PROJECTS II.1 - III.1
NANOSTRUCTURES FOR NANOELECTRONICS, PHOTONICS AND SENSORS

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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
- On-chip RF passives using porous silicon microplate technology
- 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 2008

Highly ordered hexagonally arranged nanostructures on silicon through a self-assembled silicon-integrated porous anodic alumina masking layer

Filimon Zacharatos, Violetta Gianneta and Androula G Nassiopoulou

A combined process of electrochemical formation of self-assembled porous anodic alumina thin films on a Si substrate and Si etching through the pores was used to fabricate ideally ordered nanostructures on the silicon surface with a long-range, two-dimensional arrangement in a hexagonal close-packed lattice. Pore arrangement in the alumina film was achieved without any pre-patterning of the film surface before anodization. Perfect pattern transfer was achieved by an initial dry etching step, followed by wet or electrochemical etching of Si at the pore bottoms.

Anisotropic wet etching using tetramethyl ammonium hydroxide (TMAH) solution resulted in pits in the form of inverted pyramids, while electrochemical etching using a hydrofluoric acid (HF) solution resulted in concave nanopits in the form of semi-spheres. Nanopatterns with lateral size in the range 12–200 nm, depth in the range 50–300 nm and periodicity in the range 30–200 nm were achieved either on large Si areas or on pre-selected confined areas on the Si substrate. The pore size and periodicity were tuned by changing the electrolyte for porous anodic alumina formation and the alumina pore widening time. This parallel large-area nanopatterning technique shows significant potential for use in Si technology and devices.

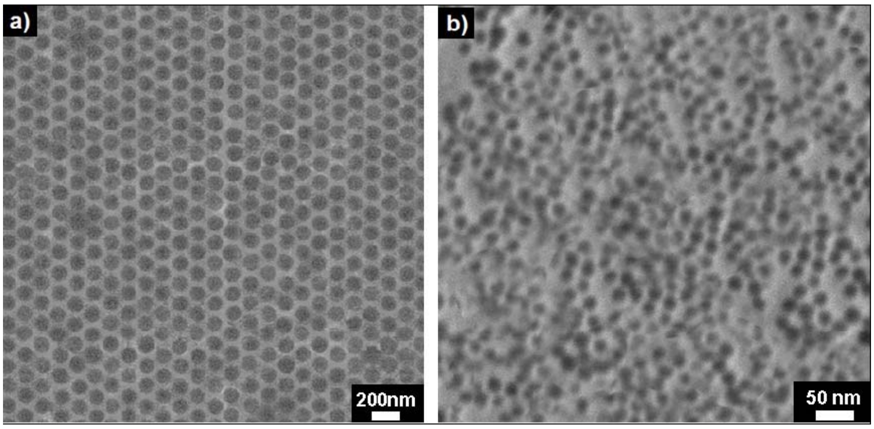


Fig. N1: SEM images of hexagonally arranged arrays of nanoconcave pits on Si, fabricated by electrochemical etching in IPA:HF:H2O 10:3:6 solution at 15 mA cm−2 for 60 s. (a) The PAA film was anodized in oxalic acid. The mean diameter of the concave pits is 120 nm, the lattice constant being 200 nm. (b) The PAA film was anodized in sulfuric acid and the diameter of the concave pits is 12 nm.

Highly ordered hexagonally arranged sub-200 nm diameter vertical cylindrical pores on p-type Si using non-lithographic pre-patterning of the Si substrate

Filimon Zacharatos, Violetta Gianneta, and Androula G. Nassiopoulou

Anodically etched two-dimensional (2-D) arrays of highly ordered sub-200 nm in diameter vertical cylindrical pores were fabricated on p-type Si wafers, with a resistivity of 6–8 Ω cm, by non-lithographic pre-patterning of the silicon substrate through a self-assembled porous anodic alumina (PAA) thin film, directly grown on the Si wafer. The PAA film was grown by electrochemical oxidation of a thin Al film in an oxalic acid aqueous solution electrolyte. Through the PAA pores, concave etch pits were formed on Si by chemical etching, that were then used as pore initiation sites for electrochemical macroporous silicon formation. The so formed vertical cylindrical pore arrays showed perfect hexagonal arrangement on the Si surface. A pore diameter down to 180 nm and a pore height up to ~1 μm were achieved for the first time on p-type Si. The developed technology is particularly interesting for photonic crystals and sensors applications.

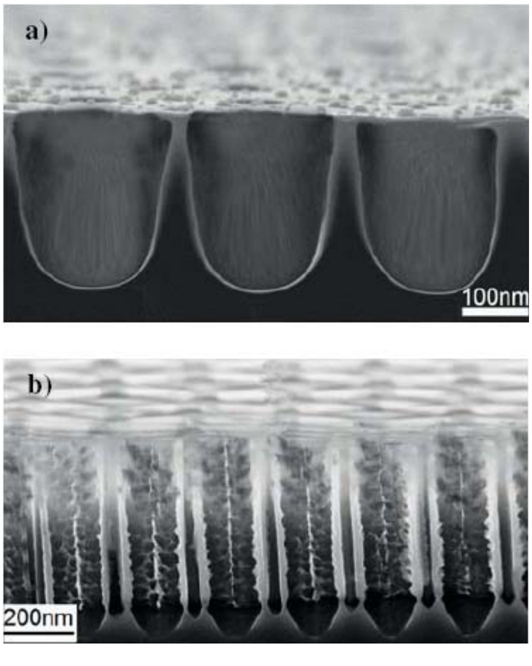


Fig. N2: a) Cross sectional view of the pits formed electrochemically through the PAA mask. b) SEM cross sectional view of the hexagonally arranged vertical pores. Pore depth is ~1 μm. The macroporeformation is initiated in the predefined areas.

Self-assembled hexagonal ordering of Si nanocrystals embedded in SiO_2 nanodots

A. G. Nassiopoulou, V. V. Gianneta, M. Huffman, M. A. Reading, J. A. Van Den Berg, I. Tsiaoussis and N. Frangis

Highly dense hexagonally ordered two-dimensional arrays of Si nanocrystals embedded in SiO_2 nanodots were fabricated on a silicon substrate by using a self-assembled porous anodic alumina thin film as a masking layer through which electrochemical oxidation of the Si substrate and ultralow energy Si implantation took place. After removal of the alumina film and high temperature annealing of the samples, hexagonally ordered Si nanocrystals embedded within SiO_2 nanodots were obtained, having sizes in the few tens of nanometers range. The fabricated ordered structures show significant potential for applications either in basic physics experiments or as building blocks for nanoelectronic and nanophotonic devices.

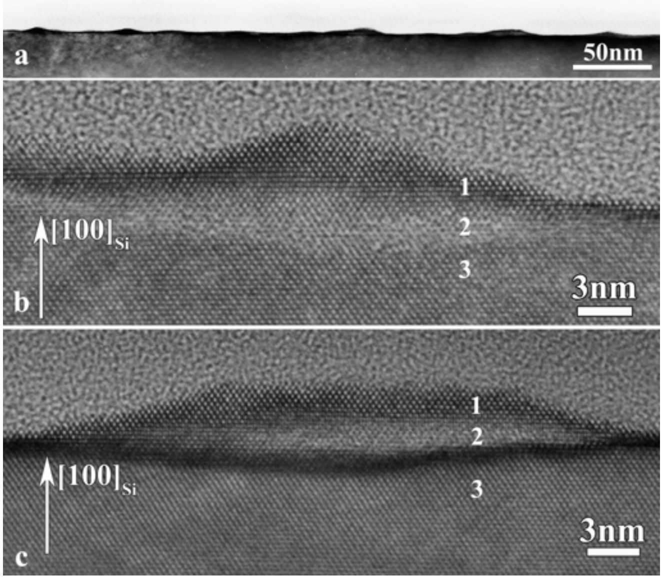
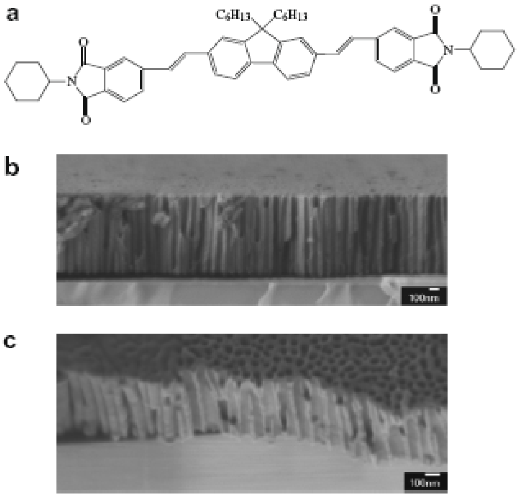


Fig. N3: TEM images of the samples after ion beam synthesis. In (a) we see a bright field image showing the presence of undulations on the Si surface. In (b) we see an HRTEM image presenting a Si nanocrystal with dome-like shape. (c) shows a HRTEM image presenting a truncated-shape Si nanocrystal. Note in both high-resolution images the epitaxial growth of the Si nanocrystals (area 1) in relation to the Si substrate (area 3), with an amorphous material (SiO_2) at the interface between the nanocrystals and the Si substrate (area 2).

Photoluminescence in the blue spectral region from fluorine molecules embedded in porous anodic alumina thin films on silicon

M. Fakis, V. Gianneta, P. Persephonis, V. Giannetas, A.G. Nassiopoulou

The photoluminescence (PL) in the blue spectral region from fluorene molecules embedded in the pores of anodic alumina thin films on silicon was investigated in detail. It was found that the PL was strongly dependent on the diameter and depth of the pores, as well as on the solvent used to dissolve the fluorene molecules. A photoluminescence blue shift with a maximum value of 30nm was observed when the fluorenes were embedded into 40nm pores of the alumina film compared to the corresponding spectrum in solution. The results have shown that the penetration of the molecules into the pores, as well as the formation of nanosize aggregates are favored when the molecules are dissolved in aromatic solvent.



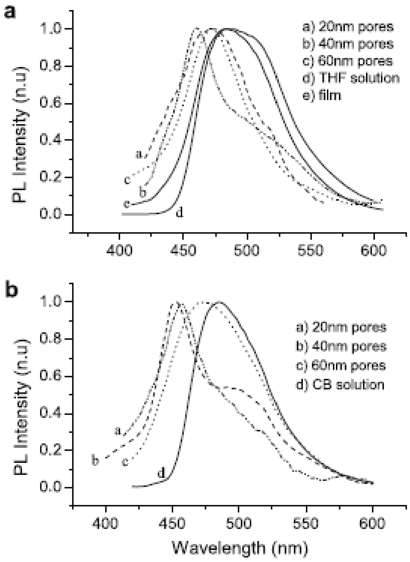


Fig. N4: (a) The chemical structure of the fluorene molecule, (b) and (c) SEM images of the porous alumina before and after the impregnation of the fluorene molecules respectively. In (b) and (c) the PAA thickness is 750nm and the pore diameter is 40nm.

Fig. N5: The PL spectra of (a) F-PHT/PAA/THF composites (750nm thickness) and (b) F-PHT/PAA/CB composites (750nm thickness) with different pore diameters together with the spectra of F-PHT in solution and film. All spectra were taken after the rinsing procedure.

Porous anodic alumina thin films on Si: Interface characterization

V. Gianneta, and A.G. Nassiopoulou, C. A. Krontiras, and S. N. Georga

Porous anodic alumina (PAA) thin films (thickness~50nm) were fabricated on Si by anodization of thin Al films under constant voltage of 20V in sulphuric acid aqueous solution. The films exhibit cylindrical vertical pores of diameter~13-15nm, arranged in hexagonal close packed structure. Electrochemical oxidation of the Si substrate through PAA, used as masking layer with openings in the pores, resulted in the for-films of SiO_2 dots at each pore tips.

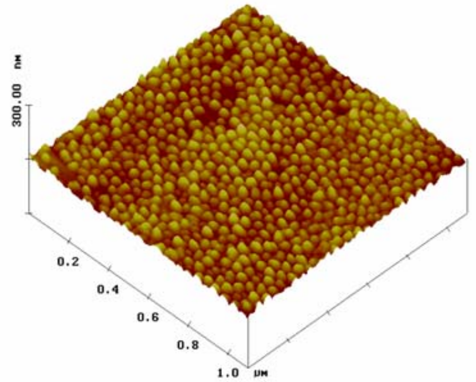


Fig. N6: AFM image of arrays of SiO_2 dots, fabricated through anodic porous alumina masking layer.

Two different kinds of films, namely with or without SiO_2 dots at pore tips, were fabricated, In order to characterize the electrical quality of the interface of PAA thin films with Si, C-V and G-V measurements were performed on Metal-Insulator-Semiconductor (MIS) structures with Al metallization. The measurements were carried out in the voltage range +1.0V to -3.0V in steps of 0.05V and in the frequency range 1MHz to 100Hz. The typical form of C-V and G-V curves of a MIS structure was obtained. In order to determine the interface trap density D_{it}, C-f and G-f measurements were performed as a function of the applied gate voltage in the depletion region. D_{it} was evaluated following the Conductance Method (E. H. Nicollian, and J. R. Brews, MOS Physics and Technology (J. Wiley & Sons, New York, 1982), p.222 [1]). Both types of samples exhibit values of D_{it} in the order of $10^{11}eV^{-1}cm^{-2}$.

Copper-filled macroporous Si and cavity underneath for microchannel heat sink technology

F. Zacharatos and A. G. Nassiopoulou

Thermal management in ICs becomes essential as integration density and total power consumption increase. The use of microchannels in high power density electronics cooling is a well-known technique for heat transfer. In this work we developed Cu-filled macroporous Si channels with a Cu-filled cavity underneath, which may be used as heat sinks in high power density electronics cooling. Macroporous Si is formed by electrochemical dissolution of bulk Si, while pore filling with copper is achieved by electro-deposition. Using appropriate design, the resulting composite material may be fabricated on selected areas on the silicon substrate for use as heat sink on Si. The surface area is defined by patterning. The macroporous Si structure is composed of either randomly distributed pores or pores arranged in two-dimensional (2-D) arrays, fabricated by pre-patterning the Si surface before anodization so as to form pore initiation pits. The pore size in this work was 5μm, while the porous layer and the cavity underneath had both a thickness of 40 μm. Copper deposition proceeds first by filling the micro-cavity underneath the porous layer. This is achieved by linearly increasing the applied potential during electro-deposition. After full Cu-filling of the cavity, pore filling starts from the bottom of each pore and proceeds laterally, while no nucleation takes place on pore wall. In this way, homogeneous copper wires within pores may be fabricated. The Cu/Si composite material is appropriate for forming channels with improved heat transfer within the Si wafer.

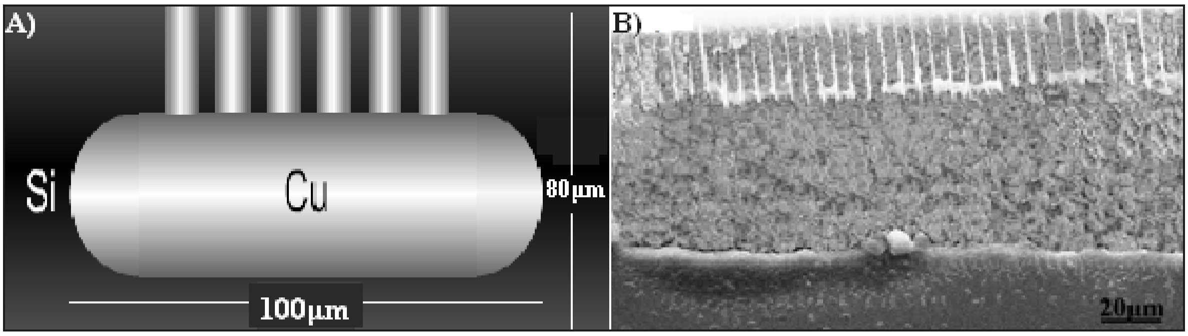


Fig. N7: A) Schematic representation of the fabricated device. The copper-filled microcavity is interconnected with the surface through the copper cylinders. The cavity is 40 μm deep and the metallic cylinders 40 μm long.
B) Cross-sectional SEM image of the resulting structure after complete pore and cavity filling with Cu. The duration of the electrochemical deposition was 60 min under variable bias voltage as in Fig. 4a. Three areas are discerned from top to bottom: Macropores filled with Cu, Cu filled cavity and the Si substrate.

Electrical characterization of HfO_2 and $HfSiO_x$ MOS capacitors

M. Theodoropoulou and A. G. Nassiopoulou

A series of samples containing HfO_2 or $HfSiO_x$ dielectrics, fabricated at IMEC were characterized electrically at IMEL as part of the ANNA project. The goal of this effort was to better understand the parameters that affect the electrical characteristics of these two high-k dielectrics. MOS capacitors with Al metallization were fabricated at IMEL and electrical measurements were performed on several devices (room temperature), using standard techniques for MOS characterization. The obtained results suggest that, in general, plasma nitridation (DPN) and post nitridation annealing produce films of slightly better quality (lower leakage currents). Strong frequency dispersion in both depletion and accumulation is observed for all the samples (Fig N8). The density of interface states is in the order of $10^{12}/cm^2$, as calculated from data plots such as Fig. N9. This is relatively high but it does agree with literature values. These characteristics could be improved by further processing of the samples such as annealing and more careful method of making electrical contact.

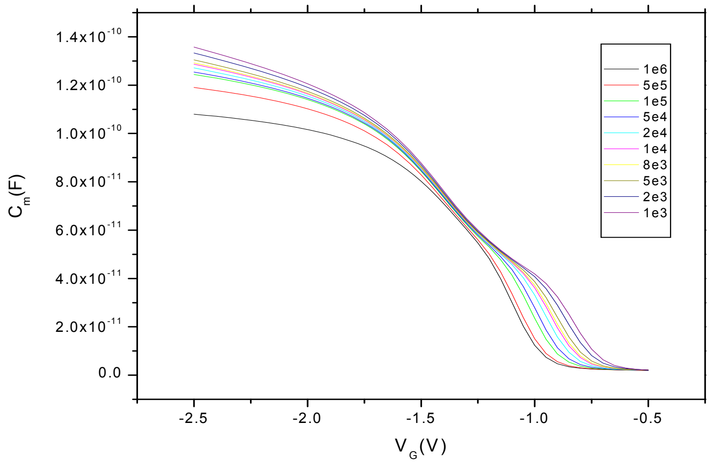


Fig. N8: C-V measurements in the high frequency region for sample DO4.

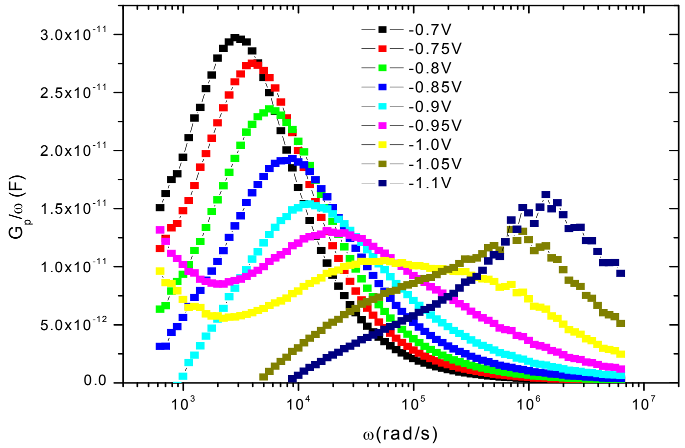


Fig. N9: Experimental G_p/ω vs ω curves for sample DO6.

High-frequency characterization of mesoporous Si: RF-shielding properties and complex permittivity extraction through on-chip co-planar waveguide measurements

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

The objective of this work is to use the technology of porous Si for RF circuits integrated on-chip in CMOS-compatible processes, operating at frequency bands of interest, namely 1GHz-6GHz where current wireless telephony operates, as well as for the 60-GHz band, where future analog RFIC's will work. The major hurdle in the operation of these devices are the Si-substrate losses as well as associated cross-coupling between closely spaced analog stages of the devices. In this work, we use porous Si as a CMOS-compatible technology that grows local microplates of specified layouts underneath the passive components, with the purpose of dramatically reducing RF losses as well as cross-coupling between adjacent devices. We have grown mesoporous Si microplates of various thicknesses, on a bare p-type Si die of ρ = 8 Ω.cm, used in standard CMOS. The measuring platform we have used is shown in Fig. N10 and consists of an on-chip Aluminum Coplanar Waveguide (CPW) fabricated on a fixed-thickness Si die using Al metallization.

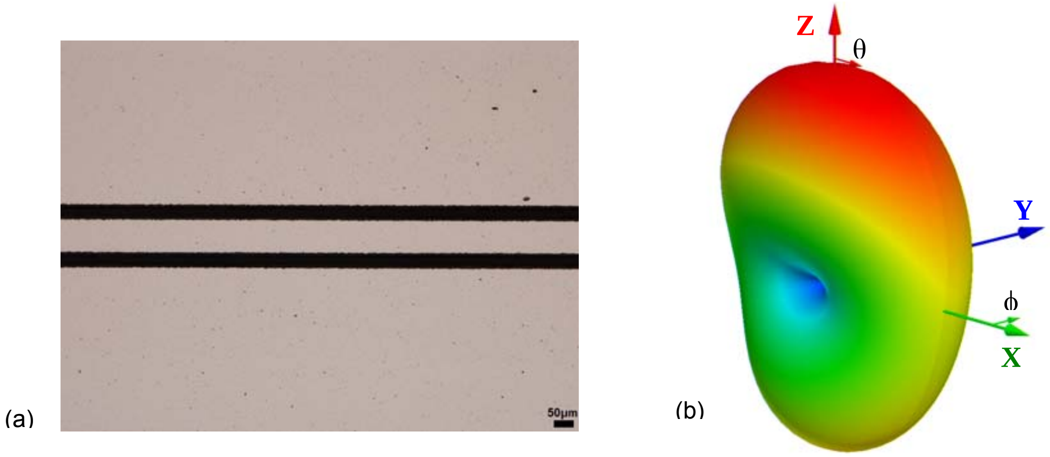


Fig. N10: a) On-chip CPW platform on the X-Y plane, with the line along Y. b) Total 3D radiative gain at 5 GHz.

Regarding losses, we use energy conservation to quantify the power lost within the CPW through the formula $PL = 1 - |S_{11}|^2 - |S_{21}|^2$. Associating this power loss with material losses only, assumes the CPW is a non-radiating transmission line. This is certainly valid in our case, due to the dimensions chosen, as illustrated in Fig. N11a, where we show the 3-dimensional total radiative gain of the CPW which is completely negligible, reaching a maximum (red region) of 4×10^{-7}. For comparison, a half-wave dipole antenna matched to a 50Ω-port similarly has a maximum gain of about 1.5.

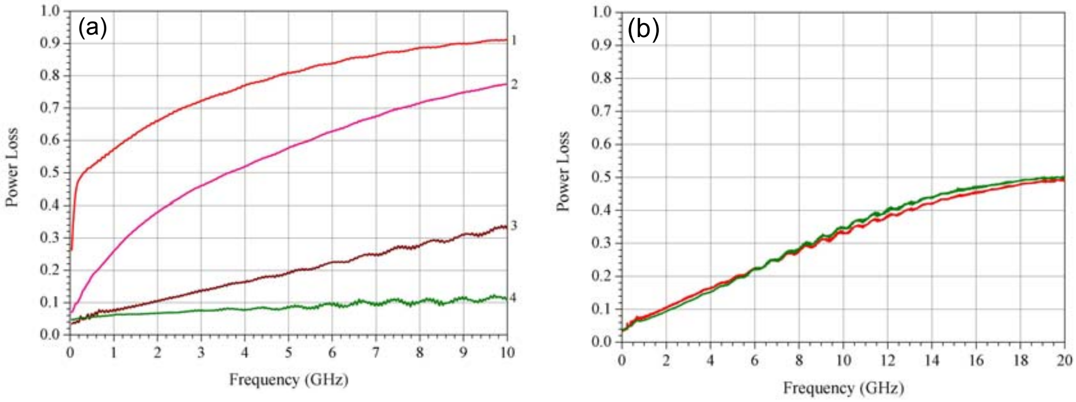


*Fig. N11: a) Measured power loss for 4 different dies: **1** no porous **2** a 25μm-thick layer of mesoporous Si **3** a 50 μm-thick layer and **4** a low-loss dielectric of tanδ<10^{-3}. b) Measured power loss of a 50-μm-thick (red) and 100-μm-thick (green) porous Si microplate.*

In fig. N11a we present the measured power loss of 3 identical CPW's fabricated on 3 different dies, all of the same total thickness, as well as the same CPW on a low-loss RF substrate. The bare Si die consumes a lot of power, but a 50μm-thick porous microplate substantially reduces the RF losses to 1/6-1/4 of these values. Therefore, this material is excellent for CMOS-compatible integration of passive RF devices. For comparison, the low-loss RF laminate (4) of Fig. N11a presents at 5 GHz a loss not less than half of that of the line on the 50μm-thick porous Si. An important issue for ease of fabrication, regards the minimum porous Si layer thickness necessary to saturate the RF isolation effects. In Fig. N11b, we show that the measured power loss on dies containing 50 and 100-micron-thick microplates turns out to be identical, hence 50 microns of porous Si effectively saturate the RF-isolation effects for the form-factors of the CPW's used.

We have used the measured S-parameters as inputs and compared them to the simulation results obtained through HFSS simulations of the same structure, each time varying the quantities Re{ε} and Im{ε}, until the best fit is obtained. The agreement is explored between several *functions* of frequency, therefore the fits are highly non-trivial. In Fig. N12a we show the result of the agreement, for the extracted value of the complex permittivity. The extracted constant value of the complex permittivity of the mesoporous Si grown is $\varepsilon_{PS} = 3.85(1 + i0.11)$. In Fig. N12b we show the corresponding comparison between measured and theoretical normalized power loss and we see again excellent agreement. An issue we are currently pursuing actively is lowering the loss tangent even further by appropriate alterations of the fabricating electrochemical conditions and the post anodization processing steps.

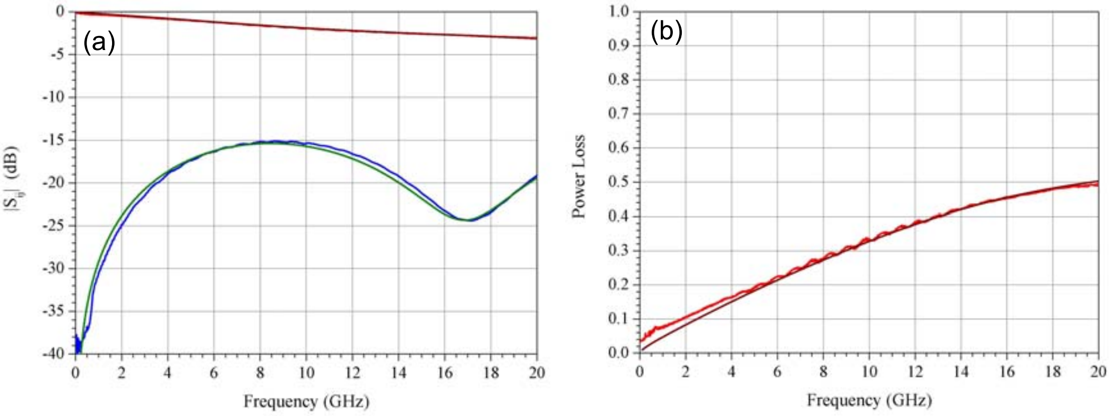
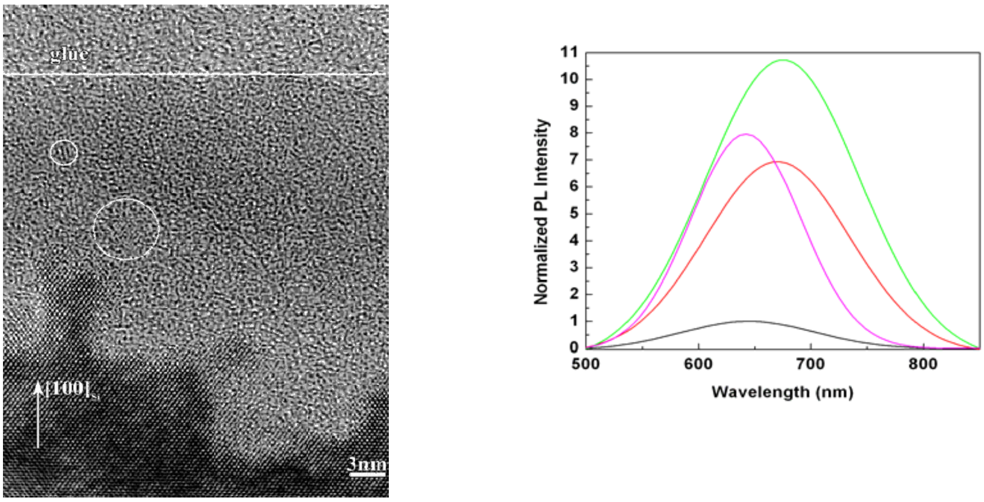


Fig. N12: a) Measured vs. theoretical S-parameters of the CPW on a composite die with a 50-μm-thick porous Si microplate on Si: Blue (|S_{11}|) & Red (|S_{21}|) = Measurements; Green (|S_{11}|) & Brown (|S_{21}|) = Simulations.
b) Measured (red) vs. simulated (brown) power loss.

Enhancement and red shift of photoluminescence (PL) of fresh porous Si under prolonged laser irradiation or ageing: Role of surface vibration modes

S. Gardelis and A. G. Nassiopoulou

We investigated the effect of a red shift and a considerable enhancement of photoluminescence (PL) intensity from a freshly etched porous Si thin film after prolonged laser irradiation or after aging in atmosphere (Fig. N13b). Both effects coincide with the appearance of Si-OH and Si-O-Si vibration modes in the Fourier Transform Infra Red (FTIR) absorption spectra (Fig. N14). The red shift is attributed to a pinning of the band gap of the light emitting Si nanocrystals due to the formation of Si-OH and Si-O-Si bonds. Using theoretical calculations, we estimated the electron and hole energy shifts caused by the interaction of the electronic states of the Si NCs with the surface vibrations, and correlated the observed PL enhancement with resonant coupling between the quantized valence sub-levels in the Si NCs and surface vibration modes (Fig. N15a, N15b).



(a) (b)

Fig. N13: (a) A typical High Resolution Transmission Electron Micrograph (HRTEM) obtained from the anodic films, showing Si nanocrystals of sizes between 1.5 to 7 nm. ***(b)*** *Photoluminescence (PL) spectra obtained from the as-grown anodic film (black), after prolonged laser irradiation (orange), after aging (green) and after immersion in hydrofluoric acid (HF).*

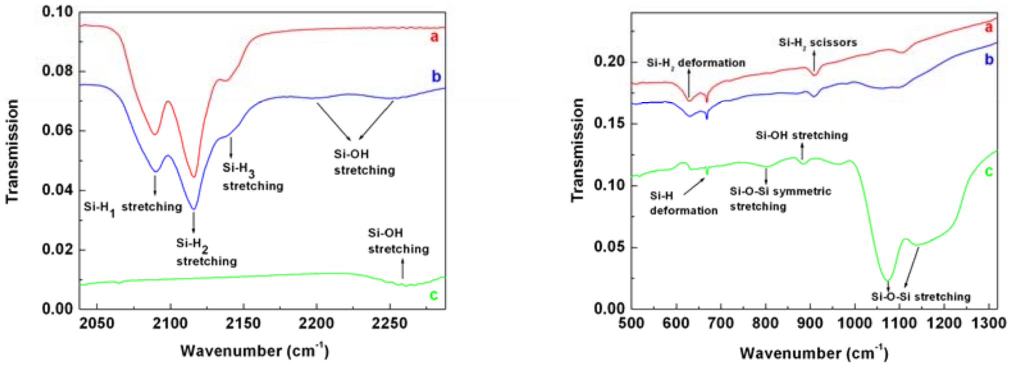
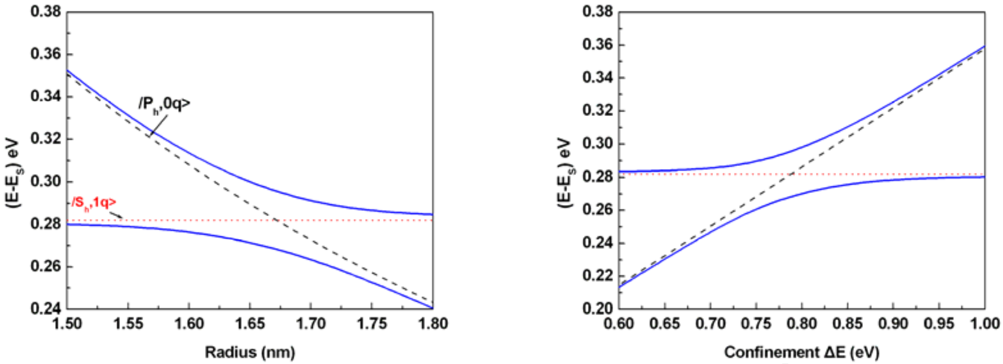


Fig. N14: FTIR absorption spectrum obtained from: (a) the as-grown fresh porous Si film, (b) after prolonged laser irradiation and (c) after aging in air.



(a) **(b)**

Fig. N15: (a) Resonant coupling between Si-OH stretching vibration modes at 282 meV and valence inter-sub-levels occurs for Si NCs with radius of about 1.7 nm. (b) Calculated energy separation of valence inter-sub-levels (VISL). The dotted line corresponds to the energy of the Si-OH stretching mode at 282 meV. The dashed line indicates the prediction of the quantum confinement model for VISL. The crossing of the two lines occurs at ΔE=0.78 eV.

S. Gardelis, A.G. Nassiopoulou, M. Mahdouani, R. Bourguiga, S. Jaziri, Physica E, http://dx.doi.org/10.1016/j.physe.2008.08.021

PHOTONICS, SURFACE PLASMONS, METAMATERIALS (Acvtivity of N. Papanikolaou)

Diploma student: P. Theodoni
PhD student: E. Almpanis

Surface plasmons, metamaterials

C. Terkezis, G. Gantzounis, N. Stefanou, N. Papanikolaou

The interaction of light with periodic, metallic or dielectric structures has revealed a plethora of fascinating new phenomena and novel ways to tailor light. In the case of metamaterials the structure determines the optical properties with unique consequences like negative refraction and cloaking and a big potential for applications. To facilitate progress in the field, reliable and efficient simulation methods are required. We are currently developing a method based on multiple scattering theory. The method was used to analyze periodic arrays of metal/dielectric/metal nanosandwiches and we have retrieved the effective permittivity and permeability of the structure (Fig N16). Depending on the particular geometry, this system shows negative magnetic permeability as high as -2 at optical frequencies, which is a basic ingredient towards negative refractive index metamaterials.

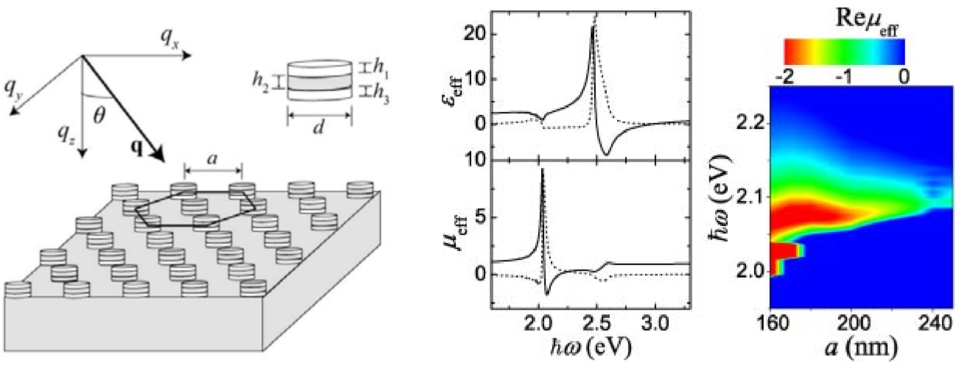


Fig. N16: Left: Metal/dielectric/metal nanosandwich arrays on a substrate. The lattice constant (a) ranges from 160 to 250nm and the diameter of the nanodisks is 100nm the heights of metal and dielectric nanodisks are 20 nm. Right: Effective electric permittivity ε and magnetic permeability μ of the structure for a=200nm. The colour plot shows the variation of μ with the lattice constant. Close packed nanosandwiches show high negative μ close to -2.

Efficient IR emitters

P. Bayiati, M. Chatzichristidi, Th. Speliotis, V. Em. Vamvakas, I. Raptis, N. Papanikolaou

Patterned metallodielectric structures have interesting optical properties. We have fabricated arrays of holes on a thin (100 nm) film on a Si substrate and transferred the hole pattern using plasma etching into the Si. The final structure is shown in Fig N17 where the diameter of the holes is around 2.5 μm. This structure shows a narrow absorption band in the infrared (~5μm) at wavelengths close to the lattice constant. Strong narrow band absorption means efficient, narrow band IR emission which is shown Fig N17 for different temperatures. Such structures could find applications in thermophotovoltaics where heat is converted to electricity.

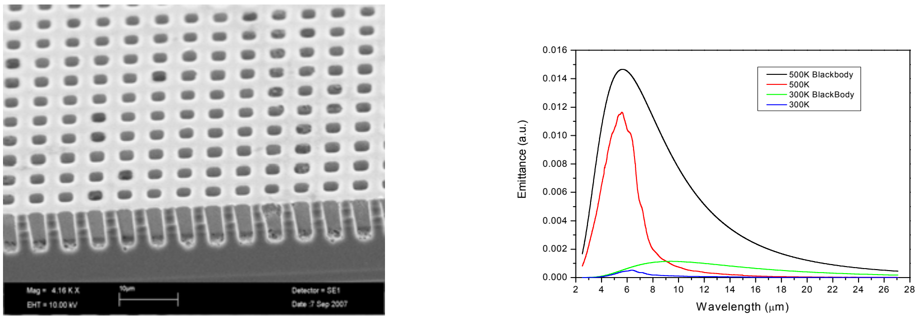


Fig. N17: SEM micrograph (left) of periodic arrays of 2-3 μm sized holes on Si covered with a thin (100nm) Au film. Fabricated using optical lithography. The structure was measured to have strong, IR absorption in a narrow band, and is expected to have efficient, narrow band, IR emittion shown on the right

Fluorescence enhancement

A.M. Gerardino, P. Petrou, S. Kakabakos, I. Raptis, N. Papanikolaou

The excitation of surface plasmons on a metal dielectric interface or close to metallic nanoparticles is accompanied by strong, subwavelength, localization of light. This effect can be used to enhance the Raman scattering or Fluorescence. An interesting concept is the use of substrates with periodic metallic nanostructures to obtain tailored plasmon excitation to achieve fluorescence enhancement. We have fabricated such periodic substrates shown in Fig N18 and measured the fluorescence enhancement of proteins with fluorescent labels. Adjusting the geometry of the substrate, light absorption can be tuned at the fluorescence frequencies, and fluorescence is enhanced as is seen in the left panel of Fig. N18.

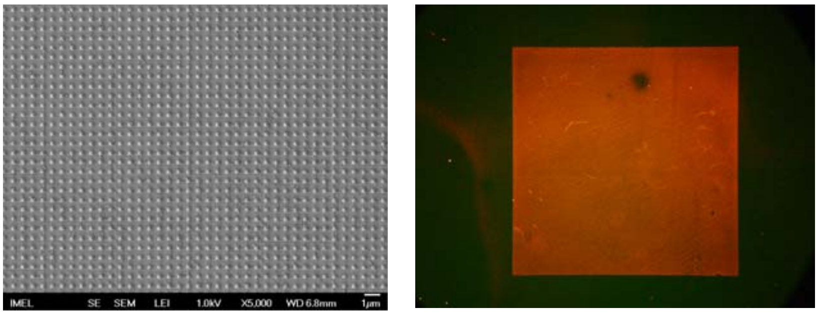


Fig. N18: SEM micrograph (left) of periodic arrays of metallic nanoparticles fabricated using e-beam lithography. The nanoparticles size is 150-200 nm in a lattice with lattice constant 300-500 nm. The whole sample was covered with AntiRabit IgG antibody with fluorescent labels alexafluor 546. The incident light was at 546 nm while the outgoing light was monitored around 575 nm. The patterned region shows much higher fluorescence (right) compared to the unpatterned one.

Thermal transport in nanowires

N. Papanikolaou

Managing heat in todays nanoelectronics industry is a major issue which cannot be neglected in the design of electronic components. It is well known that the thermal properties change upon nanostructuring a material since the dimensions become smaller than the bulk thermal mean free path. In order to investigate such effects we developed a classical molecular dynamics simulation computer code mainly for semiconductor materials, and studied SiC nanowires. Our approach was able to show some features on the dependence of the lattice thermal conductivity on the geometric parameters of the wires, and generally predict a big decrease of the thermal conductivity of the nanowires compared to the bulk.

RESEARCH PAPERS 2008

PUBLICATIONS IN REFEREED JOURNALS

1. “RF characterization and isolation properties of mesoporous Si by on-chip coplanar waveguide measurements”, Contopanagos, H., Zacharatos, F., Nassiopoulou, A.G., Solid-State Electr., 52 (11), pp. 1730-1734 (2008)
2. “Self-assembled hexagonal ordering of Si nanocrystals embedded in SiO_2 nanodots”, A. G. Nassiopoulou, V. Gianneta, M. Huffman, M. A. Reading, J. A. Van Den Berg, I. Tsiaoussis, N. Frangis, Nanotechnology 19, 495605 (2008)
3. “‘Highly ordered hexagonally arranged nanostructures on silicon through a self-assembled silicon-integrated porous anodic alumina masking layer”, F. Zacharatos, V. Gianneta and A. G. Nassiopoulou, Nanotechnology 19, 495306 (2008)
4. “Growth and electrical characterization of thin conductive Au nanoparticle chains on oxidized Si substrates between electrodes for sensor applications”, Zoy, A., Nassiopoulou, A.G., Phys. Stat. S. (a) Applications and Materials, 205 (11), pp. 2621-2624 (2008)
5. “Auger recombination in silicon nanocrystals embedded in SiO2 wide band-gap lattice”, Mahdouani, M., Bourguiga, R., Jaziri, S., Gardelis, S., Nassiopoulou, A.G., Phys. Stat. Sol. (a) Applications and Materials, 205 (11), pp. 2630-2634 (2008)
6. “Broadband electrical characterization of macroporous silicon at microwave frequencies”, Contopanagos, H., Pagonis, D.N., Nassiopoulou, A.G., Phys. Stat. S. (a) Applications and Materials, 205 (11), pp. 2548-2551 (2008)
7. “Columnar growth of ultra-thin nanocrystalline Si films on quartz by Low Pressure Chemical Vapor Deposition: Accurate control of vertical size”, Lioutas, Ch.B., Vouroutzis, N., Tsiaoussis, I., Frangis, N., Gardelis, S., Nassiopoulou, A.G., Phys. Stat. S. (a) Applications and Materials, 205 (11), pp. 2615-2620 (2008)
8. “A thermal vacuum sensor fabricated on plastic substrate - Study in various operation modes”, Petropoulos, A., Kaltsas, G., Nassiopoulou, A.G., Phys. Stat. Solidi (a) Applications and Materials, 205 (11), pp. 2639-2642 (2008)
9. “Copper-filled macroporous Si and cavity underneath for microchannel heat sink technology”, Zacharatos, F., Nassiopoulou, A.G., Phys. Stat. S. (A) Applications and Materials, 205 (11), pp. 2513-2517 (2008)
10. “Ultrafast time-resolved spectroscopy of Si nanocrystals embedded in SiO_2 matrix”, Lioudakis, E., Emporas, A., Othonos, A., Nassiopoulou, A.G., J. of Alloys and Compounds, doi:10.1016/j.jallcom.2008.07.193, Article in Press (2008)
11. “Enhancement and red shift of photoluminescence (PL) of fresh porous Si under prolonged laser irradiation or ageing: Role of surface vibration modes“, Gardelis, S., Nassiopoulou, A.G., Mahdouani, M., Bourguiga, R., Jaziri, S., Physica E: Low-Dimensional Systems and Nanostructures, doi:10.1016/j.physe.2008.08.021, Phys. Stat. Sol. (a), No 11, 2630 (2008)
12. “Morphology, structure, chemical composition, and light emitting properties of very thin anodic silicon films fabricated using short single pulses of current”, Gardelis, S., Nassiopoulou, A.G., Petraki, F., Kennou, S., Tsiaoussis, I., Frangis, N., J. of Appl. Phys., 103 (10), art. no. 103536 (2008)
13. “Surface-related states in oxidized silicon nanocrystals enhance carrier relaxation and inhibit auger recombination”, Othonos, A., Lioudakis, E., Nassiopoulou, A.G., Nanoscale Research Letters, 3 (9), pp. 315-320 (2008) and selected for open-access presentation to the OAtube Nanotechnology 1 (2008) 903 (HUhttp://www.oatube.org/2008/09/aothonos.htmlUH)
14. “Determination of critical points on silicon nanofilms: surface and quantum confinement effects”, E. Lioudakis, A. Othonos and A. G. Nassiopoulou, Phys. Stat. Sol. (c), 5, 3776 (2008)
15. “Multilevel charge storage in Si nanocrystals arranged in double-dot-layers within SiO_2”, Theodoropoulou, M., Nassiopoulou, A.G., Microelectronic Engineering 85 (12), pp. 2362-2365 (2008)

Publications in Conference Proceedings

1. “Ultrafast phenomena in ultrathin polycrystalline silicon films”, E. Lioudakis, L. Loumakos, A. G. Nassiopoulou and A. Othonos, XXII Panhellenic Solid State and Material Science conference, University of Patra -Greece, Proceedings conf. (2006).
2. “Determination of critical points on silicon nanofilms: surface and quantum confinement effects”, Emmanouil Lioudakis, Andreas Othonos, A. G. Nassiopoulou, Physica status solidi (c), Volume 5, Issue 12, December 2008, pp. 3776-3779
3. “Dielectric characterization of macroporous thick silicon films in the frequency range 1 Hz-1 MHz”, M. Theodoropoulou, D. N. Pagonis, A. G. Nassiopoulou, C. A. Krontiras, S. N. Georga, Physica status solidi (c), Vol. 5, Issue 12, December 2008, pp. 3597-3600
4. “Porous anodic alumina thin films on Si: interface characterization”, V. Gianneta, A. G. Nassiopoulou, C. A. Krontiras, S. N. Georga, Physica status solidi (c), Volume 5, Issue 12, December 2008, pp. 3686-3689
5. “Evaluation of a gas flow sensor implemented on organic substrate”, A. Petropoulos, G. Kaltsas, T. Speliotis, A.G. Nassiopoulou, Physica status solidi (c), Volume 5, Issue 12, December 2008, pp.3839-3842
6. “On-chip RF-shielding by mesoporous Si microplate measured through an integrated coplanar waveguide”, H. Contopanagos, F. Zacharatos and A. G. Nassiopoulou, Materials of the 6th International Conf. on Porous Semiconductors – Science and Technology, Mallorca, Spain, pp. 80-81 (10-14 March 2006).

Presentations in Conferences

1. “Nanoelectronics, Micro and Nanosystems”, A. G. Nassiopoulou, Information and Brokerage Event, Moscow, 21-23 October 2008
2. “Electronics and micromachining using porous silicon”, A. G. Nassiopoulou, Porous Semiconductors – Science & Technology, PSST – 2008, March 10-14 2008, Mallorca
3. “Beyond Moore flexible platform at EU level for Nanoelectronics and MEMS/NEMS”, A. G. Nassiopoulou, 14th Micromachine Summit, Daejeon, Korea, April 30 – May 3, 2008
4. “Micro&Nanoelectronics: Present status and perspectives”, A. G. Nassiopoulou, 14.4.2008, NCSR Demokritos, Athens, Greece
5. "Surface-related states in oxidized silicon nanocrystals enhance carrier relaxation and inhibit Auger recombination", A. Othonos, E. Lioudakis, A. G. Nassiopoulou, 2008 Virtual Conference on Nanoscale Science and Technology VC-NST, July 24-29, 2008 Fayetteville, Arkansas 72701, USA.
6. “CMOS-integrated low-loss porous Si technology for on-chip RF inductors”, F. Zacharatos, H. Contopanagos, and A. G. Nassiopoulou, 38th European Solid-State Device Research Conf. (ESSDERC2008), 15-19 Sept. 2008, Edinburgh, Scotland, U.K.
7. “Structural, chemical and light emission properties of very thin anodic silicon films fabricated by short single pulses”, S. Gardelis, A.G. Nassiopoulou, F. Petraki, S. Kennou, I. Tsiaoussis, N. Frangis, XXIV Panhellenic Conference on Solid State Physics and Materials Science, Heraklion, Crete, 2008, Invited
8. “Enhancement and red shift of photoluminescence (PL) of fresh porous Si under prolonged laser irradiation or ageing: Role of surface vibration modes“, S. Gardelis, A.G. Nassiopoulou, M. Mahdouani, R. Bourguiga, S. Jaziri, EMRS Spring Meeting, Strasbourg, France, 2008

Edition of a special issue of Physica Status Solidi containing the Proceeding of Micro&Nano 2007 International Conference: phys. stat. sol. (a) 205, No 11, 2505-2656 (2008) and phys. stat. sol. (c) 5, No 12, 3571-3878 (2008). Guest editors : A. G. Nasiopoulou, P. Argitis and N. Papanikolaou

Invited talks

1. “De la Micro- à la Nanoélectronique et les Microsystèmes”, A. G. Nassiopoulou, International Workshop on Research, Innovation, Enterprises in Communication Technologies, 4 November 2008, Pôle Elgazala, Tunisie
2. “Electronics and micromachining using porous silicon”, A. G. Nassiopoulou, International Conference PSST 2008, March 10-14 2008, Mallorca, Spain

3. “Porous anodic alumina thin films on Si as masking layers for silicon surface nanostructuring and as templates for nanostructure growth”, A. G. Nassiopoulou, V. Gianneta, F. Zacharatos, M. Kokonou, M. Hauffman, 1st International Conference from Nanoparticles and Nanomaterials to Nanodevices and Nanosystems, Halkidiki, Greece, 16-18 June 2008
4. “The Greek micro-nanotechnology and MEMs landscape”, A. G. Nassiopoulou, 14th Micromachine Summit, Daejeon, Korea, April 30 – May 3, 2008
5. “Electronics and micromachining using porous silicon”, A. G. Nassiopoulou, 2nd International Summer School on “Nanosciences & Nanotechnologies” (SS-NN08), Thessaloniki, Greece, 12-18 July 2008
6. “Nanoelectronics at the Center of high technologies”, A. G. Nassiopoulou, 8th Scientific Symposium on High Technologies in Physical Sciences, 3-5 October, Aegion, Greece
7. "Silicon nanocrystals in SiO2 thin layers: Growth, ordering and light emitting properties", A. G. Nassiopoulou, S. Gardelis, V. Gianneta, E. Lioudakis and A. Othonos, 2008 Virtual International Conference on Nanoscale Science and Technology VC-NST, July 24-29, 2008 Fayetteville, Arkansas 72701, USA
8. “Structural, chemical and light emission properties of very thin anodic silicon films fabricated by short single pulses”, S. Gardelis, A.G. Nassiopoulou, F. Petraki, S. Kennou, I. Tsiaoussis, N. Frangis, XXIV Panhellenic Conference on Solid State Physics and Materials Science, Heraklion, Crete, September 2008

Courses taught

1. “Introduction to CMOS devices and processes”, A. G. Nassiopoulou, course within the MSc and PhD programme on Nanosciences and Nanotechnologies, Univeristy of Thessaloniki, 2nd semester 2008
2. “Introduction to CMOS technology”, course within the MSc programmes on Microelectronics (University of Athens) and Nanoelectronic devices and MEMs (National Technical University of Athens), 1st semester 2008-2009
3. “Introduction to Sensors and MEMs”, S. Gardelis, course within the MSc programme on “Microelectronics” of the University of Athens, 1st semester 2008

Courses and Seminars

1. “From Micro- to Nanoelectronics: Challenges and Perspectives”, A. G. Nassiopoulou, Seminar, Summer School, NCSR Demokritos, 14th July 2008
2. “Current trends in Nanoelectronics and MEMS”, A. G. Nassiopoulou, 8.7.2008, NCSR Demokritos, Athens, Greece
3. “Electronics and micromachining using porous silicon”, 2nd International Summer School on “Nanosciences & Nanotechnologies” (SS-NN08), Thessaloniki, 2008

Organization of Conferences, Symposia, Workshops

1. 6th International Biennial Conference on Porous Semiconductors Science and Technology (PSST 2008). The Conference was held in Mallorca, Spain in the period 10-14 March 2008. Chairpersons of the Conference and Scientific Editors of the Proceedings were: Prof. Leigh T. Canham (pSiMedica Ltd., UK), Dr. Androula Nassiopoulou (IMEL/NCSR "Demokritos", Greece), Prof. Michael Sailor (University of California at San Diego, USA), Prof. Patrik Schmuki (University of Erlangen-Nuremberg, Germany). The Conference was attended by 280 people from 43 countries and 220 papers were presented in oral or poster sessions. The Conference Proceedings were published in a special issue of Physica Status Solidi. Available on line at www.interscience.com

PhD theses

1. “Porous anodic alumina thin films on Si: Fabrication, properties, applications”, M. Kokonou, PhD thesis, Thesis Advisor-Supervisor: Androula G. Nassiopoulou. Thesis defended at the National Technical Univeristy of Athens (2008)

Patents

1. Title: “Integrated gas flow sensor based on porous silicon micromachining”
   Application date: 7/5/97
   Greek Patent number: OBI 1003010
   International patent number PCT/GR 97/00040, Published by WIPO: 12/11/98 European patent number EP979133469, 7/11/99
   Applicants: NCSR Demokritos, A.G. Nassiopoulou
   Inventors: A.G. Nassiopoulou and G. Kaltsas

2. Title: “Thermoelectric power generator based on an integrated thermopile”
   Application date: 30/7/1999
   Greek Patent number: OBI 100260
   International patent number PCT/GB00/02936 –WO 01/09964 A1, 8/2/2001
   Applicants: NCSR Demokritos, and A.G.Nassiopoulou
   Inventors: A.G. Nassiopoulou and S. Panaghe

3. Title: “Method for the fabrication of suspended Porous Silicon microstructures and application in gas sensors”,
   Application date: 31/7/2001
   Greek Patent number: OBI 1004040
   International patent number: PCT/GR02/00008 – WO 03/011747A1
   Applicants: IMEL/NCSR “Demokritos”, C. Tsamis, A.G. Nassiopoulou
   Inventors: C. Tsamis, A. Tserepi and A.G. Nassiopoulou

4. Title “Low Power Silicon Thermal Flow Sensors and Microfluidic Devices Using Porous Silicon Sealed Air Cavity or Microchannels”
   Application date: 24/1/2002
   Greek patent number: OBI 1004106
   International Patent number: PCT GR03 0003/16.1.2003
   Applicants: IMEL/NCSR “Demokritos”, A.G. Nassiopoulou
   Inventors: A.G. Nassiopoulou, G. Kaltsas and D. Pagonis

5. Title: “Gas Flow Meter and Specially Designed Housing For Use in Medical Equipment for Respiratory Control”
   Application date: 06/03/2002
   Greek patent number: OBI 100127
   Applicants: IMEL/NCSR “Demokritos”, A.Nassiopoulou
   Inventors: A. G. Nassiopoulou and G. Kaltsas