ESRF
The European Synchrotron

X-RAYS FOR INNOVATION

MATERIALS CHARACTERISATION BEYOND LAB FACILITIES
ADVANCED INSTRUMENTATION AND TECH LABS

CONTENTS

HOW CAN YOUR RESEARCH BENEFIT FROM THE ESRF?

Synchrotron radiation is used increasingly as a response to industrial challenges related to the life cycle of materials: development, manufacturing, operation, ageing, wear-and-tear, preservation, restoration, recycling, evaluation and more. Observing, characterising and understanding the structure of matter are at the heart of these challenges for industry. Our applications cover many fields, including pharmaceuticals and biotechnology, chemistry and catalysis, consumer products, construction and transport engineering, nanotechnologies, energy, environment, metallurgy and advanced materials.

Our key assets are:

- **NON DESTRUCTIVE**
probing of material structure
- **HIGH SPATIAL RESOLUTION**
from millimetres to nanometres and even to atomic resolution
- **FAST**
to follow processes in real time
- **HIGH THROUGHPUT**
enabling routine data collection from thousands of samples
- **OPERANDO**
for working in situ under real manufacturing and operating conditions (extreme temperatures, pressure, mechanical stress, chemical environments, etc.)
- **WIDE RANGE OF SAMPLE ENVIRONMENTS**
furnaces, cryostats, diamond anvil cells, large volume press, on-line mixing, microfluidics, gas atmospheres…
- **SPECIALISED SUPPORT LABS**
for off-line characterisation, sample preparation, metrology, precision engineering and others

MACROMOLECULAR CRYSTALLOGRAPHY
FLUORESCENCE SPECTROSCOPY
MICROTOMOGRAPHY
DIFFRACTION IMAGING
TOPOGRAPHY
SURFACE DIFFRACTION
MICRO/NANO DIFFRACTION
X-RAY ABSORPTION FINE STRUCTURE
SMALL AND WIDE ANGLE X-RAY SCATTERING

THE ESRF: GOING BEYOND LAB CAPABILITIES

Today's products rely on modern and constantly evolving materials and manufacturing processes. To tackle these challenges, the **ESRF provides industry with unique insights**.

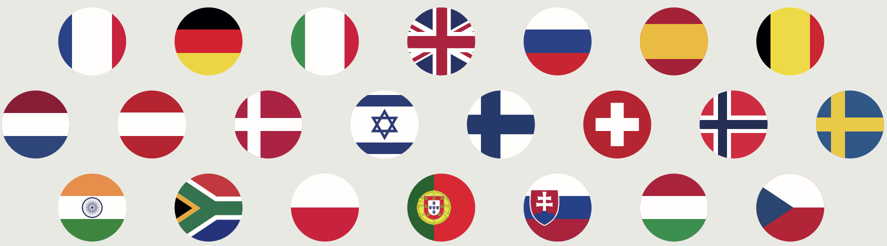
Many companies today use technical labs to support their R&D programme. The ESRF, **the world's most intense X-ray source**, goes far beyond standard laboratories.

The ESRF functions like a 'super-microscope', due to the brilliance and exceptional qualities of its X-rays (100 billion times brighter than X-rays from conventional sources), revealing the structure of matter in all its complexity. These X-rays allow **advanced characterisation of materials** for a huge range of industrial sectors, down to the micro, nano and atomic scales - often in real time and under real manufacturing or operating conditions.

Over **150 commercial clients** have used the ESRF's facilities for proprietary research over the last 5 years. Around 30% of the public research carried out by the 9000 scientists that visit the ESRF every year involves industry.

The ESRF is currently developing the **Extremely Brilliant Source**, a new, extremely powerful storage ring which will enable industrial and academic scientists **to carry out experiments that are currently impossible**. The X-rays delivered by the new storage ring will be more brilliant and more coherent than any other source worldwide.

The ESRF is a model of **international cooperation**, with the support of 22 countries.



APPLICATIONS

Synchrotron X-rays at the ESRF characterise materials in a wide array of sectors, from consumer products to engineering, from pharma to advanced materials, from food to energy. Every sector relying on material performance can benefit from synchrotron X-rays.

AEROSPACE AND AUTOMOTIVE

What can the ESRF do?

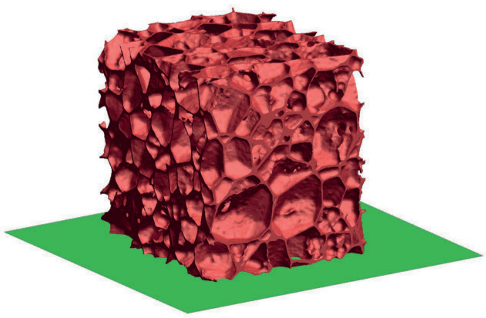
- Characterisation of composite materials and advanced alloys
- Characterisation of metal foams
- Study of materials under stress and during fatigue tests
- Stress distribution as a function of depth in materials
- Speciation of metallic coatings
- Analysis of the performance of corrosion resistant coatings
- Compressive stress profiling
- Analysis of trace elements in petroleum and petrochemical products
- Characterisation of fuel cells and hydrogen-storage media
- High speed imaging of engine components
- Following combustion processes
- Following catalysis in situ

EXAMPLES

→ ArcelorMittal with the laboratory MATEIS-INSA carried out mechanical tests on **advanced high-strength steels**. They characterised damage appearing when tensile tests were performed, using X-ray microtomography to track void nucleation.

→ Scientists at the German Aerospace Centre and Vienna University of Technology monitored the kinetic evolution of microstructural phases of **titanium-based components** during thermal and thermomechanical treatments, in order to improve the functional alloy design.

→ Infineum studied non-destructive analysis of carbonaceous deposits on car **diesel injectors**, which can alter the operation of the injector and affect the combustion process.



CASE STUDY

How do safety foams in cars deform?

Modern vehicles have a dense foam, such as expanded polypropylene (EPP), inside headrests and bumpers that decelerates passengers to minimise stresses on them in case of accidents.

Researchers from Jaguar Land Rover and the University of Warwick studied EPP's energy-absorption properties under deformation at the ESRF. Using beamline ID19, the researchers performed fast computed micro-tomography to continually image their EPP foams during compression with a dedicated press facility. By incorporating the 3D images into a computer model, the researchers could understand how to improve the foam and how much of it to use in a vehicle for optimal performance.

ADVANCED MATERIALS

What can the ESRF do?

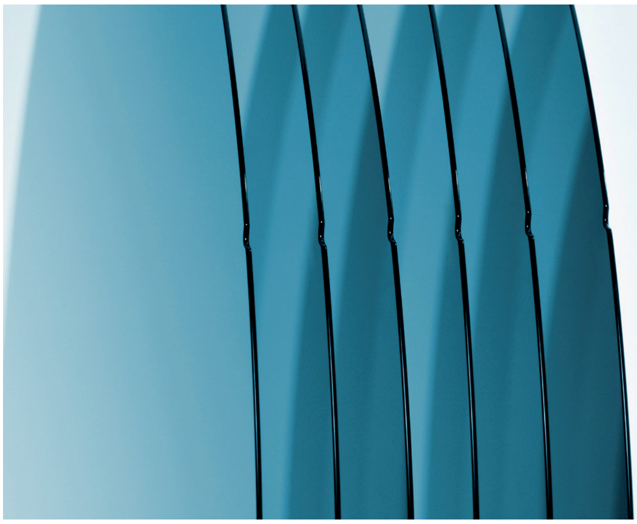
- Microfocus X-ray beams to characterise nanostructure of fibre-reinforced composites and high-performance fibres
- Analysis of open porosity in foams and residual porosity in sintered objects
- Watching sintering processes as they happen
- Analysis of residual strain and study of materials under stress
- Analysis of physico-chemical properties via X-ray spectroscopy
- In situ characterisation under manufacturing conditions and extreme conditions of operation
- Time-resolved studies to monitor molecular chains and hydrogen bonds in polymers
- Following internal failure mechanisms of composites using X-ray tomography

EXAMPLES

→ ST Microelectronics performed high-resolution strain microscopy to control the strain field in **silicon** close to copper-filled through silicon vias (TSVs).

→ Nanobeam strain imaging is used for the characterisation of strain fields in **GaInN compounds** for optoelectronic applications.

→ SAXS experiments enabled BASF to study the structure of **advanced paint and surface coatings**.



CASE STUDY

Fast in situ nano-imaging of particle sintering

Sintering is used to process dense or porous ceramics, metals or composites into often complex shapes which are impossible by other manufacturing methods. During the course of sintering, which involves heat and pressure, unacceptable defects can often occur in the desired complex shapes and/or multi-material systems. The development of models able to understand and predict the formation of such defects is crucial to avoid them.

Using our computed nano-tomography beamline ID16B, researchers obtained 3D in situ observation of particle sintering at high temperature with an unprecedented combination of high spatial resolution and fast scan time. This experiment allowed, for the first time, determination of the local neck curvature, an essential governing parameter for sintering. The work opens the door for the development of better predictive manufacturing models.

High-temperature X-ray nano-tomography has applications in many other fields to reveal previously inaccessible fast phenomena such as nucleation and growth of pores and cracks, glass synthesis and high-temperature mineralisation processes.

Villanova, J. et al, Materials Today (2017); doi: 10.1016/j.mattod.2017.06.001.

AGRICULTURE AND FOOD

What can the ESRF do?

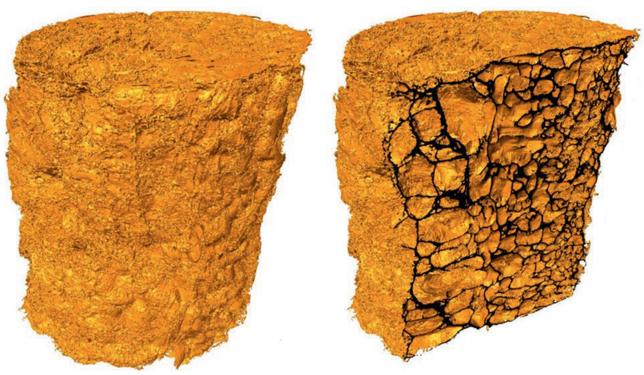
- Correlate the macroscopic properties of a sample with its microstructure
- Visualise the multi-lengthscale pore structure of samples, for example, freeze-dried vegetables and aerated food products
- Understand food microstructure changes in response to temperature abuse using high-resolution tomography imaging
- Detect trace elements and map molecular groups and structures on the nanoscale
- Understand crystallisation and phase processes in food
- Complementary characterisation services through the Partnership for Soft Condensed Matter

EXAMPLES

→ To find healthier alternatives to the crystalline triglyceride fat, present in **butter**, Unilever researchers studied γ-oryzanol mixed with β-sitosterol using small and wide-angle X-ray scattering and discovered that they create a network of tubules in edible oil.

→ High-resolution tomography enabled Unilever to see the changes in the microstructure of **ice cream** with temperature changes, leading to improved products.

→ Industrial scientists used X-ray microscopy to see the distribution of the different ingredients in a **stock cube** with the aim to improve its formulation.



CASE STUDY

Improving the properties of dehydrated carrots

Most dehydrated fruits and vegetables are produced by air drying, but their quality diminishes. Higher quality products can be obtained using more expensive freeze-drying methods. Unilever's researchers have quantitatively assessed the impact of freeze-drying, blanching and freezing rate pre-treatments on the microstructure and on the rehydration properties of winter carrots, using, amongst other techniques, X-ray micro-computed tomography. They have been able to predict a relation between freezing rate and freeze damage. Water imbibition rates could be explained from the porous structure induced during freeze-drying. In the rehydrated state, the remaining structural integrity and anisotropy could be correlated with the textural quality.

Van Dalen G. et al, InsideFood Symposium, 9-12 April 2013, Leuven, Belgium.

CATALYSIS AND CHEMISTRY

What can the ESRF do?

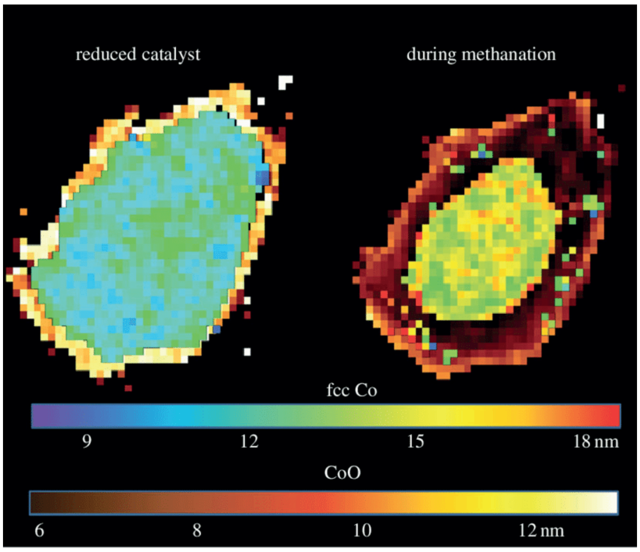
- Obtain information about chemical bonds
- In situ qualitative and quantitative measurements during catalysis at millisecond time resolution across wide concentration ranges
- Analyse the shape, size and density of nanoparticles and catalyst particles
- Obtain 3D images of matrices and detect trace elements at high resolution
- Determine quantitative oxidation states of species at ultra-dilute concentration
- Probe reaction intermediates
- Characterise working batteries and fuel cells
- Analyse phase distribution catalyst pellets

EXAMPLES

→ In pursuit of more efficient catalysts for NOx abatement, Haldor Topsøe used X-ray absorption spectroscopy to shed light on structure-property relationships of **Cu-zeolites** in operando conditions.

→ Using energy-dispersive X-ray absorption spectroscopy Toyota Motor Corporation studied the noble metal components of a working vehicle **exhaust catalyst** in real time.

→ High-energy grazing incidence X-ray diffraction and online mass spectrometry allowed scientists to monitor the behaviour of **alloy nanoparticles** during catalytic oxidation of carbon monoxide to carbon dioxide at 550 K and near-atmospheric pressures.



CASE STUDY

Improving Fischer-Tropsch catalysts

Researchers from British Petroleum, University College London and Finden Ltd investigated Fischer-Tropsch catalyst pellets in action using the powerful technique of X-ray diffraction-based computed tomography available at ESRF beamlines ID11, ID15 and ID31.

The combination of in situ X-ray diffraction computed tomography and pair distribution function computed tomography was used to study a 3 mm Co/γ-Al_2O_3 catalyst for Fischer-Tropsch synthesis. The work was done in situ on real catalyst pellets. This combination of techniques is uniquely effective for unravelling the complex Co nanoparticle phase evolution to obtain a complete understanding of the structure-activity relationships in catalytic systems.

CONSUMER PRODUCTS

What can the ESRF do?

- Microstructural insights in consumer goods for their improvement
- Correlate macroscopic properties of a sample with its microstructure
- High-throughput structural studies for formulation space analysis
- Study real product behaviour in different sample conditions (heat, humidity…)
- Provide in-depth information about the rheology and stability of products
- High-performance characterisation to visualise complex nanostructured materials across all relevant length scales
- Analysis of materials during in situ industrial process conditions
- Real time mixing and rheology studies

EXAMPLES

→ Scientists from L'Oreal used microfluidics, in combination with small-angle X-ray scattering, to understand how **deodorant** stops sweat propagation.

→ P&G researchers studied a **detergent** which boasts cleaning at 15^{0}C, using the microstructure of the colloidal formulations obtained using SAXS to tune product performance and stability.

→ X-ray micro-diffraction is used to test how **creams** penetrate into the epidermis.

CASE STUDY

Keeping hair conditioners stable over time

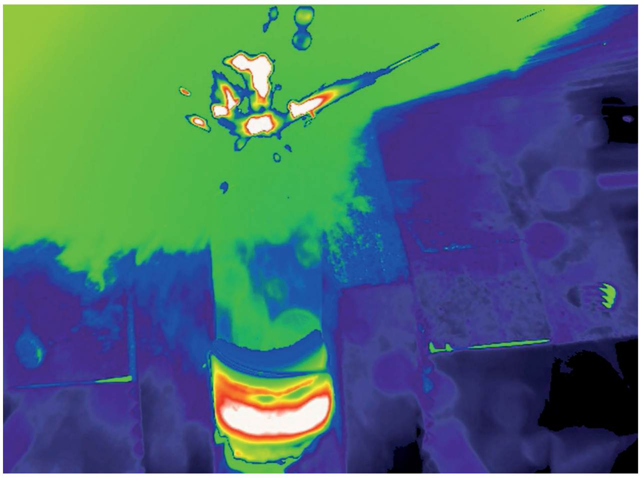
Hair conditioners are based on a dispersion of liquid crystalline phases that work with the flow of water to lubricate and protect hair fibres. The stability of these products is vital for guaranteeing consistent performance. To validate the stability of Unilever's hair conditioner products, including a variety of ingredients and their permutations, products were shipped to the ESRF to undergo a three-month stability trial.

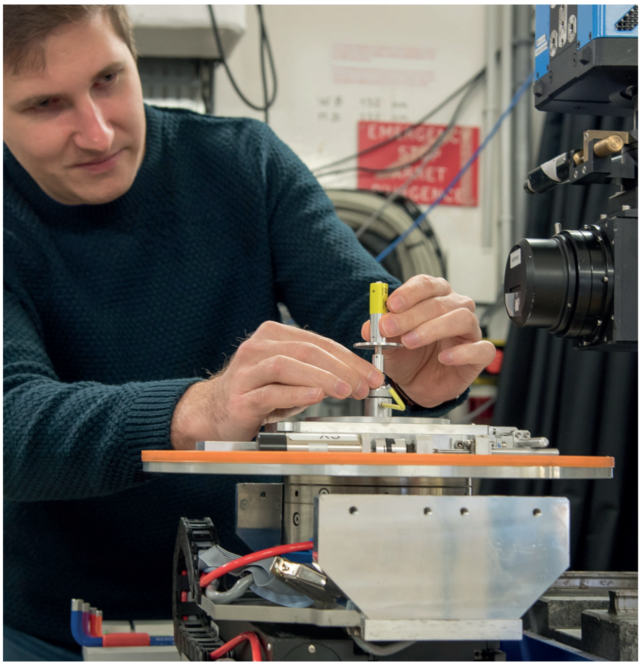
Using small-angle X-ray scattering at ESRF beamline ID02, the team monitored the microstructure evolution of the products at critical intervals during the trial period. The experiment showed how microstructures influence the bulk properties and any changes that occur over time - proving instrumental in providing a mechanistic understanding of how a hair conditioner microstructure evolves from factory to consumer.

ENERGY

What can the ESRF do?

- X-ray diffraction and spectroscopy to reveal the composition, atomic structure and crystalline state of energy materials
- X-ray topography for crystalline qualities of photovoltaic cell materials
- In situ high-performance powder X-ray diffraction to look at new energy materials such as photovoltaics and hydrogen storage
- Nano/micro-imaging of materials to track defects and aggregates
- In situ studies to follow materials in batteries under operating conditions
- Watching manufacturing processes using X-ray imaging and tomography to optimise energy use





EXAMPLES

→ The company ECOCEM recycles a by-product from the steel industry to create **concrete**. To improve its blue coloration, they used K-edge X-ray absorption near-edge structure (XANES) spectroscopy to follow the evolution of sulphur speciation during hydration.

→ The company Siltronic analysed local variations of crystal lattice imperfections to improve the manufacturing process of graded buffer-based 300 mm **SiGe substrates** for advanced CMOS applications.

→ X-ray Bragg diffraction imaging (XRDI, topography) has contributed to improving mono-like **silicon solar cells**, from ingot growth, through each stage of processing, to the final cell structure.

CASE STUDY

Revolutionary method reveals impact of short circuits on battery safety

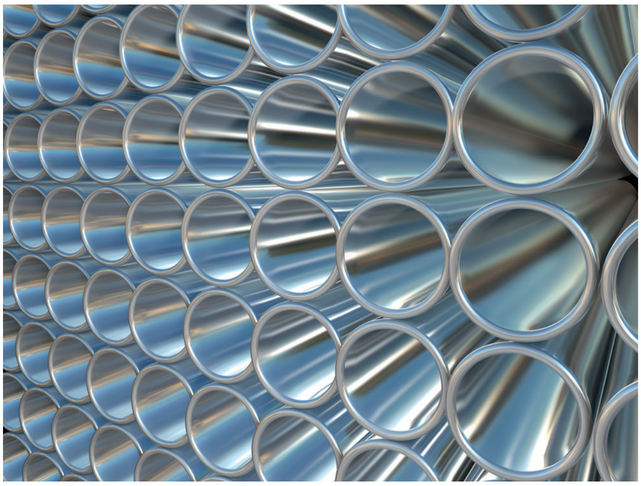
The use of high-energy density Li-ion batteries is ubiquitous – from powering portable electronics to providing grid-scale storage – but defects can lead to overheating and explosions. Short-circuiting is thought to be responsible for a number of high-profile, real world failures. Scientists from UCL came to the ESRF to characterise what happens during a controlled short-circuit of a battery, at an internal location of their choosing. They did this using ground breaking high-speed X-ray imaging. From analysing the high-speed imaging frame by frame, the researchers looked at the effects of gas pockets forming, venting and increasing temperatures on the layers inside two distinct commercial Li-ion batteries and identified consistent failure mechanisms. These new insights can be used to improve the safety of commercial battery and module designs.

Finegan D. et al, Energy Environ. Sci., (2017), DOI: 10.1039/c7ee00385d.

ENGINEERING AND METALLURGY

What can the ESRF do?

- Track changes occurring inside materials during formation on the static to millisecond scale
- Depth-profile strain analysis using high-energy X-rays
- Look inside concrete mixtures for phase and structure mapping during wetting
- Follow aging processes at microscopic scales with long-term sample monitoring
- Strain and stress analysis using energy-dispersive X-ray diffraction
- Damage and failure testing on coatings using X-ray microtomography
- Watch material flow in casting and injection processes
- Monitor solidification processes in melts and alloys
- Study buried interfaces



EXAMPLES

→ Experiments at the ESRF provided residual stress profiles in **additively manufactured components**. This could ultimately enable the design of higher performance products in, for example, the aerospace sector.

→ Rolls Royce and the University of Manchester carried out diffraction experiments to understand the structural changes taking place in aeroplane **fan blades** during the service throughout their lives.

→ X-ray diffraction has helped scientists to study undercooled **glass-forming melts** and establish a correlation between crystalline structure, liquid short range order and the crystal growth kinetics, in order to understand the mechanism governing crystal growth and glass formation.

CASE STUDY

Towards a heat-resistant steel

3D X-ray diffraction on ID11 has proven a unique technique to track the nucleation process inside steel as it is submitted to temperatures of 1000°C. Scientists developed a furnace compatible with the beamline and that had temperature control. They found that nucleation happens quicker than had been predicted: there are special places, like grain corners or edges in the material where nucleation takes place more easily than other areas.

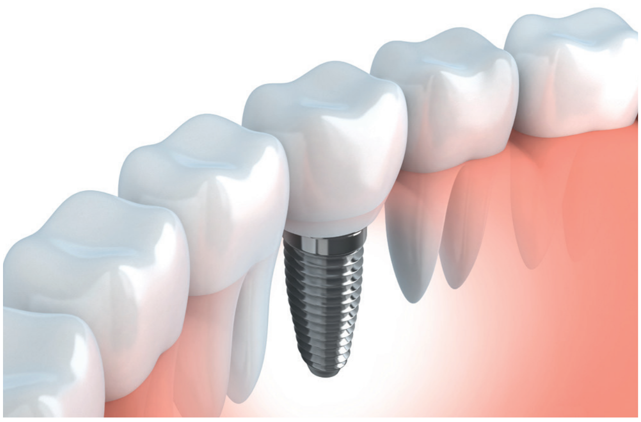
Moreover, the crystals in the steel become coarser at higher temperatures, which decreases the material's strength. With the insights, researchers are testing the replacement of scarce elements used in the alloying process of steel by other elements more widely (and cheaply) available.

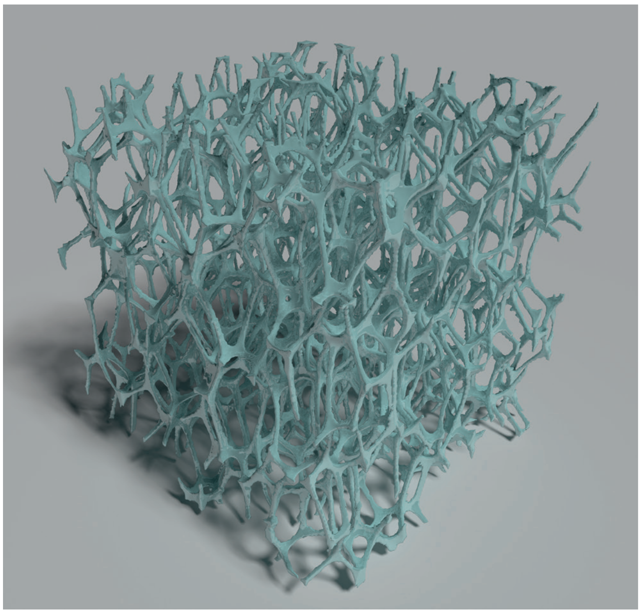
Sharma H., et al, Scientific Reports, (2016), DOI: 10.1038/srep30860

HEALTH

What can the ESRF do?

- 3D/4D computed tomography (CT) imaging to study the micro- and nano-structure of materials and devices
- Characterisation of implant structures and follow-up of their fatigue and ageing
- Structuring and dissolution models of pills
- Structuring of drug delivery vehicles and slow release mechanisms
- Watching medical devices under operation
- Speciation of environmental pollutants
- Tracking destination of metal pollutants in tissues
- Biomedical static and longitudinal imaging on tissue samples, tumour vascularisation networks, etc
- Following bone structure modifications in e.g. osteoarthritis
- Improving radio-therapy procedures





EXAMPLES

→ Chromatographic filtering could be a new way of separating cancerous from healthy blood cells. Merck, together with the University of Darmstadt, reproduced the processes taking place in this technique and **imaged the cells** in 3D using time-resolved microtomography.

→ X-ray high-resolution phase-contrast tomography has allowed scientists to simultaneously visualise three-dimensional vascular and neuronal systems, which could be suitable for pre-clinical investigation of **neurodegenerative pathologies**.

→ Comprehensive study of dynamic curing effect on **tablet coating structure**.

CASE STUDY

Improving asthma and other respiratory diseases

Prior PLM Medical, an SME supporting the medical and pharmaceutical industry to develop drug delivery devices, is studying inhalers at the ESRF as they are triggered. Inhaler efficiency is often quite poor with only 10-20% total lung deposition for most devices on the market.

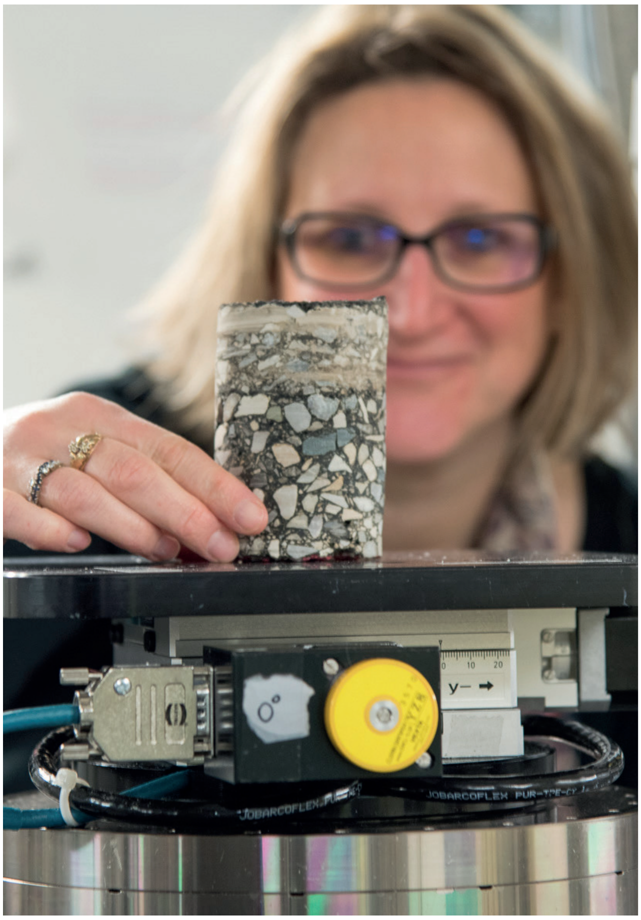
At the ESRF, the Prior team used high-speed (MHz) phase contrast X-ray radiography on ID19 to visualise for the first time ever how the dose release event from inhalers showed the propellant mixture behaviour inside the canister and actuator. In addition, the critical mechanical interactions could be viewed as they took place. The work has provided new insights and is a validation method for modelling efforts.

The radiography film showing the trigger and subsequent drug release can be seen here: vimeo.com/194356596

MINING

What can the ESRF do?

- Tracing of elements, including those in petrochemical products or identification of toxic concentrations of heavy metals
- Mineral characterisation
- High-throughput phase component analysis
- Analysis of samples on the large-volume press using X-ray diffraction
- Geological studies under extreme conditions
- Soil analysis for environmental remediation
- Permeability and determination of microstructure of rocks



EXAMPLES

→ The large volume press at the ESRF has been used for a deformation study on **olivine**, the most abundant element of the Earth's upper mantle. Its strength is key to determine the stress storage capacity of subduction rocks that may be released in deep earthquakes.

→ **Mine tailings** are a source of heavy metal pollution and their residues constitute a risk for environmental and human health. Studies using X-ray fluorescence have tracked the copper speciation and mobilisation, which indicates the level of pollution in soils and mine tailings in a mine in Mexico.

→ **Sepiolite** is a porous clay that absorbs more liquid than any other known mineral. At the ESRF, scientists obtained single-crystal X-ray diffraction images of sepiolite, opening the path to industrial synthesis and further improvement of its properties.

CASE STUDY

Modelling rocks for oil and gas industry

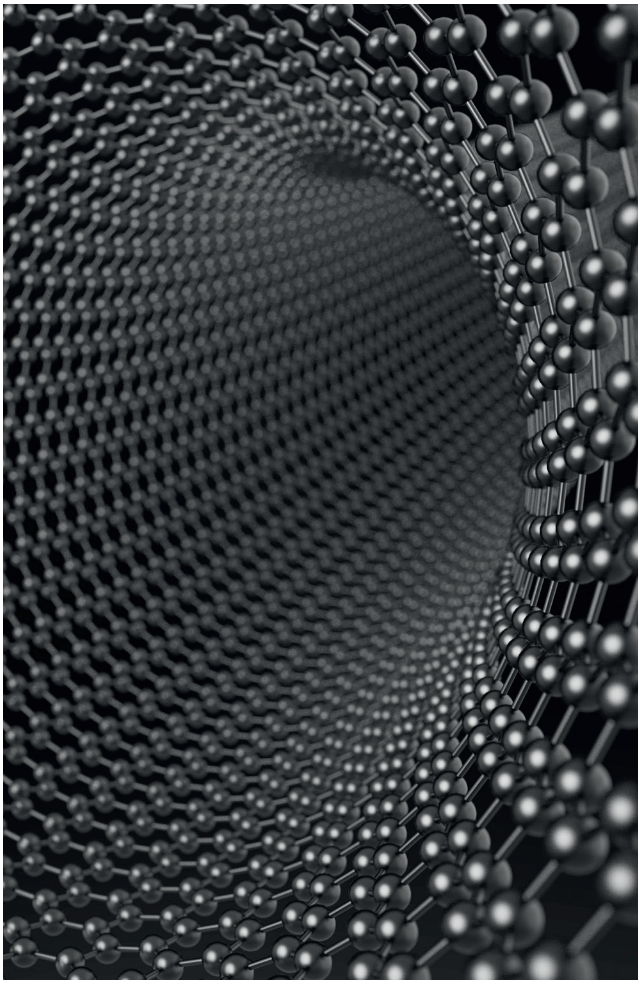
Digital rock analysis is a pore-scale imaging and numerical modelling technology to extract nanometre to centimetre scale geological and petrophysical information, as well as multi-phase fluid-flow data based on pore-scale displacement processes from digitised rock samples. The crux is that approximately more than 60% of the reservoirs worldwide consist of rocks with very small pore systems, which require imaging at voxel sizes (far) below 1 micrometre with ideal scanning resolutions between 100 and 300 nanometres/voxel.

With their flexibility in energy ranges, spot sizes and detection architecture, ESRF beamlines have carried out CT-scans of rock samples with varying sample diameters at resolutions from micro- to nano-scale for the company iRock technologies.Co.Ltd. Due to this capability it is possible to close the resolution gap, which is essential to investigate many reservoir rocks.

NANOTECHNOLOGY

What can the ESRF do?

- Identification of nanostructures for high-density data storage
- Characterisation of nanowires for new device technologies
- Designing 3D integrated structures for next-generation semiconductor devices
- Better understanding of how nanoparticles enter biological cells
- Topography for defect analysis on single crystalline substrates (wafers)
- Morphological and structural characterisation of nanomaterials using 3D imaging
- Characterisation of thin layers (roughness, interfaces)

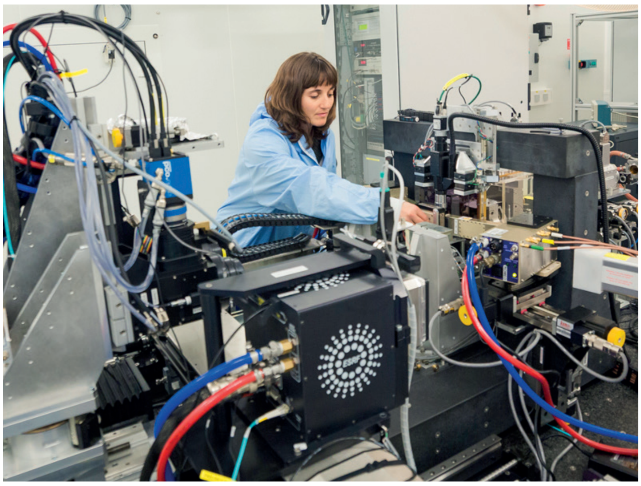


EXAMPLES

→ Self healing is a promising new approach to prolong the lifetime of steels exposed to high temperatures and stress for long time periods. Under these conditions, damage accumulates by creep cavities that continuously form at grain boundaries. X-ray nanotomography at the ESRF has shown that, for **Fe-Au model alloys**, efficient damage healing can be achieved by autonomous gold precipitation inside the cavities.

→ Scientists monitored the microstructure of a **nanocrystal** undergoing in situ mechanical loading by imaging in 3D with 13 nm resolution. They tracked the evolution of the strain field after successive loadings and the nucleation of a dislocation loop.

→ **Smart materials** can be characterised using pair distribution function analysis at the ESRF, like a new flexible smart window material that will have the ability to control both heat and light from the sun.



CASE STUDY

Crossed Ga_2O_3/SnO_2 multiwire architecture: a study of local structure with nanometre resolution

Crossed nanowire structures are the basis for the high-density integration of a variety of nano-devices. The intersections of the nanowires play a critical role in creating hybrid architectures, therefore a nanometre-scale investigation of the local structure within them is of great interest. The compositional uniformity and symmetry of point contacts between single crossed Cr-doped Ga_2O_3/SnO_2 nanowires grown by thermal evaporation have been investigated using the ESRF's hard X-ray nanoprobe. The self-assembly of crossed multiwires during a single step thermal growth appeared to be a viable strategy for organising individual nanowires. The formation mechanisms of interconnected Ga_2O_3/SnO_2 wires is extendable to other semiconductor oxide systems. The experimental technique demonstrated here opens new routes for the study of local structures with nanometre resolution.

Martínez-Criado, G., Nano Lett. (2014), DOI: 10.1021/nl502156h

PHARMA

What can the ESRF do?

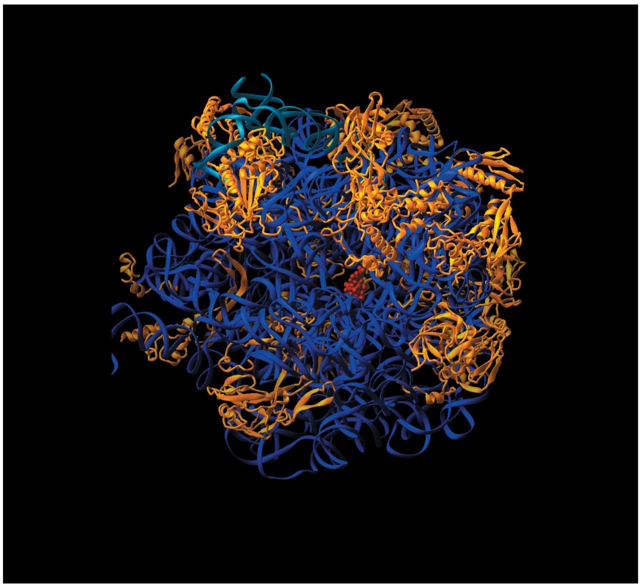
- High-throughput protein crystallography with automated systems
- Fragment-screening services
- Micro-X-ray beams and smart data collection strategies for challenging protein crystals
- Resolving the crystal structures of drug molecules with micro-crystals
- Phase analysis of APIs and formulations
- Characterisation of active pharmaceutical ingredients and formulations in situ and their behaviour under different conditions (e.g. humidity, pressure, ball milling)
- Behaviour of drug delivery vectors such as nano-holders and phospholipid/micellular structures
- Formulation and shelf-life issues for biologics
- Information on metals bound to proteins using X-ray spectroscopy
- Complementary protein characterisation services through the Partnership for Structural Biology

EXAMPLES

→ The ESRF'S modern high-throughput and automated protein crystallography beamlines are used routinely for **bulk fragment screening** for drug discovery pipelines. Advanced expert systems get the best out of crystals using X-ray mesh-scanning for centring and smart data collection strategies.

→ Small/wide and ultra-small angle X-ray scattering experiments are used to monitor **protein structure and aggregation** in biologic drug systems, which are important in optimising formulation for shelf-life issues.

→ Used by many pharmaceutical companies, high-resolution X-ray powder diffraction at the ESRF's ID22 beamline provides exceptional resolution in **complex diffraction patterns** far beyond lab source capabilities.



CASE STUDY

A multiprotein drug target unravelled

AMPK (AMP-activated protein kinase) substrates are involved in lipid metabolism, autophagy, mitochondrial biogenesis and in the maintenance of glucose homeostasis. This complex is a highly promising therapeutic drug target against diabetes, cancer and ageing. Not much known is about this complex, as, it is very complicated to make crystals, and once they are made, they are extremely sensitive to radiation damage.

Researchers at CRELUX/WuXi AppTec, a company expert worldwide in premium drug discovery solutions came to the ESRF to tackle this challenge. They successfully solved the structure of the complex at a resolution of 2.9 Ångstroms, which was enough for CRELUX/WuXi AppTec to see the detailed chemical environment of the compound in the complex binding site.

EUROPEAN PROGRAMMES

The ESRF is an active partner in large scale collaborations to support industrial and applied R&D. In particular H2020 EU, national and regional projects are particularly effective tools to build bridges between the facility and industry.

CALIPSOplus

CALIPSOplus is an EU-funded project. The aim of the CALIPSOplus project is to remove barriers for access to world-class accelerator-based light sources in Europe and the Middle East. In order to reach industry, tailor-made support and access programmes have been put in place. In particular, SMEs are targeted through the Tailor-made for SMEs Trans-national Access (TamaTA).

www.calipsoplus.eu

IRT NANOELEC

The technological research institute IRT Nanoelec is a French public-private partnership focused on a core technology programme encompassing 3D assembly integration, nanophotonics on silicon, power electronics and interconnected technologies.

In particular, the IRT Nanoelec is funding a 6.5M€ Pathfinder Programme to better open the large scale research infrastructures located in the Grenoble European Photon and Neutron (EPN) Science Campus to the semiconductors industry. In this context, the Platform for Advanced Characterisation – Grenoble (PAC-G), has been created with the objective to offer a coordinated and integrated access to synchrotron, neutrons and laboratory nano-characterisation instruments on a service basis.

www.irtnanoelec.fr

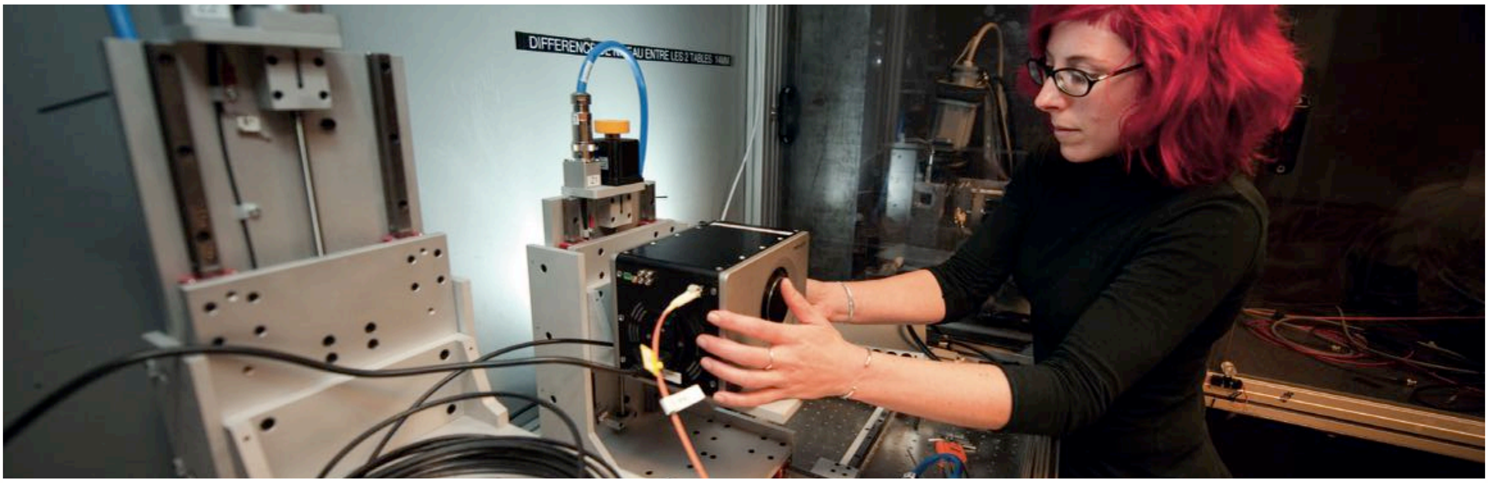
NANOSCIENCE FOUNDRIES AND FINE ANALYSIS (NFFA)

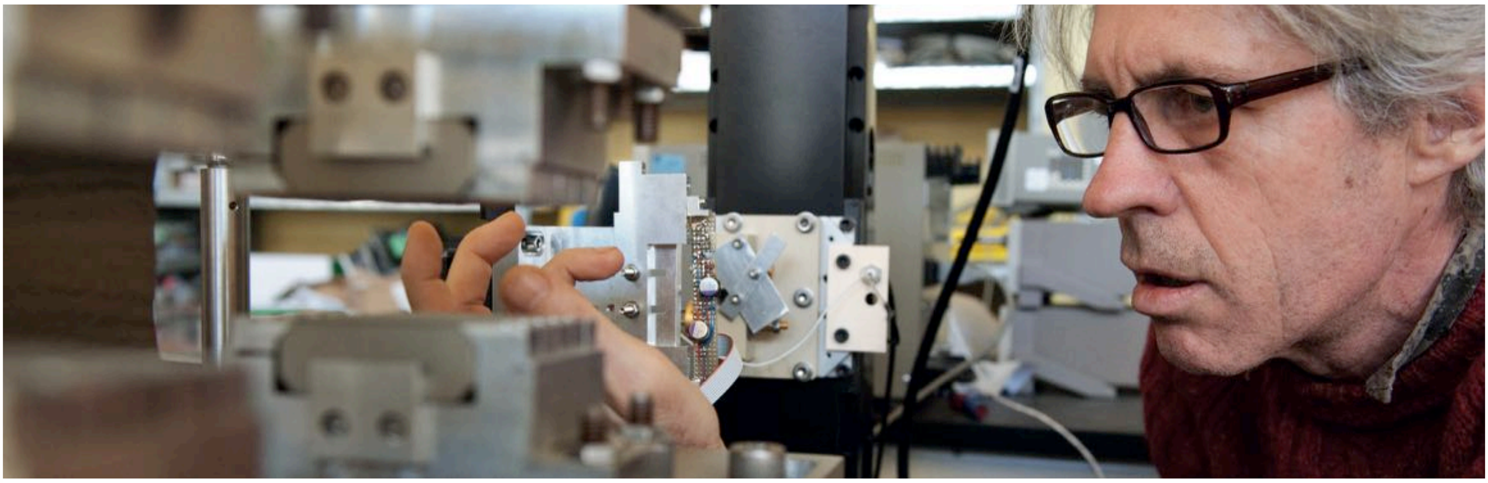
NFFA is an EU-funded programme that creates an integrated, distributed research infrastructure as a platform supporting comprehensive user projects for multidisciplinary research at the nanoscale. It covers research based on synthesis and nanolithography to nanocharacterisation, theoretical modelling and numerical simulation, through a coordinated open-access to complementary facilities.

To allow access to this platform, NFFA is funding transnational access. NFFA is encouraging users from various sectors of nanotechnology to access the distributed research infrastructure, both from academia and from industry. In particular, with respect to industrial access, NFFA promote the possibility to have feasibility access for preliminary test experiments and confidential TNA for SMEs.

www.nffa.eu

INSTRUMENTATION AND TECHNOLOGY TRANSFER





As a world-leading synchrotron, the ESRF has developed unique technologies and equipment that makes it one of the most productive synchrotrons worldwide. Our developments and technologies are available directly from the ESRF or under a licence as a technology transfer to industry.
A selection of our instrumentation developments follows.

FRELON
This fast readout low noise camera is a 14-bit dynamic CCD camera, with a 2048 x 2048 pixel chip. The system is made of a camera head, a power supply unit, a PCI board and a twin fibre-optic cable.

MUSST
The 'MUSST' is a NIM module designed at the ESRF to produce trigger patterns enabling synchronisation with external events. It is used to synchronise beamline components.

MICROJACK
The ESRF fixed-head micro-jack is a compact, high-precision motorised linear actuator. It guarantees high-load capacity whilst maintaining excellent resolution and precision.

CRYSTAL ANALYSERS
Spherical and cylindrical analysers produced at the ESRF permit very precise measurements of X-rays for spectroscopic applications. Several models are available to satisfy various experiment conditions.

DYNAFLOW CRYOSTAT
The Dynaflow Cryostat is a compact design that provides efficient sample cooling at very low temperatures (down to 2.5K).

BEAM VIEWER
The ESRF has developed a set of air X-ray beam viewers integrating a GigE CCD camera. It consists of a compact device used for focused X-ray beam visualisation.

ICEPAP

IcePAP is a motor control system developed at the ESRF and optimised for high-resolution position applications. It is fully software configurable and provides exhaustive diagnostic capabilities.

DIAMOND ANVIL CELLS

DACs are high-pressure LeToullec-type (membrane driven) diamond anvil cells using conical Boehler-Almax anvils for large angles, increased mechanical stability and ease of operation.

SCINTILLATORS

Scintillators are inorganic crystals used to convert X-rays into visible light. The ESRF produces some of the best single-crystal film scintillators based on an LPE technique.

V2F100 CONVERTER

The ESRF's voltage to frequency converter is an extremely linear device used for beam monitoring and designed to operate with a full scale output.

IONISATION CHAMBER

The ESRF has developed a family of high-sensitivity miniature X-ray compatible ionisation chambers to measure the beam's position and the beam intensity (I0) close to the sample.

MAXIPIX

Fast readout, photon-counting pixel detector system designed by the ESRF and based on the Medipix2 and Timepix readout chips designed by CERN.

MAGNETIC MEASURING BENCH

The Insertion Device field measurement systems developed at the ESRF incorporate 18 years of experience. More than 100 devices (undulators, wigglers, helical undulators, in-vacuum undulators) have been successfully processed with accurate and fast measuring systems.

MOCO

The monochromator controller (MoCo) is an electronic module designed to regulate the position of an optical component in a synchrotron radiation beamline. The controller corrects the position of the component, typically a mirror or a monochromator, by monitoring the outgoing beam and actively compensating low frequency drifts due to thermal load changes or mechanical instability.

TECHNICAL LABS

The ESRF has developed considerable off-line expertise centred in specialised support laboratories available to external clients. Staff at these labs have extensive expertise and can accommodate challenging requests.

MIRROR AND METROLOGY LAB

The Mirrors & Metrology Laboratory provides advice, support, research and development for reflective optical elements. It specialises in the surface characterisation of a variety of X-ray optical elements prior to their deployment at the ESRF and other light sources.

The Laboratory develops nanofocusing reflective systems often implemented in the Kirkpatrick-Baez (KB) configuration. These systems, which are based on mirror benders designed in-house, rely on the laboratory for the integration of the optical components and their offline adjustment and characterisation prior to installation on beamlines.

The performance of the ESRF KB systems is considerably enhanced through the combination with multilayer coating technologies. Standard ESRF KB systems have been licensed and are commercially available.

The Laboratory also performs surface characterisation of other optics (monochromator and analyser crystals). Several instruments permit surface height topography measurements with nanometre accuracy, from the full length of the mirrors (up to 1.5m) down to micrometre scale features. Optical figures as diverse as elliptical or toroidal surfaces can be measured.

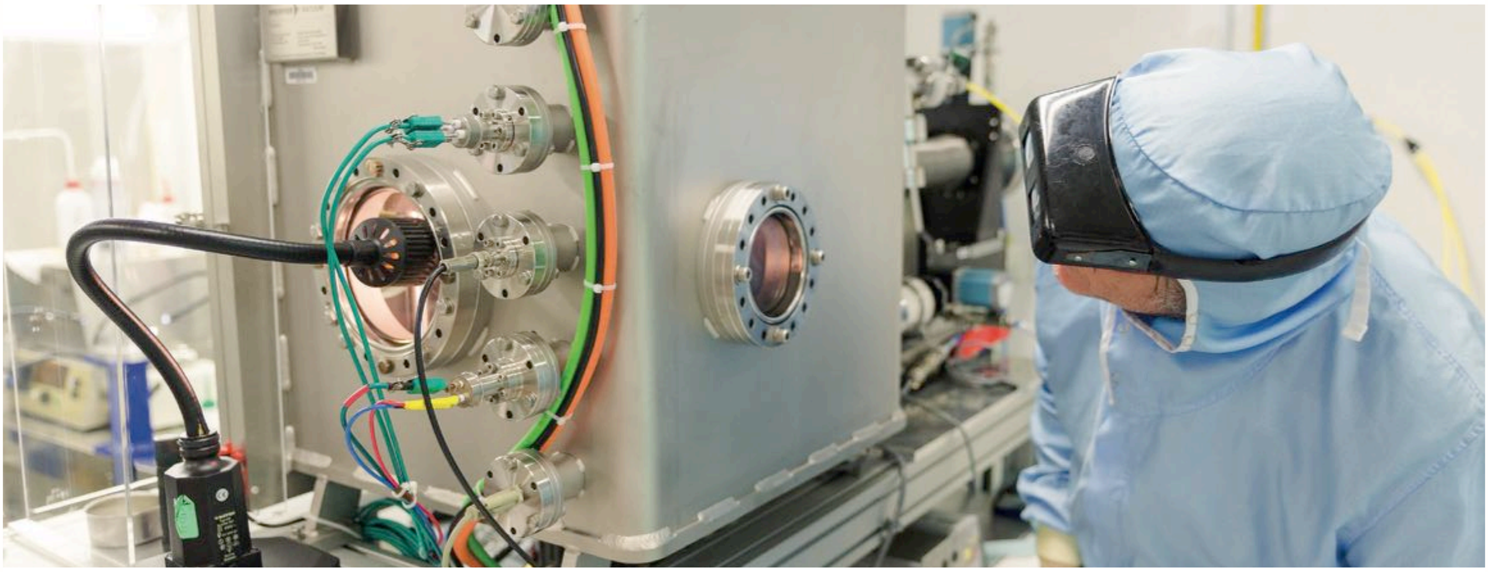
The laboratory is located in a 56m^2 class 1000 clean room with temperature control to within 0.4°C.

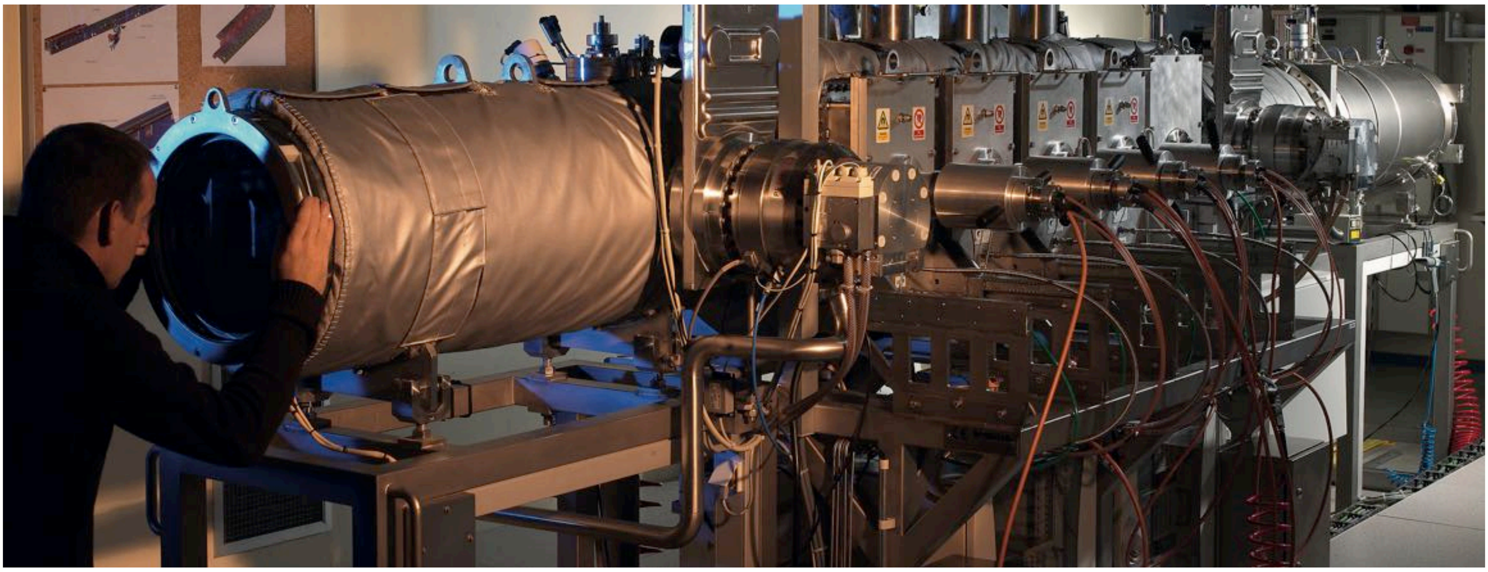
CRYSTAL POLISHING LAB

The Crystal Polishing laboratory provides advice, support, research and development in the field of crystal X-ray optics.

It also manufactures and characterises single-crystal X-ray optics for ESRF beamlines and external customers.

The Crystal Polishing Laboratory manufactures single crystal monochromators for all ESRF beamlines. Most crystals are made from 100mm diameter, high-purity silicon float-zone ingots of up to 1m long that are manufactured industrially. For the production of monochromators, these ingots must be transformed into objects of various size and shape depending on the final application.





MULTILAYER LAB

The Multilayer Laboratory provides advice, support, research and development in multilayer-based optical elements. It also characterises multilayer optics for ESRF beamlines and external partners and customers.

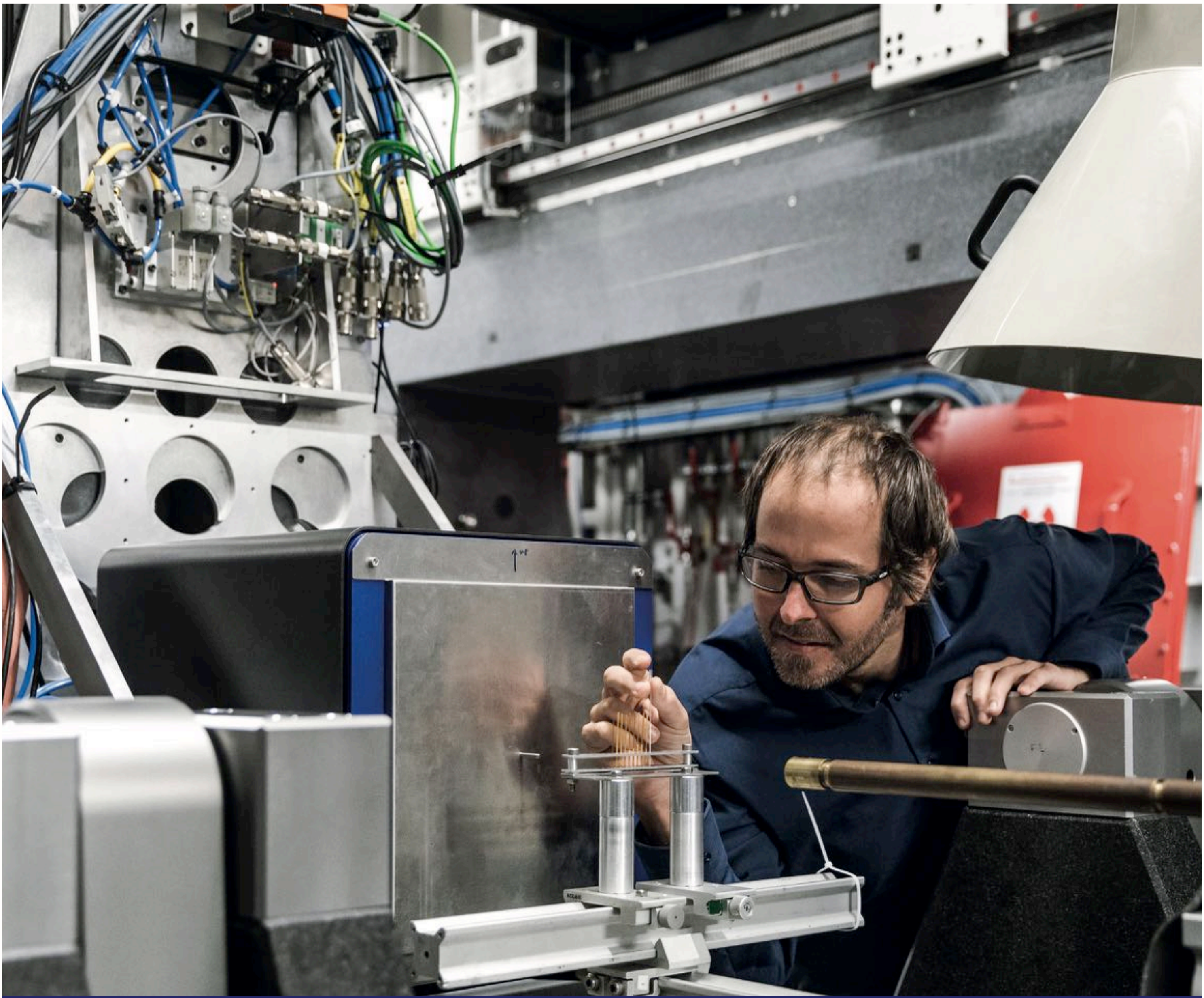
It is in charge of the development and the production of multilayer coatings for X-ray optical devices. It provides advice to ESRF beamlines and works in close collaboration with the Mirror and Metrology Laboratory, the Crystal Laboratory and the beamline BM05. In addition, the Multilayer Laboratory responds to fabrication requests from external partners and customers. The core of the laboratory is a sputter deposition facility where substrates up to 100cm long and 15cm wide can be coated with multilayers of desired repetition period and thickness gradient. All multilayers are characterised using a laboratory X-ray reflectometer. More demanding performance tests can be carried out on the beamline BM05. Computational algorithms are used to simulate the optical properties of multilayers and to retrieve their structure.

NEG COATING FACILITY

The coating facility provides infrastructure, support, research and development in vacuum chamber's NEG (non-evaporable getters) coating. With the ability to coat up to 6m long and 8mm aperture chambers, the facility produces NEG coated vacuum chambers using DC magnetron enhanced physical vapour deposition. The coating helps to overcome the vacuum conductance limitations of these flat vessels by providing distributed pumping across its length as well as lowering its photo desorption yield. Other types of coatings have been produced like gold coatings to produce very stable (inert) surfaces and thin titanium coatings to reduce the resistivity of ceramic parts.

SCIENTIFIC AND ENGINEERING EXPERTISE

For any service that relates to synchrotron X-ray studies conducted at the ESRF, including interpretation of study results, consultancy work, training on a particular synchrotron technique or any other service, the Business Development Office is able to offer you the expertise of ESRF scientists and engineers.



HOW CAN YOU ACCESS THE ESRF?

Our business development team is ready to help you in your technological innovation needs and to either match them with our services or to create customised collaborations and partnerships. We can be a full partner or act as an expert for specific outsourced requirements for your projects, be they in-house, national or Horizon2020. Joint industry-academia consortia are often involved.

Our aim is to provide the right approach for your research and innovation programme, in different modes:

ROUTINE PROPRIETARY ACCESS
Rapid, paid for, and confidential.

TAILORED PARTNERSHIPS
Longer term, deeper research programmes with industry, including training and sponsored PhD studentships, and implication in Horizon2020 grant proposals.

FREE OF CHARGE ACCESS
Available through the ESRF peer review programme, results have to be published. Applications from industry alone or with academia are welcome. In addition, Innovation-Led Long Term Proposals (3 years) open the way to working with business and academia to further develop synchrotron techniques for industrial applications.

TALK TO US

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A unique site for research and innovation, Grenoble attracts scientific talent through its exceptional environment and quality of life. A cosmopolitan city, situated at the heart of the French Alps, Grenoble is a centre of innovation, recognised around the world for its research facilities, its universities, its economic vitality and its future oriented projects.
The ESRF enjoys a strategic position, located within the European Photon and Neutron (EPN) Science Campus - a science hub hosting three major international institutes for the exploration of life and materials sciences, including the Institut Laue Langevin, the ESRF's sister institute using neutrons. The ESRF is also a partner of GIANT, Grenoble Innovation for Advanced New Technologies, a campus for global innovation and the lifeblood of economic and scientific development in Grenoble.

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