

Nanometer-Scale Science and Technology Room 210 - Session NS-ThA

Nano Processing

Moderator: D.M. Tennant, Lucent

2:00pm **NS-ThA1 Control of Germanium Nanocrystal Morphology and Surface Functionalization**, *H. Gerung*, University of New Mexico; *T.J. Boyle*, Sandia National Laboratories; *C.J. Brinker*, *S.M. Han*, University of New Mexico

We have developed a simple synthesis route for Ge nanocrystals (Ge NCs) via reduction of Ge(II) precursor at 300 °C and 1 atm. The synthesis does not require strong reducing agents and does not produce salts or undesirable byproducts. Literature reports on Ge NC syntheses have focused mainly on direct reduction of Ge(IV) to Ge(0), which requires a combination of high temperature (>400 °C), high pressure (>1 atm), and strong reduction agents. Ge[N(SiMe₃)₂]₂ is chosen as the Ge(II) precursor due to the ease of its synthesis in high yield, the absence of potential halide contamination, and the labile amido ligand sets. The synthesis involves the injection of Ge[N(SiMe₃)₂]₂ dissolved in oleylamine into non-coordinating solvent 1-octadecene at 300 °C and 1 atm Ar. The resulting Ge NCs form quickly and show a high degree of crystallinity with no oxide formation. These NCs are mostly spherical in shape. The Ge(II) precursor's ligands can be tailored to form Ge[TMPP]₂ (TMPP = 2,2,6,6-tetramethyl piperidine) and using identical reaction conditions, cuboid Ge NCs are formed. Another alternative Ge(II) precursor, Ge[DBP]₂ (DBP = 2,6-di-tert-butylphenoxide) can be isolated from an amide alcohol metathesis reaction between Ge[N(SiMe₃)₂]₂ and 2 equivalents of DBP-H. The use of Ge[DBP]₂ under identical reaction conditions as discussed above yields Ge nanowires (Ge NWs) instead of Ge NCs. These results suggest that the Ge(II)-ligand bond strength, the steric orientation of ligands, and the subsequent surfactants formed upon decomposition of the various precursors dictate the size and morphology of Ge NCs by controlling the surface kinetics during crystal growth. We will further discuss optical and electrical characterization of Ge nanocrystals and functionalizing Ge NC surface to incorporate them into a silica matrix.

2:20pm **NS-ThA2 White Luminescence from Silica Glass Containing Nanocrystalline Silicon Prepared by RF Sputtering Technique**, *K. Sato*, *Y. Sasaki*, *K. Hirakuri*, Tokyo Denki University, Japan

Nanocrystalline silicon (nc-Si) is one of promising materials for application to light-related devices because it shows the particle size-dependent luminescence. We previously obtained a red/green/blue luminescence from the nc-Si with various particle sizes. The white luminescence can be realized by the mixture of nc-Si which emits the red/green/blue light. In this paper, we report a fabrication technique of the silica glass containing red/green/blue luminescent nc-Si. Moreover, the luminescence property of the silica glass will be discussed. The silica glass containing nc-Si was formed by co-sputtering of Si chips/silicon dioxide (SiO₂) targets and subsequently annealing at high temperature. The particle size of nc-Si was varied from 1.9 nm up to 3.0 nm by changing the deposition conditions such as radio frequency power and gas pressure in order to obtain red/green/blue luminescence from the nc-Si. The sample was evaluated by using a photoluminescence (PL) measurement. The silica glass containing nc-Si showed a broad PL spectrum with a peak at 460 nm (blue light), 550 nm (green light) and 800 nm (red light). This is due to the existence of nc-Si in which the particle size differs, i.e., the nc-Si with particle size of 1.9 nm, 2.2 nm and 3.0 nm exhibits blue, green and red luminescence, respectively. When the silica glass was irradiated by using a xenon lamp with an optical band-pass filter of 313 nm, the luminescence color from the silica glass was a white light. The white luminescence could be distinctly seen by the naked eye under room illumination.

2:40pm **NS-ThA3 Silicon Quantum Dots and Nanomembranes: Tools for Quantum Information?**, *M.A. Eriksson*, University of Wisconsin-Madison
INVITED

Silicon has certain unusual properties, including a spin-0 nuclear isotope, that make quantum dots in this material excellent candidates for quantum information processing. Silicon can also form spectacular membranes, one hundred nanometers thick and centimeters across. Such silicon nanomembranes bend and flex like plastic sandwich wrap but retain their single crystal electronic properties. I will present results on silicon quantum dots fabricated using both Schottky gates and Atomic-Layer-Deposition

MOS gates on Si/SiGe modulation-doped heterostructures. These dots have excellent charge stability, but their fabrication currently requires special processing. I also will present recent results on silicon nanomembranes, a material that retains the excellent intrinsic properties of silicon, but that can be bent, strained, and rolled into tubes. These properties offer the potential to use strain in a defect-free system, potentially leading to new ways to create quantum dots with few end-processing complexities. X-ray scattering, TEM, and low temperature electronic transport measurements will be presented, and the prospects for meaningful application of such membranes will be discussed. Work performed in collaboration with L.J. Klein, K.L.M. Lewis, K.A. Slinker, L. McGuire, Srijit Goswami, W. Peng, C. Haselby, D.W. van der Weide, R.H. Blick, S.N. Coppersmith, R. Joynt, Mark Friesen, M.M. Roberts, D. Savage, M.G. Lagally (University of Wisconsin-Madison) and J.O. Chu (IBM Watson).

3:20pm **NS-ThA5 Fabrication and Characterization of ZnO Quantum Dots and Nanosheet Structure**, *R. Mu*, Fisk University; *Y.C. Liu*, *H.Y. Xu*, *S.J. Chen*, Northeast Normal University, PRC

ZnO quantum dots and nanosheets have been fabricated via oxygen plasma assisted electron-beam deposition of ZnF₂ and physical vapor transport techniques. Raman measurements of ZnO QDs showed a strong optical phonon confinement effect and the presence of surface phonon mode which does not exist in Raman spectra of ZnO films. A large blueshift in optical absorption and ultraviolet photoluminescence (UV PL) spectra were observed for ZnO QDs due to a strong quantum confinement effect of excitons. ZnO QDs possess an anomalous temperature dependent behavior in UV PL intensity. In the case of nanosheet, temperature dependent study shows a surprisingly strong high temperature (857K) photon emission. A brief discussion is given in an attempt to understand the physical mechanisms.

3:40pm **NS-ThA6 Induced Growth of Calcite and Gypsum using an Atomic Force Microscope**, *A.L. McEvoy*, *F. Stevens*, *S.C. Langford*, *J.T. Dickinson*, Washington State University

Bond breaking at surfaces due to stimuli such as exposure to energetic radiation, mechanical stress, or chemical agents is well established. We examine the consequences of combining localized mechanical stress (due to contact with the tip of an atomic force microscope) and exposure to aqueous solutions. We show that we can induce highly localized, nanometer scale growth on single crystal surfaces of calcite (CaCO₃), an important biomineral, and gypsum (CaSO₄·2H₂O) through combined exposure to supersaturated solutions and mechanical stress. Growth occurs along step edges in single atomic layers. The growth rates depend strongly on step orientation. Tip induced deposition is shown to produce surfaces free of obvious defects, in contrast with spontaneous growth in highly supersaturated solutions ($\sigma > 5$). Experimental evidence is presented for tip-enhanced transport of ions to deposition sites. Implications concerning deposition and maintenance of atomically smooth surfaces, including mammalian joints, will be discussed. This work was supported by the National Science Foundation.

4:00pm **NS-ThA7 WCx Nanoparticles as Alternate Catalyst for NOx Reduction**, *A. Rumaiz*, *S. Shah*, University of Delaware; *I. Baldytsky*, University of Delaware

WCx nanoparticles were synthesized using Laser Assisted Inert Gas Condensation (LAIGC). In this process either a metal target is ablated in the presence of a reactive gas or a compound target is used. The evaporated flux obtained by laser ablation is condensed by a circulating He gas to form WC nanoparticles. The structural properties of the samples were investigated using X-ray Diffraction (XRD) and X-ray Photo-Electron Spectroscopy (XPS). The feasibility of using nano WCx as an alternative catalyst for Pt is also addressed. A comparative study on two types of samples of WC (as prepared and carburized W) was done. The samples were used to check for the reduction of NO_x in a simple reactor. The carburized W shows activity at temperatures around 400°C, while the as prepared WC shows activity at a slightly higher temperature. The stability of both the samples was studied by exposing them to a NO_x environment at a fixed temperature (where the activity is appreciable) for an extended period of time. XPS and XRD confirm the formation of oxide phase after DeNO_x. In order to study the nature of oxidation the DeNO_x reaction was carried in a CO/O₂/Hydrocarbon gas mixture. The results of these will be presented. Valence band measurements were carried out to compare at the Density of States (DOS) for WC and Pt. Theoretical calculations of the DOS were also done using Self Consistent Field approximation using the WIEN2k code.

Thursday Afternoon, November 3, 2005

4:20pm **NS-ThA8 Photo-Induced Decomposition of Palladium Acetate for Palladium Nanoparticle Production**, *C.E. Allmond, A.T. Sellinger, G. Peman, J.M. Fitz-Gerald*, University of Virginia

Hydrocarbon reactions and rearrangements catalyzed by transition metals trigger chemical processes at the core of the petrochemical and polymer industries. The highly dispersed metal nanoparticles utilized for these reactions are generally prepared by reducing an aqueous solution of a noble metal salt or through the deposition of a precursor on a high surface area support followed by a further reduction step. Palladium acetate, [Pd(OAc)₂], is a widely favored metallorganic precursor for thin film processing on various substrates because it decomposes under ultraviolet irradiation. In this research, Pd and Pd acetate nanoparticles were deposited using a novel variation of matrix assisted pulsed laser evaporation (MAPLE). Samples were prepared by dissolving Pd(OAc)₂ into chloroform, then flash-frozen in liquid nitrogen. Deposition onto Si (100) wafers, NaCl crystals, and electron microscopy grids at room temperature was performed using a pulsed excimer laser ($\lambda = 248$ nm, 5 Hz, 25 ns FWHM) in a dynamic Ar atmosphere at 200 mTorr as a function of laser fluence and Pd metal loading. The nanoparticle sizes, distributions, and morphology of Pd and Pd acetate nanoparticles were characterized by high-resolution scanning electron microscopy (HRSEM), high-resolution transmission electron microscopy (HRTEM), X-ray energy dispersion spectroscopy (EDS), Fourier transform infrared spectroscopy (FTIR), and X-ray diffraction (XRD). Jun-Ying Zhang, Hilmar Esrom, Ian W. Boyd (1996). "Decomposition mechanisms of thin palladium excimer UV radiation." *Applied Surface Science*(96-98): 399-404. Zolt Geretovszky, Ian W. Boyd. (1999). "Kinetic study of 222 nm excimer lamp induced decomposition of palladium-acetate films." *Applied Surface Science*(138-139): 401-407.

4:40pm **NS-ThA9 Engineering of Porous, Tin Oxide Nanoparticle Microshells for Chemical Sensor Applications**, *C.J. Martinez, C.B. Montgomery, B. Hockey, S. Semancik*, National Institute of Standards and Technology

Advanced sensors for applications ranging from homeland security to space exploration will require performance characteristics that include high sensitivity and rapid response. We have sought to enhance the sensitivity and speed of conductometric gas microsensors through the design and fabrication of porous, three-dimensional tin oxide nanoparticle (10 nm) films. These films were fabricated via the self-assembly from solution of nanoparticle-decorated latex microspheres, which serve as sacrificial templates. Through heating (10⁴ °C/sec), the latex microspheres were removed to reveal a multiscale porous 3-dimensional structure composed of interconnected hollow nanoparticle microshells with ultra-thin walls (50 nm). The multiscale porous architecture promotes analyte diffusion and maximizes available active surface area. Sensor measurements were performed by depositing these films onto MEMS microsensor platforms with inter-digitated electrodes and embedded heaters. We report on film conductance changes measured at different temperatures (300 °C to 450 °C), caused by exposure to test gases at concentrations 100 ppb in a dry air background. An enhancement in sensitivity to CO, H₂O and MeOH was observed for these nanoparticle microshell films when direct comparisons were made to other nanostructured sensing films. Special attention has been given to understanding the influence that structural factors (film thickness, packing density, microshell diameter and microshell thickness) have on the sensitivity, selectivity, stability and response time of these materials.

5:00pm **NS-ThA10 Measurement of the Young's Moduli of Individual Electrospun Nanofibers**, *L.M. Bellan*, Cornell University; *J. Kameoka*, Texas A&M University; *H.G. Craighead*, Cornell University

Our measurements of the Young's moduli of individual electrospun polymer nanofibers support previous claims that electrospinning can produce polymer fibers with high degrees of molecular orientation. Electrospinning is a technique for fabricating micro- and nanoscale fibers using a strong electric field to extract a jet from a viscous solution. These fibers may be oriented by depositing them on a rotating substrate. We have used this technique to deposit oriented polyethylene oxide and silica glass nanofibers over trenches etched in silicon. The suspended fibers were depressed using an atomic force microscope, and the resulting force-displacement data was used to determine the Young's moduli of the individual fibers. The Young's moduli of the polyethylene oxide fibers were significantly larger than the reported values for polyethylene oxide bulk and films, which supports previous claims of molecular orientation in the

fibers. The Young's moduli of the glass fibers were consistent with values calculated from previously measured mechanical resonance frequencies of similar fibers. We are currently investigating mechanical properties of individual nanofibers spun from other polymers.

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