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Nanoscience and nanotechnology activities in Catalonia

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Summary

This article aims to give an overview of the activities being carried out in Catalonia in the fields of Nanoscience and Nanotechnology. These activities were initiated within the framework of the III Research Plan of Catalonia.

Nanoscience and nanotechnology: a scientific frontier

Nanoscience and nanotechnology deal with the properties of matter at an ultra-small scale, when it has at least one dimension in the nanometre range. Such small dimensions give rise to new properties, which cannot be predicted by simple extrapolation from the macroscopic properties of the same material.

Nanoscience and nanotechnology have been increasing sharply in recent years. This explosion is due to their potential to start a technological revolution, comparable to the microelectronics revolution in the second half of the 20th century.

We now have the tools needed to manufacture and manipulate materials in the range of several millionths of a millimetre. This enables us to create new devices, such as sensors that are able to weigh a single molecule, or electronic devices with millions of gigabits of memory.

Nanoscience and nanotechnology involve the use of new miniaturization and manufacture techniques on an atomic and molecular level. New properties and characteristics can be obtained by nanostructuring existing materials.

Nanotechnology will be highly beneficial to many scientific areas:

- Information Technology: Nanotechnology will play a primary role in the creation of new devices. The tendency towards miniaturization in microelectronics will reach its theoretical limit in a few years. Therefore efforts to achieve further miniaturization will require revolutionary techniques, such as using molecules to manufacture circuits (known as "molecular electronics").
- The mass of information storing devices will decrease whilst their capacity increases to terabits of memory.
- Communications: higher transmission frequencies will be used, leading to greatly increased efficiency.
- Materials Science: nanotechnology will enable lighter and harder materials to be manufactured. Nanostructured materials will provide opportunities to develop: new catalysts, new filtration materials, extremely high quality pigments and printing inks, new materials for the automotive, aeronautics and space industries.
- Nanotechnology will be a keystone in the fields of medicine and health, as biological processes are regulated by molecular systems and governed by chemical and physical laws. Integrating biological blocks into inorganic materials and synthetic devices will open new horizons. The imitation of the simplest biological systems will give rise to new developments, such as biomimetic chemistry.
- Nanotechnology will also have an impact on the fields of energy and energy storage, and consequently on environmental protection.

III Research Plan of Catalonia

The III Research Plan of Catalonia was launched at the beginning of 2001. The aim was to stimulate the Catalan science and technology system's growth and increase its quality during the period 2001-2004.

The Plan proposed actions in four main areas:

a) Convergence with the European Union
The aim was to increase R&D expenditure in Catalonia to 1.4% of GDP by the end of 2004. This target was almost achieved by the end of 2003, as R&D expenditure had already increased to 1.36% of GDP.

b) Human Resources
The goal was to increase the number of researchers in Catalonia by training more young researchers and by incorporating qualified scientists from other countries into the research system (ICREA programme).

c) Research Centres
The objective was to create a number of research centres, science parks and international research facilities in Catalonia. The following research centres were created during the III Plan period:

- Animal Health Research Centre (CRESA)
- Cardiovascular Science Institute of Catalonia (ICCC)
- Classical Archaeology Institute of Catalonia (ICAC)
- Centre for Genomic Regulation (CRG)
- Telecommunications Technological Centre of Catalonia (CTTC)
- Institute of Photonic Sciences (ICFO)
- Institute of Chemical Research of Catalonia (ICIQ)
- Catalan Institute of Nanotechnology (ICN)

All these research centres have legal status (either as Foundations or Consortiums) and are located on University Campuses. The host universities are members of the Foundations or Consortiums' governing bodies.

The most important facility to be built is a Synchrotron Light Source.

d) Internationalisation
The aim was to boost Catalonia's contribution to the development of the European Research Area, through participation in multilateral initiatives promoted by the European Union itself or by its regions and member states.

Nanoscience and Nanotechnology were regarded as areas of special interest in the III Research Plan of Catalonia. As a result, Prof. Miquel Salmeron, a researcher at Lawrence Berkeley Laboratory, was engaged as advisor to the Government of Catalonia's Minister of Universities, Research and Information Society. He undertook to carry out an analysis of Nanoscience and Nanotechnology research, and to propose some measures that could be implemented within the framework of the III Research Plan.

Prof. Salmeron's recommendations led to a Special Nanotechnology Action Plan in February 2003. This Action Plan established that three main initiatives would be carried out in Catalonia:

- A programme of grants to facilitate the training of young researchers (NANO Grants).
- The creation of a Bioengineering Reference Centre (CREBEC).
- The creation of a Catalan Institute of Nanotechnology (ICN).

NANO Grants

The aim of the call for applications is to award individual post-doctoral – and in exceptional cases pre-doctoral – grants. The grants are for research in internationally renowned University or research centres abroad.

The initial length of the grants is 12 months, although there is a provision for a 12 month extension. A second grant extension could be awarded in justified cases.

Eighteen grants had been awarded by the end of 2004. Some of the students have already finished their period abroad and have been reincorporated into Catalan universities and research centres.

The eighteen grants can be classified into research topics as follows:

– Nanomaterials	4
– Atomic Manipulation	3
– Molecular Electronics	3
– Nanobiology	3
– Nanofabrication	3
– Nanomagnetism	1
– Theory and Simulation	1

As could be expected, the chosen centres are located in the US and in those European countries with the most advanced nanotechnology. The distribution of the 18 grants by country is:

– United States of America	10
– Germany	4
– France	1
– Denmark	1
– Holland	1
– United Kingdom	1

The programme is receiving very positive feedback related to the topics of research being carried out and to the excellence of the chosen research centres. All signs indicate that the reincorporation of the NANO grant holders into the Catalan science and technology system will boost nanoscience and nanotechnology in our country.

Bioengineering Reference Centre of Catalonia (CREBEC)

The Bioengineering Reference Centre of Catalonia (CREBEC) was created by the *Generalitat de Catalunya* (Catalan Government) in March 2003. CREBEC is made up of different groups from the Technical University of Catalonia's (UPC) Biomedical Engineering Research Centre, and the University of Barcelona's (UB) Research Centre in Bioelectronics and Nanobioscience.

CREBEC's objective is to advance multidisciplinary biomedical engineering research activities in Catalonia. It also aims to strengthen interdisciplinary research by integrating basic research with clinical and industrial applications. CREBEC's directors are Prof. Josep A. Planell (UPC) and Prof. Josep Samitier (UB).

CREBEC's main research areas are:

- Cellular and molecular nanotechnology
- Tissue and cell culture engineering
- Tissue and cell culture characterization

- Design of devices for manipulating and processing cells and molecules on a chip.
- Acquisition and treatment of biomedical signals and images.

CREBEC's nanobiotechnology research is carried out in the UB-UPC Nanobioengineering Laboratory, located in the Barcelona Science Park (PCB). This location provides CREBEC with access to excellent technological facilities. Such facilities include the PCB's standard scientific services, and a Nanotechnology Platform (nanomanufacturing, nanomanipulation, analysis and characterisation of nanostructures).

CREBEC's participation in "Nano2life" is an indication of the quality of research being carried out. "Nano2life" is one of the European Networks of Excellence created by the Sixth Framework Programme. Its objective is to study existing interactions between the life sciences and nanotechnologies.

Catalan Institute of Nanotechnology (ICN)

As mentioned above, the Catalan Institute of Nanotechnology (ICN) is one of the research centres created by the *Generalitat de Catalunya* within the framework of the III Research Plan. The ICN is on the Autonomous University of Barcelona (UAB) campus. This location was chosen to facilitate synergies with the Materials Science Institute of Barcelona (ICMAB), the National Centre of Microelectronics (CNM) and CNM's Clean Room. In fact, the idea is to create a joint centre with the Spanish Council for Scientific Research (CSIC). This would be set up in a similar way to the existing Cardiovascular Research Centre (CSIC-ICCC). Currently negotiations on creating a joint CSIC-ICN centre and a nanotechnology cluster are being finalised.

The ICN was created as a Foundation in July 2003. It was promoted by the *Generalitat de Catalunya* with the participation of the Autonomous University of Barcelona. The Board chairman is the Minister of Universities, Research and Information Society, and the vice-chairman is the Chancellor of the UAB.

ICN's founding charter states that its mission is to perform world class research in the field of nanoscience, and to become an international centre of excellence and reference. Its specific targets are:

a) To explore and discover the new properties of matter when it is derived from its aggregated state and has nanometre dimensions.
b) To develop methods for the synthesis, growth and fabrication of materials on a nanometre scale.
c) To develop techniques and methods for characterizing and manipulating nanostructures.
d) To facilitate the collaboration of scientists in different areas (physics, chemistry, biology, engineering) and to combine their contributions.
e) To educate young scientists and disseminate knowledge about the nanoscience and nanotechnology field.
f) To discover and apply nanotechnologies of benefit to industry, which can aid society's economic advancement.

The Parliament of Catalonia elections and the resulting change of government caused a delay in setting up the ICN. The process was given impetus on 9 May 2004 when Miquel Salmeron was appointed by the Board as Chairman of the Scientific Council, and by the author of this article as the Institute's Executive Director.

At present, the ICN's Scientific Council has been made up of the following internationally prestigious members:

– Miquel Salmeron, Lawrence Berkeley Laboratory, Berkeley, USA.
– Fernando Briones, Microelectronics Institute of Madrid, Madrid, Spain.
– Carlos Bustamante, Howard Hughes Medical Institute, Berkeley, USA.
– Manuel Cardona, Max Planck Institut, Stuttgart, Germany
– Ernst Meyer, Institut für Physik, Basel, Switzerland.

In 2004 a public request for tenders was held in two phases. The objective was to select an architect who would design and build a 3500m^2 building on land ceded by the UAB. This land is very close to the ICMAB and CNM buildings. The architect Mr. Javier San José was awarded the contract in October 2004.

According to the initial designs, the building will be made up of a lower ground floor, a ground floor and three storeys. The lower ground floor will house the laboratories that have more specific requirements related to vibrations and magnetic fields. The upper storeys will house the more "chemical" and "nanobio" laboratories.

The proximity of CNM's Clean Room means that it is not necessary to provide another one in the new building. In fact, CNM's Clean Room is currently being extended so that 200m^2 of it can be set aside for nanofabrication.

ICN's main research areas are as follows:

- Synthesis and applications of nanoparticles, nanoclusters and nanotubes.
- Design and synthesis of macromolecules for integration into nanodevices.
- Magnetism of thin films and spintronics.
- Imaging and manipulation of atoms and molecules.
- Theory and simulation of surfaces and interphases.
- Interaction of biomaterials with inorganic matter.

ICN is currently beginning to recruit its own research staff in parallel with the creation of the joint centre with CSIC. If project deadlines are met, ICN's building should become operational at the beginning of 2007. When this happens, ICN should be able to function at full capacity. Together with the universities and research centres, this will contribute to advancing nanoscience and nanotechnology in Catalonia.

Additional nanotechnology activities

One of the main characteristics of nanoscience and nanotechnology is its interdisciplinary nature. It affects all branches of

science and technology. As a result of this, and of its intrinsic interest and applications, nanotechnological research is growing at an accelerated rate. Therefore the scope of nanotechnology in Catalonia extends beyond the aforementioned CREBEC and ICN. Though it is by no means an exhaustive list, other institutions carrying out research in this area are described below:

- Universities
  As stated above, CREBEC is made up of groups from the UB and the UPC. In addition, the UAB participates in the ICN. However, the number of researchers from these three universities carrying out quality nanotechnology work is much higher. Other Catalan universities also conduct research in this field; in particular the Rovira and Virgili University (URV).

- CSIC
  The considerable contribution that the ICMAB and the CNM are making to the field of nanoscience was mentioned above. In addition, the CNM is building a Nanofabrication Clean Room. However, nanotechnology research and CISC's involvement is not limited to these two centres. We should also mention, for example, the nanobiology research being carried out in the Molecular Biology Institute of Barcelona (IBMB).

- Institute of Chemical Research of Catalonia (ICIQ)
  ICIQ's two main research areas are catalysis and supramolecular chemistry. Molecular nanotechnology has an important role to play in both of these areas.

- Institute of Photonic Sciences
  One of the four research areas in this Institute is Nanophotonics. In particular, nanostructured material applications for light emitting diodes and plasmon-based sensors are studied. This Institute is also researching nonlinear interactions in photonic crystals.

- Advanced Materials for Energy Reference Centre (CeRMAE)
  This reference centre was created in 2003 by the *Generalitat de Catalunya.* It researches nanostructured material applications for sensors and for efficient, clean energy production.

- Barcelona Science Park (PCB)
  As already mentioned in the description of CREBEC, the UB-UPC Nanobioengineering Laboratory is located in the Barcelona Science Park. Furthermore, PCB also has its own Nanotechnology Platform.

Finally, it should be mentioned that a URV initiative is setting up a Master's Degree in Nanotechnology in Catalonia.

All of the aforementioned initiatives clearly demonstrate that Catalonia is taking its position in the nanoscience and nanotechnology fields. It is important to attain a high level of coordination and synergy between the different initiatives, and to have the Administration's support. This is the only way to ensure that Catalonia plays a leading role in a field that will change the future.