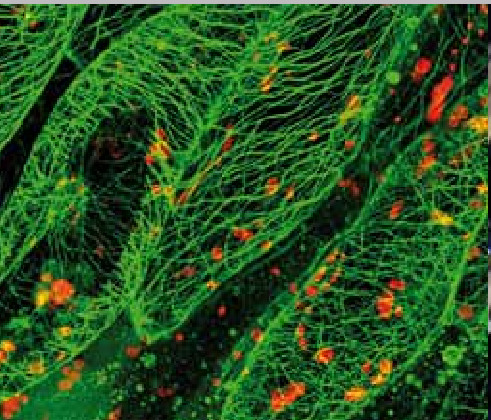
GIANT

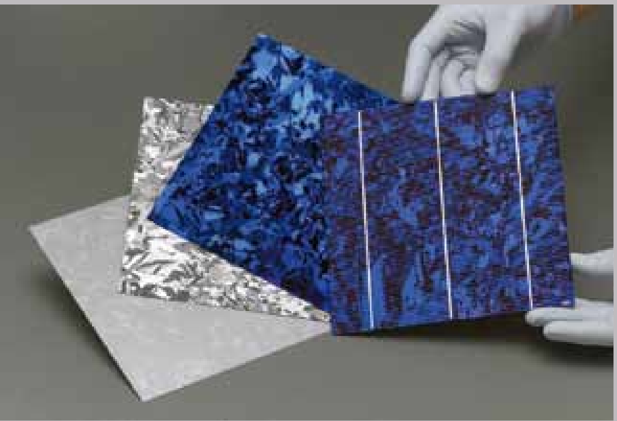
GRENOBLE INNOVATION FOR
ADVANCED NEW TECHNOLOGIES

SCIENCE, TECHNOLOGY, AND TECHNOLOGY TRANSFER

IMAGINE GRENOBLE




GIANT innovation campus, Grenoble



GIANT today

6000 researchers
5000 industrial jobs
5000 students
300 residents
5000 scientific publications annually
500 patents annually
Annual budget **800 M€**

GIANT tomorrow

10000 researchers
7000 industrial jobs
10000 students
10000 residents
Investment **1300 M€** (2010-2016)

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INTRODUCTION

Louis Néel
Nobel Prize for Physics, 1970

Klaus von Klitzing
Nobel Prize for Physics, 1985

Venkatraman Ramakrishnan
Nobel Prize for Chemistry, 2009

Ada E. Yonath
Nobel Prize for Chemistry, 2009

Louis Néel, Nobel prize winner for Physics in 1970 and man of innovation, was the architect of Grenoble as a world scientific centre. Following in his footsteps, the Grenoble scientific community has over the past 60 years transformed a vacant military site within the city into a renowned centre for excellence in science and technology. The site has attracted research centres, major European laboratories and innovative companies, becoming an international hub for innovation in micro and nanoelectronics, energy, sustainable development and biotechnologies. Over a third of its 6000 researchers come from countries other than France, reflecting the international standing and attractiveness of this privileged site.

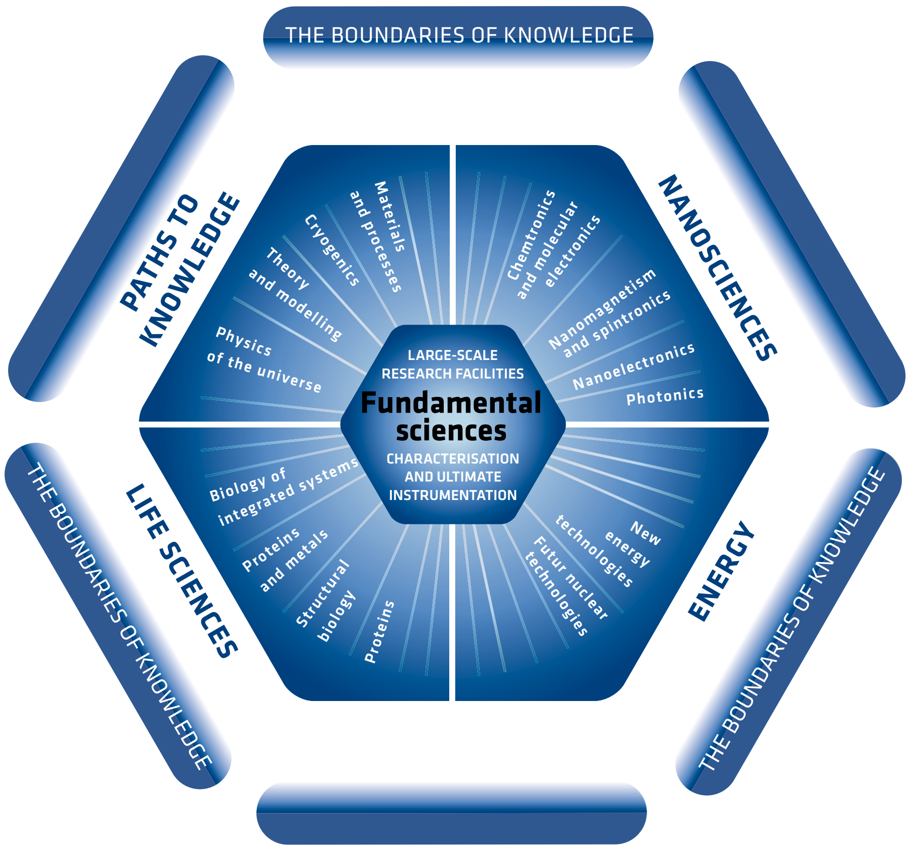
The aim of the GIANT project is to create an important campus for research and higher education in Grenoble, where thousands of students will be immersed in a stimulating environment composed of laboratories, technology platforms and industrial companies. In contact with the most advanced research facilities, they will become familiar with the innovative ideas and new knowledge produced in the crucial scientific and technological fields addressed by GIANT.

An exceptional working and living environment will be created with shops, housing and clean transportation systems. A wide array of facilities will be dedicated to exchange, discussion and study.

Higher education will be supported by a solid fabric of research teams and technology-transfer activities in a variety of fields. This will provide the backdrop for the highly focused scientific and technological approaches that will structure activities at GIANT. Together with the existing university campus in Grenoble, this site will be one of the two centres of the Grenoble University of Innovation (GUI), forming a dynamic new academic landscape.

This inter-woven organisation, proposed by Jean Therme, Director for technological research at the CEA-Grenoble, is the driving force behind the GIANT project. It is designed to respond to the major issues confronting our society in terms of information flow, transportation and housing, health care and environmental challenges. GIANT will integrate projects and partnerships on the regional, national, European and international scales. GIANT builds upon the outstanding scientific and technological reputation of the Grenoble region.

This document is divided into two main parts. The first deals with fundamental research and the second with its extension to technological applications and collaboration with industry, the key to creating the solutions for the challenges facing our society.



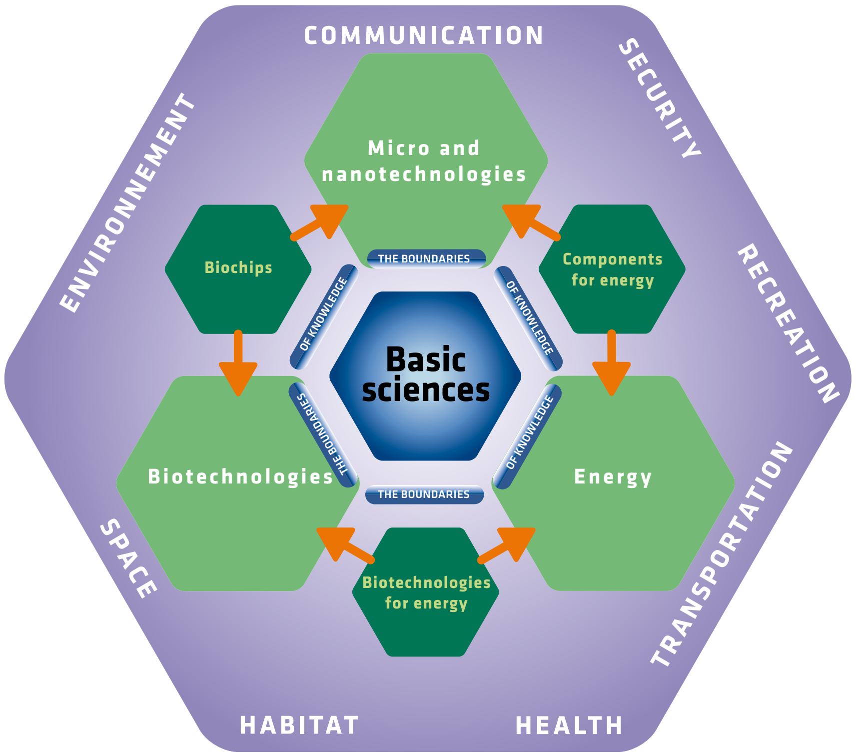
The main scientific fields addressed by GIANT

A DYNAMIC SCIENTIFIC COMMUNITY

The fundamental sciences advance through the coordinated work of partners toward shared goals. This section begins with Paths to Knowledge, presenting the full diversity of scientific activity in Grenoble, addressing the major challenges of our time. Fundamental research, using the most advanced instrumentation combined with model studies, theoretical work and the creation and study of new materials, has contributed to the reputation for excellence of Grenoble's scientific research. In this context, the Nanosciences Foundation encourages the various laboratories within GIANT to take the lead at an international level, by facilitating the presence of high-level visitors. The excellence already achieved in nanomagnetism and spintronics, inherited from Louis Néel, is a typical example of the quality of research in Grenoble.

The work on advanced materials, notably nanomaterials, and on energy production and storage technologies, particularly renewable energy, forms the basis for the development of a structured energy cluster. Including both university programmes and research, it targets ambitious technology transfer projects. The Carnot Institute for Future Energies brings together all the players in the Grenoble area in this field. It consolidates work that will be decisive for the future of our society in essential fields such as materials and processes for solar energy, energy management, energy micro-sources, energy efficiency and hydrogen applications.

A major strength of GIANT is the international structural biology cluster, unique in Europe, bringing together the Institute for Structural Biology (IBS) and large-scale European research facilities including EMBL, ESRF and ILL. The research platforms dedicated to the study of structure and function of proteins are coupled to laboratories recognized for their excellence; they combine high technology techniques and tools for diverse applications in the fields of heath, environment and energy. Moreover, all the organisations involved in GIANT, together with the University Hospital, are joining forces to launch the Biology and Health Sciences Centre.



The main fields of technological research addressed by GIANT

TECHNOLOGICAL INNOVATION SERVING INDUSTRY AND ECONOMIC DEVELOPMENT

Technology transfer in Grenoble has been based historically on three essential and tightly interwoven factors, namely world-class fundamental and technological research, laboratory and institute management enthusiastic and supportive of work with industry, and finally, professional technology transfer teams ready to accompany researchers collaborating with industrial companies and creating start-up companies.

To best serve the industrial sector and promote economic and social development, the partners of GIANT make use of the powerful capabilities regrouped in large technological platforms.

In micro and nanotechnologies, GIANT comprises a unique set of platforms for 200 and 300 mm silicon technologies and world-class nanocharacterisation platforms working in conjunction with the large-scale European research facilities. These resources are the means to transfer research on innovative components, for electronics and mechanical systems (sensors and actuators), soon to be nanometric, from initial development to the industrial-integration stage.

In the energy field, GIANT includes a number of platforms dedicated to batteries, fuel cells and distributed-energy solutions. They provide a forum for discussion and collaboration with industrial partners from all parts of the energy sector.

Biotechnologies are progressing rapidly and make heavy demands on the resources of the MINATEC micro and nanotechnology innovation campus. This novel approach is voluntarily multidisciplinary and includes the development of nanotechnologies for biology and healthcare, for example in the CLINATEC® project.

The GIANT actors, seen by companies as strategic partners, are actively involved in relevant industrial competitiveness clusters, namely Minalogic (micro-nanotechnologies and software), LyonBioPôle (biotechnologies) and TENERRDIS (renewable energies).

All GIANT participants understand the importance of technology transfer and collaboration with industry. This is clearly demonstrated by the increasing number of patents filed, the many research contracts with industrial firms and the launching of numerous start-ups. The many partners involved all share common goals. Continuous efforts to innovate and put results to work through ties with companies are a further guarantee for students that their training will allow them to keep pace with the continuous changes in the world of business and industry and the growing demands of our society.

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Over the past century, close and fruitful relations between science and industry have given rise to an array of new cutting-edge technologies. This approach, organised in close cooperation with local government and economic players, highlights and reinforces the innovative character of Grenoble and its surrounding area. The transformation of the GIANT site into a veritable innovation campus will provide even greater support for this dynamic structure, insuring its capability to address the major challenges facing our society in information and communication, energy and healthcare in the coming years.

SCIENTIFIC ACTIVITY

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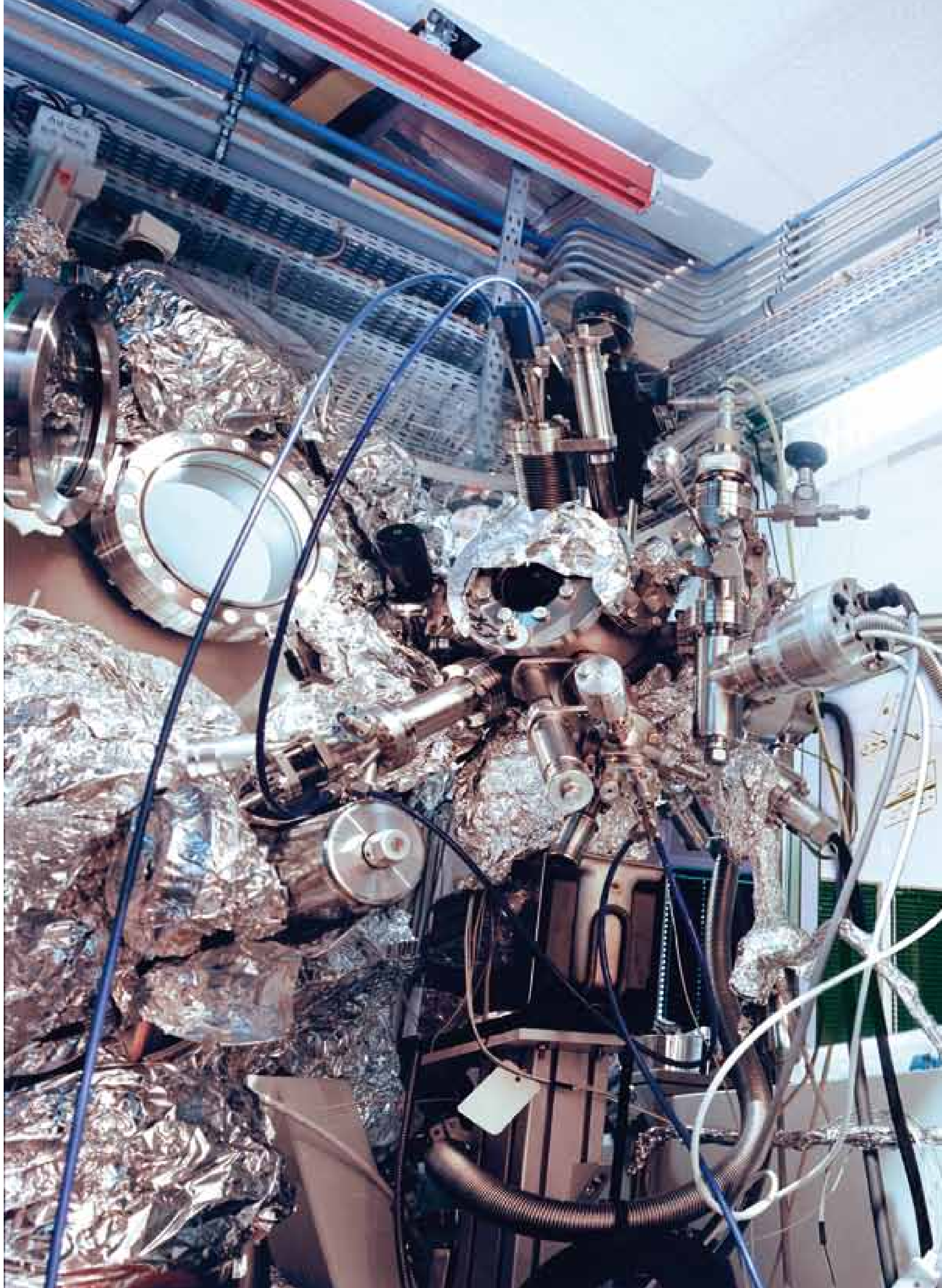

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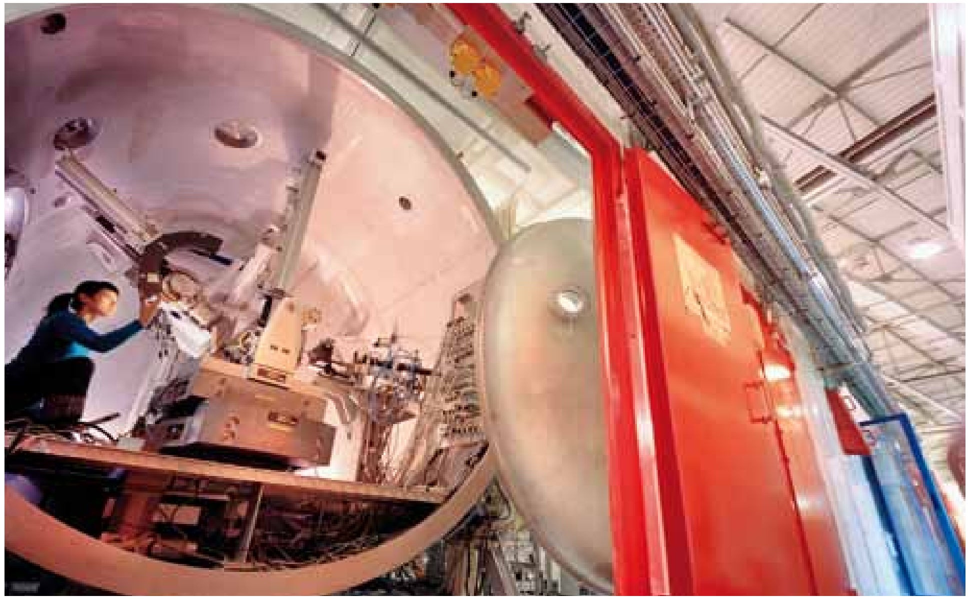
Discussions between scientists at ESRF

1.1 PATHS TO KNOWLEDGE

1.1.1 LARGE-SCALE RESEARCH FACILITIES, CHARACTERISATION OF MATTER AND ULTIMATE INSTRUMENTATIONE

Grenoble has become a leading centre in the world of experimental physics. High-performance tools have been developed to explore matter under extreme conditions, to carry out magnetic measurements and to characterise materials at a nanoscopic scale. The starting point is the observation of new states of matter. This primarily concerns materials under extreme temperatures, pressures, applied fields or organisational scales. Very low temperatures play a fundamental role in the thermodynamics of processes, and in gathering the information all the way back to the Big Bang. Very high pressures are required to improve our knowledge of our planet and the other planets in the solar system, as well as for in-depth studies on the formation of new materials. Intense magnetic fields create the conditions required to explore new properties for electronic transport.



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Very high-resolution X-ray diffractometer at ESRF

Extremes in organisational scales involve the subatomic and nanometric domains, in which unknown organisational phenomena may appear, as well as new dimensions of the Universe. Observation requires probing methods suited to the atomic scale and nano-objects, notably synchrotron X-rays and neutrons, near-field electronic microscopes capable of viewing individual atoms, as well as appropriate handling techniques. The various states of matter are explored including solids, liquids and solutions, gases, nano-particles or assemblies, nano-droplets for biology or viscous flow of molten glasses.

Grenoble must continue and diversify this field of excellence. The possibility for researchers, engineers and students to access new highly-advanced instruments and facilities to characterise matter will be one of the keys to the scientific success of GIANT. That is why the GIANT site, dedicated to both applied and fundamental research, has invested in an exceptional collection of facilities, technical competencies and scientific know-how. Long-term development of research activities in the nanosciences and nanotechnologies, materials science, microelectronics, quantum physics and lasers, cryotechnologies, biology, biotechnology and energy will continue to depend directly on the quality of available characterisation tools and the development of new metrology techniques. Two critical challenges must be met: ensuring that the site continues to be equipped with the most up-to-date facilities, and pursuing efforts to make the various characterisation platforms accessible to the scientific community. The excellence and variety of the experimental methods employed enhance the quality of education and training, as well as the attractiveness of site.

LARGE-SCALE EUROPEAN RESEARCH FACILITIES

Grenoble has attracted two remarkable, world-class «microscopes», namely ILL and ESRF. ILL, the neutron source with the world's highest performance, develops and operates high-power instruments for the study of matter. ESRF, the first third-generation synchrotron, is a highly efficient X-ray source, capable of producing very stable, focused and polarised beams. The construction of these facilities in Grenoble produced a quantum leap in the quality of the local scientific infrastructure that has, in turn, paved the way for new developments. The presence an EMBL outstation, between ILL and ESRF, strengthens Grenoble's potential for structural biology. The LNCMI, a CNRS laboratory recognised worldwide for its work on intense magnetic fields, is another example of the large-scale experimental facilities available in Grenoble.

Observation of the atomic or magnetic characteristics of nano-objects requires the extremely brilliant and collimated synchrotron beams produced by the ESRF, either to determine their structure through diffraction or for microscopy or spectroscopy experiments. In addition, ESRF has developed an array of X-ray imaging techniques making it possible to observe nano-objects, even under extreme conditions.

Neutron and synchrotron X-ray beams are used to explore matter in diverse environments thanks to their penetration capacity, such as high pressures (up to 4 Mbar), very low or very high temperatures (from 10 mK to 7000°K), nano-flows or monolayers of atoms.

The observation of matter under very high pressures requires fine ESRF X-ray beams. Inelastic scattering methods now make it possible to determine the collective behaviour of atoms and electrons. Imaging techniques are today capable of resolutions on the nanometric scale.

The instruments developed at ILL and ESRF are recognised internationally for their high level of performance and quality. The two facilities provide a remarkable range of instruments, unmatched around the world. The instrumentation at ILL continuously breaks new ground, both in particle physics and materials science for the determination of magnetic structures, the dynamics of magnetic moments and polymers, and the organisation of biological macromolecules.

Cold-neutron experiments at ILL are a means to understand phenomena in subatomic physics that are also observable at very high energies (CERN). Detectors are being developed for the Large Hadron Collider (LHC) and the Jefferson Laboratory, thus expanding the field of study from the infinitely small to the infinitely large in partnership with CNRS, UJF and Grenoble INP.

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Neutron spectrometer with applied magnetic field

Interferometer with an angular resolution of 10-9, used to check mass-energy equivalence ($E = mc^2$)

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View of ILL, EMBL and ESRF

THE MILLENNIUM PROGRAMME AT ILL AND THE UPGRADE PROGRAMME AT ESRF

ILL is equipped with the world's most powerful neutron source (57 MW reactor) and a set of 40 highly advanced instruments, making it the largest neutron-research centre in the world. ESRF offers one of the most brilliant sources of hard X-rays (6 GeV) with 40 beamlines and has also become one of the most productive with approximately 1 500 papers published each year in refereed journals. ESRF has confirmed its position as the leading synchrotron source facility in the world.

The two institutes have set up ambitious programmes to renew and modernise their methods and instruments in order to be able to provide answers to the questions that will be raised by scientists over the next 20 years.

ILL is expanding its set of instruments and creating new facilities around its neutron source. Major investments over five years have been launched in the framework of the Millennium Programme, including new neutron sources and guides, as well as the construction of innovative instruments and the development of new methods. The Millennium Programme addresses four fields:

- *soft-matter compounds and systems,*
- *slow dynamics of biological systems,*
- *complex environments,*
- *ultra-cold neutrons.*

To remain the leader in its field, ESRF has launched a seven-year programme to upgrade its X-ray source and beamlines. The main topics covered by this programme are:

- *nanosciences and nanotechnologies,*
- *structural and functional biology and soft matter,*
- *high-speed kinetic phenomena,*
- *extreme conditions (p, T, H, etc.),*
- *X-ray imaging.*

The project includes significant improvements to the accelerators and the construction of beamlines capable of producing nano-dimension beams. They will be housed in an extended experimental hall.

The coordinated use of these large-scale research facilities (LNCMI, ILL, ESRF, EMBL) is a major advantage for European scientists. X-rays and neutron beams «see» materials in different but complementary ways. The various possibilities offered by GIANT open a virtually unlimited field of study in advanced materials and nanosciences.

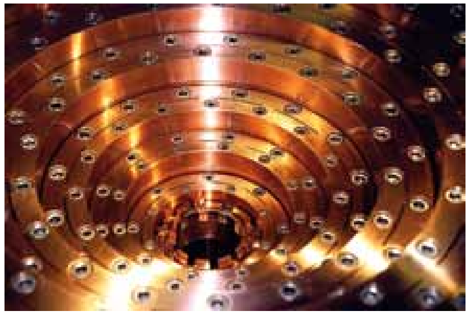
INTENSE MAGNETIC FIELDS

Magnetic fields are one of the thermodynamic parameter, along with temperature and pressure, used to explore new properties or create new states in matter. At the initiative of Louis Néel, constant and pulsed magnetic field facilities were developed in Grenoble (and also in Toulouse, for pulsed magnetic fields).

The unique facilities in Grenoble led to the discovery of the quantum Hall effect by Klaus von Klitzing, the 1985 Nobel Laureate in Physics. In 1987, a world record for a magnetic field was set (31.3 T). Today, magnetic fields among the strongest in the world (35 T) are used for experiments unmatched elsewhere in the world (nuclear magnetic resonance at very low temperatures and high pressures, electrical transport, optical to far-infrared spectroscopy), drawing scientists from many countries. The technological know-how for magnet construction is at an internationally leading level. A new hybrid magnet combining a superconducting coil and a copper coil can produce a 43 T field. The scientific topics addressed range from the physics of materials (magnetism, superconductivity, semiconductor physics, nanosciences, graphene) to chemistry and applications (tests on superconducting wires, production and orientation of new materials in magnetic fields, levitation).

A CNRS laboratory was created in 2009, bringing together the Grenoble and Toulouse teams working on intense magnetic fields as a first step towards a European magnetic fields laboratory. The efforts to develop magnetic fields in Grenoble have resulted in a concentration of the most powerful facilities for the exploration of matter. The combination of synchrotron, neutron and particle physics techniques, with extreme conditions (intense magnetic fields, very low temperatures, very high pressures), provides unique research resources available for a wide range of experiments in the fields of health sciences, energy and information technologies

Hybrid magnet



The 35 Tesla magnet at LNCMI set a world record in 2009 for a constant-field resistive magnet

NATIONAL LABORATORY FOR INTENSE MAGNETIC FIELDS (LNCMI)

Magnets producing the most intense magnetic fields in Europe

These remarkable machines are part of Grenoble's research assets. Offering magnetic fields up to 35 Tesla, they are available to the international community of researchers and engineers conducting studies under intense magnetic fields. The design of magnets is supported by an R&D programme in a number of fields including numerical methods, heat transfer at high intensities and the mechanics of conducting and superconducting materials. The magnets are the result of a long tradition of co-development, spanning decades, between CNRS, an array of SMEs in the Rhône-Alpes region and large industrial firms (Nexans, etc.). The technologies have been patented by CNRS.

The studies on superconducting materials carried out at LNCMI are crucial to the development of the technologies used in large-scale international research facilities (CERN, ITER, ILL, ESRF) and to the transmission, storage and management of electricity. LNCMI also offers a test platform that is unique in Europe to assist industrial companies in developing MRI (magnetic resonance imaging) machines or systems used to store electrical energy.

IN BRIEF

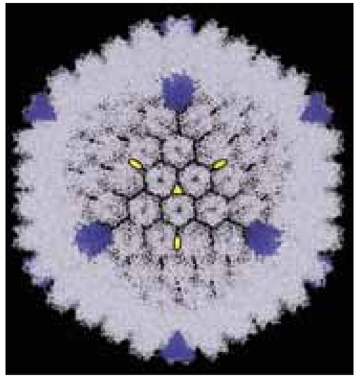
The site in Grenoble is home to two of the world's front ranking scientific facilities (ESRF and ILL) and top-level instrument platforms (EMBL, PSB, LNCMI) covering a wide scientific and technical domain ranging from the infinitely small to the infinitely large. The alliance between national and international players has made Grenoble a highly attractive site for structural biology, physics, nanotechnologies and technology transfer. This attractiveness has strengthened over the years and participants in R&D programmes all see Grenoble as a major site for innovation. Launched by Louis Néel, there have been many pioneering achievements in instrumentation in Grenoble, making it possible to compare theoretical models with precise experimental observations, the basis for any rational analysis.

CHARACTERISATION AND NEW METROLOGIES

Materials are studied using the platforms developed by various laboratories in addition to the large-scale facilities of the ILL and ESRF.

- The joint platforms between institutes or laboratories at the regional and national levels include the MINATEC Nanocharacterisation platform, the Collaborating Research Groups (CEA-CNRS) at ESRF and ILL, the PSB structural biology platform (Partnership for Structural Biology: EMBL, ESRF, ILL, UJF, CNRS, CEA), the Nanobio platform located on the university campus and at MINATEC, the Grenoble centre for magnetic resonance, the CMTC consortium for shared technological resources combining the characterisation resources of Grenoble INP, intense magnetic fields and the nanofabrication platforms (PTA, Nanofab, etc.). The cryogenic characterisation platform for materials brings together CEA and Air Liquide resources to characterise the mechanical and thermal behaviour of materials between 1.8 and 300°K.
- Laboratories have assembled their own rich and diversified characterisation techniques for organic and inorganic objects and the devices containing these objects. A unique set of probes to study and analyse the structure of materials and nano-objects on all scales, from sub-nano to macro, is available for researchers on the site, using X-rays, electrons (electron microscopes), photons (light absorption, emission and diffusion, ellipsometry, etc.), local-probe analysis (AFM, STM, SNOM, etc.) and a wide range of imaging systems sensitive to different types of contrast. For nano-objects, detection of isolated spins in sets of atoms or single molecules is now possible thanks to the development of nanoSQUIDs (superconducting quantum interference devices made using carbon nanotubes).
- An example of the interaction between these extreme techniques is the 50 mK scanning tunnelling microscope that combines energy resolution directly correlated with low temperatures and the spatial resolution of the scanning microscope. This makes it a remarkable tool to observe surface electronic phenomena (superconductivity, junction effects, etc.). Bolometers, which measure the polarisation and anisotropy of cosmic radiation on balloons (Archeops) or satellites (Planck and Herschel launched on 14 May 2009), must, of course, operate under cold conditions, but also resist shocks and accelerations. In less severe environments, on Earth in underground laboratories, efforts are underway to detect the elusive WIMPs (weakly interacting massive particles). These efforts involve a large number of Grenoble and international players using bolometric detectors operating at 20 mK.

One of the strong points in this organisational structure is that the staff of the various institutes is active in both the use and management of the facilities. This is an effective means to pool the cost of large, expensive systems and to make them available to the entire community.



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Structure at quasi-atomic resolution (5 Å) of a human adenovirus. This structure was obtained by combining cryo-electron-microscope data with crystallographic data

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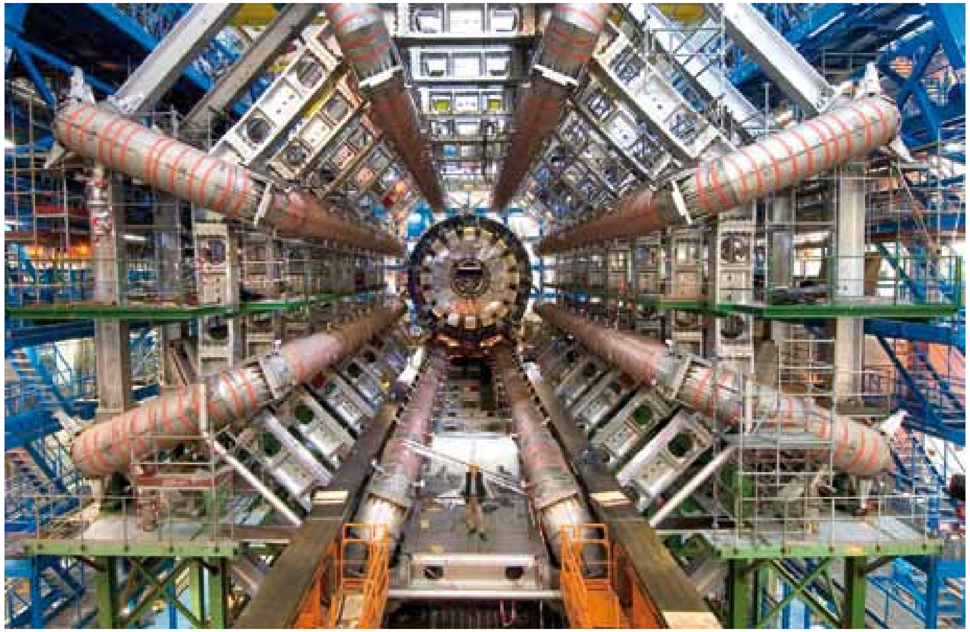
50 mK scanning tunnelling microscope.

1.1.2 PHYSICS OF THE UNIVERSE ///////////////////////////

This line of research is conducted in Grenoble by a number of laboratories from different organisations (CNRS, Grenoble INP, UJF) and by ILL. Long established, hundreds of people are involved, including researchers and research professors (CNRS and the universities), technicians, PhD students and visitors. This research is pushing back the boundaries of our knowledge and addresses some of the major mysteries in the field of physics. Examples include the origin of the mass of elementary particles, the unification of forces, black holes, the origin of matter-antimatter asymmetry, baryonic dark matter and dark energy, scenarios on star formation and the origin of the planets and life.

These topics require observations on phenomena spanning vast scales in time and space, ranging from the infinitely small to the infinitely large, from the origins of stars and planets to their future evolution.

- The infinitely small, much smaller than the nucleus of an atom, is studied to understand the properties of the basic constituents of matter and their interactions, to explore the intimate structure of common matter (the neutrons and protons forming the nucleus of atoms) and conditions near the stability limits of the nucleus of atoms. At these scales, the laws of quantum and relativistic physics dominate and some of their most advanced aspects are studied.
- The infinitely large comprises, for example, the organisational structure of the universe, its extreme and violent phenomena, and the initial moments after the Big Bang. It also includes the study of the cold, interstellar zones, the different phases in the formation of stars, brown dwarfs and circumstellar environments, as well as exoplanets.
- Contrary to appearances, these two fields have much in common. The physics of the infinitely small plays a major role in the initial moments of the universe. Laboratory research on new states of nuclear matter such as quark-gluon plasma of is closely related to the condition of the universe just after the Big Bang. Work on exotic nuclei created during fission of transuranian elements provides information on the creation of heavy elements in stellar explosions, at the origin of the planets. The life-time of the neutron determines the quantity of light nuclei created during the first minutes following the Big Bang.

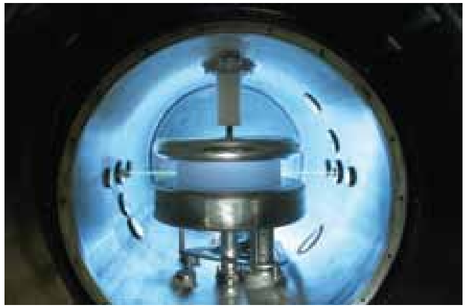


The Atlas detector at LHC at CERN

EXPERIMENTAL APPROACHES

The research teams observe and study particles created using accelerators and reactors, or simply formed in the universe. They also compare results from laboratory experiments or numerical simulations with the radiation and particles arriving from space. These were produced at different moments during the life of the universe by various astrophysical phenomena such as black holes and stars during their formation. These research topics are also part of studies on matter under extreme conditions, exploring environments presenting enormous variations of different physical quantities, of many orders of magnitude, such as density, temperature, energy scales and distances.

Whether for experimental subatomic physics or astrophysics, this research requires the development of increasingly high-performance and sophisticated devices and innovative technologies. To reach the goals that have been set, close collaboration between astronomers, physicists, engineers and technicians is indispensable. This approach is thus characterised by large, international projects (joint projects, experimental sites), by long durations up to a decade and by budgets exceeding several million euros.



Research on the electric dipole moment of the neutron to test the fundamental symmetries of time and space

For example, Grenoble laboratories are involved in:

- CERN, near Geneva, the world leader in particle physics, and the construction of large detectors (ATLAS, ALICE) for LHC, now in the start-up phase,
- the experimental programme on nuclear structure and fundamental physics at ILL, the international institute whose research reactor supplies the most intense neutron beams in the world,
- the Very Large Telescope (VLT) and the VLT Interferometer (VLTI) at the European Southern Observatory (ESO). Instruments currently under development for high angular resolution observations (adaptive optics and interferometry) will equip the largest telescope available to the international community and make it possible to characterise exoplanets,
- the European Planck satellite, launched in 2009, designed to improve our knowledge of the universe and its history by more precisely measuring the diffuse cosmic background,
- the development of new observational windows using X-ray and Gamma-ray astronomy,
- the SPIRAL2 project that, in 2012, will strengthen GANIL (Caen) in its role as a leading international centre in nuclear physics and exotic nuclei.

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First image of a planet outside the solar system from the Very Large Telescope in Chile using the NAOS instrument assembled in Grenoble

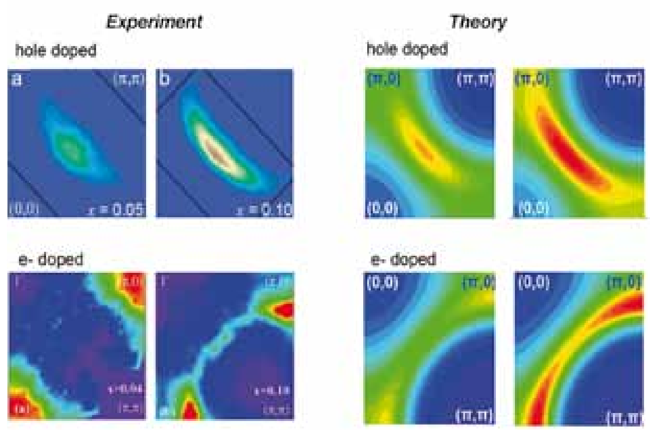
1.1.3 THEORY AND MODELLING

This field covers a number of disciplines. Working with the experimenters and engineers developing devices, the theorists contribute in terms of concepts, predictions and explanations.

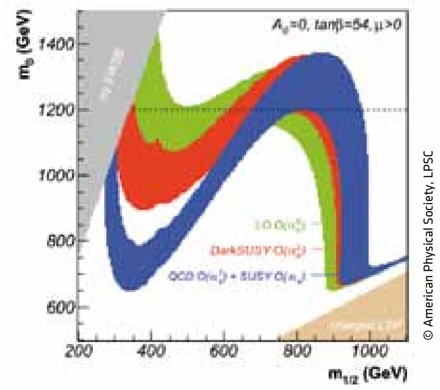
The basic models include only the essential elements of a physical problem and become themselves a topic of study. Once the concepts are clear, the model «imitates» reality as closely as possible using numerical methods. Whether analytical or numerical, the concepts, models and techniques apply to multiple disciplines. Thanks to regular contacts, theorists discuss and compare their visions and methods.

The list of scientific topics reveals a number of major fields of interest. Based on established disciplines, new subjects of study have led to the development of new fields, supported by the knowledge accumulated in the «historical» disciplines that nonetheless retain their importance.

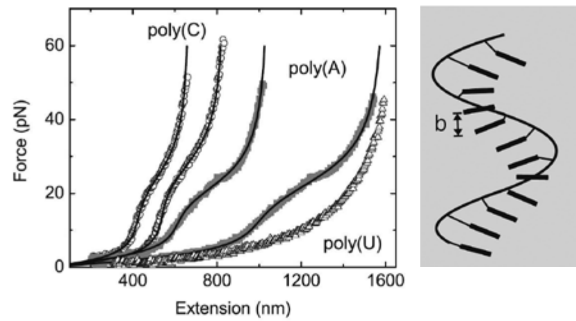
Current work deals with new materials, nanosciences and nanotechnologies (defined by their small size and function), quantum physics of systems with few degrees of freedom and quantum information, soft (poorly organised) matter and the physics of biological objects, non-standard models of high-energy physics and wave propagation in complex environments, ranging from the nanometre to the kilometre.



Comparison of experiment (angle-resolved photo-emission) and theory for high-T_c superconductors, revealing "pockets" of electronics density



Supersymmetry corrections to dark-matter annihilation



Elongation of single DNA strands observed using force measurements. Models make it possible to study the fundamental parameters

IN BRIEF

Major research in theoretical physics and numerical simulation supports the experiment and observation, from their initial definition through to the interpretation of results. The exceptional experimental and technological environment in Grenoble naturally includes very active theoretical groups. Their international reputation is excellent with many laboratories and teams having received awards for their scientific achievements.

The laboratories share their knowledge and their progress via educational programmes (including some that are highly specific, such as in the field of nuclear energy), training through research and dissemination of scientific knowledge.

Theoretical researchers in Grenoble have established solid, long-standing ties between the GIANT campus and the university campus, via seminars and workshops at the Grenoble Centre for Theoretical Physics.

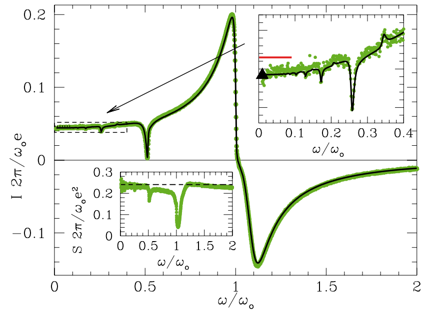
SOME EXAMPLES

The rapid development of increasingly specific and powerful numerical methods has led to the emergence of "numerical physics and chemistry", bridging the gap between «model» theory and an ever more complex experimental reality. Simulation has become an indispensable tool, for example in support of the various spectroscopies, the large-scale facilities in Grenoble or for technological developments, such as microelectronics.

Other examples include problems involving non-equilibrium and non-linear dynamics or high-energy physics for which models cannot yet be solved analytically. The evolution of microelectronics towards ever smaller dimensions brings the quantum approach into play in an increasing number of steps, combining theoretical concepts and methods drawn from mesoscopic physics with more systematic and «proven» approaches. Examples include:

- electronic transport in nanocircuits or spintronics,
- photonics and radiation-matter coupling,
- molecular electronics requiring both quantum-chemistry approaches and approaches describing electron transport in nanostructures.

On fundamental or applied levels, new objects or devices (electronic, optical, mechanical, hybrid) require new approaches suited to the complexity involved, for instance multiphysical and multiscale approaches. In terms of the interface with biology, methods from the statistical physics of non-equilibrium systems are used to address the great complexity of biological objects, either in vivo or in an «artificial» physical environment.



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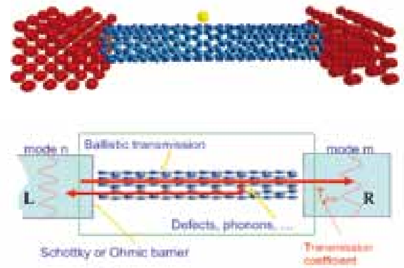
Electro-mechanical oscillations of a nanopillar



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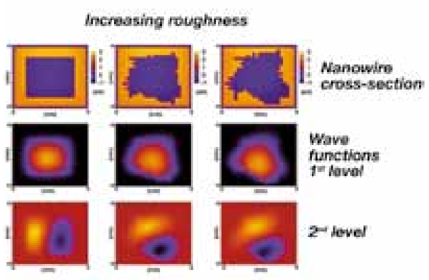
Quantum transport of electrons in a nanotube or nanowire, from ab initio calculations to mesoscopic approaches in a network



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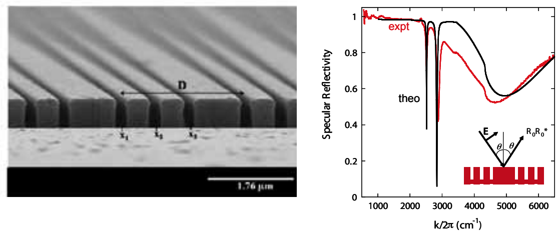
Quantum transport of charge and spin in nanometric components and magnetoresistance mobility in ultra-short transistors.



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Plasmonics: sub-wavelength amplification in a network

1.1.4 THE GRENOBLE CRYOGENICS CLUSTER ////////////////////////////////

Unique know-how in the cryogenics field has been brought together in Grenoble, including large users (CNRS, CEA, UJF, ILL, ESRF), suppliers (four liquifiers at CEA and CNRS), public R&D laboratories (CNRS, CEA) and industrial companies (in particular Air Liquide). Numerous national and international successes have been achieved by Grenoble's cryogenic experts and more are on the way in the fields of large-scale instruments and space-borne cryogenics. These results are due to over 50 years of research on very low temperatures. This research was driven by the development of condensed-matter physics in Grenoble, a field that requires the use of low temperatures. Today, the temperatures reached make it possible to study the magnetism of the superfluid phase (100 μK) of helium 3, and to develop new detectors to study the origins of the universe. It is clear that many of the successes obtained in the field of physics in Grenoble are linked to state-of-the-art cryogenics.

© Institut Néel / Air Liquide

A 10 mK dilution refrigerator which operating without cryogenic fluid

© CEA-SBT / Artechnique

The Cryoloop (CEA/CNRS/UJF/CERN)

A SOLID INFRASTRUCTURE...

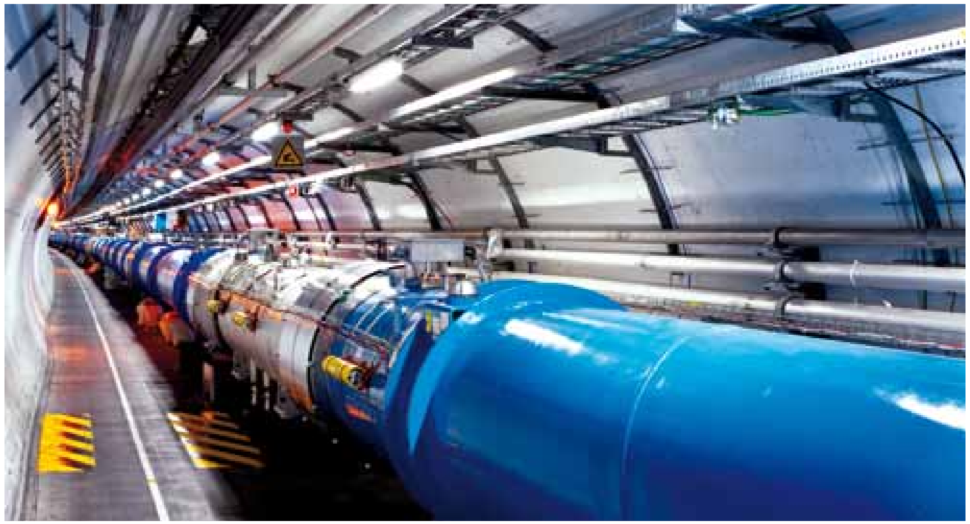
To meet the needs of their partners, CNRS and CEA have four helium liquifiers and distribute over 600 000 litres of liquid helium each year, thus making Grenoble the largest centre for helium liquefaction in France, with an overall recovery rate of 70%. In addition to the liquifiers, indispensable for daily work at very low temperatures, other basic equipment is on hand, such as the shared characterisation platforms (low-temperature characterisation of materials on the CEA-Air Liquide platform) or the characterisation platforms of each laboratory for electrical and thermal measurements.

... FOR MAJOR RESEARCH PROJECTS

In addition to fundamental research which required the development of high-performance cryostats and related instrumentation, major multi-disciplinary research projects have been set up in Grenoble thanks to the cryogenic know-how of the scientific community.

▸ CERN

Following the success of the Tore Supra tokamak at Cadarache, whose cryogenic system was designed by the CEA, the Grenoble cryogenics specialists suggested that the LHC at CERN be cooled to 1.8°K (27 km of NbTi superconducting magnets, cooled using superfluid helium, 100 m underground!). Such a radical change of scale required in-depth study, carried out first at CEA, then extended at CNRS and UJF. The Cryoloop experiment, coupled with the large 1.8 K refrigerator at CEA, confirmed the concept of inserting the heat exchanger between the pumped and the pressurised baths.



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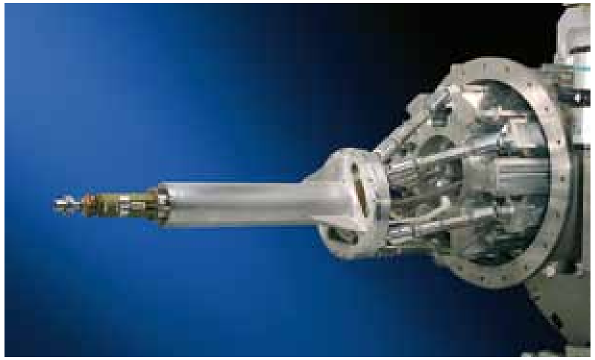
The LHC tunnel and magnets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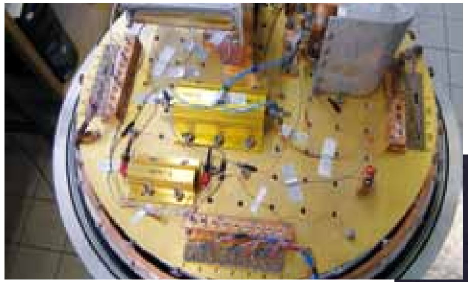
The cryogenic handling system of the Megajoule Laser (LMJ)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A prototype 50 mK magnetic refrigerator


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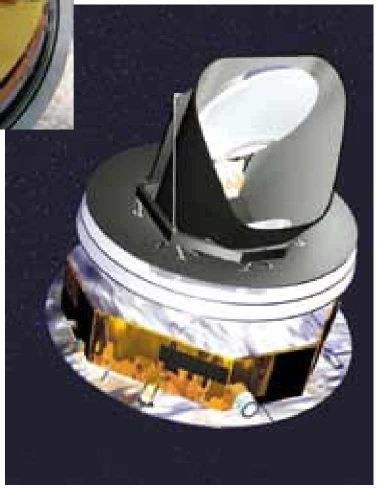
An adsorption refrigerator (Herschel)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The Planck satellite

Herschel and Planck, powerful eyes to examine the universe

The experience acquired by Grenoble laboratories in sub-kelvin cryorefrigerators enabled them to play leading roles in the cryogenics for the two European satellites, Herschel and Planck. The CNRS, a world leader in dilution refrigeration, designed the cooling device for the HFI detectors on Planck, which were then made by Air Liquide. CEA was the project leader for the two adsorption cryorefrigerators in the cryogenics system of the Herschel satellite launched with Planck, by Ariane V in 2009.

And tomorrow...

- In nuclear fusion, research has taken two paths, both of which require advanced cryogenics. Inertial fusion, notably the Megajoule Laser (LMJ) project in Bordeaux, requires solid deuterium-tritium targets to initiate ignition. Current research at CEA has demonstrated the feasibility of such targets that must be cooled to 18 K, with tolerances at the millikelvin level. The institute also developed a cryogenic handling system for the targets that is used to place them in the centre of the LMJ chamber. In the magnetic-fusion field, the ITER project in Cadarache requires a 4 K cryogenic system exceeding 60 kW power.
- Future *weather satellites* (e.g. third generation Meteosat) will certainly have pulse-tube cryorefrigerators on board, a technique in which Air Liquide and CEA have collaborated for years. New scientific missions (Xeus and Spica satellites) will require even lower temperatures (< 50 mK) for which CEA and CNRS have already joined forces to develop an ultra-light adiabatic demagnetisation refrigerator.
- Finally, the Grenoble laboratories, thanks to their extensive know-how in liquid helium technologies, now make the exceptional properties of this fluid available to the hydrodynamics research community. Fundamental progress may be expected in our knowledge on turbulence, one of the remaining great enigmas of modern science.

The CEA and CNRS research laboratories, with UJF, work together on a range of topics, both technical and fundamental, and all transfer the results to industrial companies, notably Air Liquide. SMEs in the Grenoble region have increased the quality of their mechanical work to the point that the systems developed by the laboratories can now reach spatial quality. To reinforce their collaboration, CEA, CNRS, UJF and Air Liquide have decided to organise their cryogenic activities in a scientific joint venture.

1.1.5 MATERIALS AND PROCESSES

All of the objects around us are formed from matter, molded and designed by human imagination, which thus becomes a material. Compared to matter, materials are specific in that their nature cannot be separated from the object that they form, from the function served by the object, and the process used to make it. All advanced technologies are limited by the materials used to implement the technology and by the way they are used. It is currently estimated that there are about 80 000 materials available.

The transversal and inter-disciplinary character of materials science and process engineering is a central challenge that this discipline must assume. It requires the many competencies of the engineering sciences, but also those of mechanics, physics, chemistry, biology and applied mathematics, based on carefully considered R&D programmes.

© SIMAP

Crystal-orientation map using transmission electron microscopy

ISSUES

The main issue to be considered for materials science and process engineering is to clearly define their future path to enhanced multi-disciplinarity taking full advantage of the possibilities offered by the GIANT partnership. One of the goals is to «materialise» these possibilities by setting up an integrated materials policy for research and training. Materials science and process engineering are evolving rapidly towards:

- An increasing need for modelling and in particular numerical simulation. In this field, the keywords are multi-scale techniques and process modelling. This corresponds to a need to design materials scientifically, replacing current empirical methods.
- Development of experimental methods to quantify the characterisation of structures, including nano and microstructures, in conjunction with the physical properties of materials and process instrumentation. In this context, the role of the Grenoble large-scale research facilities is particularly important.
- Progress towards extreme length scales. Nanoscopic scales are not limited to microelectronics. High-performance steels and technical ceramics are fields in which material physics is currently reaching its limits due to the very small length scales.
- A multi-disciplinary approach, e.g. understanding the structures resulting from solidification requires know-how in mechanics (liquids and solids), thermodynamics, physical chemistry and process engineering.
- An integrated approach to materials, products and assemblies. Optimisation of materials and products today requires an integrated vision of development, processing, manufacturing and implementation processes, as well as an optimised selection of materials and processes in a design framework based on clear specifications. This approach is based on the unifying concept of durable function and reliable operation.

© LMGP

Chemical reactor for thin film deposition by OMCVD

Steel wool used to lighten structures in the automobile industry

© SIMAP

a) X-ray tomography

© SIMAP

b) Scanning electron microscope tomography

The research and higher-education institutions play an active role in the evolutions mentioned above, already underway. This is particularly true when, on a single site, the physical proximity of the competences and resources in the above disciplines, taken in conjunction with relevant companies, provides significant potential for development. The originality of the two "structuring" projects, Grenoble University of Innovation (GUI) and GIANT Innovation Campus, is to provide an novel framework within which to develop studies of materials as well as nanotechnologies, energy and biotechnologies. The recent arrival on the GIANT campus of laboratories specialised in materials science and process engineering, together with the Grenoble-INP and CMTC consortium for shared technological resources is an additional asset.

Studies of materials and processes lie within the major three main research directions of GIANT:

◗ Nanosciences and nanotechnologies

The Federation for Micro and Nanotechnologies (FMNT: CNRS, Grenoble INP, UJF) in conjunction with activities run by CEA, combines the know-how of these laboratories, particularly well known in the domain of materials for nanoelectronics and photonics, but also in the field of multi-functional oxide nanostructures. Extensive work is also carried out on crystal growth with internationally recognised groups. Major technological innovations have been achieved for the development of new materials for nanoelectronics and their integration in CMOS nanoelectronic technologies (high-K and low-K materials, strained silicon, SiGe, SiGeC) and GeOI substrates. Collaborative research has led to progress at world-leading level in a large number of applied fields such as lithography patterning or plasma technologies. For the nanotechnologies, this work concerns all the materials produced by different processes such as the synthesis of nano-objects, direct growth by CVD, ALD, etc., plasma etching and lithography techniques and the SmartCut™ process.

◗ Materials for energy applications

Energy research is organised by the Carnot Institute for Future Energies which associates the Grenoble INP, UJF, CNRS and CEA laboratories. Known for its scientific excellence and success in technology transfer to industry, the institute operates at the national level, representing over 50% of the capacity of the Carnot Institutes on renewable energy. The Grenoble's institute relies on the research capacity of the materials laboratories and their industrial partners. Applications include optimisation of phase-change materials, self-cleaning materials for buildings, research on the hardness of steel and metal alloys for the nuclear sector, lighter materials for automobile and air transport, use of materials in energy transport and storage, new materials or optimisation of manufacturing processes for solar cells.

◗ Biotechnologies

The GIANT campus also possesses definite advantages for research in biotechnology, including an internationally recognised structural-biology research sector, capable of producing and characterising functional proteins, and a wide array of laboratories working on cellular adherence, differentiation and tissue formation. These materials can be used in the biomedical, food and environmental (biological water quality) sectors. Materials capable of selecting targeted macromolecules are also of interest, as well as the inherently multi-disciplinary field covering the interaction between living cells and inert matter.

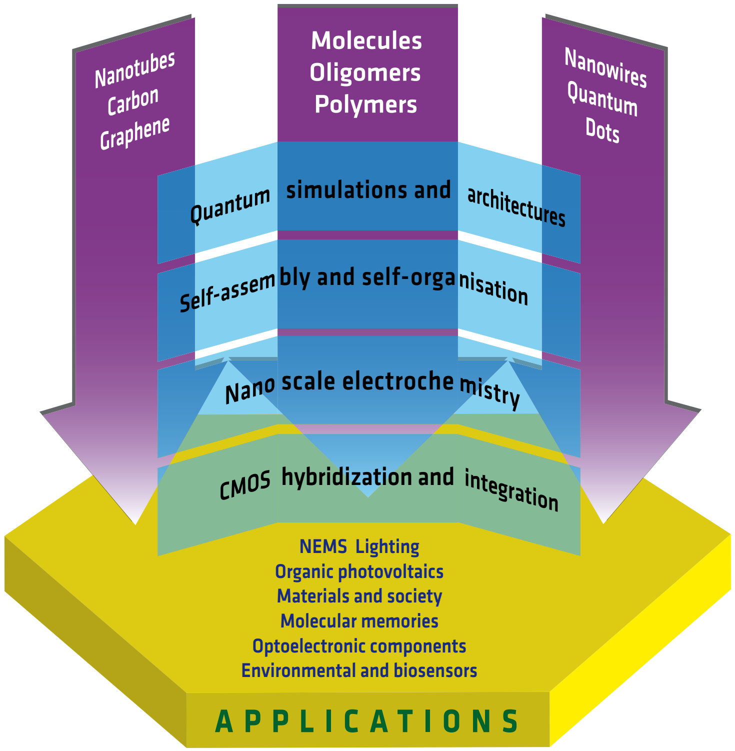
The above elements explain the special situation of materials science and process engineering in Grenoble, with a seamless continuum from fundamental to applied research, specialized laboratories and world-class technological platforms for materials development and characterisation, and strong industrial partnerships with a large number of ongoing contracts.

With the arrival of new laboratories on the GIANT campus, the site will benefit from a concentration of research groups working on structural and functional materials, development and characterisation, and modelling and experiment. This grouping of forces, where materials science and process engineering together are clearly identified as a single discipline, will be highly productive in existing and future fields of application and will constitute a particularly attractive centre for a wide array of industrial applications.

X-ray diffraction analysis of new phases of thin film materials produced by OMCVD deposition

IN BRIEF

The Materials Sciences and Engineering laboratories secure a central position for this discipline on the Grenoble site, resulting in the rapid structuring of the sector, thus improving the visibility of a large range of activities widely recognised at the national and international levels, and generating significant collaboration with industry.



Activities in the Chemtronic programme

1.2 NANOSCIENCES

1.2.1 CHEMISTRY AND ELECTRONICS FOR THE FUTURE

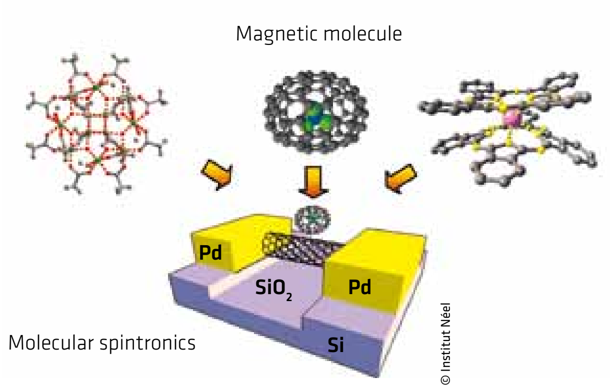
Electronics of the future lies at the crossroads of nanochemistry and nanoelectronics. In recent years, the focus has been on processes for synthesising nanomaterials and on organising these materials to obtain specific properties. The functionalisation of these materials opens the way for applications such as sensors, actuators and a wide range of components such as memories or hybrid components for spintronics. This field also deals with components based on carbon nanotubes, graphene, quantum dots and semiconductor nanowires, as well as various molecules and polymers that are electro or photo-active on the submicron scale. Aspects concerning predictive simulation, architectures, integration, synthesis of single molecules, self-assembly and functionalisation are essential for research not only on post-CMOS electronics (and particularly molecular electronics), and complementary electronics («more than Moore», with its sensing, NEMS, RF and spintronic functions), but also soft or organic electronics via applications such as OLED flat screens, RFID tags, electronic paper, photovoltaic cells and sensors.

Around 140 people work in these fields on the GIANT campus. They bring together two fields that are relatively distinct both from an economic and application point of view, that of microelectronics and the emerging field of organic electronics. Carbon nanotubes, nanowires, oligomers, graphene and molecules, all have major potential for future discoveries and innovation in Information and Communication Technology (ICT) that will benefit Europe.

RESEARCH ACTIVITIES

Within GIANT, the bulk of activities are carried out by teams from CEA, CNRS, UJF and Grenoble-INP. These collaborative efforts go back many years and span a number of regional, national and European projects.

At a fundamental level, this work takes place in close conjunction with quantum nanoelectronics, mesoscopic physics and molecular electronics/spintronics. It has clear implications for technological applications. As an example, in 2003 the CEA launched a major in-house programme on chemtronics to mobilise its fundamental research laboratories working on chemistry and physics as well as its microelectronics laboratories, structuring their work by focusing on common goals. This activity is further supported by the Nanosciences Foundation which has identified molecular electronics as a key field.



A carbon-nanotube transduction device for the detection of magnetic molecules

Fundamental aspects, in particular numerical simulation, spintronics and molecular transport, are currently undergoing strong development, with the participation of the large-scale European research facilities.

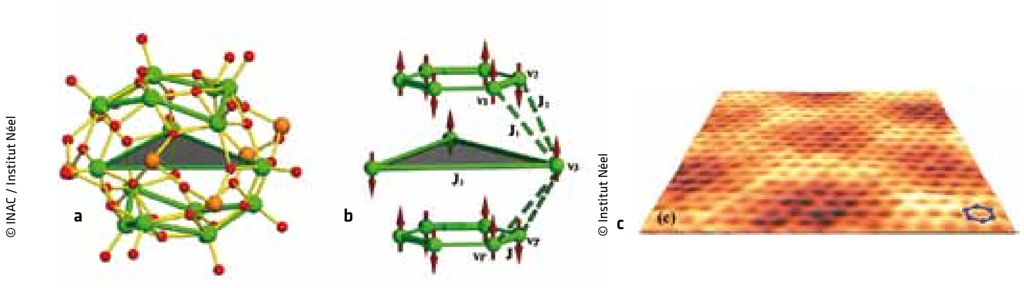
Semi-empirical quantum simulations are being developed by a number of teams and in various fields relating to chemtronics and molecular electronics:

- electron transport for the study of the structural and electronic properties of nanostructured systems such as nanotubes and, recently, graphene, with exceptional transport capabilities that should lead to new advances in nanoelectronics,
- the study of quantum-transport or Hall-effect properties,
- the study of the optical properties of doped or functionalised nanotubes and nanowires.

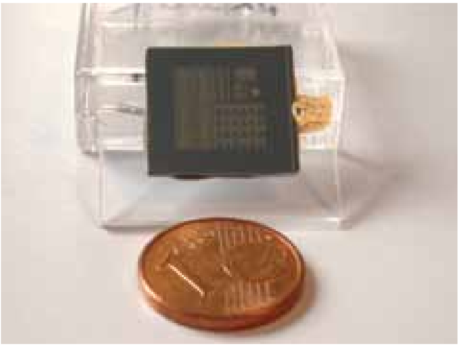
The objects studied are model systems (single atoms, molecules, nanoparticles, spin chains, 2D systems) that are sufficiently simple to enable the emergence of new phenomena resulting from fundamental interactions. Examples include the study and control of the coherent quantum dynamics of magnetisation in molecular systems or the creation and study of graphene-based components.

In parallel with the research presented above, structuring and addressing mechanisms for nanomaterials are studied using both «bottom up» and «top down» approaches, for example unorthodox lithography techniques and colloid localisation.

The Chemtronics programme involves pioneering teams. Conjugated macromolecules, model molecular semiconductors, form the basis of organic photovoltaics, or, at the scale of a macromolecular chain (oligomers), of organic and molecular electronics. The Chemtronics programme has focused on the development of hybrid nanostructure materials combining mixtures of polymers and photoluminescent nanoparticles, nanowires or carbon nanotubes. Such hybrid structures require molecular engineering to make the different types of nano-objects compatible. The various components must also be correctly positioned and functionalised. Long-standing competence in the electrochemistry of rare-earth metal complexes, which are intrinsically electroactive, contributes to the development of innovative molecular photonics. This know-how has resulted in the design of redox-based memories, a step in hybrid electronics that includes molecules in CMOS systems. Molecular electrochemistry is also instrumental in the design of bioelectrochemical sensors. The trend toward nanometric sizes in electromechanical systems on the micrometric (MEMS) and nanometric (NEMS) scales requires functionalisation of nano-objects by biological components (DNA, antibodies, etc.). Again, the necessary multidisciplinarity was made possible thanks to the collaboration of several teams. These efforts are now producing results in the form of R&D work and industrial transfers.



(a) and (b) crystal and magnetic structures of quantum bits (qbit) created using vanadium-based molecular magnets,
(c) epitaxial graphene on SiC



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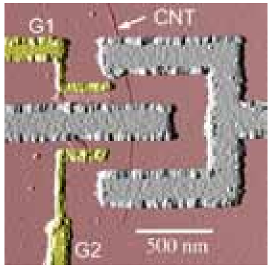
Transistor employing carbon-nanotube pillars



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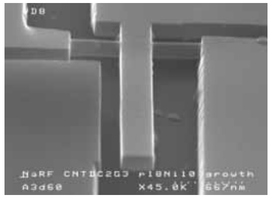
NanoSQUID using carbon nanotubes.



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Sensor using a piezoresistive nanocantilever, for mass spectrometry.

© FMNT

Electronic masking system.

A special feature of GIANT is the development of original techniques to produce nano-objects (quantum dots, nanowires, carbon nanotubes, etc.).

For several years, the CNRS Nanofab platform has developed nanofabrication techniques for non-conventional materials. The PTA upstream technological platform created by CEA, CNRS, UJF and Grenoble-INP is a high-tech, flexible clean-room where innovative ideas can become reality. Both platforms are open to site researchers who want to design and produce nanometric and heterogeneous components. There is also the new CEA chemical platform, designed for industrial transfer of innovative solutions, in compliance with REACH and AFSSAPS regulations on chemical substances.

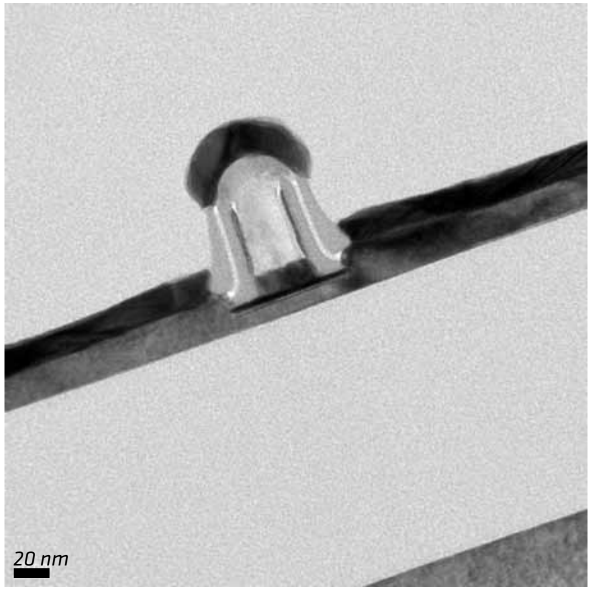
GIANT players have a long-standing tradition of developing special high-tech instrumentation that is of particular importance in this field. Applications include high spatial and temporal resolution, extreme sensitivity and very low temperature measurements for fundamental research, sensors, energy-recovery systems, and bioinstrumentation.

UPSTREAM TECHNOLOGICAL PLATFORM

The Upstream Technological Platform (PTA) comprises a 700 sq. metre clean-room (class 1000) combining the human and technical resources of CEA, CNRS, Grenoble-INP and UJF. Recognised as a leading technological exchange centre in France, it meets the specific needs of upstream research in Grenoble for technological resources in the micro and nanotechnological sectors. It is used to integrate nano-objects and nano-materials or to structure layers on the nanometric scale using various methods and tools (lithography, deposition and etching). Multi-material and multi-surface capabilities are key requirements at PTA. The platform can work on all types of substrates, from 5x5 mm² samples to 100 mm diameter wafers.

The PTA facilities are used in a number of fields, including nanoelectronics, MEMS and NEMS, magnetism and spintronics, integration of nanomaterials and nano-objects, and photonics. The mission of the platform is to permit the technological developments needed by the researchers and to promote collaboration and partnerships with other laboratories at national and international levels.

Flexibility and ease of access and use are key factors for the PTA. This pooling of resources among the major players in upstream research in Grenoble required the creation of a specific management system for the platform, run by the partners.



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Electron microscope view of an FSOI transistor

1.2.2 NANOELECTRONICS

Nanoelectronics is an important field at GIANT, covering the main microelectronic sectors, i.e. "ultimate CMOS", CMOS diversification and post-CMOS nanoelectronics. Research in these three fields is driven by miniaturisation of basic components, increasing numbers of functions in or on chips and work on new functions based on new materials or component concepts going beyond standard CMOS techniques

RESEARCH THEMES

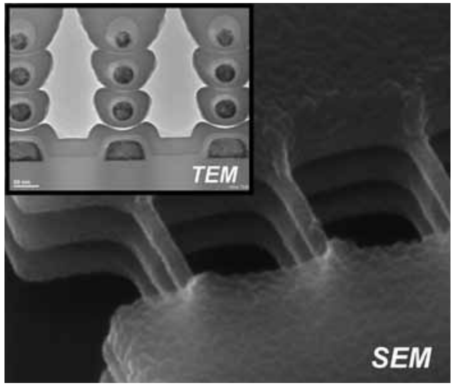
Research activities in ultimate CMOS are closely tied to the special partnerships that the CEA and the university laboratories at GIANT have with industrial semiconductor companies in the Grenoble region (STMicroelectronics, SOITEC, etc). The research teams concentrate primarily on the development of 32 nm, 22 nm and sub 22 nm technologies. Work covers processes for lithography, etching, deposition and ionic implantation that are used to manufacture new logic devices and memories. Research also addresses modelling, simulation and electric characterisation of new architectures for advanced CMOS components in the field of ultra-thin film silicon (silicon on insulator).

The teams are also working on micro and nanosystems, embedded memories and layer transfer technologies, thus gaining insight on the issues of CMOS diversification. Heterogeneous integration of new functions uses individual chip, embedded chip or on-chip approaches. The functions targeted concern applications in electronics, automobiles, energy, biotechnologies, defence, smart cards and mass-market retailing.

For post-CMOS nanoelectronics, the laboratories and institutes have launched efforts in three directions:

- building on top down CMOS, via breakthroughs in materials or logic-gate mechanisms (silicon nanowires, multi-channel transistors, etc.),
- bottom up, starting with nanomaterials and their collective organisation to create logic functions and memories (nanowires, nanodots, etc.), and
- based on the granular or quantum coding of information (qbit and elementary charges).

Due to component miniaturisation, the active zones of devices now contain only a few electrons. Coulomb and quantum effects become significant and radically modify the operation of devices. The microscopic nature of electron spin and charge play a role, as do the phase and wave-function entanglement. New devices based on either charge or spin effects or on quantum effects can be used to code and process information in a new manner. This new field of nanoelectronics uses quantum bits as the basic unit and information is processed directly from these objects. The development of basic devices based on these quanta, such as single electron transistors for the charge quantum or SQUIDs for the flux quantum, is progressing rapidly. Hybrid superconducting systems introduce a wide variety of possible functions. Implementations using semiconductors, carbon nanotubes, graphene or magnetic components are also promising.



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Cross-section of a multi-nanowire transistor

Coupling a number of elements, required for quantum processing, must maintain integrity with respect to perturbations as well as rigorous control of the electromagnetic environment and the basic materials. The information handled by these systems must be acquired and processed by more conventional integrated on-chip components. The key steps are, therefore, the fabrication of several coupled basic functions, e.g. a small group of quantum bits (charge, spin or flux), followed by integration of the quantum device in a standard component approach.

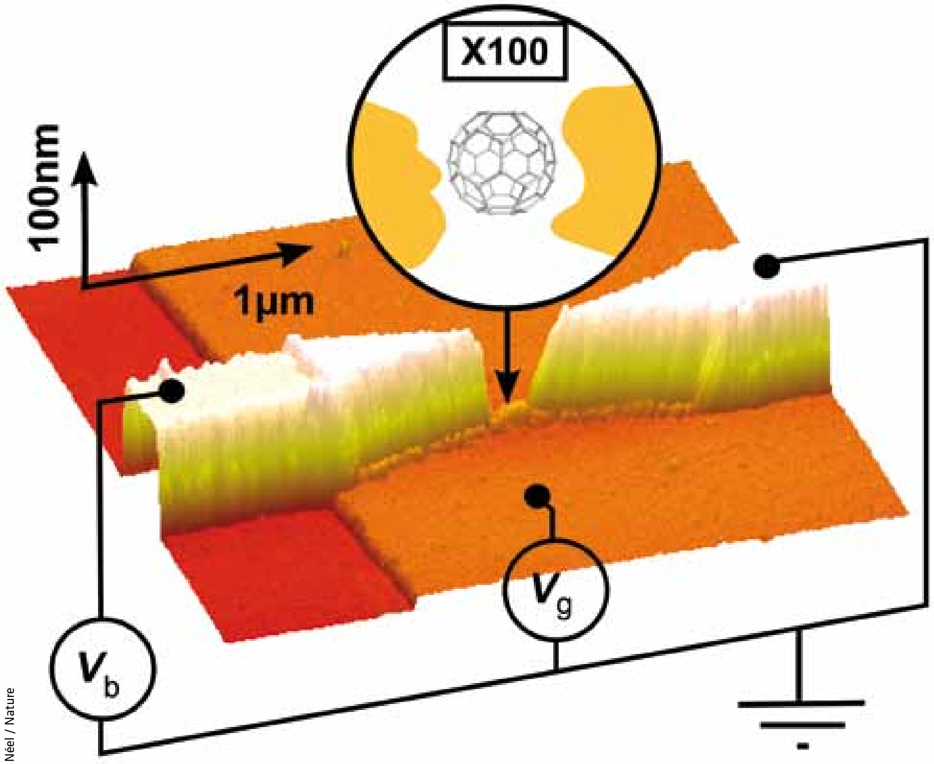
Three technological platforms support research on these topics:

- a 300 mm platform for the development of technological modules for CMOS 45-32-22 nm generations,
- a 200 mm platform to validate new architectures and the integration of new materials in these architectures, also capable of supporting the technological development of micro and nanosystems up to prototyping,
- an upstream platform specialising in exotic materials and designed to test new concepts.

Know-how in developing materials and nanofabrication, in cryogenics and instrumentation, in modelling and theory, makes it possible to carry out pioneering experiments in quantum nanoelectronics, including measurement of quantum de-coherence, handling of quantum bits based on superconducting circuits, handling of charge quanta in silicon quantum dots, tunnel spectroscopy of hybrid superconducting-normal circuits and observation of charge granularity through measurement of current noise.

IN BRIEF

GIANT laboratories and institutes are major players in European and international microelectronics. They participate in numerous European nanoscience projects, sometimes as coordinators (e.g. STREP Atomic Functionalities on Silicon Devices), and in microelectronics projects in collaboration with industrial companies (STMicroelectronics, IBM, SOITEC, Infineon, Quimonda, NXP, etc.). Their researchers are recognised internationally and are members of the technical committees of the most prestigious conferences in the field. They are also editors or associate editors for major reviews in microelectronics. Note that research in micro and nanoelectronics at GIANT fits in naturally with the topics studied by the Nanosciences at the frontiers of nanoelectronics Foundation (RTRA) and the Minalogic techno-cluster.



Nano-device developed to characterise a single fullerene molecule

NANOFAB, A PLATFORM FOR NANOFABRICATION

A part of the Néel Institute-CNRS on the GIANT site and funded in part by the French Ministry of Research, the Nanofab platform is open to the entire scientific community, thus providing access to an important group of facilities and processes.

Flexible platform operation makes it possible to welcome a wide array of researchers and students and to accompany technologically research programmes, frequently of a fundamental nature, in the nanosciences as well as in chemistry and biology. The laboratories for electronic and optical lithography or metal deposition provide a place where the different scientific communities can meet and exchange ideas.

By opening its doors to Masters students from UJF, Grenoble-INP and the European School on Nanosciences and Nanotechnologies (ESONN), training numerous PhD students and interns, Nanofab contributes to the teaching of nanosciences and the development of nanotechnological know-how in research laboratories.

1.2.3 NANOMAGNETISM AND SPINTRONICS

Nanomagnetism and spin electronics activities at GIANT span the complete field from the fundamental understanding of physical phenomena to the creation of functional demonstrators. The community is highly structured with a large degree of interaction between the laboratories involved. Over half of all projects (ANR, EU, etc.) involving a site laboratory, also involve at least a second laboratory, leading to a large number of joint publications.

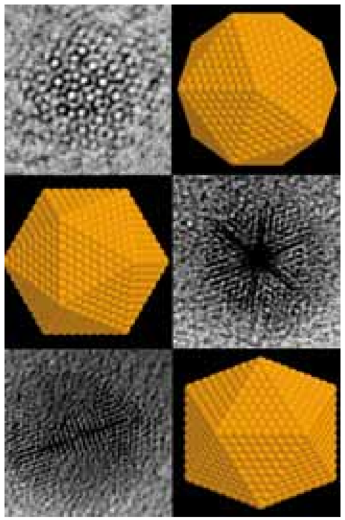
STRUCTURE OF RESEARCH ACTIVITIES

Research activities at GIANT in nanomagnetism and spintronics cover a number of fields:

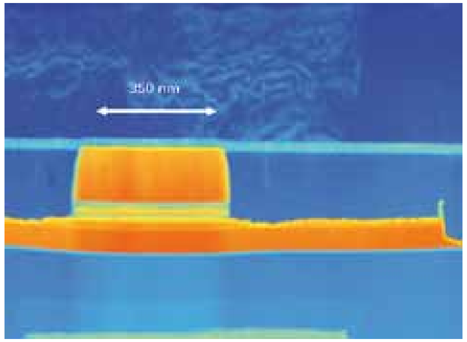
- theory of magnetism and magnetic transport,
- magnetism of nano-objects (nanoparticles, domain walls),
- new functional materials,
- spintronics in nanopillars and unique objects,
- imaging (Kerr, Lorentz microscopy, MFM, PEEM, etc.),
- numerical simulation and modelling,
- physics of complex media and biological objects,
- spin transfer and RF components,
- physics of magnetic components.

Spin electronics should make it possible to add new functions to standard electronic components. Over the long term, this could lead to the creation of a new form of electronics without any charge current, resulting in very low energy dissipation and frequencies approaching the THz range. Researchers in Grenoble work closely with industrial partners to determine how these new concepts can be used in future applications. This work is based on a firm foundation of upstream research on magnetic nano-objects and spin-dependent electron transport. The work carried out at GIANT can be divided into the following sectors.

- Understanding and controlling magnetisation dynamics on sub-nanosecond and sub-nanometre scales. This includes viewing and understanding the dynamics of elementary magnetic objects (walls, vortices, etc.) in nanostructure magnetic layers and model systems (dots, self-organised wires), handling such objects (surface and interface effects, spin transfer used to reverse magnetisation, assisted thermally or through propagation of magnetic walls) and gaining the knowledge required to miniaturise spintronic components (memories, logic and RF components, NEMS).



Icosahedric magnetic clusters of cobalt



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Electronic-microscope image of a non-volatile memory using tunnel-junction devices

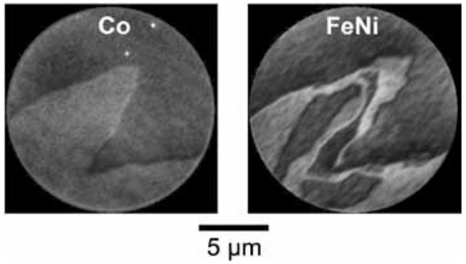

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Image of magnetic domains in a Co and permalloy layer and in a Co-Al_2O_3-FeNi trilayer, employing the chemical selectivity and sensitivity to the direction of the magnetic moment of PEEM

- Understanding and controlling spin currents and imagining new functions. This includes tunnel barriers and new methods, as well as the use of spin currents in semiconductors (particularly type IV) to create post-CMOS electronics offering greater functionality (non-volatile, reprogrammable).

- Extending spin-dependent transport to ultimate nanostructures by combining transport and optical or microwave spectroscopy / handling. This includes quantum magnetism and transport in molecular magnets down to individual magnetic molecules and the use of spin and magnetisation in 2D (quantum well), 1D (nanowire), 0D (quantum dot) nanostructures incorporating magnetic semiconductors or individual spins.

- Optimising the fusion of CMOS and magnetic technologies. This includes inventing new component architectures making the best use of the two technologies (reprogrammable logic circuits, offset memories, decoders, RF interconnections).

- Developing magnetic imaging techniques, including studies on wall movements using polarised currents that will call on competences in magnetic imaging (MFM, Kerr imaging, Lorentz imaging, PEEM, localisation by the magneto-transport effect) acquired and developed by the three laboratories and employing also the other resources available in Grenoble (large-scale European research facilities, etc.).

- Developing simulation and modelling techniques, indispensable tools to improve the understanding of local interaction between electron spin and transport and of the effects of electron spin on local magnetisation. A reinforcement of the modelling/simulation aspects of these effects in the Grenoble laboratories is desirable.

In addition, the trend toward ever smaller dimensions results in a need for nanofabrication of samples. For the development of innovative nanostructures and demonstrators, research teams working on nanomagnetism and spintronics are major users of the Grenoble nanofabrication platforms.

IN BRIEF

The expertise of GIANT teams in magnetism has been recognised internationally for many years. More recently, Grenoble has also become a major site for spintronics. This achievement is the result of efforts to create the tools required to produce and characterise magnetic nanostructures and of the high degree of synergy between players. The work covers a wide range of fields from purely fundamental research through to applications.

GIANT has the critical mass to address all the current research topics in this field. It also has internationally recognised teams and access to the nearby large-scale European research facilities.

1.2.4 PHOTONICS //////////////////

In general, research in photonics attempts to improve control over the generation, propagation and detection of light using innovative materials and micro and nanostructures. Research on optical materials (crystals, thin films and multi-layer materials, hybrid organic-inorganic structures) has been and remains an important source of innovation in laser and parametric generation sources.

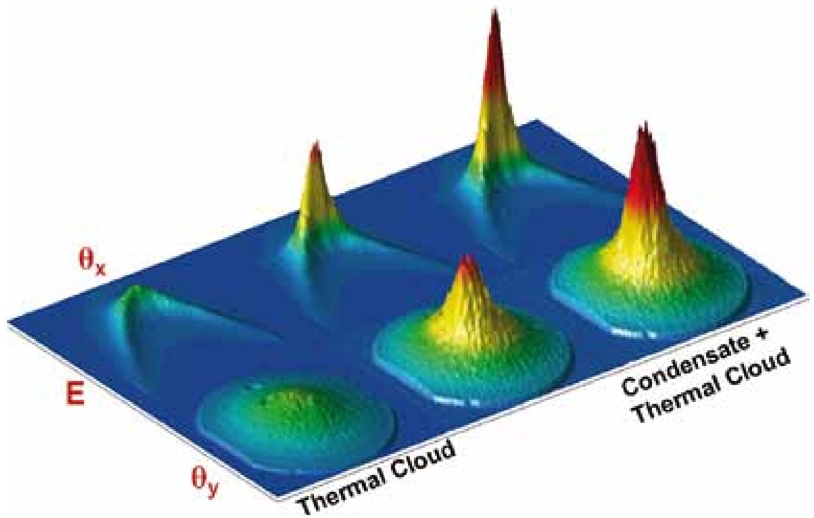
The nanophotonics field has progressed rapidly since the beginning of the 1990s, taking advantage of the development of photonic crystals, optical micro-cavities and semiconducting quantum dots. Using nanometre-scale electron confinement and/or wavelength-scale confinement of photons, a large number of fundamental physical effects have been revealed for the first time in a solid system. Examples are the generation of quantum states of light by a molecule or isolated quantum dot, stimulation or inhibition of spontaneous emission in micro-cavity emitters, vacuum Rabi oscillation for quantum wells or isolated quantum dots, or frequency conversion of light in tuneable micro-cavities.

These new effects are used to develop optoelectronic components offering new functions or significantly improved performance (single-photon sources, low-threshold lasers, high-efficiency LEDs, etc.). The result is promising new applications in numerous fields such as quantum data processing and quantum communications, lighting, photonic integrated circuits for telecom and datacom applications, high-throughput optical interconnections in or between electronic chips, and biophotonics.

IN BRIEF

Most of the resources in the Grenoble area for the fabrication and study of photonic nano/microstructures and materials are now grouped together on the Giant site. Between the GIANT laboratories and institutes and those on the university campus, the two pillars of the Grenoble University of Innovation (GUI) project, solid ties exist for photonics applications, particularly in biology (luminescent markers for in vitro studies or in vivo studies on small animals) and in astronomy.

Over the past decades, Grenoble has become an acknowledged centre for optics and optoelectronics and has contributed to a number of major industrial successes (Sofradir, Ulis, etc.). With the support of the RTRA Nanosciences, the close collaboration between laboratories involved in fundamental research and applied research is a significant advantage in exploring and exploiting the full potential of photonics in the many fields of application.

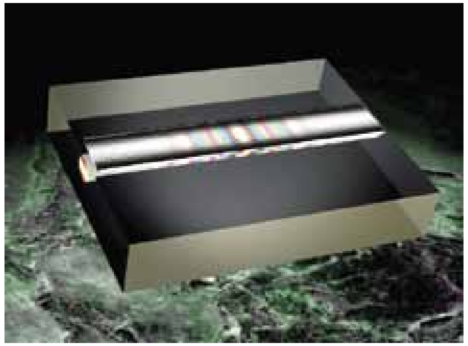


Semiconducting micro-cavities: Bose-Einstein condensation of polaritons

TOPICS

The Grenoble photonics community concentrates on the fields below:

- engineering, synthesis and experimental study of crystals for lasers and parametric sources,
- innovative semiconducting nanostructures for the UV, visible and IR spectra, including quantum dots and nanowires based on GaN/AlN or II-VI semiconductors, optoelectronic devices at telecom wavelengths using intraband transitions in GaN nanostructures,
- nanoparticles for biosciences, including engineering of semiconducting nanocrystals and their surfaces, new dual-mode optical and magnetic probes made of lanthanides and organic nanocrystals for DNA chips,
- production, handling and detection of quantum states of light, including generation of single photons and pairs of photons by semiconducting quantum dots and of entangled photon triplets in non-linear optical crystals, development of a «practical» single-mode single-photon source for quantum cryptography, superconducting photon-counting detectors and optical quantum logic gates operating at the single photon level,
- Bose-Einstein condensation of excitons-polaritons in semiconducting micro-cavities and polariton lasers,
- silicon photonics, including light generation using «microelectronic compatible» materials or nanostructures (quantum dots and nanowires made of Si and SiGe, silica doped with rare earths), silica micro-cavities with a giant overvoltage factor, guides and micro-cavities made of Si photonic crystals and SOI photonic integrated circuits,
- hybrid structures and components, including polymer/semiconductor assemblies for photovoltaics, 3D integration of passive optical functions on glass, hybrid glass/polymer lasers with mode locking,
- plasmonics, including generation and propagation of THz surface plasmons, transmission of THz radiation in metallic networks, enhanced Raman scattering and other non-linear processes in the visible spectrum by nanoparticles or metal networks and application to stationary-wave integrated Fourier-transform spectrometry,
- new, near-field imaging techniques (fluorescent nanoprobes), influence of optical effects such as the Casimir effect on electromechanical nanosystems.



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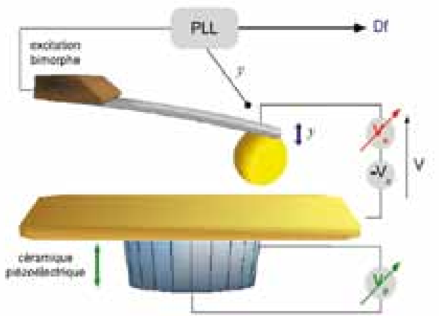
Integrated spectrometer for standing waves

These activities can call on the solid know-how of the Grenoble laboratories in the bottom-up synthesis of nanostructures using chemical techniques or epitaxy, and in the synthesis of crystals, thin films and multi-layer materials for optical applications. On the other hand, access to world-class top-down nanofabrication resources was limited until recently to silicon-based structures. This situation changed in 2007 with the creation of the new upstream technological platform (PTA) managed jointly by CEA and CNRS. Thanks to its cutting-edge electronic lithography and reactive ionic etching equipment, the PTA is in a position to meet the advanced specifications required for the fabrication of photonic microstructures for years to come. This platform is and will remain a key factor in enabling the Grenoble community to hold its own in this scientific field where international competition is particularly intense.



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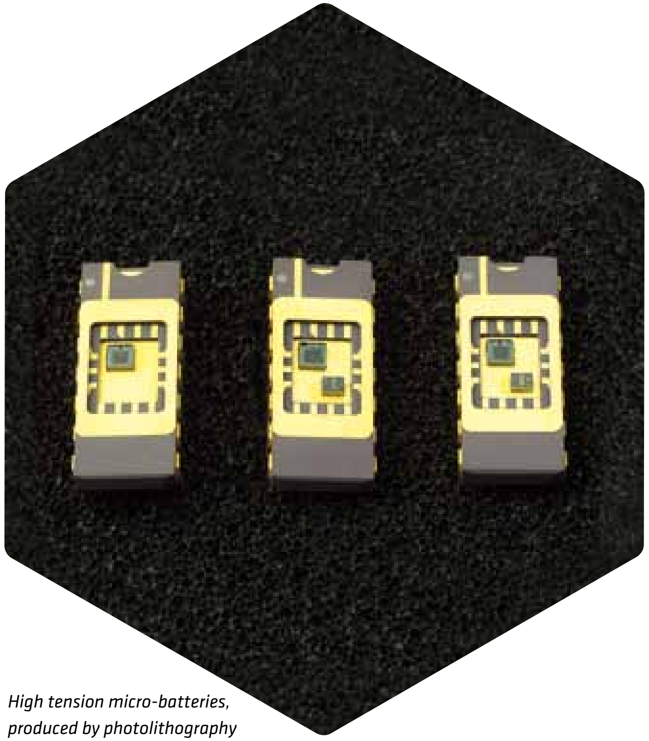
Electromechanical nanosystems: measurement of the Casimir force

1.3 ENERGY

1.3.1 NEW ENERGY TECHNOLOGIES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High tension micro-batteries, produced by photolithography

Energy represents a major socio-economic and environmental challenge for the coming decades. The strategic, economic and financial stakes are enormous, including control over energy dependence, the national balance of payments in light of planned investments and the impact on employment.

The Grenoble site has a number of significant advantages in new energy technologies and intends to become a world-class centre for expertise in the field. GIANT laboratories and institutes address the major scientific and technological topics in the energy sector:

- production, particularly renewable energy in photovoltaics, biomass, wind and water power,
- energy storage, notably using hydrogen and fuel cells.

They propose reliable, high-performance solutions in step with the latest developments in renewable energy. These energy sources are often intermittent and require grid-management systems that can accept input from numerous local production sites while maintaining energy availability. This approach must deal primarily with problems in the building and transport sectors, environmental impact and the use of new technologies.

COMPETENCIES

GIANT has brought together the multi-disciplinary forces required for new energy technologies. Materials science, electrochemistry and electromagnetism are all required to produce materials with properties adapted to energy needs. Integration of these materials in components, notably fuel cells, batteries and micro-turbines, calls on in-depth knowledge in assembly techniques, electrical engineering, thermodynamics and thermo-hydraulics. These components are then used in devices or demonstrators. These developments are all based on numerical simulation and modelling, ranging from the atomic scale (e.g. ab-initio calculations on the structure of a bi-metal catalyst for fuel cells) to macro-systems such as the management of an electrical distribution network comprising wind power, photovoltaic sources, and buildings.

The design, manufacture and testing of demonstrators are made possible thanks to the presence of the many technological platforms on the GIANT site.

STRUCTURE OF RESEARCH ACTIVITIES

The teams work together on a number of different topics:

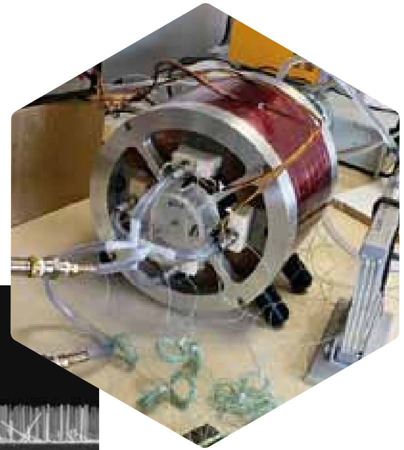
- solar (photovoltaic, PV) energy, including cell materials, processes, heterojunction cells, colorant cells, organic and inorganic cells, optimisation of PV modules and measurement of panel performance,.
- hydrogen research, including storage using hydrides, tanks, electrolysis and fuel cells.
- energy storage, including batteries, super-capacitors, materials and service lives and superconducting storage,
- energy management and efficiency, including distributed generation, impact of renewables on energy networks, energy conversion using power electronics and lighting,
- energy components and processes, including heating and refrigeration systems, exchangers, efficient industrial processes and electrical conversion systems,
- micro-sources and portable energy, including micro-batteries and micro fuel cells, flexible batteries and sources with energy recovery,
- energy applications in the home, including modelling, flow management and solar thermal energy,
- electric and hybrid vehicles, including hydrogen based, traction systems, energy conversion and management, storage and the convergence of transportation and housing.

Four examples of research work are presented below:

Solar energy

Solar energy takes two main forms, photovoltaic and thermal. Photovoltaic systems deliver electric current and thermal systems provide heat or refrigeration.

- Current goals in photovoltaic research are to reduce production costs for silicon PV cells already on the market by developing manufacturing processes for metallurgical silicon adapted to PV applications and to develop cells offering higher efficiencies via low-cost processes. Among the new types of cells are thin-film cells (CIGS, CdTe) or more innovative designs using nanomaterials (colorant cells, cells with nanowires or nanocrystals made of semi-conducting materials). The use of nanomaterials makes it possible to achieve efficiencies greater than 30% at a cost acceptable to the market, i.e. one1 euro per watt. Research is also working on integrating the cells in modules and panels to optimise the overall PV system.
- In the thermal field, work deals essentially with developing high-performance collectors with long service lives, high-performance storage systems and optimisation of components capable of supplying both heat and refrigeration.



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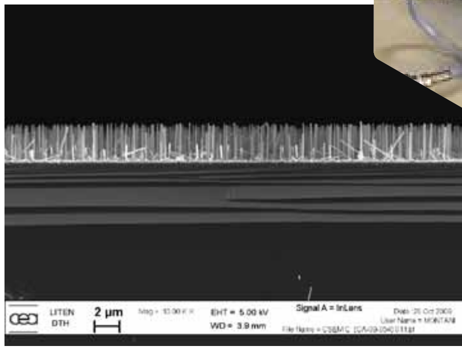
Refrigeration system implementing the magnetocaloric effect



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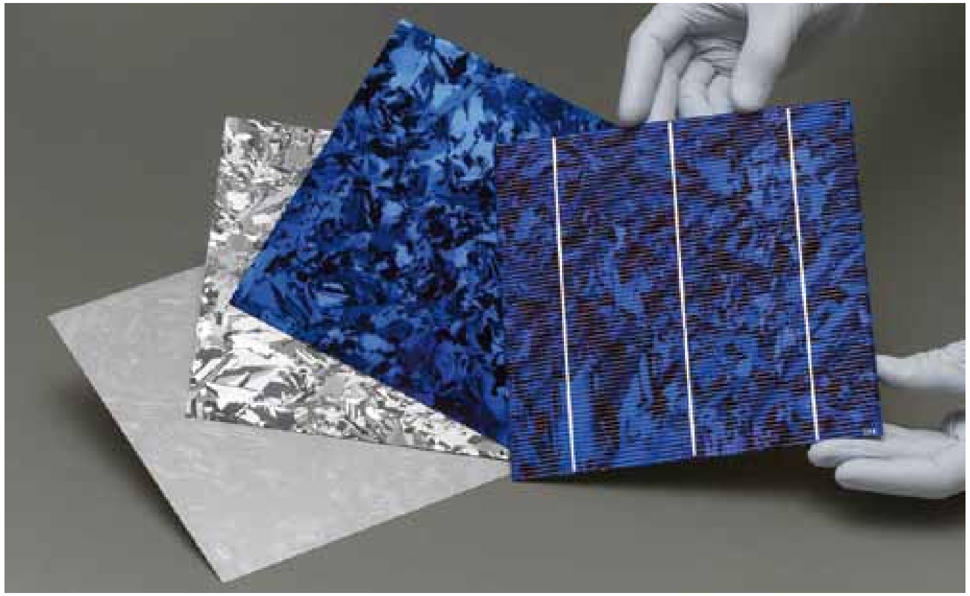
Silicon nanowires for photovoltaic cells



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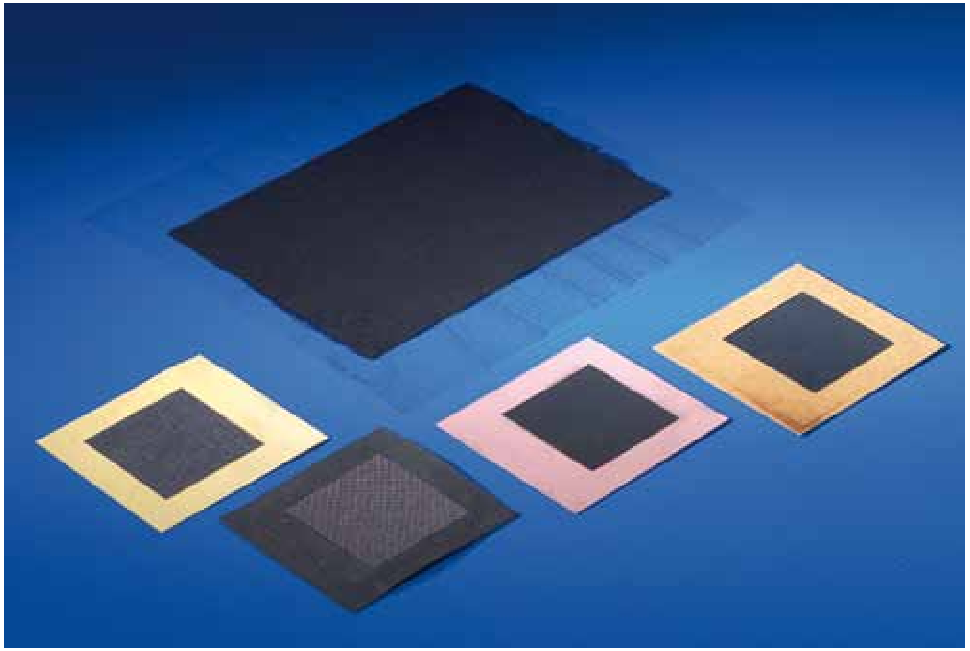
Photovoltaic cells at different steps in the manufacturing process



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Membrane-electrode assembly for a fuel cell

◗ Hydrogen

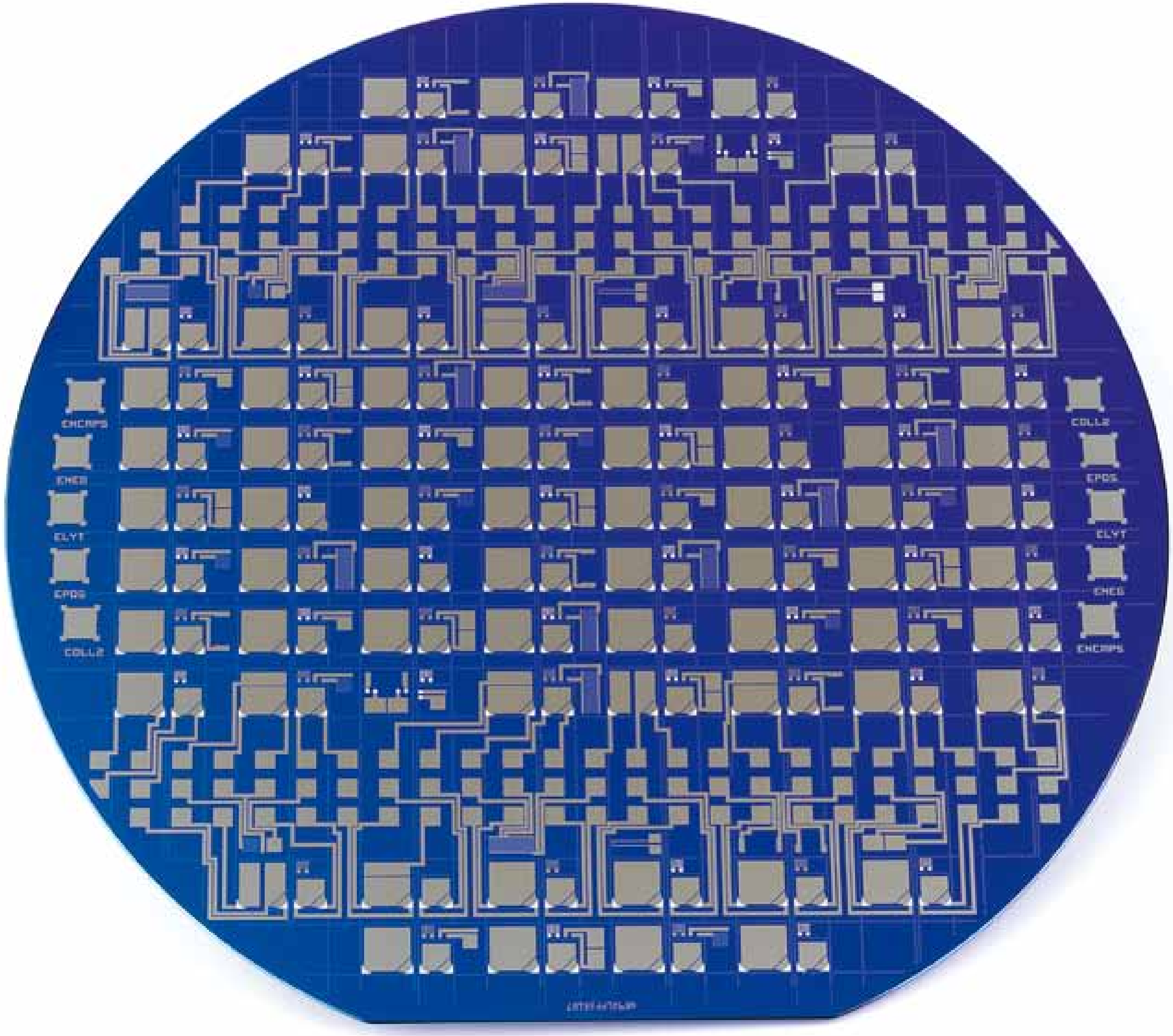
Hydrogen will be a key future energy vector, producible via technologies that do not emit greenhouse gases. Research in the field is extremely varied. Studies address hydrogen production via water electrolysis (alkaline electrolyte operating at low temperatures and high-temperature processes requiring ceramic electrolytes operating at 700 to 900°C) and biomass. Possible storage solutions include solid hydrides and high-pressure techniques. The development of new, high-performance materials and their integration in tanks make it possible to test complete storage systems. Finally, systems to convert hydrogen into electricity using different fuel-cell technologies are also studied. These complex systems require know-how in electrochemistry, corrosion, assembly techniques, thermo-hydraulics and thermo-mechanics. Initial versions of PEM (Proton Exchange Membrane) fuel cells have been produced. Future challenges concern the reduction in the quantity of platinum required for reverse electrolysis and an increase in fuel-cell service life because there are currently degradation problems that are poorly controlled and kinetics poorly suited to use in vehicles.

◗ Micro-sources

Micro-sources, also called miniature energy sources, supply a few watts and are intended for mobile applications such as mobile telephones and computers. Their development will make available reliable, autonomous sources offering operating times longer than the batteries currently on the market. The small size required for these applications has made it necessary to develop technologies very different from those used for standard applications. For example, a micro fuel cell implements microelectronics techniques such as etching and serigraphy. The goal is to develop high-performance systems (1000 mW/cm^2) at low cost.

◗ Energy efficiency

Energy management is used in very different fields including vehicles, industrial processes, buildings, and electrical networks. The goal is to develop simulation models to optimise energy systems by adapting supply to demand. For example, the use of intermittent energies such as wind and photovoltaic sources requires storage systems to meet the needs of users with different schedules. This modelling approach is pursued in parallel with the development of high-performance components such as heat pumps and thermal and electrochemical storage systems.



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Micro-batteries on a silicon wafer

IN BRIEF

In Grenoble, research on new energy technologies is structured around the Carnot Institute for Future Energies. Known for its scientific excellence and success in technology transfer, the institute operates on the national level and brings together the CEA, CNRS, Grenoble-INP and UJF laboratories.

On receiving the future GreEn (Grenoble Energies Nouvelles) centre, the GIANT site will be home to a majority of Carnot Institute members. The range of scientific fields addressed is remarkable, ranging from materials to large energy networks and including energy components and processes, electrical and thermal vectors, and research on hydrogen applications.

The multi-faceted character of the site is an advantage in terms of:

- *the goals and resources shared by the members of the Carnot Institute,*
- *the scale of the laboratories and the large-scale research facilities for physics,*
- *converging topics with micro and nanotechnologies at MINATEC and intelligent systems and software at Minalogic*

1.3.2 FUTURE NUCLEAR TECHNOLOGIES //

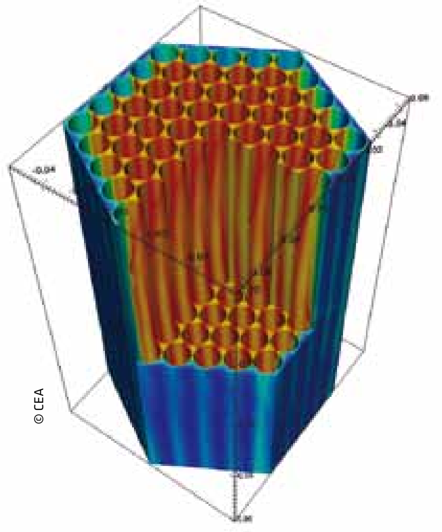
One of the major challenges that will have to be met during this century is the supply of energy. Given foreseeable population growth (8 to 9 billion in 2050) and the legitimate desire of emerging countries to live better, major increases in energy demand are expected. Even if fossil fuels were unlimited, which is not the case, it would be necessary to limit their use to ensure the climatic stability of the planet. The challenge will be to move away from virtually exclusive use of fossil fuels.

To that end, it is necessary to implement a three-pronged policy of energy savings, renewable energy and nuclear energy. It is by adding these three factors and not opposing them that we may hope to meet the challenge.

PHYSICS OF NUCLEAR REACTORS

To make nuclear energy «sustainable», two priories must be set:

- to optimise use of uranium and thorium resources, and
- to minimise the impact of nuclear waste on the environment and on society.



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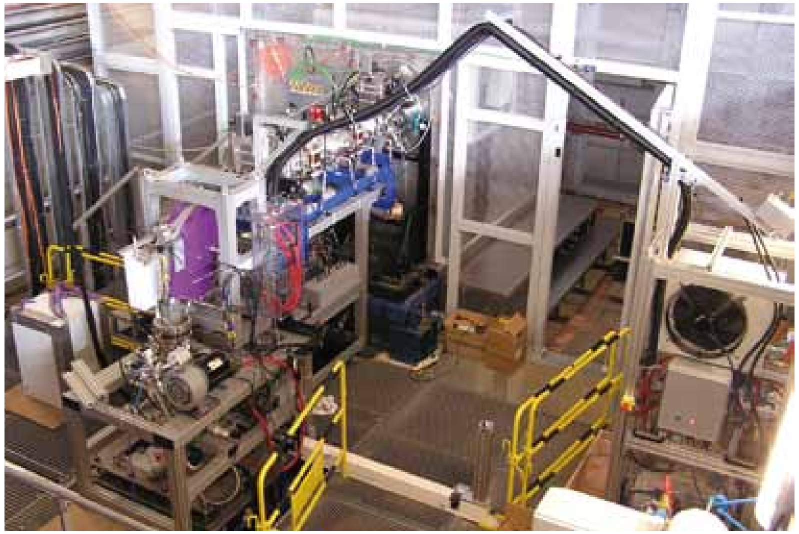
Temperature simulation (Trio_U) of sodium in a control rod assembly



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The GENEPI-3C accelerator of the GUINEVERE project

The two lines of research mentioned above are addressed by the Grenoble partners (CNRS, Grenoble-INP, UJF) in the reactor-physics group studying the thorium-uranium cycle, capable of breeding new fissile matter. This innovative solution, used in molten-salt reactors, is one of the reactor concepts selected by the Generation IV international forum for future nuclear applications. The possibility of transmuting minor actinides produced by the current generation of reactors is also being studied in a subcritical reactor driven by accelerators. These studies are carried out in collaboration with the major players in the nuclear industry (Areva, EDF) and national (CNRS and CEA) and international (European FP7) laboratories.

THERMO-HYDRAULIC SIMULATION

CEA designs, develops and validates simulation software for the study of nuclear reactors. With this software, studies are carried out, primarily in the nuclear field at the request of its partners (AREVA, EDF, IRSN, etc.). Examples of the software produced include:

- the CATHARE system, designed to simulate all the circuits in a reactor to study conditions under normal operation and during transient incidents and accidents. The software has undergone extensive validation procedures. It is heavily used by partners for studies and in preparing system safety documents,
- Trio_U (computational fluid dynamics software), offering advanced functions for in-depth turbulence analysis and interface monitoring, with the recent addition of reactive flows. The software can be massively paralleled and coupled with Cathare,
- GENEPI, for the simulation of vapour generators, using porous media models,
- Neptune_CFD, co-developed with EDF, for 3D modelling of two-phase flows.

Software validation is carried out using experimental facilities and dedicated instrumentation. All the above know-how makes CEA a leading institute worldwide for thermo-hydraulic studies in the design, functional analysis and safety studies of nuclear reactors, at all scales ranging from the microscopic up to complete systems.

TRAINING

Thanks to the UJF/Grenoble-INP tandem, Grenoble is one of the three nuclear-training sites in France, with the Ile de France and grand Ouest regions. Each year, Grenoble-INP, via the PHELMA school, trains over 40 engineers specialised in reactor-core physics, who then go on to the research and development and the operations/safety departments of the major nuclear firms. UJF has for a number of years offered Masters courses on various aspects of nuclear energy, including radioprotection, management of radioactive waste, reactor dismantling and clean-up, and nuclear safety. The 50 graduates each year occupy engineering positions in the sector.

In 2005, Grenoble-INP and UJF set up a joint platform called PEREN, dedicated to experimental training in nuclear instrumentation.

© LPSC

Graphite moderator block with channels for the insertion of various materials (PEREN Neutronics platform)

PEREN PLATFORM

Set up at LPSC (CNRS, Grenoble-INP, UJF), PEREN (platform for study and research on nuclear energy) comprises a number of facilities:

- *the PEREN Neutronics platform, based on a deuteron accelerator (250 keV) used to generate 14 MeV neutrons via a D-T fusion reaction. The neutrons are used in moderator blocks to measure the effective cross-sections for capture, fission or elastic scattering. These measurements are of interest for future nuclear reactors.*
- *the PEREN Chemistry platform includes a system of three glove boxes linked to an oven for preparation of fluoride salts used by the PEREN Neutronics platform and in the molten-salt loop.*
- *a forced-convection circulation loop for molten fluoride salts is being constructed and should be operational by the end of 2010. The goal of the loop is, first, to validate technologies implementing thermofluids (molten salts) at high temperatures and, second, to study the process of «on line» cleaning of the fluids by circulating helium bubbles.*

1.4 LIFE SCIENCES

1.4.1 PROTEINS, AN ESSENTIAL PART OF LIFE

Genome sequencing has resulted in considerable progress in genetics in recent years. The characterisation of alterations in the sequence of certain genes, which may cause serious disorders, has led to major advances in the health sector. Comparative analysis of the sequences of different genomes is the means to study fundamental questions, notably concerning the evolution of living organisms.

Genes contain the information required for protein synthesis. Proteins are macromolecules that ensure the great diversity of cellular functions, from enzyme catalysis to the structuring of living matter. In parallel with large-scale studies of genes, new fields have recently opened in the analysis of proteins and their functions.

RESEARCH ACTIVITIES

Biology teams on the GIANT site (from various national and international organisations and universities including CEA, CNRS, EMBL, ESRF, ILL, INSERM, INRA and UJF) have placed protein studies at the heart of their work and have thus assumed a front-ranking position in the field. The projects analysing living diversity and complexity attempt to understand biological processes on the molecular scale by investigating the complex architectures of the proteins involved, observing their dynamic interactions with other partners and working to understand their reactions. This research, which requires the development and implementation of advanced technological tools, is divided into three main parts:

- understanding the structure and dynamics of proteins, based on structural biology conducted on the European scale,
- understanding the chemistry of life and extending it to the study of new problems, essentially those related to metals in biology,
- integrating molecular information on a larger scale and linking the information to biological functions, based on the biology of integrated systems.

This orientation is strategic in that it feeds into other, more finalised work on biotechnologies and technologies for the life sciences and health care. Through their interaction with the nanotechnology teams to develop innovative tools for life science analyses or energy production, the university teams on the GIANT site constitute a unique group that has succeeded in establishing solid links between fundamental and targeted research. The knowledge gained via this research work contributes to solving major social issues in the fields of health care, the environment, biotechnologies, energy and agriculture..

Biological research on the GIANT site fits in well with the overall strategic vision of the Grenoble region:

- research on the GIANT site concentrates on the functional and structural biology of proteins, taking advantage of the large European research facilities, and acts as the interface between fundamental research on the one hand and technological and biotechnological research on the other,
- the university campus groups focus on the structuring operations in the Health Cluster and the BISy (integrative and systemic biology) project. In close collaboration with GIANT, the goal of the BISy project is to organise future research and training in the life sciences in Grenoble.

This organisation is based on a large community spanning the chemistry/biology/health/environment fields, on the interfaces between fundamental biology and chemistry, pharmaceuticals, physics and mathematics, on applied research (health, environment, energy), on the technological platforms, on the university experimental biology centre and on technology transfer (Nanobio, Biopolis, etc.).

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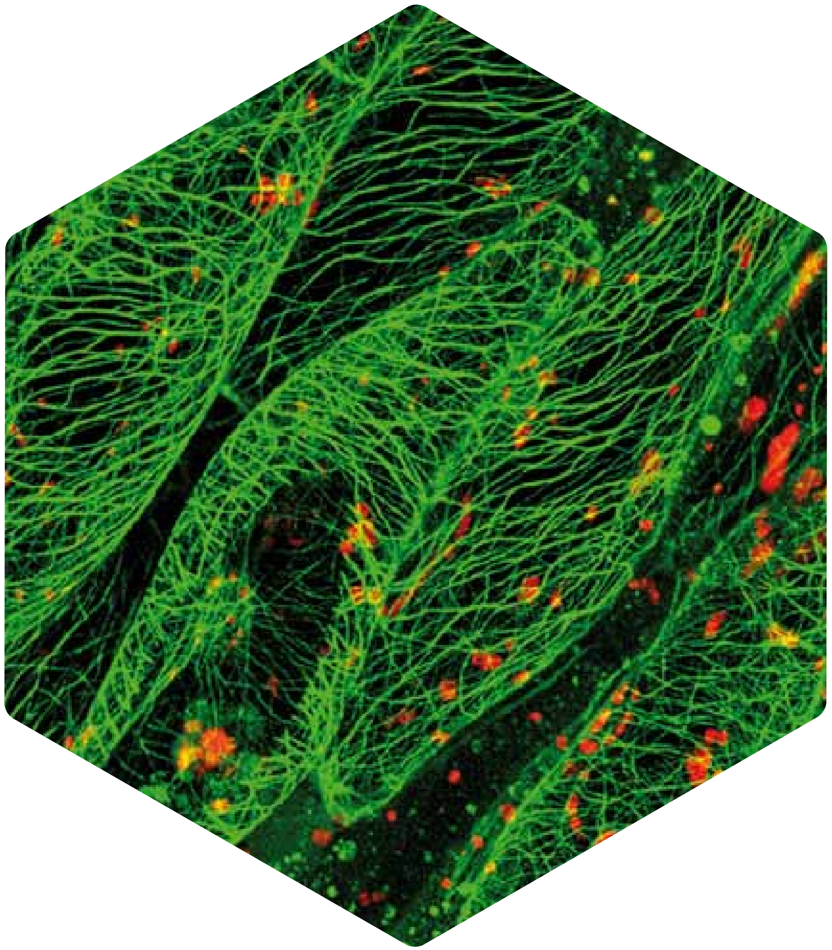

Confocal microscope image, employing a green fluorescent protein, of the network of proteins of the cytoskeleton in plant cells. The chloroplasts show up thanks to the red fluorescence of the chlorophyll

1.4.2 STRUCTURAL BIOLOGY ON THE EUROPEAN SCALE

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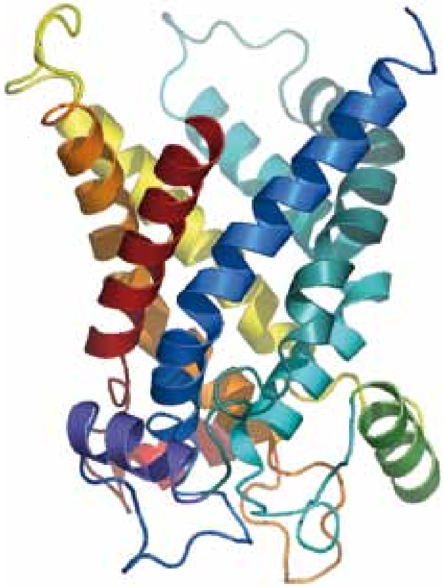
The goal of structural biology is to understand the structure of proteins and other macromolecules in living organisms (DNA, lipids, sugars) on the atomic scale and to relate this knowledge to their dynamic properties. Calling on biochemical, enzymatic and functional data, structural biology has made decisive progress in understanding the functions of proteins. Once the biological mechanisms are understood at the molecular level, unravelling the mysteries of life requires an understanding of the supra-molecular assemblies at the cellular scale and above.

The challenge for the coming years will be to innovate with experimental approaches for the study of unstructured proteins that are often implicated in neurodegenerative diseases, membrane proteins that act as gateways between cells, large assemblies such as viruses and, generally speaking, the processes by which a host cell recognises and integrates pathogens. Taken together, this work should result in a clear molecular representation ranging from the nanometric to the micron scale. In terms of final objectives, this research work addresses the fundamental questions that will lead to developments in the environment, energy, health care and agriculture fields:

- studies on the functional and structural characteristics of proteins involved in the interaction between pathogenic bacteria and hosts pave the way for new strategies for the control of bacteria,
- greater understanding of viruses (assembly, recognition and entry in the host cell, replication mechanisms, etc.) will contribute to progress in infectious diseases,
- nano-machines based on organisms living under extreme conditions are studied for their capacity to supply materials or mechanisms that can be used in nano and microtechnologies.



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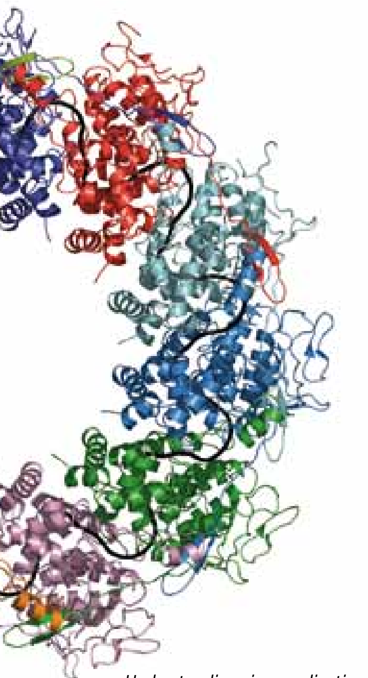
Structure of a protein that transports nucleotides through the membrane of a mitochondrion

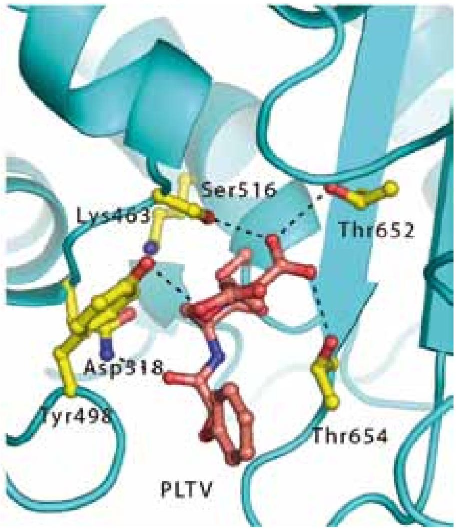
TOOLS TO UNDERSTAND STRUCTURES AND DYNAMICS

The presence of neutron and synchrotron radiation sources is a major advantage for the site. The expertise and additional resources that have grown up around the large-scale research facilities make it possible to study the structure of isolated proteins, supramolecular assemblies, the dynamics of these molecules and their interactions. Examples include crystallography, small-angle diffusion, electron microscopy (shadow casting and cryomicroscopy), high-field liquid NMR (800 MHz with a cryoprobe), enzymatic reactions on the atomic scale and studies on interactions using biophysical methods (AUC, SPR, ITC). Site teams are developing new tools to study difficult proteins (unstructured, membrane, etc.) or viral particles made up of a large number of proteins and nucleic acids:

- Approximately 60% of medicines target membrane proteins. Developments in the production and crystallisation of these proteins together with progress in micro-crystallography have resulted in significant advances.
- Intrinsically unstructured proteins, involved in neurodegenerative diseases, aggregate during pathology. NMR is a unique tool to study the dynamics of these proteins. Site expertise in NMR made it possible to identify the nucleation sites for aggregation in the structure of proteins involved in such diseases.
- Viral particles are large objects that can be observed using an electron microscope. Expert knowledge in cryomicroscopy and image analysis has resulted in a representation of the entire virus. By adding the partial results of crystallography, processing made it possible to observe the virus at a virtually atomic scale.



Understanding virus-replication mechanisms in the host cell (above) or resistance mechanisms to antibiotics (below) is important for the development of new medicines



MAIN TOPICS

Two main topics are addressed on the site:

◗ Structural infectology

The emergence of new pathogens and bacterial resistance mechanisms to antibiotics are phenomena of great concern to human health. Efforts to counteract these phenomena are required on all levels, in particular for the design of new, more precise treatments. Treatments work on the molecular level, for example by blocking an efflux pump that would reject the antibiotic from the bacteria, by blocking interaction between a virus and a receptor on the surface of a cell, or by inhibiting a viral enzyme required for viral replication. Fundamental knowledge on pathogenic organisms, their interaction with host cells, entry mechanisms into cells and the immune responses of the host organism are clearly essential.

This focus on structural infectology developed over the years has been reinforced by the creation of the RTRA project Finovi in Lyon which provides the molecular and cellular work in Grenoble with medical-research support. The Grenoble site is well known for its work in structural virology, in particular using electron cryomicroscopy. Current understanding of the interaction mechanisms between viruses and host cells implies the existence of cell-surface receptors and very special oligosaccharides. The life cycle of pathogenic bacteria reveals essential mechanisms for their growth and their pathogenicity. The identified proteins involved are thus potential new targets for antibiotics.

◗ Understanding life under extreme conditions

For certain organisms such as *archaea*, living in ocean hot springs, optimum living conditions include very high temperatures, high pressures or high salt concentrations. Some of these organisms have adapted to extreme conditions and can resist high levels of radiation or concentrations of metals. Structural biology, coupled with chemistry, is the means to understand how enzymes function under conditions close to those at the origin of life. It can also be used to dissect new enzymatic machineries. These protein nanomachines, invented by living organisms and perfected by evolution, can be used for technology. The full potential of this topic depends on the expertise at the chemistry-biology interface that is available on the site. The strong links with technological research at the nanometric level ensure rapid transfer from nanomachines in the laboratories to their potential applications.

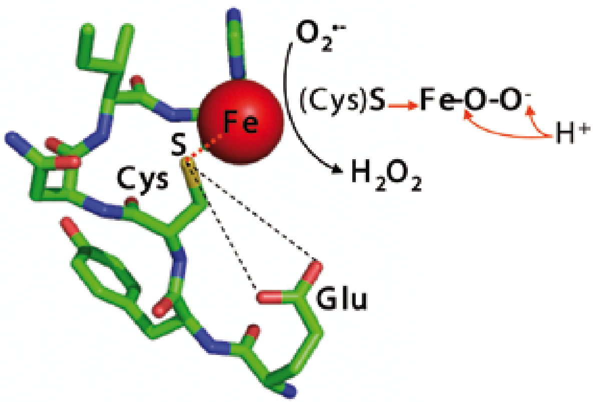
IN BRIEF

Participation of all structural-biology players in the Partnership for Structural Biology (PSB) and the presence of the large-scale research facilities have made the GIANT site a unique centre for structural biology in Europe. Thanks to the GIANT teams molecular mechanisms are now understood in intimate detail.. In coming years, the objective will be to link knowledge on the molecular level with that on the cellular level. The goal is to describe molecules on the quasi-atomic level (structure, dynamics, association) in the overall context of cells (signal channels…).

From the very start, the unique context of GIANT has drawn world-class scientists such as Professors Ada Yonath and Venkatraman Ramakrishnan, 2009 Nobel Laureates in Chemistry. Ada Yonath has worked with researchers in Grenoble for over 20 years and made use of the ESRF as soon as the beam lines became available to study the most intimate structure of ribosomes. In addition, she has been a lecturer in the HERCULES courses for ten years. Venkatraman Ramakrishnan also carried out part of his research on the same subject at the ESRF, as a regular user for several years.

IN BRIEF

At the interface between chemistry, biology, physics and mathematics (particularly modelling), research on metals in biology in Grenoble benefits from close proximity with research in structural biology and integrated-systems biology. This makes it possible to refocus molecular knowledge of metals in biology at the cellular level and more generally at that of the organism. In the years to come, this unique environment will produce new, fundamental knowledge and encourage the development or more technology-oriented research in the fields of energy, the environment and health care.



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A unique technology made it possible to «photograph» the intermediate steps in a new detoxification reaction of the superoxide radical

1.4.3 PROTEINS AND METALS - RESEARCH AT THE BIOLOGY-CHEMISTRY INTERFACE

The tradition in Grenoble of chemistry research at the interface with biology, which has been reinforced over the past 20 years in the fields of DNA and bio-organic chemistry, has developed particularly in the field of chemistry and biology of metals. Bioinorganic chemistry, a field at the crossroads between biology, chemistry and physics, studies the structure and reactivity of biological metal sites that take part in a wide variety of vital biological processes. Using chemistry to study the fundamental mechanisms of life, in particular to analyse in depth the structure and reactivity of natural molecules, it is possible to:

- Understand the chemistry of life, including the molecular mechanisms involved in biological processes,
- extend the notions of the chemistry of life to formulate new reactants, including biomimetic catalysts for chemical synthesis, energy, and the environment,
- provide biologists with new tools in the field of biochemistry applied to health care.

In biology, metals are paradoxical in that they are both essential and toxic. Certain metals are vital for cells because they participate directly in the biological processes. For example, many proteins have at their active site a metal that is the main agent in their function and the source of characteristic physical and chemical properties that directly reflect the environment of the metal and its modifications. On the other hand, the natural toxicity of metals means that accumulations in the environment can become very dangerous. That is why, in both cases, metal homeostasis is essential for the survival of living organisms. Homeostasis is the physiological process maintaining constant certain values in the internal environment of an organism (all liquids in the organism) required for correct operation, i.e. within tolerances for normal values.

These questions constitute the basis of the research carried out on the GIANT site, dealing with the structure and reactivity of biological metal sites (for the design of new catalysts and biocatalysts) and metal detoxification and homeostasis. The potential of this research, which considers micro-organisms as well as plants and animals, is vast:

- to develop new concepts in the chemistry of life, notably concerning activation of small molecules (O_2, H_2O, H_2, H_2O_2, etc.) by attempting to understand the molecular mechanisms and the role of metals in vital biological processes,
- to identify new biotechnological fields for implementation, such as energy, health care, agronomy or the environment. Examples are applications in hydrogen production, the development of new antioxidants, and the biodegradation of aromatic hydrocarbons and detoxification of heavy metals.

MAIN TOPICS

Two main topics are addressed on the site:

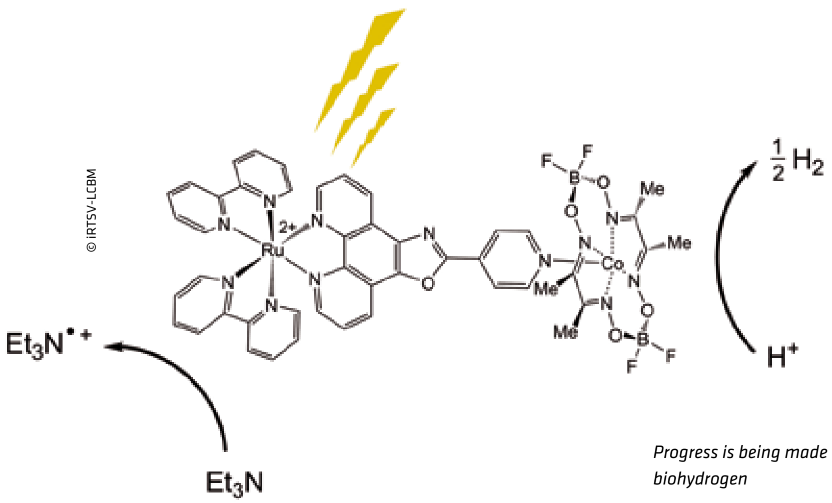
◗ Structure and reactivity of biological metal sites for new catalysts and biocatalysts

What is the purpose of mimicing the active site of enzymes? Today, chemistry cannot match the selectivity and efficiency of many biological reactions. Understanding better the molecular solutions found by life for complex chemical problems will make it possible to implement those solutions in new chemical processes (biomimetic biocatalysts, complexants, sensors). This bio-inspired approach lies at the heart of current research. For example, the study of bacterial enzymatic oxidation systems involved in biodegradation of oxidation-resistant hydrocarbons (catechol, pyrene, chrysene, etc.) targets the development of metal complexes capable of oxidising hydrocarbons. More generally, the goal is to study reactions that are difficult to control (oxidation of alkanes into alcohol and, generally, oxidation of C-H bonds, hydrolysis of P-O bonds in phosphodiesters...). Finally, it is necessary to develop new «green» catalysts that do not pollute the environment. Work on hydrogenases and the development of bio-inspired chemical models mimicking its activity has the long-term goal of using renewable solar energy to produce hydrogen, thus reproducing the hydrogenases/photosystem pair present in photosynthetic micro-organisms that produce hydrogen. The production of hydrogen by the reduction of protons and the use of the energy of the H-H bond through oxidation (fuel cells) would appear to be a particularly attractive solution.

◗ Metal homeostasis and detoxification

Free or unbound metals are highly toxic *in vivo*. That is why they are generally present in cells in complex forms and concentrations of their free forms are low and carefully regulated. Certain regulation mechanisms modulate metal inputs and outputs. That is the case for copper which, in mammals, is assimilated via specific digestive-system transporters. Any excess is excreted into the bile by a membrane ATPase. For many metals, however, there is also a type of upstream regulation that influences the biosynthesis of proteins controlling homeostasis of the metals. The study of the various mechanisms resulting in multiple and different resistances in living organisms makes it possible to analyse the relation between ionic specificity and toxicity, to understand the fundamental mechanisms in homeostasis of heavy metals (regulation of relative concentrations on the two sides of membranes) and to identify bioremediation processes (biological depollution). This work is carried out on micro-organisms (bacteria, yeast), plants and animals. For example, differential analysis of the Arabidopsis thaliana proteome shows that over half of the biosynthesis enzymes for amino acids depend on metals, either for structural or regulation needs. Generally speaking, the control mechanisms involved in homeostasis regulation of metals concerns a number of very different systems:

- ◗ Inducible expression of gene coding for the proteins that ensure metal metabolism,
- ◗ passage of metals through membranes thanks to transport proteins (ATPases, ABC proteins, ion channels),
- ◗ implication of small, shuttle proteins transporting metals to various partners in signalling phenomena or for homeostasis.



Progress is being made in biomimetic systems to produce biohydrogen

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Protein biomimetic system to study cellular motility

1.4.4 INTEGRATED SYSTEMS BIOLOGY: PROTEINS IN THEIR ENVIRONEMENT

Genes, RNA, proteins and metabolites are the basic components of complex biological systems governed by physical and chemical properties that cannot be reduced to those of the basic components. The study of biological systems attempts to integrate different levels of information to propose functional models of entire systems. The goal is therefore to understand the interaction between the various parts of the system (cells, organites, protein, gene and metabolite networks, etc.) that enable communication within a cell or between the cells in an organism. This research tests potentially transversal concepts and mechanisms in living systems. To that end, the best suited experimental systems are selected, with interactions with other disciplines to adapt the tools of physicists and chemists (mass spectrometry, imaging, etc.) to the topics studied, as well as those of mathematicians and computer experts (models).

The biology of integrated systems thus begins with the study of the genes and proteins of an organism, attempting to determine the expression of genes, proteins and metabolites in response to a given disturbance. The task is then to shift from a basic organisational level to a more complex spatial or temporal level of organisation. The biological systems studied are those of micro-organisms (bacteria, yeast, and the Dictyostellium amoeba), plants (Arabidopsis thaliana) and animals (fruit flies, mice...). Research topics concern the integration of regulation networks for gene expression, defence mechanisms and cellular response to stress, and cellular compartmentalisation and signalling.

In parallel with the fundamental issues specific to each biological topic, the technological issues of the coming years will concern a number of different fields:

- In bioinformatics, the production at the molecular level of very large quantities of experimental data and knowledge will require the development of tools to integrate the data and derive meaning at the biological level,
- in biotechnology, the study of signalling and the interaction between cells or intercellular compartments is feeding into work on fields as diverse as health care and agronomics,
- at the interface between biology and technology, proteins that self-assemble or naturally structure themselves are studied to examine their capacity to supply materials or mechanisms for use in nano and microtechnologies.

TOOLS TO STUDY THE DYNAMICS OF BIOLOGICAL SYSTEMS

On the basis of the long-standing expertise of Grenoble laboratories in protein biochemistry, new technological competencies have been developed to study proteins in their functional context, whether isolated or within complexes or subcellular compartments:

- The proteomic platform develops computer tools for high-throughput analysis and management of proteomic data, and genome annotation, as well as innovative methods based on mass spectrometry for dynamic analysis of proteomes,
- the cellular imaging centre implements strategies of optical imaging (TIRF), confocal microscopy and electron microscopy for the structural and molecular study of the dynamics of cellular processes and molecular assemblies in cells,
- the screening centre for bioactive molecules attempts to discover active molecules and pharmaceutical targets by studying the physiological functions of proteins in their cellular environment.

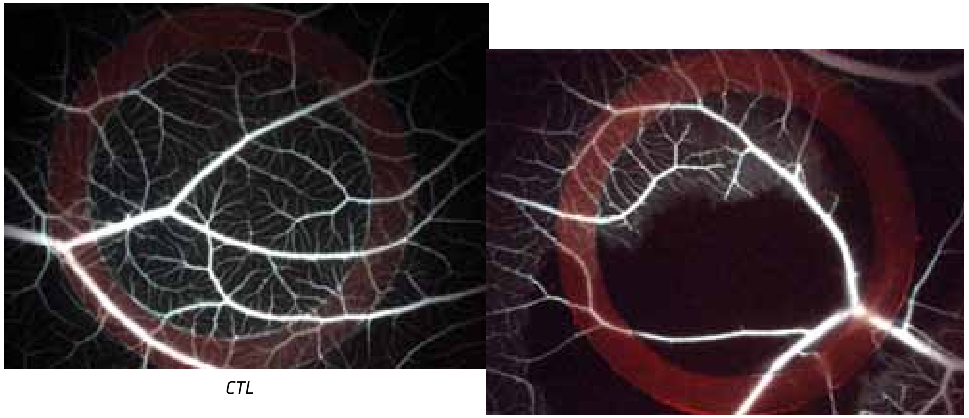
This research benefits greatly from the tools and know-how developed on site to study the structure of proteins and supramolecular complexes, as well as their interactions. It also addresses transgenesis, which makes it possible to reposition the operation of a protein within the context of the organism.

MAIN TOPICS

Two main topics are addressed on the site

Integrated response of organisms to modifications in their environment

Living organisms are capable of perceiving modifications in their environment and adapting by modulating their gene expression to set up a suitable response, e.g. defence mechanisms during an abiotic stress or aggression by a pathogen. Research on the site studies the two phases of this integrated response. First, the regulators (proteic or nucleic) of gene expression act on the transcriptional or translational level and form interconnected networks that must be characterised to understand the rapid changes in the proteomic «landscape». This field of research implements multi-disciplinary approaches linking protein chemistry and structural characterisation to cellular biology and genetics to understand biological phenomena as diverse as the appearance of flowers in superior plants, control of metal homeostasis or the creation of macromolecular machines to export toxins by pathogenic bacteria. Second, the goal is to identify the elements of the response to various stresses. For example, innate immune response constitutes the first line of defence against pathogenic agents. What is more, living systems implement complex redox chemistry and induce the synthesis of specific enzymes to produce, signal or control the production of reduced oxygen and nitric-oxide species.



The BMP9 protein controls the flow of blood in tissue around chicken embryos (CTL = control experiment)

Signalling and cellular compartmentalisation

An understanding of the fundamental laws governing cellular organisation (cellular division and morphogenesis, biogenesis of cellular compartments and the linked functions) is essential to learn how normal functions malfunction. An original aspect of GIANT is to base this work on innovative experimental strategies (microsystems). Thanks to high-performance proteomic analysis tools, an inventory of the proteins present in many subcellular compartments has been drawn up and their dynamics studied, thus making possible targeted functional analyses, e.g. study on the compartmentalisation of metabolic pathways, on protein addressing in cellular compartments, on signalling regulation by receptor endocytosis. In the same way as mutations are used in genetics, cellular screening is a means to explore, inside the cell itself, the proteome using chemical molecules to determine the function of the proteins targeted by the ligands. Finally, approaches implementing transgenesis, gene extinctions or microinjections can be used to reposition observations in the physiological processes at the level of the entire organism. Coupled with imaging techniques, these experimental approaches enable analysis of the main intracellular signalling channels and their regulation, as well as the molecular mechanisms governing, for example, cellular proliferation and vascularisation in healthy and tumorous tissue.

Starting with in-depth knowledge, at the molecular level, of proteins and their partners, the goal in this field is to describe interaction networks and understand the function of biological systems at higher levels of integration, thus providing fundamental knowledge for the development of new fields of research, particularly in biotechnology and technologies for the life sciences and health care.

The steps in proteomic analysis. (a) Cutting of gel strips containing targeted proteins separated by electrophoresis. The proteins are then analysed using mass spectrometry. (b) High-precision mass spectrometer and nano-flow liquid chromatography. (c) The protein fragments (peptides) to be analysed are dispersed by the electrospray of the mass spectrometer.

PROTEOMIC PLATFORM

The purpose of the CEA proteomic platform is to contribute to understanding biological processes by developing advanced methods in mass spectrometry applied to protein analysis. The mission of the platform is to:

- *develop new methods to address fundamental and applied issues, in particular in the fields of health care and the environment,*
- *open its doors to the academic and industrial sectors,*
- *stimulate scientific progress and training in the field of proteomics.*

The research focuses on:

- *identifying and quantifying pathology markers in biological fluids,*
- *quality-inspection techniques for water, air and food,*
- *analysing the dynamics of cellular proteomes in a context of integrative systems biology.*

Techniques include:

- *very high-resolution mass spectrometry for quantitative, high-throughput analysis of complex biological samples,*
- *absolute quantification of «target» proteins in complex biological samples,*
- *characterisation and quantification of post-translational modifications in proteins,*
- *development of software for the management and analysis of mass-spectrometry data.*

2

RESEARCH & TECHNOLOGY TRANSFER FOR THE GREATER BENEFIT OF SOCIETY

2.1 RESEARCH/INDUSTRY TECHNOLOGICAL PLATFORMS

The development of new products and services in the IT, communication, transportation, housing and health-care sectors requires integration of increasingly numerous and diversified functions in components and systems.

Only multi-disciplinary centres equipped with large-scale technological resources can play a role at the international level.

- Multi-disciplinary centres. Functional integration concerns electronic (data processing), electro-magnetic (communication) and electro-optical (image systems) components as well as chemical (sensors) and biological (diagnosis, therapy) devices. In addition, software is embedded to allow products and systems to fulfil their functions.
- Large-scale technological resources. Integration of nanometric components requires increasingly advanced and expensive manufacturing and characterisation resources. Powerful CAD tools are necessary to design components.

CEA, CNRS, UJF and Grenoble-INP have established integration platforms for a wide array of electronics applications and new energy technologies. These platforms are locations for intense collaboration between research and industry.

With CEA-LETI, Grenoble is the only public-sector site worldwide with both a complete 300 mm integration centre (i.e. capable of processing 300 mm diameter silicon wafers) for ultimate CMOS applications and a 200 mm heterogeneous integration centre for «More than Moore» work.

The platforms have contributed, often decisively, to numerous European projects, e.g. Joint Technology Initiatives or European Technology Platforms, involving the major microelectronics foundries such as STMicroelectronics, SOITEC, IBM, Infineon, Quimonda, NXP, Freescale and NEC, and production equipment manufacturers such as Applied Material, TEL, FEI and Mapper Lithography. In addition to these world-class integration facilities for nanotechnologies, the GIANT site offers integration capabilities for biotechnologies and new energy technologies.

GIANT can thus participate in integrating an array of new technologies without barriers between nanomaterials, nanotechnologies, biotechnologies and renewable energies, embedding the necessary intelligence within the components and systems. All these developments will take into account sustainability and environmental-protection factors, e.g. raw material savings, risk management for the synthesis of nano-objects, gradual replacement of traditional chemistry with «green chemistry» and life-cycle analysis. The site is thus one of the major players in the Minalogic, TENNERDIS and LyonBioPole techno-clusters.

2.1.1 NANOTECHNOLOGIES

300 MM SILICON PLATFORM

The LETI 300 mm technological platform makes GIANT one of the six world-class R&D centres for nanoelectronics, with Albany and Sematec in the USA, AIST in Japan, IMEC and FhG-CNT in Europe. The 300 mm platform in Grenoble can produce nanometric devices incorporating the latest materials and the most advanced manufacturing techniques to meet the specifications of the 22 nm and 16 nm technological generations. It has been certified by leading industrial sites such as STMicroelectronics in Crolles, France and IBM in Albany, USA, to validate the integration of new technological "building blocks" in circuits manufactured on these sites. A complete 300 mm lithography cell has been installed to reach a resolution of 10 nm and to explore new architectures capable of limiting process variability and thus continue progress in miniaturisation.

The 300 mm clean-room

The 300 mm lithography cell

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Miniature, high-resolution screen

© CEA-LETI / Ph. Stroppa

The 200 mm clean-room

The CEA-LETI 300 mm platform allows R&D programmes to be carried out in strategic partnerships with STMicroelectronics, IBM, SOITEC and the main equipment manufacturers involved in developing new manufacturing and metrology methods.

The four main programmes for «More than Moore» miniaturisation technologies address the fields below:

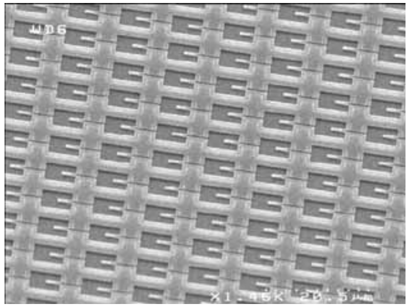
- Sub 32 nm lithography using optical technology (193 nm) and maskless technology. The 300 mm platform will be the only R&D site offering manufacturers of integrated circuits, masks and resin, and software companies the means to evaluate a new lithography system based on a technique employing multiple electron beams developed by Mapper, a European start-up.
- SOI (silicon on insulator) devices. The strategic partnership between CEA and SOITEC, the leading SOI-substrate manufacturer, and the excellence of GIANT partners in all SOI-technology development segments makes GIANT an uncontested specialist compared to the other world-class R&D centres and puts the CEA in a position to propose a viable solution for 22 nm technologies and beyond.
- Breakthrough architectures based on integration of nanowires and new logic and memory concepts that will benefit from the multi-disciplinarity of GIANT partners, the synergy between its platforms, notably for advanced technologies and characterisation, and the proximity of ESRF.
- Materials and the corresponding integration technologies, e.g. the new generations of substrates developed by SOITEC offering numerous new properties in terms of strain, thermal dissipation and electrostatic insulation, SiGe epitaxy, atomic-layer deposition, atomic-layer etching and surface preparation.

The platform also supports the development of differentiating technologies based on expertise in stacking and connection technologies, thus positioning GIANT partners at the heart of current product developments using embedded technologies.

200 MM SILICON PLATFORM

The CEA 200 mm platform can produce heterogeneous components, on a chip or in a system, using 3D integration, 2D stacking and interconnection techniques. This flexibility makes it possible to develop different technologies with industrial microsystem integrators or manufacturers from the traditional or semiconductor sectors.

The 200 mm platform has the resources for design, fabrication, quality monitoring and testing of small series of products. This «prototyping» phase makes it possible to test the market before transferring the technology to industry.



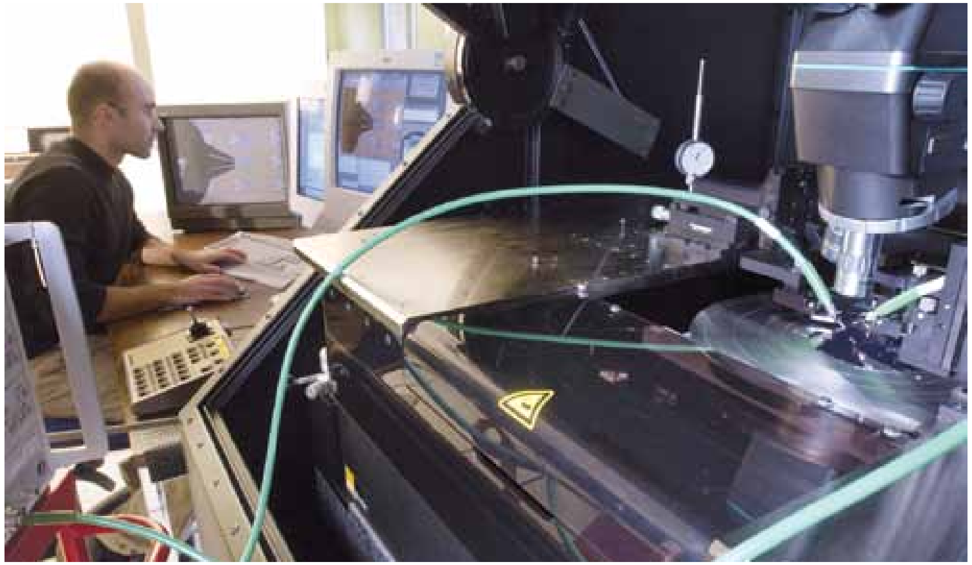
A nanoresonator (NEMS) network

A number of technologies are available, notably inertial sensors (magnetic sensors), visible-image sensors, micro bolometers (infrared), RF MEMSs, OLED microdisplays, silicon photonics and spintronics. They implement generic techniques for 3D integration, layer transfer (chip-on-plate or plate-on-plate) and packaging.

Via the HTA (Heterogeneous Technologies Alliance, grouping CSEM, FhG, VTT and CEA), the 200 mm platform is open to European industrial partners requiring access to an array of technologies that no single technological platform can offer on its own.

Strategic partnerships have been set up to handle aspects upstream of CEA-LETI activities. Concerning NEMS, for example, a partnership launched with Caltech at the end of 2007 resulted six months later in the first batches comprising millions of NEMS. A 30% gain in sensitivity for NEMS networks was achieved in 2008, paving the way for complex systems offering ultra-sensitive gas detection based on changes in the resonance frequency of nanoresonators. A joint marketing programme between CEA and Caltech will capitalise on these results.

The majority of the activity on the 200 mm platform lies within the framework of cooperation agreements between research and industry. Recent transfers include inertial sensors (produced by Freescale Japan), a 3D assembly system for image sensors (produced by STMicroelectronics), a micro-bolometer solution (produced by SOFRADIR) and integrated RF passive components (produced by STMicroelectronics).



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Measurements using RF probes

DESIGN CENTRE

Over 100 designers work in the CEA design centre, modelling, designing, producing (in conjunction with the 200 mm and 300 mm platforms and industrial companies) and testing complex integrated circuits. The centre collaborates with numerous companies, e.g. system suppliers such as Thales and Nokia, module and software producers such as Fujitsu, start-ups such as Movea and Kalray, and integrated-circuit manufacturers such as STMicroelectronics and Freescale. It provides access to foundries including the STMicroelectronics factory in Crolles, France or IBM in Fishkill, USA in order to validate new designs. Work in the design centre focuses on designing systems that make the most of the breakthrough technologies developed by CEA-LETI and on devising new functions based on current technologies available in the foundries. The combination of design, manufacture and characterisation is the means to validate innovative solutions that can be produced industrially, in a wide range of fields:

- controlled consumption, variability tolerance, redundancy
- heterogeneous circuits, 3D design
- CMOS and RF circuits (noise / crosstalk)
- new devices (FDSOI, multi-gate, RF MEMS, organic electronics)
- read circuits for infrared and visible medical imaging systems
- control circuits for near-sensor electronics.

© Grenoble INP / Alexis CHEZIERE

High-resolution scanning electron microscope

© Grenoble INP / Alexis CHEZIERE

X-ray room

© Grenoble INP / Alexis CHEZIERE

Raman spectrometer

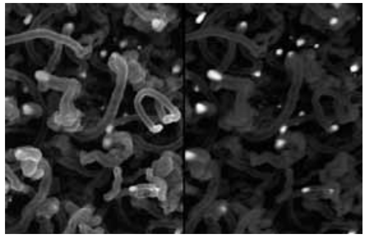
CONSORTIUM FOR SHARED TECHNOLOGICAL RESOURCES (CMTC)

Created in 1977 as part of Grenoble-INP, CMTC is a platform for physico-chemical and microstructural characterisation. It plays a fundamental role in supplying scientific and technical support for research (the materials, energy and micro-nanotechnology sectors at Grenoble-INP) and training. CMTC also provides services to other organisations and research centres, both in the public and private sectors. The characterisation resources at CMTC are split into four centres of excellence; electronic microscopy and the related analysis techniques, X-ray analysis, optical characterisation, and sample preparation. CMTC offers a number of approaches to handle the characterisation needs of its partners and clients, by:

- providing characterisation services required for research programmes carried out by Grenoble-INP and its partners,
- developing know-how and competencies,
- providing training in characterisation techniques,
- offering access to characterisation resources after training,
- providing characterisation services to other organisations, including over 100 companies in and around Grenoble and in the Rhône-Alpes region of France,
- developing new characterisation techniques.

Currently, the main lines of work concern:

- the development of Raman spectrometry in the far UV for characterisation of nano-objects in the framework of a partnership with CEA,
- the development of FIB (focused ion beam) preparation techniques in a partnership with the PFNC (nanocharacterisation platform) and PTA (upstream technological platform) platforms,
- the development of controlled pressure scanning electron microscopy.



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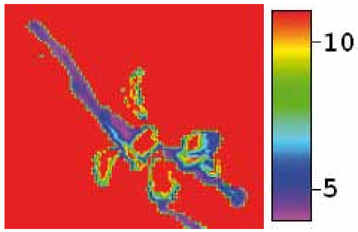
Images of carbon nanotubes



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Raman image of silicon microwires

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X-ray diffraction study of the crystal structure of a Ce oxide thin film

Transmission electron microscope

Electronic spectroscopy for chemical analysis

NANOCHARACTERISATION PLATFORM (PFNC)

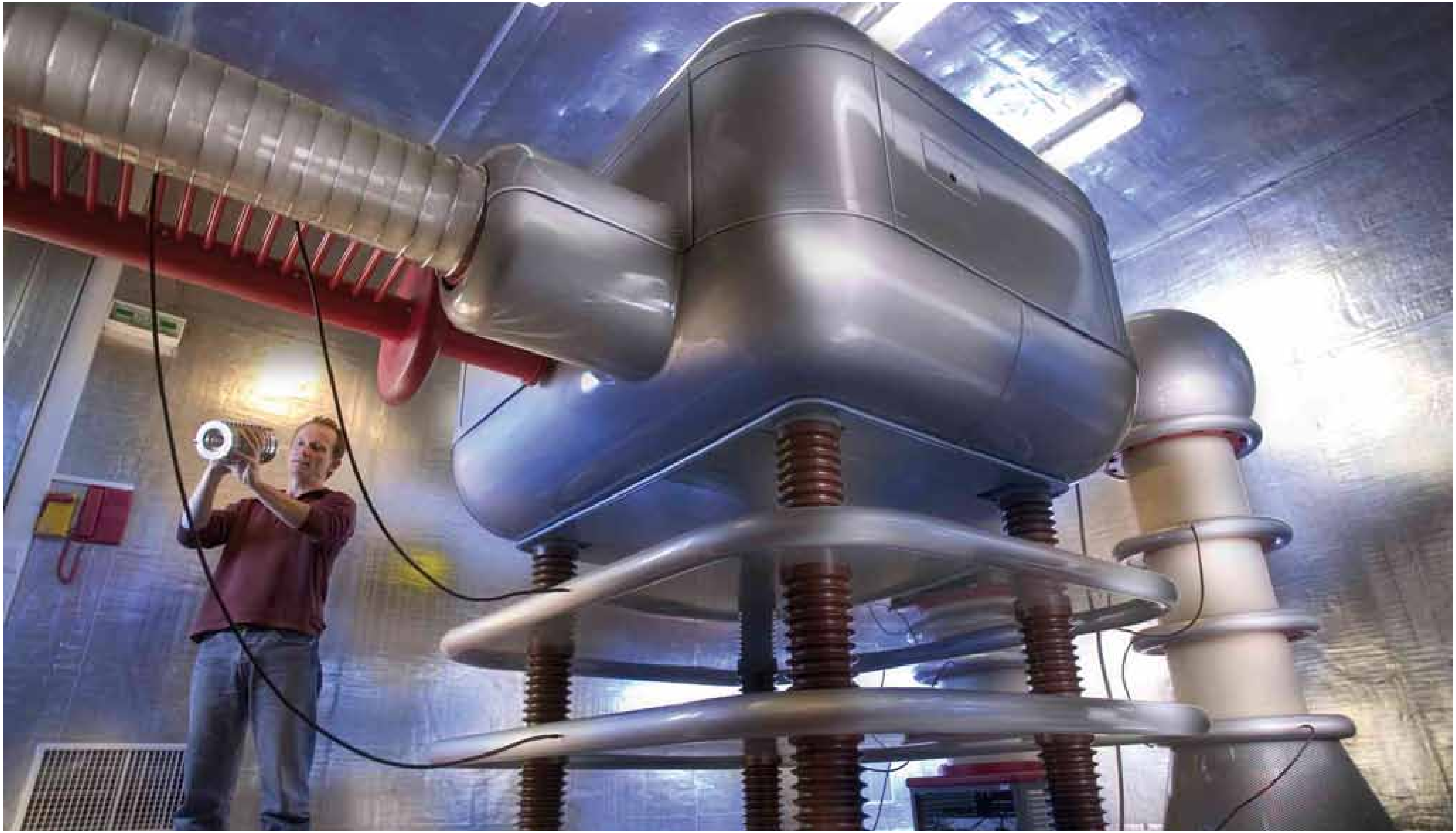
Founded in 2004 as part of MINATEC, PFNC combines the large-scale characterisation resources of the CEA institutes in Grenoble. Unique in Europe, the platform develops new techniques for physico-chemical characterisation in a number of fields, e.g. micro and nanotechnologies, nanomaterials, materials for energy and biotechnology applications.

PFNC characterisation resources are split into eight centres of excellence, i.e. ion-beam analysis, X-ray analysis, surface analysis, electronic microscopy, near-field microscopy, optical characterisation, mechanical testing and sample preparation. PFNC offers a number of approaches to handle the needs of its partners and clients in terms of physical nanocharacterisation. For this reason, it:

- develops new characterisation techniques,
- sets up joint national and international programmes to fund developments in characterisation techniques,
- carries out analyses needed by partners for a given field or technique,
- offers access to characterisation resources after training,
- provides standard characterisation services with CEA partners,
- provides training in characterisation techniques to partners,
- optimises equipment use through collaboration with a characterisation supplier (SERMA Technologie).

The main research orientations in characterisation are:

- visualisation of dopants of CMOS ultra-shallow junctions using a transmission electron holography microscope (STMicroelectronics, IBM),
- development of new X-ray analysis techniques (ESRF, XENOCS),
- development of standard and ion-beam preparation techniques (SERMA Technologie),
- characterisation of carbon nanotubes using XPEEM photoelectron imaging, and nanowires using scanning electron microscopy and Raman spectroscopy (Grenoble-INP).



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Medium-energy ion-scattering microscope

INTERUNIVERSITY CENTRE FOR MICROELECTRONICS AND NANOTECHNOLOGY (CIME NANOTECH)

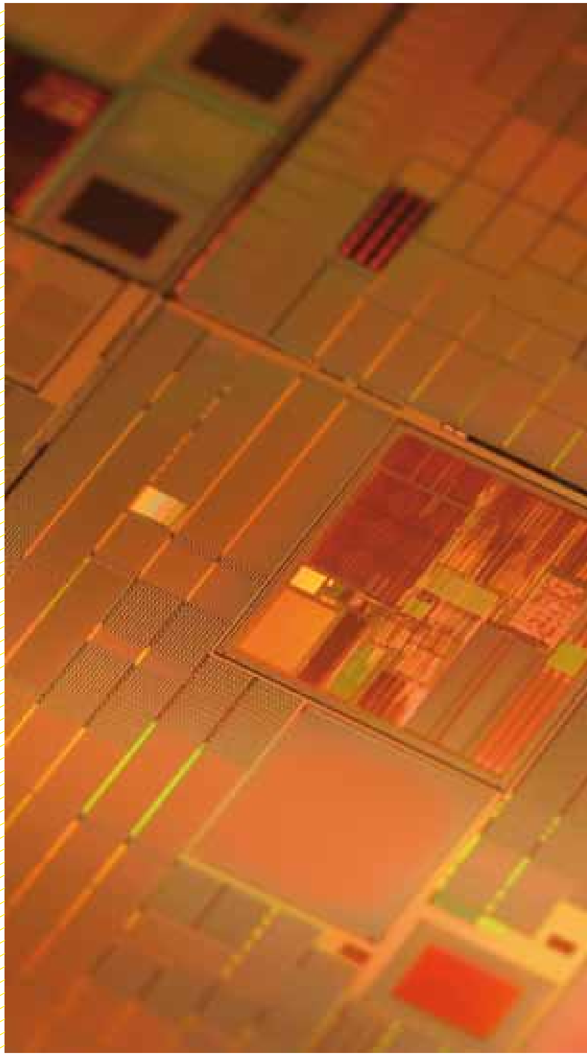
CIME Nanotech is a centre providing resources for micro and nanotechnologies. Its triple mission is training, research and technology transfer. The centre, managed jointly by Grenoble-INP and UJF, is open to French universities via the CNFM (national coordination for training in microelectronics) network. Founded in 1981, it has been on the MINATEC site since 2006.

CIME Nanotech is now made up of eight platforms addressing micro and nanoelectronics, biotechnologies, microwave and guided optics, communicating objects, microsystems and sensors. The centre is coordinated with the other research platforms on the site to offer unique services and make available to universities and research laboratories an array of high quality resources and facilities. CIME Nanotech comprises a surface area of 3 000 square metres and a 750 square metre clean-room. The clean-room platform is shared with the PTA upstream technological platform and the IMEP-LAHC laboratory.

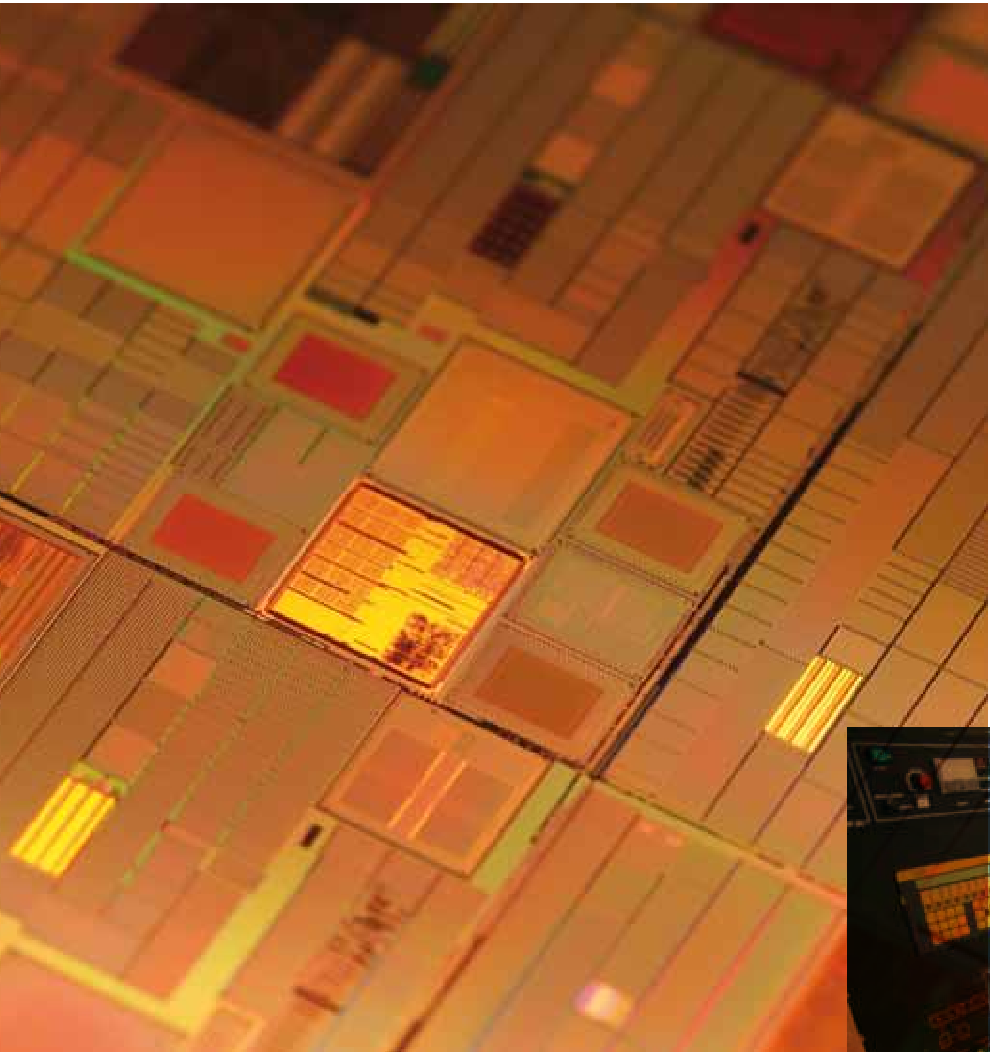
The eight CIME-Nanotech platforms, all open to researchers and industrial companies, are the following:

- *clean-room comprising all the core technologies for developing integrated circuits (deposition, etching, thermal treatments, photolithography, ionic implantation, deep etching, etc.),*
- *electrical characterisation of integrated components, e.g. current measurements (DC, transient, AC), impedance measurements, probing stations,*
- *nano-applications, e.g. nanometric near-field characterisation (AFM, STM, profilometer-vibrometer),*
- *design and testing; IC CAD for microelectronics (analogue and/or digital) and microsystems; technical tools for prototyping (FPGA cards, test stations, etc.),*
- *communicating objects, e.g. tools for implementation of technologies and methods in telecom applications (embedded systems, networks, on-chip systems, etc.),*
- *microwave and guided optics;. development and characterisation of RF and guided-optics systems (simulation and design software, test benches and related instrumentation),*
- *biotechnologies; basic biotechnical techniques and preparation of biological materials (160 square metres of floor space for molecular biology, cellular and bacterial cultures),*
- *microsystems and sensors; development and characterisation of microsensors, microactuators, microsources, microantennas (multiparameter characterisation).*

Another major activity at CIME-Nanotech is continuing education (design, characterisation, clean-room technology, etc.) for industrial companies.



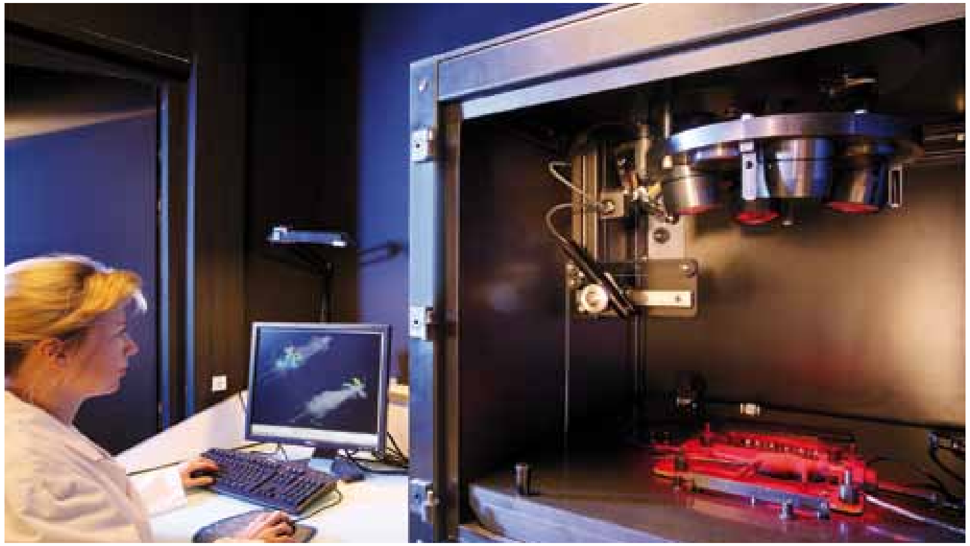
Integrated circuit developed at CIME-Nanotech



Nanomanipulator with force-feedback system

Deep etching in a clean-room

2.1.2 BIOTECHNOLOGIES



© Gérard Cottet / CEA-LETI

Instruments for optical molecular imaging

© CEA-LETI

Biological detection employing microfluid technology

NANOBIO PLATFORM

The NanoBio project was launched by CEA, UJF and the Grenoble university hospital (CHU). It groups platforms on both the university campus and the GIANT site with resources for the design, manufacture and test of devices combining biotechnologies and nanotechnologies.

At GIANT, the NanoBio platform calls on the know-how of the laboratories in medical imaging, optical molecular imaging, microsystems, instrumentation and data processing. Applications are in biology, in vivo and in vitro diagnosis and health care. Upstream research in biology also uses the resources of the platform.

Currently, the main research topics concern:

- nanomaterials and nanostructures that can be interfaced with living organisms and in vivo vectorisation/delivery of molecules,
- microsystems and chemistry for in vitro biomolecular detection and analysis,
- molecular-analysis and imaging tools.

The products and services resulting from R&D at NanoBio target improvement of the quality of life in the fields of health, safety and the environment, including the examples below:

- biological diagnostics using biochips or microsystems for near-patient testing of biological parameters and imaging systems for early detection of disease,
- therapies using medicinal «vectors» more precisely targeting the intended organ and less invasive surgical systems,
- development of systems to screen drug candidates,
- environmental monitoring and quality control of agri-food processes using miniature systems to detect traces of pathogenic substances,
- medical and life-sciences research, e.g. new concepts and instruments to gain new knowledge (biological mechanisms at the cellular level, identification of proteins involved in diseases, etc.).

The NanoBio platform works closely with the university hospitals in Grenoble and Lyon for the preclinical and clinical validation of the innovative solutions developed.

© CEA-LETI / Gilles Galoyer

Lab on a chip: a DNA chip

© CEA-LETI

Piezoelectric deposition system

© P. Avavian / CEA-LETI

Lipid emulsion used in optical imaging

CHEMISTRY PLATFORM

The Chemistry platform, which also receives funding from the NanoBio project, has the study, manufacturing and characterisation resources required to create the chemical interface between an object and its environment. These are used to either immobilise molecules or to programme functions, taking into account manufacturing and reproducibility constraints for subsequent transfer to industrial companies. The platform is equipped with the means required for the various applications developed:

- surface functionalisation on organic and inorganic substrates from the macroscopic to the nanometric scale,
- organic synthesis in solvent and aqueous media,
- colloidal chemistry.

The available expertise focuses on two main topics:

- 2D chemistry targeting chemical architectures built into microsystems, electronic circuits, batteries, etc.,
- 3D chemistry targeting autonomous chemical architectures built using nanostructures. Applications include microelectronics, sensors, biotechnologies and new energy sources.

CLINATEC® PLATFORM

CEA-Grenoble, in a partnership with the Grenoble university hospital (CHU) and INSERM, has launched the CLINATEC® project, a new centre for biomedical research on micro and nanotechnologies for health-care applications, bringing together a number of multi-disciplinary teams in a single location. Three main research topics have been addressed during the initial start-up period:

- neuroprothetics to treat motor or sensory disabilities
- neurostimulation systems,
- targeted drug delivery.

The centre is the third component of the group comprising the NEUROSPIN technical platform in Saclay (Paris), active in neuroimaging using high-field magnetic resonance to understand the human brain, its operation, development and malfunctions, and the MIRCEN centre for preclinical research in Fontenay aux Roses (Paris), which works on designing, developing and validating innovative therapies against neurodegenerative, cardiac, liver and infectious diseases.

The basic idea behind CLINATEC® is to bring together on a single location, multi-disciplinary teams made up of clinicians, biologists, technology experts and engineers to accelerate the transfer of technological and biological research to patients. The purpose of the platform is to implant innovative prototypes in patients with various diseases, under the supervision of the Patient-Protection Committee of the Grenoble CHU and AFSSAPS.

The idea is to create a home for projects, a centre equipped with the most advanced research facilities, where clinicians, neuroscience researchers and biologists can meet and discuss with experts in micro and nanotechnologies who are on hand to share their know-how and inventiveness. The technical platform will enable doctors and surgeons to develop their own medical and surgical procedures while contributing, with their therapeutical experience, to the improvement of the equipment needed for progress in their practices. The creation of a single centre grouping all research disciplines reduces the time needed to transfer new medical concepts to patients in the form of new treatments. Consequently, CLINATEC® works closely with industrial firms to ensure rapid implementation.

© Tourret Architectes

Artist's view of the CLINATEC® building

A new building on the GIANT site will include four zones:

- a technological zone to define and integrate the core technologies created at MINATEC to meet the need of clinicians,
- a zone for preclinical implementation; the first prototype-evaluation phase and studies in toxicology, biocompatibility and on device functions,
- a zone for clinical implementation of devices on patients, operated jointly with the Grenoble university hospital. This zone includes a future-oriented operating room with a mobile 1.5 Tesla MRI device, a stereotactic robot, a bidirectional radiology system, functional imaging systems including MEG, and a number of rooms for technical/clinical research and device implementation,
- a communication zone with a lecture hall and information systems for patient associations, foundations, student groups and industrial companies.

The leitmotiv for these projects is the development of effective therapies and diagnostics based on local intervention that is the least invasive as is possible. Synergies between medical, technological and biological teams on the same site are a crucial factor to ensure effective and safe procedures in validating innovative medical and technical approaches.

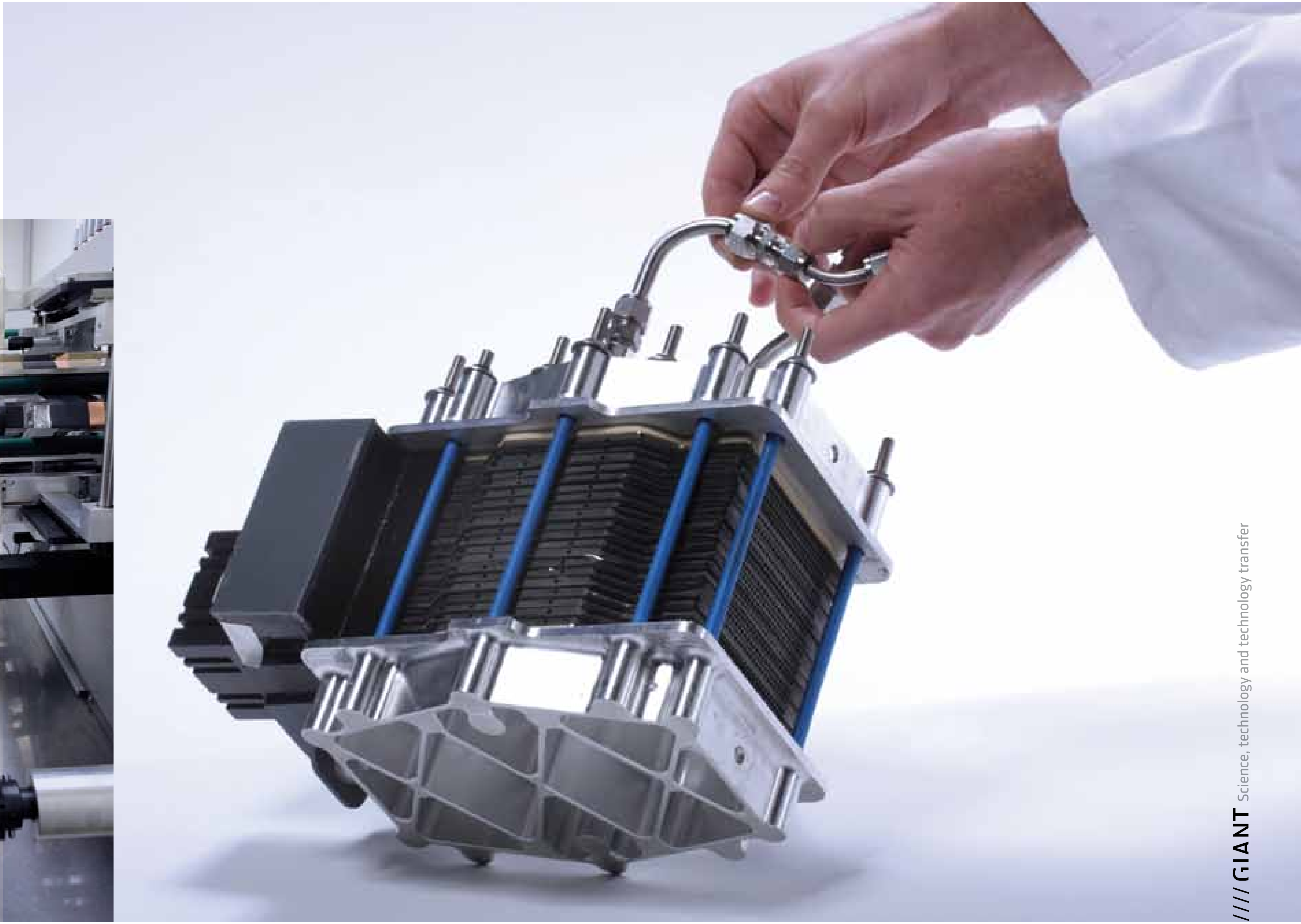
2.1.3 NEW ENERGY TECHNOLOGIES


© PF Grosjean / CEA-LITEN

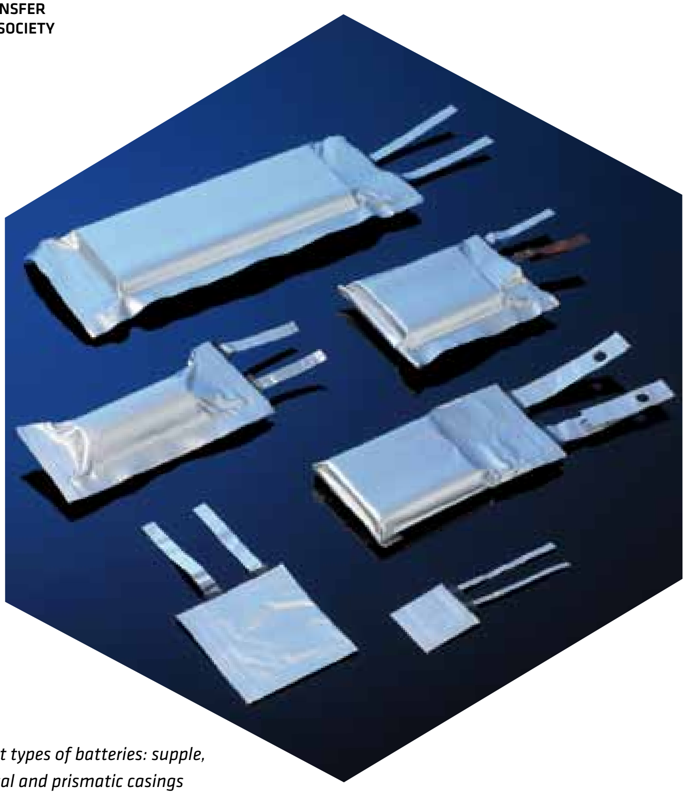
Coating machine for deposition of electrode materials

© PF Grosjean / CEA-LITEN

Li-ion battery winding machine



250 W fuel cell, used in the vehicle that took part in the Shell Eco-marathon



© D.Michon, Artechnique / CEA-LITEN

Different types of batteries: supple, cylindrical and prismatic casings

BATTERY PLATFORM

The battery platform consists of a prototyping workshop for anhydrous batteries ranging from a few mAh to several dozen Ah and of test equipment to assess the performance of all types of batteries. The batteries manufactured by the platform are intended for portable systems and transportation applications.

The platform is equipped with the means to manufacture:

- powders for electrodes, particularly controlled-dispersion nanopowders,
- anodes and cathodes,
- packaged cells,
- battery packs comprising multiple cells,
- electric and electrochemical test facilities (in conjunction with the INFES platform in Chambery) under representative usage conditions (cycles, temperature, charge and discharge characteristics).

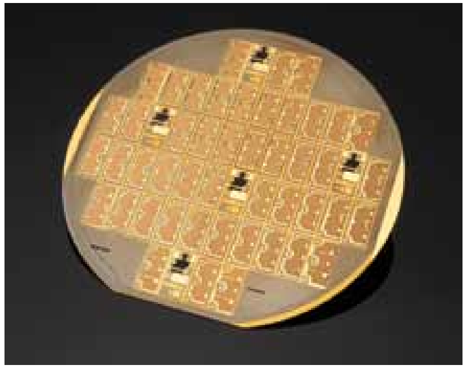
A patented lithium-iron-phosphate technology developed by the platform is particularly promising for electric and hybrid vehicles. It was recently transferred to the PRAYON company.

FUEL-CELL PLATFORM

The fuel-cell platform is a complete manufacturing and test facility for PEM (proton-exchange membrane) fuel cells. The GENEPAC technology developed by the platform with PSA (Peugeot) has the advantage of modular design, i.e. batteries ranging from a few kW to dozens of kW can be assembled simply by adding modules. Batteries employing this technology are already installed in PSA demonstrator vehicles and offer a very competitive power-to-weight ratio. The platform also works on prototypes for farm equipment, drones and boats.

The platform has developed original technology for micro fuel cells. Using both standard PEM technology and microtechnologies, the platform has developed microPEM units with hydride storage, for mobile applications. This development work is carried out with a number of large European industrial companies.

Work is also underway on SOFC (solid-oxide fuel cell) units and on high-temperature electrolysis systems for hydrogen production.



© D.Michon, Artechnique / CEA-LITEN

Micro fuel cells on a silicon wafer

PREDIS CENTRE FOR DISTRIBUTED ENERGY

The Prédis centre for innovation, education and experimentation on distributed energy offers experimental facilities to study smart energy management. The centre is a demonstration tool with configurable power networks to precisely simulate real networks linking, via a supervision expert system, different energy-generation modes intended for homes and tertiary-sector buildings.

The main facilities available at the Prédis centre include:

- various generation techniques (multi-site PV panels, fuel cells, CHP gas turbines),
- a real-time hybrid simulator for different types of energy production (wind, hydro, turbines, etc.),
- a 200 kVA industrial distribution network, at 1:10 scale,
- a distribution network at 1:1000 scale, comprising three sources and three 30 MW consumption zones,
- controllable loads,
- a fully-instrumented pilot home with high energy efficiency, representing a computer room open to site users,
- a supervision system to manage the various installations.

The Prédis centre is part of the extensive resources available at Grenoble-INP and UJF for education and research. The main research projects concern water turbines, energy quality, multi-source coupling, virtual power stations and self-healing grids, flexible networks, new network-management functions and energy management in buildings.

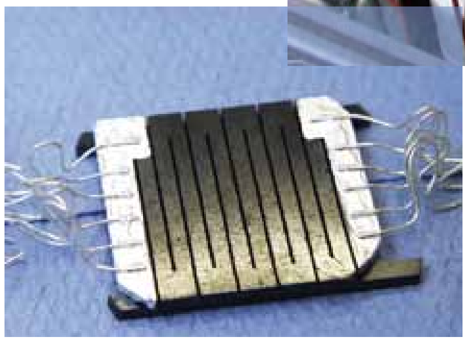
This work is carried out in a partnership with large industrial companies in the IDEA association (EDF, Schneider Electric and Grenoble-INP). An expansion of Prédis is planned with the industrial companies to enable large-scale and remote trials.

© Grenoble INP

Real-time hybrid simulation test bench (virtual and real machines), testing wind-turbine models

© CRETA

CRETA experimental hall



© CRETA

Superconducting current limiter

RESEARCH CONSORTIUM FOR ADVANCED TECHNOLOGIES (CRETA)

CRETA is a CNRS unit created to support the partnerships between the research teams in Grenoble physics laboratories and industrial companies. CRETA provides the researchers in the participating laboratories and the industrial partners with a meeting place that is conducive to project management in a context of balanced and open dialogue, under conditions of confidentiality. It provides teams with floor space and platforms for project development and characterisation that are highly flexible and constantly innovating to keep pace with new needs.

The main applications deal with materials for energy applications and magneto-science, i.e. the use of intense magnetic fields in manufacturing processes. Projects are based on an approach integrating all scientific and technological aspects of material synthesis, i.e. design of innovative manufacturing processes, instrumentation and modelling of the process, measurement of physical properties and the related fundamental studies, measurement of functional properties which retroactively determines manufacturing conditions and, in a majority of projects, the creation of demonstrators.

The multi-disciplinary operating mode at CRETA attracts many pre-PhD students and provides them with the means to enhance their fundamental knowledge, take advantage of the unique facilities in the platforms and develop their analysis skills in a given project. At the PhD level, the students play a central role in projects that often include a thesis in the collaborative effort between research and industry.

NANOSAFETY PLATFORM

The GIANT site is the first in Europe to set up a systematic plan of action to:

- *protect people working with nanomaterials from exposure at their workstation,*
- *develop the operational know-how required to qualify the risk of dispersion of nanometric powder in a given environment,*
- *pursue development of nanomaterial-synthesis technologies in a controlled environment.*

The plan of action is implemented on all GIANT platforms. On the CEA site, a number of precautions are systematically taken, e.g. identification of potential dangers, inventory of the nanoparticles manufactured, identification of handling techniques and potential for exposure during the various process steps, etc.

The platform also works on research and training programmes addressing:

- *measurement devices for nanoparticle levels, approaching the technological limits (1 nm),*
- *specific detection systems with appropriate operating modes (location selected by numerical simulation of the risk of dispersion in the atmosphere, sampling method, processing of samples),*
- *the traceability of nanoparticles (nanotracers),*
- *abrasion tests to measure the risk of release of nanofillers under usage conditions,*
- *creation of the open NanoSmile internet site for training and information, managed by UJF and intended for researchers, engineers, doctors, students and the general public.*

The goal of the platform is to expand its activities with new industrial and academic partners and to participate in defining future ISO standards on nanomaterial synthesis and handling. All the above activities are part of various European projects (Integrisk, Nanohouse, Nanex, Nanocode). The nanosafety programme in Grenoble plays a central role in the national NanoInnov programme.

© CEA-LITEN

Analysis of nanoparticles

© CEA

Vehicle equipped for initial response to nano- risks

2.2 TECHNOLOGY TRANSFER

The creation of value benefiting society as a whole requires excellence in research, but also a determined strategy to implement a collaborative project spanning the gap between research and industry.

An outstanding success story in this field for over a century, Grenoble has created great synergies between public-sector research and industrial firms. The fruitful interaction between the academic, technological and industrial sectors has turned large companies and SMEs in and around Grenoble into world leaders in their markets. Indeed, a number of what are now large industrial groups were launched as start-ups in Grenoble.

Transfer activities take place in close contact with researchers and comprise different aspects:

- stimulation of creativity and protection of results through patents,
- assistance for laboratories in setting up collaborative projects with industrial firms, but also with other organisations and universities in an international approach,
- encouragement for direct transfer of research results to existing firms,
- encouragement and assistance in the founding of new companies with breakthrough technologies,
- measures to ensure that laboratories and inventors receive a fair share of the profits.

The participants in GIANT have thus made technology transfer a key component in their strategies. With over 500 priority-right patents filed each year, GIANT is the largest public-sector patent applicant in France. GIANT is home to laboratories known worldwide for their partnership relations with industry. Grenoble was commended in 2007 by the French government for its dynamic approach in launching start-ups.

The GIANT partners have succeeded in continuously regenerating the necessary conditions for new technological and industrial growth and thus remain among the major international sites. They have grouped their forces to create new environments conducive to innovation. One of the best examples is the MINATEC innovation campus.

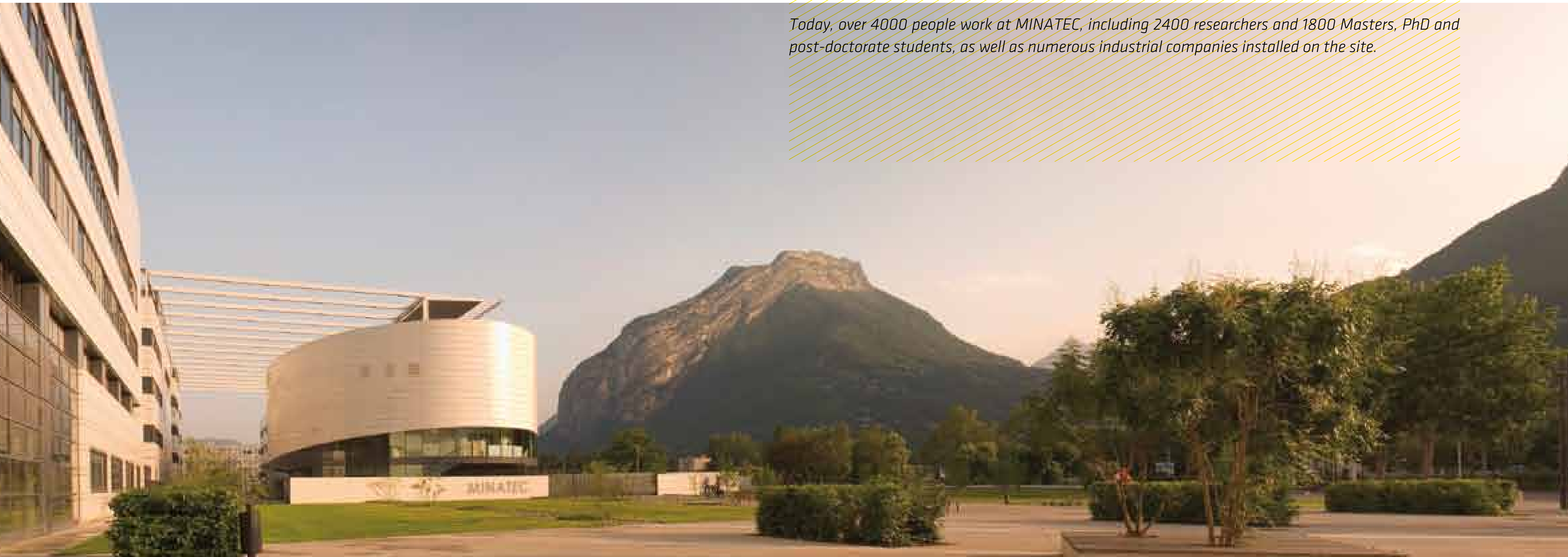
© CEA-MINATEC / pierrejayet.com

MINATEC, A FORERUNNER OF GIANT

MINATEC, the innovation campus for micro and nanotechnologies initiated in 2000 and inaugurated in 2006, is an initiative that GIANT players would like to develop further. It brings together at a single location the three necessary components: education, research and technology transfer.

- *Industrial companies can use dedicated areas, e.g. the «High-technology building», the «Integrative-industries building» and a number of collaborative platforms for research and industry.*
- *MINATEC Ideas Lab offers a novel outlook for its industrial partners by combining a series of technological, social and cultural approaches.*
- *An array of services in support of technology transfer (patent watch, marketing, industrial property management, contracts, support for start-ups, funding, etc.) are available at the Maison MINATEC.*
- *In an effort to bring together people in fundamental research and those in the social and economic sectors, MINATEC is also home to the Observatory of Micro and Nanotechnologies (CEA-CNRS). The observatory is a national grouping of researchers, financers and industrial firms. Its role is to detect and evaluate as early as possible the initial signs of breakthrough innovations in order to accelerate the innovation process.*

Today, over 4000 people work at MINATEC, including 2400 researchers and 1800 Masters, PhD and post-doctorate students, as well as numerous industrial companies installed on the site.



2.2.1 PARTNERSHIPS WITH COMPANIES

Over the years, the GIANT organisations have developed an array of partnership formulas with industrial firms, ranging from training for young students to joint laboratories for researchers and companies.

- They train students (Masters, PhD and post-doc) in state-of-the-art science and technology, and raise awareness on best practices for technology transfer and entrepreneurship. This training via research has proven its effectiveness in developing technological research and closer links between companies and academia, while at the same time creating jobs for young people. Innovative training modules are offered by Grenoble-INP, UJF, Grenoble Management School and CEA-INSTN in technology management,
- They offer large companies and SMEs access to the know-how available in the laboratories and platforms,
- They participate actively in public-industrial research consortiums to respond to regional, national and European calls for projects. Seen as indispensable partners by companies, GIANT entities are founding members of techno-clusters aimed at boosting competitiveness in fields perfectly aligned with the GIANT strategy, including micro/nanotechnologies and software (Minalogic), biotechnologies (LyonBioPôle) and renewable energy (TENERRDIS). These centres serve to network companies, research and academia. They take advantage of close proximity to form networks and veritable ecosystems for growth that are extremely profitable to SMEs,
- They offer companies partnerships precisely tailored to their needs, ranging from core technologies to applications via bilateral R&D contracts that may even include the creation of joint research-industry teams working an the same site.

GIANT's dynamic approach to partnership research has been recognised on the national level by Carnot certification granted to the laboratory consortium bringing together CEA, CNRS, Grenoble-INP and UJF for future energy applications and to CEA-LETI. GIANT currently works with many industrial companies, including a growing number of large firms, as well as with SMEs. Some of GIANT's industrial partners are presented opposite.

3D Plus
Acerde
Actia
Adeneo
AGCO
Air Liquide
Alcatel-Lucent
Alstom
AltéAd
Amesys
APC
Applied Materials
Arcale
Arcelor Mittal
Areva
Arjowiggins
Ascom
Astex
Astra Zeneca
Atos Origin

EADS
EDF

Lafarge

Movea

Nervanio Medical Sciences

PX'Therapeutics

SNR

Becton, Dickinson and Company

BioLogic

Daihatsu

Leroy Somer

L'Oreal

Nexans

Radiall Systems

Safran

Sophysa

Vicat

BioMérieux

Biosynex

Cryolog

Dauphinoise

Ma Technologies

Nexess

Raisonance

Sagem

Supertec

Thuasne

Widescreen Games

Bodycote

Boreal Plasma

Dolphin Integration

Elyo Suez

McPhy Energy

NV Organon

Renault-Nissan

Saint Gobain

Surgiqual

Tibotec

Yamatake

Bouygues

Bubendorff

Ela Medical

GlaxoSmithKline

NXP

Protein'eXpert

Sandvik

ST Microelectronics

Total

Brewer Science

Cap Gemini

Endotis Pharma

Elicityl

Mellitech

Pantechnik

Rexor

Sanofi Aventis

Tagsys RFID

Tronic's

Zenergy Power

Cedrat Technologies

Cooltech Applications

Flamel Technologies

France Telecom

Messier-Dowty

Pfizer

Pierre Fabre

Reyes

Schneider Electric

Tefal

TSV

Corial

Corning

Federal Mogul

Freescale

Fluoptics

Metalor

PSA Peugeot Citroën

RF Idées

Servier

Texas Instruments

Valeo

Crocus Technologies

Cyberstar

H3C énergies

GDF Suez

Irelec

Purple Labs

Rio Tinto Alcan

Siemens

Thales

Vario

HEF Groupe

IBM

Rolls-Royce

Rossignol

RYB

SNCF

Veolia

Vernalis

COLLABORATION WITH TOYOTA ON NEW ENERGIES FOR TRANSPORTATION

This collaboration was launched by Toyota to develop high-performance permanent magnets for the electric motors of hybrid cars. The energy density in the motors is far greater than in conventional motors with wound rotors. The magnets significantly decrease remanent magnetism that reduces the maximum energy product. CNRS is developing model materials in the form of hard magnetic layers using the superferrimagnetic concept developed and patented by the Néel Institute. Initial developments were built into a Prius motor.

Partners include Toyota Motor Company, the Néel Institute CNRS/UJF, IFW Dresden, Sheffield University and nine laboratories and research centres in Japan.

© Toyota Moteur Corporation, Japan

Prius motor and electrical generator (source T. Shoji and H. Okajima, Toyota Motor Company)

NANOELECTRONICS ALLIANCE UNITING CEA-LETI, IBM AND STMicroelectronics

Early in 2008, CEA-LETI joined the IBM semiconductor joint development alliance, contributing very specific expertise, notably in low-power CMOS technologies (e.g. SOI), e-beam lithography and nanoscale characterisation.
Work in the framework of the tripartite IBM/CEA-LETI/STMicroelectronics agreement will address three main fields:

- *advanced lithography for rapid prototyping and for 22 nm technology,*
- *CMOS technologies and low-power transistor architectures for 22 nm applications and beyond,*
- *nanoscale characterisation tools and methods for use in developing new technologies and inspection of manufacturing processes.*

The research work is carried out jointly on the 300 mm platforms of CEA-LETI in Grenoble and the College of Nanoscale Science and Engineering of Albany University (NY, USA), the STMicroelectronics site in Crolles, France and the IBM 300 mm wafer production facility in Fishkill (NY, USA).

«Research partnerships between the public and private sectors are a great way to accelerate projects. The benefits of research results show up much faster in our daily lives,» points out Daniel Chaffraix, President of IBM France.

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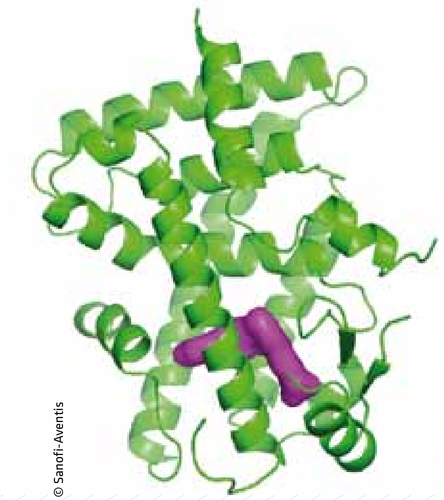
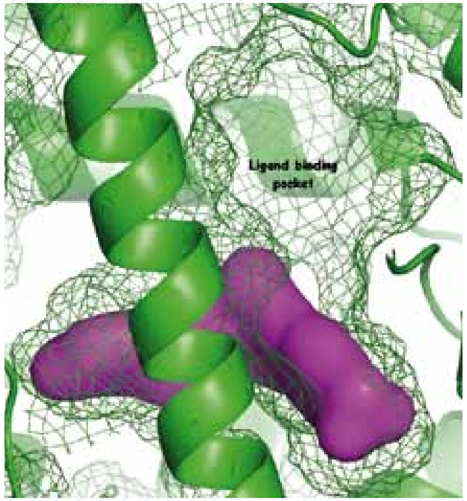
CRYSTALLOGRAPHY SERVING THE NEEDS OF THE PHARMACEUTICAL INDUSTRY

Crystallographic studies of proteins in their native or complex state with their natural ligands (as in drugs or drug candidates) are today a central step in the drug discovery process. The need to produce high-quality data on the 3D structure of proteins made it necessary to automate the MX beam lines at ESRF, dedicated to crystallographic studies of macromolecules, and to create the MXpress service. Launched in 2002 with Aventis (now Sanofi-Aventis), MXpress calls on ESRF know-how and technological resources to produce high-quality data on protein crystals submitted by pharmaceutical firms for analysis. The high level of automation required to process the increasing requests of partners means that it is now possible to analyse some 80 000 samples each year on the MX beam lines.



© Sanofi-Aventis

Simplified diagram of the structure, obtained using the ESRF MXpress service, of a target protein (green) from Sanofi-Aventis, with its natural ligand (purple)



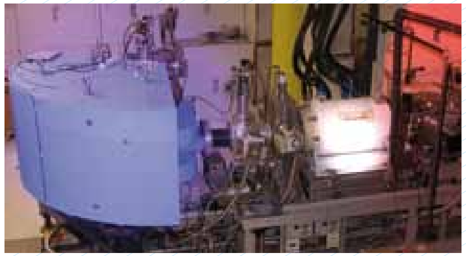
© Sanofi-Aventis

Magnified view of the ligand binding pocket (green net) inside the protein (green) showing that the natural ligand (purple) occupies only a part of the pocket, with the remaining space available for the design of inhibitors

PANTECHNIK, WORLD LEADER IN ION SOURCES

The PANTECHNIK company was founded in 1991 to transfer technologies developed from accelerator R&D at IN2P3/CNRS and GANIL. For many years, it has collaborated with research teams at GIANT, where ion sources operating at electronic cyclotronic resonance have been developed.

PANTECHNIK is now the world leader in ECR ion sources and a supplier to the new hadron-therapy centres (cancer treatment using ions). New developments are underway for a source of high-intensity protons, intended for the new ion implanters and other cutting-edge techniques, in a partnership with LPSC (UJF, CNRS/IN2P3, Grenoble-INP). With a workforce of 12, PANTECHNIK also creates custom-made equipment for research laboratories, for example in India, Italy, Germany and Poland.


© Pantechnik / LPSC

Phoenix Booster ECR ion source


© Pantechnik / LPSC

Development of high-intensity proton sources

NEW MATERIALS FROM CYBERSTAR

Cyberstar, a company in the Grenoble region, is a world leader in the development of crystal-growth equipment (PV silicon, oxides, fluorides, II-VI and III-V compounds and «exotic» materials). For over ten years, the company has worked with CNRS on developing instrumentation for synthesis of materials, particularly in the field of crystallisation.

The collaboration started with the development of an image furnace. A second development dealt with a «multifunction micro-puller». This innovative device can be used for different crystal growth geometries, e.g. Czochralski, Bridgman and «micro-pulling down», and it opens new perspectives for the development of specific materials. A new project is underway for the transfer of an arc furnace for crystal growth. The sectors concerned by this work include energy, communications, data storage, security and optoelectronics.


© Institut Néel / Cyberstar

Image furnace

LONGSTANDING COOPERATION WITH BIOMERIEUX

BioMérieux, located in Lyon, has been a world-leader in the field of in vitro diagnostics for over 40 years. The company offers diagnostic solutions (reagents, instruments, software) to determine the sources of diseases or contamination, thereby making it possible to improve the health of patients and ensure the safety of consumers.

Since 1997, researchers, engineers and technicians from bioMérieux and CEA-LETI have been working together on innovative in vitro diagnostics systems in a joint, multi-disciplinary team comprising 10 people based at CEA. To benefit even more from the know-how and resources at GIANT, bioMérieux also transferred a research centre to the site in 2005, on the Polytec premises, where 200 people will soon be working.

«BioMérieux came to LETI to gain expertise on microtechnologies, but we in fact found much more. Through our presence on site, we also have access to the know-how of the LETI experts on microsystems, e.g. fluids, optics, signal processing, etc. This diversity and the richness of the scientific environment enables us to analyse more in-depth the scientific foundation that determines the strengths and weaknesses of our existing systems and to imagine innovative solutions in line with the industrial needs of bioMérieux,» explains Frédéric Mallard, director of the joint laboratory for bioMérieux.

© BioMérieux/CEA

Carte eLab: fluidic logic card allowing the complete automation of a complex genomic protocol, on a DNA chip with optronic read-out (Collaboration between CEA-LETI, bioMérieux, Smart Packaging Solutions, Société National des Poudres et Explosifs)

STATE-OF-THE-ART INSTRUMENTATION FROM IRELEC

IRELEC, an ALCEN subsidiary, is a high-tech company that makes scientific equipment for research and industry, for example X-ray optics, particle accelerators, plasma diagnostics, synchrotron beam lines, and neutron experiments. The company exports around the world.

Set up near Grenoble, it has profited from over 20 years of close ties with GIANT players. This collaboration has put IRELEC in a position to develop increasingly advanced instruments, as noted by the company director, Jean-Loup Rechatin. «When your job is to produce custom-made scientific equipment, it is simply not possible to have all the know-how required for the work in-house. For the cryogenics part in the development of a product for a robot handling samples of protein crystals at -196°C, our collaboration with the GIANT teams enabled us to develop tools capable of handling over 1 000 samples without the risk of damaging them.»

© IRELEC

Inside view of a cryostat showing the samples in liquid nitrogen

2.2.2 START-UPS

The technological research carried out by the various partners of GIANT has resulted in a number of companies that have become world leaders in their field.

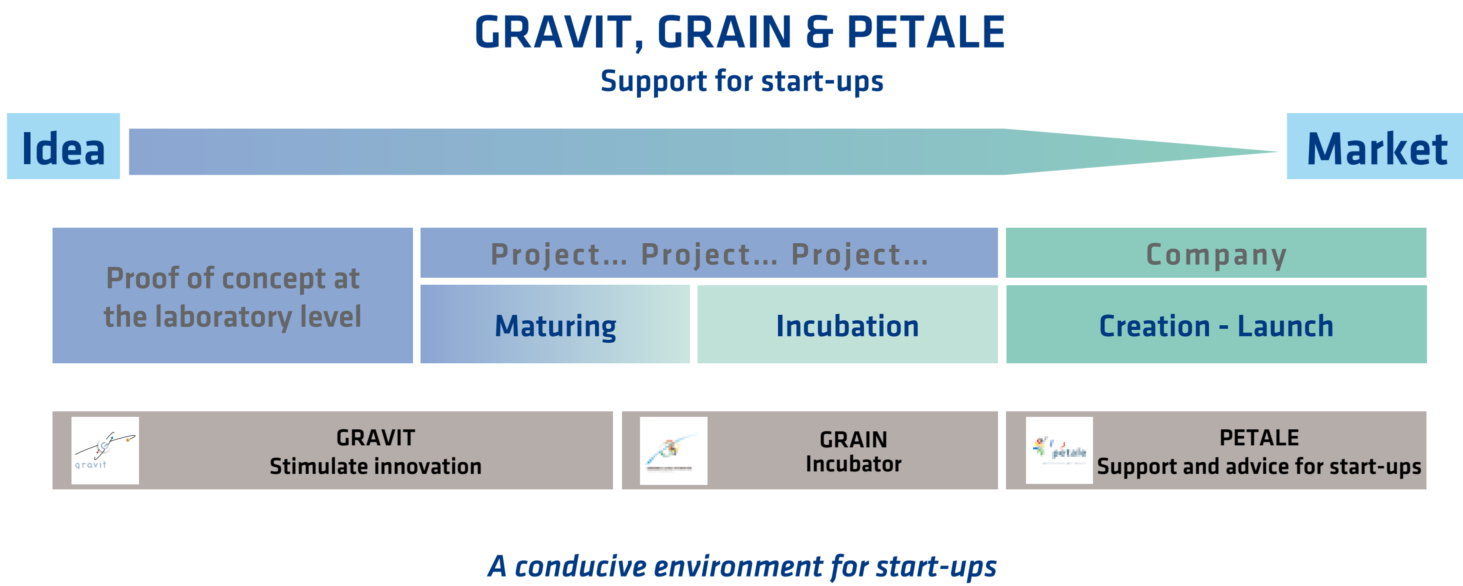
The first step was in 1972 when LETI founded the EFCIS company to manufacture MOS transistors. Ten years later, EFCIS had a workforce of 900 and in 1987 it was one of the key entities of the SGS Thomson group. In 1998, it became STMicroelectronics and is now the fifth largest manufacturer of semi-conductors worldwide, with revenues of €1.5 billion in 2008. More recently, in 2004, a new company with high potential, Crocus Technology, was created to capitalise on the spintronics research carried out in the SPINTEC laboratory. It has already raised €22 million and has set its sights on becoming world leader in MRAMs (magnetic random access memories).

Other success stories include Sofradir and its subsidiary Ulis, SOITEC and PX'Therapeutics.

THE GRAVIT-GRAIN-PETALE SYSTEM SUPPORTING START-UPS

Today more than ever, it is necessary to maintain and amplify the start-up phenomenon. To that end, the GIANT organisations have created the GRAVIT-GRAIN-PETALE system to pool resources intended to support and accompany the creation and development of new companies with high economic potential.

The GRAVIT-GRAIN-PETALE system assists from the initial laboratory idea phase to the commercial and industrial start-up of new companies. This system of mutual assistance provides resources in addition to the in-house technology- transfer means specific to the various organisations that comprise GIANT.



GRAVIT

GRAVIT was created in 2006 by CEA, CNRS, Grenoble-INP, INRIA, UPMF and UJF. It focuses on the detection and development of new projects in the laboratories, on finding agreements between the various partners concerning industrial-property rights and on promoting technologies to the industrial sector.

GRAVIT identifies approximately 50 technology transfer projects each year, of which one third receive funding for development work corresponding to the transition from a laboratory result to a demonstrator that is sufficiently advanced to justify a new company or technology transfer to an industrial partner.

GRAVIT partners have established a code of best practices for management of industrial-property rights and a monitoring/coordination committee meets monthly.

GRAIN

GRAIN, an initiative by four GIANT partners (CEA, CNRS, Grenoble-INP and UJF) and UPMF, was the first public-sector business incubator created in France, in 1999. It is open to all the research organisations operating in the Grenoble academic region.

Operating downstream from GRAVIT, GRAIN detects and accompanies projects to create innovative companies with high economic potential that implement or base their activity on technologies developed in the laboratories. GRAIN serves to structure projects via concrete actions such as bringing teams together, training, market studies, and legal work. The goal, after the incubation phase of up to 18 months, is to produce the most realistic business plan possible for the future company.

The 100th company assisted by GRAIN was launched in the spring of 2009 and a total of over 150 have been assisted.

PETALE

Created in 2007, PETALE is currently assisting 25 new, high-potential companies that wish to set up and grow in the Grenoble area.

PETALE works downstream from GRAIN to monitor companies during the start-up phase (post incubation), when they are most fragile, often due to the lack of a mature market or to insufficient funding.

PETALE's second mission is to welcome and support technology companies wishing to set up in the Grenoble area, in particular new, foreign companies looking to take advantage of the technological know-how available locally.

Though still in the consolidation phase, the GRAVIT-GRAIN-PETALE system of pooling resources has already proven its value with several new companies, created over the past year, implementing technologies developed at GIANT (Cytoo, Kalray, Fluoptics, Natx-Ray, CMDL Manaslu, Prollion, McPhy Energy, Eveon, Kapteos, Elena, BeeZik).*

START-UP FUNDING

Start-up companies created at GIANT have access to various sources of funding, ranging from government grants to assist in the technological development of projects, to private funding provided by investment firms and private investors.

In addition to the in-house structures of each organisation, GRAVIT, GRAIN and PETALE provide vital assistance for new companies by guiding them toward the best funding opportunities. In addition to funding by GRAVIT and GRAIN themselves, finance is made available via the national new-company contest, organised jointly by the French Ministry of Research and OSEO. In terms of investors, there are a number of local investment firms, for example Emertec, Rhône-Alpes Création and CEA Investissement, plus the GRENOBLE Angels association and its Grenoble Angels Participations fund. Each year in May, the Forum 41 meeting is an occasion for new companies looking for financing to make direct contact with several dozen national and international investment funds.

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Active company
Company taken-over by other company
Project in incubation
Company which no longer operate

START-UPS CREATED AT GIANT SINCE 2000

Over the period 2000-2009, some 50 new companies have been created or are in the creation process, as shown below. These companies currently represent some 600 jobs.

The creation of a company, particularly a high-tech company based on innovative research from a laboratory, is a real adventure as a number of success stories have shown, but it is not without risk. The GIANT environment comprising vast resources in terms of expertise, the tools made available to support start-ups and the dynamic industrial fabric provide a particularly favourable setting for entrepreneurs.

Asygn, Arnano
Darwineo, Manaslu ing, Ethera
Stantec, Kalray, Microoled, Eveon, BloS
Geomobile, A2 Photonic, Avenium consulting, Eléna Energie, Small Infinity
Acerde, ImmunID Technologies, Oasic, Lemoptix, Esprit, Diab
E.Mobilia, Azimut Monitoring, Presto Engineering, IF, Kapteos
Ciprian, Crocus Technology, Fluoptics, Strial
Xenocs, Tracit Technologies, Beamind, RClux, Aselta nanographics, Norway
OpsiTech, PX' Therapeutics, Apibio, Boreal Plasma, McPhy, Promise, SmD, Isorg
Soisic, PaxiTech, Infiniscale, Movea, Cytoo, NatX-ray, Helio Del
ActiCM, Ulis, Intexys, Mellitech, Tiempo

A2 Photonic	Microsensors and optical laser measurement instruments for flow characterisation.	**www.a2photonicsensors.com**
Acerde	Development and synthesis of refractory materials offering high chemical and crystallographic quality, and services for characterisation and multiscale analysis of materials.	**www.acerde.com**
Acticm	3D measurement systems, including robotised, 3D non-contact measurement, optical contact measurement and motion capture. Company now part of the Créaform group	**www.acticm.com** **www.creaform3d.com**
Apibio	Instrumentation and analysis tools (biochips) for the biological, pharmaceutical and agri-food industries. Company now part of the BioMérieux group	**www.biomerieux.fr**
Arnano	Procedures for microscopic and permanent etching for various applications. Project now in incubation	**En cours**
Aselta Nanographics	Tools for correction of proximity effects for sub 32 nm E-beam lithography.	**www.aselta.com**
Asygn	Software to accelerate analogue design.	**www.asygn.com**
Avenium Consulting	Strategy and management of industrial-property rights.	**www.avenium-consulting.com**
Azimut Monitoring	Environmental solutions for inspection and continuous monitoring of public environmental pollution, consumption of resources and substances released into the natural environment	**www.azimut-monitoring.com**
Boreal Plasma	Equipment and tooling for all applications using microwave-generated cold plasma.	**www.borealplasma.com**
Ciprian	Study and development of scientific instrumentation, in particular for pulse generators and multiplexers.	**www.ciprian.com**
CMDL – Manaslu	Energy diagnostic services.	**www.manaslu-ing.com**
Crocus Technology	New generation of MRAM memories for microelectronic applications.	**www.crocustechnology.com**
Cytoo	Development of high-tech cell culture equipment for cellular analysis and high-content cell screening products	**www.cytoo.com**
Darwineo	Services to accompany the growth of companies.	**www.darwineo.com**
Eléna Energie	Shrouded wind turbines for residential electricity generation. Project now in incubation	**www.elena-energie.com**
E.Mobilia	Services to assist companies and employees in all aspects of personnel relocation.	**www.e-mobilia.com**
Eveon	Manufacturer of automated medical injection systems incorporating microsystems.	**www.eveon.eu**
Fluoptics	Fluorescence-imaging system to assist in cancer surgery.	**www.fluoptics.com**
Geomobile	Geolocation equipment and services for vulnerable persons (eldery or disabled).	**www.whereru.eu**
ImmunID Technologies	Immunomonitoring tests for the pharmaceutical industry and the personalised-diagnostics market.	**www.immunid.com**

Infiniscale	Software solutions for behavioural modelling, synthesis and parametric yield of integrated circuits.	**www.infiniscale.com**
Intexys	Development and manufacture of active electronic components for high-speed communications systems. Taken over by Photonera	**www.intexysphotonics.com**
Kalray	Development of a new generation of multi-core processors for embedded computing applications.	**www.kalray.com**
Kapteos	Project now in incubation Design and manufacture of electro-optical systems to measure electric fields.	**En cours**
McPhy Energy	Solid-phase hydrogen storage solutions using magnesium hydrides.	**www.mcphy.com**
Mellitech	Development of drug candidates to treat type II diabetes using a zinc transporter.	**www.mellitech.com**
Movea	Human-motion capture solutions for the consumer-electronics and health-care markets.	**www.movea-tech.com**
Microoled	Design and manufacture of micro-OLED displays for mobile video applications.	**www.microoled.net**
NatX-Ray	Development of robots and services for protein crystallography. Company now being launched	**www.natx-ray.com**
Opsitech	Integrated optical components for telecom applications. Company now part of the Memscap group	**www.memscap.com**
Oasic	Development of design tools for microelectronic applications.	**www.oasic-da.com**
Paxitech	Design and manufacture of fuel cells and related systems ranging from a few watts to dozens of watts.	**www.paxitech.com**
Presto Engineering Europe	Development of complete test and analysis solutions for the semi-conductor industry.	**www.presto-eng.com**
Prollion	Battery cells and battery packs using different electrochemical energy storage technologies.	**www.prollion.com**
Promise	High added-value services in proteomic analysis. Project now in incubation	**En cours**
PX'Therapeutics	Development of therapeutic proteins and monoclonal antibodies from R&D to clinical production.	**www.px-therapeutics.com**
RClux	Development of long-life, compact UV lamps to eliminate bacteria and disinfect water supplies.	**www.rclux.com**
Scanlight Imaging - Lemoptix	Development of MEMS optical microscanners and miniature video-projection modules using the scanners.	**www.lemoptix.com**
Small Infinity	Development and manufacture of near-field microscopes.	**www.smallinfinity.com**
Soisic	Design of SOI (silicon on insulator) integrated circuits. Company now part of the ARM group	**www.arm.com**
Tiempo	Development of asynchronous clockless electronic components offering low energy-consumption and noise levels.	**www.tiempo-ic.com**
Tracit	Industrial solutions for the TRAnsfer of CIrcuiTs to the microelectronics industry. Company now part of the Soitec group	**www.soitec.com**
Ulis	Development and manufacture of uncooled infrared detectors.	**www.ulis-ir.com**
Xenocs SA	Optical components for X-rays, neutrons and extreme UV.	**www.xenocs.com**

EXAMPLES OF START-UPS IN RECENT YEARS

SOITEC
www.soitec.com

SOITEC grew out of CEA in 1992 to industrialise SOI (silicon on insulator), a new material for the microelectronics industry. Using the SmartCut™ process patented by CEA, this new material became part of the high-performance chips that have modified our daily lives. SOITEC is the world leader in its field with sales of €300 million over its latest fiscal year. It has a workforce of almost 1000 near Grenoble and in Singapore. The company has very strong R&D partnerships with CEA that enable it to maintain its advance and to offer customers innovative materials for chips combining low consumption and high performance.

Founded by:
Jean-Michel Lamure and André-Jacques Auberton-Hervé.

TRONICS
www.tronics.eu

TRONICS Microsystems is another firm that originated at CEA in 1997 to meet the need expressed by the market for microsystems in small and mid-sized series. The microsystems developed and manufactured by TRONICS are used in fields as varied as oil production, health care (heart-rate monitors and implantable pressure sensors) and RF components for telecom uses.

TRONICS is the leading French company in the field and a major European player. The company had sales of €10 million in 2008 and a workforce of 60 on its premises near Grenoble.

Founded by:
Stéphane Renard.

TEEMPHOTONICS
www.teemphotonics.com

Started in 1998 and still managed by the founders, Teem Photonics is a spinoff of the technological partnership grouping Grenoble-INP, Schneider Electric and Radiall.

During the initial phase between 1998 and 2005, Teem Photonics developed a range of components using planar waveguide technology for telecom markets, notably monomode splitters for networks accessing wide passbands (100 Mb/s full duplex).

Since 2005, Teem Photonics has also worked on the design and manufacture of pulsed lasers that are used for a number of applications such as micro-machining, marking, distance measurements and fiber-optic distributed sensors. The technological know-how for these lasers was produced at CEA-LETI in Grenoble and MIT in Boston.

Founded by:
Antoine Kévorkian and Denis Barbier.

XENOCS
http://www.xenocs.com

Xenocs was launched in 2000 to capitalise on the work at the optical laboratory of the Institut Laue-Langevin (ILL). The company designs and sells nanometric, multi-layer, optical components and systems for X-rays, neutrons and extreme UV applications, as well as products for materials analysis, semiconductor production and protein crystallography.

With a workforce of 30 and unique technology, Xenocs pursues intense R&D work in partnerships with prestigious organisations such as the European Space Agency.

Founded by:
Peter Hoghoj and Frédéric Bossan.

PX'THERAPEUTICS

www.px-therapeutics.com

Drawing on CNRS work, Protein'Expert was created in December 2000 to create a private-sector offering for engineering, development and production of complex, recombinant proteins. The work expanded to include the production of preclinical batches of therapeutic proteins with the creation of PX'Pharma in 2004. Then in 2007, PX'Monoclonals offered services for the development of antibodies. The various units were grouped in 2008 to form the PX'Therapeutics group with a workforce of 60 on the MINATEC site. PX'Therapeutics works closely with a number of laboratories at GIANT.

Founded by:

Tristan Rousselle and Nicolas Mouz.

ULIS

www.ulis-ir.com

ULIS was created in 2001 on the basis of technologies from the CEA IR laboratory. The company develops and industrialises low-cost, uncooled IR detectors (microbolometers) intended for a wide range of civil applications (security, medical imaging, night vision, preventive maintenance, etc.).

With SOFRADIR, its «big sister» created in 1986 and now world leader in cooled detectors, the two companies have joint sales of €100 million and employ a workforce of 500 in the Grenoble area. Numerous partnership agreements, particularly for the laboratories operated jointly, link the two companies to CEA.

Founded by:

Jean-Pierre Chatard, Jean-Luc Tissot and Philippe Bensussan.

CROCUS TECHNOLOGY

www.crocus-technology.com

Launched in 2004 with technology acquired from CEA and CNRS, CROCUS Technology has set its sights on becoming world leader in MRAMs (magnetic random access memories). Its unique technology was developed and patented by SPINTEC, the spintronic laboratory run by CEA and CNRS. MRAM is often considered the «ideal» memory in that it combines speed, throughput, capacity and non-volatility, thus opening up a wide range of applications (microprocessors, telephony, mobile devices, etc.).

The company has already raised €30 million and employs 25 people on two sites, at GIANT and in Sunnyvale, California. It also has a number of very close partnerships with GIANT laboratories.

Founded by:

Jean-Pierre Nozières, Christian Marc and Jean-Pierre Braun.

TIEMPO

www.tiempo-ic.com

Tiempo was founded in July 2007 on the basis of work carried out at Grenoble-INP. The company develops and sells IP cores for the design of secure integrated systems with low energy consumption at low voltages and low noise levels. The innovative, asynchronous (clockless) technology industrialised by Tiempo offers high performance and can be used to design components capable of tolerating the parameter variations in nanometric manufacturing processes, a critical problem for the 65 nm and 45 nm technologies and beyond.

Tiempo raised €1.1 million in January 2008 and employs a workforce of 14 in the Grenoble region. It is currently pursuing product developments and sales in France and abroad.

Founded by:

Marc Renaudin and Serge Maginot.

MCPHY

www.mcphy.com

McPhy Energy SA was created in January 2008 to industrialise the hydrogen-storage processes using magnesium hydrides, developed by CNRS in a partnership with UJF. The company designs, develops, manufactures and sells storage tanks for solid hydrogen. Potential applications are extremely varied and cover all the fields requiring large-scale hydrogen storage, e.g. transportation, residential and certain ICT applications, etc.

McPhy Energy SA raised €1.7 million in 2009 and has set up a number of R&D partnerships with GIANT laboratories.

Founded by:

Bruno Wiriath and Michel Jehan.

ACRONYMS AND ABBREVIATIONS

AFSSAPS: Agence Française de Sécurité Sanitaire des Produits de Santé / French Agency for the Safety of Health Products
AFM: Atomic Force Microscope
ALD: Atomic Layer Deposition
ANR: Agence Nationale de la Recherche / French National Research Agency
AUC: Analytical Ultra Centrifugation
BISy: Biologie Intégrative et Systémique / Integrative and Systematic Biology
CALTECH: Californian Institute of Technology
CAO: Conception Assistée par Ordinateur / Computer Aided Design
CEA: Commissariat à l'Energie Atomique et aux Energies Alternatives / Alternative energies and atomic energy Commission
CERN: European Organisation for Nuclear Research
CHU: Centre Hospitalier Universitaire / University Hospital
CIGS: Copper Indium Gallium (di)Selenide
CIME Nanotech: Centre Interuniversitaire de MicroElectronique et de Nanotechnologie / Inter-university Centre for Microelectronics and Nanotechnology
CMOS: Complementary Metal Oxide Semiconductor
CMTC: Consortium des Moyens Technologiques Communs / Consortium of Common Technological Capabilities
CNFM: Coordination Nationale de la Formation en Microélectronique / National Coordination for Training in Microelectronics
CNRS: Centre National de la Recherche Scientifique / French National Scientific Research Centre
CRETA: Consortium de Recherche pour l'Emergence de Technologies Avancées / Research Consortium for Advanced Technologies
CVD: Chemical Vapour Deposition
DNA: Deoxyribonucleic acid
EDF: Électricité de France / French Electrical Utility
EMBL: European Molecular Biology Laboratory
ESO: European Southern Observatory
ESONN: European School On Nanosciences and Nanotechnologies
ESRF: European Synchrotron Radiation Facility
EUV: Extreme Ultra-Violet
FD SOI: Fully Depleted Silicon on Insulator
FET: Field Effect Transistor
FIB: Focused Ion Beam
FMNT: Fédération Micro et Nano Technologies / French Federation of Micro and Nanotechnologies
FPGA: Field-Programmable Gate Array
FSOI: Free Space Optical Interconnect
GANIL: Grand Accélérateur National d'Ions Lourds, CEA-CNRS / French National Heavy Ion Accelerator
GeOI: Germanium On Insulator
GIANT: Grenoble Innovation for Advanced New Technologies
GRAIN: GRenoble Alpes Incubation
GRAVIT: GRenoble Alpes Valorisation Innovation Technologies / GRenoble Alpes Technology Transfer and Innovation
Grenoble INP: Grenoble Institut National Polytechnique / Grenoble Institute of Technology
GUI: Grenoble Université de l'Innovation / Grenoble University of Innovation
HFI: High Frequency Instrument
ICT: Information and Communication Technology
ILL: Institut Laue Langevin
INRA: INstitut de Recherche Agronomique / Institute for Agricultural Research
INSERM: Institut National de la Santé et de la Recherche Médicale / French National Institute for Health and Medical Research
INSTN: Institut National des Sciences et Techniques Nucléaires / National Institute of Nuclear Science and Techniques
IPMC: Institut de Physique de la Matière Condensée / Institute for Condensed Matter Physics
IRSN: Institut de Radioprotection et de Sûreté Nucléaire / French Institute for Radiation Protection and Nuclear Safety
ISO: International Organisation for Standardisation
ITC: Isothermal Titration Calorimetry
ITER: International Thermonuclear Experimental Reactor
LETI: Laboratoire d'Electronique des Technologies de l'Information / Electronics Laboratory for Information Technology
LHC: Large Hadron Collider
LNCMI: Laboratoire National des Champs Magnétiques Intenses, CNRS / French National Laboratory of Intense Magnetic Fields
MEG: MagnetoEncephaloGram
MEMS: Micro Electro Mechanical Systems
MFM: Magnetic Force Microscope
MOCVD: Metal Organic Chemical Vapour Deposition
MOS: Metal Oxide Semiconductor
MRAM: Magnetic Random Access Memory
MRI: Magnetic Resonance Imaging
NEMS: Nano Electro Mechanical Systems
NMR: Nuclear Magnetic Resonance
OLED: Organic Light Emitting Diode
PEEM: PhotoEmission Electron Microscope
PEM: Proton Exchange Membrane
PEREN: Plate-forme d'Etude et de Recherche sur l'Energie Nucléaire / Platform for the Studies and Research on Nuclear Energy
PETALE: PEpinière Technologique ALpine d'Entreprises / Technological Company Incubator of the Alps
PFNC: Plate-forme de NanoCaractérisation / Platform for Nano-Caracterisation
PSB: Partnership for Structural Biology
PTA: Plate-forme Technologique Amont / Upstream Technological Platform
PV: PhotoVoltaic
R&D: Research and Development
REACH: Registration, Evaluation, Authorisation and Restriction of Chemical substances.
RF: Radio Frequency
RFID: Radio Frequency Identification
RTRA: Réseau Thématique de Recherche Avancée / Thematic Networks for Advanced Research
SEB: Scanning Electron Microscope
SME: Small and Medium-sized Enterprises
SNOM: Scanning Near-field Optical Microscope
SOI: Silicon On Insulator
SPR: Surface Plasmonic Resonance
STM: Scanning Tunneling Microscope
STREP: Specific Targeted Research Project
TEM: Transmission Electron Microscope
TIRF: Total Internal Reflection Fluorescence
UJF: Université Joseph-Fourier / Joseph-Fourier University
UPMF: Université Pierre Mendès France / Pierre Mendès France University
UV: Ultra-Violet
VLT: Very Large Telescope
VLTI: Very Large Telescope Interferometer
WIMP: Weakly Interacting Massive Particle
XPEEM: X-ray Photo-Emission Electron Microscopy

ACKNOWLEDGEMENT

The GIANT partners wish to thank all those who have contributed to the production of this document, and in particular:

L. Aeschelmann
R. Baptist
A. Barbara
B. Barbara
P. Bayle-Guillemaud
E. Beaugnon
P. Besesty
J.X. Bourcherle
A. Briand
P. Brincard
R. Brissot
H. Burlet
J. Chabbal
J. Chevrier
J. Cibert
J.F. Clerc
K. Clugnet
L. Daudeville
F. Debray
S. Decossas
N. Dempsey
N. Farouki
D. Feinberg
A. Fontaine
M. Fontecave
T. Fournier
P. Gandit
J. Garin
J.M. Gérard
G. Ghibaudo
A. Girard
D. Givord
J.C. Guibert
A. Harrison
B. Hébral
D. Heuer
A. Ibanez
M.R. Johnson
O. Joubert
J. Joyard
J. Kasprzak
E. Kats
S. Kox
T. Lamy
F. Lartigue
A. Lebouc
P. Lejay
R. Madar
F. Mallard
L. Maniguet
Y. Maréchal
H. Mariette
JL. Martínez Peña
C. Mestais
E. Mitchell
E. Molva
J.L. Monin
R. Morel
J.P. Nozières
A. Pasturel
E. Pebay-Peyroula
J.P. Perin
A. Pervès
J.L. Rechatin
I. Rivat
M. Rodriguez-Castellano
R. Ruigrok
G. Schoehn
A. Schuhl
M.N. Séméria
R. Sousa
W.G. Stirling
J.L. Tholence
T. Thuillier
C. Vettier
F. Vinet
C. Voillot
O. Zimmer

and, in addition, all the administrative staff, engineers, scientists and technicians and who make GIANT work every day...

Grenoble INP

UNIVERSITÉ JOSEPH FOURIER

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énergie atomique • énergies alternatives

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