E nano newsletter

nº 12

June 2008

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E nano newsletter

Erratum

E-Nano Newsletter nº 11 March 2008 (page 10)

Glyconanoparticles for biomedical applications: Dynamic AFM and opto-magnetic detection of molecular interactions

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Dear Readers:

Nanoelectronics represent a strategic technology considering the wide range of possible applications. These include telecommunications, automotive, multimedia, consumer goods and medical systems.

Due to the approaching limits of the scalability of CMOS, basic research is still required on alternative devices for information technologies (molecular-based technologies, nanomechanics, etc.).

This E-Nano newsletter issue is therefore mainly dedicated to present "Nanoscale ICT Devices and Systems" initiatives such as the recently launched EU/FP7 nanoICT Coordination Action to support and reinforce the whole European Research Community in "ICT nanoscale devices". A brief description of the new FET collaborative projects (8) is also provided.

We would like to thank all the authors who contributed to this issue as well as the European Commission (ICT/FET/nanoICT) and the Pico-Inside Integrated Project for their close collaboration.

Dr. Antonio Correia
E nano newsletter Editor
Phantoms Foundation

EDITORIAL INFORMATION

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http://www.phantomsnet.net/Foundation/newsletters.php

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nanoICT short facts
Project acronym: nanoICT
Project full title: Nano-scale ICT Devices and Systems Coordination Action
EU Grant agreement number: 216165
Duration: 36 months (01/01/2008 - 31/12/2010)
Funding: 950.000 €
Nº of partners: 12
Instrument: Coordination Action (EU-FP7)
Coordinator: Dr. Antonio Correia
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Project web site: **http://www.nanoict.org**

1. Partners

The nanoICT CA Consortium will involve 13 major institutions from 9 different EU and associated countries (Finland, France, Germany, Italy, Poland, Spain, Sweden, Switzerland and United Kingdom).

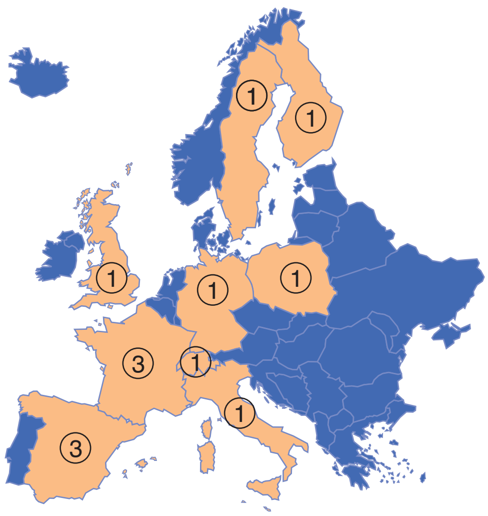

Figure 1. *Geographical distribution of nanoICT Institutions (core partners)*

Fundacion Phantoms (coordinator) - PH - (Spain)

Commissariat à l'Energie Atomique - CEA - (France)

Ecole Polytechnique Fédérale de Lausanne - EPFL - (Switzerland)

Technical Research Center of Finland - VTT - (Finland)

Consorzio Nazionale Interuniversitario per la Nanoelettronica - IUNET - (Italy)

Institut Català de Nanotecnologia - ICN - (Spain)

Universidad del País Vasco - UPV/EHU - (Spain)

Centre National de la Recherche Scientifique (CNRS-CEMES & CNRS-IEF) - CNRS - (France)

University of Cambridge - UCAM - (UK)

Lund University - ULUND - (Sweden)

Forschungszentrum Jülich GmbH - FZJ - (Germany)

Jagiellonian University - UJ - (Poland)

2. Objectives

The NanoICT Coordination Action **[1]** activities will reinforce and support the whole European Research Community in "ICT nanoscale devices", covering the following research areas expected to demonstrate unconventional solutions (disruptive technologies) to increase computing performance, functionality or communication speed, or to reduce cost, size and power consumption of ICT components beyond the expected limits of CMOS technology:

1. Demonstration of new concepts for switches or memory cells, to substantially improve performance, cost, integration density and/or power dissipation beyond those of ultimate CMOS technology using nanostructures or non-charge based approaches (complementary challenges

include circuit architectures, assembly and reconfiguration).
2. Demonstration of new concepts, technologies and architectures for local and chip level interconnects with substantial improvements over current solutions (key drivers are transmission speed, integration density, reduction in power consumption, integration of new functions, ease of design and manufacturing).
3. Demonstration of radically new functionalities by the integration of blocks from a few nanometres down to the atomic scale into high added-value systems. Candidates include NEMS and NEMS arrays; approaches based on photons, plasmons, phonons; approaches exploiting internal degrees of freedom of atoms and molecules and based on atomic precision control and addressability.

One of the main challenges is the timely identification and substantiation of new directions for the physical realisation of ICT beyond CMOS that have a high potential for significant breakthrough and that may become the foundations of the information and communication technologies and innovations of tomorrow.
Therefore, the NanoICT plan to strengthen scientific and technological excellence will go beyond the organisation of conferences, workshops, exchange of personnel, WEB site, etc., developing the following activities:
1. Consolidation and visibility of the research community in ICT nanoscale devices
2. Mapping and benchmarking of research at European level, and its comparison with other continents
3. Identification of drivers and measures to assess research in ICT nanoscale devices, and to assess the potential of results to be taken up in industrial research
4. Coordination of research agendas and development of research roadmaps
5. Coordination of national or regional research programmes or activities, with the aim to involve funding authorities in building the ERA around this topic
6. Development of strategies for international cooperation on themes related to the call, including where applicable, the development of research collaborations
Expected impact will be the enhanced visibility, shaping and consolidation of the NanoICT research community in Europe.

3. Working Groups & Roadmapping

The nanoICT CA will support the domain "ICT nanoscale devices" as a whole – the major aim of this action being to determine future drivers and measures necessary to assess research in this domain and therefore support the development of a truly competitive nanoelectronics industry in Europe. Effective mechanisms such as Working Groups will be put in place to ensure adequate coordination between the relevant stakeholders to provide research agendas and develop research roadmaps. 7 Working Groups (WG) are currently defined, each of them dealing with research areas of interest for the FET/NanoICT proactive initiative: a "global vision" one and 6 more focused.
1. WG1 - Alternative Electronics from a global point of view: WG coordinated by Robert Baptist/Jean Philippe Bourgoin (CEA, France)

2. WG2 - NEMS: WG coordinated by Juergen Brugger (EPFL, Switzerland)
3. WG3 - Carbon Nanotubes (CNT): WG coordinated by Bill Milne (University of Cambridge, UK)
4. WG4 - Semiconductor Nanowires (NW): WG coordinated by Lars Samuelson (Lund University, Sweden)
5. WG5 - Theory and Modelling: WG coordinated by Massimo Macucci (IUNET, Italy)
6. WG6 - Mono-Molecular Electronics (M2e): WG coordinated by Christian Joachim (CNRS-CEMES, France)
7. WG7 - Spintronics: WG coordinated by Claude Chappert (CNRS-IEF, France)

The mission of these working groups will be to enhance the communication among the "NanoICT" community in general and the EU ICT/FET related initiative funded projects in particular to:

- Structure "NanoICT" R&D sub-communities
- Exchange information on current work and state of the art of "nano-scale ICT devices and systems"
- Investigate opportunities that promote collaborations among the CA members, NanoICT funded projects and Working Group participants in particular
- Look for areas of common ground between different technologies
- Stimulate the emergence of ideas for new long-term and visionary ICT-related research areas

and therefore, give contributions to position papers and focused nanoICT CA reports (research agendas and roadmaps) to assess Europe's research position and potential, in particular for the preparation of future FP7 and FP8 calls (see figure 2).

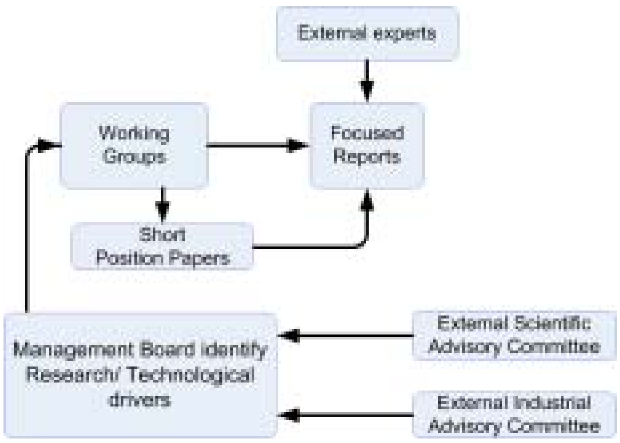

Figure 2.

4. European research landscape in "NanoICT"

To provide consolidation and visibility of the research community in "ICT nanoscale devices", a comprehensive guide -"who's who"- of groups working in related NanoICT areas will be created (nanoICT database), including two different lists:

- Core members, including active and experienced institutions in the field of "nanoscale ICT devices and systems" (emerging R&D research areas mapped by the network).
- Associated members, including institutions working on related topics, less mainstream nanoelectronics but performing relevant research.

This mapping will also provide a benchmarking of NanoICT research in Europe. Its comparison with other continents will be an element of the focused reports delivered by the Coordination Action.
In this way, the network will provide a clear vision of institutions performing research in NanoICT, transfer knowledge to teams external to the network but also integrate other groups aiding them in developing beneficial collaborations.

5. Conclusion

The nanoICT CA will therefore contribute to the emergence of new research directions and new research sub-communities, focused on selected range of emerging R&D activities, which are expected to strategically impact on future developments in the "ICT nanoscale devices" domain and their long-term applications:
1. Hybrid molecular and organic electronics to develop new functions or to improve the implementation of known functions, by incorporating new molecular-scale developments on appropriate submicron scale semiconductor platforms or flexible substrates.
2. One-dimensional structures such as nanowires for the development of devices, functions, interconnections, etc.
3. Single molecules for the development of reproducible functions and to assemble circuits. This research is likely to require progress in the understanding of electrical characteristics of single molecules and contacts. Special interest will be given to organic molecules, their potential for self-assembly and the multidisciplinary research they would motivate. This research topic concerns demonstration of building blocks at the molecular or even so atomic scale **[2]** that offer radically new functionalities.
4. Nano-Electro-Mechanical-Systems (NEMS) to develop sub-micron scale mechanical devices (beams, bridges, cantilevers, membranes, probes) with improved properties (low stiffness, high frequency and quality factors) for highly miniaturized integrated sensor and actuator systems with improved sensitivity.
5. Carbon Nanotubes (CNT) for the growth and application of this material in a variety of electronic devices, nanolithography, transistors, logic, interconnects resonators and microfluidics.

Glossary:
CA: Coordination Action
CMOS: Complementary Metal Oxide Semiconductor
CNT: Carbon Nanotubes
ERA: European Research Area
EU: European Union
FET: Future and Emerging Technologies
FP: Framework Programme
ICT: Information and Communication Technologies
M2e: Mono-Molecular Electronics
NEMS: Nano-Electro-Mechanical-Systems
NW: Semiconductor Nanowires

References:
[1] EU-FP7 funded project within the ICT/FET program (Information and Communication Technologies):
http://cordis.europa.eu/fp7/ict/
Future and Emerging Technologies:
http://cordis.europa.eu/fp7/ict/programme/fet_en.html
[2] See
ftp://ftp.cordis.europa.eu/pub/ist/docs/fet/atom-3.pdf

Project full title: Molecular Logic Circuits
Acronym: MOLOC
Instrument: FP7/FET Proactive Intiative, Nano ICT New Functionalities
EC contribution: 2.040.000 €
Contract number: 215750
Number of partners: 8
Duration: 3 years
Coordinator: Dr. Françoise Remacle
Contact person: Dr. Françoise Remacle
Contact data: Département de Chimie, B6c, Université de Liège, B4000 Liège (Belgium)
Email: fremacle@ulg.ac.be
Project WEB site: http://www.moloc.ulg.ac.be

Partners:
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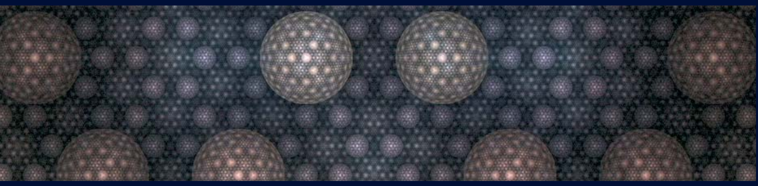
Prof. Itamar Willner (The Hebrew University, Israel)
Prof. Karl Kompa (Max Planck Institute for Quantum Optics, Germany)
Prof. R. D. Levine (The Hebrew University, Israel)
Prof. Rainer Waser (Institut für Festkörperforschung (IFF), Germany)
Prof. Rainer Weinkauf (Heinrich-Heine Universität Düsseldorf, Germany)
Prof. Sven Rogge (Kavli Institute of Nanoscience Delft, Netherlands)

Project summary:
MOLOC – Molecular Logic Circuits seeks to design and provide demonstration of principle, feasibility and significant advantages of logic circuits where the basic element is a single molecule (or assemblies of atoms or molecules) acting in itself as a logic circuit. The functionalities provided by this new post-Boolean approach differ in essential ways from using a molecule as a switch. The approach depends on molecules (or nanostructures, etc) having internal degrees of freedom and multiple (quasi)stationary states by virtue of their confined size. We therefore make an advantage of the nanosize which is imposed by the cardinal technological need to reduce the size of the circuit in order to implement complex logic functions at the hardware level and thereby add new functionalities. Exploratory work has shown that it is possible to address the states of a single molecule either electrically (or electrochemically) or optically and also that it is possible to concatenate the logic operation of two molecules. The partners to MOLOC are cognizant that to go beyond the projected limits of CMOS technology will likely be most productive if it be a surface based approach. All the same, foundational work in the gas or liquid phase is also discussed.

Project full title: Nano Optics for Molecules on Chips
Acronym: CHIMONO
Instrument: ICT - Collaborative Project
EC contribution: 5.519.901 €
Contract number: 216774
Number of partners: 6
Duration: 3 years (01/02/2008-31/01/2011)
Coordinator: Prof. Francesco Saverio Cataliotti
Contact person: Prof. F.S.Cataliotti, Laura Bartoletti
Contact data: Dipartimento di Energetica "Sergio Stecco" LENS - Laboratorio Europeo di Spettroscopia Non-Lineare, LENS - Via Nello Carrara 1, I-50019, Sesto F.no (FI), Italy
Email: fsc@lens.unifi.it
Project WEB site: http://chimono.lens.unifi.it

Partners:
Prof. Francesco Saverio Cataliotti (Laboratorio Europeo di Spettroscopie Non Lineari (LENS), Italy)
Prof. Ed Hinds (Imperial College of Science, Technology and Medicine (IMPERIAL), UK)
Prof. Jörg Schmiedmayer (Technische Universität Wien (TUW), Austria)
Prof. Gerard Meijer (Fritz-Haber-Institut der Max-Planck-Gesellschaft (MP), Germany)
Prof. Dr. Arno Rauschenbeutel (Johannes Gutenberg-Universität Mainz (JOGU MAINZ), Germany)
Prof. Dieter Meschede (Rheinische Friedrich-Wilhelms-Universität Bonn (UBONN), Germany)

Project summary:
The continuous progress of research in the field of ultracold atoms has led to spectacular developments in the past two decades well illustrated by the increasing number of laboratories all over the world engaged in this research, and by the appearance of dedicated Journals and Conferences. The last five years have seen the emergence of two new and important novelties that brought the field of ultracold-atoms in even greater contact with Information and Communication Technology. On the one hand, ultracold atoms have connected to microelectronic technology thanks to the development of the “AtomChip”, on the other hand new methods have been demonstrated to extend the trapping and control techniques from atoms to molecules. At the same time huge progress has been achieved in the detection and control of single atoms.



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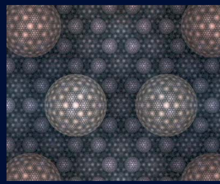
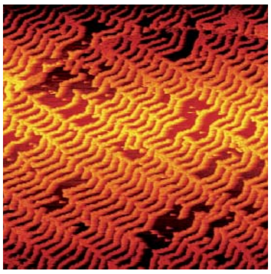
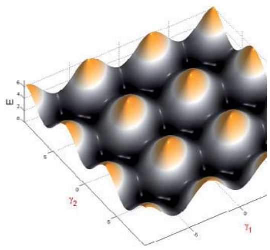


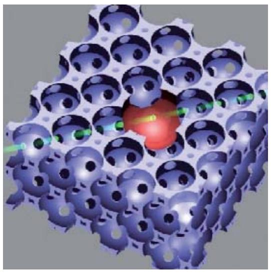
Molecular Nanoscience
Array of PCBM molecules on Au (III)

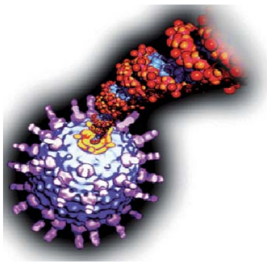




Nanoscience at very low temperatures
Potential landscape of a superconducting qubits

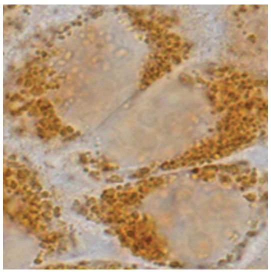
Nanoelectronics Nanophotonics
Photonic crystals

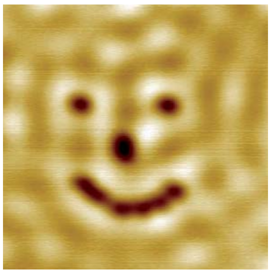




Biomachines and manipulation of biomolecules
Biological molecular motors

Nanomagnetism and the biomedical application of magnetic nanoparticles
Magnetic nanoparticles inside tumoral cells

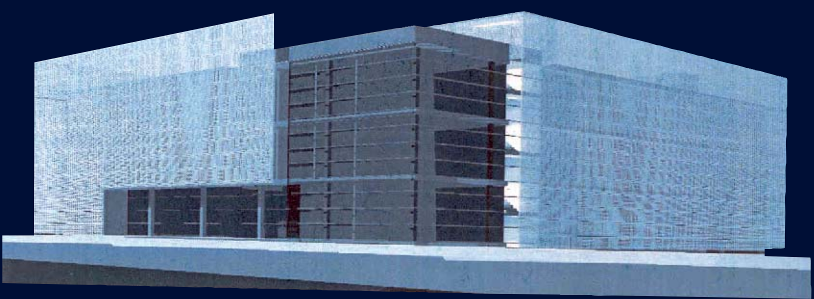




Nanofabrication and advanced instrumentation
Molecular smile assembled with STM

IMDEA- Nanociencia is a private Foundation created by joint initiative of the regional Government of Madrid and the Ministry of Education of the Government of Spain in February 2007 to manage a new research Institute in Nanoscience and Nanotechnology (IMDEA-Nanociencia), which is located in the campus of the Universidad Autónoma de Madrid, 12 km away from Madrid downtown with an excellent communication by public transportation with the Madrid-Barajas airport (25-30 min) and Madrid downtown (15-20 m).

The Institute offers attractive opportunities to develop a career in science at various levels from Ph.D. students to senior staff positions.



Contact

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Facultad de Ciencias, C-IX, 3rd floor
Campus de Cantoblanco Madrid 28049 Spain

Phone 34 91 497 68 49 / 68 51 / 68 54 Fax 34 91 497 68 55
contact@imdea.org
For further details see http://www.imdea.org

Project full title: Atomic Functionalities on Silicon Devices
Acronym: AFSID
Instrument: STREP FP7: FET Proactive Intiative: NANO-SCALE ICT DEVICES AND SYSTEMS
EC contribution: 2.200.000 €
Contract number: 214989
Number of partners: 6
Duration: 3 years (01/02/2008 - 31/01/2011)
Coordinator: Dr. Marc Sanquer, CEA
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Project WEB site: http://www.afsid.eu

Partners:
Dr. Marc Sanquer (Commissariat à l'énergie atomique, France)
Dr. Sven Rogge (Technische Universiteit Delft, Netherlands)
Prof. D. Kern (Eberhard Karls Universitaet Tuebingen, Germany)
Dr. Marco Fanciulli (Consiglio Nazionale delle Ricerche, Italy)
Dr. D. Williams (Hitachi Europe Limited, United Kingdom)
Prof. D. Jamieson (University of Melbourne, Australia)

Project summary:
In this project, we wish to take advantage of a fundamental figure-of-merit of the CMOS transistors, the doping modulation, to propose new functionalities arising from the control of a single charge and spin on individual dopants in silicon. The ultimate electrical switch is an atomic point contact. It has been realized and operated several times in laboratories at low temperature under the form of Quantum Point Contacts (QPC), metallic break junctions, molecules placed in an air gap. However a silicon atomic switch has not been realized yet.
The devices will be manufactured within a mature technology on state-of-the-art CMOS platforms. Contrarily to bottom-up approaches, there is an unavoidable dispersion in the average number and location of dopants, using masking and implantation CMOS techniques.

Project full title: Graphene-based Nanoelectronic Devices
Acronym: GRAND
Instrument: ICT-2007.8.1 – Future and emerging technologies: Nano-scale ICT devices and systems, Small or medium-scale focused research project
EC contribution: 2.389.704,25 €
Contract number: 215752
Number of partners: 6
Duration: 3 years (01/01/2008-31/12/2010)
Coordinator: Heinrich Kurz, AMO
Contact person: Matthias Baus, AMO
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Email: kurz@amo.de; baus@amo.de
Project WEB site: http://www.grand-project.eu

Partners:
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Prof. Enrico Sangiorgi (Consorzio Nazionale Interuniversitario per la Nanoelettronica (IUNET), Italy)
Dr. Thierry Poiroux (Commissariat à l'Energie Atomique (CEA-LETI) France)
Dr. Aidan Quinn (University College Cork, National University of Ireland, Cork, Tyndall National Institute (TNI-UCC), Ireland)
Prof. Charles G. Smith (University of Cambridge (UCAM DPHYS), UK)
Dr. Fabrice Payet (STMicroelectronics (Crolles 2) (STM SAS), France)

Project summary:
Will graphene really take the semiconductor industry towards the “Beyond CMOS” era? Some answers to this key question are sought through experiment and simulation in a European research project on Graphene-based Nanoelectronic Devices called “GRAND”.
The silicon semiconductor industry is the cornerstone of today’s high-tech economy. Through continuous downsizing of components and cost reductions, it has fuelled other industries for the past decades. Today the semiconductor industry is facing fundamental challenges and severe economic constraints, and it is expected that the historic trend of downscaling silicon devices will come to an end in about 10-15 years.
The major challenge is therefore to find alternatives for information processing and storage beyond the limits of existing CMOS technology. Graphene, an atomic monolayer of carbon, is particularly promising due its novel electronic properties. Initial data indicates that graphene is a prime candidate for “Beyond CMOS” switches and interconnects, and is, despite its revolutionary nature, complementary to conventional CMOS. Its remarkable properties include potential for ballistic conductance at room temperature, current densities exceeding those of current nanoscale interconnects and carrier mobilities rivalling those of III-V devices at room temperature.

Project full title: Coupling charge transport to internal degrees of freedom at the single molecule level
Acronym: SINGLE
EC contribution: 2.580.000 €
Contract number: 213609
Number of partners: 5
Duration: 3 years (01/01/2008-31/12/2010)
Coordinator: Prof. Thomas Bjørnholm
Contact person: Rikke Bøyesen
Contact data: Nano-Science Center, University of Copenhagen, Universitetsparken 5, 2100 København Ø
Email: tb@nano.ku.dk; rb@nano.ku.dk
Project WEB site: http://www.single.ku.dk

Partners:
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(Chalmers Tekniske Hoegskola AB, Sweden)
(Technische Universiteit Delft, Netherlands)
(IBM Research GmbH, Switzerland)
(Universite de Mons-Hainaut, Belgium)

Project summary:
The research project is a collaborative project - a small / medium scaled focused research project on how to couple charge transport to internal degrees of freedom at the single molecule level. The Scientific aim of the SINGLE project is to understand how single molecules can ultimately be used as transistors, diodes, switches, or memory. SINGLE-collaborators study the influence on electronic conduction of the strength of the electronic coupling between the molecule and the electrode and the intrinsic structure and dynamics of the molecule.
The project will be carried out by a collaboration of these institutions, coordinated by Prof. Thomas Bjørnholm, Nano-Science Center Copenhagen University: Chalmers Tekniske Hoegskola AB, Technische Universiteit Delft, IBM Research GmbH and Universite de Mons-Hainaut.
The strategy is to investigate well-defined test systems experimentally in two and three terminal devices and support the results with theory. Applied aspects are long term with high risk and high potential for possible applications. The work is proceeding in iterative cycles of synthesis, measurements, modeling, and eventually integrating the most promising systems in more advanced prototype systems.

Project full title: Carbon nAnotube Technology for High-speed nExt-geneRation nano-InterconNEcts
Acronym: CATHERINE
EC contribution: 2.649.998,90 €
Contract number: 216215
Number of partners: 11
Duration: 3 years
Coordinator: Stephen Trueman
Contact person: Stephen Trueman; Management: Riccardo Carelli; Arianna Santini
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riccardo.carelli@sapienzainnovazione.it
arianna.santini@uniroma1.it

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Maria Sabrina Sarto (Università degli Studi di Roma "La Sapienza" – (SAPIENZA-CNIS), Italy)
Dr. G.Q. Zhang (Technical University of Delft, The Netherlands)
Laurent Arurault (University of Toulouse (UPS – CIRIMAT), France)
Vincenzo Tucci (University of Salerno, Italy)
Yuri F. Zhukovskii (University of Latvia, Latvia)
Raluca Müllerf (National Inst. for Research and Development in Microtechnologies, Romania)
Magnus Höijer, Rolf Jonsson (Swedish Defence Research Agency, Sweden)
Stefano Bellucci (Italian National Institute of Nuclear Physics, Italy)
Dr. Olaf van der Sluis (Philips Electronics Nederland B.V. (PHILIPS), The Netherlands)
David Brud and Mohammad Shafiqul Kabir (Smoltek (SMOLTEK), Sweden)

Project summary:
CATHERINE will provide a new unconventional concept for local and chip-level interconnects that will bridge ICT beyond the limits of CMOS technology.
The new bottom-up approach proposed by CATHERINE consists in realizing CNT-based nano-interconnects for integrated circuit exploiting two different techniques: (i) a template-based CVD technique that allow high control of the growth of perfect aligned arrays of CNTs. The CNTs are synthesized within the pores of properly designed alumina nanostructures. CNTs wall thickness is controlled by the reaction time, the CNT length by the thickness of alumina nanostructures, the CNT external tube diameter by the nanostructures pore size; (ii) CVD growth of CNTs and carbon nanofibers (CNFs) on substrate patterned with nano-imprint lithography. Both techniques do not require electron beam lithography (EBL) for CNTs growth or substrate preparation.

NABAB

Project full title: NAnocomputing Building blocks with Acquired Behaviour
Acronym: NABAB
Instrument: STREP project
EC contribution: 2.100.000 €
Contract number: ICT 216777
Number of partners: 5
Duration: 3 years (01/01/2008 - 31/12/2010)
Coordinator: Christian Gamrat (CEA, France)
Contact person: Christian Gamrat (CEA, France)
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Prof. Göran Wending (Chalmers University of Technology, Sweden)
Dr Bernabe Linares (Instituto de Microelectronica de Sevilla (CSIC), Spain)
Prof. Mark Welland (University of Cambridge, UK)

Project summary:
Targeting the development of computing solutions complementing logic functions based on CMOS, the main objective of the NABAB project consists of "demonstrating that it is possible to obtain useful computing functions as the result of a post-fabrication learning/adaptation process taking advantage of the rich functionality provided by interconnected nano devices". The NABAB project will explore the feasibility of a functional nano computing block (NAB) that will be built by interconnecting molecular electronics devices based on new nanoscale organic field-effect transistors (FET), functionalised nanotubes FET or ZnO FET that provide a rich combination of functions (memory and gain, sensitivity to various local or global stimuli). The project will show, as a primarily target, that such a NAB can acquire a specific, non-trivial, computing function by means of an internal adaptation process (learning, reconfiguration, self-organization). Besides, an important aspect of the project is to show that the acquired functionality of the NAB is exploitable within a realistic and larger computing system.

VIACARBON

Project full title: Carbon Nanotubes for Interconnects and Switches
Acronym: VIACARBON
Number of partners: 4
Duration: 3 years
Coordinator: Prof. John Robertson
Email: jr214@hermes.cam.ac.uk

Partners:
John Robertson (University of Cambridge, UK)
M Scannell (CEA (Grenoble) Leti, France)
Adrian Ionescu (Ecole Polytechnique Federale Lausanne, Switzerland)
Jenny Patterson (Intel, Ireland)

Project summary:
VIACARBON aims to develop carbon nanotubes for vertical and horizontal interconnects for CMOS nodes of 22 nm and beyond, and for NEMS RF switches. Carbon nanotubes are universally proposed as interconnects because of their huge current carrying capacity of 1E9 A/cm^2. However, interconnects also need a low resistance, at least as low as copper. As CNTs are 1-dimensional conductors, they have a minimum quantum resistance of 6 kohms, which can only be reduced by laying many CNTs in parallel. The project aims to grow single wall nanotube mats with density of over 1E13 cm^{-2}, by optimisation of the growth catalyst, and convert this into an industrially compatible technology for both vertical and horizontal interconnects. A second aspect is to fabricate arrays of NEMs as RF switches to support new device functions in the interconnect layer: for reconfigurable interconnects, banks of programmable passives and power current switch.

Report of 2nd E-Nano Cluster Meeting Gran Canaria (Spain), November 13-16, 2007

Alfred Forchel, Würzburg University (Germany)

Meeting organised in collaboration with

1. Executive Summary

The 2nd E-Nano/FET Cluster Meeting, held in Las Palmas, Gran Canaria from November 13 to 16, 2007, brought together about 130 scientists primarily associated with nine FP6 and nine FP7 projects. In the plenary session invited talks as well as the ongoing FP6 projects presented internationally leading research in key areas relating to different topics of nanoelectronics. The FP7 projects, which are just at their starting point, presented research targets and strategies. In a working session on “2020 and Beyond – Long-Term Challenges for the FET-Nano Community” important new topics were proposed and discussed by the participants.

Several trends can be observed in going from FP6 via FP7 to future topics. In general the FP6 projects cover

- a wide span of topics from fundamental technology, physics and biochemistry to information processing, including architecture aspects
- top down and bottom up technologies for nanopatterning/nanostructure fabrication are used with roughly similar intensity
- the majority of the projects is semiconductor based
- several projects address long term research related to bio/molecular-nanoelectronics or work on paradigm shifts

The FP7 projects

- emphasize carbon based nanoelectronics,
- have much less a focus on semiconductors,
- increasingly target single atom/molecule scale control of individual functional devices,
- include small functional systems,
- as well as investigations of hybrid CMOS – nanoelectronic systems.

The working session discussions on “2020 and Beyond - Long-Term Challenges for the FET-Nano Community" were primarily centered on future topics of semiconductor and carbon based materials. Single molecule activities were discussed, with respect to precision fabrication rather than regarding nanoelectronic functions based on organic molecules. As discussed in more detail in the following sections several topics emerged, which have potential for PROACTIVE initiatives. These include “Energy harvesting nanosystems” and “Functional nanosystems based on a larger number (~ 100) devices”, as well as low voltage electronics, photonics for nanoelectronics etc.

In order to increase the interaction with the ICT industry it is recommended to include presentations on the status and development in main stream technologies in future plenary meetings as well as in project based workshops. Furthermore it is recommended to monitor the development of focal topics of the initiatives after a period of five years with the help of external experts in order to focus the longer term funding on fields having demonstrated a dynamical development and to replace topics which have not generated significant progress by new ones.

2. Introduction

According to the 2006 edition of the International Technology Roadmap for Semiconductors (ITRS) the DRAM metal half pitch is expected to decrease to 22 nm in 2016 and will reach 14 nm in 2020. The geometrical gate length is expected to reach 15 nm (2016) shrinking further to 9 nm in 2020, corresponding to physical gate lengths of 9 and 6 nm, respectively.

Due to the approaching limits of the scalability of CMOS – even with strong modifications in device designs like the use of FinFETs – basic research is required on alternative technologies for information technologies with potential to operate with smaller device sizes, higher integration densities, lower power consumption and higher operation speeds.

The challenges for the devices, circuits and systems to be developed are enormous. The ultimate limit of the device size scale is of course given by the size of individual atoms or molecules. This size range is characterized by strong quantization effects In parallel, surface and interface effects strongly impact the device functionality. Therefore not only the devices themselves but also the environment has to be controlled on an atomic scale. This is particularly challenging when circuits with several hundred millions of devices for storage and logics are addressed. Currents in individual nanochannels are typically small, device speed is limited by high resistances etc. However, it has to be pointed out that an abrupt and complete replacement of CMOS by an alternative technology is very unlikely. More probable are hybrid scenarios in which new nanoelectronic elements are combined with a CMOS platform. New functionalities regarding e.g. built-in sensing will help to promote the introduction of non-CMOS nanoelectronics into CMOS related applications.

As the limits of CMOS scalability will be reached within a time frame of 10 to 15 years, research on alternative nanoelectronics technologies is vital for Europe in order to keep a share of the forefront of research, development and competitive production in the international ICT arena. This is also increasingly recognized by the CMOS industry. In the 2005 version of the ITRS a 70 page section is devoted to “Emerging Research Devices” (ERD). The section presents the status of different CMOS alternatives regarding materials, memory devices, logic devices, and information processing nano - architectures. In particular the following concepts are considered as ERD by the 2005 ITRS a) Memories: nanofloating gate memories, tunnel barrier memories, ferroelectric FET memories, polymer memories and molecular memories b) 1 D structures (semiconductor nanowires and carbon nanotubes), resonant tunneling devices, single electron transistors, molecular devices, ferromagnetic logics and spin transistors. 1D materials and devices are highlighted in the ERD roadmap section as particularly promising.

The FET Proactive Initiatives in FP6 and FP7 as well as a number of projects in FET-open address fundamental research on a number of key approaches to post CMOS electronics. As described in the following sections, the research supported by the different Proactive projects includes work on nanowire and nanotube electronics, single atom or single molecule based operation principles, spintronic devices, etc. Many challenges identified by the ITRS roadmap like e.g. the need to control surfaces and interfaces in order to obtain reproducible and reliable device operation constitute important tasks of these projects. In parallel to studies of the device performance detailed microscopic characterization of e.g. energy levels and band structures with down to atomic resolution are adressed. Different to the ITRS discussions and to literature and calculated data which are usually benchmarked with the performance of Si-CMOS, the projects on average rather address proofs of principle and are typically limited to studies of an individual device or small circuits with less than ten devices. It would be interesting to compare the overall device functionalities obtained by the projects with those expected of CMOS available in about ten years from now.

3. Overview of Activities

3.1 Keynote Presentations

Gerhard Meyer, IBM Zürich, "Scanning Probe Microscopy of Adsorbates on Insulating Films: First Steps towards a modular molecular logic"

The talk highlighted results by the Zürich group on an extremely well controlled system in which individual atoms and molecules on insulating films (NaCl on copper) are investigated by STM. By changing the charge state of a Au atom by individual electrons e.g. the diffusion properties can be varied in a controlled manner. Atomic precision nanotechnology was highlighted in very impressive examples. G. Meyer demonstrated that a covalent bond can be closed and opened between an individual Au atom and an organic molecule. Most impressive were results on individual molecular switches formed by the positional bistability of hydrogen atoms in naphtalocyanine.

This talk was extremely impressive. It clearly illustrated that in special, cleverly selected situations and precisely controlled functions can be realized by individual molecular size systems. The presentation illustrated the fundamental edge of a wide range of research topics related to nanoscience and technology. A large number of breakthroughs will be required to transfer these beautiful results into individual nanoelectronic devices which can operate at/near room temperature, at sufficiently large bandwidths, if at all possible. Nevertheless it is certainly important to investigate future nanoelectronic devices starting from the point of atomically defined and controlled systems.

Sven Rogge, Delft University of Technology, "Atomistic understanding of transport through a single dopant atom"

This talk focused on scanning tunnelling spectroscopy of the properties of donors and transport in Si FinFETs. It represents to a certain degree an orthogonal approach to the previous talk by focussing on single atom effects in real devices. The FinFETs investigated are 60x60x35 nms in size and contain about 100 donors. The transport occurs preferentially near the edges of the devices in which only a small part of the total number of donors is located. In selected devices resonances can be observed in the source drain current, which are associated with different charge states of a single donor (As). By detailed calculations the eigenstates of the As are obtained including effects of the gate field. With increasing field strength the electron shifts towards a triangular potential well at the gate interface resulting in the ionization of the donor.

Similarly to the first talk this paper was extremely impressive. In a general perspective it highlighted the possibilities of nanocharacterization and detailed modelling to generate individual atom effects in state of the art Si-devices.

Jean-Christophe Charlier, Universite Catholique de Louvain, "Quantum transport in carbon nanotubes"

In another excellent talk, J.-C. Charlier discussed key features of carbon nanotube (CNT) nanoelectronics, mainly from a theoretical point of view. In a first section results on quantum transport in ideal carbon nanotubes were presented relating CNT properties to those of graphene. In the second section, doping of carbon nanotubes by B and N was addressed. The group of J.-C. Charlier has used first principle methods to determine the density of states in systems with varying B and N concentrations. The mean free path for electrons at the Fermi energy is seen to decrease for increasing B concentration as a consequence of disorder. A further part of the plenary talk presented possibilities and consequences for a functionalization of CNTs by controlled absorption of organic π -conjugated molecules like benzene. Finally point defects in graphene were discussed. Using e.g. density functional theory, local density approximations and pseudopotential approximations the electronic bandstructure of graphene with different point defects was obtained. Similarily to the situation in bulk systems the defects give rise to localized states. For comparison with experimental data STM maps of graphene without and with point defects have been calculated.

3.2 Working Session: "2020 and Beyond – Long-Term Challenges For the FET-Nano Community"

The working session was attended by the vast majority of the participants. It was chaired by David Guedj and moderated by Alfred Forchel. In order to set the scene and to encourage long term visionary views from the audience the moderator presented a couple of slides from the presentations of Wolfgang Boch and David Guedj in the morning. The slides illustrated the mission of FET Proactive and the current topics. In addition a short summary of the current status in FET-Nano was presented including a few potential topical areas like investigations on complex nanoelectronics networks, investigations of nanoelectronic devices and systems interacting with solid state environments and transfer of new experimental techniques developed in other fields to nanoelectronics, etc.

In the course of the session about ten short presentations given by different participants served as starting points for

Research/Scientific Policy

a very constructive discussion.

Heinrich Kurz (GRAND) summarized a number of opportunities for research and applications while the CMOS miniaturization is continued and beyond. He pointed out opportunities from diversification and due to increasing speed. Examples for potential diversification include nanoelectronics for sensors, systems on a chip, power electronics, polymer electronics and nanotechnologies on new materials like Graphene. In terms of speed, ballistic transport, terahertz nanotransistors and carbon interconnects etc. were mentioned. Regarding self assembly Heinrich Kurz pointed out that self assembly techniques are working well for the generation of nanometerials. In contrast, self assembly techniques to realize functional devices and circuits are missing and should be developed. H. Kurz particularly emphasized the need to investigate optoelectronics and nanoelectronics in an integrated fashion. By merging electronics and photonics using for example III-V on silicon or by developing silicon photonics important nanoelectronics problems like e.g. the interconnect bottleneck could be addressed. These approaches also have potential to realize future high bandwidths applications at affordable prices.

Charles Gould (Nanospin) pointed out the importance of energy as a driving force for future IC research. He indicated that even current ICs could be operated significantly faster if a temperature management is able to select regions with small dissipation instead of hot areas. He proposed to investigate more spin related effects as they may allow to manipulate and to minimize dissipation. In the following discussion the importance of minimizing dissipation/energy consumption was substantiated by several participants. It was suggested to investigate energy harvesting nanosystems in a future initiative.

MOLOC representatives pointed out the need to demonstrate new functionalities in devices based on atomic-scale technology. They emphasize functional logical circuits which are addressed at the atomic/molecular scale. The main challenges include scalability, interfacing to the macroscopic world, overcoming limits of Boolean logics and the development of large nanoelectronic systems for efficient parallel processing.

In a contribution by Christian Joachim (PICO-INSIDE) new driving forces for the ICT development and therefore also for nanoelectronics were highlighted. The presenter stated a shift from military driven ICT to current (nano)electronics driven by sustainability. He pointed out, that the production of a 128 Mbit chip requires among other things 6,4 kg of fuel, 230 gr of chemical products and 120 l of water. These numbers are very impressive. They clearly underline the potential benefits of a research program on sustainable nanoelectronics.

Lukas Worschech (SUBTLE) pointed out new opportunities opening up when functional nanoelectronic circuits become available. These circuits will be based on the use of phenomena like ballistic transport, spin related phenomena, coherence, etc. in combination with new architectures. In the related discussion the need for new nanospecific and e.g. fault tolerant architectures was emphasized. The availability of functional nanoelectronic system will also help to attract the interest of industry. He emphasized the merging of photonics and electronics and the need to investigate nanoelectronic/nanophotonic conversion elements between optics and electronics and vice versa. As a second general theme Lukas proposed to investigate new information carriers including for example phonons.

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3.3 FP7 Project Contributions

Nanoscale ICT Devices and Systems (nanoICT Coordination Action)
The "Nanoscale ICT Devices and Systems" (nanoICT) Coordination Action is formed by 12 members, based on universities/research institutions and one foundation. It is coordinated by the "Fundacion Phantoms".
The Coordinated Action carries out scientific networking, organizes scientific conferences and workshops, enhances scientific dissemination via a newsletter, web-page and roadmaps. By doing this the action aims to contribute to the demonstration of new nanoelectronic concepts (switches, memory cells, novel interconnect schemes, integration of nanoelectronics in high added value systems).

MOLOC - MOlecular LOgic Circuits (Single Atom/Single Molecule)
The project has 8 partners, all from public research institutes. It is coordinated by University of Liege.
The project focuses on the foundation and proof of concept of post Boolean logics based on internal degrees of freedom of nanostructures (molecules, dopants in semiconductors, etc.) addressed electrically and/or optically to implement new functionalities in logic circuits. The project plans to use (primarily) optically and electrically excited molecules as logic circuits. Logic functionality will be obtained by fast dynamics of non stationary molecule states created by optical, electrochemical or electric input. This is expected to provide access to multivalued logics. MOLOC also claims that the present approach is particularly suitable to implement parallelism.

AFSID - Atomic Functionalities on Silicon Devices
(Single Atom/Single Molecule)
AFSID is formed by 4 European research institutes, in collaboration with University of Melbourne and a company lab. Melbourne provides single ion implantation capabilities for the project. The project is coordinated by CEA.
The project is related to the keynote presentation by S. Rogge discussed above (S.R. is a partner of the project). The project objectives include building an electrical switch based on the gate control of a single atomic orbital, i.e., a single atom transistor (SAT), development of coupled SAT-FET or SAT-SET devices to measure the spin of carriers with single spin sensitivity which would allow one to investigate spintronics effects. Furthermore multi-valued logic and memory function on single element basis will be investigated. In Systems based on molecular orbitals of two coupled atoms (de)coherence and entanglement are planned to be studied. The expected results include SATs with better gate control as FETs.

SINGLE - Coupling charge transport to internal degrees freedom at the single molecule level (Single Atom/Single Molecule)
The project is based on interactions of 5 partners including one company. It is coordinated by the University of Copenhagen.
The project focuses on the synthesis of optimized molecules, which will be used for transport measurements on the single molecule level and theoretical modeling. The project intends to use the controllability of the transport by internal degrees of freedom like vibrations, conformational changes, electron correlations and spin. The final goal is to demonstrate new types of single molecule switches, memory devices, diodes and transistors that are claimed to be radically different from classical semiconducting devices

CHIMONO - Nano-Optics for Molecules on Chips
(Single Atom/Single Molecule)
The project is formed by 6 research institutes/universities and it is coordinated by LENS.
The project addresses the control of cold molecules in single quantum states by means of integrated electric, magnetic, RF, micro wave and optical fields. It has therefore a number of issues relating to quantum information processing. The long term goals include the control of single atom/molecule functionality and the provision of a basis for building nanoelectronic devices from atomic or molecular building blocks

CATHERINE - Carbon nAnotube Technology for High-speed nExt-geneRation nano-InterconNEcts (Switches and Interconnects)
This project is formed by 11 partners including two industries. The scientific coordinator is University of Rome, La Sapienza.
The project focuses on nano interconnects for high current densities, high speed, and with exceptional mechanical and thermal properties. These interconnects will be obtained by controlled growth of multiwalled carbon nanotubes inside Al_2O_3 porous membranes. Modelling results indicate the potential of multiwalled carbon nanotubes in terms of current density, resistance, delay times for the 22 nm node and below.

GRAND - Graphene-based Nanoelectronic Devices
(Switches and Interconnects)
The project has 6 partners including two companies. It is coordinated by AMO.
GRAND focuses on the realization of high perfection Graphene films and to use those for device fabrication in order to demonstrate new concepts for switches, memories and interconnects. The project is based on very promising Graphene properties like high room temperature (RT) mobility (25.000 cm/Vs), long mean free path at RT (about 400 nm) and the material stability with respect to high current densities. The material has potential for ultra high speed devices (Terahertz) as well as for ballistic devices at RT. It is well suited for the use of carbon nanotube interconnects.

NABAB - NAnocomputing Building blocks with Acquired Behaviour (Switches and Interconnects)
NABAB is formed by 5 partners, all from public research institutes and is coordinated by CEA.
As described in the abstract, the project explores the feasibility of functional interconnecting devices build on new organic FETs, functionalized nanotubes or ZnO FET. The

building blocks should display combinations of functions including memory, gain, and sensitivity to local stimuli. The main target is to show that building blocks can acquire a specific, non-trivial computing function by an internal adaption process as e.g. learning (comment: very challenging), reconfiguration (rather straightforward).

VIACARBON - Carbon Nanotubes for Interconnects and Switches (Switches and Interconnects)
Viacarbon includes 4 partners (three research institutes/universities and Intel).
The project focuses on the development of carbon nanotubes for vertical and horizontal interconnects for the 22 nm node and beyond as well as for NEMS RF switches. It starts from the current densities expected in interconnects of the 22 nm node, which are beyond the capability of copper. Single walled carbon nanotube bundles have potential to operate at the required high current densities, if they can be realized with sufficient quality at very high densities (nanotube density>10^{13} cm^{-2}). As a second focus the project investigates multi walled carbon nanotubes with horizontal orientation for RF NEMS switches for new device functions in the interconnect layer for e.g. reconfigurable interconnects.

3.4 FP6 E-Nano Project Results

ULTRAGAN - InAlN/(In)GaN Heterostructure Technology for Ultra-high Power Microwave Transistor (Emerging Nano)
ULTRAGAN is formed by 8 partners including two companies. The project is coordinated by Alcatel – Thales III-V lab. The project is now at month 24.
The main idea of the project is to replace GaN/AlGaN heterostructures with built-in strain by stress free heterostructures in the lattice matched $In_{.18}Al_{.82}N$/(In)GaN system. This material system enables the realization of very high density 2D electron gases permitting about twice as large higher current densities (3A/mm) than standard GaN/AlGaN. The use of a thin AlN layer between the 2DEG and InAlN increases the mobility significantly and improves the interface quality. The project has demonstrated the first transistor operation at a temperature of 1000°C. Further targets include to triple the power density compared to state of the art large periphery HEMTs and to demonstrate HEMTs with power densities of 30W/mm at 2-12 GHz.

D-DOT-FET - Advances on the path to a Ge dot field effect transistor (Emerging Nano)
D-DOT-FET is carried out by 6 partners including one company. The project was coordinated by Paul Scherer Institute, the coordinator has changed to Forschungszentrum Jülich recently. The project is at the end of the second year.
The project has a clear target namely to realize a high mobility CMOS compatible transistor with a strained (low effective mass) Si channel. In order to reach this, the device channel is realized by a freestanding Si bridge stabilized by the gate contact. The stress is built into the bridge by using Si grown on top of a precisely placed Ge dot. As shown by model calculations the stress is largely retained even when the Ge dot is removed. Ordering of Ge islands on a template Si substrate has been realized in the project, gate processing with good alignment to dots is in progress. Low temperature processing schemes have been developed to avoid Si-Ge intermixing, which would reduce the strain (low T capping of Ge dot, laser annealing after source drain implantation),

NANOSPIN - Semiconductor NanoSpintronics
(Emerging Nano)
NANOSPIN is formed by 8 partners including two companies. It is coordinated by University of Würzburg. The project is currently at the end of the second year of a total duration of three years.
The project addresses investigations of ferromagnetic semiconductor devices with high functionality as future MRAMs. In addition to material and device technologies the work focuses on investigations regarding writing the magnetic state, electrical information retrieval, HF operation, theory and modeling, and integration strategies. In addition the consortium also monitors systematically commercialization issues. Recently devices based on electrically controllable magnetic asymmetries introduced by nanopatterning have been demonstrated.

SUBTLE - Noise enhanced sensing and switching with nanoelectronic devices (Emerging Nano)
SUBTLE is carried out by 6 partners including one SME. It is coordinated by University of Würzburg. The project is currently at month 12 of 36.
The increasing miniaturization of CMOS devices results in highly integrated circuits, in which most of the power is converted into noise. The central objective of SUBTLE is to investigate devices and functionalities based on the principle of stochastic resonance, by which functional devices should become possible which employ noise to improve the performance. The project focuses on key devices like "residence time detector" and "electrochemical capacitance feedback transistor". These devices will be used to show subthermal signal resolution as well as noise activated switching and noise enhanced signal processing. During the first year subthermal sensitivity could be demonstrated.

GOLDEN BRAIN - Development of novel concepts for communication between living cells and silicon based electronic devices (Bio)
Golden brain is a 3 partner project including one industry. It is coordinated by IMEC.
The project is currently at the end of its 3rd year.
The objective of Golden Brain is the development of reliable and durable bidirectional electrical and chemical communication between neurons and electronic circuits. This is an area which has been investigated in different places for more than a decade, with limited results. As novel items the project uses Au micronails as potential electronic interconnects. It was observed that a large variety of cell types engulf the micronails. First electrical tests have been carried out. The participants could observe chip-guided cell growth. Neurons with micronails have been stable for more than 3 weeks.

DNA-Nanodevices (Bio)
This project is formed by 7 academic partners. It is coordinated by Tel Aviv University. The project is currently at month 18.
The general objective of the project addresses fundamental studies for DNA based future nanoelectronic devices. Goals of the project include the improvement of the control of the production process of DNA based nanowires, the realization of DNA based nanodevices with nonlinear I-V as well as a microscopic, spectroscopic and electrical characterization of nanowires and devices. Due to the limited amount of material available it is difficult to get a clear picture of the situation of the project.

PICO-INSIDE - Computing inside a single molecule using atomic scale technologies (Single Atom/Single Molecule)
This Integrated Project has 14 partners including 2 companies. It is coordinated by CEMES-CNRS. The project is currently at month 24, of a total of 42 months.
The final goal of the project is to integrate a complex logic gate inside a single molecule in a suitable periphery for single molecule logics. In order to reach the objective the project has divided the work into different building blocks. Those include e.g. the design of optimized single molecules to perform the logics, the characterization of the molecule properties by e.g. low temperature UHV STM, development of 5 levels of interconnects etc. Theoretical data on a half adder were presented. The half adder seems to be characterized by rather high resistivities (minimum resistivity of a few MOhm). Although the involved capacities may be small the operation speed of these devices might be limited to rather low values.

NODE - Nanowire-based one-dimensional electronics (Nanowires)
NODE is an Integrated Project with 12 partners including five companies (among them big EU and US based IC manufacturers like Qimonda, Philips, IBM as well as SMEs). The project is coordinated by Lund University. It is currently at month 24 of a total of 48 months.
The general objective of NODE is to realize and analyze key devices of current integrated circuits like FETs, tunneling structures, capacitors etc. based on semiconductor nanowires and to assess the potential of nanowire electronics in general. The project includes nanowire epitaxy in Si and different III-V materials. Nanopatterning technologies are developed to position nanowires, to realize contacts to the top and bottom end of free standing and horizontal nanowires, wrap gates etc. As the physical properties vary from those of bulk materials due to surface effects, transport and optical measurements are pursued. The properties of the devices are compared to state of the art CMOS structures (e.g. FinFETS).

CANDICE - Carbon Nanotube devices for integrated circuit engineering (CNTs)
The project has 4 partners including one company and is coordinated by CNRS-Ecole Polytechnique. It is currently at the beginning of its final year.
The project works on CMOS compatible industrial processes for the fabrication of FETs and circuits based on carbon nanotubes. Both bottom-up and top-down approaches are followed. The bottom-up approach uses porous alumina templates and CVD to realize vertical or horizontal devices. The top-down approach uses nanolithography and dry etching to pattern pores. The low temperatures required by CMOS compatibility require the use of catalysts. Outside the project the participants seem to work on semiconductor nanowires. On one of the slides they request to include this approach in the project. From the material available the status of the initially planned device work is difficult to assess.

4. Synthesis of Presentations and Discussions
The nine FP6 projects represented in Gran Canaria presented a number of impressive, internationally leading results in different areas relating to future nanoelectronic application. If sorted by materials, there are five semiconductor based projects (ULTRAGAN, D-DOT-FET, NANOSPIN, NODE (IP) and SUBTLE), two projects on single molecule electronics (DNA-NANODEVICES, PICO-INSIDE (IP)), one bionanoelectronic project (GOLDEN BRAIN) and one investigating carbon nanotubes (CANDICE).
In terms of patterning technologies lithography based approaches and self assembly are roughly equally represented. Several projects compare both bottom-up and top -down approaches for their objectives.
Regarding dimensionality, the projects cover a wide range. ULTRAGAN addresses a new layer system. NODE focuses on one dimensional nanowires by epitaxy. NANOSPIN and SUBTLE start from epitaxial semiconductor layers and realize devices with one dimensional element by lithography. CANDICE, DNA-NANODEVICES and PICO-INSIDE address intrinsically one dimensional transport. D-DOT FET uses quantum dots as key elements in the fabrication of high mobility transistors.
The projects differ also regarding the time horizon for applications. The molecular projects address very fundamental proof of concept type studies. These projects focus primarily on single molecule manipulation in combination with analytical techniques with single molecule sensitivity to demonstrate conclusively transport and switching in single molecule units. At the present stage, it is very difficult to foresee broad applications in the core topics of ICT. However, there is potential in niche applications in particular if the strategies for molecule manipulation are transferred to areas like biomedicine. GOLDEN BRAIN is addressing nanosystems for investigation of single cells. This is an important and challenging topic which, unfortunately, has not seen fast progress during the last years.
The semiconductor based projects as well as CANDICE have clear potential to be taken up in some form by the (semiconductor) industry for future core ICT applications. This may regard the technologies and/or devices investigated. For example, nanowires investigated in CANDICE and NODE have the potential to be used in three dimensional integration. Perhaps closest to applications is ULTRAGAN, which targets high power transistors made in the GaN/AlInN system. NANOSPIN and SUBTLE address spintronics and stochastic resonance based devices,

respectively, which within a ten to twenty year frame may be taken up by industry. SUBTLE investigates a paradigm shift by considering the potential of noise for signal amplification. Overall the FP6 projects cover:

- a wide span of topics from fundamental technology, physics and biochemistry to information processing, including architecture aspects
- Top-down and bottom-up technologies for nanopatterning/nanostructure fabrication are used with roughly similar intensity
- Majority of the projects is semiconductor based
- Several projects address long term research related to bio-nanoelectronics and/or work on paradigm shifts

The FP7 projects presented at Gran Canaria show a distinct change in the material focus. There are three projects working on carbon based systems: VIACARBON and CATHERINE investigate single and multiwalled carbon nanotubes for high speed, high current density interconnects for the 22 nm node and beyond. GRAND addresses Graphene based devices. Semiconductors are the exclusive basis of one project only (AFSID), in which devices controlled by individual dopants are investigated. SINGLE develops and studies molecules which allow to control charge transport by internal degrees of freedom. CHIMONO investigates logic operations on molecules in UHV, which are manipulated by optical and electrical fields. Two projects (MOLOC, NABAB) plan to address single nanostructure electronics based on a wide variety of materials ranging from organic molecules to semiconductors. In order to obtain the intended functionalities, each of these material systems is extremely challenging. As there are no clear synergies from which one could profit by studying different materials in parallel it would be good if the projects could determine in an initial phase the most promising material system and then concentrate on it.
There is furthermore a Coordination Action, Nanoscale ICT Devices and Systems, which works on networking in nanoelectronics including conference organizations, roadmaps, etc.
Regarding timescales for applications the carbon and semiconductor based projects are likely to generate results which can be used by the ICT industry within a ten to twenty year time frame. The required time for a transfer of the single molecule projects is extremely difficult to estimate. It is not unlikely that these projects will generate very valuable fundamental research, without a direct impact on industry.
Compared to the FP6 projects, the FP7 projects

- emphasize carbon based nanoelectronics
- have strongly reduced the semiconductor focus
- increasingly target single atom/molecule scale control of individual functional devices
- include small functional systems
- as well as investigations of hybrid CMOS - nanoelectronic systems

The working session discussions on “2020 and Beyond - Long-Term Challenges for the FET-Nano Community" were primarily centered on future topics of semiconductor and carbon based materials. Single molecule activities were discussed rather with respect to precision fabrication than regarding nanoelectronic functions based on organic molecules. As discussed in some detail below several topics emerged, which have potential for PROACTIVE initiatives. These include “Energy harvesting nanosystems” and “Functional nanosystems based on a larger number (~ 100) devices”, as well as low voltage electronics, photonics for nanoelectronics, etc.

5. Emerging Topics for future FET Proactive initiatives

A number of ideas which could serve as starting points of future FET Proactive Initiatives was brought up during the working session (see above). Those include

- Energy harvesting nanosystems. Energy harvesting is becoming a hot topic internationally. It is also directly related to ICT for example in batteryless and eventually wireless nanodevices and nanosystems for applications like (bio)sensing or biomedical monitoring. Moreover there are a number of approaches for which nanotechnologies have a particular promise including conversion of temperature gradients into electricity by one- or zero-dimensional thermoelectric materials, power generation from motion using e.g. piezoelectric nanowires (see e.g. **Science 312. 242 (2006)**, “Piezoelectric nanogenerators based on ZnO nanowire arrays”, **Science 316, 102 (2007)**, “ Direct-current nanogenerators driven by ultrasonic waves”), and power generation by nanophotovoltaics.

Within FET-ICT/nanoelectronics it would be particularly attractive to encourage in addition to research on (i) the microscopic mechanisms of energy harvesting and (ii) on more efficient power generation (iii) work on complete functional nanosystems e.g. for biosensing. In particular (ii) and (iii) could be used to increase the industrial participation in FET Proactive.
The topic has strong interdisciplinary aspects, as energy harvesting principles can be based on physics, chemistry and biology. It is also relevant from a societal point of view as it reduces conventional power consumption, permits new applications in e.g. health care.

- Functional nanosystems based on several hundred of interconnected nanodevices constitute another area which could result in a proactive initiative. This topic is important due to the following simple facts: Almost all applications require a system solution not a solution based on a single device. This is particularly true for nanodevices, which require a specific network for connection with the outside (e.g. for impedance matching, for sensing inputs). In these systems new challenges occur like fluctuations of individual device parameters, which require work on atomic scale precision technologies and/or fault tolerant architectures. New architectures taking advantage of intrinsic nanostructure properties would also be a topic. Self assembly technologies would be particularly attractive if they can be optimized to realize the required precision. New self assembly strategies for the placement and interconnection of functional devices would be highly interesting.

As both previous topics focus on nanosystems, they could potentially be combined, although the scope would become very broad. For energy harvesting systems, the system could be fairly simple, including power generation, a sensor and a transmission path to the macro world. In the functional nanosystems task e.g. logic circuits would be developed which depend critically on mastering fluctuations between similar nanodevices.

- Low voltage electronics and sustainable electronics are also very attractive topics. However, they are already addressed to a certain degree now, and they also will be in connection with better defined topics as e.g. energy harvesting nanosystems.

The same is true for photonics and electronics. Here it would be good to indicate in future calls that proposals could include both aspects.

6. Conclusions

The FET Proactive Initiatives on nanoelectronics cover a wide range of topics in FP6 and FP7 addressing building blocks for different future solutions for ICT. Two trends are apparent in the project targets i) atomic/molecular precision fabrication for nanoelectronics and ii) higher functionality nanoelectronics.

Switching units are based on nanostructured semiconductors by self assembly or by lithographic processes, semiconductor nanowires, carbon nanotubes or individual molecules. As the projects all address long term high risk fundamental research the time horizon for potential applications is on the order of ten or more years. Applications of project results will go beyond the use of the devices investigated in the projects. Novel preparation techniques as well as new experimental and theoretical technologies developed in the projects will be available for use on different device types and other material systems. At the same time people trained to use these techniques are available to industry and public research institutions. This ensures in my opinion a substantial impact of long term research projects as followed in FET Proactive initiatives on nanoelectronics. As far as the funding instruments are concerned the emphasis currently is clearly on STREPs. This is clearly adequate for the long term research topics of FET Proactive. Integrated projects should only be formed in special situations, i.e. not automatically in every call.

The long term nature of the research funded in FET Proactive Initiatives is certainly an important reason for the limited participation of industry in the projects. As fundamental research is carried out most efficiently in public research laboratories the lack of active industry participation is not critical for the progress of the projects. It is, however, important, that researchers in university and other public research institutes are aware of progress and needs in ICT industry and vice versa. This could be done most efficiently by workshops or symposia organized on the level of projects, coordinated actions and initiatives. For example at the next FET Proactive nanoelectronics meeting it would be interesting to have one or two of the plenary talks in the morning session given by research leaders from the CMOS industry/ ITRS roadmap group to highlight the achievements of the mainstream industry as well as problems within the 10-20 years timescale addressed by FET Proactive.

Due to the focused nature of the different calls, the projects in the initiatives address primarily different forms of information processing, mimicking individual electronic devices or simple logic or memory circuits. This is of course important, as it allows e.g. to benchmark the results and the prospects of the approach of the projects with respect to the performance of CMOS devices. On the other hand it would extend the output for society if other issues will be considered as well. For example, there are a number of projects investigating switching and logical functionalities based on a single organic molecule. There is no doubt, that there will be some nonlinearity which can be used for this purpose. However, due to e.g. the involved large resistances it seems unlikely that future electronics will be based on such approaches. Related topics, which might enhance the use of project results in future applications, include e.g. changes in the molecular structure with consequences for its reactivity under local current injection or in strong and coherent optical fields.

It is very difficult to assess reliably the application potential of long term research as followed in FET Proactive. As there are many more valid topics as there are initiatives it might be helpful to use a longer term (e.g. time span from 2000- 2007) progress monitoring in a given area. If a given approach – in spite of generating results (deliverables, milestones in the projects) - has not resulted in qualitative progress for five or ten years it is quite likely that there is a hidden roadblock which prevents to reach the long term objectives. In such a situation funding of entirely new directions instead of continuing to support variants of a slowly developing approach/area is advisable. In order to carry this out in a systematic manner FET Proactive could organize special “progress assessment meetings”. At these meetings coordinators of related projects as well as representatives of competing approaches could present their views on advances during the last few years and their expectations for the coming years to FET Proactive representatives and evaluators. This would constitute a new level of evaluation for an area represented by a number of projects funded under different calls - in between the level of individual projects and the initiative level.

Overall, the FET Proactive Initiative on nanoelectronics is on a very good track. The majority of the projects generate internationally visible results. It is noteworthy that in the highly selective evaluation process within the so called Excellence Initiative in Germany, EU support (not limited to the area of nanoelectronics) was regarded as an indicator for very good scientific quality.

Annex I: Report on "Shaping Future FET Initiatives", Sept. 20-21, 2007, Brussels

Executive Summary

The IST Future and Emerging Technologies (FET) Programme directs proactive research initiatives in emerging and high-risk areas of ICT. These initiatives, typically involving groups of projects clustered around common themes, aim to encourage efforts on foundational long-term research and technological innovation beneficial to the European Union. To identify topics and research areas most suitable for such initiatives, and offering the greatest opportunities, the European Commission periodically engages in focused interaction and consultation with the research community.

To help shape the work programme for 2009-2010, the Commission has launched a serie of brainstorming events with high-level scientists from relevant fields. In this regard, the meeting "Shaping FET Proactive Initiatives," held in Brussels 20-21 September, 2007, was an initial effort to consult scientific communities linked primarily to earlier FET proactive initiatives. Participants were invited to share their views and support the Commission identify strategic areas, especially those going beyond traditional lines of research and presenting novel opportunities for collaboration with other scientific communities. In more specific terms, participants were asked to suggest areas that could be the basis for proactive initiatives in 2009, 2010 and 2011, bearing in mind that three themes had already been identified in broad terms for 2009 (Massive ICT systems, Human-computer confluence and QIPC and other Quantum Technologies).

From the meeting activities, the participants proposed three broad areas as promising for future proactive initiatives. In brief, these three areas, and the challenges and opportunities they present, were as follows:

Highly Concurrent Environment-Aware Systems

ICT is moving rapidly towards parallel, distributed, and networked systems of unprecedented complexity. To manage such systems, we require novel concepts, methods and tools, and a fundamental transformation in design strategy. Participants noted, in particular, that today's computing technology has reached a fundamental barrier, with single processors unable to go any faster due to increased power consumption. We therefore face an urgent challenge in mastering parallel computation, and we require a rich science and technology that will make it as easy to develop and maintain parallel systems as it is today for sequential systems.

It is also clear that future IT systems will interact with ever-changing physical and virtual environments, including people, physical devices, robots, software environments, services, virtual agents, etc. We must, therefore, learn how to achieve predictable, reliable, and efficient system behaviour under such conditions. In this regard, we may profit from a much deeper understanding of how biological organisms achieve remarkable performance in self-constructed and adaptive distributed systems based on slow, asynchronous operations that use very little power. Our computational technology can be improved by mimicking biology.

Physical Realisations of ICT

Modern technology is racing forward with techniques for building systems on atomic and molecular scales, and for exploiting novel quantum degrees of freedom. We can expect, as a result, a vast new range of powerful ICT technologies, with applications in areas ranging from communications and computation to medicine or ecological sensing. However, we still lack practical and efficient means for fabricating and controlling such devices to achieve reliable functionality. We face an urgent challenge to develop techniques for assembling devices on an atom-by-atom basis, and for controlling their dynamics and interactions with unprecedented precision.

Experts also projected that the impact of the entire field of quantum and nano-technologies will be greatly amplified when we acquire the ability to integrate many atomic and bio-molecular nanostructures into complex networks and systems spanning many orders of magnitude in size. This achievement would bridge today's gap between individual nanodevice research and large scale integration by IC manufacturers, and support a new generation of integrated circuits using nanoelectronic devices with unprecedented functionality.

Socially Adaptive ICT

Large scale ICT systems increasingly involve many people who make their own independent decisions, and react in unpredictable ways. These “socio-technological” systems cannot be understood, engineered or managed using traditional techniques for distributed computing and communications networks. A key challenge is to develop some analytical understanding, loosely akin to a “statistical physics” of such systems, which would allow limited predictions of system behaviour and relative certainty regarding properties such as stability and security. Expected impacts would include greater efficiency in managing traffic systems, markets, etc.

We also face a challenge to learn how to prevent or discourage unwanted, malicious behaviour in such systems, while at the same time encouraging and rewarding good behaviour. Participants suggested that we must learn principles, inspired in part by social phenomena, for doing so in a natural way that preserves individual autonomy. In part, this may be possible if we can learn to make ICT systems more socially adaptive. Today's ICT systems do not take into account the social structures defined by roles, habits, power relations, etc. among individuals. We must learn how to design more adaptive ICT systems that co-evolve with the social structures in which they are embedded. If so, we can anticipate greater economic and organizational efficiency, and more adaptive business firms.

Finally, participants suggested that ICT has the capacity (through sensors, etc.) to enhance the ways people interact with one another. Such capability would likely transform care for the elderly, create new sports and arts, and improve interpersonal communication in business and elsewhere.

These three proposals, described in more detail in the following pages, will be used as initial input to stimulate follow-up meetings, in late 2007 and early 2008, aiming to consolidate ideas from this meeting, to explore other new themes, and to consult with a wider scientific community.
In what follows, this report gives a brief introduction to the workshop and its structure, and then offers the more detailed reports written by working groups active within the meeting. The two Annexes give the list of participants and the terms of reference for the workshop.

1. Introduction

The candidate areas already identified in the Work Programme 2007-2008 for 2009 were very coarsely defined as follows:
Massive ICT systems. The objective is to research, demonstrate and validate new computing architectures and algorithms that will allow designing, programming and managing future high-performance ICT components with up to one Tera (1012) devices integrated in a single chip.
Human-computer confluence. To investigate an invisible, implicit, embodied or even implanted interaction between humans and system components, for natural interaction (including communication) in surrounding environments, themselves augmented with pervasive and ubiquitous infrastructures and services.
QIPC and other quantum technologies. To overcome major scientific, technological and theoretical challenges for quantum technology to deliver on its promise to radically outperform its classical counterpart not only in terms of processing speed, capacity and communication security, but also, in the ability to solve classes of practical problems which currently cannot be solved. This initiative also invites the exploration of a wider range of non-classical implementations of ICT. More generally, it will be important to strengthen international collaboration on foundational research in this area where Europe has established itself firmly at the leading edge.
Participants were asked to advance these three themes, either by providing more detail or by taking a wider view and shifting the focus. These themes are not fixed; since they were formulated some time ago, and the crucial research challenges may have changed since then.
The Commission intends the outcome of this first meeting not as any kind of final plan for future proactive initiatives, but as a starting point and seed for further discussions. In particular, the proposals emerging from the meeting, which detail specific promising areas, will be used to help stimulate future discussions in 2007 and 2008 with a wider body of scientists.

2. Research Topics Addressed

The invited scientists included experts in computer science, atomic, molecular and quantum physics, device electronics, networked and distributed systems, parallel processing, global computing, artificial intelligence, neuroscience, nanoelectronics, complex systems science, musicology, and software engineering. The make up scientific expertise reflects the increasingly distributed and complex nature of ICT systems, and the novel challenges presented by such complexity. Participating scientists also reflected the vast range of new technologies now becoming possible through nano-science and the rapidly growing field of quantum information. Participants offered short presentations covering topics in software and hardware, in network technology and science, in physics, chemistry and nanoscience, and in the field of human computer interactions.
As a very brief summary, in the context of software, several participants noted the fundamental challenge of finding new, more reliable ways to develop software, and the difficulty of solving even relatively simple problems such as supplying reliable software upgrades. In network science and technology, researchers stressed the need for all systems to be developed and maintained as parallel systems, something we do not currently know how to do, the opportunities for developing content-centric networking paradigms, and the need for sound principles for autonomous networked systems that can provide safe and reliable computation and communications. Notably, some mentioned that we still have to learn how biological organisms achieve extremely powerful and reliable computational systems using technology very different from our own.
In physics, chemistry and nanoscience, participants discussed the tremendous promise and rapid advance of quantum information technology, and the potential for myriad new devices based on atom-by-atom construction of nano-devices and networks of such devices. In the context of human/system interactions, scientists pointed to the need for today's systems to become more socially sensitive and aware, and for engineers to exploit ideas from social science in learning how to maintain cooperative behaviour. Others suggested that ICT has tremendous potential for enhancing human interactions, with many medical implications. Finally, researchers also pointed out that today's massive ICT systems, and systems for simulation based upon them, now give unprecedented power for bringing science to bear on complex policy questions.

3. Synthesis of Presentations and Discussions

The first afternoon of the two-day workshop focused on individual presentations from the key scientists attending, each conveying his or her view of the key research areas most suitable for future FET proactive initiatives. On the morning of the second day, after the initial presentations were finished, participants and Commission representatives discussed how best to identify and formulate potential initiatives. It was eventually agreed that the individual contributions clustered naturally around three broad themes, one centered on large distributed and networked ICT systems, a second on quantum and nano-technologies, and a third on the growing relevance of social dynamics on ICT operations, in the World Wide Web and elsewhere.
Following this recognition, the meeting broke into three groups to explore these areas in more detail. After intense discussion, the groups then presented their conclusions to the main group, soliciting further comments and reactions.

The final reports of the three groups, in the pages following, reflect their visions of the key challenges, opportunities and research demands in these areas, including the proposed motivation and aim, the disciplines and stakeholders involved, and the expected impacts.

4. Reports on Candidate FET Proactive Areas

4.1 Highly Concurrent Environment-Aware Systems

ICT is moving rapidly towards extremely large concurrent (parallel, distributed, and networked) systems. These systems are of unprecedented complexity, because they are open-ended and not completely specifiable. They are subject to continual modification and must interact with an ever-changing environment that includes humans as well as other artificial systems. Such systems must maintain coherent, reliable and trustworthy behaviour despite partial failures, hostile attacks, and other unforeseen interactions with their environments. We require novel concepts, methods and tools to develop, deploy, and maintain such systems. We identify three key challenges that need to be met for the vision of such system to become reality.

Challenge 1: Making Parallel Programming Main-Stream

Motivation: Computing technology has reached a fundamental barrier: Single processors cannot go any faster due to increased power consumption; parallel systems are the only way forward to achieve greater computing power. In the future, *all* machines, from cell phones to data centers, will be parallel. In the past parallel programming was a niche discipline for specialized programmers, mainly targeting scientific applications. In the future, *all programming will be parallel*. The critical challenge is therefore to allow mainstream programmers to productively develop, deploy and maintain parallel systems.
Aim: To build up a science and technology of parallel programming that makes it as easy to develop, deploy and maintain parallel systems as it is today for sequential systems, and this for a broad class of applications extending far beyond the traditional scientific computing applications of parallel computing. At a more detailed technical level, the challenge is to develop algorithms, tools, methodologies, and language constructs to express sharing, concurrency, coherence, communication, and synchronization in the presence of failures, replication, time and power constraints, for general-purpose applications as well as for embedded systems.
Expected Impacts: Bridging today's gap between building sequential vs. concurrent systems and achieving the required levels of performance and scalability will allow us to support future needs in IT infrastructures.
Disciplines Involved: Computer architecture, programming language design and implementation, compilation and parallelization, operating/runtime systems.
Stakeholders: All of the software industry and the entire software workforce.

Challenge 2: Environment-Aware Distributed and Net-Worked Systems

Motivation: A key feature of future IT systems will be their continuous interaction with an ever-changing physical and virtual environment, including people, physical devices, robots, software environments, services, virtual agents, etc. Much of the difficulty of developing such future networked and distributed systems stems not from performing the specified task in isolation, but from operating the system in a complex and a priori not fully specified environment.
Aim: To build up an understanding of how to specify an environment, sense and act on the environment, adapt to changing and unexpected features of the environment, including nondeterministic and potentially malicious behaviour, to be able to interoperate with unspecified elements in the environment, and achieve reliability and longevity. Possible environments may range from software environments over networks of agents and services to "human-brain-in-the-loop" systems for smart prostheses. **Expected impact:** Achieving adaptation and predictable, reliable, and efficient behaviour in the presence of complex and changing environments will enable advances in overall system reliability, foster the creation and adoption of safety critical software deployments, development of new content-centric networking architectures, and "human extension artefacts".
Disciplines: Networking and distributed systems.
Stakeholders: All of software development.

Challenge 3: Make Technology More Biological

Motivation: Biology's approach to deploying coherently behaving computational systems is utterly unlike our present technology. Rather, biology uses self-construction, adaptation, and learning. These processes can provide inspiration for novel and potentially revolutionary approaches to the development of complex software and hardware.
Aim: To learn how our computational technology might be improved by mimicking biology, which, in the case of the human brain, achieves remarkable performance in self-constructed and adaptive distributed system based on slow, asynchronous operations that use very little power.
Expected Impacts: An entirely new paradigm for the development of distributed computational systems with greatly improved reliability and performance.
Disciplines Involved: Computer science, artificial intelligence, computational neuroscience.
Stakeholders: All users of computational technology.

4.2 Physical Realisations of ICT

Modern technology is racing forward with techniques for building systems on atomic and molecular scales. In the near future, devices will be assembled on an atom-by-atom basis, and provide means for controlling their dynamics and interactions with unprecedented precision. We can expect, as a result, a vast new range of ICT technologies.

Challenge 1: Functionalizing Matter at the Atomic and Molecular Scale

Motivation: Even within the domain of classical physics, our increasing ability to design, build and manipulate systems on the nanoscale promises a vast range of new technological applications in areas ranging from communications and computation to medicine or ecological sensing. Atoms and molecules, the fundamental building blocks of our world, are also the most precisely known objects in nature, and immense scientific and technological progress will ensue from improved ability in manipulating them. We still lack practical and efficient means, however, for creating such devices with reliable functionality.

Aim: Learning to design and build atomic and molecular nanostructures for specific functions, for example, as single-atom or molecule sensors or transistors. Learning to build systems up, atom by atom, while maintaining maximum control over structure and function. Learning also to make identical copies of single molecular nanostructures, which yield identical function, despite differences in their physical environments.

Expected Impacts: New ICT technologies based on maximum control over materials and deterministic control over their functionalities. New ultrahigh resolution patterning and sensing technologies. Unprecedented control over the interaction of light and matter, study of physical interactions in well defined individual nanostructures. The ability to design dedicated molecular nanostructures for special purposes.

Disciplines Involved: Physics, chemistry, quantum technology, materials science.

Stakeholders: Research institutes, universities, IT-industry.

Challenge 2: Integration of Atomic and Bio-molecular Nanostructures in Functional Systems

Motivation: The impact of atomic and bio-molecular nanostructures will be most profound when they are integrated into complex networks and systems spanning many orders of magnitude in size. This remains an out standing, but very important, problem.

Aim: Learn to build in a reliable way complex systems of interconnected molecular structures spanning many orders of magnitude. These systems may be based on nanoengineered semiconductor devices or include interconnects to natural tissue. Such systems will permit research on logic and memory circuits based on nanoelectronic effects, thereby bridging the gap between the individual nanodevice research and large scale integration by IC manufacturers. Effects used for enhanced functionality include for example the use of spins for information transfer and processing. These systems will also provide usable “interfaces” between the molecular world and our human-scale world. Learn how to optimize the network in order to realize a specific function like high resolution sensing. Communicate directly and reliably with a single element in a large collective of nano-systems or molecules. Learn to exploit dynamic self organization in forming functional networks of nanostructures, and to design systems that function even in the presence of large fluctuations. Study new ways in cell and molecule manipulation by coherent control techniques.

Expected Impacts: A new generation of integrated circuits using nanoelectronic devices with higher functionality. New high resolution sensing techniques for living organisms and high throughput screening, Emergence of new techniques for precision surgery, pharmaceutical production and enhanced molecular analysis. Systems for mapping neural circuits and novel therapies for neurological disorders.

Disciplines Involved: Physics, chemistry, materials science.

Stakeholders: IT industry, research institutes, universities.

Challenge 3: Quantum Information Sciences and Technologies

Motivation: The notion of “quantum” information underlies a revolutionary new area of science and technology based on novel features of quantum physics having no analogy in classical physics and the engineering based on it. Quantum information and technology links the most fundamental physical theory, quantum physics, with cutting-edge experimentation, whilst offering novel, practical and useful applications.

Aim: Quantum information technologies aim to control and manipulate quantum entanglement to realise novel and potentially very powerful methods of information processing and communication. The vision and aim of quantum information research in Europe is now to reach far beyond the “proof-of-principle” phase, and to bring these technologies into widespread commercial use.

Expected Impacts: Research in quantum information science has already led to a deeper understanding of the fundamental laws of the quantum world, the nature of information, information theory and computer science, and also to the conception of machines and devices able to revolutionise the way we communicate and compute. The importance of this science and technology for the future can hardly be overestimated, as it holds the promise of immense computing power beyond the capabilities of classical devices, and it guarantees absolutely secure communications. In addition, it provides new and more powerful means for modeling new materials and for solving difficult problems across science

Disciplines Involved: Quantum information science is multidisciplinary by nature, involving scientists in theoretical and experimental physics, computer science, mathematics, material science and engineering.

Stakeholders: IT industry, research institutes, universities, all users of computational technology.

4.3 Socially Adaptive ICT

Large scale ICT systems increasingly involve many people. Examples include the Internet and WWW, popular systems such as eBay, and P2P networks such as Skype. What makes these networks unique is the crucial involvement of individuals who make their own independent decisions, and react in unpredictable ways. These “socio-technological” systems cannot be understood, engineered or managed using traditional techniques for distributed computing and communications networks, but require a new approach. Today they are managed in an ad hoc and reactive manner, not on the basis of real understanding.

The challenges identified in this area aim toward an improved understanding of such systems by using ideas from social science, translated into the modern ICT setting. At the same time, it is also clear that ICT methods and capabilities offer new opportunities to social science, especially in the management of today's highly complex interlinked and interdependent systems.

Challenge 1: Understanding large socio-technological systems

Motivation: We currently do not understand the dynamics of large ICT systems, in part because they're open, multi-level, evolving, and depend on the actions of many not always predictable, or well-meaning, people. As a consequence, engineers, ICT managers and other authorities have little sound knowledge to use in guiding their decisions.

Aim: A key challenge is to develop some specific analytical understanding, loosely akin to a “thermodynamics” or “statistical physics” of such systems, which would allow limited predictions of system behaviour and relative certainty regarding properties such as stability and security. Ideally, such understanding should be developed around specific and practical goals, so that progress would have immediate impact, and be clearly measurable. Some examples of specific challenges include the reduction of email SPAM, or improved traffic flow in the Internet.

Expected Impacts: Greater efficiency in managing traffic systems, markets, the response to epidemics or natural disasters, improved banking stability, energy use and efficiency, city planning, resource and waste management, etc. Risk management based on greater knowledge. Also, general insights into functioning of distributed systems.

Disciplines Involved: Computer science, physics, mathematics, sociology, economics, evolutionary biology.

Stakeholders: People, computer science, complex systems science, governments at all levels.

Challenge 2: Engineering social benevolence and creativity

Motivation: Modern ICT systems, especially large-scale systems, suffer from widespread malicious behaviours which present security risks, and often undermine the functioning of such systems. Unfortunately, efforts to counter malicious attacks often hinder individual autonomy, and thereby destroy opportunities for benevolent individual action. We do not have any sophisticated means for engineering the prevention of unwanted behaviour, while at the same time encouraging and rewarding good behaviour.

Aim: To learn principles, inspired in part by social phenomena, for designing large-scale socio-technological ICT systems that naturally suppress or dissuade malicious behaviour, while encouraging and facilitating beneficial, cooperative behaviour and creativity. Social norms enable societies to function effectively, and have evolved in order to do so. Structures and rules that support cooperative collective dynamics have been studied in evolutionary biology and social science. This study is now receiving new energy from the emergence of computational systems capable of exploring the dynamics of collective systems in virtual experiments. Hence, the time is particularly ripe for a concerted effort to learn how modern computational technology, combined with insight from the social sciences, can help us engineer more productive behaviour within complex and evolving socio-technological networks.

Expected Impacts: Safer ICT systems, improved productivity, transformed business models that lead to influential new businesses (P2P networks, BitTorrent, Skype, etc.). Feedback into the science of social cooperation, stimulated by the study of large networks where data is available (far beyond that usually found in social science).

Disciplines Involved: Computer science, sociology, economics, evolutionary biology.

Stakeholders: Large-scale Web 2.0 businesses, all individuals who use the Internet and WWW, social science.

Challenge 3: Designing socially-adaptive ICT

Motivation: ICT systems increasingly interact with people, or involve individuals making decisions as part of the network. For such systems (Internet, WWW, P2P networks, security systems, business organizations, etc), the social structures defined by roles, habits, power relations, etc. among individuals influences the functioning of the system. Currently, ICT does not take such structures and relationships explicitly into account, nor does it evolve and adapt as they change. Hence, the structure of ICT systems often fights against natural social structures, inhibiting rather than supporting naturally productive interactions.

Aim: We must learn how to design more adaptive ICT systems that co-evolve with the social structures in which they are embedded; they should, in a sense, be “aware” of the surrounding social context.

Expected Impacts: Greater economic and organizational efficiency, more responsive and adaptive business firms.

Disciplines Involved: Computer science, behavioural psychology, organization theory.

Stakeholders: All organizations (business, government, etc.), computer science, economics.

Challenge 4: ICT for enabling/enhancing human interactions

Motivation: Human interactions have hitherto largely been limited by the physical modes supported by human senses and actions. This is, however, not logically necessary, and ICT has the capacity (through sensors, etc.) to enhance the ways people interact with one another.

Aim: A challenge is to identify and develop the key technologies that will enhance both individual human behaviour and interpersonal interactions with the most profound social benefits.

Expected Impacts: Transformed care for the elderly, new sports and arts, improved interpersonal communication in business and elsewhere, new forms of education through non-verbal means, transformed entertainment technologies.

Disciplines Involved: Computer science, behavioural and social psychology, the arts, business management.

Stakeholders: Business, society, essentially everyone.

Challenge 5: Simpler and more dependable software/hardware systems

Motivation: There is still no “science” of software or hardware development. Indeed, the continued advance of ICT systems in many ways faces a crisis, as software and devices, large and small, laptops and desktops not infrequently seize up, or cell phones require frequent rebooting. For individuals, these failures are annoying; for businesses and other large-scale enterprises, they can be very costly. At the moment, we simply do not know how to develop simpler, more adequate software, and both individuals and corporations continue to spend more on test, maintenance, repairs and operations than they do on hardware and software procurement and development put together.

Aim: This isn't a “social ICT” challenge, *per se*, but it is an important one – to change the development strategy for relatively simple software/hardware systems so as to make them far more dependable, robust and easy to use.

Expected Impacts: Provable certainty in many applications, especially involving mass products, for higher productivity, greater clarity/simplicity in thinking, the harnessing of human creativity in systems development.

Disciplines Involved: Computer science, cognitive/social science, application areas in business and life science.

Stakeholders: Businesses, organizations, society, essentially everyone.

Annex A: List of Participants

Thomas BJOERNHOLM (University of Copenhagen)
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Maria Chiara CARROZZA (Scuola Superiore S. Anna, Mitech Lab)
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Jose FIADEIRO (University of Lisbon)
Alfred FORCHEL (University of Würzburg)
Leonhard GRILL (Free University Berlin)
David HALES (University of Bologna)
Jeff JOHNSON (Open University, Milton Keynes)
Manolis KATEVENIS (University of Crete)
Marc LEMAN (University of Gent)
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Pier PAOLUCCI (Universita di Roma)
Eugene POLZIK (University of Copenhagen)
Jörg SCHMIEDMAYER (Atomchip Group)
Ioannis STAVRAKAKIS (University of Athens)
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Mark BUCHANAN (Rapporteur)

Annex B: Terms of Reference
Shaping FET Proactive Initiatives
Brussels, 20-21 September 2007

FET (Future Emerging Technologies) structures research in a number of proactive initiatives, which typically consist of a group of projects funded around a common theme. The themes are shaped through interaction with the research community, and focus on novel approaches, foundational research and initial developments on long-term research and technological innovation.

The EU started a process aiming at identifying new research challenges and opportunities through interactive brainstorming events with high level scientists. The meeting "Shaping FET Proactive Initiatives" was an initial meeting that aimed at consulting scientific communities that were primarily linked to FET and its proactive initiatives. It was followed by other events in late 2007 and early 2008 to consolidate proposals from this event and where proposals for further new themes were elaborated.

Participants are invited to share their views to help the Commission define new initiatives, going beyond traditional lines of research through both entirely new topics, and opportunities for collaboration with other communities. The final results as inputs will be used for the establishment of the work programme for 2009-2010. While we are constantly looking for new opportunities, we also invite participants to consider the evolution of proactive initiatives until now (page 22), also taking into account the timing of the different framework programmes (page 23).

Participants were asked to contribute in three areas:

1. The current work programme identifies three themes that are candidate areas for 2009. The descriptions are provided on page 22. We asked the participants to advance these themes, either by providing more detail or by taking a wider view and shifting the focus. (These themes are not fixed; since these themes were formulated some time ago, the crucial research challenges may have changed since then.)

2. Participants were asked for key challenges that could be the basis for new initiatives in 2010. These can either be completely new topics, although we invited participants to look at the evolution of previous and ongoing FET initiatives (see page 22). In the latter case, we asked to provide a view of how these would build on existing and past initiatives. Where possible such evolutionary topics should include at least one other topic that creates a bridge with another community.

3. During a final session the process of formulating and planning new proactive initiatives was discussed. Key questions included

a. What mechanism should we use to generate new proactive initiatives?

b. How should we decide whether proactive initiatives should or should not have a follow-up initiative?

c. Should all initiatives be allocated the same funding or should some sort of variable geometry be used, and if so what criteria or indicators should be applied?

d. What instruments are most suitable - targeted projects (STREP), Integrated Projects, Networks of Excellence or Coordination Actions?

e. What relationship should be built between Proactive Initiatives and FET Open?

The planned output of the meeting was first of all a set of proposals, each of which identifies research challenges, directions or areas that present opportunities for FET. This list will then be an input to follow-up meetings, together with recommendations regarding the process of arriving at new proactive initiatives, and on aspects of their implementation. Follow-up meetings will focus on specific topics, and/or aim at consulting a wider community.

Agenda
Thursday 20 September:
14:00 Welcome and introduction
14:30 – 16:30 Presentation of participant's views on new proactive initiatives for 2009 and 2010
16:30 – 17:00 Break
17:00 – 18:30 Continued - Presentation of participant's views on new proactive initiatives for 2009 and 2010
19:30 Dinner
Friday 21 September:
9:00 Wrap up of contributions from participants and discussion
10:00 Discussion on new opportunities
11:00 Break
11:30 Discussion on process of creating and (dis-)continuing proactive initiatives
12:30 Lunch
14:00 Discussion on other planning aspects
15:30 Close of meeting

Links
You are invited to look at the **FP7 FET website** **http://cordis.europa.eu/fp7/ict/fet-proactive/**, in particular to see the scope of each proactive initiative, and the composition of our portfolio of proactive initiatives. You are also invited to look at the **FP6 FET website** (**http://cordis.europa.eu/ist/fet/id-fp6.htm#speccons**) which contains reports about a previous consultation process that was used in 2005 and 2006.

Draft Initiatives for 2009 – to be adjusted to evolving challenges
Massive ICT systems
The objective is to research, demonstrate and validate new computing architectures and algorithms that will allow designing, programming and managing future high-performance ICT components with up to one Tera (10^{12}) devices integrated in a single chip.
Human-computer confluence
To investigate an invisible, implicit, embodied or even implanted interaction between humans and system components, for natural interaction (including communication) in surrounding environments, themselves augmented with pervasive and ubiquitous infrastructures and services.
QIPC and other quantum technologies
To overcome major scientific, technological and theoretical challenges for quantum technology to deliver on its promise to radically outperform its classical counterpart not only in terms of processing speed, capacity and communication security, but also, in the ability to solve classes of practical problems which currently cannot be solved. This initiative also invites the exploration of a wider range of non-classical implementations of ICT. More generally, it will be important to strengthen international collaboration on foundational research in this area where Europe has established itself firmly at the leading edge.

European Commission
Directorate General Information Society and Media
Unit F1 – Future and Emerging Technologies – Proactive
Email: **infso-ictfet@ec.europa.eu**
Web FET in the 6th Framework Programme:
http://cordis.europa.eu/ist/fet/home.html
Web FET in the 7th Framework Programme:
http://cordis.europa.eu/fp7/ict/fet-proactive/home_en.html

Annex II: List of Participants
http://www.phantomsnet.net/Picoinside/EUFET/participants.php?project=2

NANO Vacancies - http://www.phantomsnet.net/Resources/jobs.php

Job Position (Ramem, Spain): *"R&D on nanoparticle and volatile detection"*

RAMEM S.A., Spanish SME founded in 1958, is developing within its R&D activity and through its brand IONER© (www.ioner.net), an equipment for the detection of volatiles and nanoparticles based on Differential Mobility Analysis (DMA), for applications in fields such as scientific instrumentation, Environment (detection of pollutants), Security (detection of explosives and chemical warfare agents), Bio-health (breath analysis), RAMEM is currently searching a Doctor to strengthen its R&D team.

The deadline for submitting applications is September 30, 2008

For further information about the position, please contact: Eladio Montoya (ioner@ioner.net)

PostDoctoral Position (Universitat Autonoma de Barcelona, Spain): *"Quantum transport in nanodevices and nanostructures"*

A postdoctoral position is immediately available in the field of quantum transport in nanodevices and nanostructures. The successful applicant should have a solid theoretical background in quantum mechanics, solid-state-physics and nanoelectronics. A sound knowledge in mathematical and numerical modeling is also welcome.

The deadline for submitting applications is October 10, 2008

For further information about the position, please contact: Xavier Oriols (xavier.oriols@uab.es)

NANO Vacancies - http://www.phantomsnet.net/Resources/jobs.php

PhD Student Position (CIC nanoGUNE Consolider, Spain): *"Available position on nanomagnetism under supervision of Dr. Andreas Berger"*

Fabrication and characterization of natural and artificial meta-magnetic materials, multilayers and nanostructures to develop an understanding of their basic physical properties as well as evaluate their suitability for large scale applications such as hard disk drives.
The deadline for submitting applications is October 10, 2008

For further information about the position, please contact: Andreas Berger (**a.berger@nanogune.eu**)

PhD Position (CIC nanoGUNE, Spain): *"Self-assembly and electrospinning"*

The proposed research will combine self-assembly of peptides with electrospinning. This very new research direction opens up pathways to elegant nanowire and nanotube fabrication. The research project will evolve from simple dipeptides to complex structures such as complete proteins. The result is expected to yield insight into the physics of fiber and tube assembly in living beings (e.g. microtubuli or protein fibers related to Alzheimer's disease). Furthermore, the project aims at stimulating natural peptide strands that line nucleopores and thus control the transport from and to cell nuclei.
The deadline for submitting applications is October 10, 2008

For further information about the position, please contact: Alexander Bittner (**a.bittner@nanogune.eu**)

PhD Postion (CEA-GRENOBLE, France): *"Non-contact atomic force microscopy investigations of self-organized pi-conjugated molecular wires"*

The candidate must have a master degree in physics, and a great motivation to carry an experimental work in an interdisciplinary group, where physicists and chemists are working in close collaboration. A former experience in near field microscopies (STM/AFM) is not mandatory but some knowledge of basics concepts will be appreciated.
The deadline for submitting applications is March 30, 2009

For further information about the position, please contact: Benjamin Grevin (**benjamin.grevin@cea.fr**)

PhD Position (Institut Català de Nanotecnologia (ICN/UAB), Spain): *"Atomic Manipulation and Spectroscopy Group"*

The positions are granted for a duration of up to 4 years. The successfull applicant will be enrolled in the Ph.D program of the Autonomous University of Barcelona. A completed or about to be completed degree in physics or physical chemistry is required. Experience in either magnetism or scanning probe techniques and ultra-high-vacuum environment is welcome but not mandatory.
The deadline for submitting applications is September 18, 2008

For further information about the position, please contact: Gustavo Ceballos (**gustavo.ceballos.icn@uab.cat**)

Job Vacancy (British Embassy, Spain): *"Science & Innovation Officer - British Embassy, Madrid"*

The science & innovation officer will be expected to lead on developing scientific collaboration and R&D partnering between UK and Iberian research institutions and companies, and to work with British Embassy colleagues across Europe to support new multilateral collaborations.
The deadline for submitting applications is August 15, 2008

For further information about the position, please contact: Monica Martinez (**rrhh@fco.gov.uk**)


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Nano Conferences

NANO Conferences http://www.phantomsnet.net/Resources/cc.php

(September 2008)

ESF-UB Conference in Biomedicine
September 19-24, 2008. Sant Feliu de Guixols, (Spain)
http://www.esf.org/index.php?id=4649
NanoMedicine

BIOSPAIN2008.
September 17-19, 2008. Granada (Spain)
http://www.biospain2008.org/index.cfm
NanoBiotechnology, Nanotechnologies

11th International Conference on Non-contact Atomic Force Microscopy: NCAFM-2008
16-19 September, 2008. Madrid (Spain)
http://www.uam.es/otros/ncafm08/
SPM

34th International Conference on Micro and Nano Engineering 2008
September 15-18, 2008. Athens (Greece)
http://www.mne08.org/
NanoFabrication, NanoLithography

9th Trends in Nanotechnology International Conference (TNT2008)
September 01-05, 2008. Oviedo (Spain)
http://www.tntconf.org/2008/index.php?conf=08
Nanoelectronics, NanoBiotechnology, Nanotechnologies

Advertisement

NANO News - http://www.phantomsnet.net/Resources/news.php

A better image for plastic solar cells using Kelvin Probe Force Microscopy (KPFM) (July 07, 2008)
http://www.physorg.com/news134659941.html
Researchers at the Istituto per la Sintesi Organica e la Fotoreattività - Consiglio Nazionale delle Ricerche (CNR) in Bologna, Italy are using an analytical technique based on a powerful type of microscopy, to analyse materials and map their electrical properties with nanoscopic detail.
Keywords: Nanomaterials / Nanoprobes-SPM

Engineers show nanotube circuits can be made on the wafer scale (July 04, 2008)
http://www.physorg.com/news134398253.html
Stanford electrical engineers unveiled a method for making integrated circuit chips with complex nanotube components on the scale and with the parallelism that the semiconductor industry must employ to make chips that are economical.
Keywords: Nanotubes / Nanoelectronics

NEMS device gets active (July 02, 2008)
http://nanotechweb.org/cws/article/tech/34837
Philip Feng and Michael Roukes of the Kavli Nanoscience Institute, and colleagues at the California Institute of Technology, have made the first self-sustaining, ultrahigh-frequency nanomechanical oscillator (or NEMS oscillator).
Keywords: Nanofabrication / NEMS&MEMS

New Nanowire-Based Memory Could Beef Up Information Storage (July 02, 2008)
http://www.physorg.com/news134214217.html
Researchers from the University of Pennsylvania have created a type of nanowire-based information storage device that is capable of storing three bit values rather than the usual two. This ability could lead to a new generation of high-capacity information storage for electronic devices.
Keywords: Nanofabrication / Nanoelectronics

Contactless nanowriting with floating AFM tips (July 01, 2008)
http://www.nanowerk.com/spotlight/spotid=6240.php
The reduction of linewidth is one of the most important problem in integrated circuits (IC) technology because the speed and performance of computer chips is dictated by the lithographic minimum printable size.
Keywords: Nanoprobres-SPM / Nanoelectronics

Researchers form metal nanoparticles into porous structures (June 27, 2008)
http://www.physorg.com/news133793950.html
Cornell researchers have developed a method to self-assemble metals into complex nanostructures. Applications include making more efficient and cheaper catalysts for fuel cells and industrial processes and creating microstructured surfaces to make new types of conductors that would carry more information across microchips than conventional wires do.
Keywords: Nanomaterials / Energy / Nanofabrication

Tethered molecules act as light-driven reversible nanoswitches (June 23, 2008)
http://www.physorg.com/news133455358.html
The technology has been suggested as a possible basis for molecular motors, artificial muscles, and molecular electronics.
Keywords: Molecular Electronics

Carbon Nanotubes as a Single-Photon Source (June 12, 2008)
http://www.physorg.com/news132492345.html
For the first time, a team of researchers from the Institute of Quantum Electronics in Zurich, Switzerland, has observed photon in CNT photoluminescence. The study provides the first demonstration of non-classical optical emission from a CNT.
Keywords: Nanotubes

INASMET-Nano: Nanotechnology for Industry Health Applications

Isabel Obieta and José Luis Viviente

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http://www.inasmet.es

1. Introduction

INASMET-Tecnalia (**www.inasmet.es**) is a private, non-profit-making technological centre serving the productive and institutional framework with headquarters in San Sebastián (Spain). Its mission is to "contribute actively to economic and social development, promoting and facilitating technological innovation and development processes as a competitive strategy". INASMET-Tecnalia is founder member of TECNALIA Technological Corporation (**http://www.tecnalia.info/ingles/index.jsp**), the Spanish largest private research institution. Its main activities cover the research and development of new materials, their processing technologies and the environmental impact in manufacturing or products. RTD activities are focussed on key industrial sectors such us health, energy, aerospace, automotive, etc. Together with RTD projects under contract to companies and with universities and public bodies, the centre offers other services such as the management of technological innovation, training and technological difusion, design and management of technological centres and exploitation of results by the creation of new technology-based firms and the management of Industrial Property – Patents. The Centre currently comprises around 250 staff (including 21 scholarships).

Figure 1. *Diamond Like Carbon biocompatible coatings on hip-joint and knee artificial implants*

INASMET first activities in Nanotechnology started in 1991 and they were focused to the study and development of biocompatible layers as well as bioactive surface treatments. In recent years (2000), INASMET Foundation has coordinated and supported its main R&D activities by means of Strategic Programmes: the Biomaterials and Medical Devices Programme, the Nanotechnology

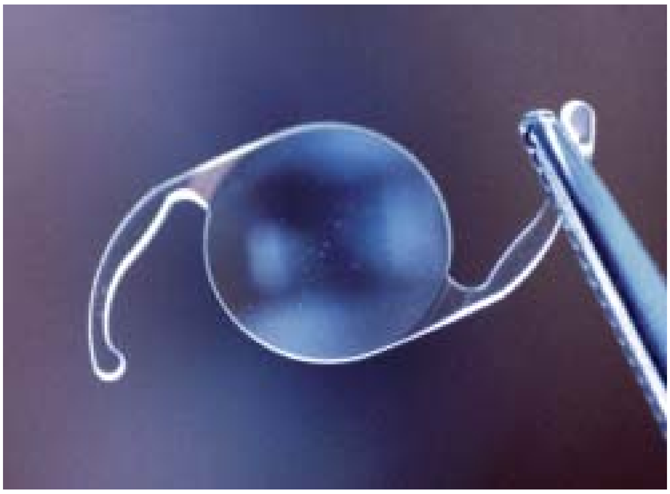

Figure 2. *Intraocular lens*

Programme or the Smart Materials and Structures and Intelligent Processing of Materials Programme, with high synergies between them. Nowadays, the "nano" R&D activities at INASMET are carried out under the umbrella of the Nanotechnology Program Phase II (2007-2010) which has a higher emphasis in the development of nanotechnology based applications or products in several industrial sectors such as health, aeronautics, space, automotive or energy.

2. INASMET Nanotechnology Programme

The main objectives of INASMET-Nano, the Nanotechnology Programme carried out by INASMET -Tecnalia, are the following:

- To improve INASMET´s competitiveness increasing our capabilities for developing innovative nanotechnology-based processes and products in the market sectors addressed by INASMET.
- To promote technology transfer and the development of a nanotechnology-based industry.
- To set up and strengthen partnerships for Nanotechnology-based innovation.
- To develop a permanent specialised group of staff in Nanotechnology R&D through integrated multidisciplinary and highly focused research projects.

The Programme is implementing a wide range of activities with actions in:

- Focused research projects
- Training and mobility of researchers
- Developing and strengthening partnerships
- Infrastructures (sharing of resources…)
- Communication and dissemination
- Technology watch and foresight
- Industrial innovation (industrial property rights, technology transfer...)

2.1 Research Activities

INASMET-Nano activities address both technology and application driven research combining basic and applied research in Nanomaterials, Nanoelectronics and Nanobiotechnology. Main areas of research are:

- Synthesis, dispersion and/or functionalisation of nanostructures (i.e.; nanoparticles, carbon nanotubes, carbon nanofibres…)

- Polymeric, Ceramic and Metallic nanostructured materials (including both nanostructured coatings and bulk materials)
- Micro- and Nanofabrication
- Surface functionalisation
- Bio / non-bio interactions
- Encapsulation
- Self-assembly and self-organisation
- Nanostructural Characterisation
- Health, safety and environmental impact of nanotechnology-based materials

2.2 Framework, Networks & Associations and International Cooperation

INASMET-Nano is carried out in the frame of the “nano” activities developed in the TECNALIA Corporation also coordinated by INASMET (TECNALIA-NANO). In addition, it is also in accordance with the strategies designed by the Basque Government for the business development of nanosciences (NANOBASK2015) and biosciences (BIOBASK2010) as well as with both the Spanish Government Programme INGENIO 2010 initiated June 2005 for relaunching the Lisbon Strategy approved by the European Council spring 2005 and the new Spanish National Plan for Scientific Research Development and Technological Innovation (2008-2011). Beside to this, specifications are also carried out in order to address industrial needs as well as European policies or strategies such as the Nanoscience and Nanotechnology Action Plan for Europe.

INASMET-Tecnalia seeks the collaborations with organisations with expertise in different nanoscience and nanotechnology fields in order to attain the critical research mass that will allow for conducting top level research and technology developments through the participation in joint projects, the writing of doctoral theses, mobility and stages in different institutions. INASMET-Tecnalia is member and it cooperates with leading national and international networks and association such as:

- NANOSPAIN, Spanish network on Nanotechnologies (co-chairman of the industrial working group)
- The Institute of Nanotechnology
- The European Nanotechnology Trade Alliance (ENTA)
- The European Society of Biomaterials (ESB)
- CIC nanoGUNE (Nanoscience Cooperative Research Center)
- CIC biomaGUNE (Biomaterials Cooperative Research Center)
- The European Center for Nanostructured Polymers (ECNP, founder member)
- NanoMedicine, the European Technology Platform “Nanotechnologies for Medical Applications” (working group of Regenerative Medicine)
- MANUFUTURE, the ETP “Future Manufacturing Technologies” (working groups: Micro- and Nanomanufacturing (MINAM) and Rapid Manufacturing), participating in the High Level Group of MANUFUTURE as TECNALIA
- EuMat, the ETP “Advanced Engineering Materials and Technologies”
- GENESIS, Spanish node linking with the European technology platforms EPoSS & ENIAC
- Spanish National Platform on Nanomedicine
- SLMA: Active Molecule Release Systems Spanish Network

An example of the international cooperation in the field of nanotechnologies is the following list of some European projects in which INASMET-Tecnalia has been involved or is participating:

- Improvement of tools for the machining of aeronautic aluminium and titanium alloys (TITALUM)
- A fundamental study of the processing-structure-properties of nanocomposites for industrial applications (PRONACOM)
- Development of cost effective PEMFC for automotive

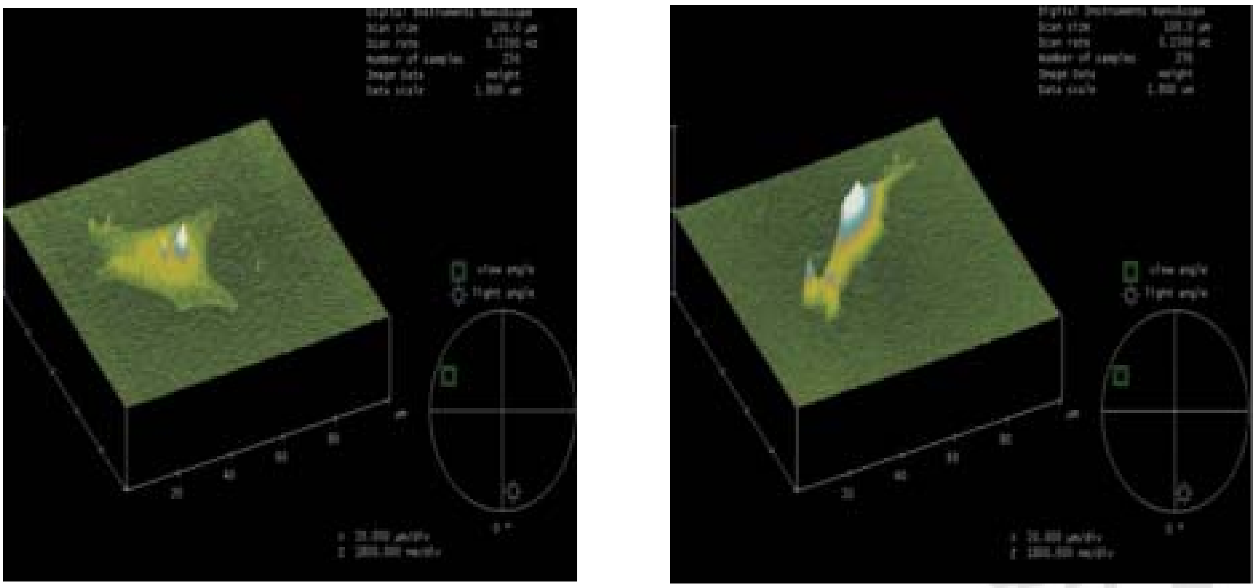

***Figure 3**. Osteoblast cell morphology after two different surface treatments of the substrate*

applications (OPTIMERECELL)

- Emerging Nanopatterning Methods (NAPA)
- Nanostructured and functional polymer-based materials and nanocomposites (NANOFUNPOLY)
- Innovative PVD nano-coatings on tools for machining titanium and nickel alloys (MATINA)
- Aerospace nanotube hybrid composite structures with sensing and actuating capabilities (NOESIS)
- Advanced environmentally friendly multifunctional corrosion protection by nanotechnology (MULTIPROTEC)
- New Ionic Liquid Solvent Technology to Transform Metal Finishing Products and Processes (IONMET)
- Development and evaluation of coatings and surface conditions on steel for antibacterial and easy to clean properties (DECOBIOF)
- Intelligent nanocomposite for bone tissue repair and regeneration (NANOBIOCOM)
- Improvement of thermal dissipation by nano-material (THERDISS)
- An innovative manufacture process concept for a flexible and cost effective production of the vehicle body in white: Profile forming (PROFORM)
- Multifunctional layers for safer aircraft composite structures (LAYSA)
- Nanopatterning, Production and Applications based on Nanoimprinting Lithography (NaPANIL)

3. Nanotechnologies for Health

In recent years, the "Fundación INASMET" has been making a major effort in researching Health-related topics. Inasmet has been trying to merge two strategic areas in Biomedicine carried out in the frame of two Strategic Programmes: Biomaterials and Nanotechnologies. The knowledge acquired and the technologies developed have constituted the Health Unit which integrates biochemists, biologists, pharmaceutics, engineers, physicists and chemists with a common strategy in Tissue Engineering and Biosensors.

***Figure 4**. PLLA scaffold obtained by thermally induced phase separation*

The technologies developed in the frame of the two Strategic Programmes above mentioned, have merged

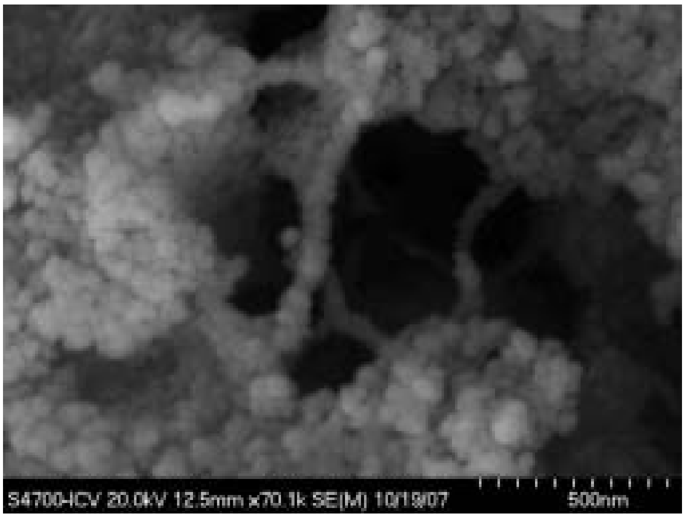

Figure 5 *MWCNT coated with nanozirconia obtained by hydrothermal synthesis*

into the development of several areas of research in which a large range of nanotechnology based health applications or products are developed. Some research areas as well as applications are detailed hereafter:

3.1 Development of Biomaterials

The biomaterials being developed are aimed as active supports and transporters of cells and biomolecules for tissue regeneration and as transducers or electrodes in biosensors. All developments are completed by mechanical, chemical, biological and surface characterization. Currently, three types of materials are being worked with:

- **Hydrogel** types derived from polyethylene glycol introducing photo-initiators to control the micro-geometries by photolithographic processes. These materials are being used as cornea substitutes
- **Linear polymers derived from poly (α-hydroxy-acids)** introducing nanoparticles (Hydroxiapatite), nanogels and carbon nanotubes for bone scaffolds. INASMET is leading a European Project STREP: NANOBIOCOM: Intelligent nanocomposites for bone tissue repair and regeneration (2004-2008)
- Ceramic matrix Nanocomposites based on the synthesis of nano-zirconia coating on carbon nanotubes to obtain bio-active prostheses for long life. The first results

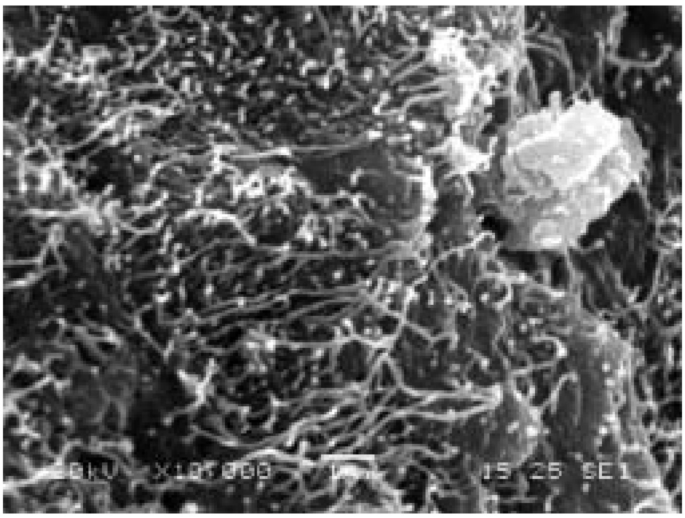

Figure 6*. PMMA wrapping SWCNTs*

on accelerated aging tests show stability of the material over 100 years, with improved mechanical and tribological properties.

A strong effort has been put in developing capacities and new knowledge on the functionalisation of carbon nanotubes, including modifications of carbon nanotubes for the adhesion of biomolecules. Some modifications are tested as a tool in diagnostic and monitoring of tissues. Inasmet has developed the synthesis and purification process of carbon nanotubes by CVD, as well as more than 5 protocols to functionalize the surface of the nanotubes with minor damage to their structure.

Another area that supports the basic lines is the development of **Micro and nanocapsules for bioactive molecules encapsulation**. Several chemical processes are being developed to obtain micro and nanogels of predetermined size, with low dispersion. They have been charged with several antibiotics and the release is being tested with good results in terms of controlling the time and dose.

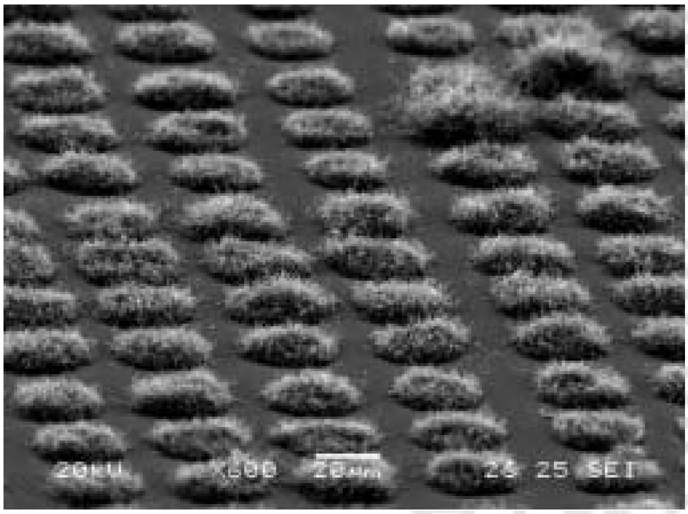

Figure 7*. MWCNTs grown on a patterned Si substrate*

3.2 Development of biocompatible and bioactive nanostructured coatings, surface treatments and surface micro-nanopatterning

Several nanostructured coatings and surface modification processes are being applied to protheses and implants. Thin films by PVD-magnetron sputtering or plasma assisted CVD), ion implantation and plasma polimerization are some of the techniques being adapted. Other processes, based on nano and microfabrication, are being developed to obtain nanostructured surfaces to improve the integration of material-tissue and to study the behaviour of cells on complex surfaces. By combining processes such as **UV-NIL** (Nanoimprint Lithography), as a tool to obtain nanometric surfaces geometries, plasma treatments and chemical modifications, local biofunctional or bioactive surfaces can be developed. Current new developments are looking for new functionalities:

- Bioactive surfaces able to monitor biological systems in diagnostic and therapeutics
- Biofunctional surfaces to be applied in advanced implantology: active materials (antibiotic, anti-thrombotic, etc.)

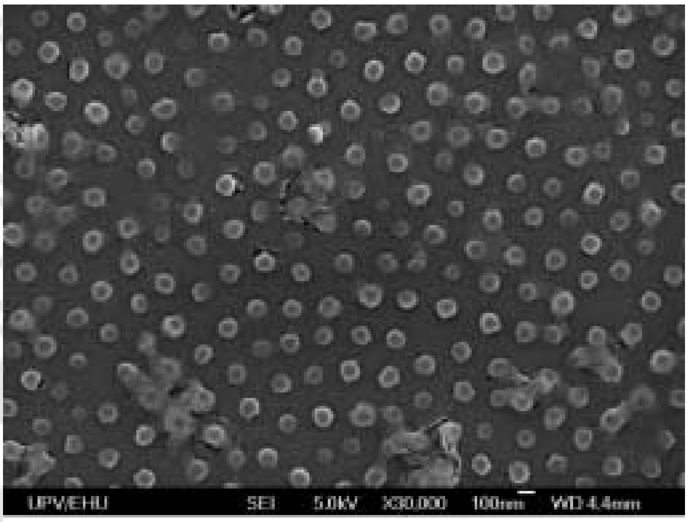

***Figure 8**. Dispersion of NIPAM nanogels on a Si substrate*

3.3 Bio-nanostructural Characterization

Nanostructural characterization by Raman, FTIR, XPS and AFM is fully developed in Inasmet, and currently, the use of AFM to measure cell adhesion and other type of cell-cell interactions and interfaces is being studied. Capacities and know-how to characterize surfaces (such as nano-indentation, bio-corrosion, adhesion, roughness, friction, etc.) are also in our portfolio.

Inasmet is fully equipped to characterize tissues and all kind of biomedical material/product. Inasmet performs Biocompatibility Assays under ISO 10993/ UNE - EN 30993 for CE marking: Citotoxicity in Vitro, Acute Toxicity, Genotoxicity, Subacute Toxicity, Hemo-compatibility, Implantation, Irritation, Chronic Toxicity, Sub-skin Reactivity, Biodegradation, Sensibilization. Other more specific normalized assays required by CE and FDA for biomedical products can be performed. This area acts as an external Service or Laboratory.

3.4 Development, evaluation and validation of products

Products are developed up to its CE marking. Technology transfer in this activity has contributed to the creation of several spin-offs such as LIFENOVA BIOMEDICAL, OSETECH or NEOS SURGERY.

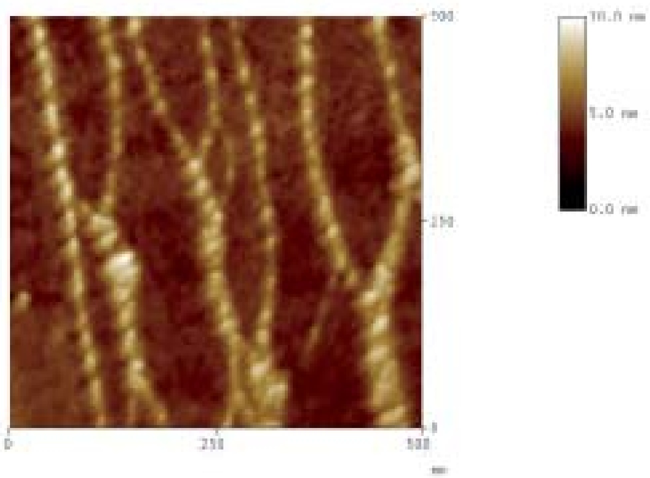

***Figure 9**. Nanostructured PMMA surface modified by fluorinated RF plasma*

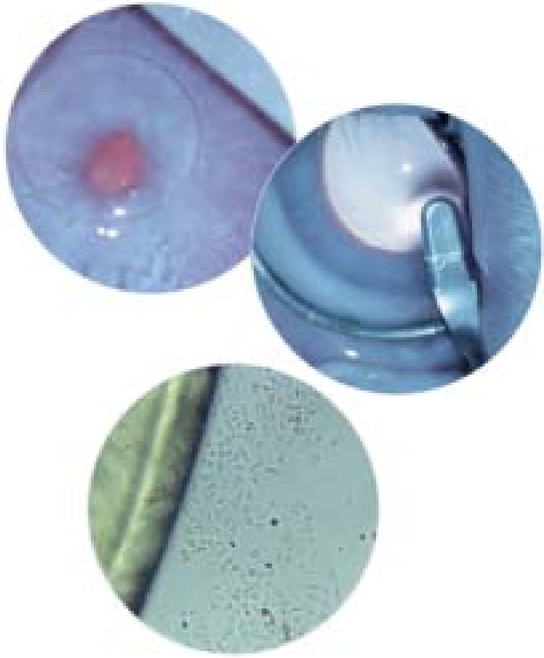

***Figure 10**. Intracorneal lens with a nanostructured biocide coating*