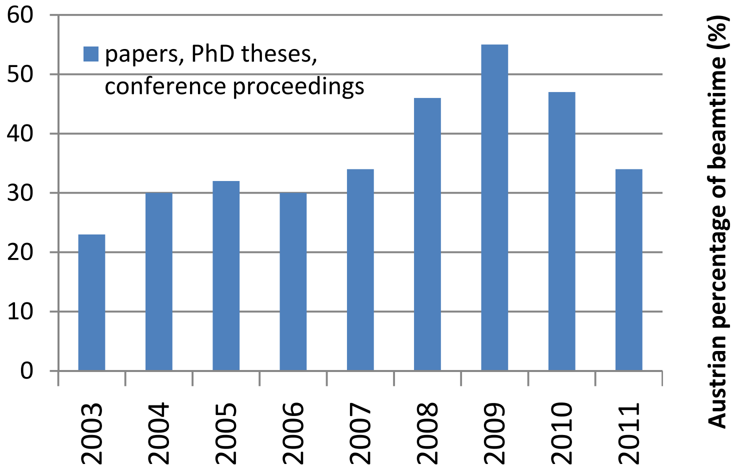


Fig. 2: Annual development of publications resulting from ESRF beamtime since Austria joined the ESRF in 2003. *Data taken from the ILL-ESRF library database: Note that 2011 data include database entries until September 2011.*

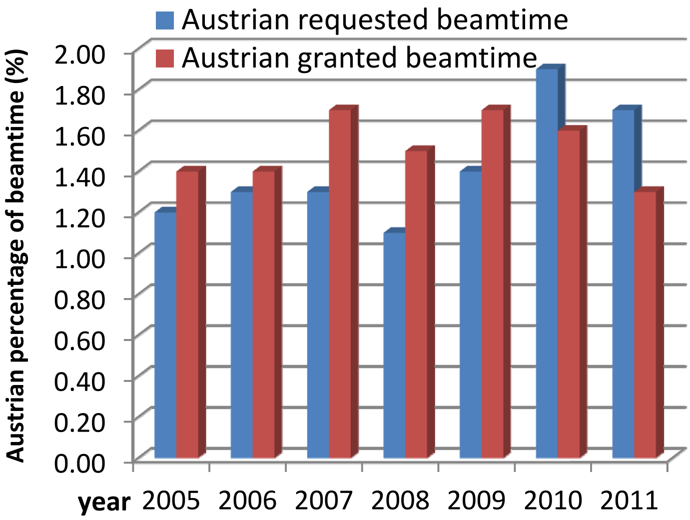


Fig. 3: Percentage of requested (blue) and granted (red) beamtime of Austrian groups from the years 2005-2011. *Data provided by the ESRF Director of Research.*

Austrian research groups at the ESRF use their beamtime very effectively. Between 2008-2011 Austria has produced the highest number of papers per percent of financial contribution of all member countries.

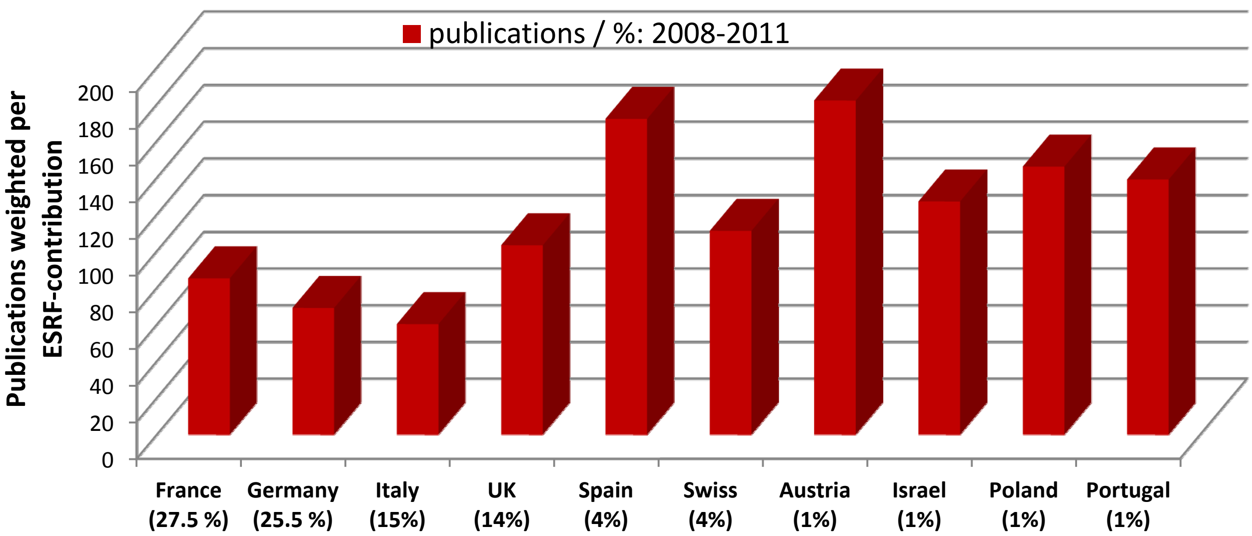
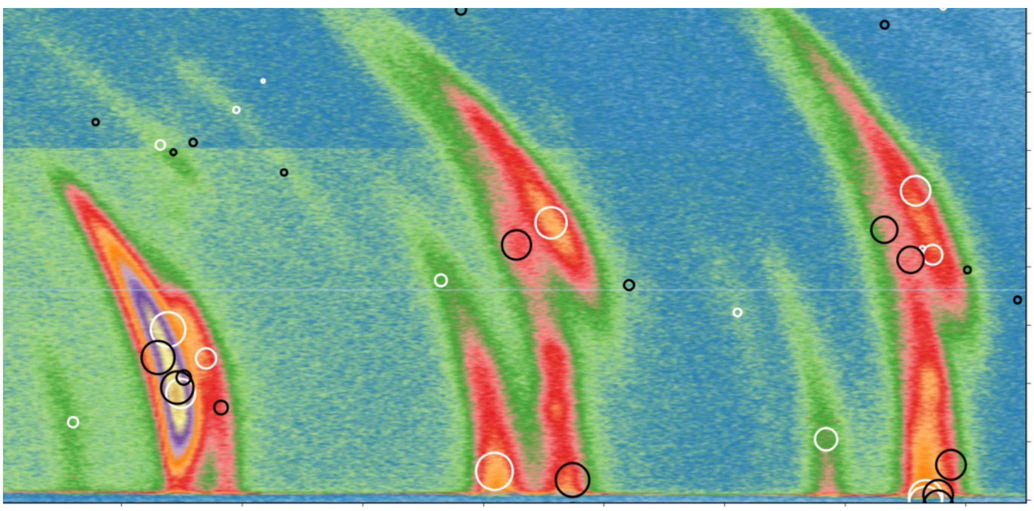
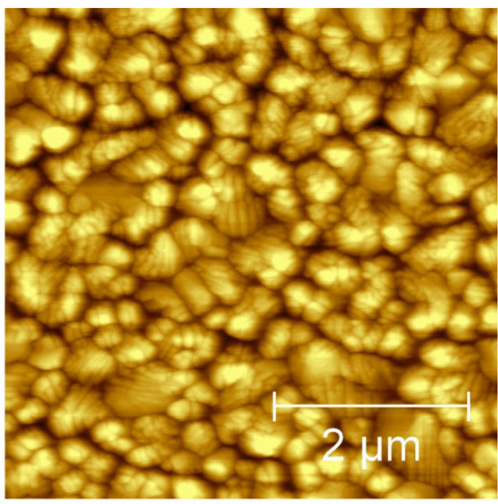


Fig. 4: Number of publications of ESRF members weighted by their percentage of financial contribution between the years 2008 - 2011. *Data taken from the ILL-ESRF library database*

Scientific Activities and Research groups in Austria at Synchrotron Radiation Sources





Protein Crystallography[2]

Macromolecular crystallography plays a pivotal role in many disciplines within the life sciences and is one of the driving forces for the construction of new synchrotron sources. The current aim of the Austrian Crystallographic Diffraction Consortium (ACDC) is to support the research programs of various macromolecular structural biology groups employing X-ray crystallography and other scattering techniques to characterize macromolecular complexes. Owing to the unique possibilities in gaining regular access to the ESRF, the block allocated group (BAG) beamtime to ACDC is an absolutely essential component in the research programs of these groups. The projects of interest comprise a wide array of topics including, but not strictly limited to, the following:

- Vienna: Molecular mechanisms of protease-chaperone machines in ***quality controlling cellular proteins,*** and ***multiprotein complexes*** involved in the assembly and maintenance of cilia. *Researchers:* Tim Clausen (clausen@imp.univie.ac.at), Research Institute of Molecular Pathology (IMP); Gang Dong (gang.dong@univie.ac.at), Max F. Perutz Laboratories (MFPL).

- Salzburg: ***Complex enzymatic factors*** involved in blood coagulation, apoptosis and co-factor biosynthesis, protein complexes and signaling platforms involved in innate immunity. *Researchers:* Hans Brandstetter (Hans.Brandstetter@sbg.ac.at), Robert Schwarzenbacher robert.schwarzenbacher@sbg.ac.at), Department Molecular Biology, University of Salzburg

- Graz: High-resolution protein structures as guides for a better understanding of enzyme function and protein design focusing in particular on ***cell-surface layer proteins and allergens***. Ulrike Wagner (ulrike.wagner@uni-graz.at), Walter Keller (walter.keller@uni-graz.at), Karl Gruber (karl.gruber@uni-graz.at), Zentrum für Molekulare Biowissensschaften, KFU Graz.

Other active groups in the field (that will hopefully soon join the ACDC BAG), include Kristina Djinovic-Carugo from MFPL (kristina.djinovic@univie.ac.at), who studies molecular features of the ***actin-based cytoskeleton*** in muscle cells and its impact for ***myopathies***, and Klaus Scheffzek (Klaus.Scheffzek@i-med.ac.at), a recent recruit of the Innsbruck University, who is interested in ***protein kinases*** implicated in ***cancer-related diseases***. While these groups cover a diverse array of biological and biomedical research areas, all of these projects are targeted at characterizing large molecular assemblies or proteins currently under-represented in the protein data base (PDB), such as membrane proteins and huge molecular machines. Corresponding high-resolution diffraction data is only obtainable through the use of synchrotron radiation sources. Thus regular synchrotron access is highly desirable to maintain a competitive advantage in our individual research fields and, in addition, to bring Austrian crystallographers into the community of top-class structural biologists.

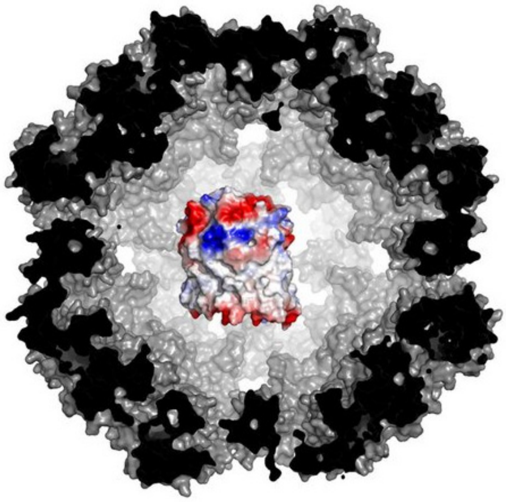


Fig. 5 Molecular cage of a quality control factor, DegP, that recognizes and captures damaged proteins. Once the client proteins are encapsulated in this protein cage, DegP takes a decision whether the client protein is degraded (so-called "hopeless" cases) or whether it is refolded (repairable molecules). Picture connected with Krojer T., Sawa J., Schäfer E., Saibil HR., Ehrmann M., Clausen T., **Nature 453:885-890 (2008).**

[2] **Author:** Tim Clausen

Soft Matter, Biophysics and Biological Materials[3]

The topics "soft matter science, biophysics and biological materials" present probably the most interdisciplinary field within this brochure. They include medicine and the life sciences, as well as physics, chemistry, materials science, and others, and cover a quite substantial amount of Austrian synchrotron research.

Research groups and topics

At the Institute of Biophysics and Nanosystems Research (IBN), Austrian Academy of Sciences, research, on the one hand, is devoted to ***membrane medicine*** with implications from pure biophysics till drug delivery and antibiotics development. On the other hand instrumentation for ***x-ray nanoanalytics*** is designed for both, Lab and synchrotron sources (heinz.amenitsch@elettra.trieste.it). Examples are rapid mixing using microfluidics, the use of laser-tweezers for single particle studies, and gas-phase scattering. Synchrotron radiation experiments conducted at ELETTRA and partly at the ESRF are used as major tools in this research. A large part of the methodical developments are the outcome and continuation of the EC research project SAXIER – a collaboration of all major European synchrotron sources including ESRF and ELETTRA.

At the Institute of Physics, MU Leoben, Research on ***biological- and bioinspired materials*** is conducted (oskar.paris@unileoben.ac.at). Topics of actual interest are for instance the (nano)composite structure of arthropod cuticles and their mechanical- and optical properties, or biomimetic routes to synthesize multifunctional hierarchical ceramics by nanocasting approaches. Microbeam diffraction methods as well as different sophisticated *in-situ* scattering techniques are employed at several European synchrotron sources.

At the Department of Materials Physics MU Leoben and the Erich Schmid Institute, Austrian Academy of Sciences, the ***structure-property relationship in cellulosics*** (jozef.keckes@unileoben.ac.at) is investigated with X-ray diffraction using synchrotron radiation.

At the Institute of Physics and Materials Sciences, BOKU Wien, research on ***biomimetic and biobased nanostructures*** has just started by the new chair (helga.lichtenegger@boku.ac.at).

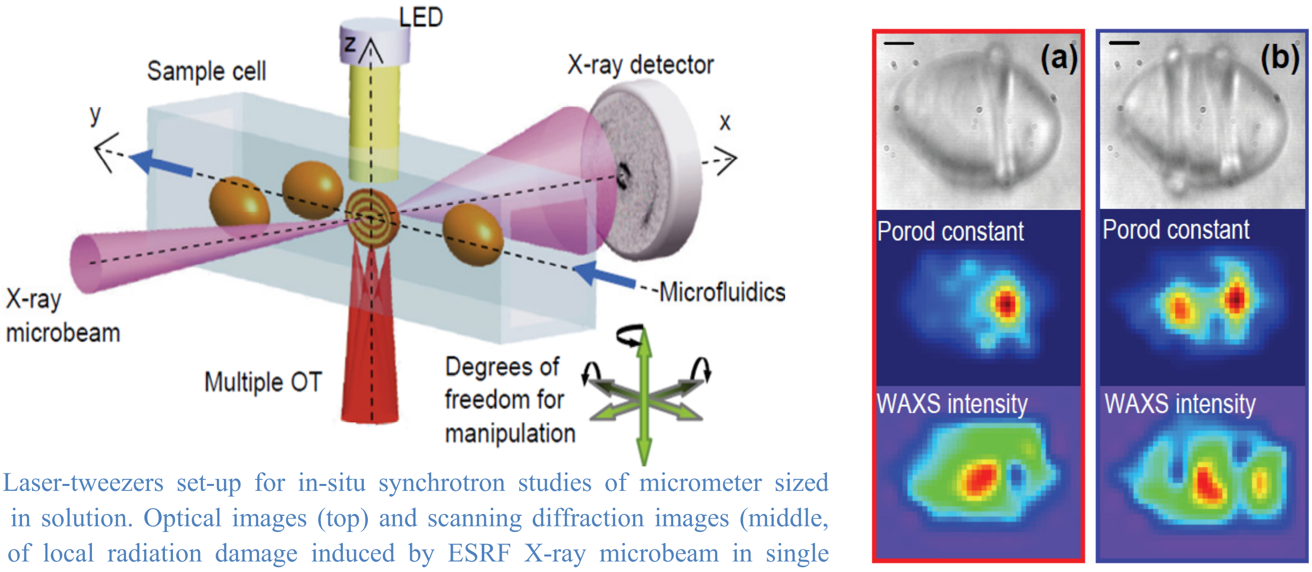


Fig. 6: Laser-tweezers set-up for in-situ synchrotron studies of micrometer sized particles in solution. Optical images (top) and scanning diffraction images (middle, bottom) of local radiation damage induced by ESRF X-ray microbeam in single starch grains held by laser-tweezers (Scale bar is 5 µm). Pictures from: D. Cojoc, H. Amenitsch, E. Ferrari, S.C. Santucci, B. Sartori, M. Rappolt, B. Marmiroli, M. Burghammer, C. Riekel, **Appl. Phys. Lett. 97, 244101 (2010)**

[3] **Authors:** Heinz Amenitsch, Oskar Paris

Functionalized Organic Materials & Surfaces[4]

Surfaces, monolayers, nanostructured films and their interfaces are the essential elements for the technological application of many functional materials. A detailed knowledge of these building blocks is the core to understanding and ultimately controlling their electronic, magnetic and optical properties that can be exploited in a wide range of applications. The structural properties of a large variety of novel materials including oxides on surfaces, inorganic nanoparticles, soft matter and functionalized organic materials are investigated. Integral methods – performed by using synchrotron sources - are used to determine fine structural details of atomic and molecular arrangements; methods like x-ray surface diffraction, near-edge x-ray adsorption spectroscopy or x-ray standing waves are used. The structure of the materials is a general basis to understand the electronic properties which are determined by electron spectroscopy techniques using synchrotron radiation. The studies are mainly fundamental science, nevertheless impact to new research fields and input to technological products appear.

Research groups and topics

Institute of Solid State Physics, Graz University of Technology,
Crystal structure and morphology of thin organic films (roland.resel@tugraz.at),
Electronic properties of molecules on surfaces (egbert.zojer@tugraz.at)

Institute of Physics, Karl-Franzens University Graz,
Growth, structural & electronic properties of conjugated molecules on surfaces
(michael.ramsey@uni-graz.at, georg.koller@uni-graz.at),
Oxide nanostructures on surfaces (svetlozar.surnev@uni-graz.at, falko.netzer@uni-graz.at)

Surface Physics, Institute of Applied Physics, Vienna University of Technology
Oxides and catalysis on surfaces (diebold@iap.tuwien.ac.at, varga@iap.tuwien.ac.at)

Faculty of Physics, University Vienna
Electronic properties of materials (thomas.pichler@univie.ac.at)

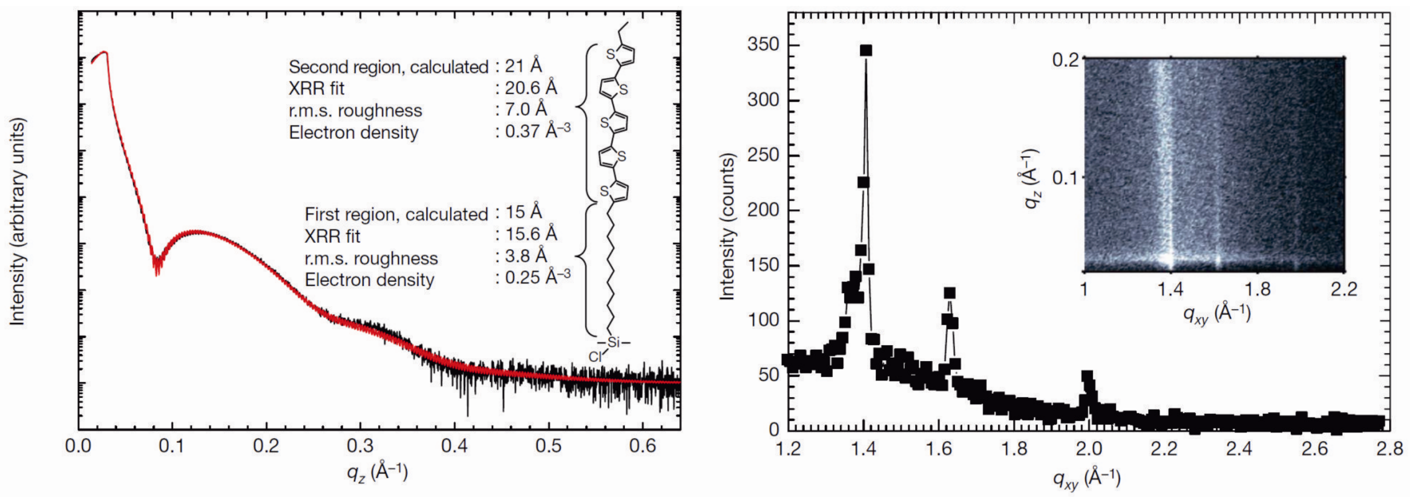


Fig. 7 The two-dimensional crystal structure of a self-assembled monolayer is proven by X-ray reflectivity (left) and grazing incidence surface diffraction (right). Pictures from Smits E.C.P., Mathijssen S.G.J., van Hal P.A., Setayesh S., Geuns T.C.T., Mutsaers K.A.H.A., Cantatore E., Wondergem H.J., Werzer O., Resel R., Kemerink M., Kirchmeyer S., Muzafarov A.M., Ponomarenko S.A., de Boer B., Blom P.W.M., de Leeuw D.M., **Nature 455, 956-959 (2008).**

[4] **Author:** Roland Resel

Dynamics[5]

In contrast to traditional engineering materials whose properties are mostly determined by their structure, the desired features in novel materials often follow from their dynamical properties: examples are the interplay of electrical conductivity and heat transport in (renewable) energy applications, the role of lattice vibration for superconductivity, atomic diffusion in the optimization of rechargeable batteries, or the (prevention of) diffusion for the stability of various functional materials.
The role of the scientific community in advancing these issues is to provide an understanding of the underlying physical phenomena. These can be broadly classified into two fields: collective oscillations of atoms (phonons) or random motion of single atoms (diffusion). In both fields scattering methods (especially at synchrotrons) have been of great impact, and can provide information that is otherwise inaccessible, for instance the vibrational behaviour of mono-atomic layers, or the full description of the motion of single atoms, with Austrian groups at the forefront.

Research groups and topics

Dynamics of Condensed Systems, Faculty of Physics, University of Vienna: ***Atomic diffusion, nuclear inelastic scattering*** (bogdan.sepiol@univie.ac.at)

Electronic Properties of Materials, Faculty of Physics, University of Vienna: ***phonon dispersion measured with inelastic x-ray scattering*** (thomas.pichler@univie.ac.at)

X-Ray Center, Vienna University of Technology: ***Lattice dynamics in strongly correlated materials***, (klaudia.hradil@tuwien.ac.at)

Semiconductor Physics Division, Johannes Kepler Universität: ***Investigations of Si and Ge interdiffusion using x-ray reflectivity***, (julian.stangl@jku.at)

Institute of Solid State Physics, Vienna University of Technology: ***Anomalous vibrational dynamics,*** (silke.buehler-paschen@tuwien.ac.at)

Institute of Physics, Surface and Interface Physics, Karl-Franzens University Graz: ***Vibrational dynamics on amorphous surfaces*** (wolfram.steurer@uni-graz.at)

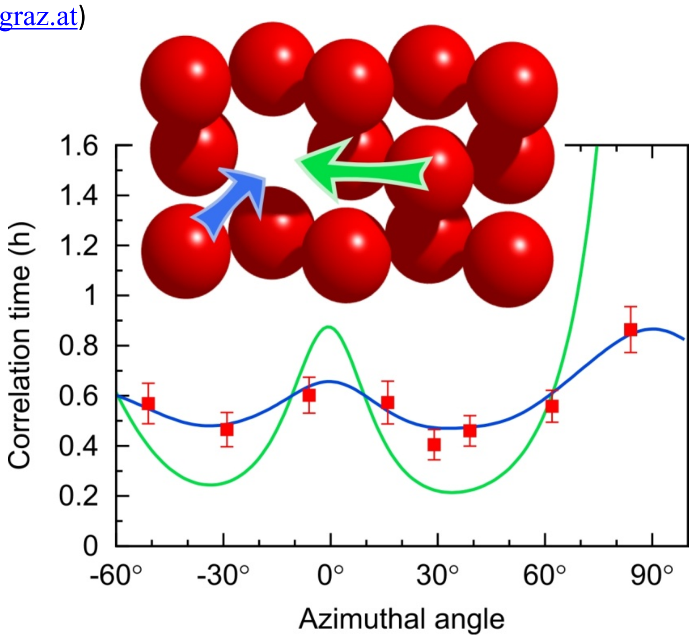


Fig. 8: Fluctuations in the scattered intensity are dependent on the spatial orientation versus crystal and shows a clear preference for nearest-neighbour jumps. Picture related to M. Leitner , B. Sepiol, L.M. Stadler, B. Pfau, G. Vogl, **Nature Materials 8**, 717 (2009).

[5] **Authors:** Bogdan Sepiol, Michael Leitner

Semiconductor Materials[6]

Semiconductor materials are at the backbone of present-day technology, from mobile phones to control electronics in cars, from electronics to control a power plant and the distribution of electricity down to the alarm clock announcing when the “Guglhupf” is ready. But also transformation of sunlight into electricity in solar cells is based on semiconductor materials. Creating light out of electricity using semiconductors provides LED lamps, lasers for DVD players and scanners in cash desks, but is also important for medical diagnose and pollution monitoring. To achieve improvements in all mentioned fields, research on new semiconductor materials and devices is essential. Austria has several research centres pursuing various topics, from faster electronics, new lasers up to better solar cells. For this research, material characterization using synchrotron radiation is crucial. Determining the chemical composition and strain distribution inside of nanostructures, for example, is virtually impossible by any other technique.

Research groups and topics

Institut für Festkörperelektronik, TU Wien:
Semiconductor lasers (gottfried.strasser@tuwien.ac.at)

Institut für Halbleiter und Festkörperphysik, Johannes Kepler Universität Linz:
Semiconductor nanostructures (julian.stangl@jku.at)
Magnetic semiconductors (alberta.bonanni@jku.at)

Institut für Photonik, TU Wien:
Terahertz devices (karl.unterrainer@tuwien.ac.at)

Institut für Physik, MU Leoben:
Magnetic semiconductor nanostructures and ***core-shell nanoparticles*** (rainer.lechner@unileoben.ac.at)
Organic semiconductors (christian.teichert@unileoben.ac.at)

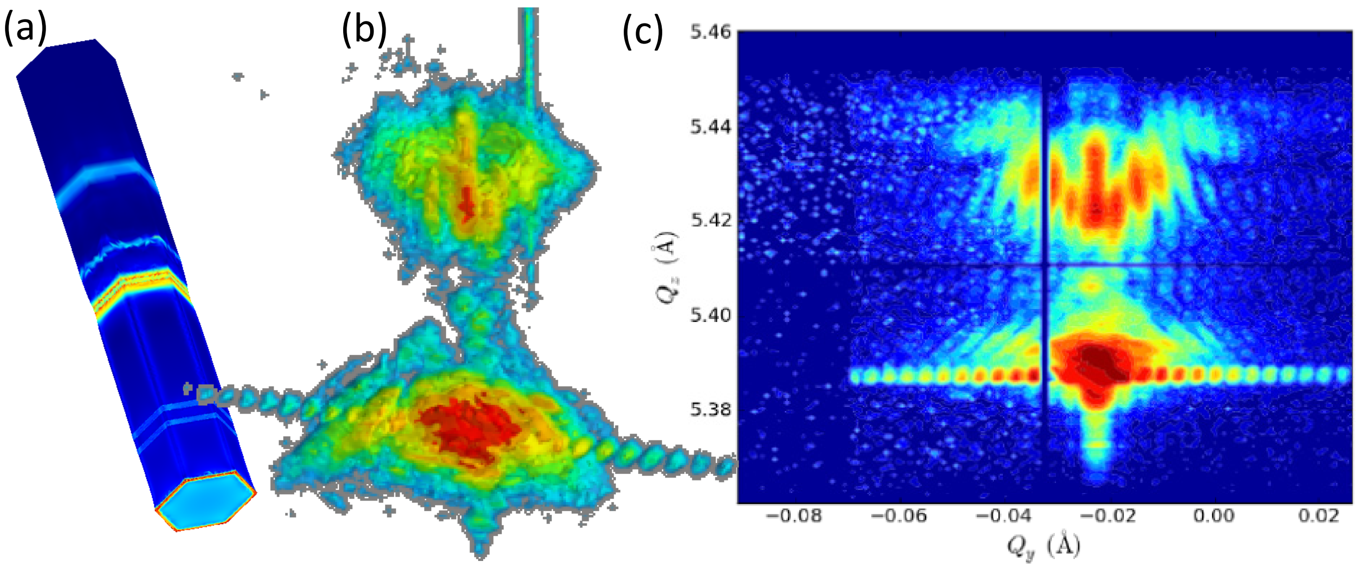


Fig. 9: (a) calculated strain distribution and corresponding measured 3D intensity distribution (b) of a single InAs/InAsP nanowire containing a quantum dot. (c) 2D slice through the data. Such structures are used in the design of next-generation high-speed electronics and efficient solar cells. Picture provided by J. Stangl (unpublished).

[6] **Author:** Julian Stangl

Materials Science and Engineering[7]

A long tradition in materials science and engineering in Austria is on structural metal based materials. They include for instance high-temperature materials for aircraft engines, high strength nanocrystalline materials, or lightweight alloys and composites. The ESRF provides unique possibilities to study the structure-property relations of such materials with *in-situ* high energy diffraction, micro- and nanobeam diffraction on a local scale, or ultra-fast (in-situ) microtomography or nanotomography using both absorption and phase contrast.

At the Institute of Materials Science and Technology, TU Vienna (guillermo.requena@tuwien.ac.at) several applied research topics on ***lightweight alloys for diesel engines and aerospace industry***, or on ***carbon fiber reinforced polymers*** are investigated using high resolution x-ray tomography.

Similar attempts for the ***development of advanced engineering materials*** are undertaken at the Institute of Physical Metallurgy and Materials Testing, MU Leoben using synchrotron based *in-situ* X-ray diffraction (helmut.clemens@unileoben.ac.at).

At the Department of Materials Physics MU Leoben and the Erich Schmid Institute, Austrian Academy of Sciences, ***plastic deformation behavior at the micron scale***, as well as ***stress design in advanced hard coatings*** (jozef.keckes@unileoben.ac.at, christoph.kirchlechner@unileoben.ac.at) are topics of current interest.

Nanocrystalline metallic materials, (michael.zehetbauer@univie.ac.at), and ***mechanical properties of carbon fibers***, herwig.peterlik@univie.ac.at are investigated at the Faculty of Physics, University of Vienna

The structure of ***functional nanomaterials*** (e.g. carbon nanostructures, cement, nanoparticles), as well as ***nanoporous systems*** and their interaction with fluid matter are investigated at the Institute of Physics, MU Leoben (oskar.paris@unileoben.ac.at)

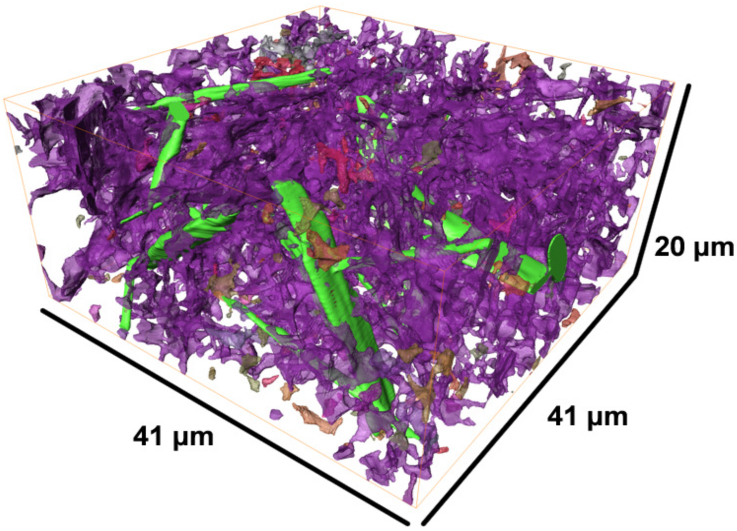


Fig. 10: High resolution synchrotron holotomography of a titanium-based composite. Ceramic reinforcing whiskers (green) form an interpenetrating structure with irregularly shaped grains of the Ti-alloy (other colours), revealing the 3D-architecture of materials non-destructively with the highest resolution currently achievable (~ 180 nm) for relatively large samples (~ 0.4 mm). Picture related to Poletti C., Requena G., Tolnai D., Cloetens P., Steiger-Thirsfeld A., **Int. J. Mater. Res. 101, 1151 (2010).**

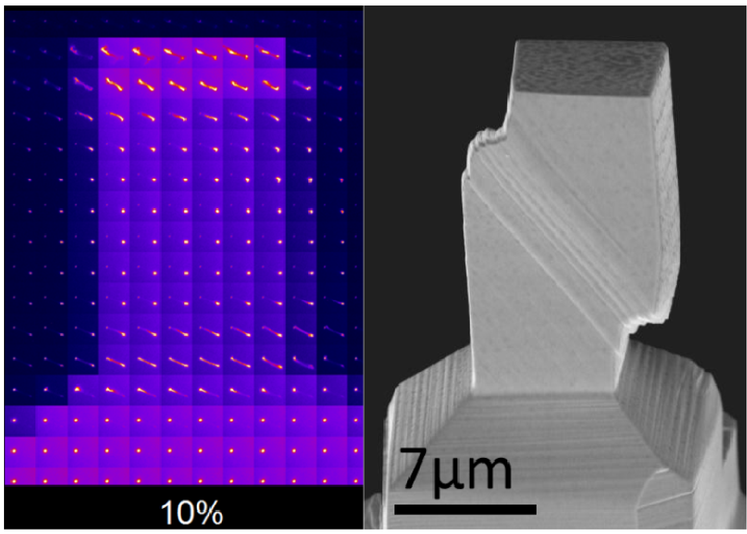


Fig. 11: (left) Micro-Laue and (right) Scanning electron image of a micron sized compression sample. The Micro-Laue image can be used to analyze the density of material defects, whereas the SEM image gives the surface of the compression pillar. Both complementary techniques are necessary to understand crystal plasticity at the micron scale. From Kirchlechner C., Kiener D., Motz C., Labat S., Vaxelaire N., Perroud O., Micha J.S., Ulrich O., Thomas O., Dehm G., Keckes J., **Phil. Mag. 91, 1256-1264 (2011)**

[7] **Authors**: Oskar Paris, Guillermo Requena, Jozef Keckes

Other Research Areas[8]

In addition to the topical fields mentioned above, several other Austrian groups perform synchrotron radiation experiments at various European sources. Besides physical and chemical sciences, they include such diverse fields as geology, medicine, anthropology, palaeontology and even arts.

Really multidisciplinary is the research of the group of Christina Streli from the Atominstitute of the Faculty of Physics, TU Wien covering ***x-ray spectrometry in various applications*** *(medicine, thin film characterization, depth profiling)* (streli@ati.ac.at). For instance, trace element distributions in ***osteoporotic bones*** in comparison to healthy bones, or thin films in the range of nm of "high-k" materials for ***semiconductor applications*** are studied with X-ray fluorescence and edged spectroscopy at various European synchrotron sources.

Novel ***magnetic materials*** are studied at the Institute of Solid State Physics, TU Wien with synchrotron based X-ray absorption spectroscopy (roland.groessinger@tuwien.ac.at).

At the Institute of Mineralogy and Crystallography, Universität Wien (ronald.miletich-pawliczek@univie.ac.at) and at the Institute of Mineralogy and Petrography, Universität Innsbruck (volker.kahlenberg@uibk.ac.at), synchrotron based ***crystallography of matter under extreme conditions*** (for instance at high pressures) are topics of current interest.

In geology, synchrotron radiation based edge-spectroscopy is employed for ***"Impact Research" on extraterrestrial bodies*** at the Department of Lithospheric Research, Universität Wien (christian.koeberl@univie.ac.at).

Synchrotron microtomography is used to scan ***dinosaur eggs*** by researchers from the Department of Geology and Geodynamic, Uni Salzburg (ana-voica.bojar@sbg.ac.at), or to tackle anthropological questions by studying ***macaque bones*** at the Department of Anthropology, Uni Wien (bence.viola@eva.mpg.de).

Finally, x-ray fluorescence and micro-x-ray diffraction at synchrotron sources have become a very valuable tool to ***analyze objects of art and archaeology in a non-destructive or even non-invasive way***. At the Institute of Science and Technology in Art of the Academy of Fine Arts in Vienna these methods were used for the characterization of ancient Roman and Ottoman coins as well as for the identification of pigments in paint layers (m.schreiner@akbild.ac.at).

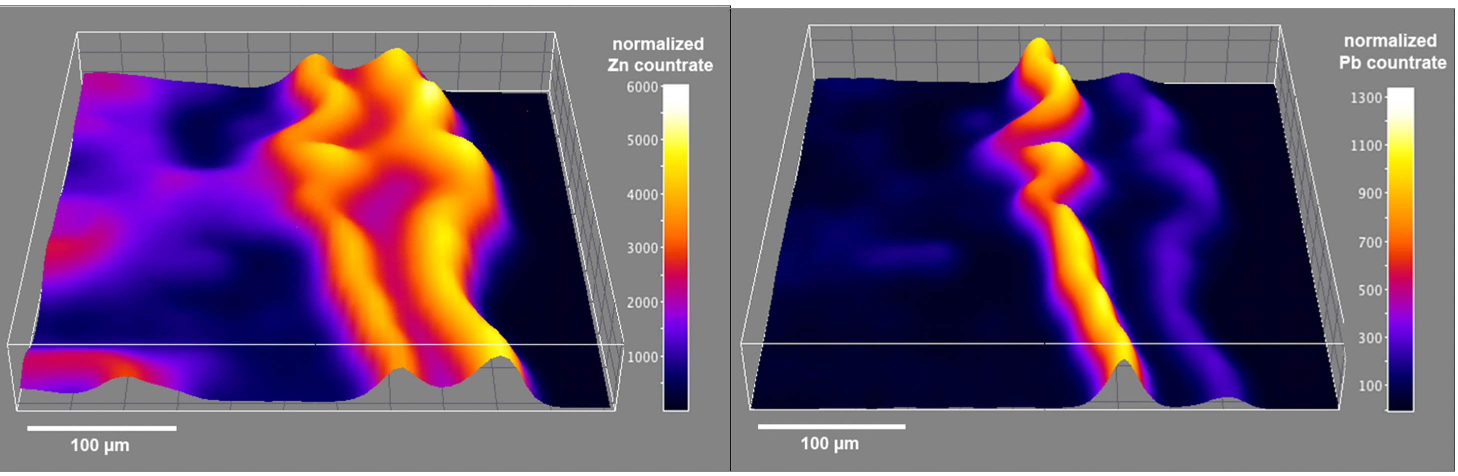


Fig. 12: Zn (left) and Pb (right) distribution from human joint bone sample at the border between articular and calcified cartilage. Picture provided by C. Streli; from A. Roschger, B. Pemmer, J.G. Hofstaetter, P. Wobrauschek, R. Simon, P. Roschger, K. Klaushofer, C. Streli, to be published (2011)

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