National Centre for Scientific Research:
NSCR "Demokritos"

imel
NCSR Demokritos
Institute of Microelectronics

Annual Report 2007

Aghia Paraskevi, Athens, Greece
www.imel.demokritos.gr

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PREFACE

IMEL (Institute of Microelectronics) was established in 1986 as one of the eight Research Institutes of NCSR (National Center for Scientific Research) "Demokritos", a medium size, multidisciplinary Research Center under the General Secretariat for Research and Technology of the Ministry of Development.

Today IMEL is established as the National Center of Excellence in Micro- and Nanofabrication, Nanoelectronics and MEMs. IMEL has developed experience and expertise, as well as unique technological advantages, which place it among the main EU Research Institutes in the field of Silicon technologies.

The strong advantages of IMEL are as follows:

- Its excellent staff, composed of a small number of experienced senior scientists, surrounded by a large number of young researchers, all fully devoted to their work
- Research facilities for silicon processing, micro and nanofabrication, characterization, testing, design, modeling and simulation of materials, structures, devices and systems, which are unique in Greece
- Important expertise and know-how, as well as important proprietary technologies, materials and devices. IMEL's intellectual property (IP) portfolio continues to expand and opens important possibilities for collaboration with industry and transfer of know how

Research at IMEL is carried out at the EU level through its participation in European research projects, networks of excellence and technology platforms. EU projects cover a number of specific priorities of the EU Research Framework Programme, including mainly Information and Communication Technologies (ICT), Nanotechnology, Materials and Production Processes (NMP), Energy, Health and Environment. IMEL's success in the above peer reviewed R&D funded programmes represents one of the strongest endorsements of IMEL's R&D competence and reflects the world-class standing of the Institute.

On the national level the expertise and infrastructure of IMEL are unique in Greece, which makes its role also unique in developing novel technologies, in transfering technology and know-how to the industry and in developing human potential. Furthermore, IMEL has developed mechanisms to promote the field at the national level through the establishment and coordination of thematic networks and scientific societies (MMN Network, Micro & Nano scientific society).

IMEL is a member of the European Academic and Scientific Association for Nanoelectronics (AENEAS-ENIAC) that aims at promoting scientific collaborations with industry and providing skills and expertise for the execution of common projects, studies, as well as education and training in Nanoelectronics. IMEL is also a partner of the "Beyond Moore" Initiative within the technology platform ENIAC for Nanoelectronics.

The year 2007 was a very important year for IMEL. The construction of a new building has been completed and important new equipment has been installed in it, including a new FEG SEM (JEOL JSM-7401F), a Veeco AFM (CPII), several electrical characterization workstations for dc and RF measurements, optical characterization equipment etc. Both the processing laboratory and the electrical characterization facilities were certified under ISO 9001. Within the EU ICT I3 project ANNA contract No 026134, IMEL provides access to its infrastructure for Si processing and electrical/optical characterization of materials, devices and structures to researchers from all around Europe.

In the year 2007, the European Institute of Nanoelectronics named SINANO has also been established, with IMEL as one of its 16 founding members.

In this annual report, the research and education activities and research output of IMEL are presented. I would like to acknowledge all those who contributed to a successful year, namely researchers, research engineers, PhD and post-doctoral students, and technical and administrative staff of the Institute. Acknowledgement is also due to the President, members of the Board of Management and technical and administrative staff of NCSR Demokritos for their support.

Dr A. G. Nassiopoulou
Director of IMEL
Member of the Board of Management
of NCSR Demokritos

IMEL at a glance

IMEL is one of the eight research Institutes of the multidisciplinary research center "NCSR Demokritos" in Aghia Paraskevi, a suburb situated 10 kilometers from the center of Athens.

Main Objectives of IMEL

The main objectives of IMEL are as follows:

- Long-term research into understanding phenomena, mastering processes and developing research tools.
- Development of fundamental knowledge
- Development of novel high added-value technology products and production processes
- Development of human potential by education and training activities
- Services in advanced technology
- Transfer of technology and know-how

The objectives of IMEL are in line with the government policy to promote excellence in research, high technology development and innovation at Research Institutes and to promote collaboration between academia and industry.

Due to the infrastructure available at IMEL for silicon processing and micro- nanofabrication, electronics and sensors, and the existing expertise and know-how developed, the role of the Institute is significant in contributing to increase the technological level of the country and to spread the knowledge through collaboration with Academia in research and education activities.

Research orientation

IMEL is mainly devoted to silicon technologies and their diverse applications in information processing, storage, transmission systems and telecommunications, environmental systems, medicine, healthcare, food industry etc.
Research Activities at IMEL are structured in 3 programmes, each one being composed of smaller projects as follows:

A. MICRO AND NANOFABRICATION
- ➢ Lithographic Polymers and Processes
- ➢ Plasma Processing and Simulation for Micro and Nano Patterning
- ➢ Front-end Processes for Micro and Nanodevices
- ➢ Thin Films by physical and chemical deposition

B. NANOSTRUCTURES and NANOELECTRONIC DEVICES
- ➢ Nanostructures for Nanoelectronics, Photonics and Sensors
- ➢ Materials and Devices for Memory Applications
- ➢ Molecular Materials as Components of Electronic Devices

C. SENSORS and MEMS
- ➢ Porous Silicon Technology for Sensors and on-chip Integration
- ➢ Mechanical & Chemical Sensors
- ➢ Bio-microsystems
- ➢ Thin Film Devices for Large Area Electronics
- ➢ Energy harvesting materials and devices
- ➢ Circuits and Devices for Optoelectronic Interconnections

Education and Training at IMEL

Due to its unique infrastructure at a national level and the important expertise and know-how of its researchers, IMEL plays an important role in post-graduate education. It participates very actively in the following educational programmes, in collaboration with Greek universities, by providing special courses and laboratory training:

1. Post-graduate program in "Microelectronics" in collaboration with the University of Athens (for MSc and PhD degrees)
2. Master program in "Microsystems and Nanoelectronic devices" in collaboration with the National Technical University of Athens
3. Post-graduate program in "Nanosciences and Nanotechnologies" in collaboration with the University of Thessaloniki (for MSc and PhD degrees)

Laboratories and Central Fabrication Facilities at IMEL

The facilities and equipment of IMEL include a full silicon processing laboratory in a clean room area, complemented by characterization laboratories (electrical, optical, structural), micromachining and packaging equipment, resist development laboratory, as well as testing facilities and design, modeling and simulation tools. The clear room is equipped with lithography (optical, e- beam) and etching tools, thermal and chemical processing, ion implantation, deposition of metals, dielectrics and poly-nanocrystalline silicon by physical and chemical processes (LPCVD, sputtering, e-gun and thermal evaporation), and process inspection equipment.

Electrical characterization equipment

FEG SEM JEOL JSM-7401F


RF probe station


Lithography and etching area


Lithography equipment


High density plasma etcher

Management

The management of the Institute is assured by its Director, who is elected by an International Scientific Committee for 5 years, assisted by a Deputy Director and an Institute Advisory Board, elected every 2 years by the Researchers. The Director represents the Institute in the Board of management of the Centre, and is responsible for the overall functioning of the Institute. An external International Scientific Advisory Committee operates at IMEL from the year 2000, which discusses with the director and the scientific staff the Institute research priorities and policy.
A scientist is in charge of the processing laboratory, which is a central facility used by all scientific groups.

Personnel

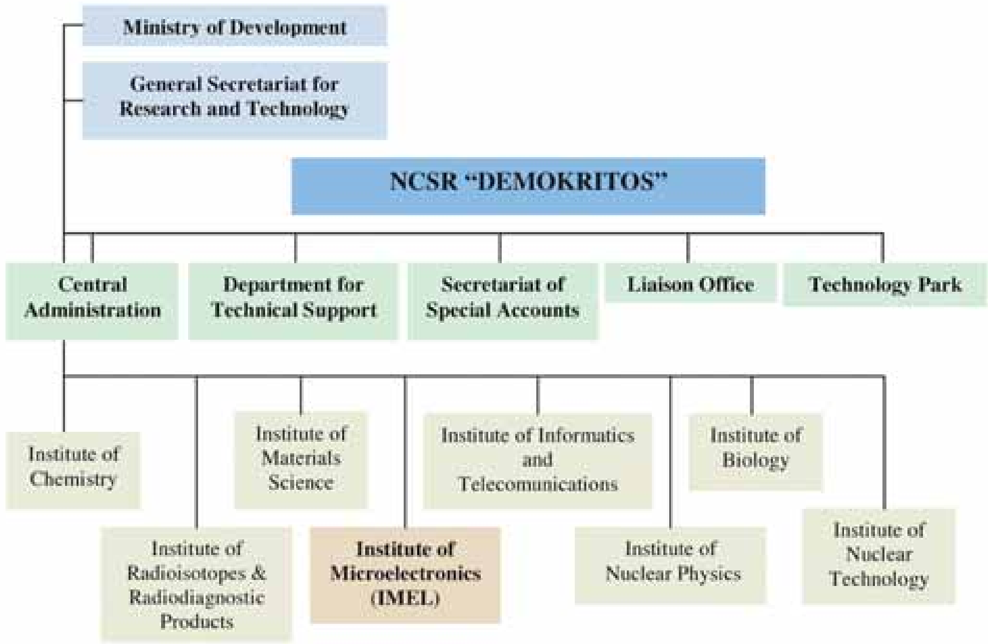
The personnel of IMEL includes 15 key researchers and several post-doctoral scientists and PhD students. It also includes a group of technicians that operate the central fabrication facility (details in annex I).


Scientific staff

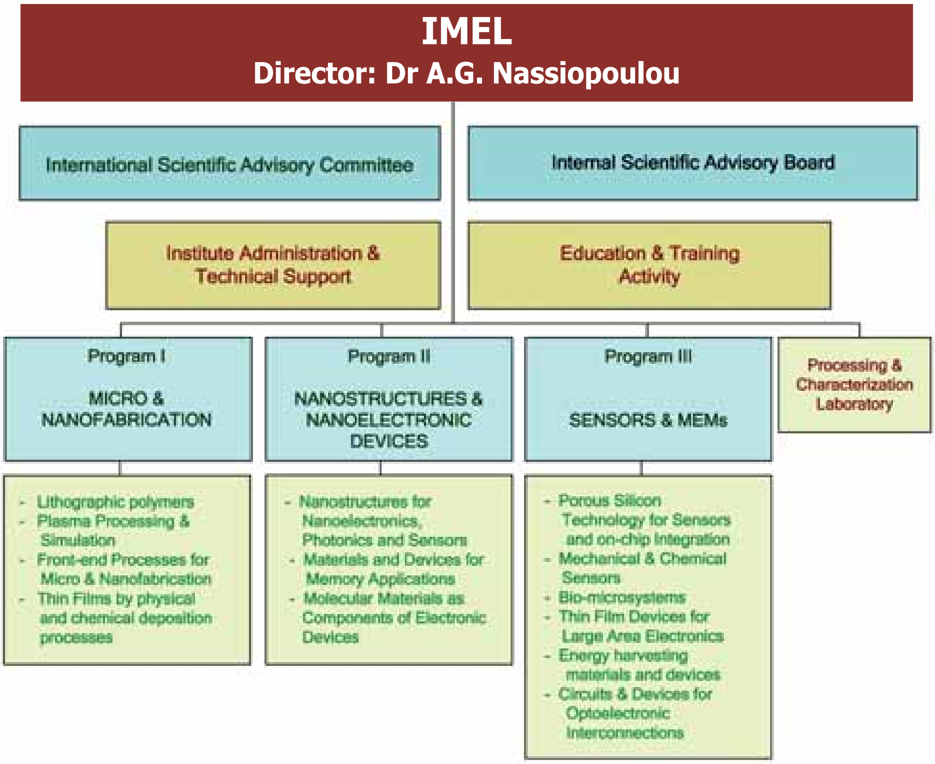

Personnel of IMEL

ORGANIZATIONAL STRUCTURE

Organizational structure of NCSR Demokritos



Organizational structure of IMEL



RESEARCH PROJECTS

FUNCTIONAL MOLECULAR MATERIALS FOR LITHOGRAPHY AND ORGANIC/MOLECULAR ELECTRONICS

Project Leader: P. Argitis

Key Researchers: P. Argitis, I. Raptis

Permanent research staff: A. Douvas, M. Vasilopoulou

Post-doctoral Research Associates: M. Chatzichristidi, L. Palilis, G. Patsis

Ph.D. candidates: D. Drygiannakis, D. Georgiadou, T. Manouras, P. Pavli, N. Tsikrikas

MSc and undergraduate students: A. Botsialas, A. Kapela

Collaborating researchers from other IMEL groups: D. Davazoglou, N. Glezos, E. Gogolides, K. Misiakos, P. Normand

External Collaborators: N. Stathopoulos (TEI Piraeus), G. Pistolis, E.A. Couladouros, V.P. Vidali, (IPC-NCSRD), P.S. Petrou, S.E. Kakabakos, (IRRP-NCSRD), A. Gerardino (IFN-CNR, Italy), I. Rajta (Atomki, Hungary), F. Watt, J. Van Kan (CIBA-NUS, Singapore), S. Tedesco, C. Vanuffel (LETI)

<u>**Research orientation:**</u>

a. Development of Resists for low LER ithography - Optimization of Resist materials and Patterning Processes

Development of resists with potential low Line Edge Roughness (LER) capable for sub-32 nm patterning. Current activities include "molecular" resists, resist based on polymer back-bone breaking and simulation studies for supporting material and process optimization.

b. Lithographic materials for new (unconventional) micro-nano structure fabrication processes

Investigation of material issues for novel radiation-assisted patterning processes, including formation of 3D structures and patterning of biological systems.

c. Materials for organic/molecular electronics

Materials research and device architecture studies for molecular/organic electronics. Current activities include materials for molecular memories, organic light emitting diodes (OLEDs), photovoltaics and new optoelectronic devices.

<u>**Funding**</u>

- **More Moore**, EU FP6 Integrated Project (IST), 2004-2007
- **Nano2Life**, EU FP6 Network of Excellence (NMP), 2004-2008
- **GSRT-PENED 03ED276**, "Critical sub-100nm Industrial scale Patterns for CMOS - NANO Architectures, (CMOS-NANO), 2005-2008
- **GSRT-NON-EU 467**, "Proton Beam NANOlithography for high aspect ratio structures of optical COMPonents" (PB.NANOCOMP), 2006-2008

EXAMPLES OF RESEARCH RESULTS IN 2007

A. Development of Resists for low LER ithography - Optimization of Resist materials and Patterning Processes

Low LER lithography with polycarbocycle – based molecular resist

The new resist family, based on functionalized anthracenes and other polycarbocycles, which has been introduced by our group and Prof. E. Couladouros group at the Inst. of Physical Chemistry, has been proved to be capable for low LER, sub 32 nm lithography, as shown in Fig.1. Evaluation has been carried out in collaboration with LETI - France and Paul Sherrer Institute-Switzerland). The research continues towards performance mprovement through both material and process optimization. The emphasis is given on sensitivity enhancement.

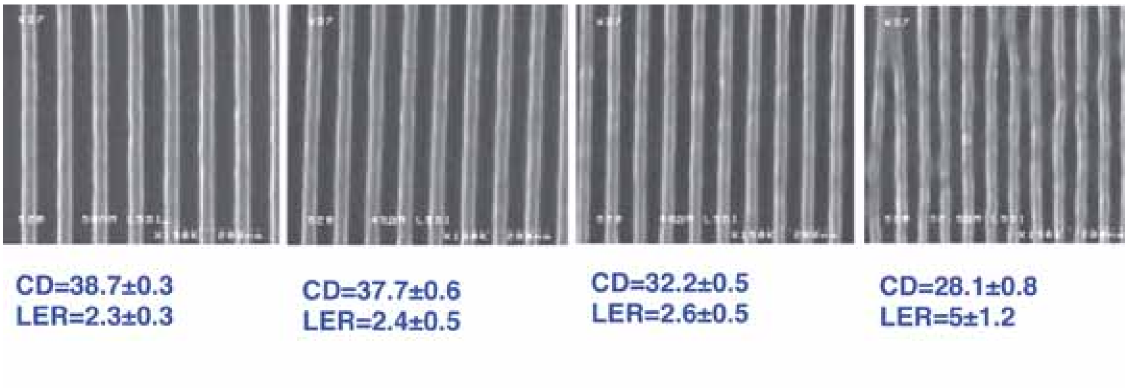


Fig. 1: Low LER sub-40nm lithography with polycarbocycle-based molecular resist (M17)

Stochastic simulation studies of molecular resists

The influence of resist material and its architecture becomes very high in the sub-45nm patterning scales in parameters like critical dimension and line-edge roughness (LER). Molecular resist exhibited very low LER compared with polymer chains of the same overall radius of gyration. Two positive molecular resist architecture, (their digital representation is shown in Fig.2), are modeled with our stochastic lithography simulator in order to predict their LER behavior. The architecture and conformations of the overall molecule followed the modeling of a randomly grafted chain and each part of it could be a different chemical group, modeling the different properties of the molecular resist. This algorithmic representation improvement resulted in very compact molecular resist film lattices with very low free volume (5 – 10% depending on the molecular architecture in 2D and even less than 5% in 3D lattices. For M21 molecules with 0.2nm/cell, 20%PAG concentration and 0.6nm diffusion length, the resulting values for a 50nm trench were LER (3σ) ≈ 0.51 nm and LWR (3σ) ≈ 0.69 nm. Another molecule, M17 of approximately the same size with M21, under the same condition of simulated processing lithography resulted in LER (3σ) ≈ 0.60 nm and LWR (3σ) ≈ 0.75 nm. The values are very promising and recent experimental data verified the low LER/LWR values of these materials.Fig.3, shows a 32nm design rule CMOS inverter gate fabrication-modeling using M17.

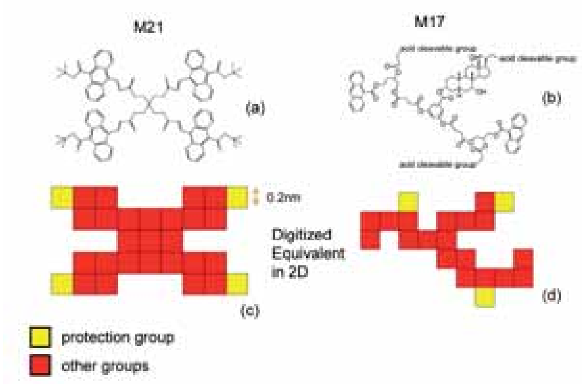


Fig. 2: The digital representation of the molecular resists was based on decomposing the material in terms of its molecular groups and their functionality and then digitizing it geometrically as tiles of size equal to the minimum chemical group size.

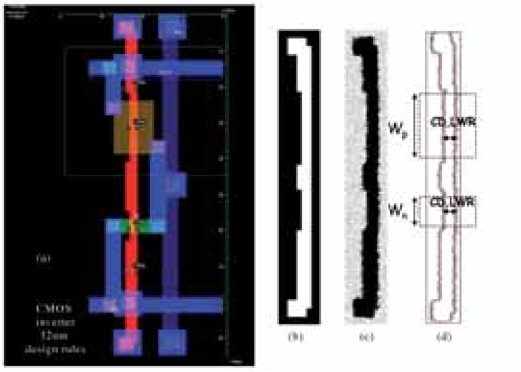


Fig. 3: Application of stochastic simulation on the design of 32nm CMOS inverter. (a) Layout design, (b) gate mask, (c) resist profile after lithography simulation, (e) etching of gate and metrology.

Electron-beam simulation over multilayer substrates

Extreme ultra-violet lithography (EUVL) mask is a complex multilayer stack, fabricated with electron-beam lithography. Detailed understanding of the scattering events and energy loss mechanism of the electron beam within this stack is mandatory due to the high accuracy requirements of the fabrication process. Simulation of electron-beam lithography is performed incorporating the details of the mask material-stack and the metrological information of the final layout is quantified. Three-dimensional modeling of the electron beam interactions inside the material stack is considered. The deposited energy calculation takes into account the location in the multilayer stack (fig. 4) where scatterings took place, the material properties (e.g., density, atomic number), and the type of scattering (elastic or inelastic). The energy deposition follows the Monte Carlo procedure of Salvat and Parellada. Hiroguchi's et al. method was incorporated in order to correctly determine the mean free path of electron track due to multi-layer presence in the Mo/Si structure. The stack model consists of 150nm PMMA resist over a film stack of 40 Mo/Si layers (thicknesses: 4 nm Si, 3 nm Mo) on top of bulk Si. Initial electron energies of 100keV is assumed. In Fig. 5 experimental results from high resolution patterns exposed on EUVL mask blanks are compared with the simulation ones and the agreement isgood.

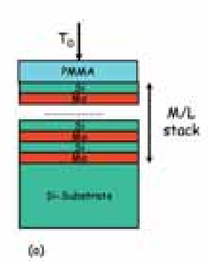


Fig. 4:
(a) Stack model.

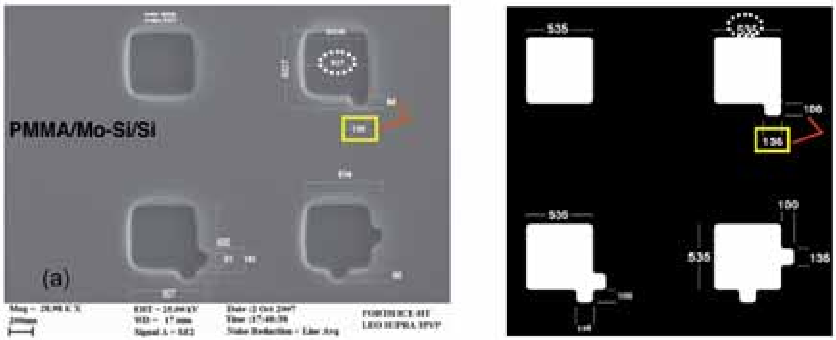


Fig. 5: (a) Metrology on the experimental SEM image. (b) Corresponding metrology on the simulated data.

Resists based on backbone breaking with acceptable etch resistance

Backbone breaking could ultimately lead to both low LER and improved sensitivity in sub50 nm lithography. Unfortunately the typical resists working by backbone breaking chemistry (e.g. PMMA) typically suffer from poor etch resistance, since they decompose easily in the reactive plasmas used in etching. A recent direction of our research targets to overcome this problem by using radiation-stable polyacetals that can only break through acid-catalysed chain scission. A polymer that has shown promising results is depicted in Fig. 6, where the acid catayzed back bone chain scission is depicted. In Fig. 7, monitoring with FTIR spectroscopy provides clear evidence that the chain scission takes place under heating in presence of H+ (Posrt Exposure Bake step) but not during exposure.

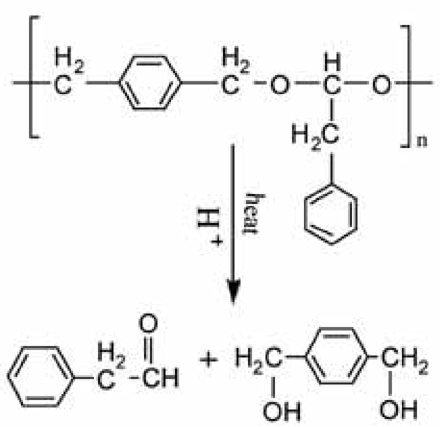


Fig. 6: Acid catalysed breaking of Poly(1,4 Phenylacetone benzyl acetal)

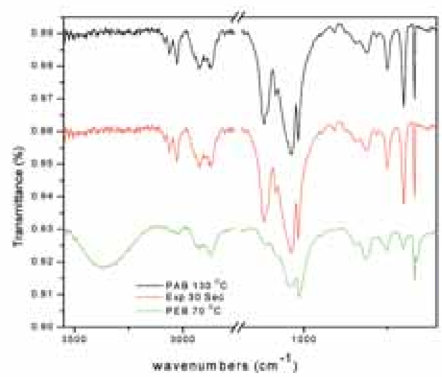


Fig. 7: FTIR monitoring during the lithographic process, revealing the critical for the scission reaction step.

B. Lithographic materials for micro-nano structure fabrication processes to be applied in MEMs and Nano-biotechnology

High aspect ratio proton beam writing

Proton Beam Writing (PBW) is a valuable tool for maskless patterning of high aspect ratio structures due to the unique ability of protons to maintain a straight path over long distances. TADEP (Thick Aqueous Developable Epoxy) resist is a new promising high-aspect-ratio chemically-amplified resist, developed by our group, which can be developed in aqueous base developer and has the capability of stripping by using conventional stripping schemes. From experimental point of view, the performance of PBW was explored and proved through the patterning of an aqueous base developable negative chemically amplified resist (TADEP). By employing PBW on TADEP resist a 280nm linewidth with a thickness of 12 μm has been resolved showing an aspect ratio of 42 which is the highest aspect ratio even fabricated on strippable resists with deep sub-micron resolution.

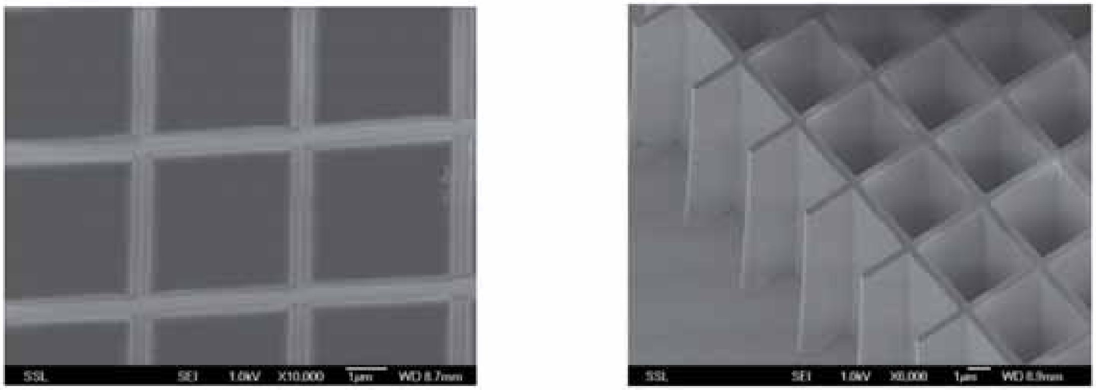


Fig. 8: SEM images of PBW double line irradiation on TADEP resist. Film thickness 12μm, line width 280nm in X-direction, aspect ratio: 42. a) Top view and b) side view (tilt 20°).

Surface functionalization for biological patterning

Towards the further development of resist – based biocompatible processes for the patterning of biological substances a research effort aiming at the investigations of the interactions of organic film coated substrates with biological substances has been launched. Emphasis has been given on the chemical binding of small biomolecules, like biotin, on patterned polymeric films. Epoxy resist (EPR) surfaces have been proved suitable for the binding of biotin if properly functionalized with either amine or NHS ester groups. The binding capability on unexposed and exposed at different doses EPR films is depicted in Fig. 9, whereas the correspondence of the different doses at a photoresist contrast curve is presented in Fig. 10.

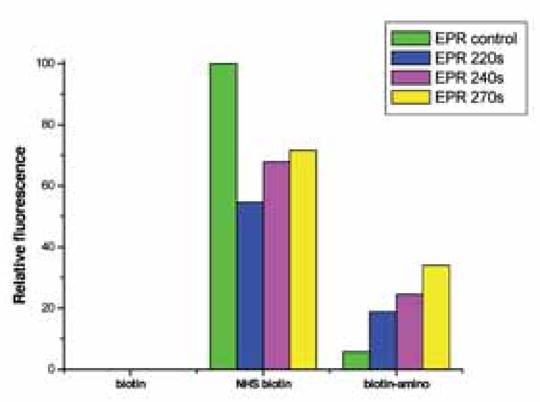


Fig. 9: Fluoresence measurements for the assessment of the chemical binding capability of epoxy resist surfaces. Unfunctionalized biotin cannot be bound but functionalization, especially with NHS ester, allows effective binding.

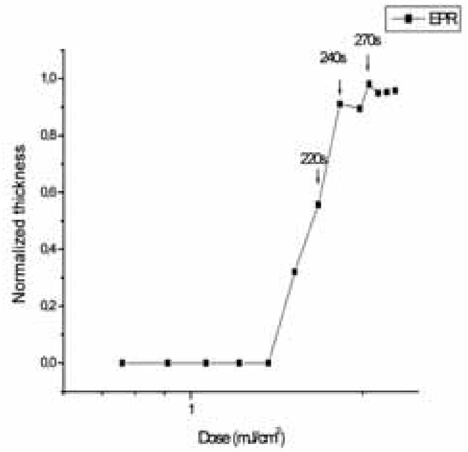


Fig. 10: Contrast curve of EPR resist showing that the exposure doses used in the biotin binding experiments are adequate for lithographic patterning.

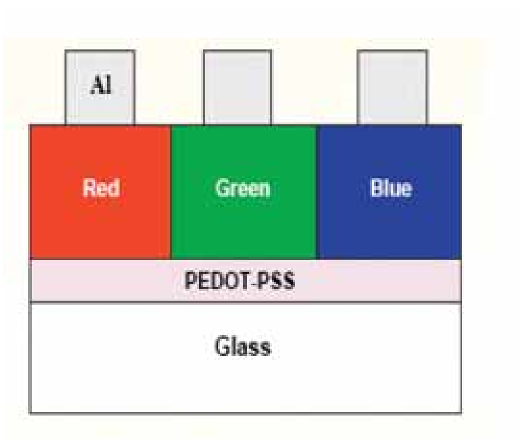
C. Materials for organic/molecular electronics

Polyoxometallates as potential molecular components of electronic devices

Polyoxometallates of Mo and W are investigated as potential molecular components of electrtronic devices and in particular memory devices. The relevant activity is carried out in collaboration with Project II.3 (leader N. Glezos) and the results are reported in the corresponding section.

Tuning the emitting colour of OLEDs

Using the proposed by our group patterning scheme of acid induced spectral changes in the active layer of OLEDs three colour (blue-red-green) pixels can be defined in the same polymer layer (see Fig. 11). The optimization of device structure (mainly the active layer thickness) is necessary for the enhancement of external efficiency and for the electroluminescence spectral distribution to follow a Lambertian pattern. Towards this end simulation (Fig. 12) and experimental work is being carried out.



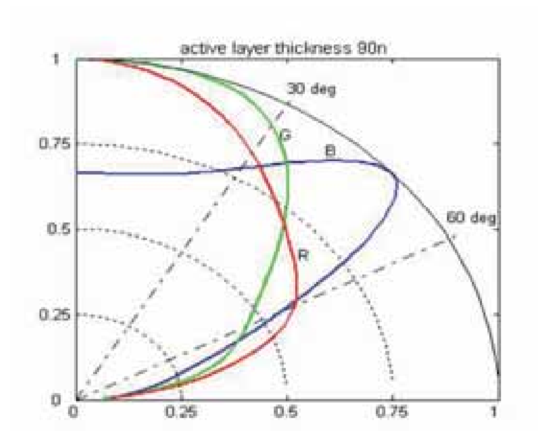


Fig. 11: Schematic of device structure (Glass/ITO/PEDOT:PSS/Active Emitting Layer (based on PVK dye-doped films)/Al)

Fig. 12: Simulated radiation pattern for three wavelengths 420, 520 and 620 nm (corresponding to the blue, green and red color pixel, respectively) for an active layer thickness of 90 nm

Photovoltaics – new organic optoelectronic devices

Research on organic/hybrid photovoltaics has been launched during 2007. Polythiophene/functionalized fullerene bulk heterojunction photovoltaic cells have been fabricated and characterized. Molecular redox active layers, like polyoxometalate-based layers, have been investigated as potential optical spacers and oxygen/water protective layers. In addition new organic optolectronic devices, such as a polymer optocoupler (Fig. 13), have been designed, fabricated and characterized as a first step towards all-plastic electronic devices.

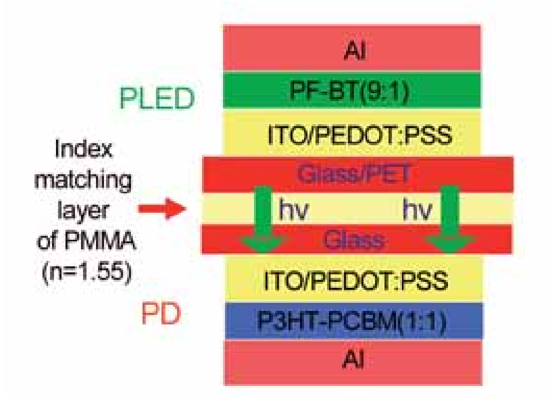


Fig. 13: Structure of a polymer optocoupler device

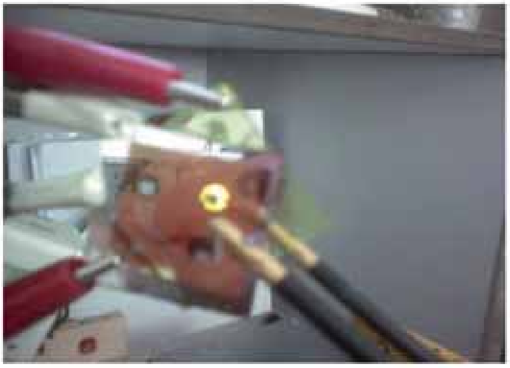


Fig. 14: Photograph of the device in operation

PROJECT OUTPUT IN 2007

Publications in International Journals

1 "A biomolecule friendly photolithographic process for fabrication of protein microarrays on polymeric films coated on silicon chips", P.S. Petrou, M. Chatzichristidi, A. M. Douvas, P. Argitis, K. Misiakos and S.E. Kakabakos, Biosensors and Bioelectronics, 22, 1994-2002, 2007.
2. "Stochastic simulation studies of molecular resists", D.Drygiannakis, G.P.Patsis, I.Raptis, D.Niakoula, V.Vidali, E.Couladouros, P.Argitis, E.Gogolides, Microelectron. Eng. 84 1062, 2007
3. "Effect of magnetic-field on metal-insulator transitions in Bi wire structures", M.Chatzichristidi, Th.Speliotis, I.Raptis, I.Haritantis, D.Niarchos, C.Christides, Microelectron. Eng. 84, 1528, 2007
4. "Proton beam micromachined buried microchannels in negative tone resist materials", I.Rajta, M.Chatzichristidi, E.Baradàcs, C.Cserhàti, I.Raptis, K.Manoli, E.S.Valamontes, Nucl. Instrum. Meth. B 260, 414, 2007
5. "Process simulation at electron beam lithography on different substrates", K.Vutova, G.Mladenov, I.Raptis, A.Olziersky, J. Mater. Process. Tech. 184 305, 2007
6. "Pattern matching, simulation and metrology of complex layouts fabricated by electron beam lithography", N.Tsikrikas, D.Drygiannakis, G.P.Patsis, I.Raptis, A.Gerardino, S.Stavroulakis, E.Voyiatzis, J. Vac. Sci. Technol. B 25, 2307, 2007
7. "Stochastic simulation of material and process effects on the patterning of complex layouts", N.Tsikrikas, D.Drygiannakis, G.P.Patsis, I.Raptis, S.Stavroulakis, E.Voyiatzis, Jpn. J. Appl. Phys. B 46, 6191, 2007
8. "Nano-scale spatial control over surface morphology of biocompatible fluoropolymers at 157 nm", E. Sarantopoulou, Z. Kollia, A. C. Cefalas, A.M. Douvas, M. Chatzichristidi, P. Argitis, S. Kobe, Materials Science and Engineering: C, Vol. 27, 1191-1196, 2007.
9. "Polymer self-assembled nano-structures and surface relief gratings induced with laser at 157 nm", E. Sarantopoulou, Z. Kollia, A.C. Cefalas, A.M. Douvas, M. Chatzichristidi, P. Argitis and S. Kobe, Appl. Surf. Science, 253, 7884-7889, 2007.
10. "Tuning the emitting colour of Organic Light Emitting Diodes through photochemically induced transformations: towards single layer, patterned, full colour displays and white lighting applications", M. Vasilopoulou, G. Pistolis, D. Georgiadou, P. Argitis, Adv. Funct. Mater., 17 (17), 3477-3485, 2007

Publications in international Conference Proceedings

1. "Exposure of molecular glass resist by e-beam and EUVIL", Cyril Vannuffel, Damien Djian, Serge Tedesco, Dimitra Niakoula, Panagiotis Argitis, Veroniki P. Vidali, Elias Couladouros, and Harun Solak, Proc. SPIE 6519, 651949, 2007.
2. "Stochastic simulation of material and process effects on the patterning of complex layouts with e-beam and EUV lithography", D.Drygiannakis, N.Tsikrikas, G.P.Patsis, G.Kokkoris, I.Raptis, E.Gogolides, SPIE Advanced Lithography conf. (Jan Jose, USA, 02/2007)
3. "Simulation of the combined effects of polymer size, acid diffusion length and EUV secondary electron blur on resist line-edge roughness", D.Drygianakis, M.D.Nijkerk, G.P.Patsis, G.Kokkoris, I.Raptis, L.H.A.Leunissen, E.Gogolides, SPIE Advanced Lithography conf. (Jan Jose, USA, 02/2007)
4. "Patterning scheme based on photoacid induced spectral changes for single layer, patterned full color light emitting diodes, in Organic Electronics-Materials, Devices and Applications", M. Vasilopoulou, G.Pistolis, A. Botsialas, N. Stathopoulos, M.Rangoussi, P. Argitis, edited by F. So, G.B. Blanchet, Y. Ohmori, Mater. Res. Soc. Symp. Proc. 965E, Warrendale, PA, 2007, no 0965-S03-24.
5. "Photolithographic Process Based on High Contrast Acrylate Photoresist for Multi-Protein Patterning, in Biosurfaces and Biointerfaces", M. Chatzichristidi, P. S. Petrou, A. M. Douvas, C. D. Diakoumakos, I. Raptis, K. Misiakos, S. S. Kakabakos, P. Argitis, edited by M. Firestone, J. Schmidt, N. Malmstadt, Mater. Res. Soc. Symp. Proc. 950E, Warrendale, PA, 2007, paper no 0950-D15-15.

Invited talks in international Conferences

1. "High-aspect-ratio micro/nanomachining with proton beam writing on aqueous developable - easily stripped negative chemically amplified resists", M. Chatzichristidi, E.Valamontes, N.Tsikrikas, P. Argitis, I. Raptis , J.A. Van Kan, F. Watt, 33rd International Conference on Micro- and Nano-Engineering (MNE), Copenhagen, Denmark, September 23-26, 2007.
2. "Polymeric and molecular glass resist models for stochastic lithography simulation", D.Drygiannakis, G.P.Patsis, I.Raptis, E.Gogolides, 5th IISB Litho workshop, Hersbruck, Germany 09/2007.

Presentations in International Conferences

1. Electrochemical detection of biomolecules patterned on electrode arrays by biocompatible photolithography", Mònica Mir, Srujan Kumar Dondapati, Maria Viviana Duarte, Ioanis Katakis, Margarita Chatzichristidi, Konstantinos Misiakos, P.S. Petrou, S.E. Kakabakos, Panagiotis Argitis, Materials Research Society (MRS) Fall Meeting, Boston, MA, USA, November 27-30 2007.
2. "Charging Effects in Hybrid Structures Based on Polyoxometalate Layers for Molecular Memory Applications", E. Makarona, A. M. Douvas, E. Kapatanakis, D. Velessiotis, P. Argitis, P. Normand, N. Glezos, J. Mielczarski, E. Mielczarski, T. Gotszalk, W. Miroslav, Materials Research Society (MRS) Fall Meeting, Boston, MA, USA, November 27-30 2007.
3. "Magnetotransport properties of [Co/Bi]n wire structures", C.Christides, Th.Speliotis, M.Chatzichristidi, I.Raptis, 18th Soft Magnetic Materials Conf., Cardiff, UK, 09/2007
4. "Electron Beam Lithography Simulation for the Patterning of EUV Masks", N.Tsikrikas, G.P.Patsis, E.Valamontes, I.Raptis, A.Gerardino, Microprocess & Nanotechnology Conf. (MNC 07), Kyoto, Japan, 11/2007
5. "Realization and simulation of high aspect ratio micro/nano structures by proton beam writing", M.Chatzichristidi, E.Valamontes, I.Raptis, J.A.vanKan, F.Watt, Microprocess & Nanotechnology Conf. (MNC 07), Kyoto, Japan, 11/2007

6. "Vertical architectures of self-assembled hybrid organic/inorganic monolayers based on tungsten polyoxometalates: a step towards molecular electronic devices", E. Makarona, E. Kapetanakis, D. Velessiotis, A. Douvas, P. Argitis, P. Normand, T. Gotszalk, M. Woszczyna, N. Glezos, 33rd International Conference on Micro- and Nano-Engineering (MNE), Copenhagen, Denmark, September 23-26, 2007.
7. "Evaluation of polymers containing ketal or acetal groups in the backbone as candidate photoresist components", T. Manouras, A. M. Douvas, V.P. Vidali, M. Chatzichristidi, N. Vourdas, E. Gogolides, E.A. Couladouros, P. Argitis, 3rd International Conference on Micro-Nanoelectronics, Nanotechnology & MEMs (Micro&Nano), Athens, Greece, November 18-21, 2007.
8. "Photoresist material and process optimization for the patterning of biomolecules on functionalized surfaces", P. Pavli, M. Chatzichristidi, A. M. Douvas, P. S. Petrou, S. E. Kakabakos, D. Dimotikali, P. Argitis, 3rd International Conference on Micro-Nanoelectronics, Nanotechnology & MEMs (Micro&Nano), Athens, Greece, November 18-21, 2007.
9. "Polyoxometalate-based multilayers: fabrication and electrical characterization", A.M. Douvas, E. Makarona, D. Velassiotis, J.A. Mielczarski, E. Mielczarski, N. Glezos, P. Argitis, 3rd Internat. Conf. on Micro-Nanoelectronics, Nanotechnology & MEMs (Micro&Nano), Athens, Greece, Nov. 18-21, 2007.
10. "VUV laser circular microstructured surface relief gratings induced on PTFEMA surface", E. Sarantopoulou, Z. Kollia, A. C. Cefalas, A. M. Douvas, M. Chatzichristidi, P. Argitis, 3rd International Conference on Micro-Nanoelectronics, Nanotechnology & MEMs (Micro&Nano), Athens, Greece, November 18-21, 2007.
11. "Hybrid polymer-inorganic solar cells based on polythiophene and phthalocyanine/polyoxometalate blends", L. C. Palilis, A. M. Douvas, G. Chaidigiannos, M. Vasilopoulou, N. Glezos, S. Nespurek, P. Falaras, P. Argitis, 3rd International Conference on Micro-Nanoelectronics, Nanotechnology & MEMs (Micro&Nano), Athens, Greece, November 18-21, 2007.
12. "Flexible WO3 based electrochromic displays using proton conducting solid electrolytes", M. Vasilopoulou, P. Argitis, G. Aspiotis, G. Papadimitropoulos and D. Davazoglou, 3rd International Conference on Micro-Nanoelectronics, Nanotechnology & MEMs (Micro&Nano), Athens, Greece, November 18-21, 2007.M. Vasilopoulou,
13. "Flexible Organic Light Emitting Diodes (OLEDs) based on blue emitting polymers", L. C. Palilis, A. Botsialas, D. Georgiadou, P. Bayiati, N. Vourdas, P. S. Petrou, G. Pistolis, N. Stathopoulos, and P. Argitis, 3rd International Conference on Micro-Nanoelectronics, Nanotechnology & MEMs (Micro&Nano), Athens, Greece, November 18-21, 2007.
14. "Energy transfer processes among emitters dispersed in a single polymer layer for colour tuning in OLEDs", D. Georgiadou, M. Vasilopoulou, G. Pistolis, D. Dimotikali and P. Argitis, 3rd International Conference on Micro-Nanoelectronics, Nanotechnology & MEMs (Micro&Nano), Athens, Greece, November 18-21, 2007.
15. "All-organic optocouplers based on polymer light-emitting diodes and photodetectors", N. Stathopoulos, L. C. Palilis, M. Vasilopoulou, A. Botsialas, P. Falaras, and P. Argitis, 3rd International Conference on Micro-Nanoelectronics, Nanotechnology & MEMs (Micro&Nano), Athens, Greece, November 18-21, 2007.
16. "An all-polymeric optocoupler based on polymer light-emitting diodes and photodetectors", L. C. Palilis, M. Vasilopoulou, A. Botsialas, N. Stathopoulos, P. Falaras, P. Argitis, 5th European Conference on Organic Electronics (ECOER07), Varenna, Italy, 01-04 October 2007.
17. "Single layer white organic light-emitting diodes for lighting applications", M. Vasilopoulou, D. Georgiadou, L. C. Palilis, G. Pistolis, P. Argitis, 5th European Conference on Organic Electronics (ECOER07), Varenna, Italy, 01-04 October 2007.

18. "Full colour single layer organic light emitting diodes (OLEDs) based on poly(9-vinylcarbazole) via photochemically induced emission tuning", M. Vasilopoulou, A. Botsialas, P. Bayiati, N. Vourdas, N. Stathopoulos, M. Rangoussi and P. Argitis, 4th International Workshop on "Nanosciences & Nanotechnologies - NN07" Thessaloniki, Greece, 16-18 July 2007.
19. "Flexible all-solid state electrochromic displays based on polymeric electrolytes", M. Vasilopoulou, P. Argitis, G. Aspiotis, G. Papadimitropoulos and D. Davazoglou, 4th International Workshop on "Nanosciences & Nanotechnologies - NN07" Thessaloniki, Greece, 16-18 July 2007.
20. "Optimization of the external efficiency of single layer full color light emitting diodes based on blue emitting polymers", N. Stathopoulos, M. Vasilopoulou and P. Argitis, Interrnational Conference on Organic Electronics, Eindhoven, 4-7 June 2007.

Presentations in National Conferences

1. "Optimization of the external efficiency of organic light emitting diodes (OLEDs using theoretical model", A. Korres, N. A. Stathopoulos, P. Argitis and M. Vasilopoulou, XXIII Hellenic Conference of Physics and Materials Science, NCSR Demokritos, Athens, Greece, 23-26 September, 2007
2. "Development of opto-electromeasuring system for OLED devices", A.Botsialas, N. A. Stathopoulos, P. Argitis, M. Vasilopoulou, XXIII Hellenic Conference of Physics and Materials Science, NCSR Demokritos, Athens, Greece, 23-26 September, 2007

Technical Reports

Final Report on Polycarbocycle-based Molecular Resists for EUV Lithography, More Moore-EU-FP6-Intergrated Project

Master theses

1. "Photochemically-induced polymer back-bone breaking for applications in lithography", Th. Manouras, Department of Chemistry", University of Athens, November 2007
2. "Photoresist material and process optimization for the patterning of biomolecules on functionalized surfaces", P. Pavli, School of Applied Mathematical and Physical Sciences, National Technical University of Athens, December 2007

Patent applications

1. "Tuning the emitting color of single layer, patterned full color Organic Light Emitting Diodes", P. Argitis, G. Pistolis, M. Vasilopoulou, Greek Patent (OBI) appl. No 20060100359, 19 June 2006. Greek Patent (OBI) appl. No 20060100359, 19 June 2006, PCT Application June 19, 2007.

LITHOGRAPHY and PLASMA PROCESSES for ELECTRONICS, MICROFLUIDCS, and SURFACE Nano-ENGINEERING

Project Leader: E. Gogolides

Key Researchers: E. Gogolides, A. Tserepi

Collaborating Researchers: K. Misiakos, I. Raptis, P. Argitis, C.Tsamis, S. Chatzandroulis

Permanent Researcher: V. Constantoudis

Researchers on Contract: G. Patsis, G. Kokkoris

PhD candidates: P. Bayiati, N. Vourdas, M. Vlachopoulou, G. Boulousis, K. Tsougeni, A. Malainou

MSc Students: D. Kotziambasis, A. Panagiotopoulos, K. Kontakis

Engineer: K. Kontakis

External collaborators: A. Boudouvis and M. Kalantzopooulou (NTUA, Greece), N. Hadjichristidis and E. Iatrou (UoA, Greece), S.Garbis and A. Vlahou (IIBEAA, Greece), S. Kakabakos and P. Petrou (IRRP, NCSR-Demokritos, Greece), G. Kaltsas (TEI Athens Greece), K. Beltsios (U. Ioannina, Greece), E. Gizeli and K. Mitsakakis (Univ. of Crete-FORTH, Greece) C. Cardinaud (U. Nantes, France), I. Rangelow and B. Volland (Univ. Ilmenau Germany), M. Cooke and A. Goodyear (Oxford Instruments Plasma Technology, UK), S. Daniels (DCU, Ireland), A. Erdmann (Fraunhofer, Germany), S. Tedesco (CEA-LETI, France)

Objectives:

Our mission is to use lithography and plasma processing as enabling technologies for electronics, MEMs, microfluidics and lab-on-a-chip fabrication and modification. We are also developing new multiscale (continuum, Monte Carlo and Molecular Dynamics) simulation tools for these processes, while we are extending our tools to device simulation:

- For nano-electronics our work focuses on Line Edge Roughness (LER) metrology, lithography process simulation and effects of LER on transistor operation (see section A).
- For MEMS fabrication a positive tone easily strippable SU8 process was developed for metallization via lift-off (see section A).
- For microfluidics we use soft lithography, Deep Plasma Etching, and plasma assisted bonding to fabricate PDMS, PMMA (and other organic polymer) based microfluidic devices, we fabricate capillary electrophoresis, and chromatography devices, we develop open microfluidics using electrowetting actuation. Finally we also demonstrate novel plasma based micro array technologies (see section B).
- For nano-Engineering of Surfaces, we have developed promising nano manufacturing processes for nano-texturing of polymers, and modifying their optical, wetting, and biological behaviour. We can now fabricate superhydrophilic, superhydrophobic, antireflective, and highly protein absorbing smart polymer surfaces (see section C).
- We have also developed the components of a total multi scale plasma simulator, comprising gas phase kinetics, surface kinetics, profile evolution, and stochastic etching simulation for nano-scale effect description (see section D)

Funding:

- EU IST IP More Moore, Contract No 507754, 1/1/2004-31/3/2007
- IEU NMP NoE Nano2Life, Contract No 500057, 1/2/2004-31/1/2008
- EU NMP2 STREP Nanoplasma, Contract No 016424 , 1/4/2006-31/3/2009
- GSRT, PENED 03 ED 202, 1/12/2005-31/11/2008
- DHMOEREUNA-2005, 1/1/2007-30/6/2008
- MNE2008, 1/7/2007-30/6/2010
- MD3, IT 214948, 1/12/2007-30/11/2009

EXAMPLES OF RESEARCH RESULTS IN 2007

A. Micro & Nanopatterning: Micro and Nano Lithography and Line Edge Roughness (LER, LWR)

a_1 Impact of LWR on transistor performance: Effects of fractal dimension of LWR on transistor threshold voltage, using simple analytic transistor equations and model functions

V. Constantoudis

Line Edge or Line Width Roughness (LER and LWR) is currently considered as one of the main challenges in the further advancement of lithography to sub-50nm resist patterning. The most commonly used LWR metric, rms value R_q, suffers from the deficiency of being dependent on the line length L included in the measurement process. Our group has suggested that this problem can be overcome by the introduction of a three parameter model for LWR characterization including a) the rms value for infinite (very large) line length $R_q(L\rightarrow\infty)$, b) the correlation length ξ and c) the roughness exponent α or fractal dimension d_f. These parameters determine the dependence of the rms on the line length L, i.e. the curve $R_q(L)$, and thus the relationship between the LWR of resist lines (estimated for large L) and the Gate Length Roughness defined for small L which affects transistor performance . In previous years, we investigated the impact of rms value and correlation length on transistor performance. This year, we focused on the effects of fractal dimension of LWR by using model self affine lines. It has been found that larger values of fractal dimension (smaller roughness exponents α) lead to a reduction of threshold voltage deviation (Fig. 1).

a_2 Impact of LWR on transistor performance: Use of state of the art transistor models

G. Patsis

The incorporation of LER effects on device performance was done using VHDL-AMS description of nMOS transistor incorporating quantum mechanical and polydepletion effects as they are described in MM11 MOSFET model by Philips (Fig. 2). VHDL-AMS offers a programming platform that easily incorporates behavioral as well as detailed modeling of device physics, necessary for accurate description of future device generations, including quantum mechanical effects, and variability.

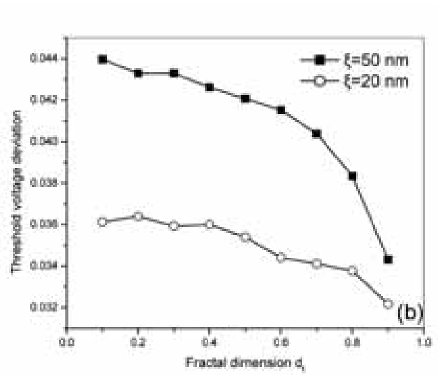


Fig. 1: Effect of Fractal dimension on Threshold voltage variation of the transistor, using simple analytic transistor equations, and model fractal edges

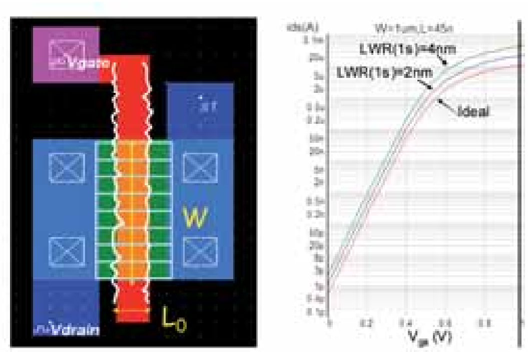


Fig. 2: The Philips MM11 MOSFET model is extended to incorporate gate length variability. This is introduced by "dividing" the device width into sub-units following a Gaussian gate length distribution, with appropriate line-width roughness. The combined model is used to determine source-drain current in terms of gate line-width roughness. The model is implemented in VHDL-AMS in order to be used for circuit simulation

a3 Simulation of lithography for LER reduction and design layout corrections
G. Patsis, G. Kokkoris, V. Constantoudis, D. Drigiannakis, I. Raptis, E. Gogolides

We try to understand how lithographic material and processing, affect LER, and device operation. Stochastic Monte Carlo techniques are used with a quasi-static dissolution algorithm to simulate dissolution of polymer lattice based on the concept of critical ionization. Etching is simulated applying an isotropic deformation on a numerically obtained line edge. Two-dimensional simulations have shown that molecular resists have lower LER (see Project: molecular resists) compared to conventional low MW resists. LER is also minimized with low acid diffusion range, and low secondary electron blur. Etching can be used to remove high frequency components of resist edges LER. The simulation was extended all the way to device operation, as discussed in task (A2) above. Combined CD and LER simulation on critical places of a design in terms of exposure, material and processes are important aspects for the quality of the devices. The current methodology could deliver CD and LER metrology on a realistic layout (Fig. 3), rather than model resist lines. Thus, it becomes possible to perform design optimization in terms of both CD and LER, while today usually only CD is considered (Fig.4).

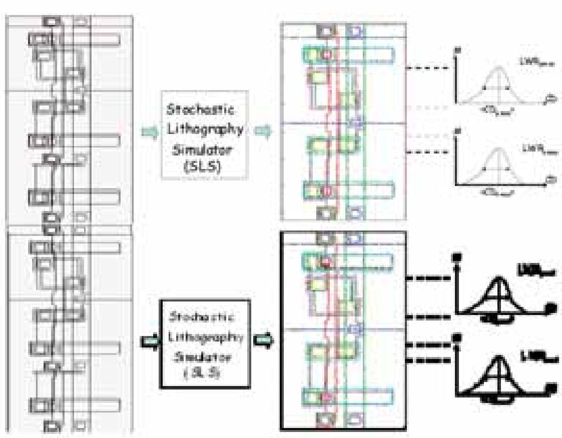


Fig. 3: Drawn layout of CMOS inverter, simulated layout with the proposed methodology, and determination of the transistor gate length distributions

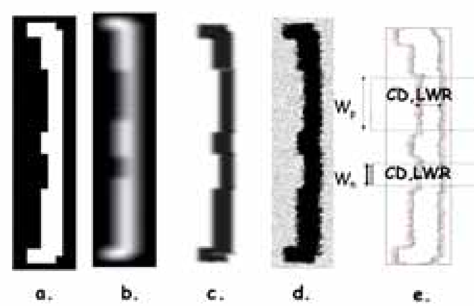
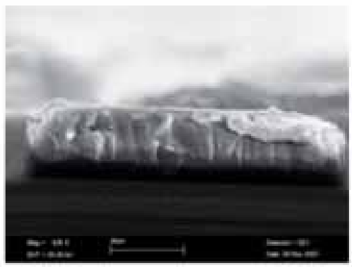


Fig. 4: (a) Drawn layout of gate mask, **(b)** E-beam energy deposition (Monte Carlo simulation results), **(c)** Translated into PAG ionization probability, **(d)** After PEB and dissolution for (CPAG=20%, DF=0.8, Diffusion range, DR=4nm), **(e)** After etching for two etching times t1 (blue) and t2 (red). Black line corresponds to (d)

a4 Dry development of SU8: A positive tone process for microsystem fabrication
D. Kontziampasis, E. Gogolides

A positive tone liquid-phase silylation process for epoxydized photoresists (such as EPON® SU-8) was proposed for microstructure fabrication and lift-off metallization. In the proposed process the development is done not with solvents but with the use of oxygen plasma. Silylation and dry development were used for 15 μm, 22 μm and 35 μm thick films. Stripping was easily achieved after plasma development using acetone and ultrasonics (within 30s) while this was not possible for several minutes for the crosslinked polymer. Metallization on a silicon substrate was achieved with the proposed process using 125 and 250 nm metal thickness.



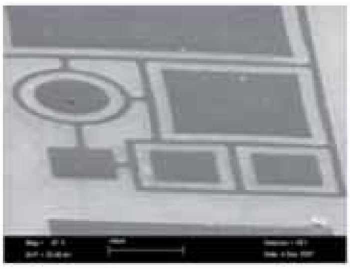
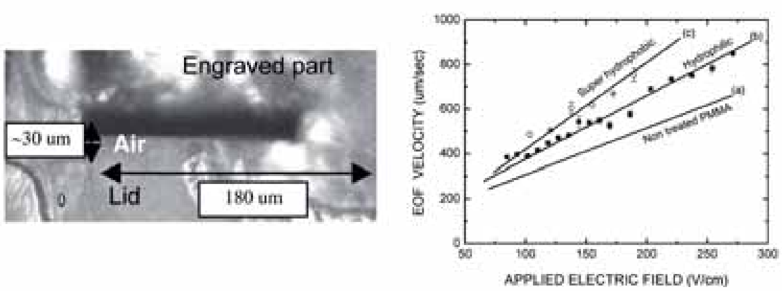


Fig. 5: Cross-section of a pattern created by silylation and dry development. Notice the difference in contrast in the upper part of the pattern, showing the silylation depth
Fig. 6: Metal pattern created with lift-off process after silylation and dry development. Metal thickness is 250 nm

B. Microfluidics fabrication and actuation using lithography and plasma processes (see also project III.3)

b_1 Plasma etching for fabrication of PMMA Microfluidic devices
N. Vourdas, K. Kontakis, K. Tsougeni, E. Gogolides

This year we worked on the fabrication and electrokinetic characterization of poly-methyl methacrylate (PMMA) microfluidics by deep O_2 plasma etching, utilizing a photosensitive poly(dimethyl siloxane) (PDMS) as a resist (in situ mask). The mass production amenability, the high throughput without the use of mold, the dry character along with the flexibility to control surface properties towards specific demands are some of the advantages of this method. Intense ion bombardment ensures high etch rates (~1.5 um/min) and anisotropy. A PMMA lid was thermally bonded to the plasma fabricated microchannel. Surface roughness and hydrophilization are some unique features induced by plasma processing, affecting the electrokinetic performance of the microfluidic and resulting in relatively high electro-osmotic flow (EOF) mobilities of $2.83 \cdot 10^{-4}$ $cm^2/V \cdot sec$. Teflon-like coating deposition on the engraved part modified the surface into a super-hydrophobic and resulted in even higher EOF mobility ($3.89 \cdot 10\text{-}4$ $cm^2/V \cdot sec$), thus proposing an alternative means in microfluidic surface modification and EOF control. Demonstration of on chip electrophoresis was done (Fig. 8)



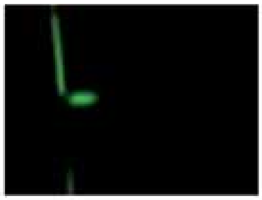


Fig. 7: (left) Cross section of a thermally bonded microfluidic (PMMA channel and lid). The sealing procedure did not deform the channel **(right)** EOF velocity vs. applied electric field (E) of (a) a typical smooth PMMA microfluidic, (b) a plasma fabricated PMMA microfluidic, and (c) a plasma fabricated PMMA microfluidic with SH walls on its engraved part (not on the lid)

Fig. 8: Dye Electrophoresis in plasma-etched PMMA microfluidic, seen from fluorescence microscope photograph

b_2 Fabrication of microfluidic devices based on soft lithography

A. Malainou, M. Vlachopoulou, and A. Tserepi

We have adopted the process of replica molding (soft lithography) using SU(8) for mold fabrication and rapid prototyping of PDMS-based microfluidic devices, as well as we have developed bonding processes (see Annual Report 2006) where permanent sealing of micro-channels is required. We have used these processes to fabricate two types of devices, shown below: a gas chromatography microcolumn and microfluidic modules integrated on a SAW bio-sensor. The micro-column (Fig. 9) used in combination with a gas sensor (hybrid system) is shown to enhance the separation efficiency of the sensor. Here, mixtures of xylene/benzene are used in the chromatography microsystem and are sufficiently separated (in collaboration with Dr. S. Chatzandroulis). The microfluidic modules integrated on a biosensor (Fig. 10) consist of many identical micro-channels which placed on the biosensor surface divide it in rather equal parts, thus allowing parallel analysis of multiple biological samples (in collaboration with E. Gizeli, K. Mitsakakis, Univ. of Crete-FORTH).

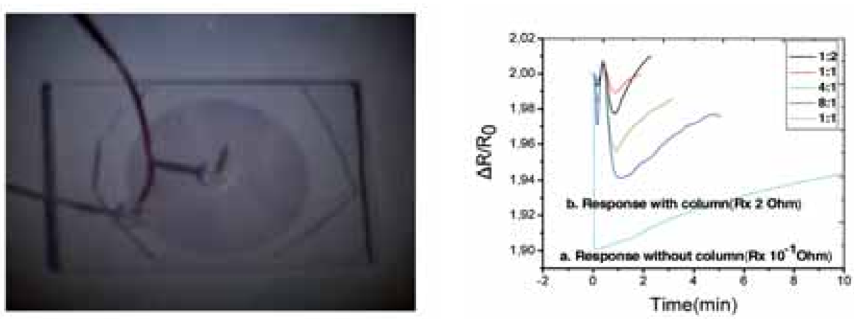


Fig. 9: A chromatography microcolumn fabricated in PDMS (left) is shown (on the right) to enhance the separation efficiency of a gas sensor

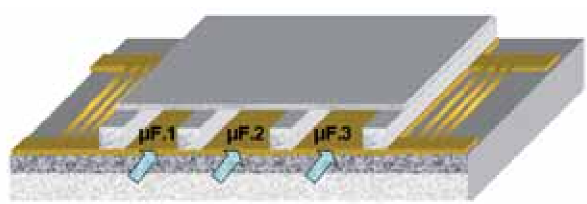


Fig. 10: Schematic of a microfluidic module consisting of 3 micro-channels on a SAW biosensor

b_3 Electrowetting-based actuation in microfluidics through the use of hydrophobic plasma-deposited fluorocarbon films **P. Bayiati, A. Tserepi, K. Misiakos, D. Goustouridis**

Optimized plasma-deposited fluorocarbon films are used in this work as the hydrophobic top layer of a droplet-based microfluidic device, where droplet actuation and transport is achieved via electrowetting. We have demonstrated electrowetting-based droplet transport on an open microfluidic device, fabricated using hydrophobic/dielectric fluorocarbon films deposited on a series of micro-electrodes, sequentially activated (Fig. 11).

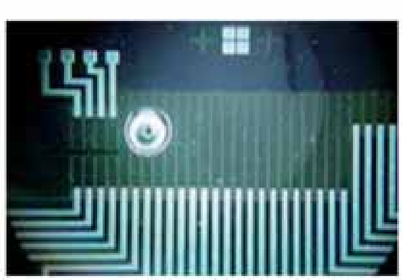


Fig. 11: Droplet transported on open microfluidic device

b_4 Method for fabrication of protein microarrays through selective plasma-induced fluorocarbon deposition **P. Bayiati, A. Malainou, A. Tserepi, P. S. Petrou, S.E. Kakabakos**

Microarrays have recently become an invaluable tool for large-scale and high-throughput bioanalytical applications, used for basic research, diagnostics and drug discovery. We have developed a simple and fast process for fabricating protein microarrays by selective protein adsorption on hydrophilic SiO_2 or Si_3N_4 patterns versus hydrophobic fluorocarbon-covered Si substrates exposed to fluorocarbon plasmas. We have demonstrated protein arrays of highly regular spots with increased signal to noise ratio (Fig. 12a), very small spot size (0.75 μm) and high spot density (Fig. 12b).

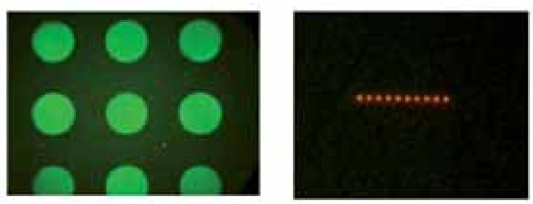


Fig. 12: Examples of **(a)** a two dimensional protein microarray of 1 mm-wide spots at 1 mm distances and **(b)** a protein microarray of 1 μm-wide spots at 1 μm distances Patent application OBI, "Method for making a micro-array", Appl. No 20070100394/20.06.2007, A. Tserepi et al., and Best Student Award for poster presentation at Micro&Nano Conference 19-22/11/2007, Athens

C. Plasma nanostructuring-nanotexturing of polymer surfaces: Optical, Wetting, and Bio applications, and periodic structure formation

c_1 Design and Control of Surface Wetting and Antireflective properties of PMMA (organic polymer) and PDMS (inorganic polymer) by plasma processing **N. Vourdas, M. Vlachopoulou, A. Tserepi, E. Gogolides**

Transparent and anti-reflective coatings are of great interest, for applications such as photodiodes, solar cells, displays and lens industry, and smart panels / windows. We have shown that SF_6 plasma etching of PDMS results in periodic columnar-like high aspect ratio structures (see Annual Report 2005). In addition plasma processing was employed to created nanostructures and control the wetting properties of poly (methyl methacrylate) PMMA surfaces from Superhydrophilic to Superhydrophobic (see Annual Report 2006). This year, super-hydrophobic (SH) yet optically transparent and antireflective surfaces were fabricated by means of highly anisotropic Oxygen plasma processing and plasma-enhanced fluorocarbon deposition on PMMA. It is also revealed that SF_6 treated PDMS surfaces for plasma durations between 1 and 3 minutes, can be used as transparent and anti-reflective coatings. After 4 minutes SF_6 plasma treatment, transmittance at 600nm decreases to 88%, while reflectance decreases to 3.5% and below.

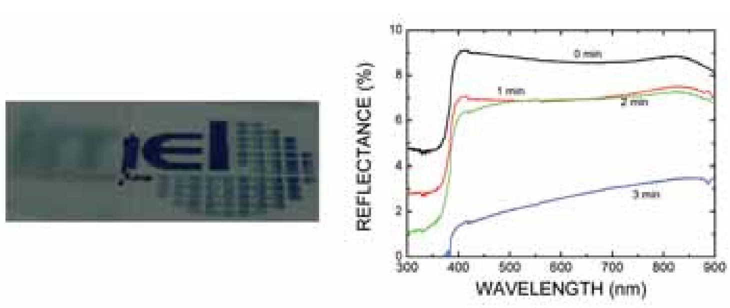


Fig. 13: (a) Photograph of the Institute of Microelectronics logo ( ) below two PMMA substrates, demonstrating the milky-like appearance of a 10 min-processed PMMA (placed over " ") contrary to the optical transparency and reduced reflectivity of a 1 min-processed PMMA (placed over " "), **(b)** Reflection spectra of PMMA substrates before and after 1, 2 and 3 min of Oxygen plasma processing. Until 2 min the surface is simultaneously optically transparent

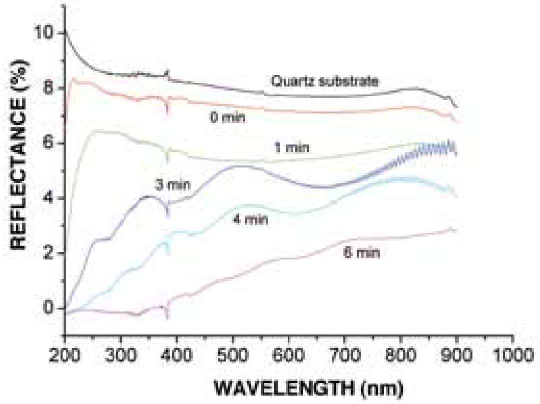


Fig. 14: Reflection spectra of untreated PDMS surface and treated in SF6 plasma for 1, 3, 4 and 6 minutes

In addition, this year we also achieved the control and reduction of SF_6 plasma-induced PDMS surface roughness, by wet etching of treated PDMS surfaces in BHF. 2-minute treated PDMS surfaces (115 nm initial rms) show significant reduction in roughness (5nm rms) after 15-minute immersion in BHF (evolution of topography is shown in Fig. 15 (a) and (b), respectively). The effect of roughness reduction in BHF is also simulated by isotropic etching of PDMS in BHF (collaboration with Dr. G. Kokkoris).

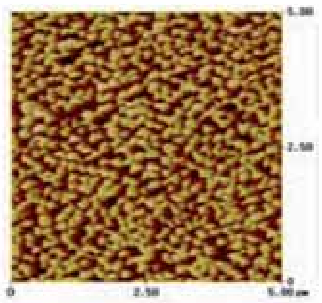


Fig. 15: (a) 2-minute SF6 treated PDMS surface. Rms roughness is 115 nm

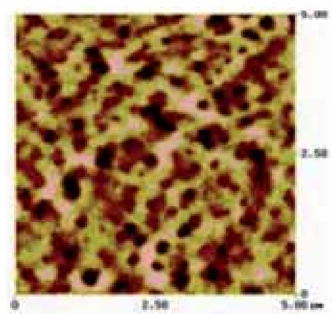


Fig. 15: (b) 2-minute SF6 treated PDMS surface, after 15-minute immersion in BHF. Rms roughness is 5 nm

c_2 Plasma Nanotexturing of PDMS for increased Protein adsorption
M.Vlachopoulou, A.Tserepi, E.Gogolides

Plasma nano-textured PDMS surfaces (see C1 above) were also investigated as platforms for protein adsorption. Fresh and aged plasma-treated PDMS surfaces, for various plasma treatment durations, are used, and their hydrophobicity evolution is simultaneously studied. An increase in protein adsorption, more than 100%, is observed on 6-min treated PDMS nano-columnar surfaces, compared to flat untreated PDMS surfaces, mainly due to increased surface area, as shown in Fig. 16. Larger fluorescence values are observed for aged samples compared to fresh ones, while best spot morphology is obtained either for fresh sasmples, even for long SF_6 treatment time or for aged samples, but for short SF_6 treatment time.

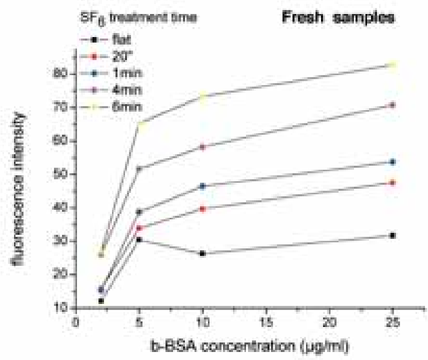
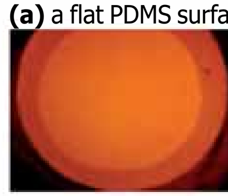


Fig. 16: Variation of fluorescence intensity of proteins adsorbed on fresh SF6 plasma-treated surfaces, with plasma exposure time and protein concentration

Fig. 17: Fluorescence of proteins adsorbed on **(a)** a flat PDMS surface

(b) a 6-minute treated PDMS surface (fresh)

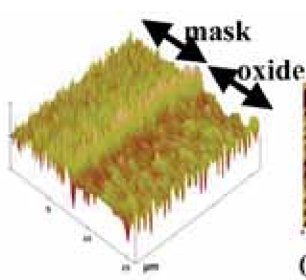


(c) a 4-minute treated PDMS surface (aged)

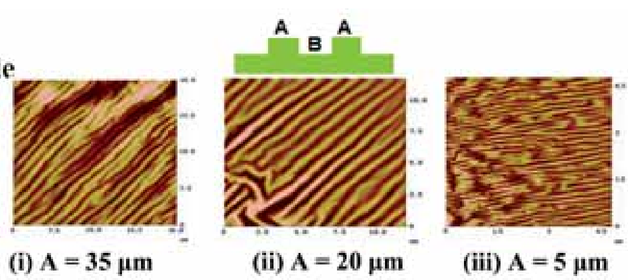
(d) a 6-minute treated PDMS surface (aged)

c_3 Plasma-based PDMS Nanotexturing: Oriented Spontaneously Formed Nanostructures on PDMS Films and Stamps **K. Tsougeni, G. Boulousis, E. Gogolides, A. Tserepi**

We also proposed a plasma-based methodology to fabricate oriented spontaneously formed nanostructures on PDMS films and stamps. Oxygen plasma treatment of PDMS produces spontaneously-formed wavy structures with high nano-scale amplitude and with periodicity of a few 100's nm as revealed by Atomic Force Microscopy (AFM). We present two plasma based methods for the fabrication of such oriented nano-structures on PDMS films and stamps. Fig.18(a) shows a 3D AFM image of a thin PDMS film after exposure to O_2 plasma for 10 min through a stencil mask placed on top of the surface. Fig. 18(b) shows AFM images of oriented nano-structures with periodicities ranging from 1150 to 170 nm formed on the top of a stamp bearing equally spaced lines A with dimensions (i) A = 35 μm, (ii) A = 20 μm and (iii) A = 5 μm. This simple oxygen plasma treatment to orient spontaneously formed nanostructures, with wavelength in the sub-micrometer range, may be used to print, for example, fine patterns of biologically active molecules onto surfaces with high spatial frequency.



(a)



(b)

Fig. 18: (a) AFM 3D view image of a PDMS film after 10 min treatment in O2 plasma through a stencil mask on top of the surface

Fig. 18: (b) AFM 2D images of a PDMS stamp after exposure to O2 plasma for 10 min: structures formed on the top of the stamp. (i) A = 35 μm, (ii) A = 20 μm and (iii) A = 5 μm

D. Simulation of micro and nano-structuring evolution from plasma processes: Towards a complete multi scale plasma process simulator

d_1 Simulation of plasma (gas phase) and surface kinetics during plasma etching **G. Kokkoris, A. Panagiotopoulos, E. Gogolides**

Control of plasma reactors in real time, as well as fast simulation of nanostructure profile evolution and surface nanotexturing with plasma processes demand the use of fast 'global' or '0-dimensional' models. Such models use average plasma variables ignoring their spatial variation (these are the so-called well stirred tank reactors in chemical engineering). A zero dimensional (Global) plasma chemistry code has been developed for 3 gases, namely O_2, SF6, C4F8 applicable for high Density plasma reactors. Surface models have also been developed for calculation of the etching rates of SiO_2 etching in C4F8 / fluorocarbon plasmas:

• Si in SF6 plasmas or Si in the gas chopping process using alternating SF6/C4F8 plasmas

• Organic polymer (PMMA) etching AND silicon containing polymer etching (silsequioxane type). This model enables simulation of bilayer lithographic processes using silicon-containing resists (an application useful for microelectronics, microsystems and microfluidic channel fabrication).

The plasma and surface kinetics codes have been coupled to permit calculation of etch rates versus reactor parameters. A schematic of the interface of the zero dimensional code is shown below. This module will be coupled to the profile evolution simulator presented in annual reports for years 2006, 2005, 2004

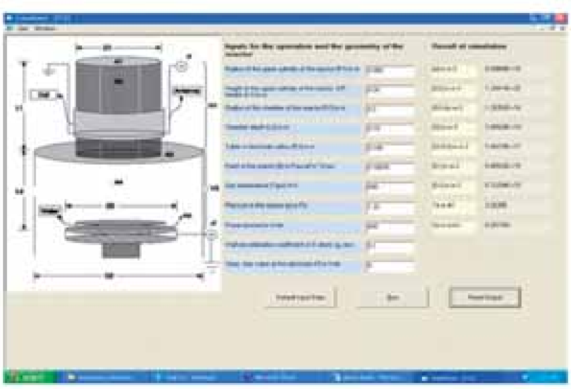


Fig. 19: The graphical interface of the plasma gas and surface kinetics simulator. This simulator is coupled with the profile evolution simulator presented in annual reports 2006, 2005, 2004

d_2 Stochastic simulation of roughness evolution of homogeneous and composite materials during plasma etching **V. Constantoudis, G. Kokkoris, G. Boulousis, E. Gogolides**

Mechansims of roughness formation on homogeneous and composite materials are being investigated. Our work targets both, Silicon based and organic materials to line up with the results presented in the previous section. The nanoroughness formation and evolution during fluorine-based plasma etching of Si surfaces was investigated this year both experimentally and theoretically. Dual nanoscale morphology, as well as, almost linear increase of both root mean square roughness and correlation length versus etching time was observed in the experiment. The effect of etch inhibitors from the plasma environment is modeled. Two kinds of etch inhibitors can explain and predict the nanoroughness formation and evolution. Key factors in the nanoroughness formation is the angular distribution of etch inhibitors versus that of ions and their sticking probability compared to that of reactive neutral species.

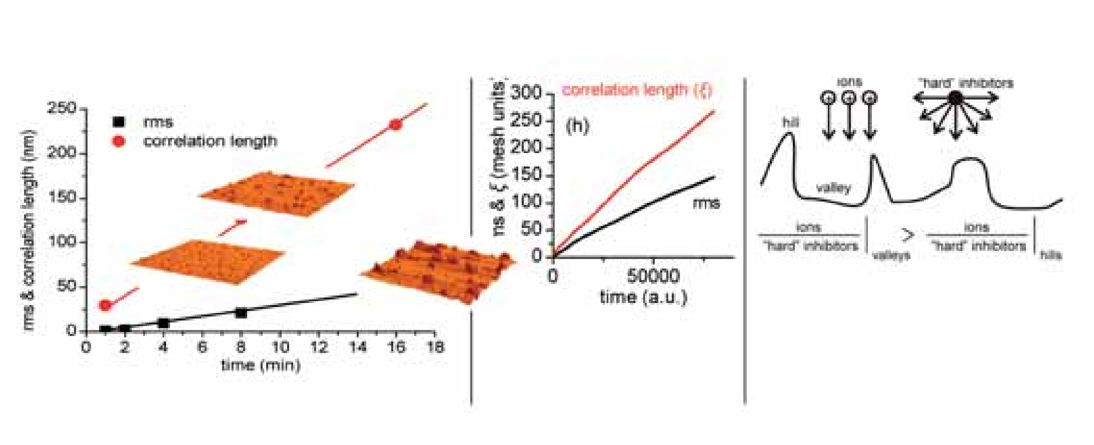


Fig. 20: (a) Experimental data of rms roughness and correlation length induced for SF6 etching on Silicon. AFM images drawn in natural scale (equal dx,dy,dz) are inset. Data: a) after 4 min etch rms=9.1nm, etch depth~16000nm, b) after 8 min rms=21 nm, etch depth~32000nm, c) after 16 min: rms=50 nm, etch depth~64000nm

Fig. 20: (b) Prediction of the rms and correlation length from our stochastic plasma process simulator

Fig. 20: (c) One possible mechanism of nanoroughness formation due to hard inhibitor deposition preferentially on the top of hills

PROJECT OUTPUT in 2007

Publications in International Journals and Reviews

1. "Tunable poly (dimethylsiloxane) topography in O2 or Ar plasmas for controlling surface wetting properties and their ageing", Tsougeni K, Tserepi A, Boulousis G, V. Constantoudis, E. Gogolides, (2007) JPN J Applied Physics 1 46 (2): 744-750.
2. "Electrowetting on plasma-deposited fluorocarbon hydrophobic films for biofluid transport in Microfluidics", Bayiati P., Tserepi A., Petrou P.S., Kakabakos S.E., Misiakos K., Gogolides E., (2007) Journal of Applied Physics, 101 (10), art. no. 103306.
3. "Control of nanotexture and wetting properties of polydimethylsiloxane from very hydrophobic to super-hydrophobic by plasma processing", Tsougeni K., Tserepi A., Boulousis G., Constantoudis V., Gogolides E., (2007) Plasma Processes and Polymers, 4 (4), pp. 398-405.
4. "Photosensitive poly(dimethylsiloxane) materials for microfluidic applications", Tsougeni K., Tserepi A., Gogolides E., (2007) Microelectronic Engineering, 84 (5-8), pp. 1104-1108.
5. "Nanostructuring of PDMS surfaces: Dependence on casting solvents", Vlachopoulou M.-E., Tserepi A., Beltsios K., Boulousis G., Gogolides E., (2007) Microelectr. Engineering, 84 (5-8), pp. 1476-1479.
6. "Biofluid transport on hydrophobic plasma-deposited fluorocarbon films", Bayiati P., Tserepi A., Petrou P.S., Misiakos K., Kakabakos S.E., Gogolides E., Cardinaud C., (2007) Microelectronic Engineering, 84 (5-8), pp. 1677-1680.
7. "Stochastic simulation studies of molecular resists", Drygiannakis D., Patsis G.P., Raptis I., Niakoula D., Vidali V., Couladouros E., Argitis P., Gogolides E., (2007) Microelectronic Engineering, 84 (5-8), pp. 1062-1065.
8. "Nanotextured super-hydrophobic transparent poly(methyl methacrylate) surfaces using high-density plasma processing", Vourdas N., Tserepi A., Gogolides E., (2007) Nanotechnology, 18 (12), art. no. 125304.
9. "Fermi acceleration in the randomized driven Lorentz gas and the Fermi-Ulam model", Karlis A.K., Papachristou P.K., Diakonos F.K., Constantoudis V., Schmelcher P., (2007) Physical Review E - Statistical, Nonlinear, and Soft Matter Physics, 76 (1), art. no. 016214.
10. "Optical characterization of Si-rich silicon nitride films prepared by low pressure chemical vapor deposition", Vamvakas V.Em., Vourdas N., Gardelis S., (2007) Microelectronics Reliability, 47 (4-5 SPEC. ISS.), pp. 794-797.
11. "Simulation of materials and processing effects on photoresist line-edge roughness", G. P. Patsis, M. D. Nijkerk, L. H. Leunissen, and E. Gogolides, International Journal of Computational Science and Enginnering (Special Issue on Computational Methods and Techniques for Nanoscale Technology Computer Aided Design) Vol. 2, 3-4, 134-143 (2007).
12. "Effects of lithography nonuniformity on device electrical behavior. Simple stochastic modeling of material and process effect on device performance", G. P. Patsis, V. Constantoudis, and E. Gogolides, J. Computational Electronics 5, 341 (2007).
13. "Stochastic simulation of material and process effects on the patterning of complex layouts", N. Tsikrikas, D. Drygiannakis, G. P. Patsis, I. Raptis, S. Stavroulakis, E. Voyiatzis, Jap. J. Appl. Phys. 46 (9 B), 6191 (2007)
14. "Dual nanoscale roughness on plasma-etched si surfaces: role of etch inhibitors", G. Kokkoris, V. Constantoudis, P. Angelikopoulos, G. Boulousis, and E. Gogolides, Phys. Rev. B 76, 193405 (2007)
15. "Roughness formation during plasma etching of composite materials: a kinetic Monte Carlo approach", Zakka, E., Constantoudis, V., Gogolides, E., IEEE Transaction on Plasma Science, vol. 35 (5) Page(s): 1359-1369 , 2007

16. "Novel microfluidic flow sensor based on a microchannel capped by porous silicon", Pagonis, D.N., Petropoulos, A., Kaltsas, G., Nassiopoulou, A.G., Tserepi, A., Physica Status Solidi (A) Applications and Materials 204 (5), pp. 1474-1479

Publications in International Conference Proceedings

1. "Correlation length and the problem of line width roughness", V. Constantoudis, G.P. Patsis, E. Gogolides, Proceedings of SPIE Vol. #6518, 6518_57, 65181N pp. 1-10, San Jose, California, February 25 – March 2, (2007)
2. "Simulation of the combined effects of polymer size, acid diffusion length and EUV secondary electron blur on resist line-edge roughness (poster)", D. Drygianakis, M. D. Nijkerk, G. P. Patsis, G. Kokkoris, I. Raptis, L. H. A. Leunissen, E. Gogolides, Proceedings of SPIE Vol. #6519, 6519_36, 65193T pp. 1-12, San Jose, California, February 25 – March 2, 2007
3. "Stochastic simulation of material and process effects on the patterning of complex layouts with e-beam and EUV lithography (poster)", N. Tsikrikas, D. Drygiannakis, G. P. Patsis, G. Kokkoris, I. Raptis, E. Gogolides, Proceedings of SPIE Vol. #6518, 6518_115, 651836 pp. 1-10, San Jose, California, February 25 – March 2, 2007
4. "Plasma processing in fabricating nano-textured, super-hydrophobic polymeric coatings", N. Vourdas, M.-E. Vlachopoulou, A. Tserepi, E. Gogolides, Proceedings of EURO-INTERFINISH 2007, Athens, Greece, 18-19 October 2007, O24 - pp165-170
5. "Protein patterning through selective fluorocarbon plasma-induced deposition on silicon", P. Bayiati, A. Tserepi, P. S. Petrou, S. E. Kakabakos, E. Matrozos, E. Gogolides, Proceedings of 11th International Conference on Miniaturized Systems for Chemistry and Life Sciences, 7 - 11 October 2007, Paris, France, pp. 92-94

Publications in Greek Conference Proceedings

1. "Plasma processes in fabrication of nano-textured, super-hydrophobic polymeric surfaces", N. Vourdas, M.-E. Vlachopoulou, A. Tserepi, E. Gogolides, Proceedings of 6th Panhellenic Conference on Chemical Engineering (full paper), Athens, 31 May-2 June 2007, pp. 225-228
2. "Nanoroughness on plasma etched Si and polymer surfaces: theory, experiment and applications", M.-E. Vlachopoulou, N. Vourdas, G. Kokkoris, V. Constantoudis, G. Mpoulousis, A.Tserepi, E.Gogolides, Proceedings of XXIII Hellenic Conference On Solid State Physics 2007, Athens, Greece, 23-26 September 2007, pp. 55-56
3. "Stochastic simulation of the solution of photosensitive materials with applications in microelectronics (poster)", D. Drygiannakis, G. P. Patsis, I. Raptis, A.G. Boudouvis, Proceedings of XXIII Hellenic Conference On Solid State Physics (2007), Athens, Greece, 23-26 September 2007
4. "Simulation, pattern matching and metrology in electron beam lithography (poster)", N. Tsikrikas, G. P. Patsis, I. Raptis, Proceedings of XXIII Hellenic Conference On Solid State Physics (2007), Athens, Greece, 23-26 September 2007, pp. 25-26

Ph. D thesis

1. "Oxygen plasma etching, surface modification and nanotexturing of PMMA: Study of mechanisms and applications in PMMA microfluidic devices", Nikolaos Vourdas, Chemical Engineer, MSc, PhD, Thesis advisor-supervisor: Evangelos Gogolides, Other co-advisors: Angeliki Tserepi, Andreas Boudouvis, Dept. Chem. Eng., National Tech. Univ. Athens

M. Sc thesis

1. "Silylation and Oxygen Plasma Development of Epoxidized Photoresists (SU8) for micromachining and other applications", Dimitrios Kontziambasis, Materials Engineer, MSc, Thesis Advisor-Supervisor: Evangelos Gogolides, Masters Programme in Microelectronics

New patent applications

1. "Method for making a micro-array", A. Tserepi, E. Gogolides, P. Petrou, S. Kakambakos, P. Bayiati, E. Matrozos, Patent application OBI, Appl. No 20070100394/20.06.2007
2. "Bonding method", K. Misiakos, A. Tserepi, M-E. Vlachopoulou, PCT/GR07/000047 (Filing date: 14/09/2007)

Products for possible licensing or other development

- Software for LER measurement and characterization from SEM images. Demo available on our web site http://www.imel.demokritos.gr/software.html
- Software for nanolithography simulation and LER prediction based on Monte Carlo methods. Demo in Preparation
- Software for topography evolution simulation during plasma processing. Demo released and tested in graduate class for Micro and Nano Fabrication for Electronics and MEMS

Awards

P. Bayiati, Best Student Award for poster presentation ("Hydrophobic plasma-deposited fluorocarbon films as a means for biofluid transport and selective adsorption of biomolecules on lab-on-a-chip devices") at Micro&Nano 2007 Int. Conference 18-21/11/2007, Athens

FRONT-END PROCESSES

Project Leader: C. Tsamis

Post-doctoral Scientists: D. Skarlatos

PhD candidates: N. Kelaidis, N. Ioannou, A. Chroneos

Collaborating researchers engaged in other projects: V. Ioannou–Sougleridis

External Collaborators: C. Krontiras (Univ. of Patras), R. Georga (Univ. of Patras), C. Galiotis (FORTH/ICE-HT), Ph. Komninou (Univ. of Thessaloniki), B. Kellerman (MEMC), M. Seacrist (MEMC), R. Grimes (Imperial College. UK), D.S. McPhail (Imperial College. UK)

Objectives

- Study of dopant diffusion/activation and point/extended defect kinetics in Group-IV semiconductors (Silicon, Strained Silicon, Germanium) for CMOS applications
- Thermal processes for ultra-thin gate dielectrics (oxides, oxynitrides) in Group-IV semiconductors for CMOS applications
- Process optimization for Nanodevices (Fabrication, Electrical Characterization)
- Continuum and atomistic simulation of processes and devices

Funding:

- GSRT-PENED-03ED496, "Dopant diffusion and activation in Group-IV semiconductors (Strained Silicon and Germanium) for novel nanoelectronic devices"

EXAMPLES OF RESEARCH RESULTS IN 2007

A. Dopant diffusion and defects in silicon

a1 Modelling of low energy – high dose Arsenic diffusion
D. Skarlatos and C. Tsamis

In this work we are developing a macroscopic model in order to simulate arsenic diffusion after low-energy, high-dose implantation and subsequent annealing. Low energy implantation suppresses TED phenomenon due to extended defects dissolution in the presence of the free silicon surface. Under these implantation conditions arsenic enhanced diffusion takes place via bulk interstitial generation due to arsenic clustering. Theoretical studies and experimental evidence indicate that As clusters form around a vacancy with the consequent injection of silicon interstitials. The most probable As – V cluster configuration consists of 2 – 4 As atoms surrounding a vacancy. It should be mentioned that modern process simulators are unable to predict the entire As diffusion profile under such experimental conditions.

The physical basis and the main assumptions of the model are the following, as illustrated to Fig. 1: (a) During drive–in annealing a part of the diffused As profile remains inactive. We assume that the inactive part of the profile, the difference of the chemical and active profiles, is in the form of clustered As atoms around vacancies. (b) The local concentration of As – vacancy clusters can be expressed as the concentration of inactive As divided by the number of As atoms per cluster. (c) One interstitial is injected from every cluster formed. As a consequence the bulk interstitial generation rate can be expressed in the form:

$$G = G_b \frac{[C_{As}(x) - C_{As\ active}(x)]}{AiC}$$

where $C_{AS}(X)$ is the chemical profile of arsenic during annealing, $C_{AS\ active}(X)$ is the corresponding active part of the profile, AiC is the number of As atoms per cluster with values between 2 and 4 and G_b is a parameter, representing the inverse of the time during which the majority of the As– vacancy clusters have been formed. (d) A part of the injected interstitials recombine at the native oxide/ Si interface (surface recombination). The rest diffuse into the bulk.

The model predictions have been evaluated by an experiment especially designed for this purpose. The approach consists in simulating the diffusion both of low energy – high dose implanted arsenic and of boron in buried δ-doped layers that exist below the implanted surface (acting as interstitial monitors) after RTA annealing at 900^0C. Secondary ion mass spectrometry (SIMS) is used to monitor arsenic and boron profiles before and after annealing. Simulations have been performed using Synopsys-Taurus process simulator and by solving the coupled arsenic, interstitial and vacancy diffusion equations including the additional interstitial generation term mentioned above. Fig. 2 shows the model predictions of As_4 – V clusters distribution in the case of 3 and KeV – $2x10^{15}$ cm^{-2} As implantation after 900^0C RTA for 30 sec. Fig. 3 shows As and B simulation results in the case of 3 KeV - $2x10^{15}$ cm^{-2} As implantation after 900^0C RTA for 30 sec. We observe a very good agreement between experiment and modeling (including the As pileup effect at the SiO_2/Si interface) taking into account the simplicity of the model.

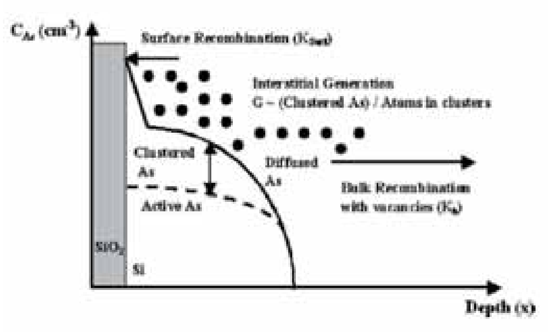


Fig. 1: Physical basis and assumptions of the model.

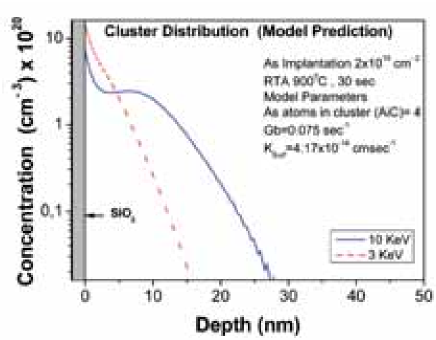


Fig. 2: Theoretical prediction of As4 – V clusters distribution in the case of 3 and 10 KeV – $2x10^{15}$ cm^{-2} As implantation after 900^0C RTA for 30 sec.

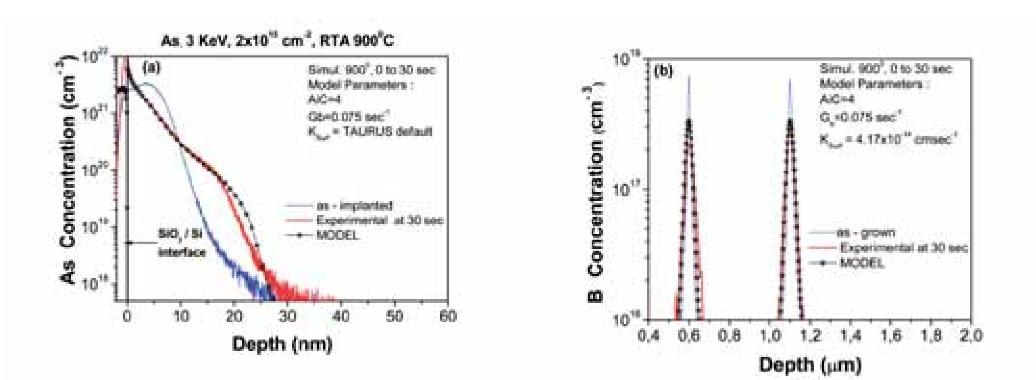


Fig. 3: Experimental and simulated (a) Arsenic and (b) Boron δ – layers profiles after 3 KeV – $2x10^{15}$ cm^{-2} As - implantation and diffusion at 900^0C for 30 sec

B. Electrical characterization and Modeling of MOS capacitors on Strained-Silicon*

N. Kelaidis, D.Skarlatos, V. Ioannou–Sougleridis and C. Tsamis

* In collaboration with Physics Dept., Univ. of Patras (C. Krontiras, R. Georga), Physics Dept., Univ. of Thessaloniki (Ph. Komninou), FORTH/ICE-HT (C. Galiotis, J. Parthenios) and MEMC Electronic Materials Inc.(B. Kellerman, M. Seacrist)

Strained-Silicon on relaxed $Si_{1-x}Ge_x$ has been extensively investigated and implemented as a means to further increase the mobility of carriers thus improving device performance without decreasing device dimensions. Therefore, the study of the oxide and oxynitride formation on strained Silicon grown on Si_xGe_{1-x} substrates is of particular interest. However, excess thermal processing of s-Si can relax the s-Si epilayer and induce Ge diffusion towards the surface, deteriorating the integrity of the s-Si layer and of the two interfaces (s-Si/SiO_2 and the s-Si/SiGe). In the present work, a systematic study is performed on the thermal oxidation of s-Si at various oxidation conditions as well as nitrogen-enriched thermal oxides fabricated by (a) oxynitridation in N_2O (b) oxidation of $N2^+$ implanted s-Si and (c) dry oxidation. For this scope, electrical characterization, structural characterization and RAMAN spectroscopy has been implemented. Computer simulations have also been performed using Synopsys -Taurus software. A wide range of process temperatures has been studied including extreme thermal budget processing conditions, in order to examine the physical phenomena involved.

Electrical measurements such as Capacitance-Voltage measurements on oxidized s-Si substrates (Fig. 4) show that two main factors influence the interfacial properties of the structures and consequently the response of the MOS capacitors: (a) the extend of the s-Si layer oxidation, i.e. the remaining s-Si thickness and (b) the duration of the post-oxidation annealing in inert ambient. Due to the bandgap discontinuity in the s-Si / SiGe heterostructure, a characteristic hump in the C-V curves appears, accompanied by a frequency dispersion of the capacitance in this region. As the oxide thickness increases and the s-Si overlayer is consumed for the oxide formation, the hump and frequency dispersion phenomena both become significant (Fig. 5). The evolution of the hump with decreasing s-Si layer thickness was confirmed with simulations performed using the commercial software Taurus / Synopsis (Fig. 6). The observed frequency dispersion is intensified probably due to an increased density of interfacial traps attributed to a formation of a defective transition layer zone at and/or near the s-Si/SiO_2 interface, most likely due to Ge diffusion from the SiGe layer. Additionally, post-oxidation annealing time affects the interfacial properties. Isothermal annealing experiments demonstrate that longer post-oxidation annealing results to almost standard C-V characteristics, showing small frequency dispersion and hump (Fig. 7). Longer post oxidation annealing may result to a much stronger Ge diffusion effect, and possibly increased amount of Ge at the s-Si/SiGe interface. This process seems to annihilate interface traps, but would also lead to a less abrupt s-Si/SiGe heterointerface, which would explain the reduction of the hump. This is in accordance with TCAD simulation analysis where it is shown that the hump phenomenon is reduced when modeling a less abrupt heterojunction. It has also been predicted by computer simulation that traps at both interfaces can play an equally important role in the electrical characteristics of the system due to their close proximity. Additional oxidation experiments in N_2O ambient indicate a significant influence of the process conditions on the quality of the oxidized structures.

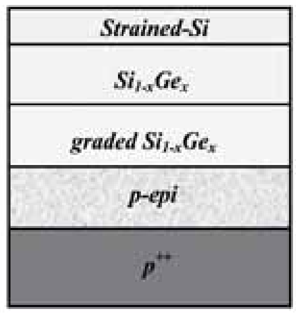


Fig. 4: Experimental structures. Strained - Silicon substrates were provided by MEMC Electronics Inc., USA.

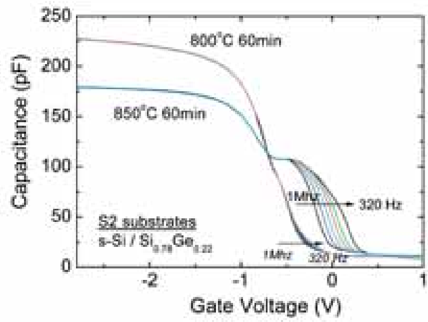


Fig. 5: The effect of Frequency Dispersion in the C-V curves for sample S2 becomes significant as the s-Si overlayer decreases.

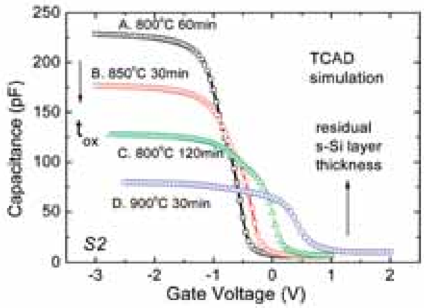


Fig. 6: Simulated C-V characteristics for various oxidation conditions for S2 substrates (s-Si / $Si_{0.78}Ge_{0.22}$).

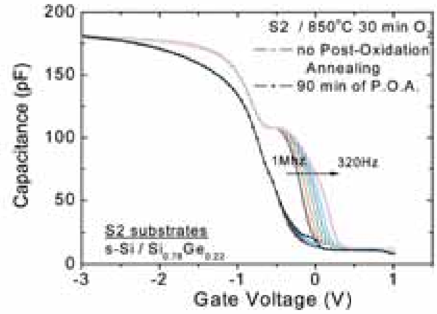


Fig. 7: C-V measurements at 1 MHz for sample S2 oxidized at 850°C for 30 min with a post oxidation annealing time of 0 min, 30 min and 90 min.

C. Dopant diffusion in Germanium*

N. Ioannou, D. Skarlatos, A. Chroneos and C. Tsamis

*In collaboration with Imperial College London (R. Grimes, D.S. McPhail

Germanium has been an important Group IV semiconductor since its initial use as the first transistor material. Although the mobility of carriers in germanium is higher than that of silicon, its study was soon abandoned due to the lack of a high quality, stable oxide that made it unsuitable for CMOS applications. However, during the last years, it has been demonstrated, that high-quality high–k materials can be deposited by various techniques on germanium substrates arising as promising gate dielectrics for Ge-CMOS applications. For that reason a lot of research efforts have focused the last years in the understanding of the fundamental properties of germanium as well as of phenomena related to the technological processes needed for device fabrication. Unavoidably, dopant diffusion and defect kinetics are expected to play a dominant role in this new technology similar to the silicon technology. It is the aim of this work to study dopant diffusion in germanium and to develop models that can predict the phenomena that take place during these processes.

In this work, we investigate Ge substrate evaporation and its influence on implanted Phosphorous from uncapped Ge substrates, during low temperature drive-in annealing. In order to study substrate evaporation, the surface of a non – implanted Ge wafer was covered with sputtered SiO_2. Lines were patterned into the oxide using lithography and wet etching, defining areas that were either passivated or non-passivated. Subsequently samples were annealed at various temperatures and times in a conventional resistance – heated furnace. After the annealing process and the silicon dioxide removal the height difference between the passivated and non-passivated areas was measured using stylus profilometry and Atomic Force Microscopy (AFM). Significant evaporation of the substrate was measured, while the average roughness of the substrate increased from 0.58 nm for the passivated areas up to 2.8 nm, for the non-passivated areas (Fig. 8).

A second series of experiments was carried out in order to investigate the influence of Ge substrate evaporation on the diffusion of implanted P in Ge. For this purpose P was implanted in Ge wafers at a low dose of $5x10^{13}$ cm^{-2} with energies of 50 keV to 150 keV. Following the implantation, part of the implanted Ge wafers was covered by a 40 nm sputtered SiO_2 layer while the rest remained uncovered. All samples were annealed at 500 ^0C for various times. P profiles were subsequently analyzed using Secondary Ion Mass Spectroscopy (SIMS). A significant P dose loss was estimated, especially in the case of the shallower implant (50 keV), where a dose loss of about 28%, 47% and 54% was calculated for 1 hr, 3hrs and 5hrs annealing respectively. In the case of the deeper implant (150KeV) the corresponding dose loss was 3%, 13% and 14% respectively (Fig. 9). The P dose loss can be attributed to substrate evaporation. In the present case of the low dose P implantation and for both implantation energies examined, the dopant dose loss is accompanied by insignificant diffusion indicating that the evaporation process does not induce defects into the substrate that could influence dopant diffusion.

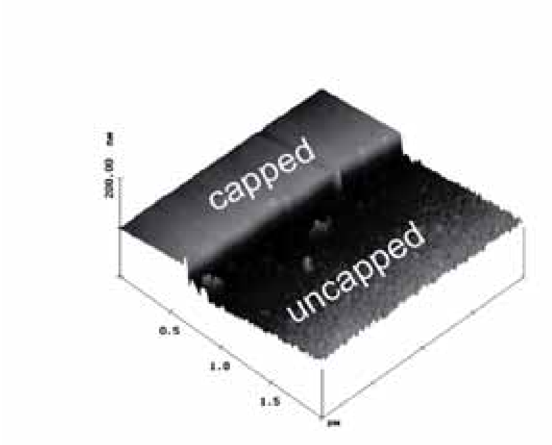


Fig. 8: AFM picture of a Ge sample annealed for 2 hrs at 500 °C showing a step between covered and uncovered area.

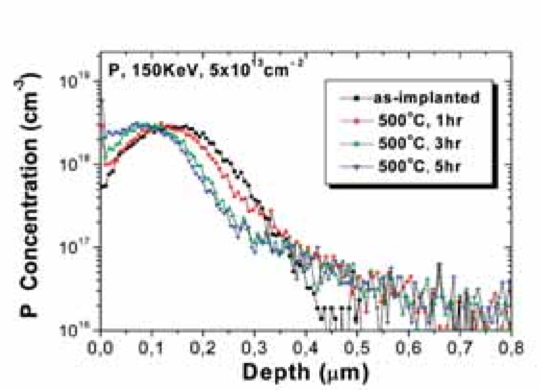


Fig. 9: Phosphorous profiles for uncapped Ge, implanted with a dose of $5x10^{13}$ cm^{-2} and energy 150 keV after annealing at 500 °C for various times.

PROJECT OUTPUT in 2007

Publications in International Journals and Reviews

1 "Modeling of low energy-high dose arsenic diffusion in silicon in the presence of clustering-induced interstitial generation", D. Skarlatos and C. Tsamis, J. Appl. Physics, Vol. 102, Issue 4, Ar. No. 043532 (2007)
2. "Atomic scale simulations of donor-Vacancy pairs in germanium", A. Chroneos, R. Grimes and C. Tsamis, J. of Materials Science: Materials in Electronics 18 (7), pp. 763-768 (2007)
3. "Influence of thermal processing on the electrical characteristics of MOS capacitors on strained-Silicon substrates", N. Kelaidis, V. Ioannou-Sougleridis, D. Skarlatos, C. Tsamis, C. A. Krontiras, S. N. Georga, B. Kellerman and M. Seacrist., To appear in Thin Solid Films
4. "Simulation of the electrical characteristics of MOS capacitors on strained-Silicon substrates", N. Kelaidis, D. Skarlatos and C. Tsamis, Submitted at Physica Statis Solidi (a)

Conference Proceedings

1. "Study of interfacial phenomena in oxidized strained – Silicon", N. Kelaidis, V. Ioannou-Sougleridis, D. Skarlatos, C. Tsamis, J. Parthenios, C. Papaggelis, C. Galiotis, B. Kellerman and M. Seacrist, Proceedings of the 8th International Conference on Ultimate Integration on Silicon (ULIS), pp. 141-144, 15-16 March 2007, Leuven, Belgium

Conference Presentations

1. "Study of interfacial phenomena in oxidized strained – Silicon", N. Kelaidis, V. Ioannou-Sougleridis, D. Skarlatos, C. Tsamis, J. Parthenios, C. Papaggelis, C. Galiotis, B. Kellerman and M. Seacrist, 8th International Conference on Ultimate Integration on Silicon (ULIS), 15-16 March 2007, Leuven, Belgium (Poster)
2. "Influence of thermal processing on the electrical characteristics of MOS Capacitors on strained-silicon substrates", N. Kelaidis, V. Ioannou-Sougleridis, D. Skarlatos, C. Tsamis, C.A. Krontiras, S. N. Georga, B. Kellerman and M. Seacrist, International Conference on Silicon Epitaxy and Heterostructures, May 20 - 25, 2007, Marseille, France (Poster)
3. "Simulation of the electrical characteristics of MOS Capacitors on strained-silicon substrates", N. Kelaidis, D. Skarlatos and C. Tsamis, Third Conference on Microelectronics, Microsystems, Nanotechnology, MMN 2007, 18-21 November 2007, Athens, Greece (Poster)

Purchase of new equipment

- Software for Process and Device modelling (Synopsys TCAD Tools 2007)

THIN FILMS by CHEMICAL VAPOR DEPOSITION (CVD)

Project leader: D. Davazoglou
PhD students: G. Papadimitropoulos
Master students: L. Zambelis (Master Programme: Microsystems)
Undergraduate students: M. Delihas, G. Aspiotis
Collaborating scientists: Dr. M. Vasilopoulou, Dr. T. Speliotis, Dr. D, Kouvatsos, N. Vourdas

Objectives:
The objectives of this group include research and development in the following:
a) Process and material development
b) Characterization of CVD films
c) Applications

Funding:
- Copper nano-electrodes and novel transistors based on tungsten oxides nano-rods CONECTOR
- Optical Smoke Detectors (PAVET)

EXAMPLES OF RESEARCH RESULTS IN 2007

A. Metal-Organic Hot-Wire Chemical Vapor Deposition (MOHWCVD) of Cu films
G. Papadimitropoulos

Copper films were deposited on Si substrates covered with W, TiN and SiLK® using a novel chemical vapor deposition reactor in which reactions were assisted by a heated tungsten filament (hot-wire CVD, HWCVD). Liquid at room temperature hexafluoroacetylacetonate Cu(I) trimethylvinylsilane (CupraSelect®) was directly injected into the reactor with the aid of a direct-liquid injection system using N2 as carrier gas. The deposition rates of HWCVD Cu films obtained on W and TiN covered substrates were found to increase with filament temperature (65 and 170 °C were tested) as seen in Fig. 1. Moreover, high quality Cu films were deposited on SiLK®, which cannot be done by conventional thermal CVD (see Fig.s 2 and 3).

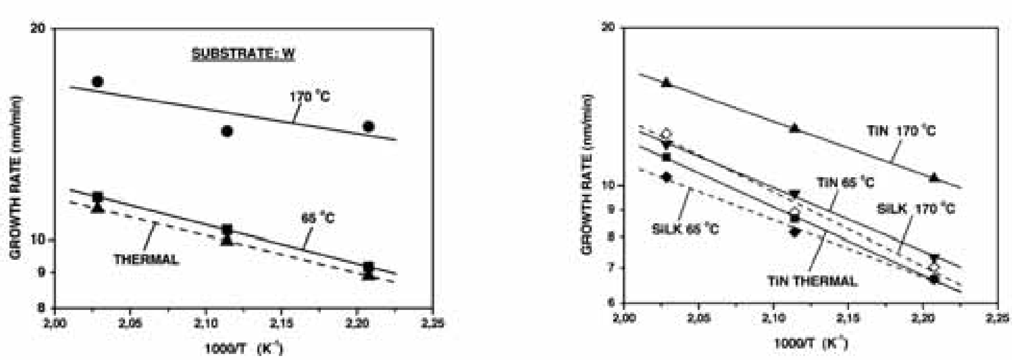


Fig. 1: (Left) Growth rate dependence on substrate temperature for HWCVD Cu films deposited on W-covered Si substrates (left) and on TiN and SiLK®-covered Si substrates **(right)**. The corresponding dependences for thermally grown films are also reported in figure.

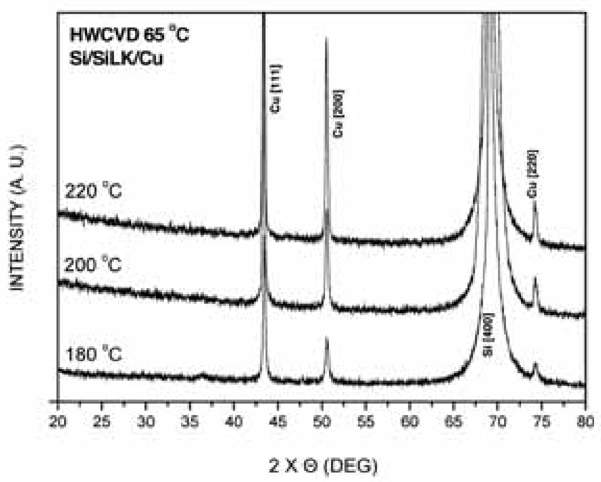


Fig. 2: XRD patterns recorded on HWCVD Cu films deposited on SiLK® at various substrate temperatures. Peaks corresponding to Cu only are observed.

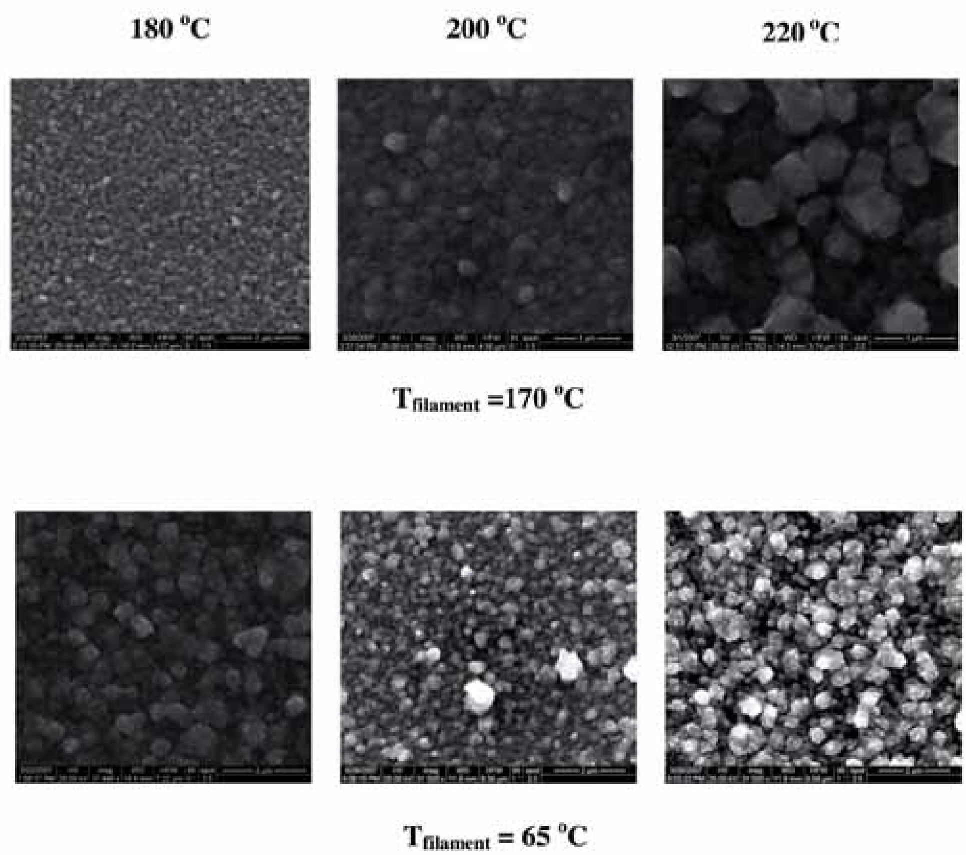


Fig. 3: SEM micrographs taken on the surface of HWCVD Cu films deposited on SiLK®-covered Si substrates at various filament and substrate temperatures (please note the changes in scale).

Independent of the nature of the substrate, resistivities of HWCVD Cu films were higher than for thermally grown films (see Fig. 4) due to carbon and oxygen contamination resulting from the incomplete dissociation of the precursor (see Fig. 5).

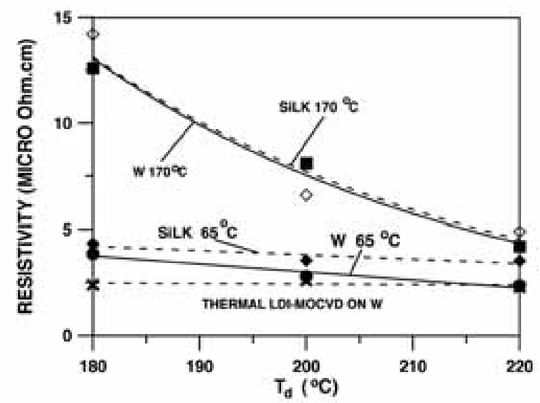


Fig. 4: Dependence of the Cu film resistivity on the temperature of deposition for HWCVD and thermal CVD films deposited on W and SiLK® substrates. Resistivities for films grown on TiN were always slightly lower than those for W

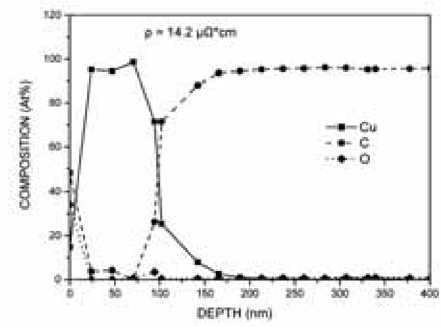


Fig. 5: Compositional depth profile of a 150 nm thick HWCVD Cu sample deposited on SiLK®.

W impurities were detected in the HWCVD Cu films confined near the interface Cu film/substrate due to the presence of the filament. Their presence does not, however, degrade catastrophically film conductivity.

B. Colloidal Lithography

L. Zambelis

Monodispersed spheres of submicrons to microns in size can readily self-assemble into highly ordered and close-packed arrays, so-called colloidal crystals. By using the ordered interstitial arrays within colloidal crystals as masks, one can succeed in sculpturing hexagonal arrays of monodisperse nanoparticles with the shape of a pyramid, ring, or rod on planar substrates, paving a colloidal lithography way. This enables rather facile and cheap fabrication of periodic nanostructures over large areas as compared to conventional lithography. In Fig. 6 arrays of hexagonally arranged Cu nano-dots with dimensions of 65 (left) and 50 nm (right) are shown. These arrays can be used as templates for the subsequent chemical vapor deposition of other materials (see next section).

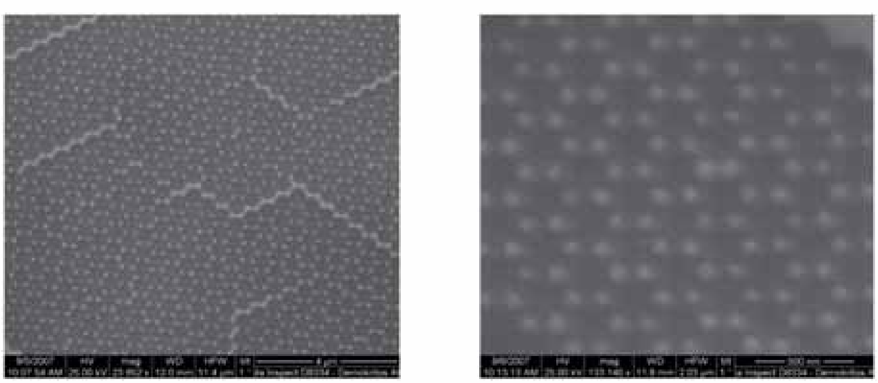


Fig. 6: (Left) SEM image of hexagonally arranged Cu nano-dots with dimensions of 65 nm obtained using PS spheres with diameter of 500 nm. **(Right)** a periodic arrangement of Cu nano-dots obtained using PS spheres with diameter of 280 nm. The dimensions of Cu dots are near 50 nm.

C. Selective CVD of Vanadium oxide films

L. Zambelis

Vanadium oxide films were selectively deposited on Cu by atmospheric pressure chemically vapor deposition (APCVD) by oxidizing Vanadium (V) tri-i-propoxy oxide ($OV(OC_3H_7)_3$) vapors with water vapor. Depositions were carried out at atmospheric pressure and at temperatures varying between 135 and 175 °C and were selectively made on Si substrates on which Cu nano-patterns, such as those seen in Fig. 6 were formed. In Fig. 7 to 9 the effect of the deposition temperature on the selectivity is shown. It is observed that this improves as the deposition temperature increases

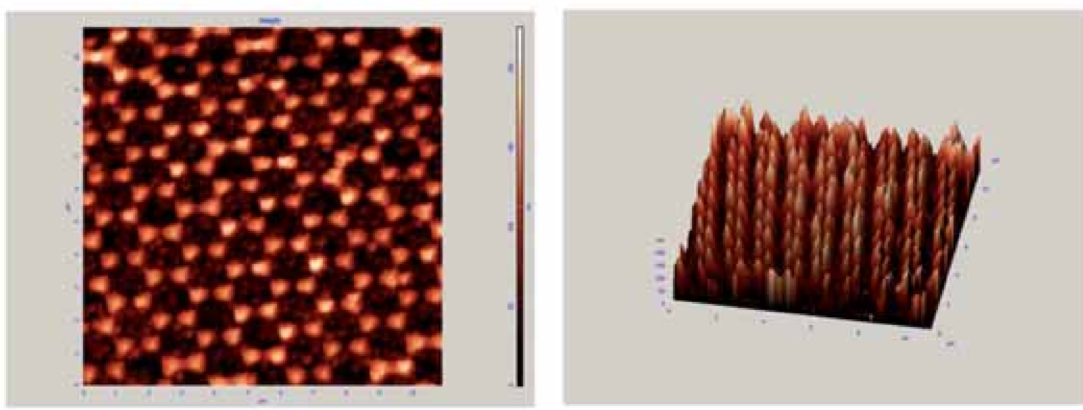


Fig. 7: Selective chemical vapour deposition of VO_x on hexagonally arranged Cu nano-dots (as shown in Fig. 6) with dimensions of 500 nm deposited at 135 °C. Most of the deposition occurs on the Cu dots but some deposition is also observed between them.

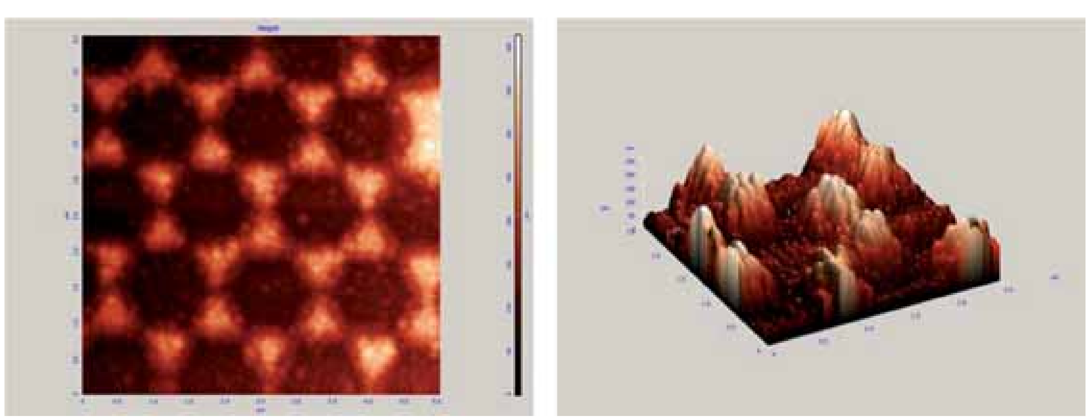


Fig. 8: Selective chemical vapour deposition of VOx on Cu nano-dots at 150 °C. Some deposition is observed on the substrate between the Cu dots.

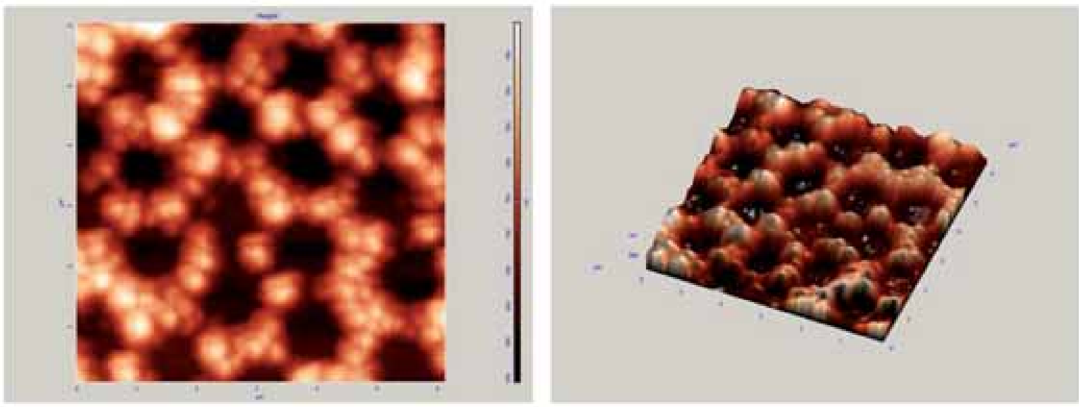


Fig. 9: At deposition temperature of 175 °C the growth rate is very fast. The height of the features shown is approximately 1 μm. The selectivity of deposition is impressive since no deposition occurs between dots is spite of the fact that the maximum distance between them is 500 nm.

PROJECT OUTPUT in 2007

Publications in International Journals and Reviews

1. “Copper metallization based on direct-liquid-injection hot-wire CVD”, G. Papadimitropoulos, D. Davazoglou Microelectronic Engineering 84 1148–1151 (2007).
2. “Hot-wire assisted chemical vapor deposition of Cu by direct-liquid-injection of CupraSelect”, G. Papadimitropoulos, D. Davazoglou Surface & Coatings Technology 201, 8935 (2007)
3. “Selective chemical vapor deposition of vanadium oxides by of Vanadium tri-i-propoxy oxide vapors”, L. Kritikos, L. Zambelis, G. Papadimitropoulos and D. Davazoglou Surface & Coatings Technology 201, 9334 (2007)
4. “Copper films deposited by hot-wire chemical vapor deposition and direct-liquid-injection of CupraSelect”, G. Papadimitropoulos and D. Davazoglou Chemical Vapor Deposition 13, 656 (2007)

Publications in Conference Proceedings

1. “Mirrors based on tal reflection for concentration PV panels”, E. Karvelas, A. Papadopoulos, D. Dousis Y. P. Markopoulos E. Mathioulakis, G. Panaras, V. Vamvakas and D. Davazoglou, 4Th International Conference on Solar Concentrators for the Generation of Electricity or Hydrogen, San Lorenzo de El Escorial, Spain, March 12-16, 2007.
2. “Crystalline Silicon solar cell design optimized for concentrator applications”, K. Kotsovos, V. Vamvakas, D. Davazoglou, K. Misiakos, V. Paschos and E. Skouras, 4Th International Conference on Solar Concentrators for the Generation of Electricity or Hydrogen, San Lorenzo de El Escorial, Spain, March 12-16, 2007.

Conference Presentations Conference Presentations

1. “Hot-wire assisted chemical vapor deposition of Cu by direct-liquid-injection of CupraSelect”, G. Papadimitropoulos, D. Davazoglou Proceedings of the 16th European Conference on Chemical Vapor Deposition EUROCVD-16, The Hague, The Netherlandsm September 16-21 (2007)
2. “Selective chemical vapor deposition of vanadium oxides by of Vanadium tri-i-propoxy oxide vapors”, L. Kritikos, L. Zambelis, G. Papadimitropoulos and D. Davazoglou Proceedings of the 16th European Conference on Chemical Vapor Deposition EUROCVD-16, The Hague, The Netherlandsm September 16-21 (2007)

Conference Participation

1. EUROCVD-16 The Hague, The Netherlandsm September 16-21 (2007)

NANOSTRUCTURES FOR NANOELECTRONICS, PHOTONICS AND SENSORS

Project leader: A. G. Nassiopoulou

Other key researchers: H. Contopanagos, S. Gardelis and N. Papanikolaou

Post-doctoral: M. Theodoropoulou

Phd students: V. Gianneta, F. Zacharatos, A. Petropoulos

Collaborating researchers: N. Frangis (University of Thessaloniki), A. Othonos (University of Cyprus), S. Kennou (University of Patras), G. Kaltsas (TEI of Athens)

Funding:

- EU IST NoE SINANO, 1/1/2004-31/12/2006, Contract N°: 506844
- EU IST NoE MINA-EAST, 1/5/2004-30/4/2006, Contract N°: 510470
- EU IST I³ ANNA, 1/12/2006 – 1/12/2010, Contract N°:026134
- EU Marie Curie/"RF on porous", re-integration grant, Contract N⁰ 016142, 29/7/2005-28/7/2007
- Contract with the company Unilever UK, Flow system for Unilever, 1/12/2005-31/5/2007
- Contract with the company ST Microelectronics SA France, RF-on-porous, 30/7/2005-30/7/2008

Research orientation:

- Semiconductor nanostructures: Growth, characterization (electrical, optical, structural), applications
- Porous Si technology for sensors
- Porous anodic alumina thin films for masking and templating applications
- RF isolation by porous silicon micro-plates on a silicon substrate
- Self-assembly of dots and nanowires
- Theory (Ballistic transport in nanostructures, Surface plasmons in thin metallic films, classical molecular dynamics and nanoscale heat transport)

a) Nanostructure growth, characterization and applications

The activity on semiconductor nanostructures started at IMEL at the early nineties and it was conducted within different EU projects, in collaboration with other European groups (Esprit-EOLIS, contract No 7228 (1992-95) Esprit FET SMILE contract No 28741 (1998-2000), IST FORUM FIB contract No 29573 (2001-2004), IST-FP6 NoE SINANO contract No 506844 etc). Worldwide original results were produced, including fabrication of light emitting silicon nanopillars by lithography and anisotropic etching and investigation of their optical and electrical properties, growth of Si nanocrystal superlattices by LPCVD and high temperature oxidation/annealing, with interesting optical properties, fabrication and characterization of LEDs based on Si nanopillars and nanodots, fabrication of Si and Ge nanocrystals embedded in SiO_2 and fabrication and investigation of the corresponding memory structure.

The present focus of research is on self-assembly and ordering of nanostructures and their different applications in nanoelectronics, photonics and sensors. Porous alumina template and masking technology are also developed. Porous alumina ultra-thin films are grown on silicon by electrochemistry.

By appropriately choosing the electrochemical conditions used, pore size and density are monitored. Through-pore silicon nanostucturing follows the pore size and density. Arrays of SiO_2 nanodots on Si are fabricated and characterized. Dot size varies from few nm up to few hundreds of nm.

Another technology under development is the growth of ultra thin porous silicon films by electrochemical dissolution of silicon in the transition regime between porosification and electropolishing. Under appropriate conditions, the obtained films are amorphous with embedded Si nanocrystals of various sizes. Under other conditions, the films are nanocrystalline. Their properties are investigated in view of different applications in nanoelectronics and photovoltaics.

The theoretical group focuses on the investigation of ballistic transport in nanostructures,surface plasmons in thin metallic films, classical molecular dynamics and nanoscale heat transport.

b) Porous silicon technology for sensors

An important effort has been devoted the last years within the group in developing materials and enabling technologies for application in sensors. One such material platform with important potential for applications in different sensor devices, microfluidics, lab-on-chip, integration of passives on silicon etc, is porous silicon technology.

Either mesoporous or nanoporous/macroporous silicon are grown. Mesoporous silicon is nanostructured and appropriate for use as micro-plate for local thermal or electrical (dc, RF) isolation on a silicon substrate. Nanoporous Si is also used in the above, after further treatment. Macroporous silicon is developed for use in via technology, in device cooling and in particle filtering.

Different technologies based on porous silicon are available at IMEL, including:

- Proprietary micromachining techniques based on the use of porous silicon as a sacrificial layer for the fabrication of free standing membranes, bridges and cantilevers on a silicon substrate
- Technologies using porous silicon for local thermal or for RF isolation on a silicon wafer, or using porous silicon as a matrix for the deposition of catalytic materials for use in chemical sensors

c) RF isolation by porous silicon micro-plates on a silicon substrate

The overall objective of this research is:

- to explore and extend porous silicon technology into the domain of CMOS-compatible integrated RF components and
- to improve the performance of currently integrated analog CMOS components by above technology, and related optimization of design methodologies.

EXAMPLES OF RESEARCH RESULTS IN 2007

A. Successive Layer Charging of Si Nanocrystals in a Double-Nanocrystal-Layer Structure within SiO_2

M. Theodoropoulou, and A. G. Nassiopoulou

Layers of silicon nanocrystals embedded in SiO_2 were fabricated by low-pressure chemical vapor deposition (LPCVD) of α-Si, followed by high temperature thermal oxidation and annealing. The thickness of the amorphous layer as well as the oxidation time are chosen to give the desired thickness of the nanocrystal layer and the top oxide.

By using the above process, double layers of silicon nanocrystals were fabricated within the gate dielectric of a MOS memory structure (Fig.1). This structure is expected to open important new possibilities in multiple bit operation memories.

To investigate the charging properties of the silicon nanocrystal layers, capacitance-voltage (C-V) measurements were performed at 1MHz at room temperature, by applying positive and negative gate pulses of different height and width on the gate. Fig. 2 shows C-V curves of a fresh capacitor (before the application of a gate pulse) and the same capacitor after application of positive or negative gate pulses. When a positive or a negative gate pulse is applied, a positive or negative shift in the flatband voltage of the MIS structure is obtained, indicative of charging the silicon nanocrystal layers with electrons (holes) respectively from the Si substrate. Fig. 3 shows the flatband voltage shift ΔV_{FB} as a function of the applied positive or negative gate pulse height. We clearly distinguish distinct steps in the curves, that correspond to the successive charging of the first and second nanocrystal layer respectively. Full charging of the first layer occurred at ±3V (shift in flat band voltage: ± 0.5 V), while of the second layer at end voltages of ±8V (positive shift: 2.1V, negative shift: -2.8V). Retention measurements show improved charge retention compared to a single-dot layer structure.

The above results are very promising for application of the structure in multi-bit memory devices.

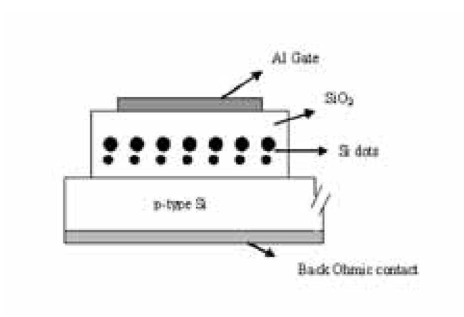


Fig. 1: 2-NC-layer MIS structure

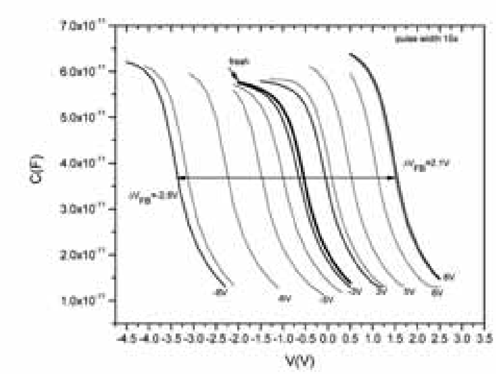


Fig. 2: Capacitance-Voltage (C-V) curves from a structure with embedded NCs showing successive charging by electrons (positive shift) or holes (negative shift), injected from the substrate under pulse application

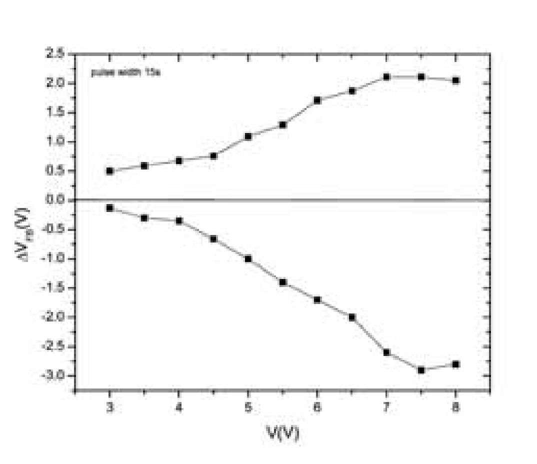


Fig. 3: ΔV_{FB} as a function of voltage for the double-NC-layer structure

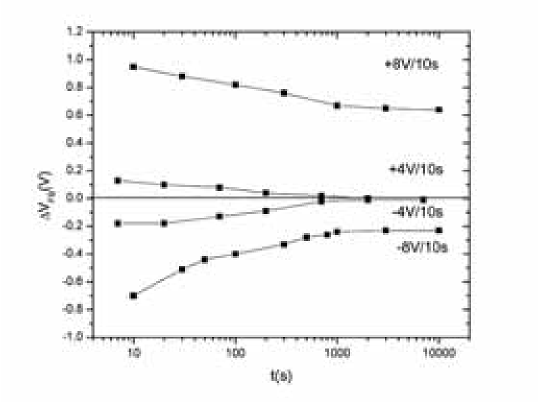


Fig. 4: Charge retention as a function of time of the first NC layer (charged by pulses at ±4V/10s pulse) and second NC layer, charged by pulses at ±8V/10s

B. Investigation of the structure, topography, chemical composition and optical properties of thin anodic silicon films, grown using short monopulses of current.

S. Gardelis and A.G. Nassiopoulou

In collaboration with N. Frangis from the Physics Depart. of Aristotle Univ. of Thessal. and with S. Kennou of the Depart. of Chemical Engineering, Univ. of Patras and FORTH/ICE-HT[3] 26504 Patras

Very thin (almost 2-dimensional (2-D)) Si nanocrystal layers were grown by anodization of bulk crystalline Si in the transition regime between porous formation and electropolishing. The films were investigated for their structure, morphology, chemical composition and light emitting properties. Two types of films were investigated. Type A was fabricated using low HF (hydrofluoric acid) concentration electrolyte and type B using high HF concentration electrolyte. Both films were grown using the same current density. Atomic force microscopy (AFM) images obtained from the two types of film showed significant difference in their morphology. Both showed a grain-like surface topography (Fig. 5a). Type A was rougher, than type B, showing an average microroughness of about 10 nm, whereas type B showed a much smoother surface morphology with an average microroughness of 1.5-2 nm. From cross-sectional bright field Transmission Electron Microscopy (TEM) images, the thickness of film A was measured at 10 nm and that of film B at 20 nm. This difference in their surface morphology and thickness was consistent with the fact that using low HF concentration electrolyte, the surface grows rougher and part of the layer is chemically dissolved in the electrolyte. High resolution TEM (HREM) images showed, in both films, Si nanocrystals embedded in an amorphous matrix (Fig. 5b). However, the nanocrystals in film B were on average smaller than in film A. Using X-ray and Ultra-violet photoelectron spectroscopies (XPS, UPS) we were able to monitor the oxidation levels at the outer surface and the internal surface of the films, revealed after sputtering (Fig. 6a). Using this information, we found that both types of films were porous and, most interestingly, film B at its outermost surface was composed of very tiny Si nanocrystals smaller than those in the internal surface. However, in film A Si nanocrystals were more uniform in depth regarding their size and generally larger than those in film B. Film B was light emitting, whereas film A was not, as it contained larger Si nanocrystals than film B. Detailed temperature dependent photoluminescence (PL) and time-resolved PL measurements showed that the light emission was due to exciton recombination in the Si nanocrystals with sizes less than 3 nm (Fig. 6b).

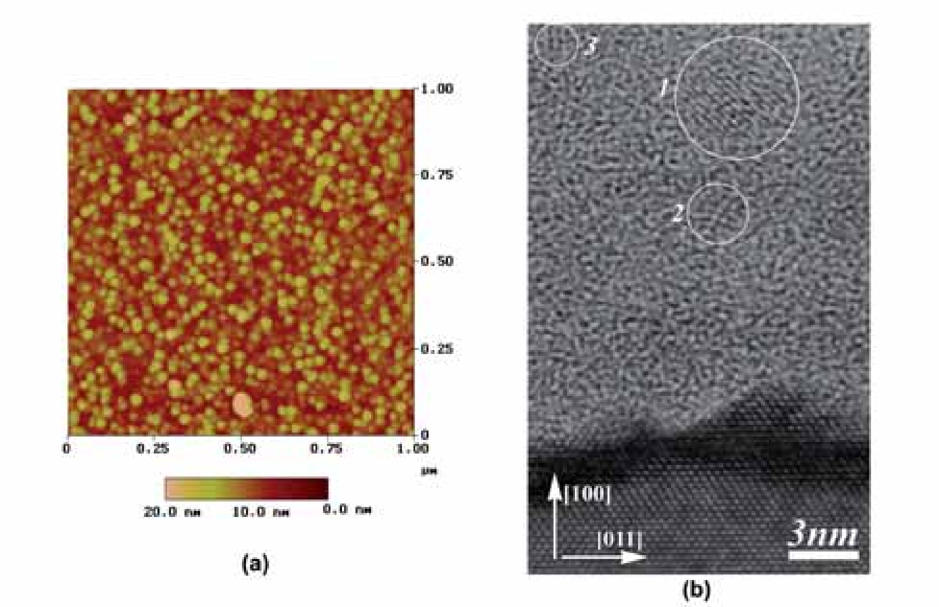


Fig. 5: (a) AFM image showing the surface morphology of film A. **(b)** HREM image obtained from film A, showing Si nanocrystals (encircled) embedded in an amorphous matrix.

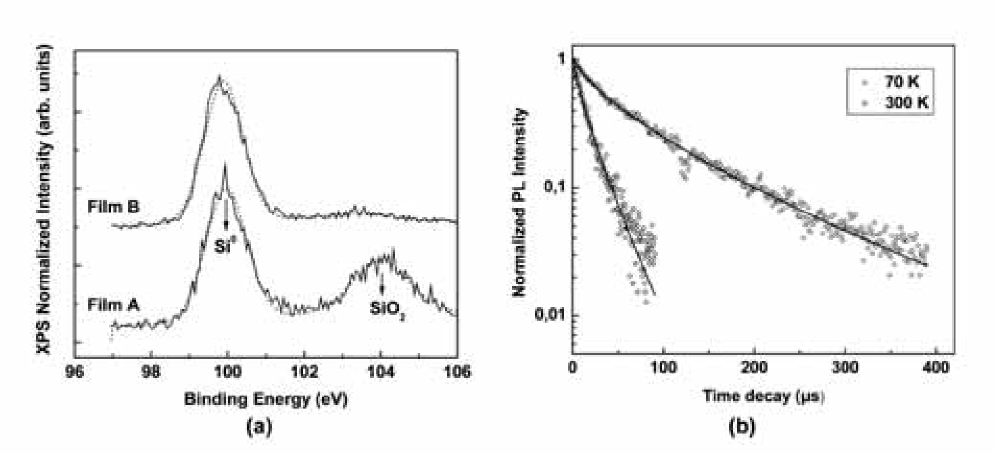


Fig. 6: (a) Si-2p core level XPS spectra obtained from films A and B. The two spectra show the oxidation condition of the outermost surface of the two films. In film A the oxide layer is much thicker than that in film B. **(b)** PL time decay curves obtained at 70 K and 300 K. Both follow the stretched exponential law which characterizes disordered systems.

C. Fabrication of porous anodic alumina on pre-selected areas on a Si substrate.

V. Gianneta and A. G. Nassiopoulou

Porous anodic alumina is a very interesting material because of the spontaneous formation of self organized arrays of pores under appropriate electrochemical conditions. Within this activity the electrochemical fabrication of porous anodic alumina (PAA) thin films on selected areas on Si substrate was developed. This is achieved by anodizing pre-patterneed aluminum thin films on Si. The aluminum films are anodized at various electrochemical conditions. It is shown that the confinement of the porous alumina membrane influences the ordering and the size of the thin porous alumina structure. The PAA films on pre-selected areas are appropriate for use as templates for growing metal or semiconductor nanowires or nanodots therein, for several applications in nanoelectronics, photonics and sensors.

Fig.7 shows a typical SEM image of the surface of porous anodic alumina thin films grown on the whole Si surface (a) and on confined areas on Si (b) in planar view (a1, a2) and in cross section (b1, b2) .

The size of the pores varied from 10 to 140 nm in diameter and 30 to 900 nm in height, depending on the electrochemical conditions used.

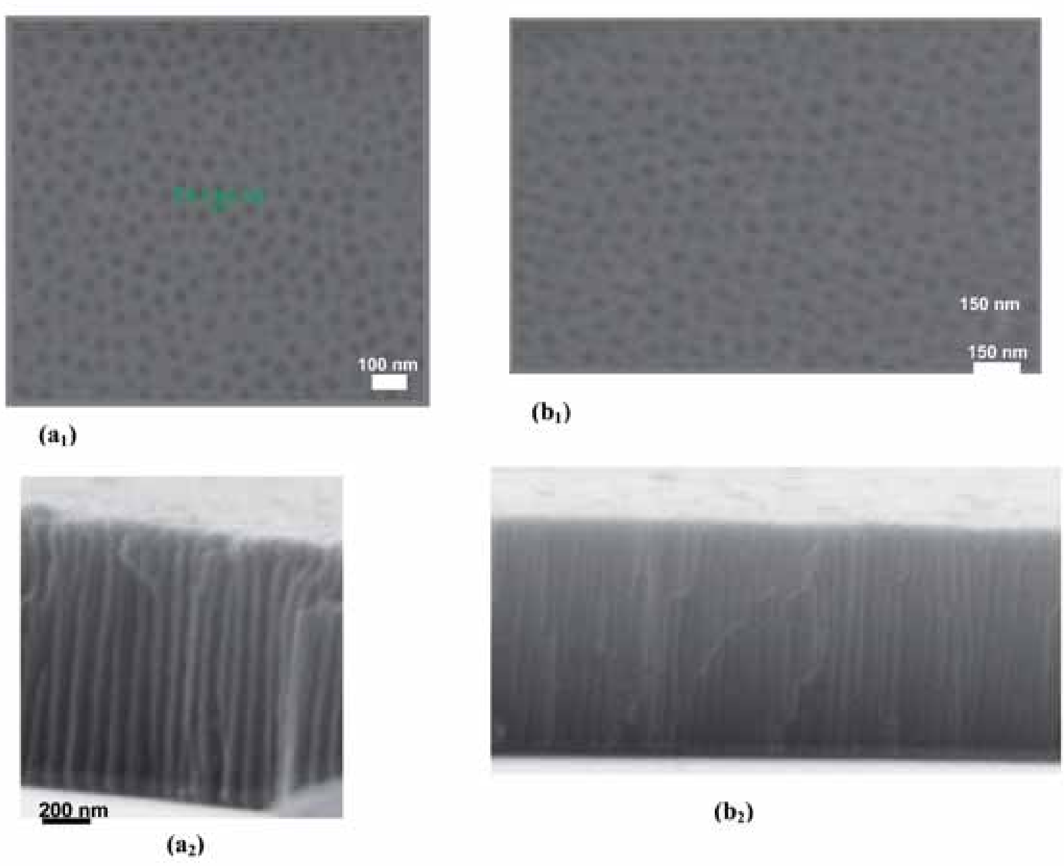


Fig. 7: SEM images of porous anodic alumina fabricated by anodization of Al thin films on the whole Si surface (a) and on confined areas on Si (b). The pore diameter in the first case (Fig 1a) is 55 nm and in (b) (Fig 1b) is 33 nm for the same electrolytic conditions.

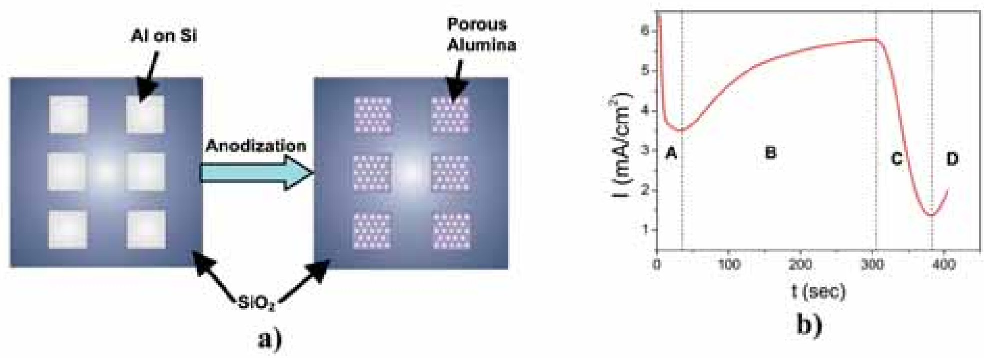


Fig. 8: (a) Schematic representation of the fabrication process of porous anodic alumina thin films on pre-selected areas on Si **(b)** typical curve of current density versus time during anodization of Al films.

Fig. 9 shows Ti dots fabricated on Si by sputtering of Ti thin film into a porous alumina thin film, used as template is presented. The image shows Ti dots after dissolution of the alumina template.

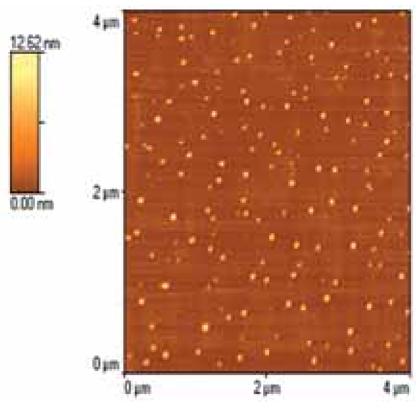


Fig. 9.: (a) AFM image of Ti dots and nanopillars on a Si substrate

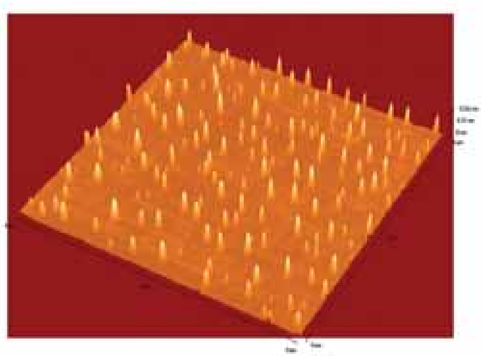


Fig. 9.: (b) AFM 3D image of Ti dots and nanopillars on a Si substrate

Fig. 10 presents a similar sample of figs 9 sample, in which electrodeposition of Au ions on Ti dots took place.

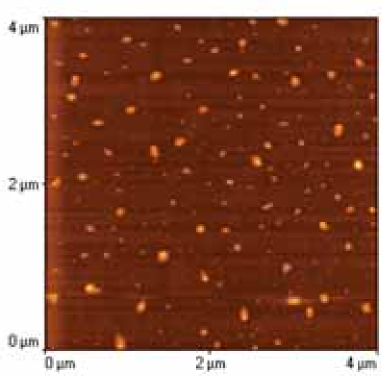


Fig. 10: (a) AFM 2-D image of Au/Ti nanodots electrodeposited on Si using anodic porous alumina template technology

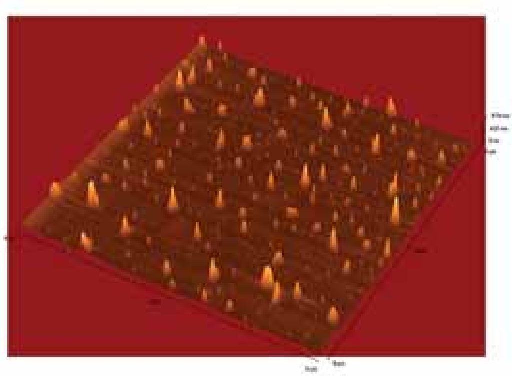


Fig. 10: (b) AFM 3D image of Au/Ti nanodots electrodeposited on Si using anodic porous alumina template technology

D. Patterning of Si substrates using porous-anodic-alumina-on-Si masking technology

F. Zacharatos, V. Gianneta and A. G. Nassiopoulou

Nano- and macroporous Si is a material grown on Si by electrochemistry. Under appropriate conditions the material shows vertical cylindrical pores. In order to introduce ordering in pore formation, pre-patterning of the Si surface is needed. We developed a Si pre-patterning technique using anodically grown porous anodic alumina films on Si as masking layers. p^+-type (100) Si wafers were used. The pores were arranged in a hexagonal close-packed structure, following the ordering of alumina pores. Pore initiation pits on Si were formed through the alumina template by HF anodic etching (semi-spherical pits) or by TMAH chemical etching (inverted pyramids), see Figs.11a,b.r

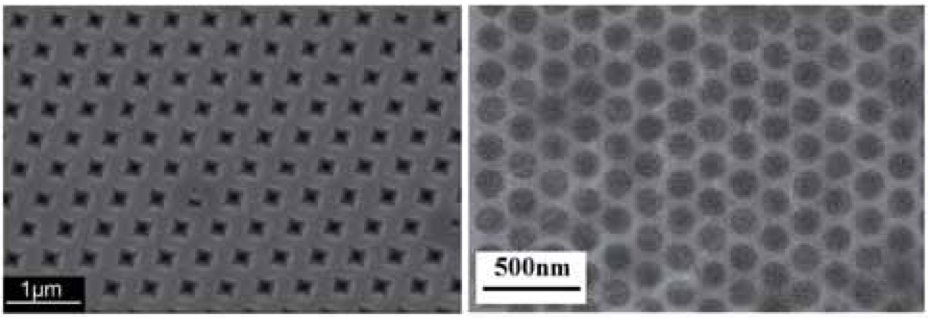


Fig. 11: SEM images of hexagonally ordered inverted pyramids **(a)** fabricated through PAA membrane by wet etching in a TMAH solution 25%w.t. at 80°C semispherical pits **(b)** following the arrangement of the PAA pores formed with electrolytic etching in a HF:H_2O:IP solution 3:6:10.

Further electrochemical etching of the pre-patterned samples leads to deep macroporous Si membrane formation with vertical cylindrical pores hexagonally arranged on the Si substrate (Figs. 12a,b). Pore density is controlled by the electrochemical conditions used for the fabrication of the alumina template. Pore size was much smaller than in a structure with randomly distributed pores, fabricated under the same electrochemical conditions. We also observed that in the case of ordered pores the thickness of macropores walls was by a factor of 2 smaller than in the case of non-ordered pores and the structure was in general more closely packed, following pore initiation pits that determine the position of each pore and consequently the pore wall thickness.

The developed process offers high flexibility in the design of photonic crystals based on macro and nanoporous silicon.

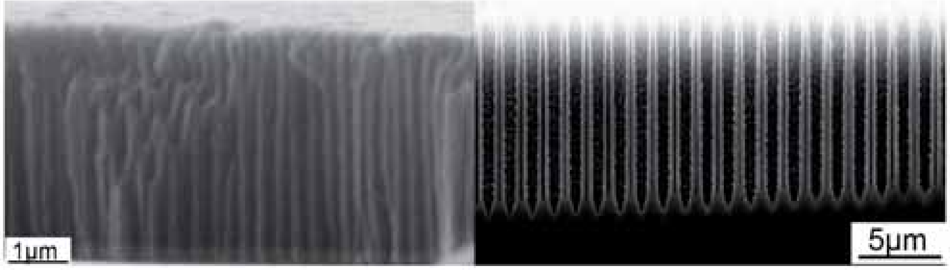


Fig. 12: Cross-sectional SEM images of macroporous Si fabricated by electrochemical etching of pre-patterned Si surfaces as follows: **(a)** Etching of a p+-type substrate in HF:ethanol 4:6 solution in volume. **(b)** Etching of a p-type substrates by electrochemical dissolution in an HF:DMF solution 12:88 in volume.

E. Dielectric characterization of macroporous silicon thick layers for use as capacitors in high voltage applications

M. Theodoropoulou, D. N. Pagonis, A. G. Nassiopoulou
In collaboration with C. A. Krontiras and S. Georga from the University of Patras

Macroporous silicon composed of cylindrical macropores perpendicularly oriented on to the surface was fabricated on selected areas on a P+ silicon substrate (resistivity: 5mOhm.cm) by anodization in HF x Ethanol solution (40%-60% in volume) at a current density of 20 mA/cm^2. The thickness of the macroporous layer was 10μm. The samples were oxidized at high temperature in N_2 ambient in order to form SiO_2 of 20, 40 and 72 nm on pore walls and sample surface. MOS capacitors with Al metallization were then fabricated (Fig.13) and the samples were characterized by dielectric spectroscopy (DS) in the frequency range 1Hz - 1MHz and in the temperature range 173 - 353K. The results reveal that at low temperatures the dielectric constant ε' is independent of frequency (t_{ox}=20nm ε'~ 3.4, t_{ox}=40nm ε'~2.8, t_{ox}=72nm ε'~ 2.6). Above a certain temperature, the dielectric constant increases versus temperature in the low frequency region (Fig.14). This behavior is attributed to the contribution of space charge carriers to the total dielectric response. A theoretical model, which calculates the static dielectric constant of the samples is proposed (Fig.15). The calculated theoretical values are in good agreement with the experimental ones. Dielectric loss data show that the oxidized samples exhibit values of tanδ $<10^{-2}$ in the frequency range used, which are smaller than those of the non-oxidized samples (Fig.16). The obtained results open important perspectives in using oxidized macroporous silicon thick layers in capacitors for high voltage applications.

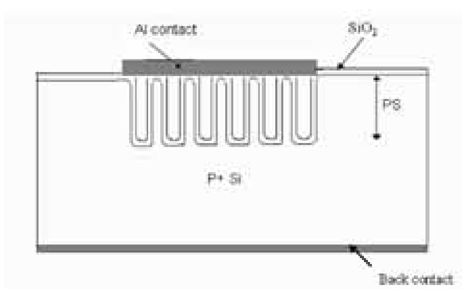


Fig. 13: Macroporous Si film on a Si substrate

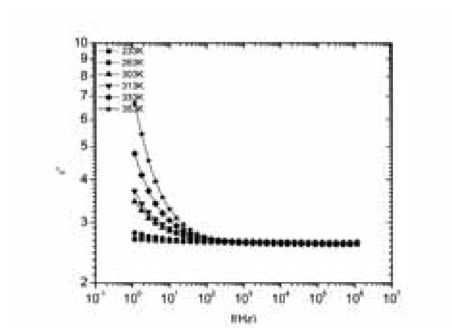


Fig. 14: Dielectric constant ε as a function of frequency at different temperatures

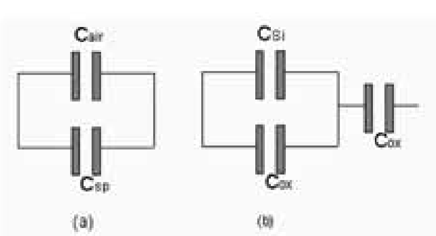


Fig. 15: Equivalent electrical circuit

$$\varepsilon_{MPS} = \varepsilon_{air} P + \varepsilon_{SP} (1-P)$$

$$\varepsilon_{sp} = \varepsilon_{Si} - \left(\frac{2t_{ox}}{t_{Si} + 1.1t_{ox}}\right)(\varepsilon_{Si} - \varepsilon_{ox})$$

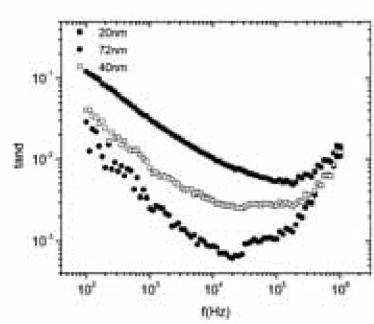


Fig. 16: Loss tangent as a function of frequency for 3 different film thicknesses

F. RF passives integrated on a porous Si microplate on the Si substrate. Porous material characterization at RF

H. Contopanagos, D. Pagonis and A. G. Nassiopoulou

A technology is under development at IMEL for the integration of RF passives on Si. It consists in Fabrication porous Si microplates locally on the Si substrate and integrate the RF passives on them. Porous Si shows very different properties than bulk Si and it appears to show low losses at RF. RF passives and high Q resonators may thus integrated on Si using porous Si as a local substrate. Different forms of porous Si are under investigation and different measuring systems were used. As an example, we will describe below measurements on macroporous Si using a macroscopic microstrip line method and on mesoporous Si using an on-chip coplanar waveguide.

F_1. Complex permittivity extraction of macroporous Si by a macroscopic microstrip line method

In this method, we have fabricated a macroscopic platform consisting of a grounded Roger's Duroid laminate on which coaxial connectors have been directly soldered creating a continuous, gapless ground plane. Then, a free-standing copper microstrip line is permanently soldered on the connectors. A wafer sample is inserted directly underneath the line. A picture of the fabricated macroscopic platform containing the grown sample, and HFSS simulator schematics are shown in Fig. 17.

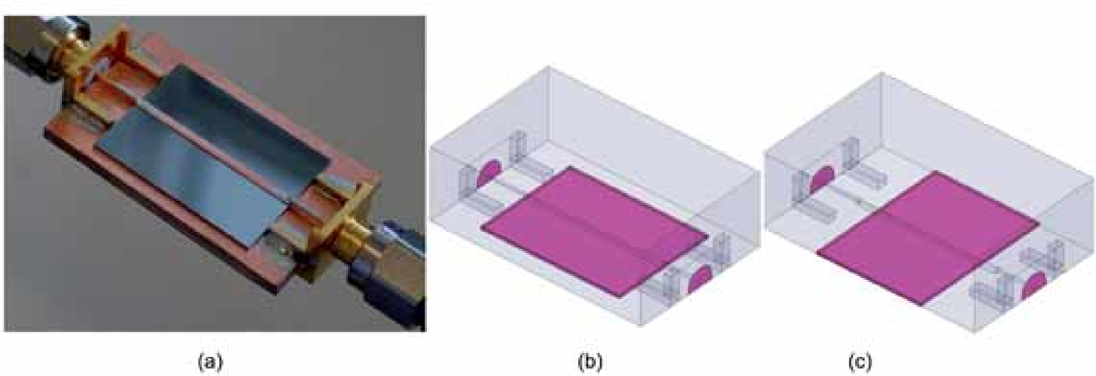


Fig. 17: (a) Macroscopic platform with wafer sample inserted. **(b)** Simulation layout in the b) long and **(c)** short orientation

The method consists of measuring the 2-port S-parameters of the system in a given frequency range using a Vector Network Analyzer. Then, to theoretically simulate the same structure using a full-wave finite elements electromagnetics solver. In the simulations, we have to build exactly the geometry of the measured system, because the sample is not laterally infinite, and the connectors cannot be deembedded, hence analytical formulas pertaining to microstrip lines are inaccurate. We performed a series of simulations varying the unknown complex permittivity of the porous Si layer until the theoretical S-parameters best fit the measured ones. The dimensions of the platform are as follows:

Cu Ground: 30.6mmx20mm

Microstrip Line Ground Clearance: 0.380+(M) 0.015mm

Connector Pin Radius: 0.375mm

Wafer: 20mmx15mmx0.380mm

Cu Microstrip Line: 20.6mmx1mmx0.05mm

Connector Length: 5mm

Connector Pin Ground Clearence: 0.25mm

Porous Si Layer Thickness: 50mm

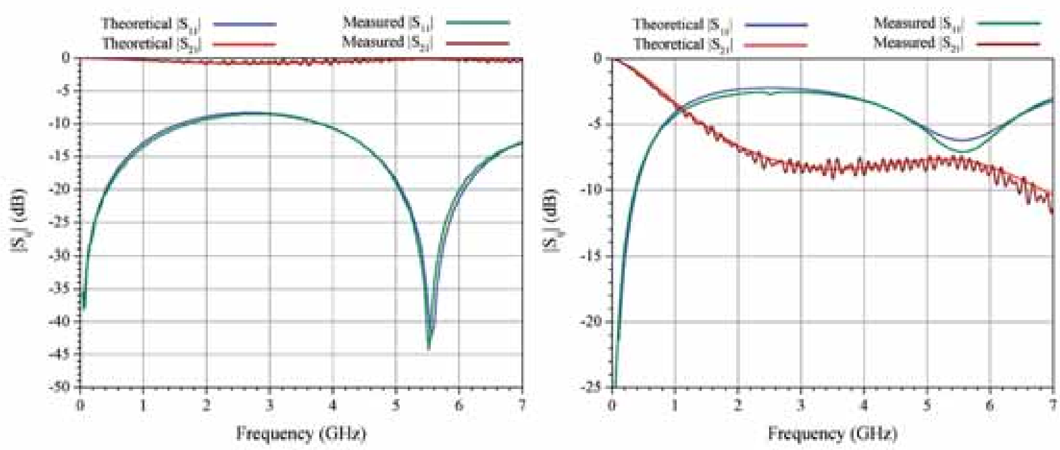


Fig. 18: **(a)** Method validation for air platform. **(b)** Short orientation: 15mm x 20mm

In Fig. 18a we compare theoretical vs measured results for the platform without the sample to validate the accuracy of the simulation and fabrication, to excellent agreement. In Fig. 18b we present an excellent fit between measured S-parameters versus theoretical ones, for a p^+ Si substrate of r = 8 Ω.cm. The extracted complex permittivity of macroporous Si is ε_{psi}=4.9x(1+i0.15).

F_2. RF-shielding of mesoporous Si measured through an on-chip coplanar waveguide

H. Contopanagos, F. Zacharatos and A. G. Nassiopoulou

In this work we have grown mesoporous Si microplates of various thicknesses, and have measured the corresponding losses within a broad range of frequencies. We have compared these losses to the corresponding losses when the same measuring platform is fabricated on a bare p-type Si die of r = 8 W.cm, of the kind used in standard CMOS. The measuring platform we have used is shown in Fig. 19 and is now at scales consistent with on-chip passive device fabrication. It consists of an on-chip Coplanar Waveguide (CPW) fabricated on a fixed-thickness Si die using Al metallization. The CPW has been optimized to present a well-matched transmission line to the 50W ports of the measurement set-up, taking into account the anticipated values of the permittivity of the mesoporous Si layer (inspired by the macroscopic measurements presented above). The dimensions for the results presented here are: L=5mm, G=780mm, S=80mm, g=35mm. The total die thickness is 380mm with any combination of porous Si layer thickness, while the Al metallization has a thickness of 0.5mm. The measurement set-up consisted of a Cascade RF prober with 100mm-pitch Ground-Signal-Ground (GSG) RF probes, and an Anritsu DC-40GHz Vector Network Analyzer.

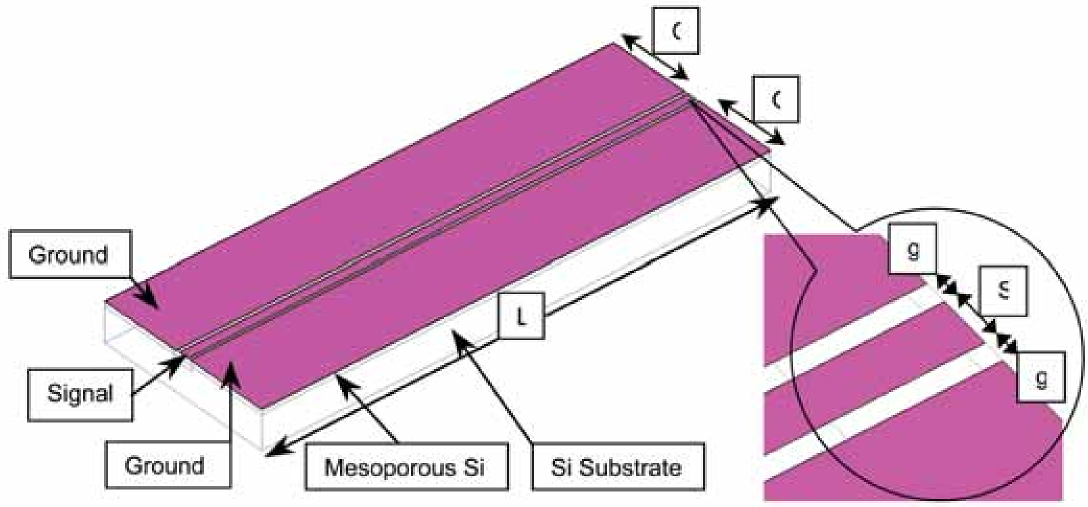


Fig. 19: On-chip CPW platform metallized on a wafer sample

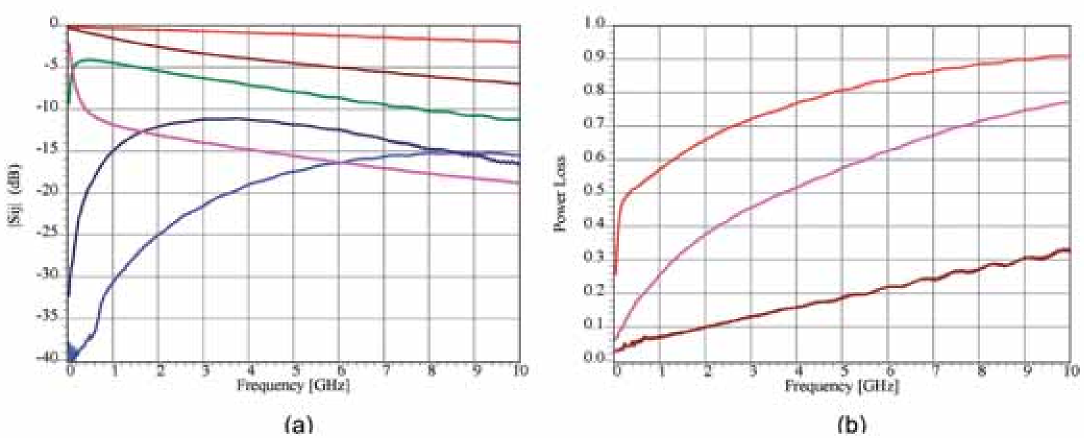


Fig. 20: (a) Measured S-parameters (in dB's) for 3 different dies. Transmittivities ($|S_{21}|$) for: 1 no porous, 2 a 25mm-thick layer of mesoporous Si, 3 a 50 mm-thick mesoporous Si layer; Reflectivities ($|S_{11}|$) for: 4 no porous, 5 25mm -thick layer of mesoporous Si, 6 a 50 mm-thick mesoporous Si layer. **(b)** Measured Power Loss (PL) defined as $PL=1-|S_{11}|^2-|S_{21}|^2$, for: 1 no porous, 2 a 25mm-thick layer of mesoporous Si, 3 a 50 mm-thick mesoporous Si layer.

In fig. 20a we present the measured scattering parameters of 3 identical CPW's fabricated on 3 different dies, all of the same total thickness. We see that without the porous the reflection is not large, even at low frequencies, but the line becomes better matched at higher frequencies. Despite that, the transmission is suppressed even at the DC limit and becomes quite small for increasing frequencies. On the contrary, when the thin porous microplate is introduced, the transmission jumps to substantial values while the reflection becomes very well matched throughout the frequency range (less than -10 dBs), and especially at low frequencies. Finally, with a 50-mm-thick microplate the reflection becomes negligible (below -15 dB's) providing excellent matching, while transmission is quite high. We notice in Fig. 20b that the bare Si die consumes a lot of power, starting at 50% at low frequencies and reaching 70-85% at the important Bluetooth-WLAN range of 2.5-5.5 GHz. The 25mm-thick porous microplate suppresses that loss, but doubling that thickness to 50mm substantially reduces the RF losses to 1/6-1/4 of the corresponding values in a bare, p-type Si die used in standard CMOS. Therefore, this material is excellent for CMOS-compatible integration of passive RF devices.

G. Theoretical investigation of the optical properties of metalodielectric micro and nanostructures

N. Papanikolaou (in collaboration with N. Stefanou from the University of Athens)

Modern nanofabrication methods and lithographic techniques have revealed new possibilities of manipulating light. New, very promising and exciting applications in non linear optics, optical filters, near field imaging and biological sensing, were successfully demonstrated over the last years. In particular the excitation of surface plasmon-polaritons (SP) offers new possibilities since at the resonance frequency the electromagnetic field is focused in subwavelenght volumes with increased intensity.

Plasmon excitations are also responsible for the effect of enhanced transmittance where light passes through optically thick metallic films perforated with a periodic array of holes smaller than the light wavelength. The transmitted intensity is higher than the one predicted for normal diffraction. Similar effects were observed also in films without holes. We have investigated theoretically the effect of enhanced transmittance through Ag films without holes interacting with a periodic array of metallic spheres in close contact. We predicted enhanced transmittance through the film and investigated different parameters influencing the effect.

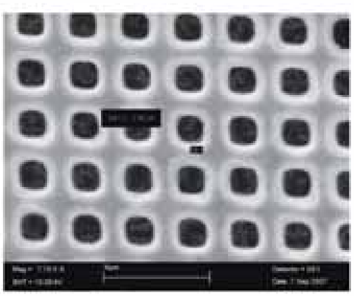


Fig. 21: SEM micro-graph of the structures prepared by optical lithography: A square array of holes on a Si substrate covered with a 100 nm thick Al film. The hole diameter is 2.7 μm and the lattice constant 5μm.

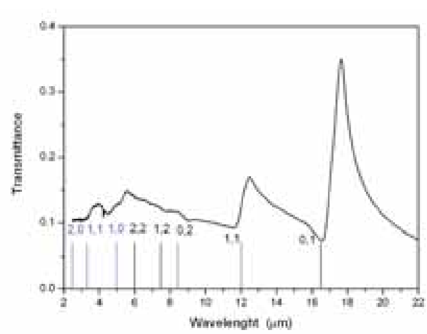
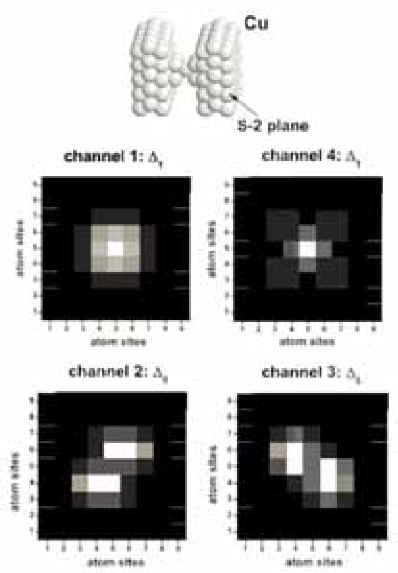


Fig. 22: Transmission spectra of 100nm Al films patterned with a periodic array of square holes (lattice constant a=5 μm, hole diameter d=3.2μm). The film lies on a uniform Si substrate, the horizontal lines denote SP frequencies for Si/Al (black, full lines), and Si/air(blue, dashed lines)

Modern nanofabrication methods and lithographic techniques have revealed new possibilities of manipulating light. New, very promising and exciting applications in non linear optics, optical filters, near field imaging and biological sensing, were successfully demonstrated over the last years. In particular the excitation of surface plasmon-polaritons (SP) offers new possibilities since at the resonance frequency the electromagnetic field is focused in subwavelenght volumes with increased intensity.

Electronic transport in few atom atomic contacts using ab initio electronic structure calculations

Understanding electronic transport in the atomic scale is an important milestone towards molecural electronic devices. The invention of the scanning tunneling microscope in 1981 and a consequent development in the beginning of the 1990s of the remarkably simple experimental technique known as mechanically controllable break junction led to the possibility of fabricating metallic point contacts approaching the atomic scale. In the experiments, the conductance measured as a function of the elongation of the nanocontacts decreases in a stepwise fashion, with steps of order of the conductance quantum $G0=2e^2/h$. Such behavior of the conductance is attributed to atomic rearrangements that entail a discrete variation of the contact diameter. We develop formalism for the evaluation of conduction eigenchannels of atomic-sized contacts from first principles.



Electron probability densities of the four dominating eigenchannels for the pyramidal Cu contact shown on the top. Wave functions resolved to atoms are visualized two atomic planes below the surface plane S-1. Colors from white to black correspond to consequently decreasing positive values. Transmission probabilities of channels are T1=0.90, T2=T3=0.71, and T4=0.08 , which are summed up to conductance G =2.57G0.

The multiple scattering Korringa-Kohn-Rostoker Green's function method is combined with the Kubo linear response theory. Solutions of the eigenvalue problem for the transmission matrix are proven to be identical to eigenchannels introduced by Landauer and Büttiker. Applications of the method are presented by studying ballistic electron transport through different single atom metallic contacts. In the figures we show the decomposition of the conductance in different channels and the spatial distribution of the electron probability in each channel for a Cu contact.

PROJECT OUTPUT IN 2007

LIST OF PUBLICATIONS IN REFEREED JOURNALS

1. "Influence of grain size on ultrafast carrier dynamics in thin nanocrystalline silicon films", E. Lioudakisa, A. Othonos, A. G. Nassiopoulou, Ch. B. Lioutas and N. Frangis, Appl. Phys. Lett. 90, 191114 2007
2. "Ultrafast transient photoinduced absorption in silicon nanocrystals: Coupling of oxygen-related states to quantized sublevels", E. Lioudakisa, A. Othonos, A. G. Nassiopoulou, Appl. Phys. Lett. 90, 171103 2007
3. "Quntum confinement and interface structure of Si nanocrystals of sizes 3-5 nm embedded in α-SiO2" E. Lioudakis, A. Othonos, G. C. Hadjisavvas, P. C. Kelires and A. G. Nassiopoulou" Physica E 38 128-134 (2007)
4. "Charging/discharging kinetics in LPCVD silicon nanocrystal MOS memory structures" V. Turchanikov, A. Nazarov, V. Lysenko, E. Tsoi, A. Salonidou and A. G. Nassiopoulou Physia E 38 89-93 (2007)
5. "Nanostructuring Si surface and Si/SiO2 interface using porous-alumina-on-Si template technology. Electrical characterization of Si/SiO2 interface" M. Kokonou, A. G. Nassiopoulou, Physica E 38, 1-5 (2007)
6. "Fundamental transport processes in assembles of silicon quantum dots" I. Balberg, E. Savir, J. Jedrzejewski, A. G. Nassiopoulou, S. Gardelis, Phys. Rev. B 75 235329 (2007)
7. "Ultrafast transient photoinduced absorption in silicon nanocrystals:Coupling of oxygen-related states to quantized sub-levels" E. Lioudakis, A. Othonos and A. G. Nassiopoulou Appl. Phys. Lett. 90 171103 (2007)
8. "Self-assembly of single thin Au nanoparticle chains on Si along V-groove-etched lines between micrometer-distant electrodes by dielectrophoresis" A. Zoy, A. A. Nassiopoulos and A. G. Nassiopoulou Nanotechnology 18 345608 (2007)
9. "Two-silicon-nanocrystal layer memory structure with improved retention characteristics", A. G. Nassiopoulou and A. Salonidou, J. Nanosci. Nanotechnol., vol. 7, 368-373 (2007)
10. "Ge quantum dot memory structure with laterally ordered highly dense arrays of Ge dots", A. G. Nassiopoulou, A. Olzierski, E. Tsoi, I. Berbezier and A. Karmous, J. Nanosci. Nanotechnol., vol. 7, 316-321 (2007)
11. "The role of surface vibrations and quantum confinement effect to the optical properties of very thin nanocrystalline silicon films", Lioudakis, E., Antoniou, A., Othonos, A., Christofides, C., Nassiopoulou, A.G., Lioutas, Ch.B., Frangis, N., J. of Appl. Physics 102 (8), art. no. 083534 (2007)
12. "Ultra-thin films with embedded Si nanocrystals fabricated by electrochemical dissolution of bulk crystalline Si in the transition regime between porosification and electropolishing", Gardelis, S., Tsiaoussis, I., Frangis, N., Nassiopoulou, A.G., Nanotechnology 18 (11), art. no. 115705 (2007)
13. "Few nanometer thick anodic porous alumina films on silicon with high density of vertical pores", Kokonou M., Giannakopoulos K.P., Nassiopoulou A.G., Thin Solid Films 515(7-8), 3602-3606(2007)
14. "A smart flow measurement system for flow evaluation with multiple signals in different operation modes", G Kaltsas, P Katsikogiannis, P Asimakopoulos, A G Nassiopoulou, Meas. Sci. Technol. 18 (2007) 3617–3624
15. "A silicon thermal accelerometer without solid proof mass using porous silicon thermal isolation" D. Goustouridis, G. Kaltsas and A. G. Nassiopoulou IEEE Sensors Journal, vol. 7 No 7 983 (2007)
16. "Formation of confined macroporous silicon membranes on pre-defined areas on the Si substrate", Pagonis, D.N., Nassiopoulou, A.G., Physica Status Solidi (A) Applications and Materials 204 (5), pp. 1335-1339 (2007)

17. "Novel microfluidic flow sensor based on a microchannel capped by porous silicon", Pagonis, D.N., Petropoulos, A., Kaltsas, G., Nassiopoulou, A.G., Tserepi, A., Physica Status Solidi (A) Applications and Materials 204 (5), pp. 1474-1479 (2007)
18. "Integrated inductors on porous silicon", Contopanagos, H., Nassiopoulou, A.G., Physica Status Solidi (A) Applications and Materials 204 (5), pp. 1454-1458 (2007)

PAPERS IN CONFERENCE PROCEEDINGS

1. "Nanostructuring SiO2/Si(100) surface for lateral ordering of self-assembled semiconductor quantum dots" (invited) A. G. Nassiopoulou and M. Kokonou, Physics, Chemistry and Applications of Nanostructures, World Scientific Publishing, Edited by V E Borisenko, S V Gaponenko and V S Gurin p. 407 (2007)
2. "Structural and light-emitting properties of ultra thin anodic silicon films formed at the early stages of bulk silicon anodization" (invited) S. Gardelis, A. G. Nassiopoulou, I. Tsiaoussis and N. Frangis, Physics, Chemistry and Applications of Nanostructures, World Scientific Publishing, Edited by V E Borisenko, S V Gaponenko and V S Gurin p. 407 (2007)
3. "Spectroscopic characterization of thin anodic silicon layers grown by short monopulses of current", Gardelis, S., Jaziri, S., Nassiopoulou, A.G., AIP Conference Proceedings 935, pp. 87-91 (2007)
4. "A novel microfabrication technology on organic substrates - Application to a thermal flow sensor", G. Kaltsas, A. Petropoulos, K. Tsougeni, D. N. Pagonis, T. Speliotis, E. Gogolides and A. G. Nassiopoulou, Journal of Physics: Conference Series 92 (2007) 012046

CONFERENCE PRESENTATIONS

1. "Nanopatterning the Si Surface Through Porous Anodic Alumina Masking Layers", F. Zacharatos, V. Gianneta, A. G. Nassiopoulou, 3rd International Conference "Micro & Nano" 2007 on Micro-Nanoelectronics, Nanotechnology and MEMs, held at NCSR "Demokritos", 18-21 November 2007
2. "Determination of critical points of nanocrystalline silicon films: the role of grain boundaries in the optical properties", E. Lioudakis, A. Othonos and A. G. Nassiopoulou, 3rd International Conference "Micro & Nano" 2007 on Micro-Nanoelectronics, Nanotechnology and MEMs, held at NCSR "Demokritos", 18-21 November 2007
3. "Monitor the properties of silicon nanocrystals embedded in SiO2 matrix using ultrashort laser pulses", E.Lioudakis, A. Othonos, A. Emporas and A. G. Nassiopoulou, 3rd International Conference "Micro & Nano" 2007 on Micro-Nanoelectronics, Nanotechnology and MEMs, held at NCSR "Demokritos", 18-21 November 2007
4. "Anodic Porous Alumina Thin Films on Si: Interface Characterization", V. Gianneta, S. N. Georga, C. A. Krontiras, A. G Nassiopoulou, 3rd International Conference "Micro & Nano" 2007 on Micro-Nanoelectronics, Nanotechnology and MEMs, held at NCSR "Demokritos", 18-21 November 2007
5. "Auger Recombination in Silicon Nanocrystals", M. Mahdouani, R. Bourguiga, S. Jaziri, S. Gardelis, A.G. Nassiopoulou, 3rd International Conference "Micro & Nano" 2007 on Micro-Nanoelectronics, Nanotechnology & MEMs, held at NCSR "Demokritos", 18-21 November 2007
6. "Assembly and electrical investigation of tiopronin- and citrate-stabilized Au nanoparticle chains between electrodes on patterned oxidized Si substrates under the influence of an electric field", A Zoy and A G Nassiopoulou, 3rd International Conference "Micro & Nano" 2007 on Micro-Nanoelectronics, Nanotechnology and MEMs, held at NCSR "Demokritos", 18-21 November 2007

7. "TEM characterization of ultra-thin nanocrystalline Si films grown on quartz and presenting quantum properties", Ch.B. Lioutas, N. Vouroutzis, I. Tsiaoussis, N. Frangis and A.G. Nassiopoulou, 3rd International Conference "Micro & Nano" 2007 on Micro-Nanoelectronics, Nanotechnology and MEMs, held at NCSR "Demokritos", 18-21 November 2007
8. "Structural study of ultra thin anodic silicon layers for nanoelectronic and photonic applications", S. Gardelis, F. Petraki, S. Kennou, A. G. Nassiopoulou, 3rd International Conference Micro & Nano 2007 on Micro-Nanoelectronics, Nanotechnology and MEMs, held at NCSR "Demokritos", 18-21 November 2007
9. "Broadband Electrical characterization of Porous Silicon at Microwave Frequencies", H. Contopanagos, D. Pagonis, A. G. Nassiopoulou, 3rd International Conf. "Micro & Nano" 2007 on
10. "A thermal vacuum detector fabricated by a combination of MEMS and PCB technologies", A. Petropoulos, G. Kaltsas, A. G. Nassiopoulou, 3rd International Conf. "Micro & Nano" 2007 on Micro-Nanoelectronics, Nanotechnology & MEMs, held at NCSR "Demokritos", 18-21 November 2007
11. "Fabrication and evaluation of a gas flow sensor, implemented on organic substrates by a novel integration technology", A. Petropoulos, G. Kaltsas, A. G. Nassiopoulou, 3rd International Conference "Micro & Nano" 2007 on Micro-Nanoelectronics, Nanotechnology and MEMs, held at NCSR "Demokritos", 18-21 November 2007
12. "Copper Wires in Macroporous Si Template for Microchannel Heat Sink Technology", F. Zacharatos and A. G. Nassiopoulou, 3rd International Conference "Micro & Nano" 2007 on Micro-Nanoelectronics, Nanotechnology and MEMs, held at NCSR "Demokritos", 18-21 November 2007
13. "Dielectric Characterization of Macroporous Silicon Thick Layers For Use As Capacitors In High Voltage Application", M. Theodoropoulou, D. N. Pagonis, A. G. Nassiopoulou, C. A. Krontiras, S. N. Georga, 3rd International Conference "Micro & Nano" 2007 on Micro-Nanoelectronics, Nanotechnology and MEMs, held at NCSR "Demokritos", 18-21 November 2007

INVITED TALKS

1. "Ordering of Si and Ge nanocrystals in 2-D layers for nanodot memory devices", A. G. Nassiopoulou (invited talk), International Conference on Physics, Chemistry and Applications of Nanostructures, Nanomeeting 2007, Belarus, 22-25 May 2007
2 "Structural and light-emitting properties of ultra thin anodic silicon films formed at the early stages of anodization of bulk silicon", S. Gardelis (invited talk), International Conference on Physics, Chemistry and Applications of Nanostructures, Nanomeeting 2007, Belarus, 22-25 May 2007
3. "Self-assembly of Si nanostructures on nanopatterned substrates: Application in nanocrystal memories" (invited talk) A. G. Nassiopoulou, 4th International Workshop on Nanosciences & Nanotechnologies (N&N07), Thessaloniki, 16-18 July 2007
4. "Silicon Nanocrystals embedded in SiO2: Optical and transport properties" A. G. Nassiopoulou (invited talk), 2nd European Optical Society Topical Meeting on Optical Microsystems, Italy, 30 September – 3 October 2007
5. "Characterization of Silicon Nanocrystal non-Volatile Memory Structures with Double Nanocrystal Layers", A. G. Nassiopoulou (invited talk), ANNA-Analytical Network for Nanotech, held at Munich, 29 November 2007
6. "Microelectronics beyond Moore" A. G. Nassiopoulou, (invited talk), Summer Scool NCSR Demokritos, 9-20 July 2007

PhD THESES

1. "Growth and electrical characterization of Au nanowires between electrodes", PhD thesis: Argyro Zoy, Thesis supervisor: Dr A. G. Nassiopoulou, Examination: National Technical University of Athens, 7-9-2007, Examination Committee:
   Assoc. Prof. D. Tsoukalas, NTUA-Athens
   Assoc. Prof. S. Georga, University of Patras,
   Prof. E. Liarokapis, NTUA, Athens
   Dr A. G. Nassiopoulou, Director of Research, IMEL/NCSR Demokritos
   Prof. P. Pissis, NTUA, Athens
   Assoc. Prof. I. S. Raptis, NTUA, Athens

ORGANIZATION OF CONFERENCES, SYMPOSIA, WORKSHOPS

1. 3rd International Conference "Micro & Nano" 2007 on Micro-Nanoelectronics, Nanotechnology and MEMs, held at NCSR “Demokritos”, 18-21 November 2007. Chairperson of the Conference was Dr Androula G. Nassiopoulou
2. 3rd International Conference "Micro & Nano" 2007 on Micro-Nanoelectronics, Nanotechnology and MEMs, held at NCSR “Demokritos”, 18-21 November 2007. Chairperson of the Conference was Dr Androula G. Nassiopoulou

MATERIALS AND DEVICES FOR MEMORY APPLICATIONS

Project leader: P.Normand

Key researchers: P. Normand, V. Ioannou-Sougleridis, P. Dimitrakis

Collaborating Researchers: P. Argitis, N. Glezos

Post-doctorals: E. Kapetanakis, V. Em. Vamvakas

PhD candidate: P. Goupidenis

Objectives:

- Development of high-throughput synthesis routes to create functional dielectrics and nanostructured materials for electronic memory applications.
- Study of the structural and electrical properties of the generated materials and demonstration of material functionality enabling the development of low-voltage high-density memory devices.
- Realization and testing of memory devices and manufacturability assessment of the developed fabrication routes in an industrial environment.

Funding

- NEON, Nanocrystals for Electronic Applications, EU GROWTH GRD1, No 25619
- Bilateral French-Greek Project, Si-Nanocrystal Synthesis by Plasma-Immersion Ion-Implantation for Non-Volatile Memory Applications, EPAN. M.4.3.6.1E.

Activities:

Our research activities in generating and evaluating new materials and structures for memory applications started in 1996 with the development of the low-energy ion-beam-synthesis (LE-IBS) technique. Two-dimensional arrays of Si nanocrystals in thin gate dielectrics were demonstrated and successfully exploited in the fabrication of nanocrystal memories (NCMs). This activity was first supported by the EU project, FASEM (1997-2000). LE-IBS development with target the realization of non-volatile NCMs in an industrial environment has been conducted further within the framework of the EU project, NEON (2001-2004), in collaboration with the US implanter manufacturer Axcelis.

In addition to our LE-IBS-NCM activities, major efforts have been devoted the last five years for examining novel NCMs alternatives including: (a) Memory devices by Si^+ irradiation through poly-Si/SiO_2 gate stack in collaboration with FZR and ZMD AG both sited in Dresden (DE), (b) Memory devices using Ge-NCs produced by MBE in collaboration with Aarhus Univ. (DK), (c) hybrid silicon-organic and SiGe-organic memories in collaboration with Durham Univ. (UK); this last activity was conducted within the framework of the EU IST-FET project, FRACTURE (2001-2003), (d) formation of LE-IBS Ge-NCs in high-k dielectrics in collaboration with CEMES/CNRS (FR), FZR Dresden and CambridgeNanoTech (USA).

In 2007, our main activities focused on the following tasks: (A) Wet oxidation of silicon nitride implanted with low-energy Si ions for ONO memory stacks in collaboration with CEMES/CNRS and MDM-INFM (IT), (B) MOS structures with low-energy Ge-implanted thin gate oxides in collaboration with LETI/CEA (FR), (C) Room-temperature silicon oxidation by high-density helicon plasma reactor, in collaboration with project I.2 and NTUA (GR), (D) Proton radiation tolerance of nanocrystal memories in collaboration with NTUA and, (E) Formation of Si nanocrystals in thin SiO_2 layers by PIII in collaboration with CEMES/CNRS and Ion-Beam-Services (IBS, French SME).

EXAMPLES OF RESEARCH RESULTS IN 2007

A. Wet oxidation of silicon nitride implanted with low-energy Si ions for ONO memory stacks

V. Ioannou-Sougleridis, P. Dimitrakis, V. Em. Vamvakas, P. Normand

Nitride-based memory technology has the potential to fulfill the stringent requirements of non-volatile memory cell downscaling. This technology exploits the presence of discrete charge storage nodes in the form of deep traps distributed in nitride materials. Due to its promising in terms of scalability, the conventional SONOS (poly-Silicon/Oxide/Nitride/Oxide/Silicon) memory cell has today regained a lot of attention. Typical fabrication of the ONO stack consists in the growth of a thin SiO_2 layer on a Si substrate and subsequent deposition of a Si_3N_4 layer. The top silicon oxide is obtained either by deposition techniques or high-temperature wet oxidation of the Si_3N_4 layer. The latter approach has two main advantages. First, the quality of a thermal top oxide is higher in comparison to that of a deposited oxide. Second, during the oxidation step a silicon oxynitride transition layer containing a high density of traps forms between the top oxide and the remaining silicon nitride.

However, fabrication of functional thermal blocking oxides requires high oxidation temperatures (typically within the 1000°C range). For deep-submicron integration purposes, it is important to explore new technological routes that could lead to the formation of a thermal top oxide at lower oxidation temperatures. In this direction, we proposed in collaboration with CEMES/CNRS and MDM-CN-INFM, an alternative method that combines low-energy (1 keV) silicon ion implantation into a thin nitride-oxide (NO) stack and subsequent low-temperature wet oxidation (~850°C). TEM imaging and ToF-SIMS analysis (see Fig.1) show that for an implanted dose of $1.5x10^{16}$ Si cm^{-2}, (1) a 8nm-thick SiO_2 layer develops on the NO surface while in the case of unimplanted NO stack, the SiO_2 thickness does not exceed 3nm, (2) transformation of the implanted silicon nitride to oxygen-rich silicon nitride materials and (3) pilling-up of nitrogen atoms at the Si/SiO_2 interface. The resulting ONO stack exhibits strong charge storage effects and excellent charge retention properties leading to a 1.5 V 10-year extrapolated memory window at 125°C (Fig. 2). These results suggest that this new fabrication route may lead to gate dielectric stacks of substantial impact for mainstream nitride-based memory devices.

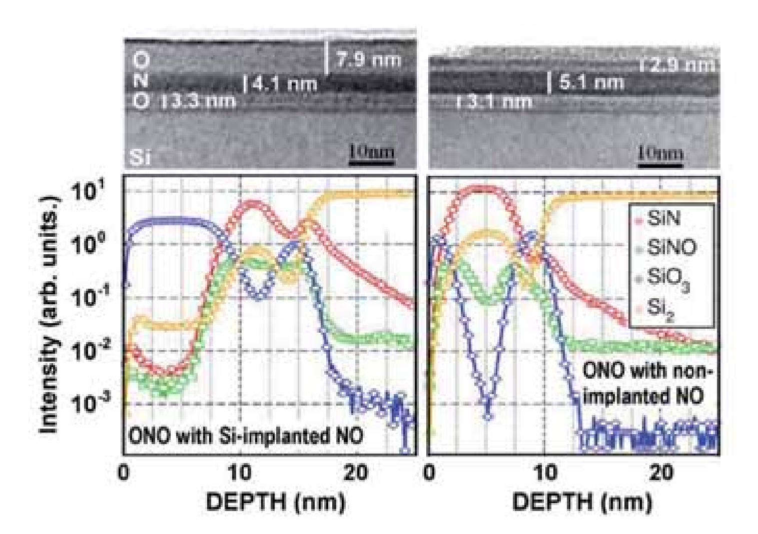


Fig. 1: TEM images and ToF-SIMS depth profiles of wet oxidized Si implanted (left) and non-implanted (right) nitride-oxide stacks.

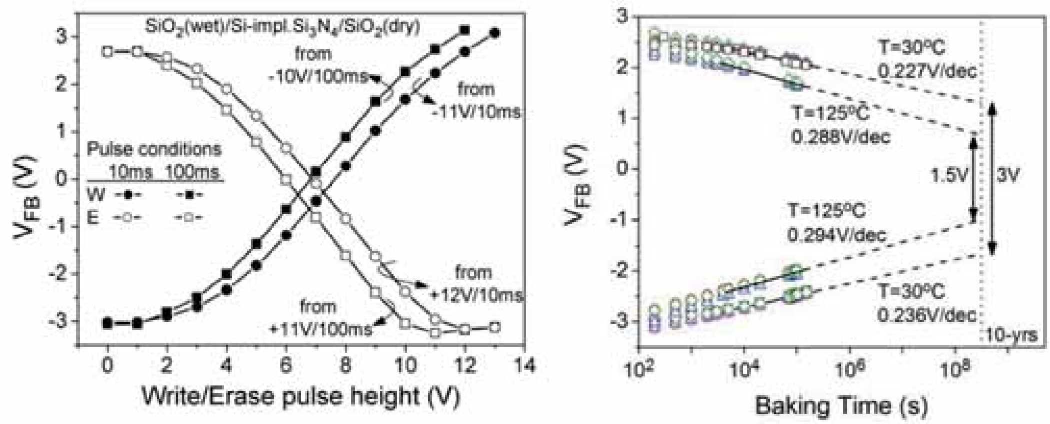


Fig. 2: Write/Erase (left) and charge retention (right) characteristics of ONO capacitors obtained by wet oxidation of Si implanted nitride-oxide stacks.

B. MOS structures with low-energy Ge-implanted thin gate oxides
E. Kapetanakis and P. Normand

During the last few years, part of our research activities was concentrated on the formation of Si nanocrystals in thin oxide layers by low-energy (typically 1keV) ion-beam-synthesis (LE-IBS). Advances in fabrication allowed for overcoming several technological issues and successfully exploit LE-IBS to built low-voltage non-volatile Si-nanocrystal memories. In contrast to Si-implanted oxides, no clear indications of phase separation or other contrast were detected within low-energy (3keV) Ge-implanted and annealed SiO_2 films. In the latter case, phase separation of the implanted material has been observed only under long-time TEM electron irradiation conditions. The latter allowed for concluding that most of the Ge stays distributed within a band instead of forming separate pockets (e.g. in the form of Ge nanocrystals).

This year we focused our efforts on the electrical characteristics of MOS capacitors using 3 keV Ge-implanted and annealed thin gate oxides. Capacitance measurements at flat-band voltage before and after application of constant voltage stress in the accumulation regime indicate that the charge trapping behavior of the devices undergoes a major change after annealing at temperatures higher than 910°C. The latter change was identified as a relocation of Ge atoms mainly towards the upper portion of the oxide with a significant fraction of them leaving the oxide; a finding in harmony with SIMS measurements (Fig. 3) performed at LETI/CEA. The interface trap density (D_{it}) for the thin (9-12 nm) implanted oxides decreases with increasing annealing temperature, approaching at 950°C, the D_{it} levels in the mid-10^{10}eV-1cm^{-2} range of the non-implanted samples.

At elevated annealing temperatures (>1000°C), the device C-V characteristics are substantially disturbed. In this case, the presence of electrically active Ge atoms at an extended depth in the substrate modifies the intrinsic electrical properties of the n-type Si substrate, lending a p-type conductivity character to the device high-frequency C-V curves (Fig. 4). Substrate electrical modification was interpreted through a model that takes into account the formation of a SiO_2/Ge-rich-Si/n-Si system. The SiO_2/Ge-rich-Si interface presents very low D_{it} levels as revealed by conductance loss characteristics. The present study suggests that a combination of Ge implantation into SiO_2 thin films and thermal annealing may be exploited in damage-free SiGe epitaxial growth technology based on Ge implantation.

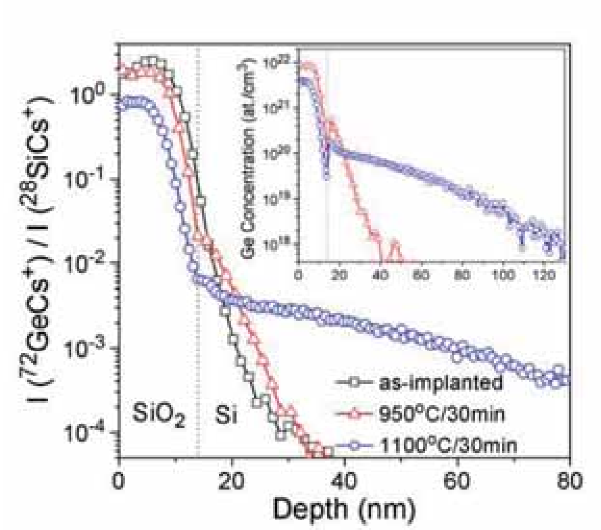


Fig. 3: $^{72}GeCs^{+}$ signals normalized to $^{28}SiCs^{+}$ signals for 12nm-thick SiO_2 films implanted with 3 keV ^{72}Ge ions to a dose of 10^{16} cm^{-2} and annealed at 950 or 1100°C for 30 min. Inset: Extracted Ge concentration profiles for the annealed samples.

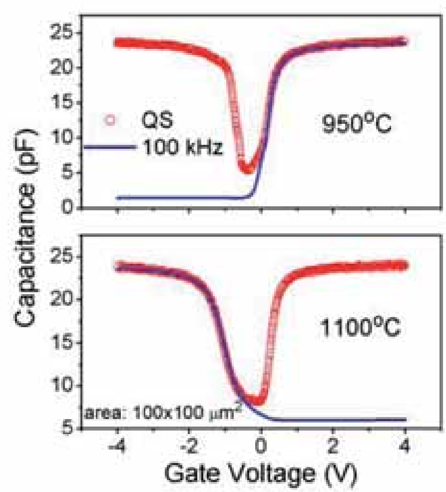


Fig. 4: Quasistatic and high-frequency C-V characteristics of MOS structures with $1x10^{16}$ Ge^{+} cm^{-2} implanted gate SiO_2 of 12nm nominal thickness as a function of post-implantation annealing treatment.

C. Room-temperature silicon oxidation by high-density helicon plasma reactor

M-E. Vlachopoulou, P. Dimitrakis, A. Tserepi, V. Em.Vamvakas, S. Koliopoulou, P. Normand, E. Gogolides, D. Tsoukalas*
*National Technical University of Athens

The physical and technical problems associated with the thermal growth of very thin silicon oxide layers in deep-submicron CMOS technology opened the opportunities either for exploring new dielectric materials or investigating low-thermal budget oxidation processes. In this direction, plasma oxidation (PO) of silicon appears attractive as it offers the rapid growth of an oxide film with good insulating properties at low processing temperatures. In collaboration with people from project I.2, we recently developed a room temperature PO process for producing silicon oxide films thinner than 8nm as gate oxides of MOSFET devices.

Silicon-PO experiments have been carried-out in a high-density helicon plasma reactor utilizing a gas mixture of Ar/O2, with oxygen partial pressure of about 1.5%. Silicon oxide films with a thickness in the 4-7nm range were successfully produced. Oxide thickness increases with plasma exposure time and substrate bias (Fig. 5); thus indicating that oxide growth is an ion-enhanced process. The electrical properties of the PO produced oxides were evaluated using MOS capacitors. Typical high-frequency (1MHz) C-V characteristics of a 7nm-thick oxide layer after forming-gas post-metallization annealing (FG-PMA) are shown in Fig. 6 and compared to those of a thermally grown dry oxide. It should be here emphasized that the FG-PMA improves substantially the quality of the as-grown oxides. PO was utilized to fabricate gate oxides of SOI-MOSFETs. Inset of Fig. 6 shows typical output characteristics of the tested transistors at various front gate voltages (V_{GF}) with back-gate bias V_{GB}=0V. High current and low-leakage can be achieved at saturation regime, indicating good functionality of the plasma gate oxides.

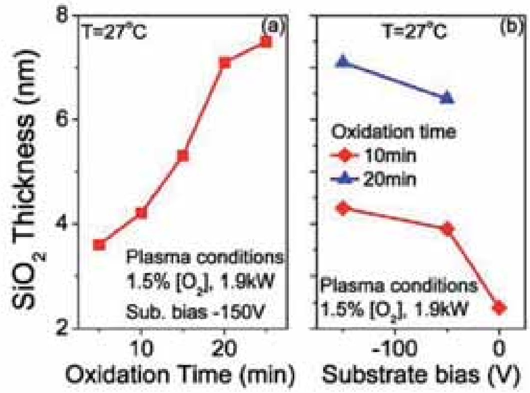


Fig. 5: Plasma oxide thickness as a function of (a) PO time at fixed V_{BS}=-150V and (b) V_{BS} for 10min and 20min PO times.

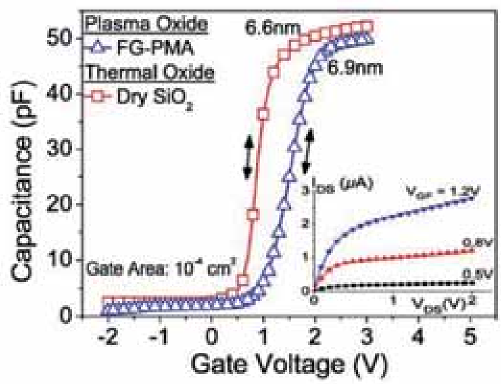


Fig. 6: C-V plots (1MHz) for plasma oxide and thermal oxide MOS capacitors after FG-PMA. Inset: Typical output-characteristics of SOI-MOSFET with 2μm gate length and 10μm gate width using 7nm-thick plasma oxide.

D. Proton radiation tolerance of nanocrystal memories

E. Verrelli*, I. Anastassiadis*, D. Tsoukalas*, M. Kokkoris*, R. Vlastou*, P. Dimitrakis, P. Normand
*National Technical University of Athens

Radiation environments are encountered in military applications, nuclear power stations, nuclear waste disposal sites, high-altitude avionics, medical and space applications. Radiation type, energy, dose rate and total dose may be very different in each of these application areas and require in many cases radiation-tolerant electronic systems. The way radiation damages electronic systems depends strongly on the environment and can be classified as total ionizing dose effects (TID) and single event effects (SEE). Of particular interest are the radiation effects on non-volatile memory devices (NVM). While a major issue relates to the radiation sensitivity of the NVM control circuitry, radiation also affects the performance of the memory cells. At present, the dominant device technology for NVM is based on the floating gate (FG) concept. A promising route for overcoming the technological constraints imposed in device downscaling lies in the use of nanocrystal memories (NC-NVM). Compared to standard FG-NVMs (e.g. Flash EEPROMs), NC-NVMs are expected to show higher tolerance to both TID and SEE effects because of the discrete nature of the charge storage centers.

In this direction, we examined the effect of high-dose proton irradiation on Si-nanocrystal (Si-NC) NVMs (MOS capacitors and nMOS transistors). Irradiation experiments were conducted using protons of 1.5 MeV and 6.5 MeV. The irradiation doses investigated ranged from 1 to 120 Mrad (SiO_2). A 2-D layer of Si NCs with ~3nm mean diameter and 10^{12} cm^{-2} surface density was successfully achieved by low-energy (1 keV) ion-beam-synthesis in thin SiO_2 layers. The final gate dielectric stack includes 6.5nm-thick injection oxide, 2.5nm-thick Si-NC layer and 5nm-thick control oxide. Irradiated devices exhibit a negative threshold-voltage shift compared to non-irradiated samples, in agreement to the well-known observation that irradiation creates a net trapped positive charge (Q_{ot}) into the gate SiO_2 layer. Q_{ot} increases with the irradiation dose and saturates for the high-irradiation regime. No bit flip has been observed on programmed NC-nMOS devices. Charge retention measurements at room temperature for the write and erase states of irradiated and non-irradiated samples reveal that a significant memory window exists at an extrapolated time of ten years even after high irradiation dose. Endurance measurements on irradiated NC nMOS transistors do not show any degradation or drift of the memory window. These preliminary studies suggest that the nanocrystal NVMs may be a attractive route for radiation tolerant electronics.

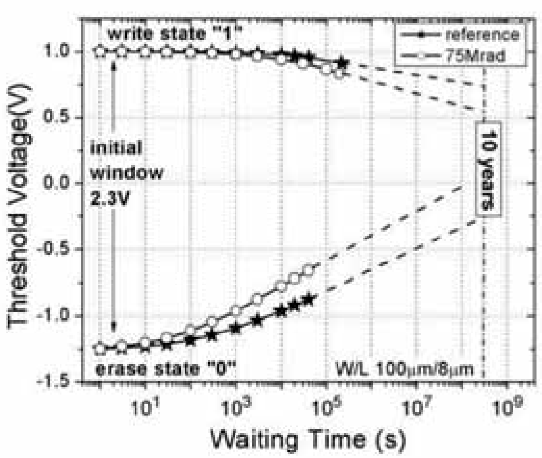


Fig. 7: Charge retention characteristics for unirradiated and irradiated NC nMOS transistors at room temperature.

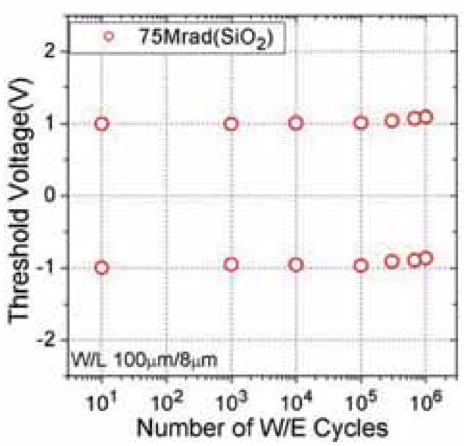


Fig. 8: Endurance characteristics of 75Mrad(SiO_2) irradiated NC nMOS transistors tested through 10^6 15ms +9V/-9V write/erase cycles. No degradation or drift in memory window is observed.

E. Formation of Si nanocrystals in thin SiO2 layers by plasma-immersion ion-implantation

E. Kapetanakis, P. Dimitrakis, P. Normand

Here, we are concerned with the development of a new Si-NC synthesis route based on plasma-immersion ion-implantation (PIII) in collaboration with CEMES/CNRS and one French SME (Ion Beam Services). Potentially, the PIII technique presents attractive advantages over the conventional low-energy-IBS technique: 1) Access to lower implantation energy that should allow NC fabrication in thinner SiO2 films; a critical parameter for memory performance. 2) Elimination of energy contamination effects associated with the deceleration mode used in LE-ion implanters; a critical parameter for preserving the integrity of the implanted structures. 3) Ability at providing high ion flux at low energy and therefore, implantation at high doses required for NC formation is possible in reasonable period of time. 4) Finally, the PIII-related instrumentation is relatively simple and thereby, leads at much lower product costs than LE-ion-implanters. Also, PIII is a high throughput technique compatible with conventional CMOS fabrication processes; an important point for further industrial PIII applications.

Our first experiments were conducted using SiF4 as the plasma gas and 7nm-thick SiO2 films. Different implantation conditions were tested including Si doses in the $10^{16} – 10^{17}$ cm^{-2} range and Si energy of 1 and 3.7keV. After post-implantation annealing, the resulting structures were examined by TEM analysis and Al gate MOS capacitor measurement. All in all, our first investigations indicate absence of Si-NCs into the gate oxides as well as significant swelling and dielectric property modification of the implanted matrices. Current work focuses on the use of SiH_4 instead of SiF_4 for avoiding incorporation of high fluorine contents.

PROJECT OUTPUT in 2007

Publications in International Journals

1. "Wet oxidation of nitride layer implanted with low-energy Si ions for improved oxide-nitride-oxide memory stacks", V. Ioannou-Sougleridis, P. Dimitrakis, V.E. Vamvakas, P. Normand, C. Bonafos, S. Schamm, N. Cherkashin, G. Ben Assayag, M. Perego, M. Fanciulli, Applied Physics Letters 90, 263513 (2007).
2. "Proton radiation tolerance of nanocrystal memories", E. Verrelli, I. Anastassiadis, D. Tsoukalas, M. Kokkoris, R. Vlastou, P. Dimitrakis, P. Normand, Physica E: Low-Dimensional Systems & Nanostruct. 38, 67-70 (2007).
3. "Parasitic memory effects in shallow-trench-isolated nanocrystal memory devices", P. Dimitrakis and P. Normand, Solid-State Electronics 51, 125-136 (2007).
4. "Oxide-nitride-oxide memory stacks formed by low-energy Si ion implantation into nitride and wet oxidation", V. Ioannou-Sougleridis, P. Dimitrakis, V.E. Vamvakas, P. Normand, C. Bonafos, S. Schamm, N. Cherkashin, G. Ben Assayag, M. Perego, M. Fanciulli, Microelectronic Engineering 84, 1986-1989 (2007).
5. "Oxide-nitride-oxide dielectric stacks with Si nanoparticles obtained by low-energy ion beam synthesis", V. Ioannou-Sougleridis, P. Dimitrakis, V.E. Vamvakas, P. Normand, C. Bonafos, S. Schamm, A. Mouti, G. Ben Assayag, V. Paillard, Nanotechnology 18, 215204 (2007).
6. "Proton radiation effects on nanocrystal non-volatile memories", E. Verrelli, D. Tsoukalas, M. Kokkoris, R. Vlastou, P. Dimitrakis and P. Normand, IEEE Trans Nuclear Science 54, 975-981 (2007).
7. "Electronic memory device based on a single-layer fluorene-containing organic thin film", C. Pearson, J.H. Ahn, M.F. Mabrook, D.A. Zeze, M.C. Petty, K.T. Kamtekar, C. Wang, M.R. Bryce, P. Dimitrakis, D. Tsoukalas, Appl. Phys. Lett. 91, 123506 (2007).
8. "Nickel nanoparticle deposition at room temperature for memory applications", E. Verrelli, D. Tsoukalas, K. Giannakopoulos, D. Kouvatsos, P. Normand, D.E. Ioannou, Microelectronic Engineering 84 (9-10), 1994-1997 (2007).
9. "Electrical properties of metal-oxide-semiconductor structures with low-energy Ge-implanted and annealed thin gate oxides", E. Kapetanakis, P. Normand, P. Holliger, Journal of Applied Physics, In Press.

Publications in International Conference Proceedings

1 "Oxide-nitride-oxide dielectric stacks with embedded Si-nanoparticles fabricated by low-energy ion-beam-synthesis", V. Ioannou-Sougleridis, P. Dimitrakis, V. Em. Vamvakas, P. Normand, C. Bonafos, S. Schamm, G. Ben-Assayag, in Materials and Processes for Nonvolatile Memories II, edited by Tingkai Li, Yoshihisa Fujisaki, J.M. Slaughter, Dimitris Tsoukalas, Mater. Res. Soc. Symp. Proc. Volume 997, 0997-I03-1, Warrendale, PA, 2007.
2. "SONOS-type memory structures using thin silicon nitride films modified by low-energy Si+ implantation", P. Dimitrakis, V. Ioannou-Sougleridis, V. Em.Vamvakas, P. Normand, C. Bonafos, S.

Schamm, N. Cherkashin, G. Ben Assayag, M. Perego, M. Fanciulli, Proceedings of 2nd International Conference on Memory Technology and Design 2007, ICMTD 07, pp.213-216, Giens, France, May 7-10, 2007.

Conference Presentations

1. "High-density plasma silicon oxide thin films grown at room-temperature", M-E. Vlachopoulou, P. Dimitrakis, A. Tserepi, V. Em.Vamvakas, S. Koliopoulou, P. Normand, E. Gogolides, D. Tsoukalas, 29th International Conference on Micro- and Nano-Engineering, MNE 2007, Copenhagen, Denmark, September 23-26, 2007.
2. "Memory and luminescence properties of Si nanocrystals fabricated by ion beam mixing", V. Beyer, K.-H. Heinig, B. Schmidt, K.-H. Stegemann, P. Dimitrakis, , International Workshop on SEMIconductor NANOstructures 2007 (SEMINANO 2007), Bad Honnef, Germany, June 13-16, 2007.
3. "Microscopy of semiconductor nanocrystals embedded in very thin high k layers by low energy ion-beam-synthesis for memory applications", C. Bonafos, S. Schamm, P. Dimitrakis, P. Normand, V. Ioannou-Sougleridis, A. Mouti, M. Carrada, A. Slaoui, J. Grob, G. Ben Assayag, B Schmidt, J. Becker, A. Claverie, Microscopy of Semiconducting Mater. XV, P3.009, Churchill College, Cambridge, UK (IOP), April 2-5, 2007.
4. "Oxide-nitride-oxide memory stacks formed by low-energy Si ion implantation into nitride and wet oxidation", V. Ioannou-Sougleridis, P. Dimitrakis, V.E. Vamvakas, P. Normand, C. Bonafos, S. Schamm, N. Cherkashin, G. Ben Assayag, M. Perego, M. Fanciulli, 15th International Biennial Conference on Insulating Films on Semiconductors, INFOS 2007, Glyfada, Athens, Greece, June 20-23, 2007.
5. "Nickel nanoparticle deposition at room temperature for memory applications", E. Verrelli, D. Tsoukalas, K. Giannakopoulos, D. Kouvatsos, P. Normand, D.E. Ioannou, 15th International Biennial Conference on Insulating Films on Semiconductors, INFOS 2007, Glyfada, Athens, Greece, June 20-23, 2007.

Conference Organisation

1. 15th International Biennial Conference on Insulating Films on Semiconductors, INFOS 2007, Glyfada, Athens, Greece, June 20-23, 2007 (HYPERLINK "http://www.infos2007.gr" http://www.infos2007.gr). This conference was organized by the Institute of Materials Science (IMS) and the Institute of Microelectronics (IMEL) from NCSR Demokritos, the National Technical University of Athens and the University of Ioannina. The 134 papers (119 contributed and 15 invited) presented at the conference are published in A. Dimoulas and P. Normand (Eds), Microelectronic Engineering 84 (9-10), 2007.

Patent

1. Greek Patent Application, No 20070100171, Publication date: 14-03-2007, Method of oxidizing silicon nitride materials at low thermal budgets, Inventors: P. Normand, V. Ioannou-Sougleridis, P. Dimitrakis, V. E. Vamvakas, C. Bonafos, G. Ben Assayag, M. Perego, M. Fanciulli.

MOLECULAR MATERIALS AS COMPONENTS OF ELECTRONIC DEVICES

Project leader: N. Glezos

Key researchers: N.Glezos, P.Argitis, P.Normand

Post Doctorals: A.Douvas, E.Makarona, E. Kapetanakis, D.Velessiotis, V. Chinnuswami

PhD candidates: G. Chaidogiannos, G.Tatakis

External Collaborators: D. Yannakopoulou and E. Mavridi (Institute of Physical Chemistry, NCSR "D"), S. Kennou (Department of Chemical Engineering, University of Patras), S.Nespurek (Intitute of Macromolecular Science, Prague), G.Papavasiliou (National Hellenic Research Foundation), G. Kaltsas (Technical University of Athens), Z.Pikramenou (University of Birmingham)

Research orientation:

- To investigate the potential of molecular materials to be used as active components in molecular devices e.g. as switching or memory elements.
- to develop consistent evaluation methods based on the electronic transport properties at the nano- level for the characterization of single layered and few-layered systems.
- to produce physical parameters (film thickness, surface molecular density, contact potential) that could be cross-checked with other surface characterization methods
- To evaluate elements of the class of organic crystals as components of organic FETs
- To develop techniques for thin film deposition and characterization of molecular materials.

Funding:

- NMP STREP TASNANO, 1/1/2005-30/7/2008, Contract N° 516865
- EU RTN project Uninanocups, 1/1/2004-31/12/2007, Contract N° MRTN-CT- 2003-7504233

EXAMPLES OF RESEARCH RESULTS IN 2007

A. Vertical devices of Self-assembled Hybrid Organic/inorganic Monolayers

M. Douvas, E. Makarona, D. Velessiotis, E. Kapetanakis, N. Glezos, P. Argitis, P. Normand

We worked on a new approach to fabricate capacitor-like metal-insulator-semiconductor (MIS) devices the functional part of which is made of hybrid organic/inorganic self-assembled monolayers (SAMs) of tungsten polyoxometalates (POMs). This approach consists in the combination of the layer-by-layer (LBL) method for the growth of the molecular layers and a CMOS-compatible process, and results in functional, large active area devices of up to 300x300μm^2 with high yield (>95%). The LBL method, which in essence is based on the successive adsorption of oppositely charged molecules from a solution on a surface, was chosen because of its simplicity, effectiveness, and its ability to produce mechanically and chemically stable molecular layers regardless of the chosen substrate. POMs of the Keggin structure were opted as the functional molecules because of their unique combination of properties: they are stable molecules of well-defined structure and fixed size (~1nm), they can accept one or more electrons without significant structural changes, and these electrons can be delocalized over several metal centers of their framework. In other words, POMs can be viewed as zero-dimensional n-type semiconductors with low charging energies (from the Fermi level of Al or Au electrode to their lowest unoccupied molecular orbital, LUMO, level) in the range of 0.1-0.4eV, i.e. with discrete electronic levels at room temperature.

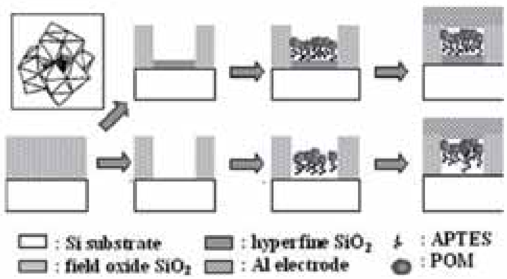


Fig. 1: Schematic diagram of the fabrication process. The inset shows the Keggin structure of the tungstate polyoxometallate

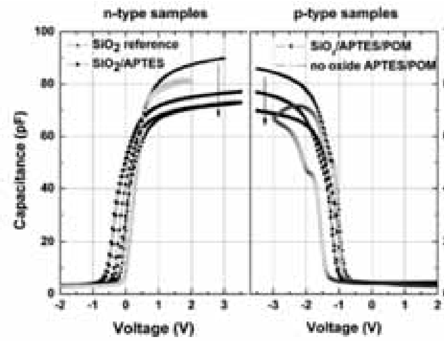


Fig. 2: C-V characteristics for both p-and n-type samples

From the 1MHz C-Vs of both n- and p-type devices it can be established that, as expected, the capacitance of the devices decreased with the addition of each SAM. The values of the effective thickness of the layers were estimated both through the C-Vs and the corresponding Maserjian plots, and were in good agreement with the actual sizes of the molecules. Fits showed that the APTES layer acts as a dielectric of an effective constant $\varepsilon \sim 3.57 \times 10^{-11}$ F/m (a value close to the dielectric constant of SiO_2) assuming that the length of the molecules is ~1nm. Furhtermore, the dielectric behavior of the APTES SAM was further substantiated by the I-Vs under forward bias, where a drop in conductivity was observed after the deposition of the APTES SAM atop the SiO_2. Hysteresis phenomena appeared for the devices deprived of the gate dielectric, and they were especially pronounced for the p-type samples. In detail, the insertion of the POM SAM resulted in the injection of charge (electrons) from the substrate and their storage in the available states of the POMs.

STM measurements were also performed on n-type substrates to further investigate the transport mechanisms. The samples were structurally similar to the devices so that a direct qualitative comparison would be feasible. Specifically, n-type Si wafers with Al back gate were subjected to the LBL method in order to obtain either the APTES or the APTES/POM layer on top of them. Current Spectroscopy measurements were then performed, using a NT-MDT Solver Pro® Scanning Probe Microscope (SPM) equipped with a PtIr tip in STM mode. The resulting I-V curves showed increased conductivity upon the addition of POMs -a similar behavior to the devices'- supporting that the transport mechanisms remain the same both on microscopic and on the device level, and advocating to the fact that these mechanisms are dictated by the POM's properties.

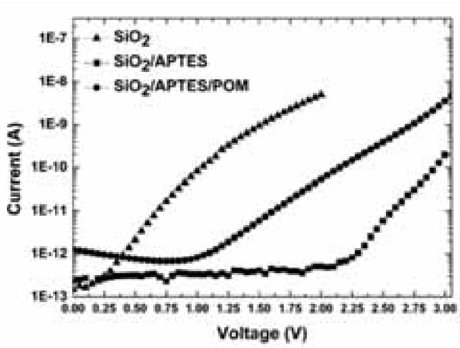


Fig. 3: I-V characteristics for n-type devices. The increase in conductivity for the n-type device including POMs is obvious.

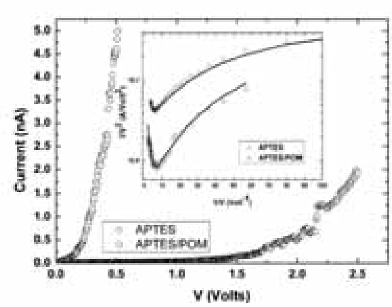


Fig. 4: STM curves for a SAM of APTES (diamonds) and APTES/POM (hexagons) on n-type Si. There is a clear increase of the conductivity with the insertion of POMs. Inset: F-N representation of the I-V curves. Solid lines are theoretical fits according to Simmons's model.

B. Study of the transport and charge storage properties of cyclodextrin nanowires for molecular devices

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[1]Institute of Physical Chemistry, NCSR "Demokritos"

[2]Marie Curie Post Doc (Dec 2006- Dec 2007)

b_1 Study of cyclodextrin nanowires using STM spectroscopy

The aim of this work was to evaluate the potential of CD monolayers to be used as active components in nanoelectronic devices. Specially we were interested in the transport poroperties of molecular nanowires based on CD and guests containing metals.STM measurements were performed in a NT-MDT P47Pro® machine with the purpose of obtaining information about the coverage of gold surface and the electrical behaviour of the SAMs. The work was focused on the transport porpoerties of composite nanowires containing metals. Alpha-THIO, Alpha-Ru, dM-beta-THIO anf gamma-THIO were used as hosts while a Fe complex was used as a guest molecule for alpha-CDs and an Ir complex for beta-CDs.

Good coverage of the surface was established, especially in the DMBTHIO case. Current-voltage spectroscopy measurement revealed that only the low voltage tunnelling regime is present in the cases of ATHIO and DMBTHIO, with low hysteresis presented. This hysteresis loop was symmetric for the DMBTHIO case and non-symmetric for ATHIO. In aRuCD samples, a clear hysteresis loop was observed and attributed to the presence of the metallic atom in the molecular structure: electric charge was trapped by the molecule during the first voltage scan (from positive to negative values) and released during the second scan. The presence of a Fowler-Nordheim tunnelling region in this case was also indicative of the presence of Ru atom. The Au reference sample showed no such charging effects.

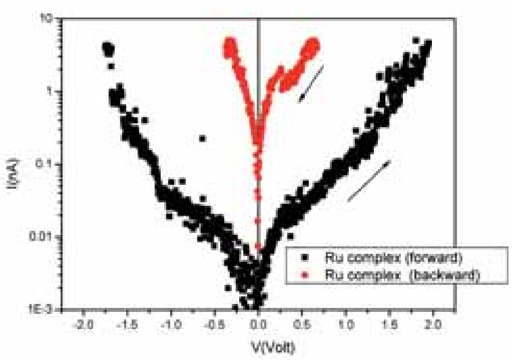

Fig. 5: IV characteristics of the Ru complex molecule on an Au surface. The currents are much higher than the reference sample and also higher thn the case of CDs not containing metals. Also hysterisis effects are present.

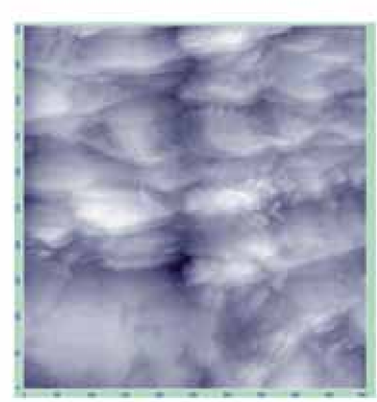

Fig. 6: Morhpology of the covered surface (dimension: 500x500nm)

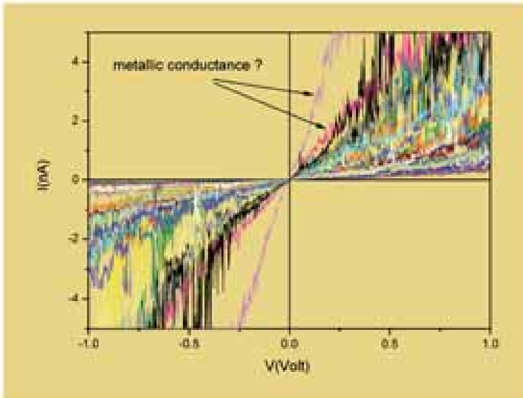

Fig. 7: Family of curves in the case of the Ru complex wcovered by the Ir guest. The resulting chain demonstrates metallic behaviour of much higher conductance than the single Ru molecule.

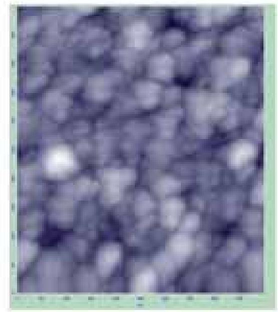

Fig. 8: Mprphology of the nanowire. (Dimension: 500x500nm)

b_2 Planar nanodevices containing CDs bridged with Au nanoparticles

A first attempt to fabricate and electrically connect CD nanowires was made. The final structures consisted of back-to-back molecular diodes connected to planar gold nanoelectrodes through CD guest-host chemistry. Intermediate functionalised gold nanoparticles served as a bridges for the nanowires.Three different compounds were studied: a thiolated alpha-CD (ATHIO), a thiolated beta-CD (DMBTHIO) and an alpha-CD (aRuCD) that was modified by an organic complex (ending with S), which contained Ru (II). On the other hand, if one wished to construct bak-to-back diodes, using SAM and Au nanoparticles, he should keep the nanoparticles still in their position. This could be done by modifying the nanoparticles with a suitable group, so that they stick to the SAM. In our case, modification was made by an adamantyl thiol molecule, which is both a CD guest (the admantyl group) and can also be attached to gold nanopatricles (thiol group).

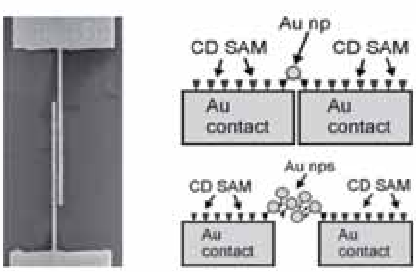

Fig. 9: SEM micrograph of the active area of gold electrodes (top view) Actual bridging of the electrodes (bottom) compared to the ideal case (up)

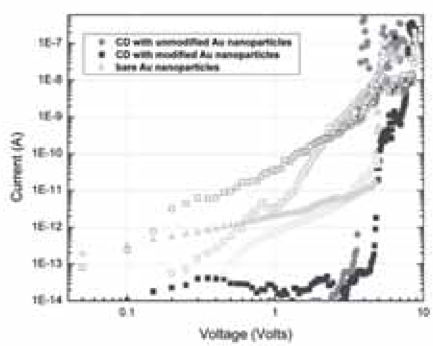

Fig. 10: Current-voltage characteristics for planar devices with modified (squares), unmodified (circles) nanoparticless and in absence of CD SAM (triangles)

Planar gold electrodes of sub-100nm distances were used for the electrical measurements, while pure gold substrates were used for the STM study. The electrode fabrication was achieved by electron-beam lithography and a conventional lift-off process on Si wafer covered by a 200nm SiO2. CD SAMs were grown on the surface (either pure gold or electrodes) through immersion of the sample to a solution containing the CD molecules. Attachment of gold nanoparticles to the CDs was achieved by a second immersion step.

C. Low voltage operating OFETs based on solution processed metal phthalocyanines

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[2]Department of Chemical Engineering, University of Patras
[3]Institute of Macromolecular Chemistry, Academy of Sciences of the Czech Republic

We investigated the class of sodium salts of sulfonated metal phthalocyanines (MePCSxs) as candidates for p-type channels in organic transistors. These materials are selected because of their enhanced solubility compared to their non-sulfonated counterparts. MePCSxs were either synthesized (Me = Ni, Co, Zn or Al), or purchased by Aldrich Co. (Me = Cu). The comparison among phthalocyanines under study is based on their electric behavior depending on the type of the central metal and the presence of substituents. The objective is to select the type of the material and the film preparation process with the optimal performance of electrical parameters. The semiconducting layers of MePCSx were prepared by spincoating at room temperature. The samples were dried at 50oC for 20 minutes. MePC based OFETs which served as a reference were fabricated by vacuum evaporation of metal phthalocyanine thin films (Me = Ni, purchased by Aldrich Co., or Me = Co, synthesized, see Fig. 11a) in high vacuum onto the substrates.

The sodium salts of sulfonated metal phthalocyanine were all synthesized from the non-substituted ones. The number of substituents produced in the synthesis process depends on the oleum concentration, temperature and duration of the reaction. Mono- , di-, tri- and tetra – sulfonated species may be separated using high pressure liquid chromatography analysis (TLC).

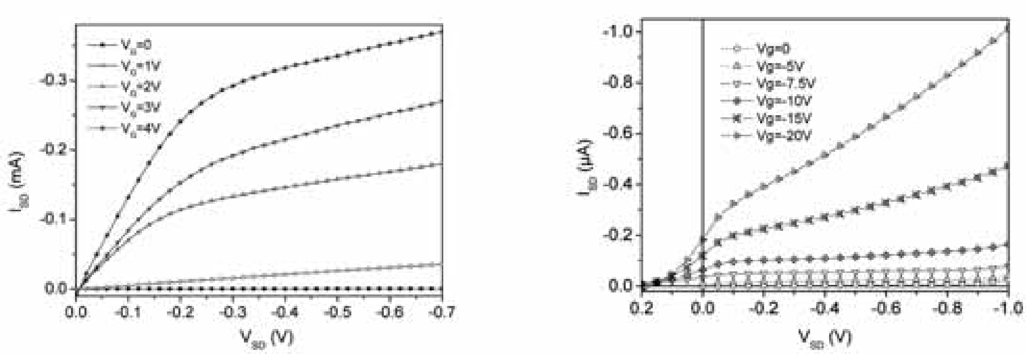


Fig. 11: Dependence of drain current on the drain voltage of an OFET with 50 nm $NiPCS_x$ layer, W/L ratio of 23275 and 42 nm thick SiO_2 oxide dielectric, deposited by spin-coating and annealed at 50°C: (a) $NiPCS_{2.4}$ and (b) $NiPCS_4$.

The ion movement which results in the formation of an additional field was studied by current vs time measurements for a given gate biasing. This allowed the determination of the total charge shifted to the interface.

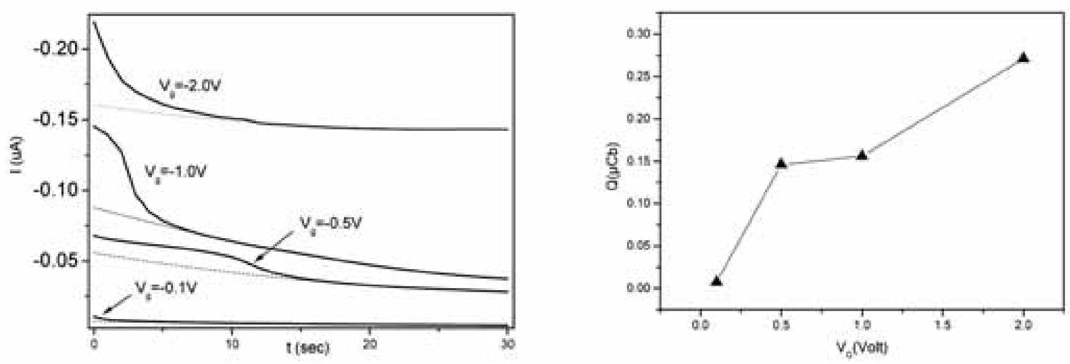


Fig. 12: Determination of the charge transfer in the case of the NiPC. The charge shift is responsible for the low voltage operation of the device.

PROJECT OUTPUT IN 2007

Publications in International Journals and Reviews

1. "Some new nickel 1,2-dichalcogenolene complexes as single-component semiconductors", Papavassiliou, G.C.a , Anyfantis, G.C.a , Steele, B.R.b , Terzis, A.c , Raptopoulou, C.P.c , Tatakis, G.d, Chaidogiannos, G.d , Glezos, N.d , Weng, Y.e , Yoshino, H.e , Murata, K.e, Zeitschrift fur Naturforschung - Section B Journal of Chemical Sciences ,vol. 62, Issue 5, May 2007, pp. 679-684
2. "Soluble Phthalocyanines: Perspective Materials for Electronics", S. Nespurek, G. Chaidogiannos, N.Glezos, G.Wang,S. Bohm, J.Rakusan, M.Karaskova, Mol. Cryst. Liq. Cryst., Vol. 468, pp. 3=[355]–21=[373], 2007

Papers in Conference Proceedings

1. "Evaluation of sulfonated metal phthalocyanines for OTFT applications", G.Chaidogiannos, N.Glezos, K.Yannakopoulou, I.M.Mavridi, S. Kennou, F. Petraki, S. Nespurek, Rakusan, M. Karaskova, ICOE, Eindhoven, June , Oral presentation
2. "Charging Effects in Hybrid Structures Based on Polyoxometalate Layers for Molecular Memory Applications", E. Makarona, A.M. Douvas, E.Kapetanakis, D.Velessiotis, P.Argitis, P.Normand, N.Glezos, J.Mielczarski, E. Mielczarski T.Gotszalk , M. Woszczyna, MRS Boston, November, Oral presentation
3. "Soluble Substituted Phthalocyanines for OFET Applications", G. Chaidogiannos, N. Glezos, S. Ne?p?rek, NN Thessaloniki, July, Oral presentation
4. "Molecular Nanodevices based on Functionalized Cyclodextrins", Dimitrios Velessiotis, Davide Maffeo, Eleni Makarona, Viswanathan Chinnuswamy, Constantinos Milios, Konstantina Yannakopoulou, Irene Mavridis, Zoe Pikramenou and Nikos Glezos, MMN Athens, November, Oral presentation
5. "Vertical Devices of Self-assembled Hybrid Organic/inorganic Monolayers based on Tungsten Polyoxometalates: a step towards molecular electronic devices", E.Makarona, E.Kapetanakis, D.Velessiotis, A.Douvas, P.Argitis, P. Normand, T.Gotszalk, M. Woszczyna, N.Glezos, MNE, Copenhagen, September, Oral presentation

Conference Presentations

1. "Appications of water soluble metal containing phthalocyanines in organic transistors", G.Chaidogiannos, F.Petraki, N.Glezos S.Kennou and S.Nespurek, XXIII Panhellenic Conference of Solid State Physics, September 2007, Athens

PhD Thesis

1. "Applications of oligomeric crystal materials in Organic Field Effect Transistors" G.Chaidogiannos, Faculty of Electrical and Computer Engineering NTUA, December 2007

MECHANICAL AND CHEMICAL SENSORS

Key Researchers: P. Normand, I. Raptis, C. Tsamis

Collaborating Researchers: S. Chatzandroulis, D. Goustouridis, A. Tserepi,

Post-doctoral scientists: E. Makarona, F. Farmakis

Phd students: R. Triantafyllopoulou, V.Tsouti, I. Ramfos, M. Kitsara, K. Manoli

External Collaborators: M. Sanopoulou (IPC, NCSR 'Demokritos'), K. Beltsios (Materials Sci. Dept. Uni. Ioannina), E. Sarantopoulou, Z. Kollia, A.C. Cefalas (NHRF), J. R Morante (Univ. of Barcelona), G. Petersson (Chalmers Univ.), M. Kompitsas (NHRF)

Objectives:

- Development of micromachining processes for the realization of novel chemical and mechanical sensors.
- Development of low power silicon sensors based on new materials and new processes.
- Design, fabrication and testing of microsystems using silicon sensors.
- Realization of sensors for specific industrial applications with emphasis on medical, food and automotive fields.

Funding:

- EU - IST-FP6-STREP-027333 Micro2DNA, "Integrated polymer-based micro fluidic micro system for DNA extraction, amplification, and silicon-based detection", P. Normand
- EU, IST, IP, GOODFOOD, "Food Safety and Quality Monitoring with Microsystems", contract No. 508774, C. Tsamis
- GSRT Greece-Italy bilateral cooperation "Fabrication and characterization of an array of transparent conductive thin film polymeric composite as multiparametric sensitive layers for a new e-nose", D. Goustouridis
- GSRT-PENED 03ED630, "Micromachined chemical sensors for controlling food safety and quality", C. Tsamis
- GSRT- ENTER 05EP032, "Development of MOSFET type chemical sensors for wireless sensor networks", C. Tsamis

EXAMPLES OF RESEARCH RESULTS IN 2007

A. Low power Metal-Oxide (MOX) Chemical Sensors

R. Triantafyllopoulou, S. Chatzandroulis, A. Tserepi and C. Tsamis

Solid state chemical sensors are one of the most common devices employed for the detection of hazardous gases, like NH_3. Their principle of operation is based on the changes of the conductivity of a sensitive material, which is deposited between two electrodes, due to the adsorption of reducing or oxidizing agents onto its surface. Many techniques have been developed for the deposition of catalytic materials. One of the most widely used techniques is to prepare a sol gel solution with metal additives, in order to enhance its sensitivity and then deposit the additive-modified nanostructured metal oxides on micro-hotplates, by microdroping (Fig. 1a). In this way, the use of Porous Silicon micro-hotplates allows for the fabrication of sensor arrays (Fig. 1b) that incorporate varying sensitive materials, while at the same time they exhibit a significant reduction of the power consumption. Porous Silicon provides improved thermal isolation, thus reducing heat dissipation to the substrate.

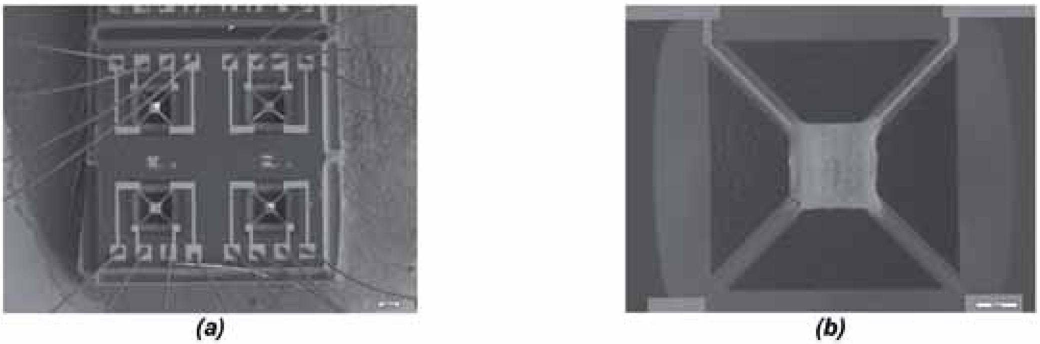


Fig. 1: SEM image of the micro-drop sensors (a) mounted on a package, after the wire-bonding and (b) the micro-dropped sensitive material SnO2:Pd

During this year, we developed gas sensors for food safety and quality applications as well as for environmental monitoring, fabricated by the micro-drop technique. The sensors are based on suspended porous silicon micro-hotplates. Two different nanostructured materials were deposited on top of the micro hotplates using micro-drop technique: a) SnO_2:Pd and b) WO_3:Cr. For the characterization of the SnO_2:Pd and WO_3:Cr micro-drop sensors, measurements in NH_3 ambient took place. The detection of the gas was conducted in isothermal operation mode, which means that the sensors were applied with a constant power. The response of the SnO_2:Pd sensors was measured for high concentrations of NH_3, as it is shown in fig. 2a. Lower concentrations of NH_3 were detected by both SnO_2:Pd and WO_3:Cr sensors, as it is shown in fig. 2b. The gas sensors with micro-dropped sensitive materials and especially SnO_2:Pd exhibit the highest sensitivity towards NH_3, with lower power consumption.

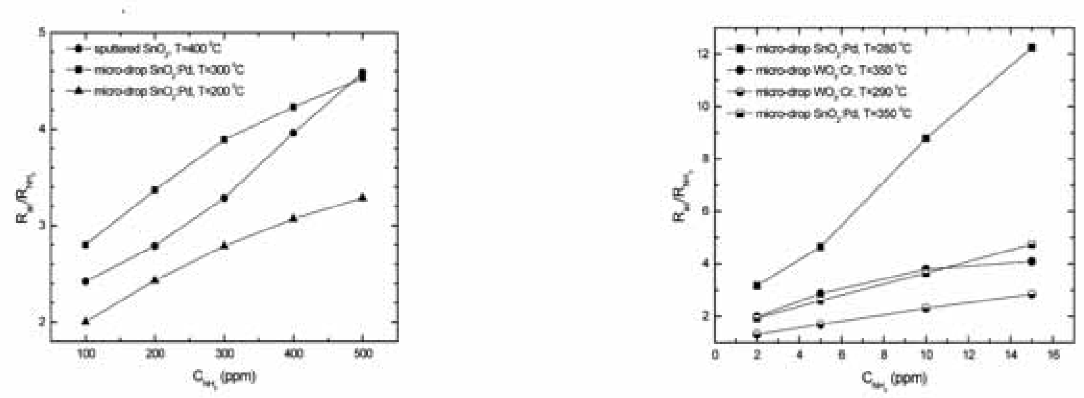


Fig. 2: (a) Comparison of the sensitivity of gas sensors with undoped sputtered SnO_2 sensitive material and sensors with micro-dropped SnO_2:Pd sensitive material, (b) Sensitivity of gas sensors with SnO_2:Pd and WO_3:Cr micro-dropped sensitive materials, in various temperatures, for low concentrations on NH_3.
For more information please contact Dr. C. Tsamis (e-mail:ctsamis@imel.demokritos.gr

B. FET-type chemical sensors for wireless applications

F. Farmakis, K. Alexandrou, C. Tsamis, M. Kompitsas[1], I. Fasaki[1], P. Jedrasik[2], G. Petersson[2], B. Nilsson[2]

[1] National Hellenic Research Foundation, Theoretical and Physical Chemistry Institute

[2] Dept. of Microtechnology and Nanoscience, MC2, Chalmers Univ. of Technology

Chemical sensors for wireless applications are of major interest since they turn into reality the possiblity to sense and monitor environmental changes in hard-accessible mediums or even to escort environment-sensitive products (such as food) in order to monitor and build environment-related database. Low-energy consumption (low current operation), room-temperature operation as well as integration in small dimension are some of the most important requirements of such sensors. To this end, we investigate two candidate devices: i) MOS capacitive sensors and ii) FET-type sensors with active catalytic layer. During this year, we focused our efforts on both types of devices.

i) MOS capacitive sensors of Si/SiO_2/Pt and Si/SiO_2/SnO_2/Pt, with thin and thick silicon dioxide layer were fabricated and are about to be tested whether they can effectively sense gas mixtures containing NH_3, H_2, CO, etc. In our preliminary research, it has been found that a correlation between MOS gas sensor and NH3 is present at room temperature.

ii) Interdigitated bottom-gate FET devices (gasFET) with various channel lengths (from 0.3 μm to 2 μm) were developed (Fig. 3). Palladium was used as source and drain electrodes and thin SiO_2 layers as gate insulator. Thin zinc oxide layer was grown with the aid of pulsed laser deposition (PLD) method at room temperature. The above-mentioned fabricated gasFET sensors were tested at CO environment at 200 °C as demonstrated in Figs 4 and 5.

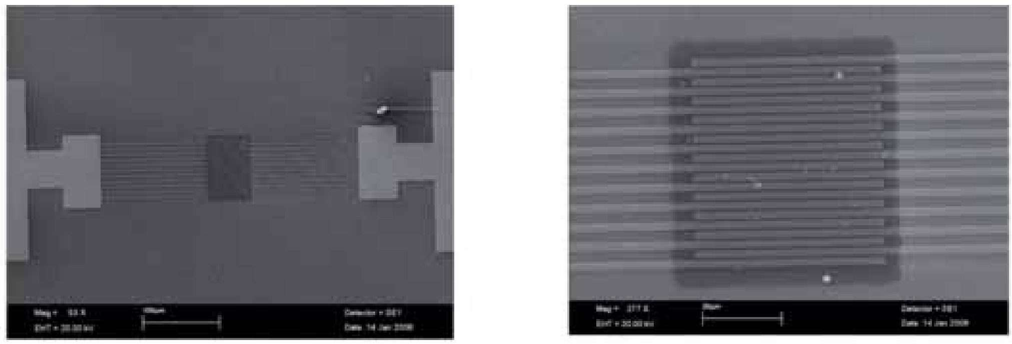


Fig. 3: SEM images showing the interdigitated source and drain electrodes of the bottom gate FET device.

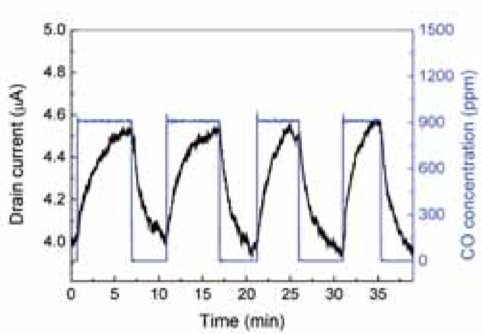


Fig. 4: Drain current increase at the presence of 900 ppm of CO in dry air at 200 °C.

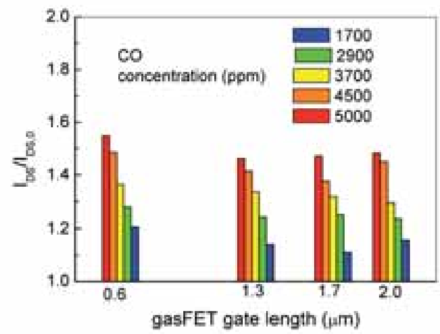


Fig. 5: Drain current increase depends linearly with CO concentration in dry air, independently of the gate length of the gas FETs. (Measurements at 200 °C).

For more information please contact Dr. F. Farmakis (e-mail: farmakis@imel.demokritos.gr)

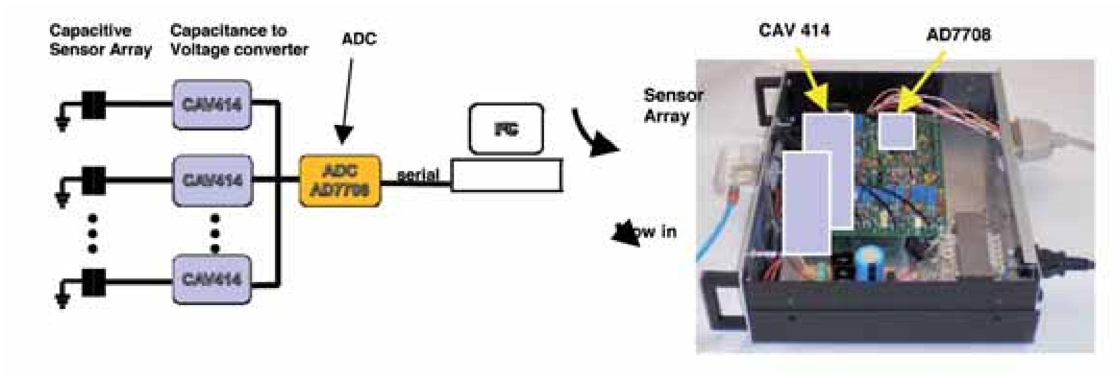
C. Polymer based chemical sensor arrays

K. Manoli, M. Kitsara, S. Dimopoulos, D. Goustouridis, S. Chatzandroulis, I. Raptis, K. Beltsios, M. Sanopoulou, E. Sarantopoulou, Z. Kollia, A.C. Cefalas

Low power capacitive type chemical sensors using polymer coated InterDigitated Electrodes (IDE) are the focus of this research. An InterDigital Electrode (IDE) chemical sensor may be fabricated by covering the electrodes with a polymer layer. The transduction then relies on the permittivity changes and swelling of the covering polymer, to inflict a change in the capacitance between the two electrodes structure. InterDigital Capacitive (IDC) sensors are perhaps one of the most promising devices in terms of fabrication costs and ease of integration in a standard CMOS process, requiring only minimum post-processing.

In our work a capacitive array of IDC chemical sensors with an electronic interface, which converts capacitance changes into digital signal, has been developed. Photolithographic deposition has been used to apply four different polymer sensing layers (PHEMA, PMMA, EPR, PDMS) onto IDEs fabricated on a glass substrate to minimize parasitic capacitances. The electronic interface is able to handle up to eight capacitive sensors (fig. 6). It is built around a 16 bit analog to digital converter

(Analog Devices, AD7708). This chip has 8 input channels, which are driven by 8 corresponding capacitance to voltage converters (CAV414) connected to one of the capacitive chemical sensors in the array.



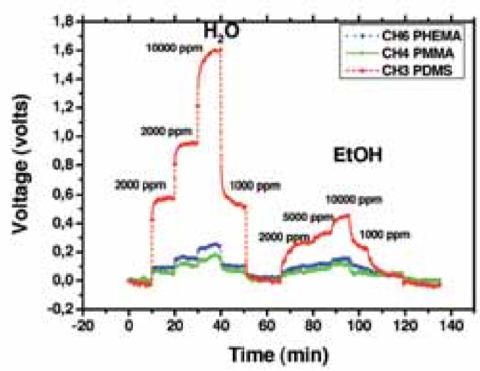


Fig. 6: (Top Left) Block diagram of the electronic interface. (Top right) Electronic interface and sensor array, homed in a dedicated Plexiglas chamber plugged in position. (Left) Response of the system under water and ethanol vapors.

Sensing properties enhancement of polymeric films via irradiation

The use of patternable polymeric films and their subsequent treatment with VUV, DUV irradiation and plasma to engineer individual sensitivities in chemical sensor arrays was proposed and studied. The effect of the treatment on the swelling properties of poly(methyl methacrylate) (PMMA) thin films in certain analytes was studied using White Light Reflectance Spectroscopy. The relative expansion of the PMMA film was clearly found to depend on the irradiation conditions (fig. 7,8) From the treatment methods examined the one with the higher sensing sensitivity amplification (5 times higher in certain cases) was the VUV irradiation. Further studies of the VUV processed areas with AFM, FTIR were carried out in order to reveal the mechanism of this enhanced sensing capability.

The successful fabrication of the macropore arrays is followed by a thin thermal oxide development and a second electrochemical process. During this procedure, whose duration may exceed 120 min, copper particles are forced to deposit on the pore walls (fig. III.1.8a) and inside the macroporous film, until the pores are completely filled. The efficiency of the electrolytic solution is very sensitive in terms of composition and pH. The implementation of appropriate conditions followed by annealing, result in the development of homogeneous and consistent 50μm long copper wires (fig III.1.8b).

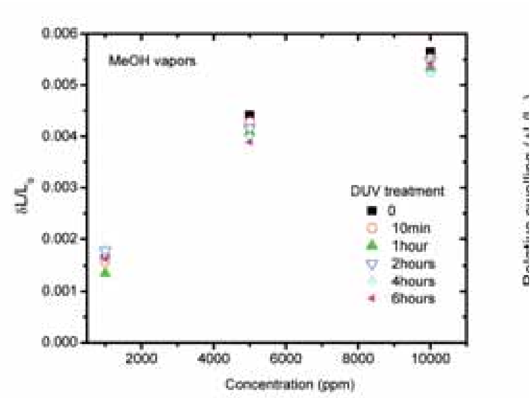


Fig. 7: DUV irradiation effect on the PMMA swelling. Exposures up to 6h did not present any gain in the swelling of the studied vapors

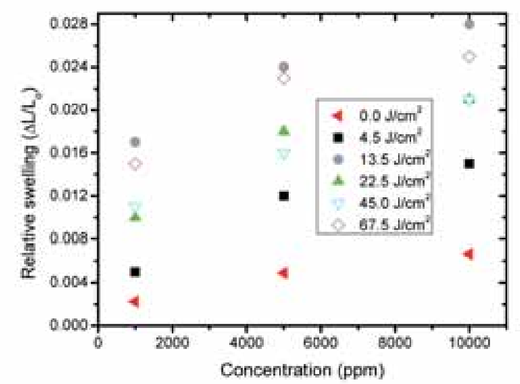


Fig. 8: Relative swelling values of PMMA films for irradiated samples at different VUV exposure doses for methanol vapors.

Conductometric chemical sensors

Conductometric chemical sensors based on polymer composite films, synthesized by adding conductive fillers to the polymer solutions and deposited between two predefined electrodes, are well established. The available methods for deposition of the sensitive composites lack in pattern precision and repeatability. In order to overcome pertinent problems a novel methodology based on conventional patterning methods was developed and applied. The definition of two conductive polymer composites (poly(dimethylsiloxane) /carbon black and epoxy polymer / carbon black areas on the same substrate was demonstrated (fig. 9). The two sensors performance is evaluated and considered as a first step towards the fabrication of a conductometric polymer composite array. Electrical sensitivity is enhanced over dimensional sensitivity, especially for low dimensional-sensitivity cases. In addition it was found that electrical response depends on the exact electrode configuration (fig. 10). Short-circuiting situations can have a substantial effect on the electrical sensitivity of the composites in consideration.

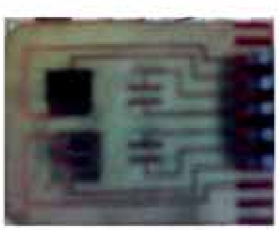


Fig. 9: Photograph of the patterned EPR-CB and PDMS-CB polymer composite sensor pair.

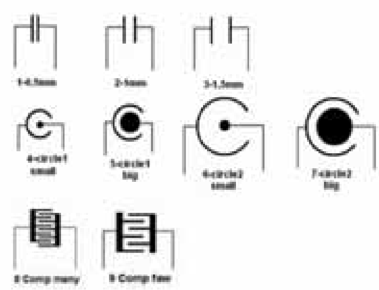


Fig. 10a: Different electrode configurations examined.

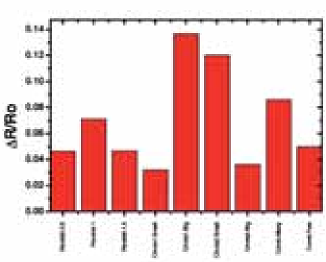


Fig. 10b: Relative resistance change of a PDMS/CB sensor to 5000 ppm of water vapors for the nine different electrodes

For more information please contact Dr. I. Raptis (e-mail: raptis@imel.demokritos.gr)

D. Capacitive Type Sensors

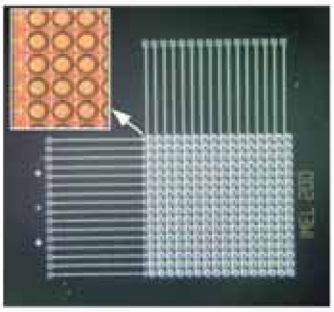
S. Chatzandroulis, D. Goustouridis, V.Tsouti, I. Ramfos, C. Boutopoulos*, I. Zergioti*, D. Tsoukalas*, P. Andreakou, D. Kafetzopoulos**, P. Normand**

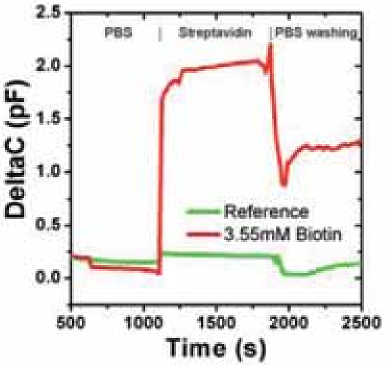
*National Technical University of Athens, **IMBB/FORTH

Capacitive DNA Sensors Arrays

Unlabeled DNA detection has been the focus of great interest in recent years as it simplifies sample preparation and testing procedures. To this end and within the framework of the European Project Micro2DNA, we work towards exploiting surface stress changes and subsequent bending of microelectromechanical structures combined with capacitive detection. A first sensor employing capacitive detection and silicon micromachined membranes has been developed. The sensor accommodates in a single chip a capacitive DNA sensor array of 256 elements. Each sensor in the array consists of a single crystal silicon membrane that is covered with receptor DNA after surface functionalization and deflects upon exertion of surface stress hybridization. Membrane deflection is detected as a change in device capacitance.

Testing of the sensors is performed in a special setup that allows for the concurrent measurement of multiple sensors in real-time during biological interactions. The setup uses a hybridization chamber designed by CEA-LETI and a custom switch matrix array. To date, operation of the capacitive biosensor array has been tested by monitoring the biotin – streptavidin interaction. The latter is detected as a clear step increase of the biotin functionalized sensor capacitance, while unfuctionalized reference sensors remain stable. In these experiments, unspecifically bound streptavidin is removed during washing at the end of the interaction, as evidenced by the drop in sensor capacitance during washing.





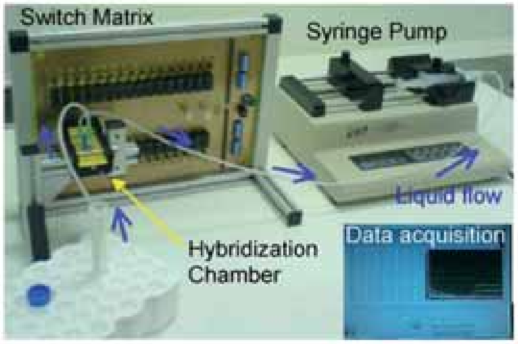


Fig. 11: Top-left: 16x16 sensor array before Al deposition and functionalization. Bottom: Measurement set-up. Liquids are pumped out of the reservoir and then through the hybridization chamber to end up in the syringe. Top-right: Typical change in capacitance of biotin-functionalized and unfunctionalized (reference) sensors.

Furthermore, a dedicated ASIC has been designed, using 0.35um CMOS technology, and fabricated at AustriaMicrosytems. The interface is designed around a relaxation oscillator and produces a square wave with frequency which is dependent on the value of the sensor capacitance being read. Additional circuitry allows for trimming of the output according to the sensor capacitance and sensitivity. Moreover the interface is able to read the whole array of 256 capacitive sensing elements by using a 16 x 16 addressing mode to select the sensor to be measured. In a next step the sensor and the ASIC chips will be connected together to allow easy readout of the array.

PROJECT OUTPUT in 2007

Publications in International Journals

1. "Impact of structural parameters on the performance of silicon micromachined capacitive pressure sensors", V. Tsouti, G. Bikakis, S. Chatzandroulis, D. Goustouridis, P. Normand, D. Tsoukalas, Sensors and Actuators A: Physical 137 (1), 20-24, 2007.
2. "Humidity effects in spin-coated films of polythiophene-polystyrene blends" J.Jaczewska, A.Budkowski, A.Bernasik, I.Raptis, J.Raczkowska, D.Goustouridis, J.Rysz, M.Sanopoulou J. Appl. Polym. Sci. 105 67(2007)
3. "Fabrication of conductometric chemical sensors with a novel lithographic method" N.Andreadis, S.Chatzandroulis, D.Goustouridis, K.Beltsios, I.Raptis Microelectron. Eng. 84 1211(2007)
4. "Composite Chemical Sensors Based on Carbon-Filled, Patterned Negative Resists" S.Chatzandroulis, N.Andreadis, D.Goustouridis, L.Quercia, I.Raptis, K.Beltsios Jpn. J. Appl. Phys. B 46 6423(2007)
5. "Enhancement of sensing properties of thin poly(methyl methacrylate) films by VUV surface modification" I.Raptis, J.Kovac, M.Chatzichristidi, E.Sarantopoulou, Z.Kollia, S.Kobe, A.C.Cefalas J. Laser Micro/Nanoengineering 2 200(2007)
6. "Sequential polymer lithography for chemical sensor arrays" M.Kitsara, K.Beltsios, D.Goustouridis, S.Chatzandroulis, I.Raptis Eur. Polymer J. 43 4602(2007)
7. "Single chip interdigitated electrode capacitive chemical sensor arrays" M.Kitsara, D.Goustouridis, S.Chatzandroulis, M.Chatzichristidi, I.Raptis, Th.Ganetsos, R.Igreja, C.J.Dias Sens. Act. B. 127 186(2007)
8. "Swelling of poly(3-alkylthiophene) films exposed to solvent vapours and humidity: Evaluation of solubility parameters" J.Jaczewska, I.Raptis, A.Budkowski, D.Goustouridis, J.Raczkowska, M.Sanopoulou, E.Pamula, A. Bernasik, J.Rysz, Synth. Met. 157 726(2007)
9. "Disposable bismuth-sputtered electrodes for the determination of trace metals by anodic stripping voltammetry" Ch.Kokkinos, A.Economou, I.Raptis, Th.Speliotis C.E.Efstathiou Electrochem. Commun. 9 2795(2007)
10. "Field-effect transistors with thin ZnO as active layer for gas sensor applications", F. V. Farmakis, A. Speliotis, K. P. Alexandrou, C. Tsamis, M. Kompitsas, I. Fasaki, P. Jedrasik, G. Petersson, B. Nilsson, To appear in Microelecronics Engineering
11. "Nanostructured Oxides on Porous Silicon Microhotplates for NH3 Sensing", R. Triantafyllopoulou, X. Illa, O. Casals, C. Tsamis, A. Romano-Rodriguez, J.R. Morante, To appear in Microelecronics Engineering

Publications in International Conference Proceedings

1. "Wireless Measurement System For Capacitive Pressure Sensors Using Strain Compensated SiGeB", K. Arshak, E. Jafe, T. McGloughlin, T. Corbett, S. Chatzandroulis, D. Goustouridis, IEEE SENSORS 2007 Conference Proceedings, p.4, Atlanta, Georgia, USA, October 28-31, 2007.

2. "Development of Wireless Pressure Measurement System for Short Range medical Applications", K. Arshak, E. Jafer, T. McGloughlin, T. Corbett, S. Chatzandroulis, D. Goustouridis, D.Tsoukalas, P.Normand, O. Korostynska, 30th Internat. Spring Seminar on Electronics Technology, ISSE 2007, pp. 94–99, May 9-13, 2007.
3. "Thermal characterization of Porous Silicon micro-hotplates using IR thermometry", R. Triantafyllopoulou, C. Tsamis, S. Chatzandroulis , T. Speliotis, J. Parthenios, K. Papagelis and C. Galiotis, Solid-State Sensors, Actuators and Microsystems Conference Proceedings,, TRANSDUCERS 2007. International, p. 2271-2274, DOI: 10.1109/SENSOR.2007.4300622

Conference Presentations

1. "Design and fabrication of a micromechanical capacitive DNA sensor array", V.Tsouti, S.Chatzandroulis, D.Goustouridis, P.Normand, D.Tsoukalas, 33th International Conference on Micro- and Nano-Engineering, MNE 2007, Copenhagen, Denmark, September 23-26, 2007.
2. "Direct laser printing of biomolecules on capacitive sensors", C. Boutopoulos, P. Andreakou, S. Chantzandroulis, D. Goustouridis, I. Zergioti, D. Kafetzopoulos, D. Tsoukalas, 3rd International Conference on Micro-Nanoelectronics, Nanotechnology & MEMS, Athens, Greece, November 18-21, 2007.
3. "Direct laser printing of biomolecules on capacitive sensors", I. Zergioti, C. Boutopoulos, P. Andreakou; C. Chatzandroulis, D. Goustouridis, D. Tsoukalas, , 9th International Conference on Laser Ablation, COLA 2007, Tenerife, Spain, September 24-28, 2007.
4. "Thermal characterization of Porous Silicon micro-hotplates using IR thermometry", R. Triantafyllopoulou, C. Tsamis, S. Chatzandroulis , T. Speliotis, J. Parthenios, K. Papagelis and C. Galiotis, TRANSDUCERS'07/ EUROSENSORS XXI, June 10-14 2007, Lyon, France, (Poster)
5. "Detection of CO and NO using low power Metal Oxide sensors", R. Triantafyllopoulou & C. Tsamis, Third Conference on Microelectronics, Microsystems, Nanotechnology, MMN 2007, 18-21 November 2007, Athens, Greece (Poster)
6. "Field-effect transistors with thin ZnO as active layer for gas sensor applications", F. V. Farmakis, A. Speliotis, K. P. Alexandrou, C. Tsamis, M. Kompitsas, I. Fasaki, P. Jedrasik, G. Petersson, B. Nilsson, Micro- and Nano-Engineering, MNE 2007, 23-26 September 2007, Copenhagen, Denmark (Poster)
7. "Nanostructured Oxides on Porous Silicon Microhotplates for NH3 Sensing", R. Triantafyllopoulou, X. Illa, O. Casals, C. Tsamis, A. Romano-Rodriguez, J.R. Morante, Micro- and Nano-Engineering, MNE 2007, 23-26 September 2007, Copenhagen, Denmark (Poster)
8. "Electrical characterization of field-effect zinc oxide transistors for gas sensing applications", F.V.Farmakis, P.Jedrasik, C.Tsamis, M.Kompitsas, I.Fasaki, A.Speliotis, IMA 2007, 30 September – 04 October 2007, Rio-Patras, Greece (Oral)

BIO-MICROSYSTEMS

Project Leader: K. Misiakos

Key Researchers: A. Tserepi, I. Raptis, E. Gogolides, P. Argitis, H. Contopanagos

Post-doctoral scientists: K. Kotsovos

External Collaborators: S.E. Kakabakos (IRRP/NCSRD), P.Petrou (IRRP/NCSRD)

Graduate Students: M. Zavali

Objectives:

- Development of bioanalytical lab-on-a-chip devices based on monolithic optoelectronic transducers (bioactivated optocouplers). Development of white light interferometric setup for label free monitoring of biomolecular reactions.
- Develop highly sensitive and/or label free assays suitable for point of care applications
- Develop microfluidic channels integrated on transducer silicon chips
- Use soft lithography, Deep Plasma Etching, and plasma assisted bonding to fabricate PDMS, PMMA (and other organic polymer) based microfluidic devices
- Fabricate capillary electrophoresis, and chromatography devices
- Develop open microfluidics using electrowetting actuation
- Develop novel plasma based micro array technologies

Funding:

- EU, IST, STREP, "NEMOSLAB", NanoEngineered Monolithic Optoelectronic transducers for highly Sensitive and LAbel-free Biosensing (coordinated by K. Misiakos start 1-1-2006, end 31-12-2008)

EXAMPLES OF RESEARCH RESULTS IN 2007

A. Single binding event detection

Label-free protein detection through one dimensional monolithic photonic crystal engineering
SU-8 microchannel integration on optocoupler chips.
Lithography and plasma processes for microfluidics fabrication

Optocouplers employing fibers of 2 μm in width can demonstrate the effect of single binding event detection if big enough labels are used. Such a demonstration is outlined in Fig. 1 where the Biotin-Streptavidin model assay is employed and 1 μm polystyrene beads as labels. Each binding event introduces an identifiable step downwards in the detector photocurrent.

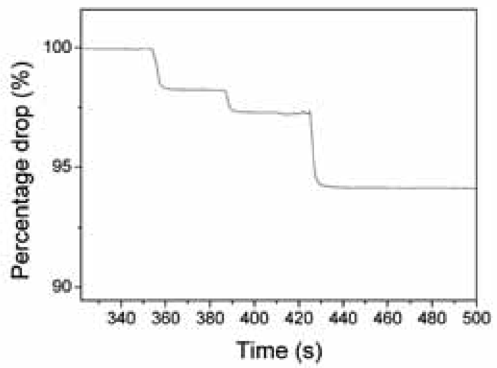


Fig. 1: Single binding event detection assay. Biotinylated BSA was spotted on a 2 micron wide fiber. Streptavidin labeled with polystyrene coated paramegnetic beads (one micron in diameter) was introduced in a dilute solution (108/cm3) so that at each moment only one bead (on average) was present in the fluidic channel above the fiber. Each binding event introduces a significant and identifiable drop in the photocurrent due to scattering of waveguided photons .

The optocoupler chips can be applied to label free detection by grafting on the waveguide a latent photonic crystal through APTES pattering. Biomolecular coating and binding on the patterned waqveguide surface induces wavelength filtering and subsequent signal transduction as shown in Fig.2.

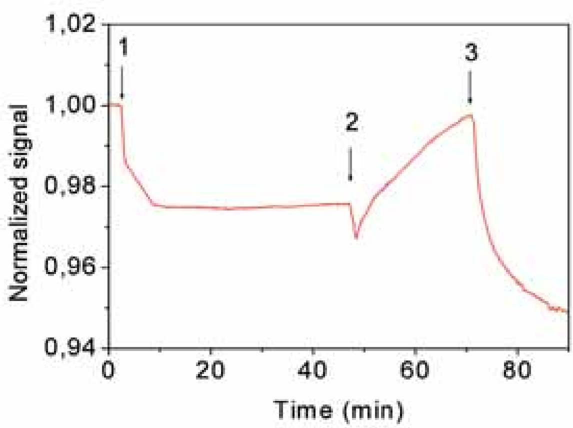


Fig. 2: Representative real time monitoring of reactions performed onto fibers engineered with photonic crystals. The sequence is as follows: up to arrow 1: washing with coating buffer; arrows 1-2: coating a with 400 nM biotinylated BSA solution (0.0025 %); arrows 2-3: blocking solution (1% BSA); arrow 3 to end: 10 nM streptavidin buffer in blocking solution. The signal was normalized in respect to its initial value.

Microfluidic channels are nessacary in biosensing microdevices to supply sample and reagents. They are made by SU-8 photoresist coating (Fig. 3) and form channels after being covered with elastomeric covers and pressed.

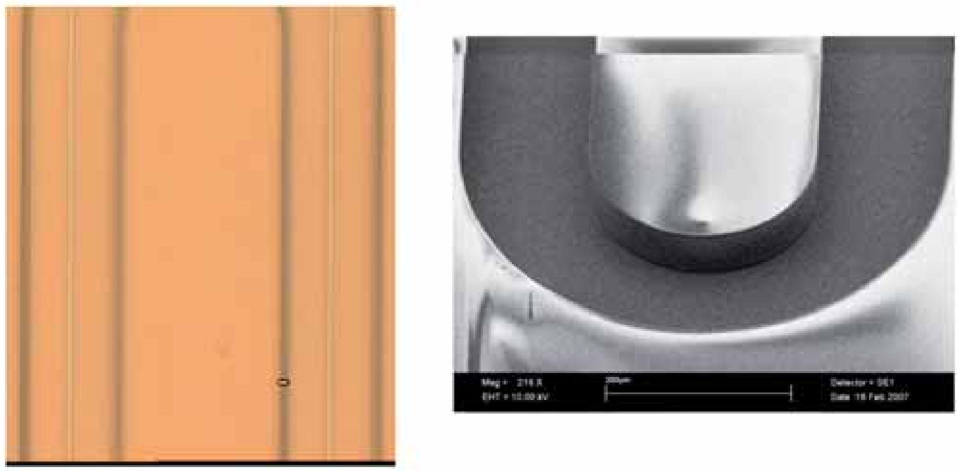


Fig. 3: Open fluidic channels. Left: A view of 150 μm fluidic channels with the 8μm waveguide within. The fluidic walls are 50 microns high. Right: A SEM picture on a test wafer showing how vertical the fluidic walls are. The artifacts on top of the SU-8 film are charging effects.

B. Lithography and plasma processes for microfluidics fabrication

Results:

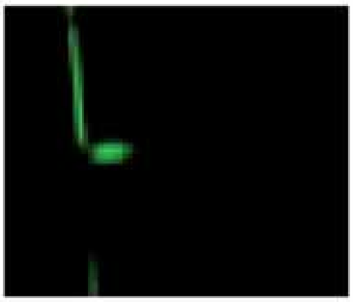
Development of fabrication processes for PMMA and PDMS microfluidics: soft lithography, deep plasma etching, bonding

Fabrication of capillary electrophoresis devices on PMMA using plasma etching. Investigation of the effect of superhydrophilic, or superhydrophobic wall on electroosmotic flow.

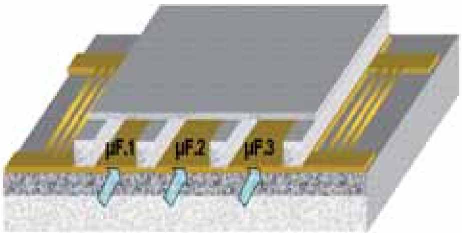
Fabrication of a gas chromatography microcolumn and multi-channel microfluidic modules integrated on a biosensor

Development of actuation technology for microfluidics based on electrowetting. Electrowetting-based transport of liquid droplets was demonstrated on open microfluidic devices.

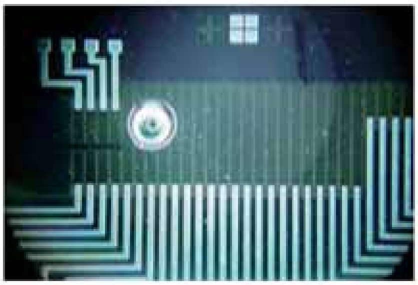
Development of methodology for fabrication of protein micro-arrays based on selective plasma-based surface modification of patterned Si/SiO_2 substrates



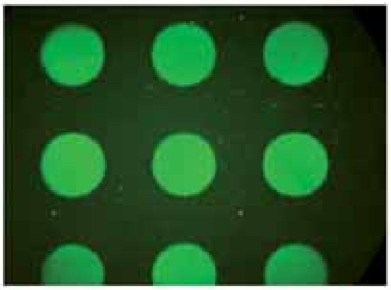
Electrophoresis in PMMA microfluidic



PDMS microfluidic on top of SAW device



Electrowetting-based droplet transport on open microfluidic device



Protein micro array by novel technology

For details on the above, please see Project : LITHOGRAPHY and PLASMA PROCESSES for ELECTRONICS, MICROFLUIDICS, and SURFACE Nano-ENGINEERING (Part B)

PROJECT OUTPUT in 2007

Publications in International Journals

1. "Electrowetting on plasma-deposited fluorocarbon hydrophobic films for biofluid transport in microfluidics", Bayiati, P., Tserepi, A., Petrou, P.S., Kakabakos, S.E., Misiakos, K., Gogolides, E. Journal of Applied Physics 101 (10), 2007
2. "Biofluid transport on hydrophobic plasma-deposited fluorocarbon films", Bayiati, P., Tserepi, A., Petrou, P.S., Misiakos, K., Kakabakos, S.E., Gogolides, E., Cardinaud, C., Microelectronic Engineering 84 (5-8), pp. 1677-1680, 2007
3. "A biomolecule friendly photolithographic process for fabrication of protein microarrays on polymeric films coated on silicon chips", Petrou, P.S., Chatzichristidi, M., Douvas, A.M., Argitis, P., Misiakos, K., Kakabakos, S.E. Biosensors and Bioelectronics 22 (9-10), pp. 1994-2002, 2007

Conference Papers

1. "Real-time and label-free determination of analytes using a bioanalytical microsystem based on a monolithic silicon optoelectronic transducer", P.S. Petrou, E. Mavrogiannopoulou, S.E. Kakabakos, K. Misiakos, 4th pHealth Conference, Porto karras Chalkidiki, Grrece June 20-22, 2007
2. "Detection of BRCA1 gene mutations in real-time using a monolithic optoelectronic transducer", P.S. Petrou, E. Mavrogiannopoulou, S.E. Kakabakos, K. Misiakos 5th International Conference on Instrumental Methods of Analysis Modern Trends and Applications, IMA 2007, Rio, Patras Greece, 30 September-4 October, 2007.

THIN FILM DEVICES for LARGE AREA ELECTRONICS

Project leader: Dr. D.N. Kouvatsos

Collaborating researchers from other projects: Dr. F.V. Farmakis, Dr. D. Davazoglou

Ph.D. candidates: D.C. Moschou, G.P. Kontogiannopoulos, L. Michalas (University of Athens).

External collaborators: Dr. G.J. Papaioannou (University of Athens), Dr. M. Exarchos (Royal Holloway University of London), Dr. N. Stojadinovic (University of Nis), Dr. A.T. Voutsas (Sharp Laboratories of America).

Objectives

This research aims at the optimization of the active layer of polysilicon films obtained using advanced excimer laser crystallization methods and of the resulting performance parameters of thin film transistors (TFTs) fabricated in such films. Such advanced TFTs are necessary for next generation large area electronics systems, which are now in the research and development phase. Specifically, the targets of the project are:

- Evaluation of device parameter (a) hot carrier and (b) irradiation stress-induced degradation and identification of ageing mechanisms in TFTs fabricated in advanced excimer laser annealed (ELA) polycrystalline silicon films utilizing sequential lateral solidification (SLS) techniques.
- Investigation of the influence of the polysilicon crystallization technique and the film thickness on TFT performance, defect densities and degradation for ELA technology optimization.
- Investigation of polysilicon active layer defects using transient drain current analysis in ELA TFTs.
- Investigation of effects of variations in TFT device structure and in the fabrication process on device performance and reliability.
- Assessment of material properties of advanced ELA polysilicon TFTs using optical measurements.
- Evaluation of bias stress-induced instabilities in solid phase crystallized (SPC) TFTs.

Funding:

- PENED contract, project code 03ED550, 19/12/2005 – 18/12/2008.
- GSRT bilateral project Greece-Serbia, Polysilicon TFT reliability, 1/11/2004 – 30/4/2007.

EXAMPLES OF RESEARCH RESULTS IN 2007

A. Hot carrier stress investigation in ELA TFTs

TFT degradation under hot carrier stress (HCS) was investigated for devices fabricated in advanced 2-shot SLS ELA polysilicon films. TFTs with different channel widths and orientations relative to the grain boundary directions were compared. It was observed that the degradation of device parameters during HCS experiments was dependent on the channel width. Fig.1 shows the V_{th} evolution with stress time for a stress condition ($V_{GS,stress,}$ $V_{DS,stress}$) = (3 V, 6 V), for X-directed TFTs. We observe an increase of ΔV_{th} for increasing stress time as a common behavior in all devices except the narrower ones, which exhibit an initial decrease and then an increase. The amplitude of the positive ΔV_{th} shift scales up with width. Narrower devices (W of 4 and 8 μm) demonstrate a less pronounced ΔVth positive shift. The degradation behavior of Y-directed TFTs was in accordance with observations in X-directed devices. We also observed that devices with W = 16, 32 and 100 μm exhibit an initial increase in $G_{m,max}$ (transconductance "overshoot") and then a reduction after a maximum $G_{m,max}$ value.

In order to investigate the width scaling of the additional energy source during hot-carrier experiments, we proposed that two width-dependent effects are involved, the floating body effect (FBE) and the self-heating effect (SHE). Concerning floating-body effects, we performed I_{DS}-V_{GS} electrical measurements with various drain voltages on wide and narrow devices, as shown in Fig.2. For higher drain voltages the parasitic bipolar transistor is activated giving rise to an abrupt drain current increase even at negative values of gate voltage (Fig.2), which indicates presence of FBEs. By performing various rates of drain voltage sweeps at V_{GS} = 3 V we could observe no significant increase or decrease of the drain current resulting from self-heating effects. However, it is possible that a temperature gradient may arise from the drain current, which is not observable in the output characteristics and at the same time may provide additional energy to the carriers; thus, the presence of SHEs is not excluded.

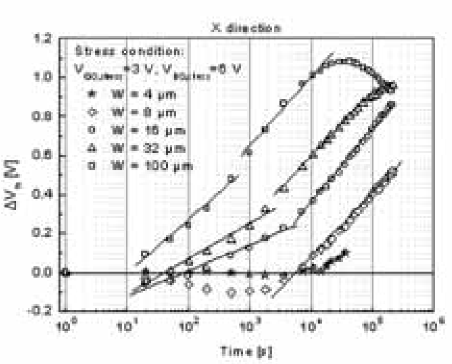


Fig. 1: Threshold voltage variation versus stress time for X-directed polysilicon TFTs with various channel widths

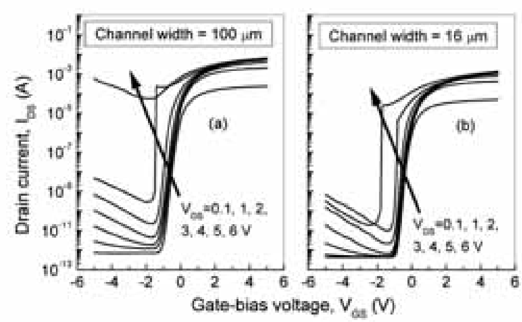


Fig. 2: Transfer characteristics of polysilicon TFTs with channel widths of 100 μm and 16 μm for various drain-bias voltages.

Moreover, degradation phenomena due to HCS were investigated in double gate TFTs. We varied the HCS conditions at the front-gate channel by applying various back-gate voltages. We demonstrated that severe degradation phenomena may occur at the back interface depending on the back-gate voltage during stress. We observed that:

- Electrical stress with negative back-gate voltage enhances hot-hole injection in the back-gate oxide; hot-electron induced phenomena at the front polysilicon / SiO_2 interface also occur (Figs. 3, 4).
- Electrical stress with positive back-gate voltage enhances hot-electron injection in the back-gate oxide; hot-hole injection occurs in the front oxide, combined with front interface state generation (Figs. 5, 6).

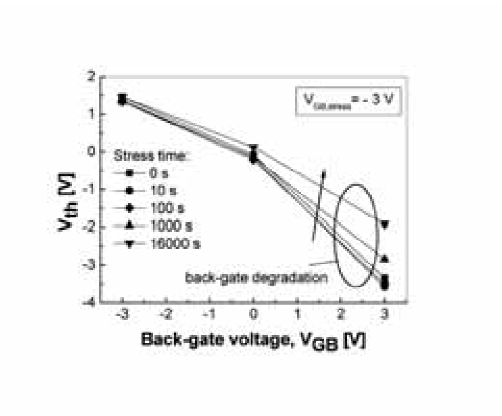


Fig. 3: Threshold voltage as a function of back-gate voltage for various durations under stress condition with $V_{GB,stress}$= - 3 V.

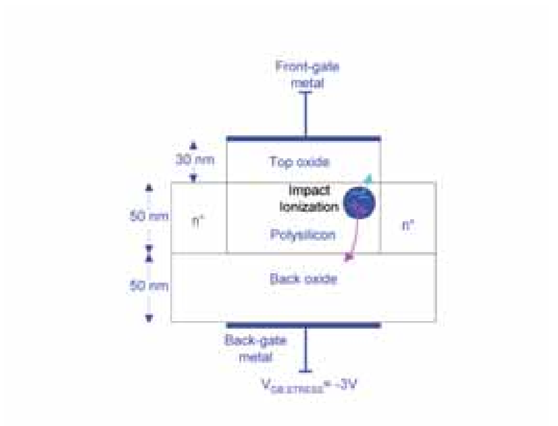


Fig. 4: Schematic of top gate device and the degradation behavior for negative back-gate bias during stress.

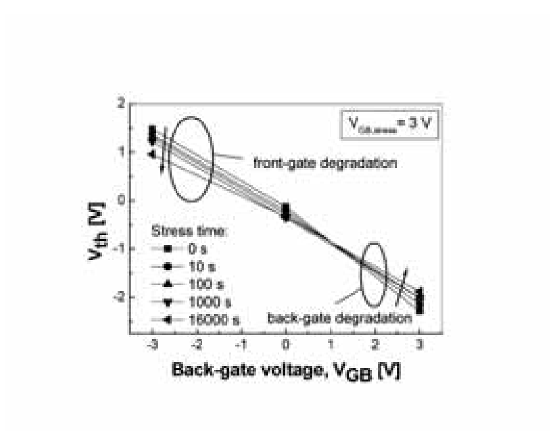


Fig. 5: Threshold voltage as a function of back-gate voltage for various durations under stress condition with $V_{GB,stress}$= 3 V.

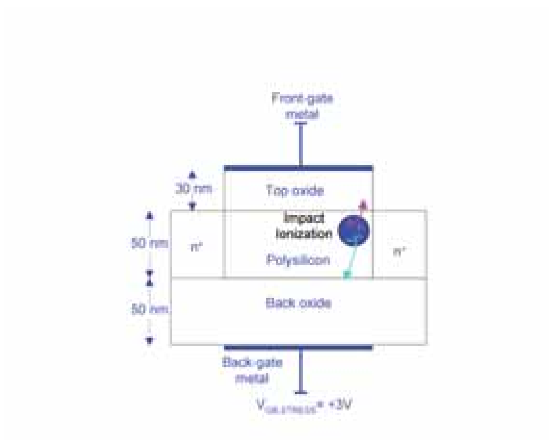


Fig. 6: Schematic of top gate device and the degradation behavior for positive back-gate bias during stress.

In Table I we summarize the different degradation mechanisms for double gate devices for three stress regimes that were applied.

Stress $V_{GB,stress}$ [V]	Front interface degradation mechanisms	Back interface degradation mechanisms
- 3 V	State generation by hot-electrons at the polysilicon/SiO_2 interface and/or within the grain boundaries	Severe hot-hole injection and associated interface state generation
0 V	State generation by hot-electrons at the polysilicon/SiO_2 interface and/or within the grain boundaries	Mild hot-hole injection
+ 3 V	Severe hot-hole injection and interface state generation	Hot electron injection and associated interface-state generation

Table I: Degradation mechanisms for double gate ELA TFTs under hot carrier stress.

B. Characterization of experimental ELA and IMEL-fabricated TFTs

Advanced variations of SLS ELA crystallization (termed 2^N-shot, MxN, Dot) have been applied for pilot fabrication of TFTs at Sharp; results from their characterization were presented in the 2006 report. This work was recently expanded to their reliability investigation, through the application of DC stress. We concluded that the different microstructural properties of the films resulted in different degradation behavior, both for the threshold voltage (Fig. 7) and for the maximum transconductance (Fig. 8).

Furthermore, we fabricated polysilicon TFTs at IMEL (with ELA crystallization at Sharp or SPC at IMEL) to probe the best technique for gate dielectric deposition and the effect of the crystallization technique on TFT performance and reliability. The mean performance parameters of all the fabricated TFTs can be seen in the following Table II.

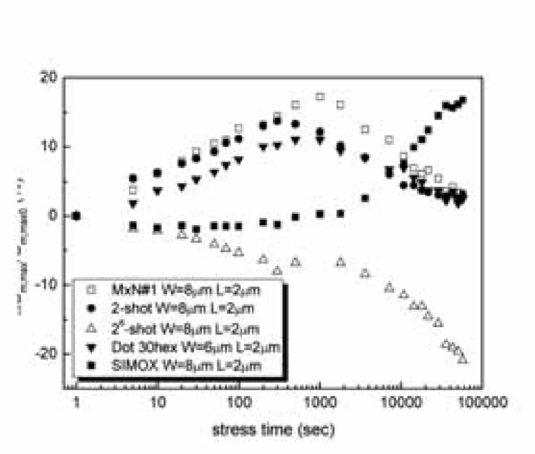


Fig. 7: Evolution of ΔV_{th} with stress time for differently crystallized poly-Si TFTs.

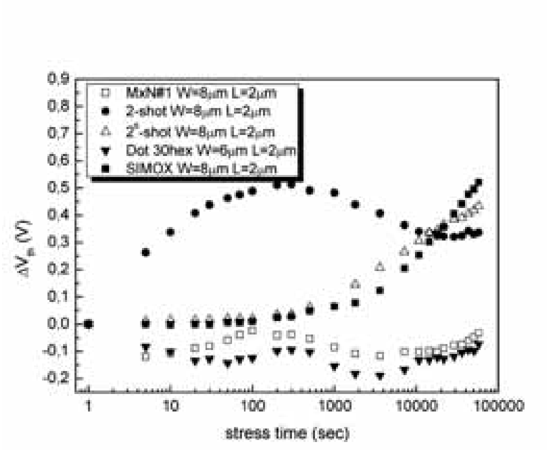


Fig. 8: Evolution of $\Delta G_{m,max}/G_{m,max0}$ with stress time for differently crystallized poly-Si TFTs.

			BEFORE FGA	AFTER FGA	BEFORE FGA	AFTER FGA	BEFORE FGA	AFTER FGA	BEFORE FGA	AFTER FGA
SAMPLE	POLY-SILICON	GATE DIELECTRIC	V_{th} (V)		μ (cm^2/V·sec)		D_{ts} ($eV^{-1}\cdot cm^{-2}$)		N_t (cm^{-2})	
T1	D/S	PECVD SiO_2	1,32	0,37	51,12	91,07	$2{,}80\cdot10^{12}$	$8{,}97\cdot10^{11}$	$5{,}33\cdot10^{11}$	$2{,}27\cdot10^{11}$
T3	2-shot	PECVD SiO_2	2,11	1,00	32,02	65,99	$3{,}24\cdot10^{12}$	$1{,}25\cdot10^{12}$	$4{,}79\cdot10^{11}$	$2{,}40\cdot10^{11}$
T4	2-shot	TEOS SiO_2	0,79	0,72	82,44	104,33	$2{,}16\cdot10^{12}$	$1{,}07\cdot10^{12}$	$3{,}34\cdot10^{11}$	$2{,}33\cdot10^{11}$
T7	SPC	TEOS SiO_2	7,20	8,56	10,85	11,09	$7{,}81\cdot10^{12}$	$7{,}54\cdot10^{12}$	$9{,}23\cdot10^{11}$	$9{,}54\cdot10^{11}$

Table II: Performance parameters of TFTs fabricated at IMEL.

As far as reliability is concerned, we observed more severe degradation for the TFTs with 2-shot SLS ELA polysilicon (Fig.9), in comparison to ones with directional SLS ELA polysilicon, ascribed to the increased surface roughness of the film. Also, we observed different degradation mechanisms for TFTs with gate dielectric deposited with different techniques (Fig.10), ascribed to differences in the dielectric film quality.

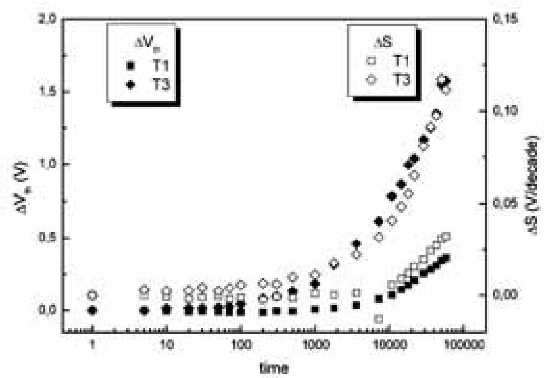


Fig. 9: Evolution of ΔV_{th} and ΔS with stress time for differently crystallized poly-Si TFTs.

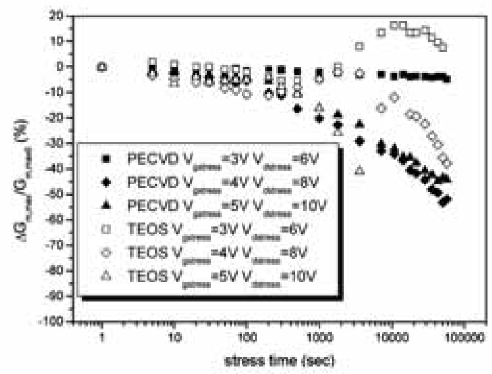


Fig. 10: Evolution of $\Delta G_{m,max}/G_{m,max0}$ with stress time for differently crystallized poly-Si TFTs.

In an effort to investigate the use of a high-k material, HfO_2, as gate dielectric in TFT fabrication, we fabricated MOS capacitors with HfO_2 dielectric, to investigate the best HfO_2 sputter deposition and post-treatment conditions, and also determine which gate material would be suitable for this dielectric. Finally, we determined that the best performing MOS capacitors were the ones utilizing a thin SiO_2 oxide between the silicon and the HfO_2 film. We tried three different gate electrode materials, poly-Si, Al and W, and found that poly-Si is not a suitable material, since the capacitors exhibited high parasitic capacitances (Fig.11) and very low reliability. W gate samples performed acceptably (Fig.12), showing however some hysteresis, indicating charge trapping.

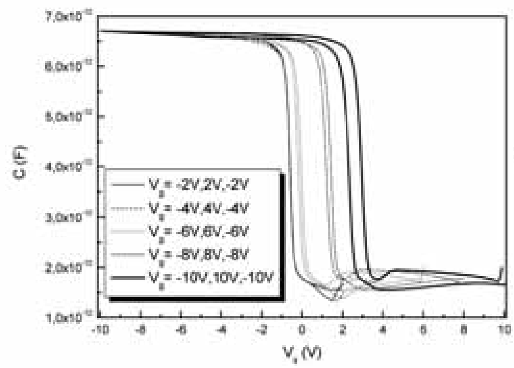


Fig. 11: Capacitance-Voltage characteristics for HfO_2 capacitors with poly-Si as gate electrode.

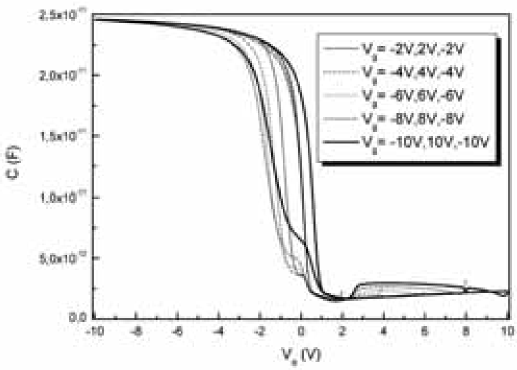


Fig. 12: Capacitance-Voltage characteristics for HfO_2 capacitors with W as gate electrode.

C. Low temperature and transient current characterization

In the past year this research, carried out in collaboration with the University of Athens, was expanded in the investigation of the thermally activated mechanisms that determine the electrical properties of polysilicon TFTs (only a small part of the collaborative research at UoA is covered here). Temperature seems to have negligible effect on the ON regime, but significant influence below threshold, as indicated from the transfer characteristics in Fig.13; the OFF current and the subthreshold swing are thermally activated. The threshold voltage decreases with increasing temperature (Fig.14); in non-crystalline devices, the excitation of trapped carriers from band gap states into the conduction band plays a significant role, because the rise in temperature increases the free carrier density, leading to channel formation at lower gate voltages.

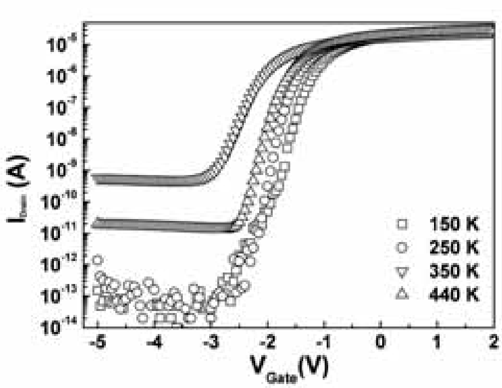


Fig. 13: Transfer characteristics of a TFT in a 100 nm thick polysilicon film at different temperatures.

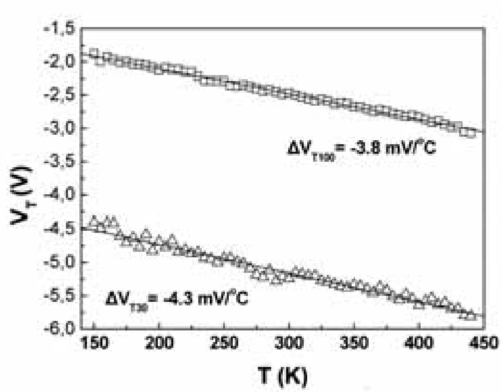


Fig. 14: Temperature dependence of threshold voltage for TFTs in 30 nm and 100 nm thick polysilicon films.

In polysilicon, carrier trapping, emission and thermal generation are determined by a continuous distribution of band gap states, which consists of band tails and deep traps. As the contribution of each state is thermally activated, the effective generation lifetime will also be, with effective activation energy E_A, which will depend on the distribution of the density of states. This allows the determination of E_A from the Arrhenius plot of the leakage current, in Fig.15; E_A was 0.20 eV and 0.56 eV for the 100 nm and 30 nm thick devices, respectively. The above values suggest that in thicker films the generation takes place mainly through deeper states, while in thinner films the contribution of tail states becomes significant. As tail states are mainly introduced due to the lack of periodicity in the crystal potential, by the presence of grain boundaries, a large density of tail states is expected in thinner SLS polysilicon films where the grains are smaller.

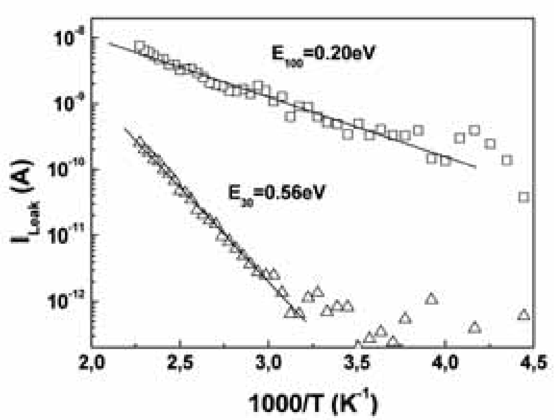


Fig. 15: Temperature dependence of drain leakage current for TFTs in 30 nm and 100 nm thick films.

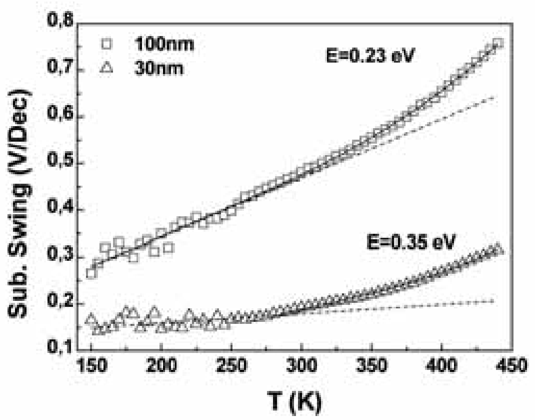


Fig. 16: Exponential terms obtained in the subthreshold swing increase with temperature for 30 nm and 100 nm TFTs.

In TFTs the subthreshold swing is temperature dependent primarily due to the increase in the intrinsic carrier concentration, while the Fermi level and mobility variations are also involved. In bulk MOSFETs, a linear swing increase with increasing temperature is expected due to the diffusion nature of the current. In polysilicon TFTs the generation of carriers takes place through grain boundary trap states. In principle, the generation mechanism in the depletion layer is the same with the one for the leakage current. Therefore, the activation energies, derived from the subthreshold swing, must have similar values and follow the same trend, with respect to the film thickness, with the ones obtained from the OFF state leakage current. Comparing (Fig.16) the values of the activation energies we find that for TFTs in 100 nm films the activation energies are practically the same. In contrast, in the case of 30 nm thick film devices the activation energies are different; lower values are obtained from the temperature dependence of the subthreshold swing. This difference may be attributed to the effect of coupling of the front and back interfaces, which is directly affected by the inefficient screening from body defects, as the electron mean free path is estimated in the range of 5–30 nm that is close to the film thickness. Such a situation seems not to occur for the 100 nm devices, where the polysilicon film thickness is much larger than the electron mean free path.

The temperature dependence of TFT parameters (leakage current, subthreshold swing) was thus found to stem from the same thermally activated carrier generation mechanism through grain boundary trap states, which determines device operation; deeper states contribute more to the generation in 100 nm films than in 30 nm ones. The leakage current, the exponential increase of the subthreshold swing and the switch-ON overshoot transient current amplitude exhibit the same temperature onset; the threshold temperature of those thermally activated processes is found to be thickness dependent, indicating the varying contribution of trap states. The dependence of thermally activated mechanisms, which are strongly related to material properties and which shape the electrical characteristics, on film thickness suggests that TFT operation is strongly related to the polysilicon film properties, in particular to the contribution of trap states.

D. Irradiation investigation

The γ-irradiation induced degradation of SLS ELA TFTs has also been studied, in collaboration with the University of Nis. During 2007, while the effect of polysilicon film thickness was further explored, the research was expanded to investigation of the effect of device direction relative to the preferred direction of directional SLS ELA polysilicon films, as well as to the assessment of the grain boundary trap state density. Fig.17 shows the threshold voltage shift after irradiations of 100 Gy and 500 Gy, for various film thicknesses; TFTs fabricated in intermediate thickness films seem to have higher immunity to irradiation. The V_{th} shift strongly depends on the gate voltage applied during irradiation for TFTs in 30 nm and 100 nm polysilicon films, while for TFTs in 50 nm films the influence of this gate bias is no so pronounced, especially in devices oriented with the current flow orthogonal to the elongated grains.

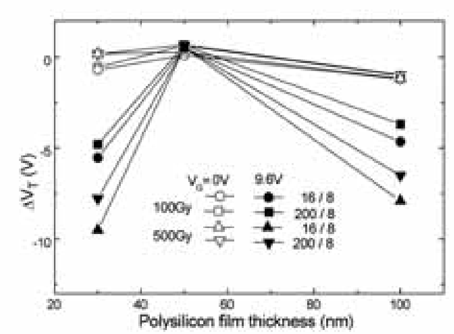


Fig. 17: Dependence of threshold voltage shift on poly-Si film thickness for doses of 100 & 500 Gy.

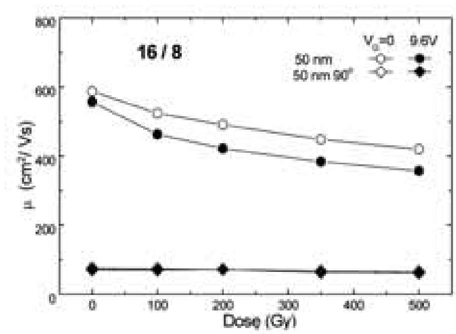


Fig. 18: Carrier mobility behavior of two groups of irradiated TFTs having different direction of current flow.

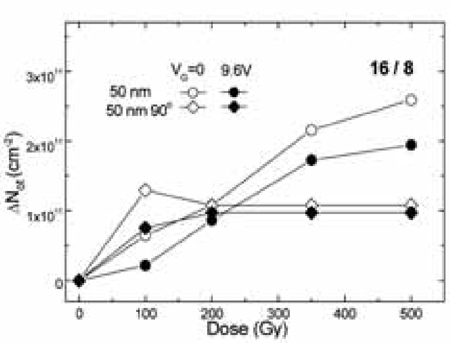


Fig. 19: Oxide trapped charge density for irradiated TFTs having different direction of current flow.

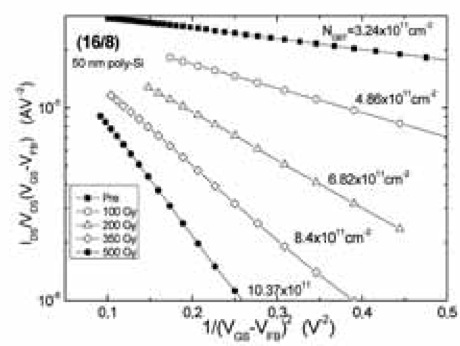


Fig. 20: Typical graph for grain boundary trap-state density extraction of stressed TFT devices.

Fig. 18 shows the electron mobility for TFTs in 50 nm films oriented in parallel or perpendicularly (90°) to the preferred grain direction. The weak dependence of mobility on irradiation dose, as well as on gate bias during irradiation, which is observed, could be attributed to domination of scattering mechanisms and trapping at grain boundaries over scattering on charged interface defects. This conclusion can be further supported from the comparison of the mobility in devices having current flow direction orthogonal to the grain boundaries; in these TFTs the mobility is not only low and independent of γ-irradiation dose, but also almost independent of applied gate bias during irradiation.

TFTs in 50 nm polysilicon films exhibit a small irradiation-induced degradation of the oxide trapped charge density (ΔN_{ot}), which is significantly smaller in devices having orientation at 90° with respect to the preferred grain direction, as shown in Fig.19; moreover, for these devices there is almost no effect of gate bias application during irradiation. Besides the grain size, the quality of polysilicon films is also defined by trap states at grain boundaries, which influence the mobility at higher gate voltages. Using the procedure described by Proano et al (IEEE TED-36, 1915, 1989), a modification of the Levinson method), the density of grain-boundary trap states (NGBT) in virgin and stressed devices can be determined from the slopes of the straight lines of the plots shown in Fig. 20. As can be seen, virgin TFTs have N_{GBT} = 3-5x10^{11} cm^{-2}, while γ-irradiation generates new traps at grain-boundaries, degrading the device parameters. Fig.21 shows the shift in NGBT against the irradiation dose for TFTs (parallel to grains) in 30, 50 or 100 nm films. TFTs in 100 nm films are much less resistant to irradiation when a gate bias is applied for duration of it. Fig. 22 shows the N_{GBT} against irradiation dose for TFTs in 50 nm films oriented in parallel or vertically to the elongated grains; the effect of an applied gate bias during irradiation is not significant here. While the difference is small, the vertically oriented devices are more resistant to γ-irradiation.r

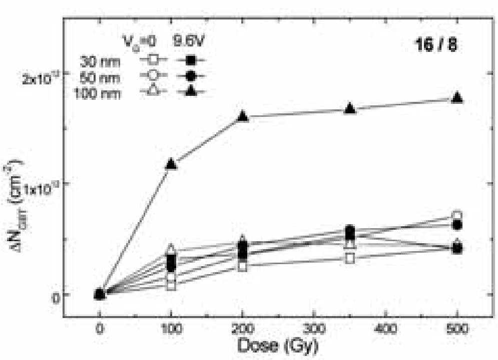


Fig. 21: Density of grain boundary traps for irradiated TFTs having different thickness of polysilicon films.

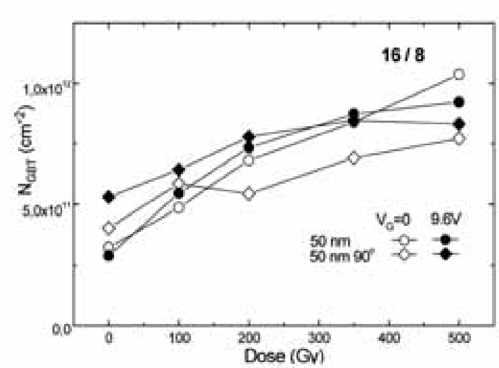


Fig. 22: Density of grain boundary traps for irradiated TFTs having different direction of current flow.

E. Material/optical characterization

An optical characterization of three differently crystallized SLS ELA polysilicon films was performed. TFTs fabricated in these three types of films (directional, 2-shot and 2^6-shot) have also been electrically characterized. The transmission spectra of the polysilicon films were obtained (Fig.

23). We fitted these spectra with a software developed here, utilizing the Tauc-Lorentz model for the refractive index of the material, in order to extract the real (Fig. 24) and the imaginary part of the refractive index of the films. This way, structural differences between the various polysilicon films could be probed. Through the optical parameters extracted, a correlation between structural and electrical characteristics will be attempted.

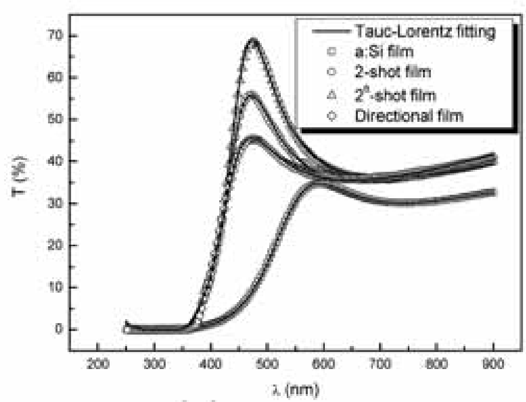


Fig. 23: Transmission spectra of the SLS ELA poly-Si films and application of Tauc-Lorentz model.

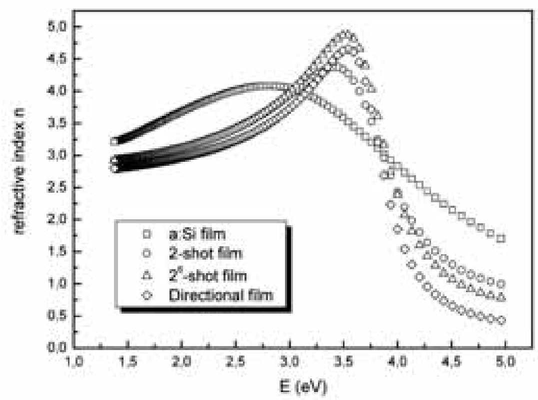


Fig. 24: Refractive index n of SLS ELA poly-Si films, as obtained by the Tauc-Lorentz model.

PROJECT OUTPUT in 2007

Publications in International Journals and Reviews

1. "An experimental study of the thermally activated processes in polycrystalline silicon thin film transistors", Michalas, L., M. Exarchos, G.J. Papaioannou, D.N. Kouvatsos and A.T. Voutsas, Microelectronics Reliability, 47 (12), 2058, December 2007.
2. "Influence of polysilicon film thickness on radiation response of advanced excimer laser annealed polycrystalline silicon thin film transistors", Davidovic, V., D.N. Kouvatsos, N. Stojadinovic and A.T. Voutsas, Microelectronics Reliability 47 (9-11), 1841, September-November 2007.
3. "Degradation of double-gate polycrystalline silicon TFTs due to hot carrier stress", Farmakis, F.V., G.P. Kontogiannopoulos, D.N. Kouvatsos and A.T. Voutsas, Microelectronics Reliability 47 (9-11), 1434, September-November 2007.
4. "Performance and reliability of SLS ELA polysilicon TFTs fabricated with novel crystallization techniques", Moschou, D.C., M.A. Exarchos, D.N. Kouvatsos, G.J. Papaioannou and A.T. Voutsas, Microelectronics Reliability 47 (9-11), 1378, September-November 2007.
5. "Front and Back Channel Properties of Asymmetrical Double-Gate Polysilicon TFTs", Farmakis, F.V., D.N. Kouvatsos, A.T. Voutsas, D.C. Moschou, G.P. Kontogiannopoulos and G.J. Papaioannou, Journal of the Electrochemical Society 154 (10), H910, October 2007.
6. "Nickel nanoparticle deposition at room temperature for memory applications", Verelli, E., D. Tsoukalas, K. Giannakopoulos, D. Kouvatsos, P. Normand and D.E. Ioannou, Microelectronic Engineering, 84 (9-10), 1994, September-October 2007.

7. "Device degradation behavior and polysilicon film morphology of TFTs fabricated using advanced excimer laser lateral solidification techniques", Kouvatsos, D.N., A.T. Voutsas, L. Michalas, F. Farmakis and G.J. Papaioannou, Thin Solid Films 515 (19), 7413, July 2007.
8. "Characterization of double gate TFTs fabricated in advanced SLS ELA polycrystalline silicon films", Kouvatsos, D.N., F.V. Farmakis, D.C. Moschou, G.P. Kontogiannopoulos, G.J. Papaioannou and A.T. Voutsas, Solid State Electronics 51 (6), 936, June 2007.

Publications in Conference Proceedings

1. "The impact of gate oxide polarization on drain current transient behavior of advanced excimer laser crystallized polysilicon thin film transistors", Exarchos, M.A., L. Michalas, G.J. Papaioannou, D.N. Kouvatsos, and A.T. Voutsas, Proceedings of the 3rd International Thin Film Transistors Conference (ITC '07) / 2007 Society for Information Display Europe Chapter Meeting, p. 196, Rome, Italy, 2007.
2. "Characterization of advanced directional SLS ELA polysilicon TFTs – Dependence of device parameters on orientation and geometry", Moschou, D.C., D.N. Kouvatsos, F.V. Farmakis and A.T. Voutsas, Proceedings of the 3rd International Thin Film Transistors Conference (ITC '07) / 2007 Society for Information Display Europe Chapter Meeting, p. 192, Rome, Italy, January 2007.
3. "Investigation of the Undershoot Effect in Polycrystalline Silicon Thin Film Transistors", Michalas, L., G.J. Papaioannou, D.N. Kouvatsos, and A.T. Voutsas, Proceedings of the 3rd International Thin Film Transistors Conference (ITC '07) / 2007 Society for Information Display Europe Chapter Meeting, p. 116, Rome, Italy, January 2007.
4. "Hot carrier stress induced degradation of SLS ELA polysilicon TFTs – Effects of gate width variation and device orientation", Kontogiannopoulos, G.P., F.V. Farmakis, D.N. Kouvatsos, G.J. Papaioannou and A.T. Voutsas, Proceedings of the 3rd International Thin Film Transistors Conference (ITC '07) / 2007 Society for Information Display Europe Chapter Meeting, p. 100, Rome, Italy, January 2007.

International Conference Presentations

1. "The effect of crystallization technology and gate insulator deposition method on the performance and reliability of polysilicon TFTs", Moschou, D.C., G.P. Kontogiannopoulos, D.N. Kouvatsos and A.T. Voutsas, 3rd International Conference on Micro- and Nanoelectronics, Nanotechnology and MEMS (MicroNano 2007), Athens, Greece, November 2007.
2. "Performance of Thin-Film Transistors fabricated by Sequential Lateral Solidification crystallization techniques", Exarchos, M.A., D.C. Moschou, G.J. Papaioannou, D.N. Kouvatsos and A.T. Voutsas, 3rd International Conference on Micro- and Nanoelectronics, Nanotechnology and MEMS (MicroNano 2007), Athens, Greece, November 2007.
3. "Investigation of top gate electrode variations for high-k gate dielectric MOS capacitors", Moschou, D.C., E. Verelli, D.N. Kouvatsos, P. Normand, D. Tsoukalas, A. Speliotis, P. Bayiati and D Niarchos, 3rd International Conference on Micro- and Nanoelectronics, Nanotechnology and MEMS (MicroNano 2007), Athens, Greece, November 2007.
4. "An Experimental Study of Band Gap States Electrical Properties in Poly-Si TFTs by the Analysis of the Transient Currents", Michalas, L., G.J. Papaioannou, D.N. Kouvatsos and A.T. Voutsas, 3rd International Conference on Micro- and Nanoelectronics, Nanotechnology and MEMS (MicroNano 2007), Athens, Greece, November 2007.
5. "Degradation of double gate polycrystalline silicon TFTs due to hot carrier stress", Farmakis, F.V. G.P. Kontogiannopoulos, D.N. Kouvatsos and A.T.Voutsas, 18th European Symposium - Reliability of Electron Devices, Failure Physics and Analysis (ESREF 2007), Arcachon, France, October 2007.

6. "Influence of polysilicon film thickness on radiation response of advanced excimer laser annealed polycrystalline silicon thin film transistors", Davidoviċ, V., D.N. Kouvatsos, N. Stojadinoviiċ, A.T. Voutsas, 18th European Symposium - Reliability of Electron Devices, Failure Physics and Analysis (ESREF 2007), Arcachon, France, October 2007.
7. "Performance and reliability of SLS ELA polysilicon TFTs fabricated with novel crystallization techniques", Moschou, D. C., M. A. Exarchos, D. N. Kouvatsos, G. J. Papaioannou and A. T. Voutsas, 18th European Symposium - Reliability of Electron Devices, Failure Physics and Analysis (ESREF 2007), Arcachon, France, October 2007.
8. "Characterization of thin film transistors fabricated on different sequential lateral solidified polysilicon substrates", Michalas, L., G.J. Papaioannou, D.N. Kouvatsos, F.V. Farmakis and A.T. Voutsas, 33rd International Conference on Micro- and Nano-Engineering (MNE 2007), Copenhagen, Denmark, 2007
9. "A novel SLS ELA crystallization process and its effects on polysilicon film defectivity and TFT performance", Moschou, D. C., M. A. Exarchos, D. N. Kouvatsos, G. J. Papaioannou and A. T. Voutsas, 33rd International Conference on Micro- and Nano-Engineering (MNE 2007), Copenhagen, Denmark, September 2007.
10. "Nickel nanoparticle deposition at room temperature for memory applications", Verelli, E., D. Tsoukalas, K. Giannakopoulos, D. Kouvatsos, P. Normand and D.E. Ioannou, 15th bi-annual Conference – Insulating Films on Semiconductors (INFOS 2007), Athens, Greece, June 2007.

Conference Participation

1. 3rd International Thin Film Transistors Conference (ITC '07) / 2007 Society for Information Display Europe Chapter Meeting, Rome, Italy, January 2007.
2. 15th bi-annual Conference – Insulating Films on Semiconductors (INFOS 2007), Athens, Greece, 2007.
3. 33rd International Conference on Micro- and Nano-Engineering (MNE 2007), Copenhagen, Denmark, September 2007.
4. 18th European Symposium - Reliability of Electron Devices, Failure Physics and Analysis (ESREF 2007), Arcachon, France, October 2007.
5. 3rd International Conference on Micro- and Nanoelectronics, Nanotechnology and MEMS (MicroNano 2007), Athens, Greece, November 2007.
6. 23rd Panhellenic Conference for Solid State Physics and Materials Science, Athens, Greece, September 2007 (5 presentations).

Organization of Conferences, Workshops and Project meetings

Member of the Technical Programme Subcommittee of the 18th European Symposium - Reliability of Electron Devices, Failure Physics and Analysis (ESREF 2007), Arcachon, France, October 2007.

Reviewer – Member of the Technical Programme Subcommittee of the 26th International IEEE Conference on Microelectronics (MIEL 2008) (Nis, Serbia & Montenegro, May 2008).

CIRCUITS & DEVICES FOR OPTOELECTRONIC INTERCONNECTIONS

Project Leader: G. Halkias
Other Key Researchers: S. G. Katsafouros
PhD Candidates: K. Minoglou
External Collaborators: E.D. Kyriakis-Bitzaros

Objectives:

The main objective of the activity is the development of the technologies for future high-density and high-speed optoelectronic interconnections. In the context of this objective the research targets of optoelectronic device modeling and simulation, implementation of optoelectronic technology in spacecraft environment as well as packaging in terms of photonic link integration above CMOS integrated circuits have been identified and pursued.

Funding:

- EU- IST PICMOS - Contract No 002131, "Photonic Interconnet Layer on CMOS by Wafer-Scale Integration", Duration: 1/1/2004-31/3/2007

EXAMPLES OF RESEARCH RESULTS IN 2007

A. Development of a model for simulating Vertical Cavity Surface Emitting Lasers (VCSELs)

A compact non-linear circuit model for the input of packaged high-speed VCSELs is presented. The model includes the thermal effects as well as the parasitics, due to the various levels of the packaging hierarchy, to ensure a realistic representation of the input of the VCSELs. The values of the model parameters are extracted from dc current-light-voltage characteristics and S_{11} vector measurements using a two-step parameter extraction procedure. Extraction of the model parameters and comparison between measured and simulated results have been performed for two different commercially available VCSELs operating at 2.5 Gb/s. The achieved agreement between the measured and simulated results is very satisfactory for the dc as well for the S_{11} curves in the frequency range from 3MHz to 3GHz.

B. Heterogeneous integration of optical interconnects onto CMOS ICs

The employment of a photonic layer above CMOS integrated circuits (ICs) has been proposed as an alternative solution for the global interconnection regime. Photonic dies with fully integrated optical paths, sources and detectors coupled to waveguides, are bonded onto a CMOS integrated circuit (IC) using a metallic bonding technique. The proposed approach utilizes a thin multilayer structure of the 80Au-20Sn eutectic alloy along with a thin starting layer of rare earth Gd and contains versatile structures for passive alignment. Its main advantage is the fact that it accomplishes mechanical bonding and electrical connectivity in a single step. The proposed approach resembles the flip-chip approach, but the solder volume and size are considerably lower making it appropriate for high-density integration. Pattern uniformity, limited alloy spreading and contact resistance in the mΩ range across a 4-inch wafer has been verified. Fig. 1 below shows on top a portion of a patterned 4in wafer where convex structures are formed to match with the corresponding concave structures patterned on the dies and below IR images of bonded dies. It becomes clear that the goal of alignment has been achieved as also revealed by electrical measurements of the test structures shown in fig. 2. This project is executed in collaboration with IMEC, Belgium, ST, CEA, CNRS-FMNT, France, and TUE, Holland, in the framework of the European project PICMOS.

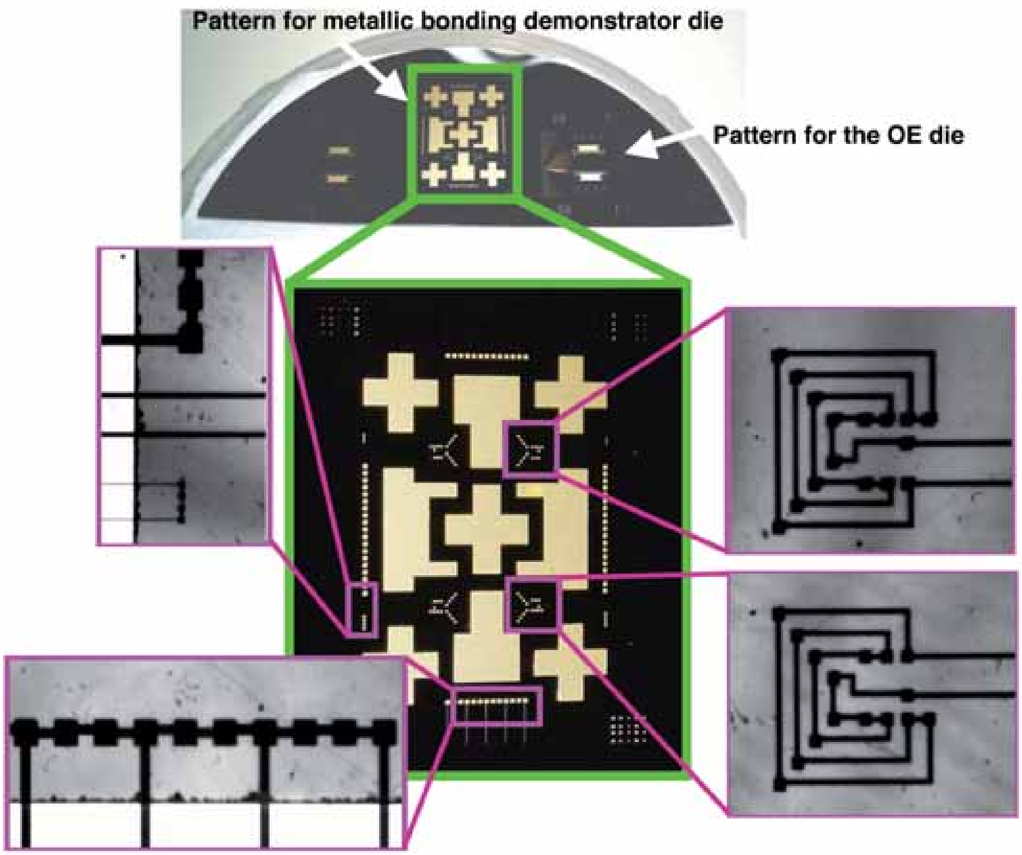


Fig. 1: Wafer and die photographs and IR images of bonded structures

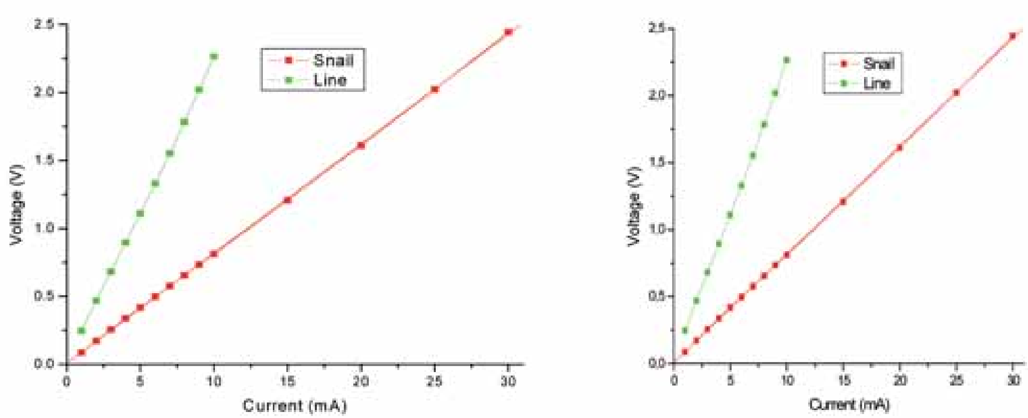


Fig. 2: Electrical measurements of bonded test structures.

PROJECT OUTPUT IN 2007

PUBLICATIONS in REFERREED JOURNALS

1. "Input and intrinsic device modeling of VCSELs", K. Minoglou, G. Halkias, E. D. Kyriakis-Bitzaros, D. Syvridis, Journal of Computational Electronics, Springer Science, Vol. 6, 2007, pp.309–312

CONFERENCE PRESENTATIONS

1. "VCSEL device modeling and parameter extraction technique", K. Minoglou, G. Halkias, E. D. Kyriakis-Bitzaros, D. Syvridis, A. Arapogianni, IEEE 14th ICECS 2007, Marrakesh, Morocco, 11-14 Dec. 2007, pp. 14-17
2. "High density integrated optoelectronic circuits for high speed photonic Microsystems", K.Minoglou, E.D.Kyriakis-Bitzaros, S.G. Katsafouros, G.Halkias, A.Arapogianni, D.Syvridis, PRIME 2007, Bordeaux, France, pp. 57-60.

PhD Thesis

1. "High density optoelectronic integrated circuits for high speed photonic microsystems", K. Minoglou, Department of Informatics and Telecommunications, University of Athens, March 2007.

PAPER AWARDS

Paper C2 was awarded the "Bronze Leaf" (third prize)

ANNEXES

ANNEX I : PERSONNEL

Researchers

1. Nassiopoulou A.G., Director
2. Argitis P.
3. Davazoglou D.
4. Gardelis S.
5. Glezos N.
6. Gogolides E.
7. Halkias G.
8. Ioannou-Sougleridis V.
9. Kouvatsos D.
10. Misiakos K.
11. Normand P.
12. Papanikolaou N.
13. Raptis I.
14. Tsamis C.
15. Tserepi A.

Research Engineers

1. Tsoi E.
2. Katsafouros S.

Research Associate

1. Contopanagos H.

Other Scientific Staff

1. Dimitrakis P. (IDAX)
2. Douvas A. (IDAX)
3. Konstandoudis K. (IDAX)
4. Vassilopoulou M. (IDAX)
5. Huffman M. (Contract)

Post Doctoral Scientists

1. Goustouridis D.
2. Vambakas V.
3. Makarona E.
4. Kapetanakis E.
5. Chatzandroulis S.
6. Skarlatos D. (6 months in 2007)
7. Catzichristidi M. (Contract 6months in 2007)
8. Pagonis D. N. (Contract 6months in 2007)
9. Chalampalakis G (Contract 6months in 2007)
10. Theodoropoulou M. (Contract)
11. Farmakis P. (Contract)
12. Palilis L. (Contract)
13. Velessiotis D. (Contract)
14. Patsis G. (Contract)
15. Kokoris G. (Contract)
16. Kotsovos K. (Contract)

PhD Students

1. Bayati P.
2. Chaidogiannos G.
3. Vourdas N.
4. Chronaios A.
5. Kelaidis N.
6. Goupidenis P.
7. Minoglou K.
8. Malenou A.
9. Niakoula D.
10. Papadimitropoulos G.
11. Polymenakos S.
12. Vlachopoulou M
13. Kitsara M.
14. Kontziampasis D. (Contract)
15. Drigiannakis I. (Contract)
16. Tsougenni A. (Contract)
17. Gianetta V. (Contract)
18. Grivas E. (Contract)
19. Ioannou N. (Contract)
20. Kontogiannopoulos I. (Contract)
21. Ramfos I. (Contract)
22. Tsikrikas N. (Contract)
23. Moschou D. (Contract)
24. Boulousis G. (Contract)
25. Triantafillopoulou R. (Contract)
26. Zacharatos F. (Contract)
27. Zampelis L. (Contract)
28. Theodoni P. (Contract)
29. Vissio C. (Contract)
30. Pavli P. (Contract)
31. Tsouroutas P. (Contract)
32. Petropoulos A. (Contract)
33. Tsouti V. (Contract)

Technical and Administrative Personnel

1. Georgiou C.
2. Lagouvardou M.
3. Makridi Z.
4. Makridis Z.
5. Mavropoulis I.
6. Sergis E.
7. Aspiotis I. (Contract)
8. Bolomiti E. (Contract)
9. Boukouras K. (Contract, part time)
10. Kalpouzou M. (Contract)
11. Karmpadaki M. (Contract)
12. Kontakis K. (Contract)
13. Linarakis E. (Contract)

ANNEX II: INFRASTRUCTURE AT IMEL

PROCESSING

Equipment

Silicon processing laboratory in a clean room area of 500 m2, equipped with the following:

- 4 laminar flow chemical benches
- 7 horizontal hot-wall furnace tubes
- 2 horizontal LPCVD tubes for nitride, oxide (TEOS), polysilicon
- 1 horizontal LPCVD tube for LTO
- Ion Implanter (EATON medium current, 200 KeV)
- Optical lithography systems (resolution down to 0,6 μm)
- Reactive Ion Etcher
- Metallization equipment (thermal, e-gun evaporation, sputtering) Process inspection equipment

Processing equipment not in clean room:

- High Density Plasma Etcher
- Different thin film deposition systems (Sputtering, MOCVD)

Techniques/competences

- Nanopatterning technologies
- Plasma etching
- Growth of metals and dielectrics
- Growth of polycrystalline and nanocrystalline Si
- Growth of Si nanostructures embedded in a dielectric matrix, ordering of nanostructures
- Fabrication of MOS capacitors and MOSFETs
- Nanocrystal non-volatile memories
- Micromachining, sensor fabrication, microfluidics
- Molecular materials and devices
- Thin film devices

CHARACTERIZATION & MODELLING

Electrical

- Several probe stations
- HP measuring systems (4142B, 4084B, 8110A, 700i series, 4140B, 4284, 4192A, 34401, 16500A)
- Keithley measuring equipment (230, 220, 617, 195A, 6517A)
- Oxford optistat cryostat for temperatures in the range 4.2-320K
- Wafer level cryogenic measurements (Janis probe station)
- Cascade Microtech Summit 9101 Analytical Probe Station for 150mm wafers
- Anritsu 37269D Vector Network Analyzer 40MHz-40GHz

Optical

- Jobin Yvon spectrometer,wavelengths 300-1600nm
- Ar+ laser

Characterization of Dielectrics

- Admittance measurements (1Hz up to 1MHz, 25-150°C)
- I-V measurements (2 up to 4-terminal devices, 25-150°C)
- Charge-to-breakdown measurements
- Bias-Temperature-Stress measurements

Characterization of MIS Devices

- Admittance measurements (1Hz up to 1MHz, 25-150°C)
- I-V measurements (2 up to 4-terminal devices, 25-150°C)
- Hot-carrier stress measurements
- Bias-Temperature-Stress measurements

EEPROM device characterization and reliability measurements
Characterization of RF components

HeCd 10mW 325 nm laser
- UV lamp with monochromator
- Oxford optistat cryostat, 4.2-320K
- FTIR: Bruker, Tensor 27

Morphology, structural characterization
- Leo 440 SEM with Elphy/Raith e-beam lithography attachment, JEOL JSM-7401F FEG SEM
- AFM (Veeco CP-II), STM (NT-MDT)
- Stylus profilometer model XP-2 of Ambios Technology

Testing equipment
- Systems for testing of gas flow, gas pressure, acceleration, humidity sensors, biosensors and systems, microfluidics testing etc.

Modeling and simulation software
- SILVACO tools for process and device modeling (Athina and Atlas)
- Suprem and Pisces
- Floops and Floods
- Synopsis – Coventorware
- FEMlab
- Mentor graphics

Optical characterization
- Absorption measurements, wavelength range UV-VIS-IR
- Photoluminescence (PL)
  - Laser excitation: 325 nm, 457.8nm, 488nm, 514.5nm
  - Spectrometer: 350nm-1600nm
- Electroluminescence (EL): 350nm-1600nm
- Photocurrent-photovoltage (UV-VIS)
- FTIR

Characterterization of sensors
- Gas sensors
- Microflow sensors
- Accelerometers
- Optical devices
- Biosensors
- Microfluidics

Modeling and simulation
- Process and device modeling
- RF modeling








ANNEX III: RESEARCH AND EDUCATION OUTPUT

LIST OF PUBLICATIONS IN REFEREED JOURNALS

1. "Influence of grain size on ultrafast carrier dynamics in thin nanocrystalline silicon films", E. Lioudakis, A. Othonos, A. G. Nassiopoulou, Ch. B. Lioutas and N. Frangis, Appl. Phys. Lett. 90, 191114 2007
2. "Fundamental transport processes in assembles of silicon quantum dots" I. Balberg, E. Savir, J. Jedrzejewski, A. G. Nassiopoulou, S. Gardelis, Phys. Rev. B 75 235329 (2007)
3. "Ultrafast transient photoinduced absorption in silicon nanocrystals: Coupling of oxygen-related states to quantized sublevels", E. Lioudakis, A. Othonos, A. G. Nassiopoulou, Appl. Phys. Lett. 90, 171103 2007
4. "Self-assembly of single thin Au nanoparticle chains on Si along V-groove-etched lines between micrometer-distant electrodes by dielectrophoresis" A. Zoy, A. A. Nassiopoulos and A. G. Nassiopoulou Nanotechnology 18 345608 (2007)
5. "Two-silicon-nanocrystal layer memory structure with improved retention characteristics", A. G. Nassiopoulou and A. Salonidou, J. Nanosci. Nanotechnol., vol. 7, 368-373 (2007)
6. "Ge quantum dot memory structure with laterally ordered highly dense arrays of Ge dots", A. G. Nassiopoulou, A. Olzierski, E. Tsoi, I. Berbezier and A. Karmous, J. Nanosci. Nanotechnol., vol. 7, 316-321 (2007)
7. "The role of surface vibrations and quantum confinement effect to the optical properties of very thin nanocrystalline silicon films", Lioudakis, E., Antoniou, A., Othonos, A., Christofides, C., Nassiopoulou, A.G., Lioutas, Ch.B., Frangis, N., J. of Appl. Physics 102 (8), art. no. 083534 (2007)
8. "Ultra-thin films with embedded Si nanocrystals fabricated by electrochemical dissolution of bulk crystalline Si in the transition regime between porosification and electropolishing", Gardelis, S., Tsiaoussis, I., Frangis, N., Nassiopoulou, A.G., Nanotechnology 18 (11), art. no. 115705 (2007)
9. "Few nanometer thick anodic porous alumina films on silicon with high density of vertical pores", Kokonou M., Giannakopoulos K.P., Nassiopoulou A.G., Thin Solid Films 515, pp. 3602-3606 (2007)
10. "A silicon thermal accelerometer without solid proof mass using porous silicon thermal isolation" D. Goustouridis, G. Kaltsas and A. G. Nassiopoulou IEEE Sensors Journal, vol. 7 No 7 983 (2007)
11. "Quntum confinement and interface structure of Si nanocrystals of sizes 3-5 nm embedded in α-SiO2" E. Lioudakis, A. Othonos, G. C. Hadjisavvas, P. C. Kelires and A. G. Nassiopoulou, Physica E 38 128-134 (2007)
12. "Charging/discharging kinetics in LPCVD silicon nanocrystal MOS memory structures", V. Turchanikov, A. Nazarov, V. Lysenko, E. Tsoi, A. Salonidou and A. G. Nassiopoulou Physia E 38 89-93 (2007)
13. "Nanostructuring Si surface and Si/SiO2 interface using porous-alumina-on-Si template technology. Electrical characterization of Si/SiO2 interface" M. Kokonou and A. G. Nassiopoulou, Physica E 38, 1-5 (2007)
14. "Formation of confined macroporous silicon membranes on pre-defined areas on the Si substrate", Pagonis, D.N., Nassiopoulou, A.G., Physica Status Solidi (a) 204 (5), pp. 1335-1339 (2007)
15. "Novel microfluidic flow sensor based on a microchannel capped by porous silicon", Pagonis, D.N., Petropoulos, A., Kaltsas, G., Nassiopoulou, A.G., Tserepi, A., Physica Status Solidi (a) 204 (5), pp. 1474-1479 (2007)
16. "Integrated inductors on porous silicon", Contopanagos, H., Nassiopoulou, A.G., Physica Status Solidi (a) 204 (5), pp. 1454-1458 (2007)
17. "A smart flow measurement system for flow evaluation with multiple signals in different operation modes", G. Kaltsas, P. Katsikogiannis, P. Asimakopoulos, A. G. Nassiopoulou, Meas. Sci. Technol. 18 (2007) 3617–3624
18. "Input and intrinsic device modeling of VCSELs", K. Minoglou, G. Halkias, E. D. Kyriakis-Bitzaros, D. Syvridis, Journal Computational Electronics, Sringer Science, Vol. 6, 2007, pp. 309–312.
19. "An experimental study of the thermally activated processes in polycrystalline silicon thin film transistors", Michalas, L., M. Exarchos, G.J. Papaioannou, D.N. Kouvatsos and A.T. Voutsas, Microelectronics Reliability, 47 (12), 2058, 2007
20. "Influence of polysilicon film thickness on radiation response of advanced excimer laser annealed polycrystalline silicon thin film transistors", Davidovic, V., D.N. Kouvatsos, N. Stojadinovic and A.T. Voutsas, Microelectronics Reliability 47 (9-11), 1841, September-November 2007
21. "Degradation of double-gate polycrystalline silicon TFTs due to hot carrier stress", Farmakis, F.V., G.P. Kontogiannopoulos, D.N. Kouvatsos, A.T. Voutsas, Microelectronics Reliability 47 (9-11), 1434, 2007

22. "Performance and reliability of SLS ELA polysilicon TFTs fabricated with novel crystallization techniques", Moschou, D.C., M.A. Exarchos, D.N. Kouvatsos, G.J. Papaioannou and A.T. Voutsas, Microelectronics Reliability 47 (9-11), 1378, 2007
23. "Front and Back Channel Properties of Asymmetrical Double-Gate Polysilicon TFTs", Farmakis, F.V., D.N. Kouvatsos, A.T. Voutsas, D.C. Moschou, G.P. Kontogiannopoulos and G.J. Papaioannou, Journal of the Electrochemical Society 154 (10), H910, 2007
24. "Nickel nanoparticle deposition at room temperature for memory applications", Verelli, E., D. Tsoukalas, K. Giannakopoulos, D. Kouvatsos, P. Normand and D.E. Ioannou, Microelectronic Engineering, 84 (9-10), 1994, 2007
25. "Device degradation behavior and polysilicon film morphology of TFTs fabricated using advanced excimer laser lateral solidification techniques", Kouvatsos, D.N., A.T. Voutsas, L. Michalas, F. Farmakis and G.J. Papaioannou, Thin Solid Films 515 (19), 7413, 2007
26. "Characterization of double gate TFTs fabricated in advanced SLS ELA polycrystalline silicon films", Kouvatsos, D.N., F.V. Farmakis, D.C. Moschou, G.P. Kontogiannopoulos, G.J. Papaioannou and A.T. Voutsas, Solid State Electronics 51 (6), 936, 2007
27. "Effective parameters for metamorphic materials and metamaterials through a resonant inverse scattering approach", N. Alexopoulos, C. Kyriazidou and H. Contopanagos, IEEE Trans. Microwave Theory Tech. Vol. 55, No 2 (Feb. 2007), pp. 254-267.
28. "Parasitic memory effects in shallow-trench-isolated nanocrystal memory devices", P. Dimitrakis, P. Normand, Solid-State Electronics 51, 125-136 (2007)
29. "Proton radiation tolerance of nanocrystal memories", E. Verrelli, I. Anastassiadis, D. Tsoukalas, M. Kokkoris, R. Vlastou, P. Dimitrakis, P. Normand, Physica E: Low-Dimensional Systems and Nanostructures 38, 67-70 (2007)
30. "Oxide-nitride-oxide memory stacks formed by low-energy Si ion implantation into nitride and wet oxidation", V. Ioannou-Sougleridis, P. Dimitrakis, V.E. Vamvakas, P. Normand, C. Bonafos, S. Schamm, N. Cherkashin, G. Ben Assayag, M. Perego, M. Fanciulli, Microelectr. Engin. 84, 1986-1989 (2007)
31. "Oxide-nitride-oxide dielectric stacks with Si nanoparticles obtained by low-energy ion beam synthesis", V. Ioannou-Sougleridis, P. Dimitrakis, V.E. Vamvakas, P. Normand, C. Bonafos, S. Schamm, A. Mouti, G. Ben Assayag, V. Paillard, Nanotechnology 18, 215204 (2007)
32. "Wet oxidation of nitride layer implanted with low-energy Si ions for improved oxide-nitride-oxide memory stacks", V. Ioannou-Sougleridis, P. Dimitrakis, V.E. Vamvakas, P. Normand, C. Bonafos, S. Schamm, N. Cherkashin, G. Ben Assayag, M. Perego, M. Fanciulli, Appl. Phys. Let. 90, 263513 (2007)
33. "Proton radiation effects on nanocrystal non-volatile memories", E. Verrelli, D. Tsoukalas, M. Kokkoris, R. Vlastou, P. Dimitrakis, P. Normand, IEEE Trans Nuclear Science 54, 975-981 (2007)
34. "Electronic memory device based on a single-layer fluorene-containing organic thin film", C. Pearson, J.H. Ahn, M.F. Mabrook, D.A. Zeze, M.C. Petty, K.T. Kamtekar, C. Wang, M.R. Bryce, P. Dimitrakis, D. Tsoukalas, Appl. Phys. Lett. 91, 123506 (2007)
35. "Impact of structural parameters on the performance of silicon micromachined capacitive pressure sensors", V. Tsouti, G. Bikakis, S. Chatzandroulis, D. Goustouridis, P. Normand, D. Tsoukalas D., Sensors and Actuators A: Physical 137 (1), 20-24 (2007)
36. "Copper metallization based on direct-liquid-injection hot-wire CVD", Papadimitropoulos G and Davazoglou D, Microelectronic Engineering 84 (5-8): 1148-1151 May-Aug. 2007
37. "Hot-wire assisted chemical vapor deposition of Cu by direct-liquid-injection of CupraSelect", Papadimitropoulos G, Davazoglou D, Surface & Coatings Technol. 201 (22-23): 8935-8938, 2007
38. "Structure and electrical properties of selectively chemically vapor deposited vanadium oxide films from Vanadium tri-i-propoxy oxide vapors", Kritikos L, Zambefis L, Papadimitropoulos G, and Davazoglou D, Surface & Coatings Technology 201 (22-23): 9334-9339 Sep. 25 2007
39. "Modeling of low energy-high dose arsenic diffusion in silicon in the presence of clustering-induced interstitial generation", D. Skarlatos, C. Tsamis, J. Appl. Physics 102 (4), 043532 (2007)
40. "Atomic scale simulations of donor-Vacancy pains in germanium", A. Chroneos, R. Grimes and C. Tsamis, J. of Materiials Science: Materials in Electronics 18 (7), pp. 763-768 (2007)
41. "Magneto-transport properties of NiMnSb thin films on InSb single crystals: Negative giant magnetoresistance", S. Gardelis, J. Androulakis, Z. Viskadourakis, EL. Papadopoulou, J. Gaipintzakis, S. Rai, G.S. Lodha, S.B. Roy, /Physica Status Solidi (A) Applications and Materials/ 204, 92 (2007)
42. "Optical characterization of Si-rich silicon nitride films prepared by low pressure chemical vapor deposition", V. Em. Vamvakas, N. Vourdas, S. Gardelis, /Microelectr. Reliability/ 47, 794-797 (2007)

43. "FTIR characterization of light emitting Si-rich nitride films prepared by low pressure chemical vapor deposition", V. Em. Vamvakas, S. Gardelis, /Surface and Coatings Technology /201, 9359 (2007)
44. "A biomolecule friendly photolithographic process for fabrication of protein microarrays on polymeric films coated on silicon chips", P.S. Petrou, M. Chatzichristidi, A. M. Douvas, P. Argitis, K. Misiakos and S.E. Kakabakos, Biosensors and Bioelectronics, 22, 1994-2002, 2007
45. "Nano-scale spatial control over surface morphology of biocompatible fluoropolymers at 157 nm", E. Sarantopoulou, Z. Kollia, A. C. Cefalas, A.M. Douvas, M. Chatzichristidi, P. Argitis, S. Kobe, Materials Science and Engineering: C, Vol. 27, 1191-1196, 2007
46. "Stochastic simulation studies of molecular resists", D. Drygiannakis, G.P. Patsis, I. Raptis, D. Niakoula, V. Vidali, E. Couladouros, P. Argitis & E. Gogolides, Microelectron. Eng., 84, 1062-65, 2007
47. "Polymer self-assembled nano-structures and surface relief gratings induced with laser at 157 nm", E. Sarantopoulou, Z. Kollia, A.C. Cefalas, A.M. Douvas, M. Chatzichristidi, P. Argitis and S. Kobe, Appl. Surf. Science, 253, 7884-7889, 2007
48. "Tuning the emitting colour of Organic Light Emitting Diodes through photochemically induced transformations: towards single layer, patterned, full colour displays and white lighting applications", M. Vasilopoulou, G. Pistolis, D. Georgiadou, P. Argitis, Adv. Funct. Mater., 17 (17), 2007, p. 3477-3485
49. "Light-emission characteristics of silicon nanocrystals formed by anodization of bulk crystaline silicon in the transition regime", S. Gardelis, A.G. Nassiopoulou, Phys. Status Sol. c/ 4, 2165 (2007)
50. "Humidity effects in spin-coated films of polythiophene-polystyrene blends", J.Jaczewska, A.Budkowski, A.Bernasik, I.Raptis, J.Raczkowska, D.Goustouridis, J.Rysz, M.Sanopoulou J. Appl. Polym. Sci. 105 67(2007)
51. "Fabrication of conductometric chemical sensors with a novel lithographic method", N.Andreadis, S.Chatzandroulis, D.Goustouridis, K.Beltsios, I.Raptis Microelectron. Eng. 84 1211(2007)
52. "Proton beam micromachined buried microchannels in negative tone resist materials", I.Rajta, M.Chatzichristidi, E.Barad?cs, C.Cserh?ti, I.Raptis, K.Manoli, E.S.Valamontes Nucl. Instrum. Meth. B 260 414(2007)
53. "Effect of magnetic-field on metal-insulator transitions in Bi wire structures", M.Chatzichristidi, Th.Speliotis, I.Raptis, I.Haritantis, D.Niarchos, C.Christides Microelectron. Eng. 84 1528(2007)
54. "Process simulation at electron beam lithography on different substrates", K.Vutova, G.Mladenov, I.Raptis, A.Olziersky J. Mater. Process. Tech. 184 305(2007)
55. "Stochastic simulation of material and process effects on the patterning of complex layouts", N.Tsikrikas, D.Drygiannakis, G.P.Patsis, I.Raptis, S.Stavroulakis, E.Voyiatzis Jpn. J. Appl. Phys. B 46 6191(2007)
56. "Composite Chemical Sensors Based on Carbon-Filled, Patterned Negative Resists", S.Chatzandroulis, N.Andreadis, D.Goustouridis, L.Quercia, I.Raptis, K.Beltsios Jpn. J. Appl. Phys. B 46 6423(2007)
57. "Enhancement of sensing properties of thin poly(methyl methacrylate) films by VUV surface modification", I.Raptis, J.Kova?, M.Chatzichristidi, E.Sarantopoulou, Z.Kollia, S.Kobe, A.C.Cefalas J. Laser Microelectronic Engineering 2 200(2007)
58. "Sequential polymer lithography for chemical sensor arrays", M.Kitsara, K.Beltsios, D.Goustouridis, S.Chatzandroulis, I.Raptis Eur. Polymer J. 43 4602(2007)
59. "Single chip interdigitated electrode capacitive chemical sensor arrays", M.Kitsara, D.Goustouridis, S.Chatzandroulis, M.Chatzichristidi, I.Raptis, Th.Ganetsos, R.Igreja, C.J.Dias Sens. Act. B. 127 186(2007)
60. "Swelling of poly(3-alkylthiophene) films exposed to solvent vapours and humidity: Evaluation of solubility parameters", J.Jaczewska, I.Raptis, A.Budkowski, D.Goustouridis, J.Raczkowska, M.Sanopoulou, E.Pamu?a, A. Bernasik, J.Rysz Synth. Met. 157 726(2007)
61. "Pattern matching, simulation and metrology of complex layouts fabricated by electron beam lithography", N.Tsikrikas, D.Drygiannakis, G.P.Patsis, I.Raptis, A.Gerardino, S.Stavroulakis, E.Voyiatzis J. Vac. Sci. Technol. B 25 2307(2007)
62. "Disposable bismuth-sputtered electrodes for the determination of trace metals by anodic stripping voltammetry", Ch.Kokkinos, A.Economou, I.Raptis, Th.Speliotis C.E.Efstathiou Electrochem. Commun. 9 2795(2007)
63. "Electrowetting on plasma-deposited fluorocarbon hydrophobic films for biofluid transport in microfluidics", Bayiati, P., Tserepi, A., Petrou, P.S., Kakabakos, S.E.,Misiakos, K., Gogolides, E., Journal of Applied Physics 101 (10), art. no. 103306 (2007)
64. "Biofluid transport on hydrophobic plasma-deposited fluorocarbon films", Bayiati, P., Tserepi, A., Petrou, P.S., Misiakos, K., Kakabakos, S.E., Gogolides, E., Cardinaud, C., Microelectronic Engineering 84 (5-8), pp. 1677-1680 (2007)

65. "Tunable poly(dimethylsiloxane) topography in O2 or Ar plasmas for controlling surface wetting properties and their ageing", Tsougeni K, Tserepi A, Boulousis G, V. Constantoudis, E. Gogolides, (2007) JPN J Applied Physics 1 46 (2): 744-750.
66. "Control of nanotexture and wetting properties of polydimethylsiloxane from very hydrophobic to super-hydrophobic by plasma processing", Tsougeni K., Tserepi A., Boulousis G., Constantoudis V., Gogolides E., (2007) Plasma Processes and Polymers, 4 (4), pp. 398-405.
67. "Photosensitive poly(dimethylsiloxane) materials for microfluidic applications", Tsougeni K., Tserepi A., Gogolides E., (2007) Microelectronic Engineering, 84 (5-8), pp. 1104-1108.
68. "Nanostructuring of PDMS surfaces: Dependence on casting solvents", Vlachopoulou M.-E., Tserepi A., Beltsios K., Boulousis G., Gogolides E., (2007) Microelectronic Engineering, 84 (5-8), pp. 1476-1479.
69. "Nanotextured super-hydrophobic transparent poly(methyl methacrylate) surfaces using high-density plasma processing", Vourdas N., Tserepi A., Gogolides E., (2007) Nanotechnology, 18 (12), art. no. 125304.
70. "Fermi acceleration in the randomized driven Lorentz gas and the Fermi-Ulam model", Karlis A.K., Papachristou P.K., Diakonos F.K., Constantoudis V., Schmelcher P., (2007) Physical Review E - Statistical, Nonlinear, and Soft Matter Physics, 76 (1), art. no. 016214.
71. "Simulation of materials and processing effects on photoresist line-edge roughness", G. P. Patsis, M. D. Nijkerk, L. H. Leunissen, and E. Gogolides, International Journal of Computational Science and Enginnering (Special Issue on Computational Methods and Techniques for Nanoscale Technology Computer Aided Design) Vol. 2, 3-4, 134-143 (2007)
72. "Effects of lithography nonuniformity on device electrical behavior. Simple stochastic modeling of material and process effect on device performance", G. P. Patsis, V. Constantoudis, and E. Gogolides, J. Computational Electronics 5, 341 (2007)
73. "Dual nanoscale roughness on plasma-etched si surfaces: role of etch inhibitors", G. Kokkoris, V. Constantoudis, P. Angelikopoulos, G. Boulousis, &E. Gogolides, Phys. Rev. B 76, 193405 (2007)
74. "Some new nickel 1,2-dichalcogenolene complexes as single-component semiconductors", Papavassiliou, G.C. , Anyfantis, G.C. , Steele, B.R. , Terzis, A. , Raptopoulou, C.P. , Tatakis, G. , Chaidogiannos, G. , Glezos, N. , Weng, Y. , Yoshino, H.e , Murata, K., J. of Chemical Sciences, Vol. 62, (5), 679 (2007)
75. "Soluble Phthalocyanines: Perspective Materials for Electronics",Nespurek, S., Chaidogiannos, G., Glezos, N., Wang, G., Böhm, Rakusan, J., Karásková, M., Molecular Crystals & Liquid Crystals 468 (1), pp. 3-21 (2007)
76. "Roughness formation during plasma etching of composite materials: a kinetic Monte Carlo approach", Zakka, E., Constantoudis, V., Gogolides, E., IEEE Transaction on Plasma Science, vol. 35 (5) Page(s): 1359-1369 , 2007
77. Copper films deposited by hot-wire chemical vapor deposition and direct-liquid-injection of CupraSelect® G. Papadimitropoulos and D. Davazoglou Chemical Vapor Deposition 13, 656 (2007)

PAPERS IN CONFERENCE PROCEEDINGS

1. "Nanostructuring SiO2/Si(100) surface for lateral ordering of self-assembled semiconductor quantum dots" (invited) A. G. Nassiopoulou and M. Kokonou, Physics, Chemistry and Applications of Nanostructures, World Scientific Publishing, Edited by V E Borisenko, S V Gaponenko and V S Gurin p. 407 (2007)
2. "Structural and light-emitting properties of ultra thin anodic silicon films formed at the early stages of bulk silicon anodization" (invited) S. Gardelis, A. G. Nassiopoulou, I. Tsiaoussis and N. Frangis, Physics, Chemistry and Applications of Nanostructures, World Scientific Publishing, Edited by V E Borisenko, S V Gaponenko and V S Gurin p. 407 (2007)
3. "Spectroscopic characterization of thin anodic silicon layers grown by short monopulses of current", Gardelis, S., Jaziri, S., Nassiopoulou, A.G., AIP Conference Proceedings 935, pp. 87-91 (2007)
4. "A novel microfabrication technology on organic substrates - Application to a thermal flow sensor", G. Kaltsas, A. Petropoulos, K. Tsougeni, D. N. Pagonis, T. Speliotis, E. Gogolides and A. G. Nassiopoulou, Journal of Physics: Conference Series 92 (2007) 012046
5. "Characterization of advanced directional SLS ELA polysilicon TFTs – Dependence of device parameters on orientation and geometry", Moschou, D.C., D.N. Kouvatsos, F.V. Farmakis and A.T. Voutsas, Proceedings of the 3rd International Thin Film Transistors Conference (ITC '07) / 2007 Society for Information Display Europe Chapter Meeting, p. 192, Rome, Italy, January 2007.
6. "Hot carrier stress induced degradation of SLS ELA polysilicon TFTs – Effects of gate width variation and device orientation", Kontogiannopoulos, G.P., F.V. Farmakis, D.N. Kouvatsos, G.J. Papaioannou and

A.T. Voutsas, Proceedings of the 3rd Internat. Thin Film Transistors Conf. (ITC '07) / 2007 Society for Information Display Europe Chapter Meeting, p.100, Rome, Italy, 2007.

7. "The impact of gate oxide polarization on drain current transient behavior of advanced excimer laser crystallized polysilicon thin film transistors", Exarchos, M.A., L. Michalas, G.J. Papaioannou, D.N. Kouvatsos, and A.T. Voutsas, Proceedings of the 3rd Internat. Thin Film Transistors Conf. (ITC '07) / 2007 Society for Information Display Europe Chapter Meeting, p. 196, Rome, Italy, January 2007
8. "Investigation of the Undershoot Effect in Polycrystalline Silicon Thin Film Transistors", Michalas, L., G.J. Papaioannou, D.N. Kouvatsos, and A.T. Voutsas, Proceedings of the 3rd International Thin Film Transistors Conference (ITC '07) / 2007 Society for Information Display Europe Chapter Meetin, p. 116, Rome, Italy, January 2007
9. "Effective description and power balance of Metamaterials", C. Kyriazidou, H. Contopanagos and N. Alexopoulos, 23rd Annual Review of Progress in Applied Computational Electromagnetics, 19-23 March 2007, Verona, Italy, published in ACES 2007 Conference Proceedings, pp. 260-264 (2007)
10. "Oxide-nitride-oxide Dielectric Stacks with Embedded Si-nanoparticles Fabricated by Low-energy Ion-beam-synthesis", V. Ioannou-Sougleridis, P. Dimitrakis, V. Em. Vamvakas, P. Normand, C. Bonafos, S. Schamm, G. Ben-Assayag, in Materials and Processes for Nonvolatile Memories II, edited by Tingkai Li, Yoshihisa Fujisaki, J.M. Slaughter, Dimitris Tsoukalas (Mater. Res. Soc. Symp. Proc. Volume 997, Warrendale, PA, 2007), 0997-I03-10
11. "SONOS-type memory structures using thin silicon nitride films modified by low-energy Si+ implantation", P. Dimitrakis, V. Ioannou-Sougleridis, V. Em.Vamvakas, P. Normand, C. Bonafos, S. Schamm, N. Cherkashin, G. Ben Assayag, M. Perego, M. Fanciulli, Proceedings of 2nd International Conference on Memory Technology and Design 2007 (ICMTD 07), p.213-216 (IEEE) May 7-10, Giens, France
12. "Exposure of molecular glass resist by e-beam and EUVIL", Cyril Vannuffel, Damien Djian, Serge Tedesco, Dimitra Niakoula, Panagiotis Argitis, Veroniki P. Vidali, Elias Couladouros, and Harun Solak, Proc. SPIE 6519, 651949, 2007.
13. " Patterning scheme based on photoacid induced spectral changes for single layer, patterned full color light emitting diodes", Maria Vasilopoulou, Giorgos Pistolis, Athanasios Botsialas, Nikos Stathopoulos, Maria Rangoussi, Panagiotis Argitis, in Organic Electronics ? Materials, Devices and Applications, edited by F. So, G.B. Blanchet, Y. Ohmori (Mater. Res. Soc. Symp. Proc. 965E, Warrendale, PA, 2007), paper no 0965-S03-24.
14. " Photolithographic Process Based on High Contrast Acrylate Photoresist for Multi-Protein Patterning", Margarita Chatzichristid`, Panagiota S. Petrou, Antonios M. Douvas, Constantinos D. Diakoumakos, Ioannis Raptis, Konstantinos Misiakos, Sotirios S. Kakabakos, Panagiotis Argitis, in Biosurfaces and Biointerfaces, edited by M. Firestone, J. Schmidt, N. Malmstadt (Mater. Res. Soc. Symp. Proc. 950E, Warrendale, PA, 2007), paper no 0950-D15-15.
15. "Plasma processes in fabrication of nano-textured, super-hydrophobic polymeric surfaces", N. Vourdas, M.-E. Vlachopoulou, A. Tserepi, E. Gogolides, Proceedings of 6th Panhellenic Conference on Chemical Engineering (full paper), Athens, 31 May-2 June 2007, pp. 225-228
16. "Correlation length and the problem of line width roughness", V. Constantoudis, G.P. Patsis, E. Gogolides, Proceedings of SPIE Vol. #6518, 6518_57, 65181N pp. 1-10, San Jose, California, February 25 – March 2, (2007)
17. "Simulation of the combined effects of polymer size, acid diffusion length and EUV secondary electron blur on resist line-edge roughness (poster)", D. Drygianakis, M. D. Nijkerk, G. P. Patsis, G. Kokkoris, I. Raptis, L. H. A. Leunissen, E. Gogolides, Proceedings of SPIE Vol. #6519, 6519_36, 65193T pp. 1-12, San Jose, California, February 25 – March 2, 2007
18. "Stochastic simulation of material and process effects on the patterning of complex layouts with e-beam and EUV lithography (poster)", N. Tsikrikas, D. Drygiannakis, G. P. Patsis, G. Kokkoris, I. Raptis, E. Gogolides, Proceedings of SPIE Vol. #6518, 6518_115, 651836 pp. 1-10, San Jose, California, February 25 – March 2, 2007
19. "Plasma processing in fabricating nano-textured, super-hydrophobic polymeric coatings", N. Vourdas, M.-E. Vlachopoulou, A. Tserepi, E. Gogolides, Proceedings of EURO-INTERFINISH 2007, Athens, Greece, 18-19 October 2007, O24 - pp165-170
20. "Nanoroughness on plasma etched Si and polymer surfaces : theory, experiment and applications", M.-E. Vlachopoulou, N. Vourdas, G. Kokkoris, V. Constantoudis, G. Mpoulousis, A.Tserepi, E.Gogolides, Proceedings of XXIII Hellenic Conference On Solid State Physics 2007, Athens, Greece, 23-26 September 2007, pp. 55-56

21. "Stochastic simulation of the solution of photosensitive materials with applications in microelectronics (poster)", D. Drygiannakis, G. P. Patsis, I. Raptis, A.G. Boudouvis, Proceedings of XXIII Hellenic Conference On Solid State Physics (2007), Athens, Greece, 23-26 September 2007, pp. 53
22. "Simulation, pattern matching and metrology in electron beam lithography (poster)", N. Tsikrikas, G. P. Patsis, I. Raptis, Proceedings of XXIII Hellenic Conference On Solid State Physics (2007), Athens, Greece, 23-26 September 2007, pp. 25-26
23. "Protein patterning through selective fluorocarbon plasma-induced deposition on silicon", P. Bayiati, A. Tserepi, P. S. Petrou, S. E. Kakabakos, E. Matrozos, E. Gogolides, Proceedings of 11th International Conference on Miniaturized Systems for Chemistry and Life Sciences, 7 - 11 October 2007, Paris, France, pp. 92-94
24. "Wireless Measurement System For Capacitive Pressure Sensors Using Strain Compensated SiGeB", K. Arshak, E. Jafe, T. McGloughlin, T. Corbett, S. Chatzandroulis, D. Goustouridis, IEEE SENSORS 2007 Conference Proceedings, p.4, Atlanta, Georgia, USA, October 28-31, 2007.
25. "Development of Wireless Pressure Measurement System for Short Range medical Applications", K. Arshak, E. Jafer, T. McGloughlin, T. Corbett, S. Chatzandroulis, D. Goustouridis, D.Tsoukalas, P.Normand, O. Korostynska, 30th International Spring Seminar on Electronics Technology, ISSE 2007, pp. 94–99, May 9-13, 2007
26. "Thermal characterization of Porous Silicon micro-hotplates using IR thermometry", R. Triantafyllopoulou, C. Tsamis, S. Chatzandroulis , T. Speliotis, J. Parthenios, K. Papagelis and C. Galiotis, Solid-State Sensors, Actuators and Microsystems Conference Proceedings,, TRANSDUCERS 2007. International, p. 2271-2274, DOI: 10.1109/SENSOR.2007.4300622
27. "Mirrors based on tal reflection for concentration PV panels", E. Karvelas, A. Papadopoulos, D. Dousis Y. P. Markopoulos E. Mathioulakis, G. Panaras, V. Vamvakas and D. Davazoglou, 4Th International Conference on Solar Concentrators for the Generation of Electricity or Hydrogen, San Lorenzo de El Escorial, Spain, pp. 165, March 12-16, 2007.
28. "Crystalline Silicon solar cell design optimized for concentrator applications", K. Kotsovos, V. Vamvakas, D. Davazoglou, K. Misiakos, V. Paschos and E. Skouras, 4Th International Conference on Solar Concentrators for the Generation of Electricity or Hydrogen, San Lorenzo de El Escorial, Spain, pp. 197, March 12-16, 2007.

CONFERENCE PRESENTATIONS

1. "Nanopatterning the Si Surface Through Porous Anodic Alumina Masking Layers", F. Zacharatos, V. Gianneta, A. G. Nassiopoulou, 3rd International Conference "Micro & Nano" 2007 on Micro-Nanoelectronics, Nanotechnology and MEMs, held at NCSR "Demokritos", 18-21 November 2007
2. "Determination of critical points of nanocrystalline silicon films: the role of grain boundaries in the optical properties", E. Lioudakis, A. Othonos and A. G. Nassiopoulou, 3rd International Conference "Micro & Nano" 2007 on Micro-Nanoelectronics, Nanotechnology and MEMs, held at NCSR "Demokritos", 18-21 November 2007
3. "Broadband Electrical characterization of Porous Silicon at Microwave Frequencies", H. Contopanagos, D. Pagonis, A. G. Nassiopoulou, 3rd International Conf. "Micro & Nano" 2007 on Micro-Nanoelectronics, Nanotechnology MEMs, held at NCSR "Demokritos", 18-21 November 2007
4. "Monitor the properties of silicon nanocrystals embedded in SiO2 matrix using ultrashort laser pulses", E.Lioudakis, A. Othonos, A. Emporas and A. G. Nassiopoulou, 3rd International Conference "Micro & Nano" 2007 on Micro-Nanoelectronics, Nanotechnology and MEMs, held at NCSR "Demokritos", 18-21 November 2007
5. "Anodic Porous Alumina Thin Films on Si: Interface Characterization", V. Gianneta, S. N. Georga, C. A. Krontiras, A. G Nassiopoulou, 3rd International Conference "Micro & Nano" 2007 on Micro-Nanoelectronics, Nanotechnology and MEMs, held at NCSR "Demokritos", 18-21 November 2007
6. "Auger Recombination in Silicon Nanocrystals", M. Mahdouani, R. Bourguiga, S. Jaziri, S. Gardelis, A.G. Nassiopoulou, 3rd International Conference "Micro & Nano" 2007 on Micro-Nanoelectronics, Nanotechnology & MEMs, held at NCSR "Demokritos", 18-21 November 2007
7. "Assembly and electrical investigation of tiopronin- and citrate-stabilized Au nanoparticle chains between electrodes on patterned oxidized Si substrates under the influence of an electric field", A Zoy and A G Nassiopoulou, 3rd International Conference "Micro & Nano" 2007 on Micro-Nanoelectronics, Nanotechnology and MEMs, held at NCSR "Demokritos", 18-21 November 2007

8. "TEM characterization of ultra-thin nanocrystalline Si films grown on quartz and presenting quantum properties", Ch.B. Lioutas, N. Vouroutzis, I. Tsiaoussis, N. Frangis and A.G. Nassiopoulou, 3rd International Conference "Micro & Nano" 2007 on Micro-Nanoelectronics, Nanotechnology and MEMs, held at NCSR "Demokritos", 18-21 November 2007
9. "Structural study of ultra thin anodic silicon layers for nanoelectronic and photonic applications", S. Gardelis, F. Petraki, S. Kennou, A. G. Nassiopoulou, 3rd International Conference Micro & Nano 2007 on Micro-Nanoelectronics, Nanotechnology and MEMs, held at NCSR "Demokritos", 2007
10. "A thermal vacuum detector fabricated by a combination of MEMS and PCB technologies", A. Petropoulos, G. Kaltsas, A. G. Nassiopoulou, 3rd International Conf. "Micro & Nano" 2007 on Micro-Nanoelectronics, Nanotechnology & MEMs, held at NCSR "Demokritos", 18-21 November 2007
11. "Fabrication and evaluation of a gas flow sensor, implemented on organic substrates by a novel integration technology", A. Petropoulos, G. Kaltsas, A. G. Nassiopoulou, 3rd International Conference "Micro & Nano" 2007 on Micro-Nanoelectronics, Nanotechnology and MEMs, held at NCSR "Demokritos", 18-21 November 2007
12. "Copper Wires in Macroporous Si Template for Microchannel Heat Sink Technology", F. Zacharatos and A. G. Nassiopoulou, 3rd International Conference "Micro & Nano" 2007 on Micro-Nanoelectronics, Nanotechnology and MEMs, held at NCSR "Demokritos", 18-21 November 2007
13. "Dielectric Characterization of Macroporous Silicon Thick Layers For Use As Capacitors In High Voltage Application", M. Theodoropoulou, D. N. Pagonis, A. G. Nassiopoulou, C. A. Krontiras, S. N. Georga, 3rd International Conference "Micro & Nano" 2007 on Micro-Nanoelectronics, Nanotechnology and MEMs, held at NCSR "Demokritos", 18-21 November 2007
14. "Ordering of Si and Ge nanocrystals in 2-D layers for nanodot memory devices", A. G. Nassiopoulou (invited talk), International Conference on Physics, Chemistry and Applications of Nanostructures, Nanomeeting 2007, Belarus, 22-25 May 2007
15. "Structural and light-emitting properties of ultra thin anodic silicon films formed at the early stages of anodization of bulk silicon", S. Gardelis (invited talk), International Conference on Physics, Chemistry and Applications of Nanostructures, Nanomeeting 2007, Belarus, 22-25 May 2007
16. "Silicon Nanocrystals embedded in SiO2: Optical and transport properties" A. G. Nassiopoulou (invited talk), 2nd European Optical Society Topical Meeting on Optical Microsystems, Italy, 30 September – 3 October 2007
17. "Characterization of Silicon Nanocrystal non-Volatile Memory Structures with Double Nanocrystal Layers", A. G. Nassiopoulou (invited talk), ANNA-Analytical Network for Nanotech, held at Munich, 29 November 2007
18. "Confined porous alumina thin films on Si for local silicon substrate nanopatterning", V. Gianneta, F. Zacharatos and A. G. Nassiopoulou, Europ. Mater. Resear. Soc. (E-MRS) Conference, Symposium K, May 28th - June 1st 2007
19. "Ordered highly dense macroporous Si arrays through anodic porous alumina thin films on Si", F. Zacharatos, V. Giannetta and A. G. Nassiopoulou, Europ. Mater. Resear. Soc. (E-MRS) Conference, Symposium K, May 28th - June 1st 2007
20. "Self-assembly of Si nanostructures on nanopatterned substrates: Application in nanocrystal memories" (invited talk) A. G. Nassiopoulou, 4th International Workshop on Nanosciences & Nanotechnologies (N&N07), Thessaloniki, 16-18 July 2007
21. "Copper-filled macroporous Si for microchannel heat sink technology", F. Zacharatos and A. G. Nassiopoulou, 13th Therminic Workshop, 17 – 19 September 2007 Budapest
22. "Copper Wires in Macroporous Si for Microchannel Heat Sink Technology", F. Zacharatos and A. G. Nassiopoulou, Micro&Nano 2007, 18-21 November 2007 Athens
23. "Successive layer charging of Si nanocrystalls in a double layer nanocrystalls structure within SiO2", M. Theodoropoulou, A. Salonidou and A. G. Nassiopoulou, 23nd Panhellenian Solid State and Materials Science Conference, held at NCSR Demokritos, Athens, 23 – 26 September 2007
24. "Electrochemical growth of ordered Si nanostructures on a silicon substrate for photonic applications", F. Zacharatos, V. Giannetta and A. G. Nassiopoulou, 3rd Panhellenian Symposiun on Porous Materials, Thessaloniki, 1-2 November 2007
25. "Ordered nanostructures on Si through porous anodic alumina thin films for photonic applications", F. Zacharatos, V. Gianneta and A. G. Nassiopoulou, 23nd Panhellenian Solid State and Materials Science Conference, held at NCSR Demokritos, Athens, 23 – 26 September 2007

26. "Growth of ordered SiO2 nanodots on selected areas on Si through porous anodic alumina thin films", V. Gianneta and A. G. Nassiopoulou, 3rd Panhellenian Symposiun on Porous Materials, Thessaloniki, 1-2 November 2007
27. "The effect of crystallization technology and gate insulator deposition method on the performance and reliability of polysilicon TFTs", Moschou, D.C., G.P. Kontogiannopoulos, D.N. Kouvatsos and A.T. Voutsas, 3rd International Conference on Micro- and Nanoelectronics, Nanotechnology and MEMS (MicroNano 2007), Athens, Greece, November 2007
28. "Performance of Thin-Film Transistors fabricated by Sequential Lateral Solidification crystallization techniques", Exarchos, M.A., D.C. Moschou, G.J. Papaioannou, D.N. Kouvatsos and A.T. Voutsas, 3rd International Conference on Micro- and Nanoelectronics, Nanotechnology and MEMS (MicroNano 2007), Athens, Greece, November 2007
29. "Investigation of top gate electrode variations for high-k gate dielectric MOS capacitors", Moschou, D.C., E. Verelli, D.N. Kouvatsos, P. Normand, D. Tsoukalas, A. Speliotis, P. Bayiati and D Niarchos, 3rd International Conference on Micro- and Nanoelectronics, Nanotechnology and MEMS (MicroNano 2007), Athens, Greece, November 2007
30. "An Experimental Study of Band Gap States Electrical Properties in Poly-Si TFTs by the Analysis of the Transient Currents", Michalas, L., G.J. Papaioannou, D.N. Kouvatsos and A.T. Voutsas, 3rd International Conference on Micro- and Nanoelectronics, Nanotechnology and MEMS (MicroNano 2007), Athens, Greece, November 2007
31. "Degradation of double gate polycrystalline silicon TFTs due to hot carrier stress", Farmakis, F.V. G.P. Kontogiannopoulos, D.N. Kouvatsos and A.T.Voutsas, 18th European Symposium - Reliability of Electron Devices, Failure Physics and Analysis (ESREF 2007), Arcachon, France, October 2007
32. "Influence of polysilicon film thickness on radiation response of advanced excimer laser annealed polycrystalline silicon thin film transistors", Davidovi?, V., D.N. Kouvatsos, N. Stojadinovi?, A.T. Voutsas, 18th European Symposium - Reliability of Electron Devices, Failure Physics and Analysis (ESREF 2007), Arcachon, France, October 2007
33. "Performance and reliability of SLS ELA polysilicon TFTs fabricated with novel crystallization techniques", Moschou, D. C., M. A. Exarchos, D. N. Kouvatsos, G. J. Papaioannou and A. T. Voutsas, 18th European Symposium - Reliability of Electron Devices, Failure Physics and Analysis (ESREF 2007), Arcachon, France, October 2007
34. "Characterization of thin film transistors fabricated on different sequential lateral solidified poly-silicon substrates", Michalas, L., G.J. Papaioannou, D.N. Kouvatsos, F.V. Farmakis & A.T. Voutsas, 33rd Internat. Conf. on Micro- and Nano-Engineering (MNE 2007), Copenhagen, Denmark, 2007
35. "A novel SLS ELA crystallization process and its effects on polysilicon film defectivity and TFT performance", Moschou, D. C., M. A. Exarchos, D. N. Kouvatsos, G. J. Papaioannou and A. T. Voutsas, 33rd International Conference on Micro- and Nano-Engineering (MNE 2007), Copenhagen, Denmark, September 2007
36. "Nickel nanoparticle deposition at room temperature for memory applications", Verelli, E., D. Tsoukalas, K. Giannakopoulos, D. Kouvatsos, P. Normand and D.E. Ioannou, 15th bi-annual Conference – Insulating Films on Semiconductors (INFOS 2007), Athens, Greece, June 2007
37. "Effective description and power balance of Metamaterials", C. Kyriazidou, H. Contopanagos and N. Alexopoulos, 23rd Conference on Progress in Applied Computational Electromagnetics, 19-23 March 2007, Verona, Italy
38. "Memory and luminescence properties of Si nanocrystals fabricated by ion beam mixing", V. Beyer, K.-H. Heinig, B. Schmidt, K.-H. Stegemann, P. Dimitrakis, International Workshop on SEMIconductor NANOstructures 2007 (SEMINANO 2007), June 13-16, Bad Honnef, Germany
39. "Design and fabrication of a micromechanical capacitive DNA sensor array", V. Tsouti, S. Chatzandroulis, D. Goustouridis, P. Normand, D. Tsoukalas, 29th International Conference on Micro and Nano Engineering, MNE 2007, Copenhagen, Denmark, September 23-26, 2007
40. "Microscopy of semiconductor nanocrystals embedded in very thin high k layers by low energy ion-beam-synthesis for memory applications", C. Bonafos, S. Schamm, P. Dimitrakis, P. Normand, V. Ioannou-Sougleridis, A. Mouti, M. Carrada, A. Slaoui, J. Grob, G. Ben Assayag, B Schmidt, J. Becker, A. Claverie, Microscopy of Semiconducting Materials XV, P3.009, April 2-5, 2007, Churchill College, Cambridge, UK (IOP)
41. "Hot-wire assisted chemical vapor deposition of Cu by direct-liquid-injection of CupraSelect®" G. Papadimitropoulos and D. Davazoglou, EUROCVD 16, The Hague, Netherlands, Sept. 15-21 2007

42. "Structure and electrical properties of selectively chemically vapor deposited vanadium oxide films from Vanadium tri-i-propoxy oxide vapors", L. Kritikos, L. Zambelis, G. Papadimitropoulos, and D. Davazoglou, EUROCVD 16, The Hague, Netherlands, Sept. 15-21 2007
43. "Spectroscopic characterization of thin anodic silicon layers grown by short monopulses of current", S. Gardelis, S. Jaziri, A.G. Nassiopoulou, Fundamental and Applied Spectroscopy: Second International Spectroscopy Conference, ICS 2007, Sousse, Tunisia 2007
44. "Electrochemical detection of biomolecules patterned on electrode arrays by biocompatible photolithography", M?nica Mir, Srujan Kumar Dondapati, Maria Viviana Duarte, Ioanis Katakis, Margarita Chatzichristidi, Konstantinos Misiakos, P.S. Petrou, S.E. Kakabakos, Panagiotis Argitis, MRS Fall meeting, Boston, November 2007
45. "Charging Effects in Hybrid Structures Based on Polyoxometalate Layers for Molecular Memory Applications", E. Makarona, A. M. Douvas, E. Kapatanakis, D. Velessiotis, P. Argitis, P. Normand, N. Glezos, J. Mielczarski, E. Mielczarski, T. Gotszalk, W. Miroslav, Materials Research Society (MRS) Fall Meeting, Boston, MA, USA, November 27-30 2007
46. "Vertical architectures of self-assembled hybrid organic/inorganic monolayers based on tungsten polyoxometalates: a step towards molecular electronic devices", E. Makarona, E. Kapetanakis, D. Velessiotis, A. Douvas, P. Argitis, P. Normand, T. Gotszalk, M. Woszczyna, N. Glezos, 33rd International Conference on Micro- and Nano-Engineering (MNE), Copenhagen, Denmark, September 23-26, 2007
47. "Evaluation of polymers containing ketal or acetal groups in the backbone as candidate photoresist components", T. Manouras, A. M. Douvas, V.P. Vidali, M. Chatzichristidi, N. Vourdas, E. Gogolides, E.A. Couladouros, P. Argitis, Micro&Nano 2007, Athens, 18-21 November 2007
48. "Photoresist material and process optimization for the patterning of biomolecules on functionalized surfaces", P. Pavli, M. Chatzichristidi, A. M. Douvas, P. S. Petrou, S. E. Kakabakos, D. Dimotikali, P. Argitis, 3rd International Conference on Micro-Nanoelectronics, Nanotechnology & MEMs (Micro&Nano), Athens, Greece, November 18-21, 2007
49. "Polyoxometalate-based multilayers: fabrication and electrical characterization", A. M. Douvas, E. Makarona, D. Velassiotis, J. A. Mielczarski, E. Mielczarski, N. Glezos, P. Argitis, 3rd International Conference on Micro-Nanoelectronics, Nanotechnology & MEMs (Micro&Nano), Athens, Greece, November 18-21, 2007
50. "VUV laser circular microstructured surface relief gratings induced on PTFEMA surface", E. Sarantopoulou, Z. Kollia, A. C. Cefalas, A. M. Douvas, M. Chatzichristidi, P. Argitis, 3rd International Conference on Micro-Nanoelectronics, Nanotechnology & MEMs (Micro&Nano), Athens, Greece, November 18-21, 2007
51. "Hybrid polymer-inorganic solar cells based on polythiophene and phthalocyanine/polyoxometalate blends", L. C. Palilis, A. M. Douvas, G. Chaidigiannos, M. Vasilopoulou, N. Glezos, S. Nespurek, P. Falaras, P. Argitis, 3rd International Conference on Micro-Nanoelectronics, Nanotechnology & MEMs (Micro&Nano), Athens, Greece, November 18-21, 2007
52. "Flexible WO3 based electrochromic displays using proton conducting solid electrolytes", M. Vasilopoulou, P. Argitis, G. Aspiotis, G. Papadimitropoulos and D. Davazoglou, Micro&Nano 2007, Athens, Greece, 18-22 November 2007
53. "Flexible Organic Light Emitting Diodes (OLEDs) based on blue emitting polymers", M. Vasilopoulou, L. C. Palilis, A. Botsialas, D. Georgiadou, , P. Bayiati, N. Vourdas, P. S. Petrou, G. Pistolis, N. Stathopoulos, and P. Argitis, Micro&Nano 2007, Athens, Greece, 18-21 November 2007
54. "Energy transfer processes among emitters dispersed in a single polymer layer for colour tuning in OLEDs", D. Georgiadou, M. Vasilopoulou, G. Pistolis, D. Dimotikali and P. Argitis, Micro&Nano 2007, Athens, Greece, 18-21 November 2007
55. "All-organic optocouplers based on polymer light-emitting diodes and photodetectors", N. Stathopoulos, L. C. Palilis, M. Vasilopoulou, A. Botsialas, P. Falaras, and P. Argitis, Micro&Nano 2007, Athens, Greece, 18-21 November 2007
56. "An all-polymeric optocoupler based on polymer light-emitting diodes and photodetectors", L. C. Palilis, M. Vasilopoulou, A. Botsialas, N. Stathopoulos, P. Falaras, P. Argitis5th European Conference on Organic Electronics (ECOER07), Varenna, Italy, 01-04 October 2007
57. "Single layer white organic light-emitting diodes for lighting applications", M. Vasilopoulou, D. Georgiadou, L. C. Palilis, G. Pistolis, P. Argitis, 5th European Conference on Organic Electronics (ECOER07), Varenna, Italy, 01-04 October 2007

58. "Full colour single layer organic light emitting diodes (OLEDs) based on poly(9-vinylcarbazole) via photochemically induced emission tuning", M. Vasilopoulou, A. Botsialas, P. Bayiati, N. Vourdas, N. Stathopoulos, M. Rangoussi and P. Argitis, 4th International Workshop on "Nanosciences & Nanotechnologies - NN07", Thessaloniki, Greece, 16-18 July 2007
59. "Flexible all-solid state electrochromic displays based on polymeric electrolytes", M. Vasilopoulou, P. Argitis, G. Aspiotis, G. Papadimitropoulos and D. Davazoglou, 4th International Workshop on "Nanosciences & Nanotechnologies - NN07" Thessaloniki, Greece, 16-18 July 2007.
60. "Optimization of the external efficiency of single layer full color light emitting diodes based on blue emitting polymers", N. Stathopoulos, M. Vasilopoulou and P. Argitis, Interrnational Conference on Organic Electronics, Eindhoven, 4-7 June 2007.
61. "Stochastic simulation of material and process effects on the patterning of complex layouts with e-beam and EUV lithography", D.Drygiannakis, N.Tsikrikas, G.P.Patsis, G.Kokkoris, I.Raptis, E.Gogolides SPIE Advanced Lithography conf. (Jan Jose, USA, 02/2007)
62. "Simulation of the combined effects of polymer size, acid diffusion length and EUV secondary electron blur on resist line-edge roughness", D.Drygianakis, M.D.Nijkerk, G.P.Patsis, G.Kokkoris, I.Raptis, L.H.A.Leunissen, E.Gogolides, SPIE Advanc. Lithography conf. (Jan Jose, USA, 02/2007)
63. "Pattern matching, simulation and metrology of complex layouts fabricated by electron beam lithography", N.Tsikrikas, D.Drygiannakis, G.P.Patsis, I.Raptis, A.Gerardino, S.Stavroulakis, E.Voyiatzis EIPBN 2007 (Denver, USA, 05/2007)
64. "Modification of sensing properties of thin polymer films by VUV irradiation", E.Sarantopoulou, Z.Kollia, K.Manoli, M.Sanopoulou, D.Goustouridis, S.Chatzandroulis, I.Raptis Transducers 2007 (Lyon, France, 06/2007)
65. "Swelling of Poly(3-alkylthiophene) films exposed to solvent vapors and humidity: effects of head to tail regioregularity", J.Jaczewska, A.Budkowski, J.Raczkowska, I.Raptis, D.Goustouridis IXth Int. Conf. Front. Pol. Adv. Mater. 2007 (Cracow, Poland 07/2007)
66. "Swelling of Poly(3-alkylthiophene) films exposed to solvent vapors and humidity: effects of head to tail regioregularity", J.Jaczewska, A.Budkowski, J.Raczkowska, I.Raptis, D.Goustouridis 46th Microsymp. Nanostruct. Polym. & Polym. Nanocomp.(Prague, Czech Republic, 07/2007)
67. "Magnetotransport properties of [Co/Bi]n wire structures", C.Christides, Th.Speliotis, M.Chatzichristidi, I.Raptis 18th Soft Magnetic Materials Conf. (Cardiff, UK, 09/2007)
68. "A chemocapacitive sensor array for the detection of volatile compounds and humidity"K.Manoli, E.Karonis, D.Goustouridis, S.Chatzandroulis, I.Raptis, M.Sanopoulou Instrumental Methods of Analysis (IMA 2007) (Patras, Greece, 10/2007)
69 "Real time monitoring of biomolecular interactions by a label-free reflectance spectroscopy sensor", M.Zavali, P.S.Petrou, S.Kakabakos, I.Raptis, K.Misiakos Instrumental Methods of Analysis (IMA 2007) (Patras, Greece, 10/2007)
70. "Disposable Fabrication, characterization and applications of bismuth-sputtered sensors for trace metals monitoring by stripping voltametry", Ch.Kokkinos, A.Economou, I.Raptis, Th.Speliotis, C.E. Efstathiou Instrumental Methods of Analysis (IMA 2007) (Patras, Greece, 10/2007)
71. "Electron Beam Lithography Simulation for the Patterning of EUV Masks", N.Tsikrikas, G.P.Patsis, E.Valamontes, I.Raptis, A.Gerardino, Microprocess & Nanotechnology Conf. (MNC 07) (Kyoto, Japan, 11/2007)
72. "Realization and simulation of high aspect ratio micro/nano structures by proton beam writing", M.Chatzichristidi, E.Valamontes, I.Raptis, J.A.vanKan, F.Watt Microprocess & Nanotechnology Conf. (MNC 07) (Kyoto, Japan, 11/2007)
73. "Plasma processing for fabrication and modification of PMMA Microfluidics", N. Vourdas, K. Kontakis, A. Tserepi, A.G. Boudouvis, E. Gogolides, EIPBN-2007, Denver Colorado, USA, May 29 - June 1, 2007
74. "Nanoplasma – nanoscale plasma etching: simulation of the profile evolution of high aspect ratio features", M. Hauguth, V. Ishshuk, D. Dreßler, T. Danz, B. Volland, I.W. Rangelow, M. Cooke, G. Chance, A. York, A. Goodyear, G. Hassall, S. Daniels, J. Lawler, D. Kavanagh, E. Gogolides, G. Kokkoris, E. Geka, N. Vourdas, V. Constantoudis, P. Angelikopoulos, G. Mpoulousis, K. Tsougeni, A. Panagiotopoulos, G. Xidi, H. Hartmann, A. Petrashenko, C. Ivanov, V. Gueorguiev, Plasma Etching and Stripping in Microelectronics (PESM07), Leuven, Belgium, 10-11 September 2007
75. "Plasma etching of thin and ultra-thin polymeric films probed with in situ spectroscopic ellipsometry", N. Vourdas, G. Kokkoris, E. Gogolides, Plasma Etching and Stripping in Microelectronics (PESM07), Leuven, Belgium, 10-11 September 2007

76. "Plasma processing in microfluidics fabrication", N. Vourdas, K. Kontakis, A. Tserepi, E. Gogolides, Micro&Nano Engineering 2007 (MNE07), Copenhagen, Denmark, 23-26 September 2007
77. "Etching performance of thin polymeric and photoresist films", N. Vourdas, G. Kokoris, E. Gogolides, AVS07, Seattle, USA, 14-19 October 2007
78. "Modeling of deep Si nano-stracture etching by neutral beams", G. Kokkoris, A. Tserepi, E. Gogolides, 16th International Colloquium on Plasma processes, June 4-8, Toulouse, France
79. "Protein patterning through selective fluorocarbon plasma-induced deposition on silicon", P. Bayiati, A. Tserepi, P. S. Petrou, S. E. Kakabakos, E. Matrozos, E. Gogolides, 11th Internat. Conference on Miniaturized Systems for Chemistry and Life Sciences, 7 - 11 October 2007, Paris, France
80. "Correlation length and the problem of line width roughness", V. Constantoudis, G.P. Patsis, E. Gogolides, SPIE 2007, San Jose, California, February 25 – March 2, (2007)
81. "Mechanisms of nano-roughness formation and evolution in plasma etching: application to Si etching (poster)", G. Kokkoris, V. Constantoudis, G. Mpoulousis, P. Angelikopoulos, E. Gogolides, 1st International Workshop on Plasma Etch and Strip in Microelectronics, September 10-11, Leuven, Belgium (2007)
82. "Stochastic simulation studies of molecular resists for the 32nm technology node (poster)", D. Drygiannakis, G. P. Patsis, I. Raptis, Micro&Nano Engineering 2007 (MNE07), Copenhagen, Denmark, 23-26 September 2007
83. "Processing effects on the dissolution properties of thin chemically amplified photoresist films (poster)", D. Drygiannakis, G. P. Patsis, I. Raptis, Micro&Nano Engineering 2007 (MNE07), Copenhagen, Denmark, 23-26 September 2007
84. "High density plasma silicon oxide thin films grown at room temperature", M.-E. Vlachopoulou, P. Dimitrakis, A. Tserepi, V.Em.Vamvakas, S.Koliopoulou, P.Normand, E. Gogolides, D.Tsoukalas, Micro&Nano Engineering 2007 (MNE07), Copenhagen, Denmark, 23-26 September 2007
85. "Oriented spontaneously formed nanostructures on poly(dimethylsiloxane) films and stamps treated in O2 plasmas (poster)", K. Tsougeni, G. Boulousis, E. Gogolides, A. Tserepi, Micro&Nano Engineering 2007 (MNE07), Copenhagen, Denmark, 23-26 September 2007
86. "Gas chromatographic micro-column using polydimethylsiloxane as structural and functional material", A. Malenou, M.E. Vlachopoulou, R. Triantafyllopoulou, A. Tserepi, S. Chatzandroulis, Micro&Nano Engineering 2007 (MNE07), Copenhagen, Denmark, 23-26 September 2007
87. "Integration of microfluidics on surface acoustic wave biosensors for multi-sensing purposes", K. Mitsakakis, A. Tserepi, M-E. Vlachopoulou, E. Gizeli, Micro&Nano Engineering 2007 (MNE07), Copenhagen, Denmark, 23-26 September 2007
88. "Electron beam lithography simulation algorithm over multilayer substrates (poster)", N. Tsikrikas, G. P. Patsis, I Raptis, Third International Conference on Micro- Nanoelectronics, Nanotechnology and MEMs, Athens, Greece, 18 – 21 November 2007
89. "Photoresist models for stochastic lithography (poster)", D. Drygiannakis, G. P. Patsis, I. Raptis, Third International Conference on Micro- Nanoelectronics, Nanotechnology and MEMs, Athens, Greece, 18 – 21 November 2007
90. "Modeling mosfet gate length variability for future technology nodes (poster)", G. P. Patsis, Third Internat. Conference on Micro- Nanoelectronics, Nanotechnology and MEMs, Athens, Greece, 2007
91. "Plasma processing in fabricating nano-textured, super-hydrophobic polymeric coatings", N. Vourdas, M.-E. Vlachopoulou, A. Tserepi, E. Gogolides, EURO-INTERFINISH 2007, Athens, Greece, 18-19 October 2007
92. "Processing for polymeric microfluidic fabrication: electrokinetic studies in PMMA", N. Vourdas, A. Tserepi, P.S. Petrou, S.E. Kakabakos, E. Gogolides, 5th International Conference on Instrumental Methods of Analysis (IMA07), Rio, Patras, Greece, September 30-October 4 2007
93. "A method for biomolecular microarray fabrication via selective fluorocarbon plasma-induced deposition", P. Bayiati, A. Tserepi, P. S. Petrou, S. E. Kakabakos, E. Matrozos, E. Gogolides, 5th International Conference on Instrumental Methods of Analysis, Modern Trends and Applications, 30 September – 4 October, 2007, Rio, Patras, Greece
94. "Control of nano-topography and wetting properties of polymers: application in PMMA and PDMS", N. Vourdas, M.-E. Vlachopoulou, A. Tserepi, E. Gogolides, Third International Conference on Micro-Nanoelectronics, Nanotechnology and MEMs, Athens, Greece, 18 – 21 November 2007
95. "Hydrophobic plasma deposited fluorocarbon films as a means for biofluid transport and selective adsorption of biomolecules on lab-on-a-chip devices", P. Bayiati, A. Tserepi, P. S. Petrou, S. E. Kakabakos, E. Matrozos, D. Goustouridis, K. Misiakos, E. Gogolides, 3rd International Conference on Micro-Nanoelectronics, Nanotechnology and MEMs, Athens, Greece, 18 – 21 November 2007

96. "Plasma nanostructuring of pdms surfaces and its effects on protein adsorption (poster)", Maria-Elena Vlachopoulou, Panagiota Petrou, S. Kakabakos, A.Tserepi, E.Gogolides, 3rd Internat. Conf. on Micro-Nanoelectronics, Nanotechnology and MEMs, Athens, Greece, 18–21 November 2007
97. "Modelling of nano-roughness formation during plasma etching of silicon surfaces", V. Constantoudis, G.Kokkoris, G. Boulousis, P. Angelikopoulos, E. Gogolides, 4th International Workshop on Nanosciences & Nanotechnologies (NN07), Thessaloniki, Greece, 16-18 July 2007
98. "Plasma processes in fabrication of nano-textured, super-hydrophobic polymeric surfaces", N. Vourdas, M.-E. Vlachopoulou, A. Tserepi, E. Gogolides, 6th Panhellenic Conference on Chemical Engineering (full paper), Athens, 31 May-2 June 2007
99. "Nano-textured polymer surfaces with controlled wetting and optical properties using plasma processing", N. Vourdas, M.-E. Vlachopoulou, A. Tserepi, V. Constantoudis, G. Boulousis, E. Gogolides, 4th International Workshop on Nanosciences & Nanotechnologies (NN07), Thessaloniki, Greece, 16-18 July 2007
100. "Nanoroughness on plasma etched Si and polymer surfaces : theory, experiment and applications", M.-E. Vlachopoulou, N. Vourdas, G. Kokkoris, V. Constantoudis, G. Mpoulousis, A.Tserepi, E.Gogolides, XXIII Hellenic Conf. on Solid State Phys , Athens, Greece, 23-26 September 2007
101. "Effects of photopolymer architecture on 45nm lithography (poster)", D. Drygiannakis, G. P. Patsis, I. Raptis, XXIII Hellenic Conf. On Solid State Physics, Athens, Greece, 23-26 September 2007
102. "Evaluation of sulfonated metal phthalocyanines for OTFT applications", G.Chaidogiannos, N.Glezos, K.Yannakopoulou, I.M.Mavridi, S. Kennou, F. Petraki, S. Nespurek, Rakusan, M. Karaskova, ICOE, Eindhoven, June , Oral presentation
103. "Soluble Substituted Phthalocyanines for OFET Applications", G. Chaidogiannos, N. Glezos, S. Ne?p?rek, NN Thessaloniki, July, Oral presentation
104. "Molecular Nanodevices based on Functionalized Cyclodextrins", Dimitrios Velessiotis, Davide Maffeo, Eleni Makarona, Viswanathan Chinnuswamy, Constantinos Milios, Konstantina Yannakopoulou, Irene Mavridis, Zoe Pikramenou and Nikos Glezos, MMN Athens, November,
105. "Study of interfacial phenomena in oxidized strained – Silicon", N. Kelaidis, V. Ioannou-Sougleridis, D. Skarlatos, C. Tsamis, J. Parthenios, C. Papaggelis, C. Galiotis, B. Kellerman and M. Seacrist, 8th International Conference on Ultimate Integration on Silicon (ULIS), 15-16 March 2007, Leuven, Belgium (Poster)
106. "Influence of thermal processing on the electrical characteristics of MOS capacitors on strained-Silicon substrates", N. Kelaidis, V. Ioannou-Sougleridis, D. Skarlatos, C. Tsamis, C.A. Krontiras, S. N. Georga, B. Kellerman and M. Seacrist, International Conference on Silicon Epitaxy and Heterostructures, May 20 - 25, 2007, Marseille, France (Poster)
107. "Thermal characterization of Porous Silicon micro-hotplates using IR thermometry", R. Triantafyllopoulou, C. Tsamis, S. Chatzandroulis , T. Speliotis, J. Parthenios, K. Papagelis and C. Galiotis, Transducers'07/Eurosensors XXI, June 10-14 2007, Lyon, France, (Poster)
108. "Implementation of hard magnetic thin films on suspended cantilevers for electromagnetic energy harvesters", E. Makarona, T. Speliotis, A. Darsinou, C. Tsamis, S. Chatzandroulis, D. Niarchos, SPIE Conf. on " Microtechnologies for the New Millenium 2005", 2-4 May 2007, Maspalomas, Spain
109. "Simulation of the electrical characteristics of MOS capacitors on strained-Silicon substrates", N. Kelaidis, D. Skarlatos and C. Tsamis, Third Conference on Microelectronics, Microsystems, Nanotechnology, MMN 2007, 18-21 November 2007, Athens, Greece (Poster)
110. "ZnO nanowire growth based on a low-temperature, silicon-compatible combinatorial method", E. Makarona, Th. Speliotis, G. Niarchos, D. Niarchos, C. Tsamis, 3rd Conference on Microelectronics, Microsystems, Nanotechnology, MMN 2007, 18-21 November 2007, Athens, Greece (Poster)
111. "Effect of deposition pressure and post deposition annealing on SmCo thin film properties", Th. Speliotis, El. Makarona, F. Chouliaras C. A. Charitidis Ch. Tsamis and D. Niarchos, Third Conference on Microelectronics, Microsystems, Nanotechnology, MMN 2007, 18-21 November 2007, Athens, Greece (Poster)
112. "Detection of CO and NO using low power Metal Oxide sensors", R. Triantafyllopoulou & C. Tsamis, Third Conference on Microelectronics, Microsystems, Nanotechnology, MMN 2007, 18-21 November 2007, Athens, Greece (Poster)
113. "Field-effect transistors with thin ZnO as active layer for gas sensor applications", F. V. Farmakis, A. Speliotis, K. P. Alexandrou, C. Tsamis, M. Kompitsas, I. Fasaki, P. Jedrasik, G. Petersson, B. Nilsson, Micro- and Nano-Engineering, MNE 2007, 23-26 September 2007, Copenhagen, Denmark

114. "Nanostructured Oxides on Porous Silicon Microhotplates for NH3 Sensing", R. Triantafyllopoulou, X. Illa, O. Casals, C. Tsamis, A. Romano-Rodriguez, J.R. Morante, Micro- and Nano-Engineering, MNE 2007, 23-26 September 2007, Copenhagen, Denmark
115. "Oxygen plasma development of silylated epoxydized photoresists for micromachining applications", D.Kontziampasis, E. Gogolides, Micro&Nano Engineering 2007 (MNE07), Copenhagen, Denmark, 23-26 September 2007
116. "Nano-textured polymer surfaces with controlled wetting and optical properties using plasma processing", N. Vourdas, M.-E. Vlachopoulou, A. Tserepi, V. Constantoudis, G. Boulousis, E. Gogolides, 4th International Workshop on Nanosciences & Nanotechnologies (NN07), Thessaloniki, Greece, 16-18 July 2007
117. "Stochastic simulation of the solution of photosensitive materials with applications in microelectronics (poster)", D. Drygiannakis, G. P. Patsis, I. Raptis, A.G. Boudouvis, XXIII Hellenic Conference On Solid State Physics (2007), Athens, Greece, 23-26 September 2007
118. "Simulation, pattern matching and metrology in electron beam lithography (poster)", N. Tsikrikas, G. P. Patsis, I. Raptis, XXIII Hellenic Conference On Solid State Physics (2007), Athens, Greece, 23-26 September 2007
119. "Direct laser printing of biomolecules on capacitive sensors", C. Boutopoulos, P. Andreakou, S. Chantzandroulis, D. Goustouridis, I. Zergioti, D. Kafetzopoulos, D. Tsoukalas, 3rd International Conference on Micro-Nanoelectronics, Nanotechnology & MEMS, Athens, Greece, November 18-21, 2007.
120. "Direct laser printing of biomolecules on capacitive sensors", I. Zergioti, C. Boutopoulos, P. Andreakou; C. Chatzandroulis, D. Goustouridis, D. Tsoukalas, , 9th International Conference on Laser Ablation, COLA 2007, Tenerife, Spain, September 24-28, 2007.
121. "Electrical characterization of field-effect zinc oxide transistors for gas sensing applications", F.V.Farmakis, P.Jedrasik, C.Tsamis, M.Kompitsas, I.Fasaki, A.Speliotis, IMA 2007, 30 September – 04 October 2007, Rio-Patras, Greece (Oral)
122. "VCSEL device modeling and parameter extraction technique", K.Minoglou, G.Halkias, E.D.Kyriakis-Bitzaros, D.Syvridis, A.Arapogianni, IEEE 14th ICECS 2007, Marrakesh, Morocco, 11-14 Dec. 2007

INVITED TALKS

1. "Ordering of Si and Ge nanocrystals in 2-D layers for nanodot memory devices", A. G. Nassiopoulou (invited talk), International Conference on Physics, Chemistry and Applications of Nanostructures, Nanomeeting 2007, Belarus, 22-25 May 2007
2. "Structural and light-emitting properties of ultra thin anodic silicon films formed at the early stages of anodization of bulk silicon", S. Gardelis (invited talk), International Conference on Physics, Chemistry and Applications of Nanostructures, Nanomeeting 2007, Belarus, 22-25 May 2007
3. "Self-assembly of Si nanostructures on nanopatterned substrates: Application in nanocrystal memories" (invited talk) A. G. Nassiopoulou, 4th International Workshop on Nanosciences & Nanotechnologies (N&N07), Thessaloniki, 16-18 July 2007
4. "Silicon Nanocrystals embedded in SiO2: Optical and transport properties" A. G. Nassiopoulou (invited talk), 2nd European Optical Society Topical Meeting on Optical Microsystems, Italy, 30 September – 3 October 2007
5. "Characterization of Silicon Nanocrystal non-Volatile Memory Structures with Double Nanocrystal Layers", A. G. Nassiopoulou (invited talk), ANNA-Analytical Network for Nanotech, held at Munich, 29 November 2007
6. "Microelectronics beyond Moore" A. G. Nassiopoulou, (invited talk), Summer Scool NCSR Demokritos, 9-20 July 2007
7. "High-aspect-ratio micro/nanomachining with proton beam writing on aqueous developable - easily stripped negative chemically amplified resists", (invited talk) M. Chatzichristidi, Jeroen Anton Van Kan, Frank Watt, P. Argitis, I. Raptis , 33rd International Conference on Micro- and Nano-Engineering (MNE), Copenhagen, Denmark, September 23-26, 2007
8. "Polymeric and molecular glass resist models for stochastic lithography simulation", (invited talk) D.Drygiannakis, G.P.Patsis, I.Raptis, E.Gogolides, 5th IISB Litho workshop (Hersbruck, Germany 09/2007)

PhD THESES

1. "Growth and electrical characterization of Au nanowires between electrodes", PhD thesis: Argyro Zoy, Thesis supervisor: Dr A. G. Nassiopoulou, Examination: National Technical University of Athens, 7-9-2007, Examination Committee:

Assoc. Prof. D. Tsoukalas, NTUA-Athens
Assoc. Prof. S. Georga, University of Patras,
Prof. E. Liarokapis, NTUA, Athens
Dr A. G. Nassiopoulou, Director of Research, IMEL/NCSR Demokritos
Prof. P. Pissis, NTUA, Athens
Assoc. Prof. I. S. Raptis, NTUA, Athens

2. "Oligomeric Crystalline Materials for Organic Field Effect Transistor Applications", G. Chaidogiannos, National Technical University of Athens, 2007
3. "Oxygen plasma etching, surface modification and nanotexturing of PMMA: Study of mechanisms and applications in PMMA microfluidic devices", N. Vourdas, National Technical University of Athens, School of Chemical Engineering, 2007
4. "High density Integrated Optoelectronic Circuits for High Speed Photonic Microsystems", K. Minoglou, National & Kapodistrian University of Athens, 2007)

PATENTS

"Tuning the emitting color of single layer, patterned full color Organic Light Emitting Diodes", P. Argitis, G. Pistolis, M. Vasilopoulou, Greek Patent (OBI) appl. No 20060100359, 19 June 2006, PCT Application June 19, 2007

ORGANIZATION OF CONFERENCES, SYMPOSIA, WORKSHOPS

1. MEMs, held at NCSR "Demokritos", 18-21 November 2007. Chairperson of the Conference was Dr Androula G. Nassiopoulou
2. 15th International Biennial Conference on Insulating Films on Semiconductors, INFOS 2007. This conference was organized by the Institute of Materials Science (IMS) and the Institute of Microelectronics (IMEL) from NCSR Demokritos, the National Technical University of Athens and the University of Ioannina, in Glyfada Athens, Greece, between 20 and 23 June, 2007 (see http://www.infos2007.gr). The 134 papers (119 contributed and 15 invited) presented at the conference are published in Microelectronic Engineering (see A. Dimoulas and P. Normand, Microelec. Eng. Volume 84, Issue 9-10, September 2007, Pages xiii).
3. 3rd Nano2life Summer School "Methods in Micro-Nano Technology and Nanobiotechnology", June 25th-July 6th 2007, http://imel.demokritos.gr/SummerSchool2007/index.htm

SEMINARS – LECTURES AT IMEL

1. "Thin films and nanocrystals: study with high resolution transmission electron microscopy", N. Frangis, Department of Physics, Aristotle University of Thessaloniki
2. "Hierarchical simulations of polymeric materials", prof. D. Theodorou, Department of Chemical Engineering, University of Athens
3. "Advanced Functional Carbon-based Nanostructured Materials", Nikos Tagmatarchis, Collaborating Researcher, National Hellenic Research Foundation, Theoretical and Physical Chemistry Institute
4. "The capacitance in organic chemical analysis", prof. K. Eustathiou, Department of Chemistry, University of Athens
5. "Advances and problems in the development of a new narrow band gap semiconductor InN", ass. prof. A. Georgakilas, Department of Physics, University of Crete and Institute of Electronic Structure and Laser, Foundation for Research and Technology
6. "Polymer based nanophotonics devices fabricated by nanoimprint lithography", Dr N. Kechagias, Tyndall Research Center, Ireland
7. "Photo-Carrier Radiometry and Deep-Level Photo-Thermal Spectroscopy: Two New Non Contact Methodologies For Opto-Electronic Material And Device Diagnostics", Dr A. Madelis, Center for Advanced Diffusion-Wave Technology (CADIFT), Departments of Mechanical and Industrial, and Electrical and Computer Engineering, University of Toronto
8. Monolithic Biosensors based on Broad-band Mach-Zehnder Interferometry for the Early Diagnosis of Human Diseases, b) Dual Transduction Power Microgenerators for Autnomous Powering of MEMS", Dr E. Makarona, IMEL/NCSR Demokritos
9. "Applications of electromagnetic methods in RF and photonic systems", Dr H. Contopanagos, IMEL/NCSR Demokritos
10. "Development of Micromechanical devices for sensors and measurement methodologies", D. Goustouridis, IMEL/NCSR Demokritos
11. "Development of Physical and Chemical Sensor Microsystems ", S. Chatzandroulis, IMEL/NCSR Demokritos

ANNEX IV: Funded projects

A. EU Projects

- **NANOSIL (FP7-IST-NoE)** - Contract No 216171, "Silicon based nanostructures and nanodevices for long term nanoelectronics applications"
  Duration: 1/1/2008-1/1/2011
  Project leader: A. G. Nassiopoulou
  www.sinano.org

- **ANNA (FP6-IST-I3)** - Contract No 026134, "European Integrated Activity of Excellence and Networking for Nano and Micro-Electronic Analysis"
  Duration: 1/12/2006-1/12/2010
  Project leader: A. G. Nassiopoulou
  www.anna-i3.org

- **SINANO (FP6-NoE-IST)** - Contract No 506844, "Silicon based Nanodevices"
  Duration: 1/1/2004-31/12/2008
  Project leader: A. G. Nassiopoulou
  www.sinano.org

- **FP6 – MD3** - Contract No 214948, "Material Development for Double exposure and Double patterining"
  Duration: 1/12/2007-30/11/2009
  Project leader: E. Goggolides

- **NANOPLASMA (STREP-NMP-FP6)** - Contract No 016424, "Plasma Etching for desired nanofeature shape and nanotexture: An advanced reactor and simulation software for feedback loop plasma control"
  Duration: 1/4/2006-31/3/2009
  Project leader: E. Goggolides

- **Micro2DNA (MMP-STREP)** - Contract No 027333, "Integrated polymer-based micro fluidic micro system for DNA extraction, amplification, and silicon-based detection"
  Duration: 1/2/2006-31/1/2008
  Project leader: P. Normand

- **MORE-MOORE (IP-IST-FP6)** - Contract No 507754, "Exploring new limits to Moore's law",
  Duration: 1/1/2004-31/3/2007
  Project leader: E. Goggolides

- **GOOD-FOOD (IP-IST-FP6)** - Contract No 508774, "Food Safety and Quality Monitoring with Microsystems"
  Duration: 1/1/2004-30/6/2007
  Project leader: C. Tsamis, A. G.Nassiopoulou

- **PICMOS (STREP-IST-FP6)** - Contract No 002131, "Photonic Interconnet Layer on CMOS by Wafer-Scale Integration"
  Duration: 1/1/2004-31/3/2007
  Project leader: G. Halkias

- **UNINANOCUPS (STREP-NMP-FP6)** - Contract No MRTN-CT-2003-504233, "Unidirectional nanoscale supramuleculawires assembled by photo – and electro-active metallocyclodextrine cups"
  Duration: 1/1/2004-31/12/2007
  Project leader: N. Glezos

- **NANO2LIFE (NoE-NMP-FP6)** - Contract No 500057, "Unidirectional nanoscale supramuleculawires assembled by photo – and electro-active metallocyclodextrine cups", Duration: 1/2/2004-31/1/2008
  Project leader: K. Misiakos

- **TASNANO (STREP-NMP-FP6)** - Contract Nr 516865, "Tools and Technology for the Analysis and Synthesis of Nanostructures"
  Duration: 1/1/2005-31/12/2007
  Project leader: N. Glezos

- **MARIE-CURIE re-integration grant (FP6)** - Contract No 016142, "Convergence of Microelectronics, Nanotechnology and High Frequency RF engineering (CMNHFRF)"
  Duration: 29/7/2005-28/7/2007
  Project leader: A. G. Nassiopoulou

- **NEMOSLAB (IST-NoE- FP6)** - Contract No 027804, "NanoEngineered Monolithic Optoelectronic transducers for highly sensitive and Label-free Bionsensing"
  Duration: 1/1/2006-31/12/2008
  Project leader: K. Misiakos

- **ESA - ESTEC** - Contract No 21339/08/NL/GLC - "Silicon Remote RF Powring and Passive Telemetry Link for a Wireless Strain Sensor System"
  Duration: 1/3/2008–31/5/2009
  Project leader: S.G. Katsafouros

- **PYTHIA (FP7)** Contract No 224030
  "Monolithically Integrated Interferometric Biochips for label-free Early detection of Human Diseases"
  Duration: 1/5/2008-30/4/2011
  Project leader: I. Raptis

- **ESA** Contract with ITE Crete
  "Investigation of the use of III-Nitride quantum dot-resonant tunneling diodes structure as tuneable wavelength UV-VIS Detectors"
  Duration: 28/11/2007-31/10/2008
  Project leader: P. Normand

B. Other International projects

- **Photothermal project (Research agency-Cyprus)** - "Towards a safe hydrogen production: Photothermal analysis at the limits of parts per trillion", Duration: 1/7/2004 – 30/6/2008, Project leader: A. G. Nassiopoulou

- **ESA/ ITE** - "Investigation of the use of III-Nitride Quantum Dot-Resontant Tunneling Diodes Structure as Tuneable Wavelength UV-VIS Detectors", Duration: 28/11/2007-31/10/2008, Project leader: P. Normand

C. Contracts with Industry

- Contract with the company **UNILEVER U.K.** - "Flow system for Unilever"
  Duration: 1/12/05 - 31/5/07
  Project leader: A. G. Nassiopoulou
- Contract with the company **ST Microelectronics** SA, France - "Microporous silicon and porous alumina grown electrochemically on silicon substrates applied to the fabrication of passive components and nanoelectronic devices"
  Duration: 30/7/05 - 30/7/08
  Project leader: A. G. Nassiopoulou

- Contract with the company **ZENON SA** - "Novel photovoltaic panels with vertical positioning of concentration Si cells"
  Duration: 1/7/06 - 31/12/08
  Project leader: D. Davazoglou

D. Projects funded by GSRT

- **Excellence fund** for: "Funding of Excellence at IMEL "
  Duration: 1/12/2005 - 30/6/08
  Project leader: A. G. Nassiopoulou
- **AKMON -"Laboratory of Nanotechnology and Microsystems"**
  Duration: 1/3/06 - 30/6/2008
  Project leader: A. G. Nassiopoulou
- **GSRT-PENED-03ED276** - "Critical sub-100 Industrial scale Patterns for CMOS - NANO Architectures' (CMOS-NANO)
  Duration: 1/12/2005 – 30/11/2008
  Project leader: I. Raptis
- **GSRT- PENED-03ED202** - "Fabrication, Properties, and Actuation Technologies for Microfluidic Devices",
  Duration: 1/12/05-31/112008
  Project leader: A. Tserepi
- **PB.NANOCOMP (GSRT/Non-EU)** - Contract No 224030, "Proton Beam NANOlithography for high aspect ratio structures of optical COMPonents"
  Duration: 1/4/2007-31/3/2008
  Project leader: I. Raptis
- **GSRT- PENED-03ED579** - "Macroporous silicon and anodic porous alumina on silicon for integrated RF components and nanoelectronics"
  Duration: 15/7/2005-14/7/2008
  Project leader: A. G. Nassiopoulou
- **GSRT-PENED-03ED630** - "Micromachined chemical sensors for controlling food safety and quality"
  Duration: 1/11/2005 - 1/11/2008
  Project leader: C. Tsamis
- **GSRT- PENED-03ED496** - "Dopant diffusion and activation in Group-IV semiconductors (Strained Silicon and Germanium) for novel nanoelectronic devices"
  Duration: 28/12/2005 - 27/12/2008
  Project leader: C. Tsamis
- **PENED-03ED550** - "Development of polysilicon TFT technology with advanced techniques of film annealing and device characterization"
  Duration: 15/12/2005 - 14/12/2008
  Project leader: D. Kouvatsos
- **GSRT- ENTER-05 EP032** - "Development of MOSFET type chemical sensors for wireless sensor networks"
  Duration: 1/12/2005 - 1/12/2007
  Project leader: C. Tsamis
- **GSRT- PAVE** - " Optical smoke detectors "
  Duration: 1/7/2006 - 31/12/2007
  Project leader: D. Davazoglou

E. Bilateral projects

- **Bilateral project (Greece-Romania)** - "Drug delivery system based on microreservoirs array with porous silicon resorbable membrane caps"
  Duration: 1/2/2006-31/3/2008
  Project leader: A. G. Nassiopoulou
- **Bilateral project NON-EU-99 (Greece-Tunisia)** - "Optical non-volatile memory using Si nanocrystals",
  Duration: 19/7/2006- 19/7/2008
  Project leader: A. Nassiopoulou
- **Bilateral project (Greece-France)** - "Silicon nanocrystal synthesis by plasma immersion ion implantation for electronic memory applications"
  Duration: 1/4/2006 – 31/3/2008
  Project leader: P. Normand
- **Bilateral project (Greece-Italy)** – "Fabrication and characterization of an array of transparent conductive thin film polymeric composite as multiparametric sensitive layers for a new e-nose"
  Duration: 29/1/2007 – 31/3/2008
  Project leader: D. Goustouridis
- **Bilateral project NON-EU-99 (Greece-Singapore)** –
  Duration: 1/2/2007-31/3/2008
  Project leader: I. Raptis
- **Bilateral project (Greece-Yugoslavia)** - "Performance, stress degradation and reliability characterization of thin film transistors for the investigation of defects in polycrystalline silicon films"
  Duration: 5/11/2004-31/12/2007
  Project leader: D. Kouvatsos
- **Bilateral project NON-EU-204 (Greece-USA)** - "Process-induced strain modification in strained silicon layers and influence on device performance ",
  Duration: 1/3/2006-28/2/2008
  Project leader: C. Tsamis
- **Bilateral project NON-EU-99 (Greece-Japan)** - "Cooper nano-electrodes and novel transistors based on tungsten oxides nano-rods (CONECTOR)",
  Duration: 1/ 4/2006-31/3/2008
  Project leader: D. Davazoglou

DHMOEREYNA

- "Patterning and surface modification of substrates in the micro- and nano- scale for the fabrication of protein micro-arrays"
  Duration: 1/1/2007-31/5/2008
  Project leader: Tserepi
- "Influence of surface plasmon-polariton excitation in nanostructured metallic surfaces on the fluorescence of biological materials"
  Duration: 1/1/2007-31/5/2008
  Project leader: N. Papanikolaou