INVITATION

EuroTraining Course at
Politehnica University of Bucharest
16-17 November 2009, Bucharest, Romania

NANOTECHNOLOGY FOR ELECTRONICS

Introduction

EuroTraining is the part of the EC initiated EUROPRACTICE service, which aims to stimulate the wider exploitation of state-of-the-art micro/nano electronics and microsystems technologies by the European industry. EuroTraining invites engineers and scientists from companies, SMEs, universities and institutes to upgrade their knowledge by the Awareness Course and learn about **NANOTECHNOLOGY FOR ELECTRONICS** from highly qualified experts. Lecturers: **Prof. Göran Wendin**, Department of Microtechnology and Nano-science, Chalmers University of Technology, Sweden; **Dr. Harry Heinzelmann**, Nanotechnology & Life Sciences, CSEM Centre Suisse d'Electronique et de Microtechnique SA, Switzerland; and for practical parts, **Mr. Dirk Brüggemann**, Raith GmbH, Germany as well as researchers from **IMT-Bucharest**, the National Institute for Research and Development in Microtechnologies for laboratory demonstrations.

The course hosted by the **Politehnica University of Bucharest** provides a unique opportunity for graduate and PhD students, scientists and engineers coming from universities, research centers and industrial laboratories to meet and learn the newest developments in nanotechnology applied for electronic devices and systems. EuroTraining is happy to organize the Nanotechnology for Electronics Course at the prestigious Politehnica and IMT in Bucharest, Romania.

Focuses of the training program

- **Awareness:** lectures to introduce to trends, principles, technologies and applications of nanoelectronics.
- **Technology:** this module will teach the details of the technologies, including design opportunities, key process technologies and other topics of importance.
- **Practical demonstration:** another half day optional module where the participants will get experience with high tech equipment and practical demonstrations in the laboratories of IMT-Bucharest.

Important data

When	**16-17 November 2009**	
	16th November, Monday, at Politehnica:	
	08.30 – 13.30	**Prof. Göran Wendin:** Introduction, theory, basic approaches and applications
	14.30 – 17.45	**Dr. Harry Heinzelmann:** Processing techniques & tools, applications in biosensing & optics
	17th November, Tuesday, at IMT:	
	08.30 – 09.30	**Mr. Dirk Brüggemann:** Electron & ion beam lithography, nanoengineering
	09.30 – 10.15	**Dr. Mircea Dragoman:** Introduction to IMT–MINAFAB centre
	10.30 – 13.30	Laboratory visits and practical demonstrations
Where	**Monday: Politehnica University of Bucharest & Tuesday: IMT-Bucharest**	
Local organizer	**UPB, Faculty of ETTI, Department of Electronics Technology and Reliability**	
Address	**Monday: Blvd. Iuliu Maniu 1-3, 061071 Bucharest, Building A 104** **Tuesday: 126A, Erou Iancu Nicolae street, 077190, Bucharest**	
Website	www.ett.bme.hu/ET_NE2/	
Registration fee	**150 Euro** for the whole Course: 100 Euro for Monday and 50 Euro for Tuesday Full fee includes coffee breaks, Monday lunch and printed & CD proceedings **Discount fee** available for: - participants from EU New Member States – half price - students and young researchers of EU member states – half price - students and young researchers of EU New Member States – free of charge Discount fee includes coffee breaks and CD proceedings **Number of seats** is limited at the sessions: Monday and Tuesday tutorials: 50 persons, Tuesday laboratory visit: 30 persons Applications will be accepted until all seats are taken	
Contact person	**Zsolt Illyefalvi-Vitéz: illye@ett.bme.hu or +36 1 4632753**	
Registration open	**24th October – 12th November 2009 by email to the contact person**	

NANOTECHNOLOGY FOR ELECTRONICS – COURSE PROGRAM

16th November, Monday, at Politehnica University of Bucharest:

08.30 – 10.00 Prof. Göran Wendin: Introduction to Nanotechnology for Electronics

Nanoscience and nanotechnology. Nanotechnology is the study of phenomena and fine-tuning of materials at atomic, molecular and macromolecular scales, where properties differ significantly from those at a larger scale. Products based on nanotechnology are already in use and their applications can contribute to the European Union's growth, competitiveness and sustainable development objectives and its policies including public health, employment safety, information society, industry, innovation, environment, energy, transport, security and space.

Electronic and transport properties of nanostructures. Electronic properties: Introduction to quantum mechanics; Bulk and surface states; Density of states; From 3D to 0D systems. Transport properties: Quantum conductivity (quantum point contact); 2D electron gas, hetero-structures; Coulomb blockade - single electron transistor.

Definitions, theoretical aspects and practical problems. Due to the scaling down of microelectronics, the field has already entered the nanoelectronics era with commercial CMOS transistors for processors and memory having 50-100 nanometer dimensions. Moore's law suggests that around 2020 essential dimensions may reach the 5-10 nanometer range. Theoretical and practical problems should be explained that appear, when scaling down CMOS and memory devices into the 50-100 nm range and below. Number of reasons, which may make scaling break down, including quantum effects, power dissipation problems, fabrication difficulties and possibilities, costs, etc.

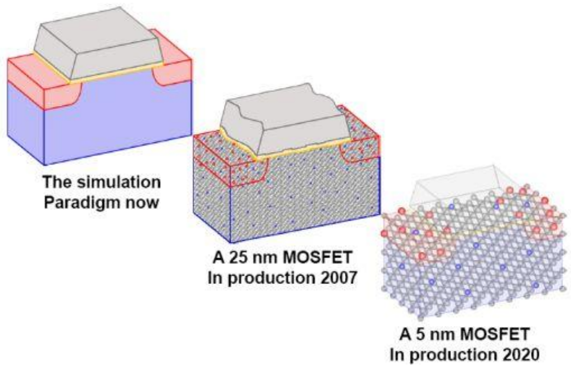


Fig. 1. Illustration of the concerns associated with scaling down of MOSFETs.
Hadis Morkoc, Y. Taur: A View of Nanoscale Electronic Devices, Journal of the Korean Physical Society, vol 42, Feb 2003, pp. S555-573.

10.00 – 10.15 Coffee break

10.15 – 11.45 Prof. Göran Wendin: Near-term Significant Nanoelectronics Approaches

More Moore, **More than Moore** and **Beyond CMOS** are the three main approaches concerning the future development of electronics. Presently nobody imagines that silicon and CMOS technology will be replaced in the near future, even by 2020. The discussion rather concerns "more of Moore", i.e. how to develop new types of semiconductor devices and architectures that fit into the old framework, and "beyond Moore" or "more than Moore", i.e. how to develop complementary nanoelectronics that can be integrated on silicon chips to extend the performance.

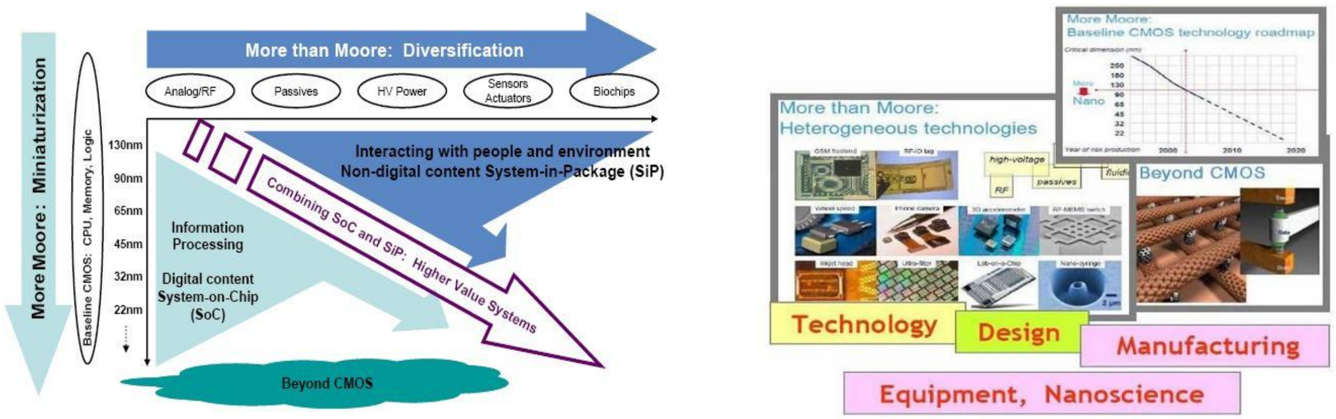


Fig. 2. a) Nanoelectronics development approaches; b) in practice.
Rosalie Zobel: Implementing (part of) the SRA on nano-electronics for Europe; http://www.eniac.eu/

11.45 – 12.00 Coffee break

12.00 – 13.30 Prof. Göran Wendin: Novel nanoelectronics devices and applications

Novel nanoelectronics devices and architectures, low power design methods and CAD tools. Application of nanoscale sensors, field emission, thermoelectric, and other nanoelectronics devices.

Application of nanoscale devices with more functionality: sensors, devices in biomedical/chemical/other interdisciplinary fields, actuators. Nanoelectronics applications for great diversity: ambient intelligence; nanoscale medical diagnostics and treatment; cleaner, safer and more comfortable transport; anti-terrorism and security applications, etc.

Materials for nanoelectronics: carbon nanotubes, inorganic nanowires and other nano materials vs the miniaturization techniques in the nanoscale of SOI, SiGe, GaAs, etc devices.

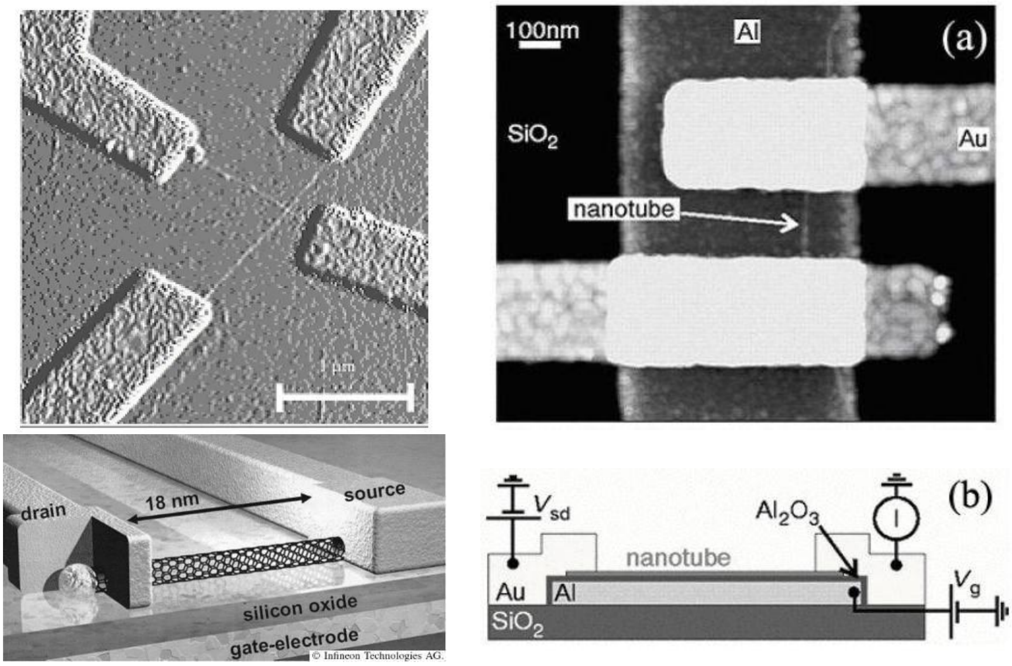


Fig. 3. Single-walled nanotubes (SWNT), devices and models.
Hadis Morkoc, Y. Taur: A View of Nanoscale Electronic Devices, Journal of the Korean Physical Society, vol 42, Feb 2003, pp. S555-573.

Beyond CMOS. Here e.g. molecular electronics could play a role. Moreover, quantum-effect devices involving controlled tunneling and resonance phenomena in semiconductor heterostructures might become important. Ballistic such devices can behave like wave guides for electrons and provide coherent devices based on interference effects. Ultimately, this brings us to quantum computing where superconducting electronic circuits and semiconductor quantum dots are currently intensely investigated in order to investigate the potential for developing "digital" quantum computers based on quantum bits - qubits. Finally, a major application of nanoelectronics is most likely going to be to create interfaces between artificial and biological "computational matter", with potential for truly revolutionary development.

13:30 – 14.30 Lunch break

14:30 – 16.00 Dr. Harry Heinzelmann: Processing techniques and tools, top-down techniques

Top-down and bottom-up processing techniques of nanoelectronics devices.

Key instrumentation, technologies, manufacturing, and applications of nanotechnology, including the technical background necessary to understand the newest developments, in particular new phenomena when scaling down from micro to nanometer dimension. An overview of methods and tools for accessing the nanometer length-scale is provided. It covers the principles of scanning probe techniques ranging from surface physics to biology, from highly specialized experiments to routine materials testing, demonstrating the usefulness of these methods also for industrial work. It describes state-of-the-art micro- and nano-engineering methods to create nanostructures that are needed in the future for various applications (nanolithography, nano-electronics, nano-optics, data storage and bio-analytical nanosystems). The content is adapted to the rapid changes in science, technology and society.

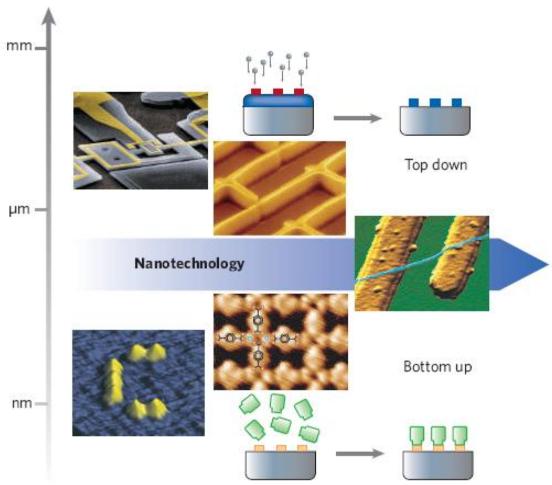


Fig. 4. Illustration of the difference between top-down and bottom-up processing techniques. **From *Nature 437 671-678 (2005)***

Top down methods essentially 'impose' a structure or pattern on the substrate being processed. Most important technologies: Nanolithography – electron beam lithography, UV lithography, X-ray lithography, soft lithography (nanoimprinting); Maskless techniques: E-beam lithography, Focused Ion Beam lithography, FIB-Chemical Vapour Deposition, Scanning Probe Lithography, etc.; comparison of the methods.

16:00 – 16.15 Coffee break

16:15 – 17.45 Dr. Harry Heinzelmann: Bottom-up techniques. Applications in optics & biosensing

Bottom-up technologies: The aim of these methods is to guide the assembly of atomic and molecular constituents into organized structure through processes inherent in the manipulated system.

Self-organized growth: Guided growth of metal islands, Selective growth by Local Anodic Oxidation (LAO), Selective growth by Focused Ion Beam (FIB), Semiconductor artificial atoms

Self-assembling methods – physical and chemical approaches: Supramolecular engineering, Metallosupramolecular assembly, Constructive nanolithography. Hybrid technologies: guided growth of nanostructures.

The contribution of the nanotechnology platform for different applications like fabrication of micro-optical components and nanoscale photonics devices; nanoscale structuring of surfaces and functional materials; fabrication of micro- and nanoscale components for biological applications; nanoscale tools that allow new approaches in biological research; advanced technologies and innovative applications of biosensing for integrated and wearable sensing, etc.

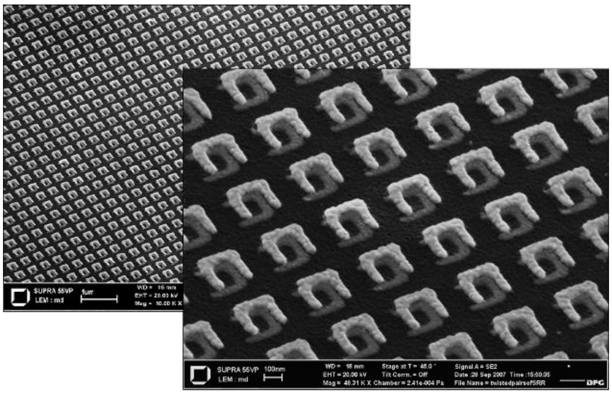
17th November, Tuesday, at IMT-Bucharest:

08.30 – 09.30 Mr. Dirk Brüggemann: Electron & ion beam lithography, nanoengineering

Research and development of nanotechnology require versatile and flexible instruments. State of the art performances, multi user management, instrument reliability and ease of operation are the critical requirements. Automation is mandatory even for small batch applications. This lecture provides information about the solutions provided by Raith for:

- Micro and nano-patterning with electron beam lithography or ion beam lithography for research & development and small batch production
- Competent technical support and transfer of technology, for the above mentioned areas of activities

a)



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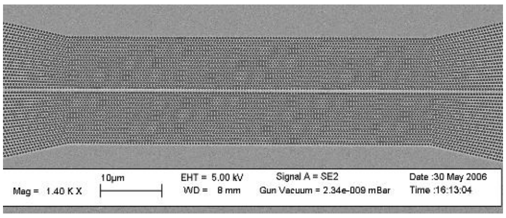

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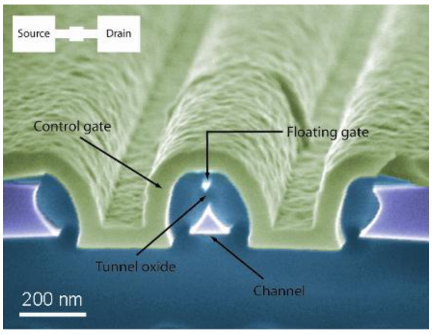

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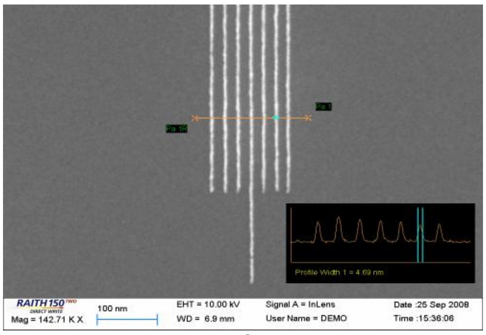


e)

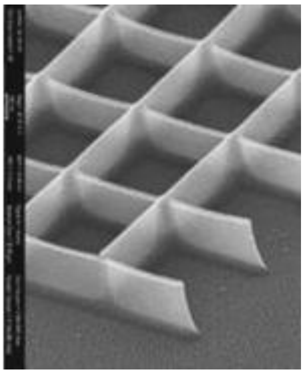
Fig. 5. a) Raith ELPHY Plus - A universal lithography system, Raith GmbH, Germany;
b) Chiral metamaterial consisting of pairs of gold split-ring resonators, M. Decker, University of Karlsruhe, Germany;
c) Fabrication of 2D-Photonic Crystals, W. Whelan-Curtin et al., St. Andrews University, Scotland, UK;
d) Room temperature single-electron memory device with self-aligned floating gate and triangular channel, T. Xiaohui, Uni Louvain la Neuve, Belgium; **e) ~ 5nm lines exposed in HSQ resist,** J. Yang, MIT, and J. Klingfus, Raith, unpublished.

09.30 – 10.15 Dr. Mircea Dragoman: Introduction - The scientific work at IMT and at IMT-MINIFAB centre

10.30 – 13.30 Laboratory visits and practical demonstrations in IMT-Bucharest (www.imt.ro)

Researchers of Centre of nanotechnologies from IMT will show the practical aspects of nanotechnology in the facilities of the IMT–MINAFAB centre (www.imt.ro/MINAFAB). Demonstrations will be organized regarding selected technologies and characterization methods for surfaces, nanostructures, micro-nano fabrication methods and applications.

a)



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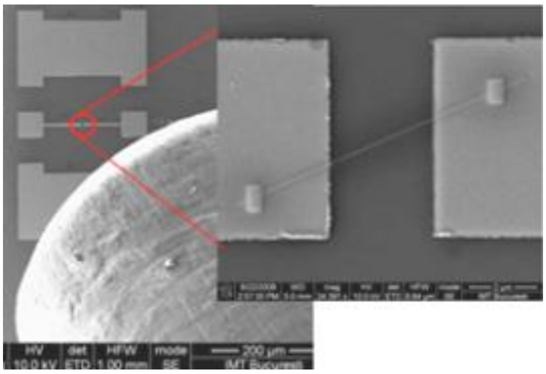

Fig. 6. Using the Raith nanoengineering workstation in IMT: a) High aspect ratio nanostructures (12:1) obtained using e-beam lithography; b) Application of Electron Beam Induced Deposition (EBID) for electrical characterization of CNTs