INNOVATIVE MATERIALS PLATFORM

A system of open research facilities for industrial research

SISTEMA ARGO is an industrial development initiative supported by:

Ministero dell'Università e della Ricerca

Ministero dello Sviluppo Economico

Regione Autonoma Friuli Venezia Giulia

coordination of activities:

AREA Science Park

COMPETENCES AND FACILITIES FOR INDUSTRIAL RESEARCH

Scientific and technological platforms are *places* where **open research infrastructures** - based upon core facilities and skills - create specialized functions, capable of providing know-how and services to carry out experimental tests as well as applied and industrial research projects. These platforms are a **relevant asset to support research and development**, since they provide companies with optimal scientific and technological conditions to **carry out their experimental activities.** They do so by granting access to research laboratories with core scientific expertise as well as equipment and instrumentation hardly found elsewhere.

The **Innovative Materials Platform** integrates equipment and expertise available at Area Science Park's major laboratories (i.e. Elettra synchrotron light source, FERMI free electron laser, CNR-IOM nanoscience and nanotechnology laboratories, CNR-IC structural biology laboratory). This way the platform provides companies with a system of **expertise and facilities** dedicated to the application of **imaging techniques, structural analysis and chemical characterization.** The above creates the conditions to collect quantitative and qualitative information on materials' chemical composition and structure, both on surface and at atomic level, with a very wide range of possible applications, from nanotechnologies and development of nano-structured materials to failure analysis and process control in industrial activities.

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ISTITUTES AND LABORATORIES

ELETTRA SINCROTRONE TRIESTE | www. elettra.trieste.it

Elettra Sincrotrone Trieste is an international research centre, specialized in the study of materials. Its state-of-the-art research facilities work like "giant microscopes". They exploit the power of synchrotron light to reveal the structure and the behaviour of atoms and molecules at an unprecedented detail.

The main assets of the research centre are two advanced light sources, the electron storage ring Elettra and the free-electron laser (FEL) FERMI, continuously (H24) operated supplying light of the selected "colour" and quality to more than 30 experimental stations.

Detailed study of materials structure and behaviour can be performed over a wide range of wavelengths, from IR to hard X-ray.

Moreover 10 laboratories have been set up to support the beamlines and run their independent research in different investigation fields: X-ray optics, Structural Biology, conventional Imaging, surface physics, and software development.

INSTITUTE OF MATERIALS (CNR-IOM) | www.iom.cnr.it

CNR-IOM manages the nanoscience and nanofabrication laboratories of the National Research Council (CNR) at Area Science Park's Basovizza Campus. The laboratories are at the cutting edge of synthesis and characterization of advanced materials, electromechanical and biomedical devices micro and nanofabrication, surfaces and interfaces functionalization and nanostructuring.

IC CRYSTALLOGRAPHY INSTITUTE (CNR-IC) | www.ic.cnr.it

CNR-IC manages the structural biology laboratory of the National Research Council (CNR) at Area Science Park's Basovizza Campus. CNR-IC uses innovative methodologies for the study and characterization of intermolecular interactions and of molecular structure, crucial in the development of new materials for electronics, nutraceuticals and new pharmacologically active molecules.

AREA SCIENCE PARK | www.areasciencepark.eu

Area Science Park - a public national research organization - promotes the development of innovation processes. For 40 years, its mission has been to boost connections between research and enterprise, public administration and the private sector, supporting national and international initiatives and fostering territorial development. Area coordinates the Innovative Materials Platform.

MAIN APPLICATION

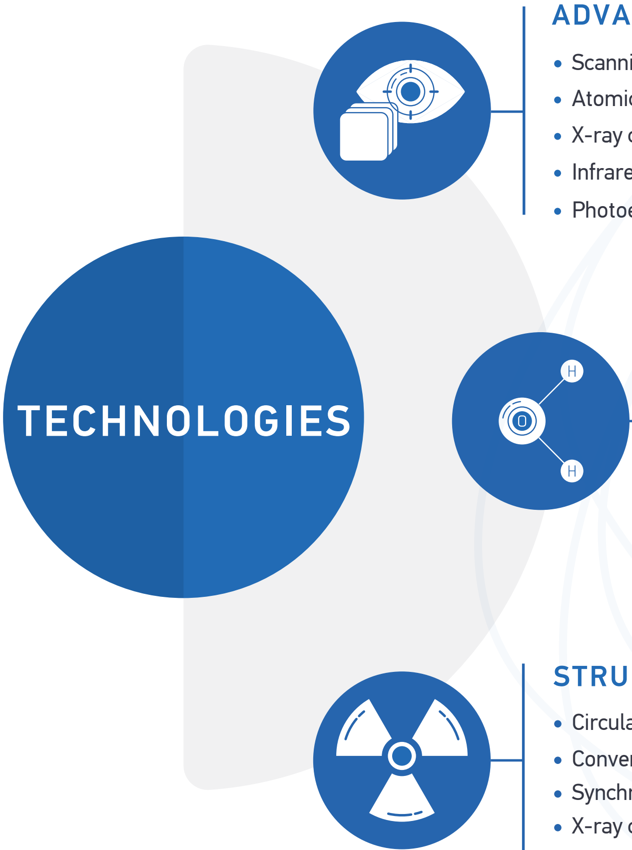
The Innovative Materials Platform integrates and systematizes the participating institutes' and laboratories' equipment and competences dedicated to the study and development of advanced surfaces and materials, i.e.:

- Elettra synchrotron light source
- FERMI free electron laser
- CNR-IOM nanoscience and nanotechnology laboratories
- CNR-IC structural biology laboratory

The Innovative Materials Platform is available to producers of raw materials, semi-finished and finished products and components interested in carrying out:

- atomic- and molecular-level analyses
- measurements and experiments on materials
- defects investigations
- chemo-physical study of intermolecular interactions

TECHNOLOGIES



ADVANCED STRUCTURE AND CHEMICAL IMAGING

- Scanning electron microscopy - SEM
- Atomic force microscopy - AFM
- X-ray computed micro-tomography using synchrotron radiation - microCT
- Infrared microscopy using synchrotron radiation
- Photoemission microscopy using synchrotron radiation

CHEMICAL CHARACTERIZATION

- Energy dispersive X-ray spectrometry – EDS
- Raman spectroscopy
- Isothemal titration calorimetry – ITC
- In operando spectroscopy
- X-ray photoelectron spectroscopy using synchrotron light radiation - XPS
- Fourier-transform infrared spectroscopy using synchrotron light radiation - FTIR

STRUCTURAL ANALYSIS

- Circular dichroism spectroscopy - CD
- Conventional X-ray powder diffraction – XRD
- Synchrotron X-ray diffraction - XRD
- X-ray computed microtomography using synchrotron radiation - microCT
- Nanoscale infrared spectroscopy using synchrotron radiation - NanoFTIR

[ADVANCED STRUCTURE AND CHEMICAL IMAGING]

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Scanning electron microscopy - SEM

SEM is one of the most widely used imaging techniques for analyzing the morphological and micro-structural properties of materials with sub-micrometric lateral resolution. Due to its great versatility and ability to perform non-destructive analyses, it covers an extremely wide range of applications ranging from nanotechnologies and nanostructured materials development to failure analysis and process control in industrial activities.

Atomic force microscopy - AFM

AFM is a scanning probe imaging technique (a kind of profilometer) capable of displaying topographic images of the sample surface with significantly better resolution than it is obtained with optical microscopes. It is a highly versatile tool, which can be used for a wide range of applications, e.g. metallurgy, semiconductors technology, surface study, magnetic materials, polymer science, composite materials, optics, chemistry, biology and medicine.

X-ray computed microtomography using synchrotron radiation - microCT

It is one of the most advanced techniques in the field of nondestructive evaluation tests. It allows imaging of the internal microstructure of different materials, including porous media, like metallic and polymeric foams. It provides 2D and 3D images of a sample overcoming samples size limitation of electron microscopy and delivers better resolution than that of visible light microscopes, especially when the sample is opaque to visible light. There is a wide range of industrial fields of interest, from mechanical components and electronic devices, to aerospace manufacturing.

Infrared microscopy using synchrotron radiation

Infrared microscopy produces spatial information at micrometric and nanometric resolution levels of several materials, allowing the possibility to correlate the sample morphological features with its chemical local pattern. A new multipurpose platform allows collecting chemical and morphological information at the nanoscale, with 10-100 nm of lateral resolution.

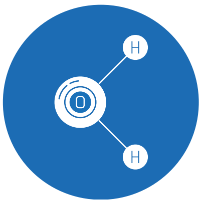
Photoemission microscopy using synchrotron radiation

The use of a photoemission microscope allows to characterize areas of specimens both morphologically and chemically. It enables the mapping of the topography and chemical composition of sample surfaces to be performed at nanometre levels of detail. It is a powerful investigation tool suitable for studying and following the evolution of chemical processes on a microscopic scale.

Solutions developed/ Tests performed for industry

- **Polymeric Foams.** It is possible to examine the microstructure of polymer foams used in the automotive industry, when subjected to various deformation processes. Analyses allow to correlate material's structure, its mechanical performance and insulation properties.
- **Sails Fabrics.** The use of phase contrast microradiography allows to study at nanometric level the sails structures for racing yachts. Traditional radiographic techniques are not able to reach such scale of analysis.
- **Analysis of textiles.** Micro computed tomography (microCT) imaging technique was used both to study in depth the morphology of different fabrics available for the production of sterile hospital gowns, and to evaluate hot-melt glue seams at critical points in the seams. The analyses enabled the identification of more resistant and easier-to-clean fabrics and the improvement of the gluing process for sewing of gowns.

[CHEMICAL CHARACTERIZATION]



- Energy dispersive X-ray spectrometry – EDS
- Raman spectroscopy
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- In operando spectroscopy
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Energy dispersive X-ray spectrometry - EDS

EDS is a technique associated with SEM scanning electron microscopy and allows microanalysis of chemical elements, also in the form of a bi-dimensional map related to selected chemical elements. SEM coupled with EDS is a powerful tool for obtaining microscopic chemical maps on chemically inhomogeneous solids.

Raman spectroscopy

It is a molecular spectroscopy involving molecules' rotational and vibrational energy levels, commonly used in chemical analyses and studies on the structure of complex chemical compounds such as organic compounds.
Raman spectroscopy provides an impression of a specific molecule and allows the investigation of its chemophysical environment, which is also very useful in the study of composite and polymeric materials.

Isothermal titration calorimetry - ITC

ITC is a technique that determines the heat developed during the interaction between two molecules in volumes below the milliliter and with concentrations below the millimole. This makes it possible to study the strength and thermodynamics of the interaction between the two molecules. It is a widely used technique in the development of new pharmacologically active molecules.

In operando spectroscopy

A new setup for performing X-ray absorption spectroscopy (XAS) at ambient pressure makes possible to analyse the mechanisms of chemical reactions on surfaces. This type of setup enables the study of the behaviour of materials used in the energy sector in "operando" mode. Indeed, the instrumentation, which is only available in a few other research centres around the world, enables spectroscopic characterisation of catalysts during the reaction catalysed by them, providing detailed information on the reaction pathway. Further development of the device also allows simultaneous characterisation by infrared (IR) spectroscopy of the analysed material, providing useful information for the optimisation of the catalyst thus improving the green energy production.

X-ray photoelectron spectroscopy using synchrotron light radiation - XPS

Photoemission spectroscopy allows to perform real time studies on processes occurring in intervals of time ranging from several seconds to approximately one hundred microseconds. It is thus an ideal tool for analysing catalytic systems. Using the technique it is possible to implement systems analysis with more complex chemistry and detect the presence of compositional gradients or contaminations such as surface treatments, corrosion or contamination, composite materials or interfaces between different materials.

Fourier-transform infrared spectroscopy using synchrotron radiation - FTIR

IR spectroscopy uses energy levels associated with the vibrational transitions of molecules. It allows the semi-quantitative and qualitative chemical characterization of organic and inorganic molecules and permits to study their spatial distribution. It provides information on mass transport processes, chemical heterogeneity or electronic properties of complex materials with micrometric and nanometric lateral resolution. The chemical information provided by the analyses can be exploited for a wide range of research fields, including surface and material science, high-pressures studies, and many others.

Solutions developed/Tests performed for industry

- **Fuel Cells.** The new spectroscopic approach of ambient pressure X-ray photoemission, absorption and X-ray emission with synchrotron radiation, is applied to the study of low-temperature direct hydrogen proton exchange membrane fuel cells (PEM-FC) and direct methanol fuel cells (DM-FC), to improve the quality and the performances of fuel cells by using new type of supports for catalyst nanoparticles.
- **Clean Steel**. In traditional steels, non-metallic microinclusions are produced during hot working processes and can generate microfractures that can cause total structural failure. X-ray photoemission microspectroscopy techniques have been used to identify the chemical characteristics of these minute impurities and the phases of production primarily responsible for contamination.
- **CO_2 Valorization Technologies**. To ensure progress in the field of energy conversion technologies, a better understanding of the correlations between structure and electrocatalytic properties of the materials used is essential to develop versatile electrodes for electrochemical and fuel cell applications. Studies based on multianalytical approach including X-ray diffraction (XRD), transmission electron microscopy (TEM), field-emission scanning electron microscopy (FE-SEM), and operando near-edge X-ray absorption fine structure spectroscopy (NEXAFS) can be performed to characterize the functional properties of materials with potential applications in CO_2 valorization and H_2 production technologies.
- **Industrial catalysts.** Electronic spectroscopies, such as UV–vis and NEXAFS, can be fully exploit to provide direct information on the electronic properties of industrial catalysts even under reaction conditions. The application of these techniques to a platform of Ziegler–Natta catalysts (widely used in chemical industry for the production of polypropylene) under different conditions allow to reveal the electronic features of the sites involved in the polymer formation during the catalytic process, discriminating between active and inactive species.

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[STRUCTURAL ANALYSIS]

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Circular dichroism spectroscopy – CD

CD is a spectroscopic technique used to study macromolecular conformation and although it is very often used to study the three-dimensional structure of proteins and their complexes, it can be also used to analise the structure of polymeric materials deposited on inorganic matrices.

Conventional X-ray powder diffraction - XRD

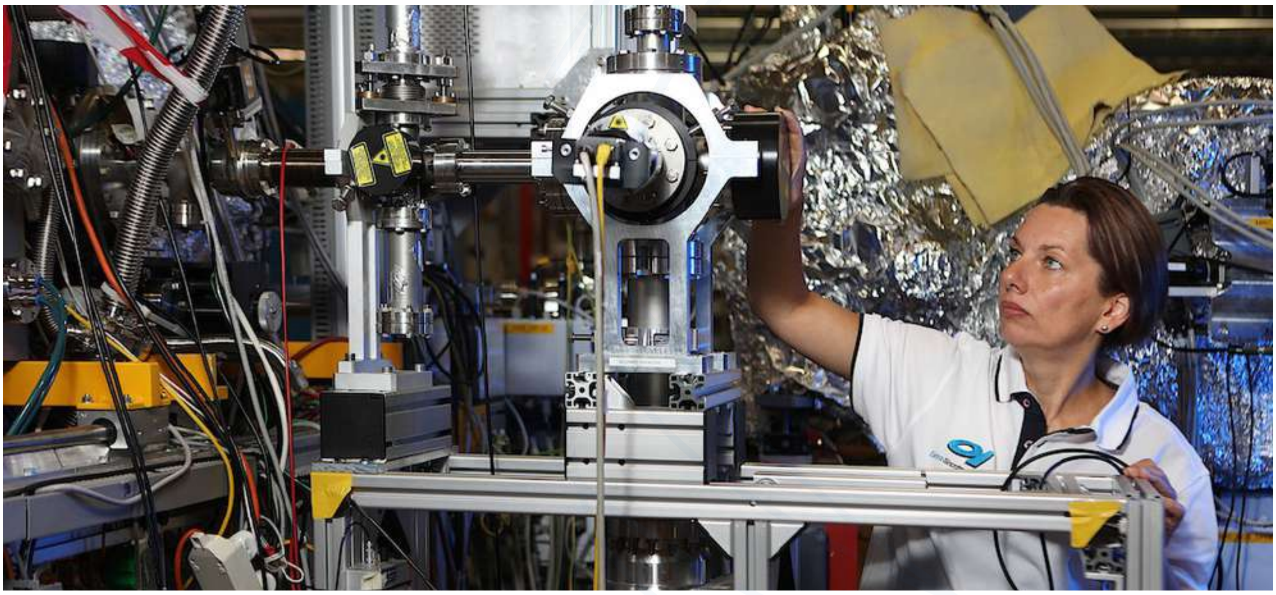
XRD is a non-destructive technique used to determine the structure of materials, generally inorganic, crystalline and solid. X-ray diffractometer is designed to allow X-ray diffraction analysis on a wide range of materials, from micrometric powders to thin films and/or nano-engineered hetero-structures, by using special modules which optimize experimental configuration.

Synchrotron X-ray diffraction - XRD

It is possible to perform X-ray powder diffraction, x-ray single crystal diffraction and high-pressure diffraction. Diffraction techniques allow analysing the structure of crystalline materials, acquiring information on their formation, growth, microscopic structure, macroscopic feature and physical properties. They can be performed to detect and analyse the phases of amorphous materials. Moreover, diffraction analyses can be used to study phase change over time of materials subject to mechanical stress and/or thermal loads.

X-ray computed microtomography using synchrotron radiation - microCT

In material sciences, a micro-CT analysis is capable to analyze failure mechanisms, micro-cracks formation and propagation, internal defects, morphological details, stress-strain behaviour, and is generally useful when a correlation between physical and microscopic properties is required.



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Nanoscale infrared spectroscopy using synchrotron radiation - NanoFTIR

Nano-FTIR collects chemical and morphological information at the nanoscale, with 10-100 nm of lateral resolution, allowing the study of local heterogeneities, such as nano-contaminations, local defects, variations in polymer chain orientation and crystallinity of synthetized films or fibers. It is possible to perform analyses from bulk measures, to microscopy, to nanoscopy. In polymer science, this permits to thoroughly study problems related to macroscale defects and unexpected poor performances and, for example, to compare the nanoscale defectively to the bulk average chemical composition.

Solutions developed/Tests performed for industry

- **Protective nickel coatings.** Stress and texture gradients were measured on an electrodeposited Nickel coating on steel. These coatings are very common in corrosion protection applications, and constitute an ideal case study as their residual stress state, as well as preferred orientation of crystalline domains sensibly vary as a function of deposition conditions. Residual stress and texture measurements are conveniently performed by means of X-ray diffraction.
- **Polymorphism in organic semiconductors.** Organic semiconductors offer versatility in the electronics industry due to their solution processability and low production cost. However, polymorphism, which refers to the ability of organic molecules to adapt to different crystalline packings, can influence the electronic, mechanical, and optical properties of such semiconductors. Innovative studies have been conducted on the polymorphism of a new organic semiconductor, revealing the presence of three different crystalline forms characterized by varying stability. These discoveries open up new possibilities for optimizing the functional properties of organic semiconductors without the need for chemical modifications. This promotes the development of more advanced and adaptable electronic devices, contributing to innovation in the field of organic electronics.

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HOW TO ACCESS THE INNOVATIVE MATERIALS PLATFORM

A dedicated channel is made available to companies for them to be able to submit technical issues or innovation needs, thus initiating a process which, starting from an idea, a need or an identified opportunity, leads to the provision of services or the development of collaborative research projects.

STAGE	ACTIVITY	TIMING
First Contact	**Send an email** to: openlab@areasciencepark.it	*Recall* within **1 working week**
Need definition	**Request and acquisition of technical information** to focus on the company's needs and **identify the best-suited technical and scientific competences** to address them.	**1 working week** (from need definition)
Scientific and technical analysis	**Follow-up meetings** (which may also take place by teleconference) with the involvement of the most suited technical and scientific experts to further **analyze the proposed topic.**	
Feasibility checks	**Testing and experiments** are conducted to ensure the feasibility of the identified techniques **to address the proposed topic.**	Initiation within **2 working weeks** (from follow up meeting)
Definition of a work-plan for experimental activities	**Results of feasibility checks are shared** and a **work-plan elaborated for experimental activities**, including detailed descriptions, machine time for the required instrumentation, definition of goals and milestones, estimated timing and costs.	**2 working weeks** (from completion of feasibility checks)
Contractual agreements	**Definition and signing of contract** (research project or collaborative project agreement) including clauses for the **management of know-how and intellectual property** either pre-existing or resulting from the implementation of the work-plan	**2 working weeks** (net of negotiations)
Project implementation	Implementation of experimental activities work-plan compliant to contractual agreements	n/a

For more information

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