Manufacturing Science and Technology
Room: 311 - Session MS+NC-MoM

CMOS Extension and Metrology
Moderator: V. Ku, TSMC

8:20am **MS+NC-MoM1 A Metal Hardmask Approach for the Contact Patterning of a 0.186 µm² SRAM Cell Exposed with EUV Lithography**, ***J.-F. de Marneffe****, D. Goossens, A. Vandervorst, S. Demuynck, A.M. Goethals, J. Hermans, F. Van Roey, B. Baudemprez, S. Brus, C. Vrancken*, IMEC, Belgium

In order to overcome patterning challenges brought by dimensional scaling and aggressive pitches, extreme ultra-violet (EUV) lithography has been recently pushed forward as a possible solution for IC manufacturing, allowing extended exposure latitude at sub-50nm dimensions. This work address the technological solutions used for contact holes patterning by means of EUV lithography. A 0.186 µm² SRAM cell has been used as a test-vehicle, showing down to 55nm circular and boomerang-shaped contacts.[1] A metal hard-mask (MHM) approach has been selected, in order to combine the etch of high-aspect ratio features with thin EUV photoresist. The pre-metal dielectric stack covering the active fins was composed of 15nm Si_3N_4 as an etch-stop liner, covered by 240nm SiO_2. The MHM was made of a 30nm TiN film on top of which was spun 20nm of organic underlayer and 100nm of EUV photoresist. This paper will describe in details the various patterning steps (lithography, MHM opening and ash, SiO_2 followed by Si_3N_4 etch, residue cleaning) leading to the successful patterning of small contacts by EUV lithography.

[1] Imaging Performance of the EUV Alpha Demo Tool at IMEC, G.F. Lorusso et al., SPIE conference 6921-24 (2008).

8:40am **MS+NC-MoM2 Improved Mechanistic Understanding of Millisecond Annealing Techniques for Ultrashallow Junction Formation**, ***Y.V. Kondratenko****, C.T.M. Kwok, E.G. Seebauer*, University of Illinois, Urbana-Champaign

Formation of pn junctions in advanced Si-based transistors employs rapid annealing techniques after ion-implantation in order to increase the electrical activation of dopants while minimizing their diffusion. Over the past decade, these techniques have evolved from rapid thermal processing, with time scales of about 1 s, to millisecond methods accomplished by flashlamps or lasers. Although the dopant behavior in terms of diffusion and electrical activation clearly improves as a result of the shortened time scale, the technology transition has taken place on a largely phenomenological basis with little understanding of the physical mechanism for the improvement. The present work provides the key elements of that understanding and explains nonthermal contribution of illumination on the diffusion of dopants. Continuum-based simulations were used to model experimental data in order to obtain mechanistic picture of improvement in dopant diffusion and activation during millisecond annealing. The same method was applied to explain photostimulated effects on dopant diffusion during soak annealing. The simulations solve the partial differential equations for diffusion and reaction of interstitial atoms, with activation energies for elementary diffusion and reaction steps computed by Maximum a Posteriori parameter estimation. The fundamental reason for improvements of diffusion and electrical activation in the millisecond regime is that the short time scale promotes exchange of dopant interstitial atoms with the lattice in preference to exchange with interstitial clusters. Photostimulated diffusion of dopants, however, exhibited more complicated features. Depending on annealing temperature and time, boron diffusion in silicon could be either enhanced or inhibited. Dopant activation was similarly affected. Simulations using continuum equations for the reaction and diffusion of defects were used to determine whether illumination affects cluster dynamics or steady state boron diffusion.

9:00am **MS+NC-MoM3 Challenges and Opportunities for 32nm Node CMOS and Beyond**, ***B. Doris***, IBM Research at Albany Nanotech **INVITED**

Future CMOS technologies require significantly more transistors per unit area with improved transistor performance. Gate-length, spacer, and contact scaling are the enablers for increasing transistor density. Scaling these features for future technology nodes is a significant challenge and new processes, materials and integration schemes will be needed. Ultimately new device architectures may be needed to achieve increased density or enhanced performance. Fully depleted SOI devices like Extremely Thin Silicon on Insulator (ETSOI) and FinFETs are the possible choices for alternate architectures. Either option would be a major shift for the semiconductor industry and would pose new challenges compared to conventional planar CMOS. Performance enhancement beyond previous technologies will be needed regardless of the particular device architecture choice. Recent experiments and simulation have shown that as the transistor density increases it is even more challenging to achieve similar performance. Specifically, recent technologies have relied on local mechanical stress techniques to enhance channel mobility and thereby improve performance. As the transistor density increases, the size of features and the distance between features decreases. This situation limits the ability of stress enhancement techniques to have impact on channel mobility. Thus, new performance elements are also needed for future technology nodes. This presentation highlights the opportunities and challenges for 32nm Node CMOS and beyond.

10:20am **MS+NC-MoM7 Multi Level "Air Gap" Integration for Advanced Technology Nodes**, ***F. Gaillard****, D. Bouchu,* CEA-Leti-MINATEC, France*, R. Gras,* STMicroelectronics, France*, S. Moreau,* CEA-Leti-MINATEC, France*, G. Passemard, J. Torres*, STMicroelectronics, France

In order to extend device's performance and more particularly to improve interconnects RC delay, crosstalk and power consumption, continuous and innovative materials development have been realised over the twenty five past years to decrease dielectric constant. After the use of fluoride doped silicon oxide, low-k and later on porous ultra low k materials have emerged as serious candidates to isolate copper lines for the 90 - 32 nm nodes. Nowadays, "air cavities" introduction also named "Air Gap" represents the ultimate solution in this classical dielectric material evolution and is an attractive solution to meet the ITRS performance for advanced interconnects (22 nm technology node and below). We present an architecture where a sacrificial SiO_2 material deposited on few metal levels (two or more) is further removed by a hydrofluorhydric (HF) chemical etching agent. This HF chemistry diffuses through out patterned apertures localized in a silicon carbide (SiCN) capping layer deposited at the end of the multi level scheme. Thus, full air gaps realization is performed when possible, but SiO_2 pillars are still needed on long metal lines patterns to avoid any collapse when complete air cavities are made underneath. This global approach allows air cavities localization, keeps mechanical integrity and avoids any via misalignment issues, as air cavities are introduced at the end of the integration. In this work, we will present a three metal level interconnect realisation achieved at 65 nm design rules on a 300 mm diameter wafer; air cavities will be integrated on two metal levels and further completed up to pads realizations. Associated morphological and electrical results will be discussed. Based on simulation data and supported with experimental results, we have also predicted and demonstrated that an adequate stack composed of different doped or undoped SiO_2 materials deposited on the different metal levels can be useful to optimise the SiO2 pillar shape. It consequently improves the coupling capacitance gain on both metal levels, which is directly linked to the air cavities volume. Indeed, if the initial stack is composed of the same SiO_2 material, the air cavities present a spherical profile because the HF chemistry removes isotropically the SiO_2 layers through the specific apertures. These encouraging "Air Gap" results could represent a promising and low cost solution to move towards the next technology nodes.

10:40am **MS+NC-MoM8 Chemical Vapor Deposition of Manganese Self-Aligned Diffusion Barriers for Copper Interconnections in Microelectronics**, ***H. Kim****, Y. Au, H. Wang, H. Bhandari, Y. Liu,* Harvard University*, D.K. Lee,* Samsung*, Y. Lin, R.G. Gordon*, Harvard University

Barriers to prevent diffusion of copper (Cu) and oxygen were formed by chemical vapor deposition (CVD) using a manganese (Mn) precursor vapor that reacts with silica-containing surfaces of low-k dielectrics. The manganese metal penetrates a few nanometers into the silica surface to make highly conformal, amorphous and insulating manganese silicate ($MnSi_xO_y$) layers on the walls of trenches and vias in interconnects. These $MnSi_xO_y$ layers were found to be excellent barriers to diffusion of Cu, oxygen and water. The adhesion of Cu to $MnSi_xO_y$ was also found to be sufficiently strong to satisfy the semiconductor industry requirements. The $MnSi_xO_y$ barrier/adhesion layers become part of the insulator structure, so that they maximize the space available for Cu in the trenches and vias. Thus $MnSi_xO_y$ is a "zero-thickness" barrier that exceeds the ITRS requirements for interconnections in future microelectronic devices. The same Mn CVD process can be applied to cap interconnect structures after chemical-mechanical polishing (CMP). On the tops of Cu wires exposed by CMP, the CVD process forms Mn that is initially dissolved in the Cu near its upper surface. During subsequent deposition of an insulator on the Cu, Mn diffuses back to the upper surface of the Cu where it forms a $MnSi_xO_y$ layer

that is strongly adherent to the Cu. These capping $MnSi_xO_y$ layers can increase the lifetime of interconnects against failure by electromigration.

11:00am **MS+NC-MoM9 What Photoemission Can Tell Us About High-K Dielectrics**, ***R.L. Opila***, *G. Liu*, University of Delaware **INVITED**

Angle-resolved photoelectron spectroscopy is an ideal probe films of candidate high dielectric constant films because the thickness of these very smooth films is comparable to the escape depth of the photoelectrons. We have successfully analyzed silicon oxynitride films of the range of thickness of 1 to 4 nm. From the N 1s spectrum we were able to identify four different binding states for N in these films: N bonded to three atoms: three silicon, two silicon and one oxygen atom, and one silicon and two oxygen atoms. In addition we identified a binding state corresponding to N bound to two silicon atoms with one unsatisfied, dangling bond. We also showed that converting the angle resolved data to a compositional depth profile could be done effectively using the maximum entropy algorithm. Recently we have been studying nitrided $(HfO_2)_x(SiO_2)_{1-x}$ films. The breadth observed in the N1s peak can be attributed to N binding to varying amounts of Si and the relatively electropositive Hf. There appears to be a tendency for N to preferentially bind to Hf in these films. We used the maximum entropy algorithm to analyze these films. Nitridation at successively higher temperatures results in more incorporation of N into these films, and more of this N is incorporated near the oxide/Si interface. Using maximum entropy we were able to convert the angle resolved data to compositional depth profile that had adventitious oxide on the surface, preferential oxidation at the outer surface and the oxide/silicon interface, and otherwise relatively smooth composition of Si^{+4} and Hf^{+4} through the film. These results were confirmed qualitatively by medium energy scattering.

11:40am **MS+NC-MoM11 Influence of Room Temperature Control System on AFM Imaging**, ***J. Fu***, National Institute of Standards and Technology, *W. Chu*, Harbin Institute of Technology, China, *T. Vorburger*, National Institute of Standards and Technology

As the technology progresses, the control of the thermal and vibrational environment for experiments is also becoming more sophisticated. In particular, temperature control to within ± 0.25° C for a general purpose lab is fairly common place. However, even with such a stringent temperature control specification, the variation of temperature can be observed in the AFM (atomic force microscopy) images of a straight edge. In this paper we show the correlation between edge distortion of a semiconductor linewidth standard and the thermal recycling in the lab imposed by a two-level infrastructural temperature control system. A Fast Fourier Transform (FFT) analysis of the AFM images of the line links the frequency of the waviness at the line edge to the damper and reheating coil of the air conditioning feedback system. The unique frequency components present in all three axes of AFM images lead us to conclude that the temperature variation affected the PZT scanner which affected the measurements.

Nanomanufacturing Focus Topic
Room: 309 - Session NM+MS+NS+NC-WeM

Beyond CMOS
Moderator: A. Diebold, University at Albany

8:00am **NM+MS+NS+NC-WeM1 Excitronics: Excitonic Circuits for post-CMOS Electronics**, ***J.-U. Lee***, University of Albany **INVITED**

In this talk, I will describe the properties of excitons in one-dimensional semiconductors that make them attractive as a post-CMOS state variable. The essential properties needed for any new state variable are: creation, transport and detection. These properties will be described for excitons created within single-walled carbon nanotube p-n diodes, one of the most fundamental of all electronic devices. The p-n diodes are formed along individual nanotubes and can show ideal diode behavior, the theoretical limit of performance for any diode. I will describe their dc, optical and the interplay between transport and optical properties. As an optical detector, these diodes are extremely sensitive and are able to probe the complete excited states of SWNTs, including the lowest exciton transition and the continuum. Based on these results, we extract properties that are meaningful for electronic applications, including exciton binding energy, transport, and optical cross section. This work was supported by the NRI/INDEX program and the University at Albany.

8:40am **NM+MS+NS+NC-WeM3 Magnetism in Mn Ion Implanted Si**, ***C. Awo-Affouda***, Naval Research Laboratory, *M. Bolduc,* Tekna Plasma Systems, Inc., *V.P. LaBella*, University at Albany-SUNY **INVITED**

Magnetic semiconductors hold great potential to produced spin based devices with increased functionality and performance. Making Si ferromagnetic via ion implantation of Mn will aid in integrating such devices with conventional semiconductor manufacturing. Although observations room temperature ferromagnetic phases in Mn-doped Si have been reported by several groups, the origin of the ferromagnetism remains elusive.[1-3] We investigate the influence of annealing on the lattice disorder and dopant distribution of Mn ion implanted Si samples. These depth profiles reveal a strong influence of annealing temperatures on the magnetization of the samples. Specifically, above 800°C a drastic drop in the Si lattice disorder is observed which is coincident with a decrease in magnetization. Furthermore the correlation of the structural and magnetic properties suggests that the magnetization of the samples originates from Mn atoms located in the least damaged implanted region.[4] Finally, analysis of the magnetization of the samples reveals the presence of superparamagnetic phases magnetically active at low temperatures.

[1] Bolduc et al., Phys. Rev. B, 71, p.033302 (2005)
[2] Yoon et al., J. Magn. Magn. Mater./331, p.693
[3] Kwon et al. Solid State Commun., 136, p. 257 (2005)
[4] Awo-Affouda et al. J. Vac. Sci. Tech. A, 25, p. 976 (2007).

9:20am **NM+MS+NS+NC-WeM5 Graphene Electronic Devices**, ***A. MacDonald***, *S.K. Banerjee, L.F. Register, M. Gilbert, J.-J. Su, R. Bistritzer, H. Min*, University of Texas at Austin **INVITED**

Graphene is an atomically two-dimensional material which is described by ultra-relativistic quantum mechanics. I will review progress toward graphene-based electronic devices based on both conventional ideas and on the properties of novel broken symmetry states which might be realized when two graphene layers are separated by a nm scale dielectric barrier. The absence of a mass (a gap) in ultra-relativistic quantum mechanics presents a challenge in adopting conventional device physics to this material. I will discuss progress in inducing gaps by making narrow graphene ribbons or by places graphene bilayers in external electric fields. The broken symmetry which might be realized in systems with two separated graphene layers is one in which phase coherence is established spontaneously between separate layers. These states are counterflow superfluids in which current can flow in opposite directions in the two layers without dissipation. I will discuss some ideas for electronic devices based on the properties of these unusual superfluids.

10:40am **NM+MS+NS+NC-WeM9 Intrinsic and Extrinsic Limits of Charge Carrier Mobility in Graphene**, ***M.S. Fuhrer***, University of Maryland **INVITED**

Graphene, a single atom-thick sheet of graphite, is a zero-gap semiconductor with an unusual linear dispersion relation (analogous to the Dirac equation for massless relativistic particles) and a density of states that vanishes at a singular point. Due to the high conductivity and charge carrier mobility, graphene is being considered for a number of applications ranging from transparent, conducting thin films to high-speed electronics. Here I will discuss experiments performed on atomically-clean graphene on SiO_2[1] in ultra-high vacuum to determine the intrinsic and extrinsic limits of mobility in graphene,[2,3] which point out both the promise of the material as well as the technological challenges that lie ahead in realizing better graphene samples. Intrinsic scattering by the acoustic phonons of graphene[3] limits the room-temperature mobility to 200,000 cm^2/Vs at a carrier density of 10^{12} cm^{-2}, higher than any known material. However, conduction in current graphene samples is limited almost entirely by extrinsic scattering due to charged impurities in the substrate[2] and substrate polar optical phonons[3] currently, pointing out the importance of substrate engineering for improving graphene devices.[4] I will discuss the implications for the future of graphene technologies in terms of the manufacturing methods for large-area graphene currently being explored, such as solution processing methods, chemical vapor deposition, and epitaxial growth on metals and insulators.

[1] "Atomic Structure of Graphene on SiO_2," Masa Ishigami, J. H. Chen, W. G. Cullen, M. S. Fuhrer, and E. D. Williams, Nano Letters 7, 1643 (2007).
[2] "Charged Impurity Scattering in Graphene," J. H. Chen, C. Jang, M. S. Fuhrer, E. D. Williams, and M. Ishigami, Nature Physics 4, 377 (2008).
[3] "Intrinsic and Extrinsic Performance Limits of Graphene Devices on SiO_2," J. H. Chen, C. Jang, S. Xiao, M. Ishigami, M. S. Fuhrer, Nature Nanotechnology 3, 206 (2008).
[4] "Printed Graphene Circuits," Jian-Hao Chen, Masa Ishigami, Chaun Jang, Daniel R. Hines, Michael S. Fuhrer, and Ellen D. Williams, Advanced Materials 19, 3623 (2007).

11:20am **NM+MS+NS+NC-WeM11 Tunneling Conductance of Molecular Wires**, ***E. Prodan***, Yeshiva University

Tunneling transport through long, insulating molecular chains is characterized by the exponential decay law g = g_c e^-\beta N, where N is the number of monomers. In the modern formulation of the tunneling transport, is determined from the complex band structure of the isolated molecular chain, a procedure that extends far beyond the limitations of simple models that approximate electron tunneling in molecular devices using square potential barriers. However, until recently, an analytic expression for the contact con- ductance gc was missing. In the rst part of the talk, I will review a newly formulated theory of tunneling transport in long molecular wires. This theory provides a rigorous way of computing the exponential decay constant and gives gc as an overlap integral between three well de ned and physically relevant quantities: the spectral density of the device at the Fermi level, the potential perturbation of the metallic contacts on the molecular chain, and the evanescent electron waves traversing the molecular chain.[1] The formalism will be exempli ed on molecular devices made of alkyl[2] and phenyl chains linked to gold wires via amine groups. If the time allows, I will present the extension of the theory to the spin dependent transport, in particular to the problem of tunneling magneto-resistance.

[1]E. Prodan and R. Car, DC Conductance of Molecular Wires, Phys. Rev. B 76, 115102 (2007).
[2]E. Prodan and R. Car, Tunneling conductance of amine linked alkyl chains, Nano Letters (in press).

Nanomanufacturing Focus Topic
Room: 309 - Session NM+MS+NS+NC-ThA

Nanomanufacturing II: Nanostructures
Moderator: J. Murday, University of Southern California

2:00pm **NM+MS+NS+NC-ThA1 Superionic Electrochemical Patterning of Metallic Nanostructures**, ***P.M. Ferreira****, N.X. Fang, K. Hsu, K. Jacob, A. Kumar, P. Schultz*, University of Illinois, Urbana **INVITED**

Nanoscale metallic nanostructures find widespread and critical application in many micro and nanoscale technologies. Processes such as electrochemical and electro-discharge machining lack the fine control to obtain sub-micron resolution. As a result, such structures are generally fabricated using indirect patterning techniques, resulting expensive, lengthy multi-step manufacturing operations. In this presentation, we introduce a new means of directly patterning metal films into metallic nanostructures. The process, Solid-State Superionic Stamping (S4), uses a patterned solid-electrolytic stamp or mold to directly create metallic nano- and microstructures through electrochemical anodic dissolution. As a result, it requires very small mechanical forces and no contaminating liquids, and is capable of producing structures with nanoscale precision over large areas. This presentation will discuss the mechanism that underpins the process; characterize its capabilities in creating silver and copper nanostructures; discuss the fabrication of stamps, and some applications that such a process enables. The presentation will conclude with a description of the process technology under development and directions for future research.[1]

[1] This research was supported by NSF through the Center for Chemical-Electrical-Mechanical Manufacturing Systems (Nano-CEMMS) under Grant DMI-0312862, the Office of Naval Research under grant N00173-07-G013 and the University of Illinois through the Grainger Foundation grant. We are grateful that part of this work was carried out in the Center for Microanalysis of Materials, University of Illinois, which is partially supported by the U.S. Department of Energy under grant DEFG02-ER45439.

2:40pm **NM+MS+NS+NC-ThA3 Designing Semiconductor Nanocrystals for Optoelectronic and Biological Applications**, ***M. Bawendi***, Massachusetts Institute of Technology **INVITED**

Semiconductor nanocrystals, aka quantum dots, have become the prototypical material for the emergence of new properties when dimensions are reduced to the nanometer range. The size dependent properties of excitons and multiexcitons in quantum dots, coupled with a material that can be engineered and processed from solution, has led to potential applications in fields that include emissive displays, solar energy conversion, and biological and biomedical fluorescence imaging. A fundamental understanding of exciton processes is critical for any of these applications to become realized. The design and synthesis of well characterized materials is obviously key, not only of the functional inorganic particle itself, but also the ligand shell that protects it and couples it chemically to molecules and matrices of interest. This talk will review some of the chemistry and photophysics of quantum dots and then explore the fundamental properties and challenges behind broadly applying quantum dots as light emitters and light absorbers in devices and for biological imaging.

3:20pm **NM+MS+NS+NC-ThA5 Controlled Assembly and Nanoscale Doping of Semiconductor Quantum Dots Using Focused Ion Beams**, ***J.F. Graham****, C.D. Kell,* University of Virginia*, J.L. Gray,* University of Pittsburgh*, J.A. Floro, S.A. Wolf,* University of Virginia*, L. Bischoff,* Research Center Dresden-Rossendorf Inc., Germany*, R. Hull*, University of Virginia and Rensselaer Polytechnic Institute

Self-assembled semiconductor quantum dots are a candidate for use in potential nanoelectronic device architectures such as quantum cellular automata and magnetic spin exchange switches. It is possible to grow quantum dots (QDs) with relatively uniform size-distributions using heteroepitaxial techniques, but in order to apply QDs in such nanoelectronic devices they must also be spatially ordered into patterns of varying complexity. In addition, the QDs must posses the magnetic or electronic properties required for device operation. We have previously demonstrated the use of Ga^+ focused ion beam (FIB) templating of Si surfaces prior to growth in order to fabricate patterns of Ge(Si) QDs of any desired complexity. Our current work employs a mass-selecting FIB with liquid metal alloy ion sources, enabling the generation of a wide range of separated species in focused beams, to template QD structures and electrically or magnetically dope them at a dot-by-dot level for nanoelectronic device applications. Ions can be selected according to isotope mass and charge state by using a mass-selecting Wien filter. Suitable alloy sources then provide the ability to template a Si substrate with electrically non-invasive ions (i.e. Si or Ge) and implant dopant ions for electronic or magnetic activation (e.g. with B or Mn), with resolution of < 50nm and doses down to a few ions per dot. Key technical issues we are addressing include i) the attainable limits of spatial resolution and the dot-by-dot implantation dose, ii) comparisons between Ga and Si ion templated growth, iii) physical alignment between a templating ion beam and a dopant implantation ion beam and iv) procedures for eliminating unwanted exposure of adjacent areas of the sample to implantation ions.

4:00pm **NM+MS+NS+NC-ThA7 Semiconductor Nanowires: From Materials Science to Device Physics**, ***L. Samuelson***, Lund University, Sweden **INVITED**

In the general trend towards the use of self-assembly for realization of ultra-small devices on the 10nm-scale, semiconductor nanowires (NWs) have emerged as one of the most interesting candidates. In this talk I will describe different materials science aspects of NW growth, with a focus on III-V NWs grown epitaxially on a single-crystalline substrate as a top-down guided bottom-up growth of NWs . I will present recent progress in studies of structural properties of such NWs, including the importance and control of the stacking sequence of subsequent layers in NWs. I will then describe the controlled formation of axial and radial heterostructures, which is of great importance for the use of NWs for basic physics studies as well as for applications in electronics and photonics. As examples of recent physics studies of NWs I will describe transport via single and multiple quantum dots and optical studies of excitonic recombination in single quantum dots in NWs. Finally, I will give an update on the progress in realizing electronic as well as photonic devices using NWs, and will here primarily present progress in technology and performance of wrap-gate field-effect transistors. I time allows I will conclude with some visions for where I think NW-based science and technology may be heading in the future.

4:40pm **NM+MS+NS+NC-ThA9 Surface Plasmon Enhanced Photoluminescence from Noble Metal/CdS Hybrid Semiconductor Nanowires**, ***W. Luo****, S.C. Kung, W.V. Veer, R.M. Penner, J.C. Hemminger*, University of California, Irvine

Surface plasmon enhanced techniques provide promising methods to improve the light emission efficiency of semiconductor materials. In this talk, we present the growth of noble metal/CdS hybrid semiconductor nanowires, and the plasmon-enhanced photoluminescence from these nanowires. In our previous studies, we demonstrated the straightforward fabrication of ordered linear arrays of spherical silver nanoparticles with gaps between the individual nanoparticles of less than 10 nm on highly oriented pyrolytic graphite (HOPG) surfaces using physical vapor deposition (PVD) under controlled experimental conditions. These silver nanoparticle arrays were capable of supporting very strong surface plasmon resonances, which was demonstrated by our polarized surface enhanced Raman scattering experiments. In this presentation, we describe experiments where following the PVD growth of Ag or Au nanoparticle arrays on HOPG surfaces, we electrochemically deposit cadmium around these nanoparticle arrays to form hybrid nanowires as thin as 50-60 nm in width. Further annealing of these hybrid nanowires in H_2S at temperatures of 300-320°C enables the formation of CdS nanowires around the Ag or Au nanoparticle cores. Using this combined PVD/electrochemistry/chemical modification approach we have been able to generate ordered 2-D arrays of hybrid semiconductor nanowires that are as small as 100 nm in diameter and 100s of microns in length. Under light illumination, the surface plasmon supported by the Ag or Au nanoparticle cores enhances the photoluminescence of the outer CdS nanowires.

5:00pm **NM+MS+NS+NC-ThA10 Metal Oxide Nanowires by Near Field Electrospinning**, *M. Rinaldi, F. Ruggieri,* University of L'Aquila, Italy, ***L. Lozzi***, CNISM and University of L'Aquila, Italy*, S. Santucci*, CNR-INFM and University of L'Aquila, Italy

The growth of metal oxide nanowire is an important challenge for the realization of nanostructured devices, as for example highly sensitive gas sensors.[1] A very easy method to deposit metal oxides is the electrospinning.[2] This simple and low cost technique allows the growth of very thin nanofibers, whose diameter can be varied from 50 nm to about 1 µm. It is based on the effect of an electric field on a charged liquid (polymer or solution) ejected from a nozzle. The charged jet is accelerated by the electric field, dries and is deposited onto a grounded substrate, forming nanofibers. Generally the nozzle-substrate distance is about 10-15 cm and the applied voltage is about 10-15 kV. Unfortunately this method does not allow easily the growth of well ordered nanofibers. In the present study TiO2 nanofibers were electrospun with a novel approach of electrospinning called NFES (Near-Field Electrospinning), in which the tip-substrate

distance is strongly reduced to few millimetres, decreasing also the applied bias voltage to few hundreds of volts.[3] Significant advancement in collecting aligned electrospun nanofibers has been made with this improved technique that complements conventional electrospinning by providing the feasibility of controllable deposition for sub-100-nm nanofabrication. Well aligned TiO2 nanofibers were grown onto a silicon dioxide substrate. These nanofibers were up to several millimetres long with a diameter of about 200-400 nm. The scanning electron microscopy showed the presence of microcystallites, whose crystalline nature was confirmed by X-ray diffraction measurements after a thermal process, also used for removing the polymer. The chemical composition was investigated by X-ray photoemission spectroscopy showing that the nanofibers are composed by stoichiometric TiO2 crystallites.

[1] S. Piperno, M. Passacantando, S. Santucci, L. Lozzi, S. La Rosa, J. Appl. Phys., vol. 101, (2007) 124504.

[2] W.E. Teo and S. Ramakrishna, Nanotechnology, vol. 17, (2006) R89.

[3] D. Sun, C. Chang, S. Li, and L. Lin, Nanoletters, vol 6, (2006), p. 839.

5:20pm **NM+MS+NS+NC-ThA11 Luminescent Rare-Earth Doped Metal Oxide Nanostructures**, ***Y. Mao**, J. Dorman, J.P. Chang*, University of California at Los Angeles

Advanced luminescent materials have practical applications in nearly all devices involving the artificial production of light and considerable research has been carried out to synthesize new luminescent materials. Their luminescent properties have been shown to be dependent on the size and morphology of the crystallites, hence materials with dimensions in the nanometer regime emerges as promising materials. These attributes make them viably applicable in nanoscaled electronics, photonics, display and advanced bioanalysis. In this talk, we present our recent work on the fabrication of rare-earth doped metal oxide nanostructures, including $Er:Y_2O_3$ nanotubes (NTs) and nanoparticles (NPs) and $Er:La_2(Zr_xHf_{1-x})_2O_7$ NPs, by hydrothermal and molten-salt syntheses.[1,2] The formation of nanostructures were probed in-situ by time-resolved synchrotron x-ray diffraction and absorption spectroscopy to delineate the process-structure-property relations. The as-synthesized nanostructures were further characterized by electron microscopy and various spectroscopy[3] to be single crystalline, with well controlled size distributions around 100-400 nm in outer diameter and 2-5 µm in length for $Er:Y_2O_3$ NTs, around 80 nm in diameter for $Er:Y_2O_3$ NPs, and around 15 nm in diameter for Er: $La_2(Zr_xHf_{1-x})_2O_7$ NPs. The erbium coordination number and local bonding environment were shown to dictate the measured photoluminescent characteristics, including photoluminescence and cathodoluminescence. Specifically, these 0-100% erbium-doped oxide nanostructures have sharp and well-resolved photoluminescent behavior in the near-infrared region, outstanding green and red upconversion emissions, and excellent cathodoluminescent properties. These properties make these nanostructures promising for applications in display, bioanalysis and telecommunications.

[1] Mao, et al. Synthesis and luminescence properties of erbium-doped Y_2O_3 nanotubes, J. Phys. Chem. C, 112, 2278 (2008).

[2] Mao, et al. Molten salt synthesis of highly luminescent erbium-doped yttrium oxide nanoparticles, submitted (2008).

[3] Mao, et al. Correlation between luminescent properties and local coordination environment for erbium dopant in yttrium oxide nanotubes, J. Appl. Phys. in press (2008).

Authors Index

Bold page numbers indicate the presenter

— A —

Au, Y.: MS+NC-MoM8, 1
Awo-Affouda, C.: NM+MS+NS+NC-WeM3, **3**

— B —

Banerjee, S.K.: NM+MS+NS+NC-WeM5, 3
Baudemprez, B.: MS+NC-MoM1, 1
Bawendi, M.: NM+MS+NS+NC-ThA3, **4**
Bhandari, H.: MS+NC-MoM8, 1
Bischoff, L.: NM+MS+NS+NC-ThA5, 4
Bistritzer, R.: NM+MS+NS+NC-WeM5, 3
Bolduc, M.: NM+MS+NS+NC-WeM3, 3
Bouchu, D.: MS+NC-MoM7, 1
Brus, S.: MS+NC-MoM1, 1

— C —

Chang, J.P.: NM+MS+NS+NC-ThA11, 5
Chu, W.: MS+NC-MoM11, 2

— D —

de Marneffe, J.-F.: MS+NC-MoM1, **1**
Demuynck, S.: MS+NC-MoM1, 1
Doris, B.: MS+NC-MoM3, **1**
Dorman, J.: NM+MS+NS+NC-ThA11, 5

— F —

Fang, N.X.: NM+MS+NS+NC-ThA1, 4
Ferreira, P.M.: NM+MS+NS+NC-ThA1, **4**
Floro, J.A.: NM+MS+NS+NC-ThA5, 4
Fu, J.: MS+NC-MoM11, **2**
Fuhrer, M.S.: NM+MS+NS+NC-WeM9, **3**

— G —

Gaillard, F.: MS+NC-MoM7, **1**
Gilbert, M.: NM+MS+NS+NC-WeM5, 3
Goethals, A.M.: MS+NC-MoM1, 1
Goossens, D.: MS+NC-MoM1, 1
Gordon, R.G.: MS+NC-MoM8, 1
Graham, J.F.: NM+MS+NS+NC-ThA5, **4**
Gras, R.: MS+NC-MoM7, 1
Gray, J.L.: NM+MS+NS+NC-ThA5, 4

— H —

Hemminger, J.C.: NM+MS+NS+NC-ThA9, 4
Hermans, J.: MS+NC-MoM1, 1
Hsu, K.: NM+MS+NS+NC-ThA1, 4
Hull, R.: NM+MS+NS+NC-ThA5, 4

— J —

Jacob, K.: NM+MS+NS+NC-ThA1, 4

— K —

Kell, C.D.: NM+MS+NS+NC-ThA5, 4
Kim, H.: MS+NC-MoM8, **1**
Kondratenko, Y.V.: MS+NC-MoM2, **1**
Kumar, A.: NM+MS+NS+NC-ThA1, 4
Kung, S.C.: NM+MS+NS+NC-ThA9, 4
Kwok, C.T.M.: MS+NC-MoM2, 1

— L —

LaBella, V.P.: NM+MS+NS+NC-WeM3, 3
Lee, D.K.: MS+NC-MoM8, 1
Lee, J.-U.: NM+MS+NS+NC-WeM1, **3**
Lin, Y.: MS+NC-MoM8, 1
Liu, G.: MS+NC-MoM9, 2
Liu, Y.: MS+NC-MoM8, 1
Lozzi, L.: NM+MS+NS+NC-ThA10, **4**
Luo, W.: NM+MS+NS+NC-ThA9, **4**

— M —

MacDonald, A.: NM+MS+NS+NC-WeM5, **3**
Mao, Y.: NM+MS+NS+NC-ThA11, **5**
Min, H.: NM+MS+NS+NC-WeM5, 3
Moreau, S.: MS+NC-MoM7, 1

— O —

Opila, R.L.: MS+NC-MoM9, **2**

— P —

Passemard, G.: MS+NC-MoM7, 1
Penner, R.M.: NM+MS+NS+NC-ThA9, 4
Prodan, E.: NM+MS+NS+NC-WeM11, **3**

— R —

Register, L.F.: NM+MS+NS+NC-WeM5, 3
Rinaldi, M.: NM+MS+NS+NC-ThA10, 4
Ruggieri, F.: NM+MS+NS+NC-ThA10, 4

— S —

Samuelson, L.: NM+MS+NS+NC-ThA7, **4**
Santucci, S.: NM+MS+NS+NC-ThA10, 4
Schultz, P.: NM+MS+NS+NC-ThA1, 4
Seebauer, E.G.: MS+NC-MoM2, 1
Su, J.-J.: NM+MS+NS+NC-WeM5, 3

— T —

Torres, J.: MS+NC-MoM7, 1

— V —

Van Roey, F.: MS+NC-MoM1, 1
Vandervorst, A.: MS+NC-MoM1, 1
Veer, W.V.: NM+MS+NS+NC-ThA9, 4
Vorburger, T.: MS+NC-MoM11, 2
Vrancken, C.: MS+NC-MoM1, 1

— W —

Wang, H.: MS+NC-MoM8, 1
Wolf, S.A.: NM+MS+NS+NC-ThA5, 4