2nd REGMINA workshop on MEMS and NEMS technologies

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- Abstracts of Presentations–

REGMINA – Project status summary

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Regmina project had two main objectives: to improve the structure of scientific research personnel and to increase the level and quality of equipment of the ICTM-CMTM. Presentation chronologicaly shows how these two goals are achieved. By achieving these two objectives the Centre will be able to join on an equal basis in the research community of the European Union.

So far, REGMINA investment has enabled the purchase of several new pieces of equipment, all of which are greatly important to R&D activities at the Centre. A gap in lithography has been overcome, with Laser writer-LW405 allowing direct writing on different types of substrates at submicron resolution. The wafer bonding system is now capable of bonding whole wafers (Si-Si, Si-glass), whilst the team at the Centre have previously developed a method for Si-glass bonding at the chip level. A new NTEGRA atomic force microscopy system by NT-MDT Prima is a multifunctional platform, enabling AFM experiments to be performed in a variety of controlled environments (ie. in specific gas mixtures, in a vacuum, in liquids or across a range of temperatures), crucial for experimental studies of adsorption-desorption processes and their influence on MEMS sensors.

Our existing equipment purchased before REGMINA was mostly older and even outdated, and we had to devise the optimum way to upgrade it with new items so that they complemented each other in the best possible way.

During the course of the project, several young reseracher have been engaged in research thanks to the REGMINA funds. These young researchers have been hired on permanent basis on the national project, like other researchers in the Centre.

We also present the training of the Centre researchers in the field of NEMS/MEMS in renowned european laboratories: DESY (Deutsches Elektronen-Synchrotron), Hamburg, Germany; Institute of Microelectronics (IMEL)/NCSR “Demokritos”, Athens, Greece; EPFL, Lausanne, Switzerland; Delft Institute of Microsystems and Nanoelectronics (DIMES) – TU Delft, The Netherlands.

Application of TiO_2 nanowires

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We can synthesize the anatase phase of TiO_2 at different length scales: bulk single crystals, single crystalline nanotubes/ nanowires and nanoparticles. These forms of anatase offer the possibilities for fundamental research, applications in photovoltaics, spintronics and in biophysical studies.

This presentation will focus on the synthesis and application of single crystalline anatase nanowires. Our method, beyond the high structural quality, allows the doping and manipulation of nanowires in order to have active nano-sized materials. For example, nanowires were fused into a 3D fibrous network. It was used in a photovoltaic cell with solid electrolyte. This architecture possesses a high roughness factor, significant light scattering and up to several orders of magnitude faster electron transport which plays an important role in a high conversion efficiency.

Single Electron Nano Probes

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We have developed the concept of single-electron nanoprobes that meets the requirements of electrical characterization of biological and other low-conductivity nanostructures. The nanoprobe is a MEMS cantilever with an atomically sharp and electrically-conductive tip at its end. The integral part of the probe system is a computer-controlled electronic instrument. The electronic instrument can impose a biasing voltage on the probe tip, and measure the resulting current with single-electron-transfer resolution; or detect single ions in the proximity of the tip. The key part of the electronic instrument is a CMOS electronic circuit incorporating a novel electron device called SEBAT (Single Electron Bipolar Avalanche Transistor). The SEBAT enables sub-pico-amp current measurement with much lower noise and much faster response than that which were possible with conventional amplifiers. In order to exploit the full potential of this electronic circuit, its input device (a SEBAT, or a MOSFET in front of the SEBAT) must be positioned near the probe tip. Ultimately, the input part of the electronic circuit should be integrated with the probe cantilever. We plan to demonstrate the operation of such a single-electron nanoprobe in the scanning-probe microscopy involving electrical measurements on the biological samples.

NanoTools for ultrafast DNA sequencing

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In recent years development of new technologies for high-throughput and affordable DNA sequencing is in the focus of wider scientific community. One of many approaches, with strong potential to deliver technology with such capabilities, is based on the electrical characterization of individual nucleobases while DNA passes through a nanopore with integrated nanotube side-electrodes. Despite significant efforts, the answer on proof-of principle question still lack.

In this talk, I will present progress report of our ongoing FP7 project "nanoDNAsequencing". In particular, the IV characteristics of four nucleotides (including the sugar-phosphate group) between two H-terminated (3,3) carbon nanotubes at finite bias are studied using density functional theory with the non-equilibrium Green's function representation of the density matrix of the system in a finite electric field, as implemented in Transiesta program. The results show that the application of bias of about a few Volts can induce currents, depending on the base, of up to 10 nA.

A new technology which allows direct integration on flexible substrates – Application to microfluidics and various thermal sensors

Prof. Dr. Grigoris Kaltsas

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A novel fabrication method for developing thermal sensors on flexible organic substrates will be presented. The proposed technique combines microsystem technology and standard PCB methods. The demonstration of the proposed technology was made through the fabrication of specific devices which are directly connected to macroscale copper structures of commercial flexible copper-clad laminated composites. The constructed devices consist of Pt thermistors which are directly integrated to the copper tracks of a flexible copper-clad laminate. They reside on top of a 12μm thick SU-8 planarization layer, while a sacrificial layer utilized by the negative photoresist ma-N was used in order to define the thermistor pattern. The thermistors can act as both heating and temperature sensing elements, while due to small thickness and the low thermal conductivity of the Kapton substrate a very effective thermal isolation is achieved. The minimum radius of curvature of the fabricated devices was found to be 5mm. As the device is in direct communication to the macrowolrd, the need for wire bonding is eliminated, while the final surface of the produced sensor is relatively planar. The overall process is simple and cost-effective with minimal requirements in fabrication time. The potential application field of the presented devices is considered quite extensive as they can be directly expanded into flexible sensors able to measure quantities such as fluid flow rate, displacement or vacuum. Applications to thermal flow sensors, microfluidics and posistion sensors will be presented and demonstrated.

Single Photon Avalanche Diode (SPAD) for biological applications

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Fluorescence measurements for biological applications demand photodetectors with ultra-high sensitivity (down to the single photon level), low noise and parallel readout capability. Single photon avalanche diodes (SPAD) detectors fabricated in planar technology on silicon substrates offer the typical advantages of solid state devices (miniaturization, ruggedness, low voltage, low power and low cost) together with very high sensitivity, due to the ability to detect single photons with high efficiency and low detector noise. A fully-parallel monolithic array of SPADs with timing circuitry monolithically integrated in the detector chip for fluorescence measurements will be presented. Using this array it is possible to simultaneously acquire spectral and temporal fluorescence data at every cell region under investigation, allowing a better understanding of the biological process involved at cellular level.

Application of LTCC technology for innovative sensors and transformers

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In the first part an innovative design of a wireless, passive LC sensor and its application for monitoring of water content in building materials will be described. The sensor was embedded in test material samples so that the internal water content of the samples could be measured with an antenna by tracking the changes in the sensor’s resonant frequency. Since the dielectric constant of water was much higher compared with that of the test samples, the presence of water in the samples increased the capacitance of the LC circuit, thus decreasing the sensor’s resonant frequency. The sensor was fabricated in Low Temperature Co-fired Ceramic (LTCC) technology, and consists of an inductor and an interdigitated capacitor, in one metal layer.

The second part design presents a LTCC transformer for application in DC/DC converters. The transformer possesses a compact structure with the coils surrounded by dielectric (or ferrite) material and between the coils one dielectric layer is placed. Simulation and measured results for inductance, coupling coefficient and quality factor of the proposed transformer will be presented.

MEMS Silicon Micro-Evaporator

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Process intensification in chemical applications and size reduction in space industry and integrated circuits lead to an increase of the energy density which can generate intensive local heating. To deal with high heat fluxes, properly designed devices for heat absorption (cooling), such as evaporators, are essential. This talk addresses a miniaturized evaporator with a fin structure fabricated in silicon using microsystems technology (MEMS). Demonstrator devices with high aspect ratio channels (10 µm and 20 µm wide, 100 µm deep) were fabricated by deep reactive ion etching of silicon and anodic wafer bonding to glass, and tested with de-ionized water as coolant. An integrated resistive silicon heater which mimics external heat source and acts as a temperature sensor is included. The tested devices successfully turned liquid water into the vapour for the tested flow rates up to 5 ml/h. Effective absorbed power flux was up to 40 W/cm^2. Furthermore, optimization of the fin-channel structure successfully solved the vapour backflow problem and led to more stable operation.

Report on Three Months Specialized Training on X-ray single photon counting detectors at DESY (Deutsches Elektronen Synchrotron), Hamburg, Germany

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Supervisor: Dr. Heinz Graafsma

Milija Sarajlić has been a guest at the group for detectors development in DESY (Deutsches Elektronen-Synchrotron), group leader Dr. Heinz Graafsma. He has contributed in testing and modeling of MEDIPIX family X-ray Detectors. This combines different types and different modes of operation. Namely Medipix3 in Single Pixel and Charge Summing mode, Medipix2 in Single Threshold mode and Energy Window mode, and Timepix in Medipix mode. He gave modeling of the charge sharing effect taking into account statistics of the charge distribution in sensor pixels. Medipix family threshold values are deduced from measurements and corrected by charge sharing simulation.

Report on Two Months Specialized Training at the Institute of Microelectronics (IMEL)/NCSR “Demokritos”, Athens, Greece

Dr. Danijela Randjelović, Senior Research Associate
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Supervisors: Dr Christos Tsamis (AFM)
Dr Angeliki Tserepi (Plasma etching)

During the two months training period funded by REGMINA EU project Dr Danijela Randjelović has benefited from the previous collaboration and experience that she has gained working at the Institute of Microelectronics (IMEL)/NCSR “Demokritos”, in 2000 and 2009, and took part in the following activities:

1) AFM characterization of novel materials,
2) Training at Plasma etching system,
3) Preparation of project proposal for bilateral scientific collaboration between Serbia and Greece.

AFM training has been performed under supervision of Dr Christos Tsamis, Director of Research and in collaboration with researchers working in his team, Dr Eleni Makarona, Post-doctoral Scientist, and PhD candidate Giorgos Niarchos. Dr Makarona was the 2010 recipient of the Greek L’Oreal-Unesco Award for Young Women in Science (Materials Sciences).

Training at plasma etching equipment was performed under supervision of Dr Angeliki Tserepi, Senior Researcher, and in collaboration with researchers working in her team BSc EE Angelos Zeniou, Plasma Etch Engineer, and PhD candidate Antonia Malainou.

Report on Two Months Specialized Training at Laboratory of Nanostructured & Complex Matter - LPMC EPFL-SB-ICMP-LPMC Lausanne, Switzerland

2D(3D) Finite Element Method based simulation of the random Brownian motion of a spherical particle in water

Dr Katarina Radulović, Senior Research Associate
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Supervisor: Prof. Dr. László Forró

A spherical silica particle in water is subjected to random thermal force. The object of the problem is to determine 2D(3D) trajectory, and mean square displacement (MSD) of the particle. Also, the influence of both symmetric and asymmetric optical trap on the particle movement is considered. The problem is modeled and simulated in commercial software ANSYS 12.1-Mechanical APDL.

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Report on Two Months Specialized Training at Ecole Polytechnique Federale de Lausanne (EPFL), Institute of Microelectronic Technologies (IMT) Microsystems Laboratory 1 (LMIS1) Lausanne, Switzerland

Characterization of Au microstructures fabricated using stencil lithography and intended for flexible electronics

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Ivana Jokić, Dipl. Ing. E. E., ijokic@nanosys.ihtm.bg.ac.rs

Supervisor: Prof. Dr. Jürgen Brugger

The group of Professor Brugger is dedicated to research in the field of micro/nanofabrication. Current topics include stencil litography and ink jet printing. Apart from other applications of stencil lithography, the group uses this technique for fabrication of flexible micro/nanoelectronic components based on organic materials, e.g. thin film transistors and conductive patterns on flexible substrates. The goal is to enable fabrication of flexible electronic building blocks suitable for application in implants and mobile devices.
After a brief introduction into the field of stencil lithography and after fabrication of structures using this technique in a cleanroom, the two researchers performed characterization of both mechanical and electrical parameters of thin film conductors fabricated by evaporation of gold on a flexible polyimide substrate. The change in electrical resistance was investigated before and after subjecting the sample to a varying intensity of tensile stress and to an increasing number of tensile stress cycles. A scanning electron microscope is utilized for analysis of degradation of thin film golden conductors due to the tensile stress of the flexible substrate.

Report on Two Months Specialized Training at Laboratory for Bio- and Nano- Instrumentation (LBNI) EPFL-School of Engineering-Institute of Bioengineering –Ibni Lausanne, Switzerland

Design and fabrication of a digitally controlled high speed Analog PID controller for high speed atomic force microscopy

MSc Maja Djukić, maja.djukic@nanosys.ihtm.bg.ac.rs

Supervisor: Prof. Georg E. Fantner

One of LBNIs core interest and core technology is time resolved atomic force microscopy (AFM) imaging of biological processes. For this purpose, specialized AFMs, cantilevers, controllers and protocols were developed.

Bandwidth of the AFM Proportional-Integral- Derivative (PID) controller is one of the limiting factors in time resolved AFM, where higher bandwidths enable fast collecting of sample images and higher resolution. In order to improve image quality, high speed digitally controlled PID controller was developed and tested both in FPGA and custom analog design.

Report on Two Months Specialized Training at Delft Institute of Microsystems and Nanoelectronics (DIMES) Delft University of Technology (TU Delft) Delft, The Netherlands

Unique DIMES TU "Hands-on" Training Course for well-eqipped Micro/Nano Cleanrooms

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Supervisor/Main trainer: Silvana Milosavljević
Safety trainer: Charles de Boer
Module trainers: Johan van der Cingel (AFM, ellipsometry), Luigi Mele (bonding), Mario Laros (SEM)

This course is created for the PhD students and researchers; it helps them to get, not only the basic process and equipment skills needed for Si fabrication, but also emphasizes the procedures necessary for selfguarding the cleanroom quality for all other users. The program educated students to think actively, creatively and responsibly with respect to potentials and restriction of the cleanroom environment thus preparing them for future challenges to be faced in the real engineering world.

The training program is nominally 8-week program covering all parts of the basic manufacturing process and is divided into 3 main parts: an initial two-day safety course, 4-week educational course and 4-week diploma course where students independently process an IC run.

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