



## Research Infrastructures and Nano-materials: *Genesys, Dynasync and NanoQuanta Cases*

### THE BIG PICTURE

#### *A Tiny Revolution that Changed the World*

Not that long ago, boardrooms of mighty industries were talking about silicon technology and how this relatively simple material revolutionised electronics and computing. But now, another revolution is hogging conversations in laboratories – and most probably boardrooms – across Europe and beyond. This revolution is being fanned by the exciting potential of new materials, applications and technologies emerging from the science of the infinitesimally small – nano-science.

And it is through increased awareness of nano-science and nano-materials that the world has been awakened to the potential of materials science to change everyone's lives profoundly. The impact will be felt not only by scientists and engineers, but also by many sectors of industry, including electronics, telecommunications, chemicals, transport, energy and the environment, to name a few.

Thanks to EU efforts, nano-material research in Europe has received a great boost, both in the way it is organised and the actual fundamental research taking place in labs across the Union. While many examples of cutting-edge research could be cited, three cases – **Genesys, Dynasync and NanoQuanta** – have been chosen to illustrate the value of European research co-operation and the importance of setting the standard and taking a leadership position in materials science, especially nano-materials.

#### *Scaling up the nano-results*

By understanding and controlling changes in the structure of a material – at the microscopic scale, nano-scale and potentially smaller – scientists can greatly enhance its physical and chemical properties on the large scale, making it possible to build better, more sustainable materials and improve our quality of life.

The next challenge for scientists is to scale-up nano-fabrication methods for use in mass production. Ongoing and future investigation – in small and large Research Infrastructures in both public and private settings – is needed to take full advantage of this burgeoning materials science.

### THE WHAT

#### *What are Nano-materials?*

The science of materials underpins human development. Briefly, it is the study of the composition, structure and processing of materials taking into account their properties and uses<sup>1</sup>.

Something in the 'nano-scale' indicates extreme smallness – so small, in fact, that scientists use microscopes that magnify 1 000 million times to study nano-structures.

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<sup>1</sup> Crystalline structures in matter are made up of rows, sheets and networks of atoms. A materials scientist explores this world of atoms, learning how they move, their stability and behaviour and how they interact under certain conditions.

Delimiting the nano-world is not a simple task, but three broadly discernible (although sometimes overlapping) groups are evolving: nano-electronics, nano-biotechnology and nano-materials. What's more, there are tools used to measure and manipulate ultra-small structures, such as nano-scale resolution microscopes, lasers and spectroscopes.

### ***What are Research Infrastructures?***

Research Infrastructures are defined as major instruments, installations, or facilities that provide services to support the work of researchers. Examples include actual physical facilities like clean rooms, synchrotrons or neutron sources, but also virtual facilities like libraries, databases and on-line archives.

## **THE WHY**

### ***Rationale – Research Infrastructures for Materials***

Research Infrastructures are vital in helping Europe develop top-class research –fundamental and applied – in materials science. The EU recognises the strategic role that emerging science and technology play in stimulating new knowledge which drives growth and industrial competitiveness – thus helping the Union achieve its Lisbon Agenda, ensuring job creation and sustainable growth in the 'knowledge-based society'.

The Union's aim – to develop a leadership position in materials science – is illustrated by the prominent position accorded to research in this field in the Sixth Research Framework Programme (FP6). As one of six thematic priorities – 'Nano-technologies, Knowledge-based Materials and New Production' or the NMP priority – €1.3 billion has been set aside to promote research projects in a wide range of related subjects, including work carried out on major Research Infrastructures.

## **THE CASES**

A quick scan of the world around us and we see tailored materials at work – from the elderly women walking thanks to an artificial hip to the young man on his mobile phone or the boy on his bike, they all owe a debt to developments in materials science. And with nano-materials and -technologies striding forward, more possibilities are on the horizon. But limitations do exist due to the complexity of the science involved, as well as technical and practical hurdles. To properly test new materials, more *in-situ* analysis is necessary on high-powered X-ray and neutron facilities.

Nano-science and nano-technology have become the Holy Grail of materials scientists, and a favourite of policy-makers and forward-looking industries. This is no wonder, as developments in the field offer an array of possibilities in vast areas such as health and medicine, electronics, information technology and manufacturing, to name a few.

The following three cases show the current move at European level to link better nanomaterials scientists with research infrastructures.

### **1. GENNESYS**

Today, basic research into nano-sciences is still too much fragmented across the EU, and not enough is known about the analytical and technological needs for developing nano-materials. Through the Genesys initiative led by the Max Planck Institute, a huge consortium of institutes, universities, and neutron and synchrotron facilities spanning Europe is working to bridge the gap between the research needs and future challenges of the nano-technology community, and matching this with the latest neutron and X-ray techniques.

"In order to stay competitive, Europe has to make the best use of its highly developed network of large-scale facilities," the team say in their literature. "This implies matching the infrastructure to the real needs of public and private research institutions." Genesys is out to do this in the domain of materials science and technology on the nano-scale.

The project is ambitious, the team admits, but vitally important nonetheless. Indeed, Genesys stands for 'Grand European Initiative on Nano-science and Nano-technology using Neutron and Synchrotron Radiation Sources'.

The project aims at assessing the state-of-the-art in nano-materials science and technology, identifying those areas where material analysis with synchrotron radiation and neutrons (SRN) would be most profitable for Europe and for its research community. It is also building a picture of the future industrial and societal challenges in this domain – the results of which are entered into its 'European Green Book' for guiding European research strategy in SRN for nano-materials science and technology. Their work would feed into European policy-making and research programmes.

The initiative has currently identified some 6 000 users of these Research Infrastructures from close to 50 institutions, universities and facilities Europe-wide, plus a host of supporting organisations. There are too many to mention here, however the following are a cross-section of the contributions being made to Genesys by different countries in the network:

- Rutherford Appleton Laboratory and Daresbury Laboratory (UK),
- Consiglio Nazionale delle Ricerche (IT),
- the Dansk Fundamental Metrologi (DA),
- Max Planck Society and Helmholtz Association (DE),
- University of Antwerp (BE),
- Norges teknisk-naturvitenskapelige Universitet, Trondheim (NO),
- Budapest Neutron Centre (HU),
- Interfacultair Reactor Instituut (TUDelft, NL),
- Institut Laue Langevin (FR),
- Studsvik Neutron Research Laboratory (SE),
- Neutron Physics Laboratory (CZ),
- DESY Deutsches Elektronen Synchrotron (DE),
- European Synchrotron Radiation Facility (FR),
- Laboratori de Llum de Sincrotron (under construction, ES),
- and the Swiss Light Source (PSI, CH).
- For a full list, visit the 'Leading Institutions' page of Genesys' website.

### **Contact**

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## **2. DYNASYNC**

Witnessing the advances in bio-technology and nano-technology being made in the USA and Japan, the EU made a bold move in its Sixth Framework Programme for research (2002-2006) to prioritise collaborative pan-European research into new materials and nano-sciences. Dynasync took up the challenge and assembled seven laboratories from Austria, Belgium, France, Germany, Hungary and Poland for an ambitious research project to address size-dependent quantum phenomena at the nano-scale, both theoretically and experimentally.

### ***Dynamic formula***

From the moment it was launched, the project set out to foster the long-term development of nano-science and technology in Europe. It is achieving this by boosting knowledge about dynamic phenomena in nano-structures and developing new ways of characterising and preparing nano-materials – methods that will meet, not just current, but also future industrial, economic, social and cultural needs and standards.

The project also aims to improve transnational co-operation across Europe in this field, especially for synchrotron research. The partners are focusing on advanced technologies and materials which have the potential to satisfy the ever-increasing demands – i.e. more power and faster data transfer – of computer systems. According to the team, they also want to raise the standard of nano-material and technological research in order to improve Europe's competitiveness and industrial position. Specific attention will be paid to the size dependence – and dynamics – of nano-scaled objects, for which synchrotron radiation is the main research tool.

The project involves

- the Institute of Catalysis and Surface Chemistry PAS (PL), in collaboration with
- the Institut für Materialphysik der Universität Wien (AT),
- the European Synchrotron Radiation Facility, NRG Grenoble (FR), the Stiftung Deutsches Elektronen-Synchrotron, HASYLAB, Hamburg (DE),
- the Instituut voor Kern- en Stralingsfysica, KU Leuven (BE),
- the Institute of Nuclear Physics, DMRC Cracow (PL),
- the KFKI Research Institute for Particle and Nuclear Physics, DNP, Budapest (HU).

### **Contact**

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Dynasync website: <http://www.dynasync.kfki.hu/>

### **3. NANOQUANTA**

A network of ten European universities and publicly-funded research groups, called NanoQuanta, is pooling its members' expertise in the electronic structures of nano-systems, in quantum-mechanical theory and in computer simulation in order to advance our understanding of the electronic properties of new materials.

By combining knowledge of quantum-mechanical theory with that of computer simulation, the consortium is delving into the properties of electrons and how they absorb and emit light. The data will be subjected to nano-specific experiments, as well as to electronic, dynamic and optical processes, in order to study in more depth the behaviour of electrons in the nano-structures and their interaction with external fields and light.

The EU-funded project aims to gather world-class research teams studying the electronic and spectroscopic properties of nano-structures through computer simulations. Through strong co-operation, new theories and insight into this exciting new field of investigation should emerge. The hope is that it will lead to future breakthroughs for nano-scale systems, such as bio-molecules or carbon nano-wires.

#### ***Ambitious research***

NanoQuanta is funded via the Sixth Framework Programme using the Network of Excellence instrument, an EU funding tool designed to strengthen research excellence. The key ingredient in such networks is to assemble a 'critical mass' of talent and resources in a particular field.

Putting together a strong team of experts and resources from across Europe in this field is essential because existing computer programmes, capable of accurately measuring excited electrons in nano-scale systems, require huge computing power and – until now – tended to be limited in scope. But, together, the consortium hopes to develop new fundamental theories and algorithms to improve these methods and make them applicable to complex and realistic nano-structures. Basic knowledge generated in the network by studies of model structures will be applied to more specific fields, with potential impact on industrial research later down the line.

An ambitious 'reach-out' programme is at the heart of the project, which starts with the dissemination of ideas, theories and computer programs to the wider European academic community, but also through contact with applied research groups. At the end of the four-year project, the NanoQuanta team plan to set up and maintain an effective 'European theoretical spectroscopy facility' which will further develop the activities pursued by the project, involving input and funding from a variety of sources. Most importantly, this platform will allow users to carry out simulations using shared software.

The consortium is made up of ten institutes or research centres in seven countries. The others are

- the Fritz-Haber-Institut, Berlin (DE),
- the Freie Universität Berlin (DE),
- Friedrich-Schiller-Universität Jena (DE),
- the Université Catholique de Louvain, Louvain-la-Neuve (BE),
- Lund Universitet (SE),
- the Università degli Studi di Milano (IT),
- the Laboratoire des Solides Irradiés (CNRS/CEA/Ecole Polytechnique) (FR),
- the Istituto Nazionale per la Fisica della Materia, Roma Tor Vergata (IT),
- and the Universidad del País Vasco/Euskal Herriko Unibertsitatea, San Sebastián/Donostia (ES).

**Contact**

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NanoQuanta website: <http://www-users.york.ac.uk/~rwg3/nanoquanta.html>

***What Do Europeans Think About Nano-sciences and Nano-technology?***

*The EU-funded thematic network 'Nanoforum' hosted an on-line consultation – a survey of opinions and ideas for improving policy-making – to find out what citizens thought about developments in nano-science and nano-technology. Held between August and October 2004, the survey was conducted in co-operation with the European Commission. The results confirmed that nano-technology will have a strong impact on European industry (90% deeming this so) and its citizens (80%) within ten years. Chemistry and materials, ICT and healthcare are perceived to be key areas in which nano-tech will have most impact, the report reveals.*

***More information***

*Nano-technology in the ERA (portal on CORDIS): <http://www.cordis.lu/nanotechnology/>*

*Nanoforum website: <http://www.nanoforum.org/>*

*State of play in the Union's NMP priority (Headline, 7 January 2005):*

*[http://europa.eu.int/comm/research/headlines/news/article\\_05\\_01\\_07\\_en.html](http://europa.eu.int/comm/research/headlines/news/article_05_01_07_en.html)*