Project no.: 500328-2

Project acronym: FRONTIERS

Project title: Research, processes and facilities directed at instrumentation for manufacturing and analysis of single molecules, individual nanostructures and 2-3 D architectures of them, targeted at life sciences

Instrument: Network of Excellence (NoE)

Thematic Priority: NMP 3.4.1.4

Publishable Final Activity Report

Period covered: from 01-08-2007 to 01-02-2009 Date of preparation: 15-01-2010

Start date of project: 01-08-2004 Duration: 4.5 years

Project coordinator name: Prof. Dr. Vinod Subramaniam
Project coordinator organization name: University of Twente

FRONTIERS:
Where Life Science and Nanotechnology Meet and Commercialization begins

FRONTIERS (*www.FRONTIERS-eu.org*) is a European Commission Network of Excellence focused on the crossover between Life Sciences and Nanotechnology supported by the Sixth Framework Program (FP6). FP6 supports research cooperation and integration of research efforts, promotes mobility and coordination and invests in mobilizing research in support of other EU policies. FRONTIERS aims at establishing leadership in research and innovation in life science related nanotechnology by creating structures that build on the existing strengths and facilities of the network partners. The FRONTIERS program is one vehicle created by the European Commission to strengthen the EU position in Nanotechnology.

Specifically the FRONTIERS initiative focuses on creating a critical mass in life science related nanotechnology. The FRONTIERS Program does this by leveraging and focusing existing strengths, expertise, and investments within Europe. One goal of the program is to focus the development of this Nanoscience cluster around industrial problems whose solutions will lead to marketable new technologies, processes, tools and devices that will in turn have great effects on science, industry, and society. The FRONTIERS program has an impressive list of partners (see Table below) located throughout Northern and Western Europe (see figure on the left) and are represented through approximately two hundred researchers with varying backgrounds that bring together a considerable knowledge of nanotechnology-related life science research.

FRONTIERS Partners	
MESA+ Research Institute, MESA+, The Netherlands	www.mesaplus.utwente.nl
University of Åarhus, Denmark	www.phys.au.dk/main/home-uk.shtm
University of Cambridge, IRC in Nanotechnology, United Kingdom	www.nanoscience.cam.ac.uk/irc/
Interuniversitair Micro-elektronica Centrum, Belgium	www.imec.be
Forschungszentrum Karlsruhe GmbH, Germany	www.fzk.de/
CeNTech GmbH, Germany	www.centech.de
Chalmers University of Technology, Sweden	www.fy.chalmers.se/
National Center of Competence for Nanoscience, Switzerland	www.nccr-nano.org/nccr
Max Planck Institute for Solid-State Research, Germany	www.fkf.mpg.de/kern/index.html
Nanoscience Group CEMES/CNRS, France	www.cemes.fr/
University Münster, Germany	www.uni-muenster.de/Physik.PI/

What does FRONTIERS do?

Nanotechnology is a field that by its very nature is multidisciplinary. The FRONTIERS program has developed a meritocracy based process creating centers of excellence in science as well as facilities. Partners concentrate more on focused core areas, spending less effort on R&D and facilities outside these areas. The main elements of FRONTIERS are aimed at increasing research, infrastructure, and education efficiencies and at building more and better business cases. FRONTIERS joint program of activities is organized into four blocks:

- Coordination of research, leading to a joint research program amongst the partners;
- Implementation of a Virtual European Nanoscience Laboratory to ensure efficient use of infrastructure as well as the availability of equipment for researchers through sharing;
- Creation of an integrated European Joint Curriculum, a master-level educational program on life science related nanotechnology; and
- Spreading of excellence, with a focus on joint management and the development of new business cases (science-to-industry). The science-to-industry chain must capitalize on the knowledge generated in the network by transforming it into applications and products.

Coordination of research

The research program in FRONTIERS is created and continuously adjusted in a bottom-up fashion. Over the course of the activities of FRONTIERS, associated researchers initiated more than 50 research collaborations which had their genesis in network-sponsored exchanges, meetings and workshops. Through this process of interactions, research focus areas gradually started to evolve, and most of the research projects could be assigned to one of the following categories:

- **Drug-delivery**

Typical examples: intracellular trafficking of drug-delivery nanoparticles, nanotechnology based targeted drug-delivery, 3D Nanopore Scaffolds for Drug-delivery, disassembly of drug delivery nanoparticles in cells.

- **Nanopores**

Typical examples: DNA sequencing with nanopores, DNA in nanopores, DNA in solid-state nanopores, the fabrication of solid-state nanopores, the mechanism of DNA traversal in a nanopore, nanopores for probing DNA-protein interactions, nanopores for RNA (un)folding, and nanopores for measuring the charge screening of DNA and RNA, creation and characterization of nanoporous structures, spanning lipid bilayers.

- **(Bio) Sensors**

Typical examples: Bio/nano hybrid structures, coupled plasmon affinity biosensors, cantilever sensor experiments, experiments using cantilever array sensors in biochemical environment.

- **Analytical Techniques**

Typical examples: Various manipulation techniques, such as nanoneedles, probes, and tweezers (optical and magnetic), local surface plasmon enhancement, near-field optical microscopy, atomic force microscopy imaging with functionalized probes, non-contact AFM, Virtual AFM, STM, single cell MS, leading edge top-down lithography.

- **Bio-interfaces and –compatibility**

Typical examples: Tissue engineering & implants (biomolecule adsorption as well as cell and tissue growth on biofunctional nanostructured surfaces, bio-interfacial processes including adhesion, interaction, signal transport, and molecular and nanoparticle transport), membrane-based strategies and technologies, addressing and manipulation of biomolecular structures, cell adhesion (neurons-on-chip), protein attachment techniques.

- **Nanostructured Surfaces**

Typical examples: Self-assembly, self-organization, and functionalization of surfaces (monolayers, multilayers) and probes, surface structuring and molecular printboards, nanoparticle 3D assemblies, patterning for guided neuronal growth, two-dimensional surface arrays, functionalized linear nanostructures.

- **Molecular Machines**

Typical examples: Single molecules, molecular motors, theoretical and computational simulations.

Virtual European Nanoscience Laboratory

The Virtual European Laboratory for Nanosciences enables network members to use instruments and facilities at any other FRONTIERS network partner. The Virtual Laboratory is accessible through the FRONTIERS website (members only) and contains two searchable databases; one on expertise and one on equipment. Both databases contain hundreds of entries including names and details of responsible contact persons. The use of the databases is user-friendly and fully automated. As a further consequence of making an inventory of the infrastructure available for nanotechnology for the life-sciences within the consortium, the workpackage responsible for the virtual laboratory was also able to identify gaps and white spots in available equipment and expertise. This information is essential input for building a roadmap for the relevant European infrastructure.

European Joint Curriculum

Interdisciplinary education and training for research personnel are prerequisites to develop and maintain centers of excellence in Europe. FRONTIERS has developed an integrated *European Joint Curriculum (EJC)*; a master level educational program on life sciences related nanotechnology. Student and teacher exchange is a key aim. The FRONTIERS educational program is based on the strong current programs at the partners in the area of life science related nanotechnology. The strength of the EJC lies in the harmonization of these educational programs. The EJC works with the European Credit Transfer System (ECTS); a minimum of 10 ECTS is needed for a FRONTIERS student. Students can combine the FRONTIERS theoretical curriculum with research projects as their master thesis work. Guidance occurs through an implemented e-based learning structure and research supervisors from both their home institution and the visited institution. Hence, in addition to the developed educational program, the EJC was able to contribute to the integration of research collaborations within FRONTIERS by initiating cross-institute technology projects via student exchange.

A highlight during the course of the network was a series of student-organized international conferences called INASCON. The INASCON conferences (with significant inputs from students at FRONTIERS partners NCCT, iNANO, and MESA+) were designed for nanosciences students, and were partially supported by FRONTIERS. All the organization and execution of the conference was driven by the students. The conference was a great success with international speakers, including many from the FRONTIERS network. Students had the opportunity to meet their peers and present and discuss their own work on an international level. Several workshops and discussion sessions were organised with such themes as employment, nanotoxicology, nanosciences in the media and combining an academic career with family life. The conference was very successful and the invited speakers were impressed by the high level of engagement by the participants. Several partners have committed sponsoring from alternative funding sources for the third edition of the conference in the fall of 2009, after the formal end of FRONTIERS.

Science-to-Industry

The transfer of generated scientific knowledge and of new technologies developed within the network into products is a key issue within this part of the FRONTIERS network. An effective transfer of know-how and technology towards the industry requires one to:

- Assess the business and market potential of the research projects
- Identify and to monitor the proprietary know how within the network
- Define the needs of the market and of potential industrial cooperation partners

In order to meet these requirements FRONTIERS established a task force "Science to Industry", a working group on IPR Management and an Application Committee containing members from industry for advice on research directions.
The network has developed a roadmap on nanotechnology and life-sciences with focus on:

1) Drug-delivery
2) Molecular Imaging
3) Bio-chips/sensors
4) Tissue Engineering & Implants
5) Market trends in Life Science Nanotechnology

Each chapter describes: market drivers, potential of nanotechnology, research within FRONTIERS, industrial involvement, trends and challenges.

FRONTIERS has facilitated technology transfer (patent transfer), indicating the significance of nanotechnology for industry. Several projects have also been considered for formation of spin-off companies and a case study of one such project was completed. With the support of the science-to-industry workpackage three joint patents, based on collaborative research initiated within FRONTIERS, were filed.

Technology Assessment and ELSA issues

The development of nanotechnology based products in a safe and responsible manner requires participation in social and ethical discussions surrounding this new technology. Regular communication to the general public, policy makers, investors and members from industry is ensured through the FRONTIERS PR-Policy plan including flyers, promotion banners, press releases, interviews, publications and posters. Additionally, FRONTIERS actively participates in societal discussions through its Ethical Advisory Board representing prominent members in the nanotechnology field.

A comprehensive Technology Assessment Program was launched, offering workshops to members on concrete, close-to-market nanotechnology applications (www.technologyassessment.info/) and their possible social / ethical implications. A full description of the technology assessment program, and outcomes from several workshops held during the course of the network are available.

Gender, Equality and Diversity

To increase the number of female scientists working in the field FRONTIERS nominated a Gender Awareness Group which developed a Gender Action Plan, which implemented Gender Monitors which helped continuously update the action plan. This working group developed and deployed two Equality and Diversity surveys to assess and monitor the effect of gender awareness plans. The report of the first survey was extremely well received and was distributed to members of the NMP program committee as an example of best practice.

In the final period, the second Equality & Diversity Survey was held, building on the experience from the first survey. A final report on the E&D survey is available.

Communication

An essential aspect of the mission of FRONTIERS is public engagement and communication. Some of the highlights of these activities included an art competition for children based on images taken from nanotechnology and in house Summer schools. With projects such on science on tour the general audience was reached, while other activities such as school visits aimed at children of particular age groups.

Lasting Integration

During the course of the network's life the partners actively explored the options for lasting integration beyond the end of the formal funding period. Several legal vehicles were considered, including a non-profit foundation structure that would comply with the legal wishes of all participating partners. Organizational rules of some partners prohibited their participation in a new structure. In parallel several discussion were held with other networks of excellence, and in particular with our sister network, Nano2Life, operating broadly in the same area. Finally, the core partners of FRONTIERS and Nano2Life decided to launch a joint initiative, NaBiA, the European Alliance in Nanobiotechnology. NaBiA's goal is to join forces of the two networks and to exploit their best practices for the benefit of the European S&T community in nanobiotechnology. Thus, NaBiA represents the single, largest and most competent network in Europe in nanobiotechnology. NaBiA has chosen not to adopt a legal status or invoke membership fees to prevent any unnecessary administrative burden. The activities to be implemented in the next 12 months will be supported by the internal resources of the partners, and includes:

- Research implementation
- Education and training
- Communication and dissemination
- Ancillary aspects: ELSA, technology assessment
- Strategy and enlargement
- Technology transfer

Exploitable knowledge and its use

Exploitable results with potentials for industry are arising from the network. A first case was described in the second reporting period: Medimate B.V.
Medimate (MESA+) brings Lab on a Chip technology to the Point of Care. The first product will be the Medimate Lithium Analyzer for patient and professional use and enables direct measurements at any location from one blood droplet. The target is to start marketing the Lithium Analyzer in January 2008. Other countries will be targeted within months from that. Parallel to the marketing Medimate will continue research for other product market combinations as well.
The support of FRONTIERS enabled further research to improve the disposable and to investigate other cost saving possibilities. Like for instance the use of external measurement electrodes and polymers. With the Forschungszentrum in Karlsruhe experience is exchanged leading to better insight and faster results. Besides this also support was found in the intellectual property area where FRONTIERS supported two patent applications financially.

In the third period three opportunities for the creation of spin-off companies have arisen. The interested scientists (Luisa De Cola (WWU), Regina Luttge (MESA+) and Guido Böse (WWU) have contacted FRONTIERS for support on IP strategy and commercialization strategies and discussions are ongoing. Deliverable 4.11 of the current reporting period describes a case study of Intellectual Capital Management in FRONTIERS.

In the fourth period the formation of two more spin-offs was supported:
Smart Membranes is a producer of high quality macro- and nano- porous alumina and silicon membranes with highly ordered structures and a narrow pore size distribution. These products can be used for ultra and nano filtration membranes (bio separation and bio analysis). The

company was founded by four scientists. One of them is Monika Lelonek from University of Münster/CeNTech. Initially these four women participate in the BMBF contest (power for female founders; Power für Gründerinnen" with this concept. Within the start up phase of this company Monika Lelonek was supported by the CeNTech GmbH.
Nanospot GmbH was founded as a spin off of the CeNTech in 2007. The co-founder and managing director Gudio Böse was, - while working at the University of Münster -, actively involved in FRONTIERS joint program of activities. He headed the FRONTIERS roadmap activities in *Molecular and Medical Imaging*. Today Nanospot GmbH develops new innovative arrays for the Optical Single Transporter Recording (OSTR) technology.
In the fourth period three FRONTIERS patents were established.