

Tuesday Afternoon Poster Sessions

Nanometer-scale Science and Technology Division

Room: East Exhibit Hall - Session NS-TuP

Nanometer-scale Science and Technology Division Poster Session

NS-TuP1 Electromigration Assisted Single Silver Nanowire Ammonia Sensing, W. Xing, S. Kung, R. Penner, University of California, Irvine

Due to small size, high sensitivity, and low power consumption, 1 dimensional nanowire sensors have attracted a lot of attention and may substitute for traditional thin film sensors in the future. To further improve the sensitivity, there is an obvious need to make sensors with a single nanowire and some seminal work has already been done using semiconductor nanowires in this direction. In this work, a single silver (Ag) nanowire was prepared on glass surface using Lithographically Patterned Nanowire Electrodeposition (LPNE) method. The produced Ag nanowire had a mean grain size of around 30nm and a height and width in the range from 20-80nm and 100-400nm, respectively. Chemiresistor type sensors were fabricated from these single electromigrated Ag nanowires with 4 probe contacts, and their resistances upon exposure to different concentrations of NH₃ gas were investigated at room temperature. Furthermore, electromigration was used to create a narrow junction inside the nanowire, which enhanced the sensing performance dramatically. The electromigrated sensors showed a resistance change, $\Delta R/R_0$, that was large (90% for 7% NH₃), fast (<30s) and reversible with a detection limit of approximately 200ppm. In addition, the characterization of these nanowires by AFM, TEM, and SEM will be presented.

NS-TuP2 Inhomogeneous Density Distribution of Silicon Dioxide Thin Film Thermally Grown at 1000 °C on Si (100) Surface, K. Odaka, A. Kurokawa, Y. Azuma, L. Zhang, T. Fujimoto, National Institute of Advanced Industrial Science and Technology (AIST), Japan

We would report on the XRR (X-ray reflectivity) analysis to observe the density distribution of the SiO₂ thin film which is thermally grown on Si (100) at 1000 °C. The results show the non-uniform distribution in depth, and once the high density SiO₂ was formed during ramp-up it would remain under the following 1000 °C oxidation.

Experimental We measured XRR using an apparatus equipped with a shower of high purity N₂ to protect a specimen from contamination for a few hours of measurement. We analyzed the data with a fitting method [1], [2] which is well established to evaluate thicknesses, densities, and surface roughness of laminated layers of a specimen. We assumed a two-layer-fitting model consisting of a transition layer and an upper layer where each had uniform density in it. We oxidized a H-terminated Si (100) specimen of 15x15 mm² in dry O₂ flow at 1 atm. with a quartz tube furnace. The ramp rate was 33 Kmin⁻¹. We kept specimens at 1000 °C for 0 through 120 min to form SiO₂ films of 7.4 through 95.9 nm.

Results We measured XRR for the as grown samples. Then we etched the 95.9 nm sample with dilute HF solution and measured XRR at some thicknesses. The densities of the etched samples as a function of the thickness coincided with those of the as-grown samples. The transition layer was 1 nm thick and about 2.46 gcm⁻³ in density for all the samples. The upper layer density changed from 2.35 to 2.25 gcm⁻³ as the thickness increased. The upper layer density obtained above was an averaged value in its thickness according to our assumption. The density between the two-neighboring-measured points of the etched data might correspond to the real density distribution in depth. The results were as follows. The pre-formed layer of 7.4 nm including the transition layer which grew during the ramp-up process had density of 2.35 gcm⁻³ or more. The density of the main layer formed at 1000 °C decreased rapidly to 2.25 gcm⁻³ at 20 nm, however the non-uniformity occurred mainly within 10 nm. The pre-formed layer remained stable at 1000 °C in 1 atm. O₂ for 120 min. The thermal SiO₂ films had stoichiometric composition. [3] The non-uniformity might be caused by change in structure of SiO₂-network.

Conclusions The XRR analysis revealed the non-uniform density distribution of the thermally grown SiO₂ thin films which may originate from structural change in SiO₂-network near SiO₂/Si interface region.

[1] Paratt, L. G., Phys. Rev. **95** (1954) 359. [2] Awaji, N., Ohkubo, S., Nakanishi, T., Sugita, Y., Takasaki, K., and Komiya, S., Jpn. J. Appl. Phys. **35** (1996) 67. [3] Kurokawa, A., Odaka, K. and Ichimura, S., Abstract 47th Ann. Meeting Vac. Soc. Jpn. (2006) in Japanese.

NS-TuP3 Growth and Characterization of Au-implanted MBE Grown CeO₂ Thin Films for Plasmonic Based Chemical Sensors, N.A. Joy, University of Albany-SUNY, M.I. Nandasiri, Western Michigan University, T. Varga, V. Shutthanandan, W. Jiang, P. Nachimuthu, S.V.N.T. Kuchibhatla, S. Thevuthasan, Pacific Northwest National Laboratory, M.A. Carpenter, University of Albany-SUNY

Au doped cerium oxide (CeO₂) material system has exhibited high activity, good selectivity and stability for low-temperature catalytic reactions. Recently, highly dispersed Au nanoparticles supported on metal oxides including CeO₂ have attracted a great deal of attention due to their high catalytic activity. Au nanoparticles are also promising candidates for plasmonic applications due to the sensitivity of their surface plasmon resonance (SPR) band to changes in the environment. In this study, we report the growth, characterization, and gas sensing properties of Au nanoparticles embedded in CeO₂ as optical beacons for the detection of H₂, CO and NO₂ in harsh environment.

CeO₂ thin films were grown on Al₂O₃(0001) by oxygen plasma-assisted molecular beam epitaxy (OPA-MBE). Following the MBE growth and in-situ characterization by reflection high energy electron diffraction (RHEED), as-grown CeO₂ thin films were irradiated by 2.0 MeV Au²⁺ ions generated in a tandem accelerator with high fluence of 1×10^{17} ions/cm² at 600°C. Subsequently, Au implanted ceria films were annealed at 600°C for 10 hours in air to form well defined Au nanoclusters. As-grown, irradiated, and annealed CeO₂ thin films were characterized by Rutherford backscattering spectrometry (RBS), x-ray photoelectron spectroscopy (XPS), and x-ray diffraction (XRD) techniques. The streaky RHEED patterns from the as-grown films indicate the epitaxial growth of the CeO₂ thin films. Glancing incidence XRD (GIXRD) pattern of the as-grown 300 nm thick ceria film indicates the presence of some polycrystalline material. Following the Au implantation at 600°C, GIXRD pattern shows the Au peaks and the reflections associated with ceria-alumina inter-mixing phase (CeAlO₃) in addition to CeO₂ peaks. It suggests the inter-diffusion of metal atoms at the ceria-alumina interface, which is possibly due to the bombardment of high energy Au²⁺ ions. RBS data of the Au-implanted CeO₂ sample also confirmed the inter-diffusion of the metal atoms at the film/substrate interface. Furthermore, the broader x-ray rocking curve of the CeO₂(111) reflection after Au implantation confirm the crystalline disorder of the CeO₂ film caused by irradiation. Despite the inter-diffusion and poor crystalline quality, both CeO₂ and Au crystallites are highly-oriented in (111) direction. After annealing and ex-situ characterization of Au/CeO₂ sample, SPR analysis and gas exposure experiments were performed in a high temperature optical transmission cell. The ppm level gas exposure experiments with the Au/CeO₂ sample has shown promising sensing characteristics towards the detection of H₂, NO₂ and CO in an air background at 500°C.

NS-TuP4 Facile Metal Oxide Nanosheet Synthesis using Atomic Layer Deposition, K. Lee, G.N. Parsons, North Carolina State University

Two dimensional nanosheets have attracted great interest due to their unique thermal and electrical properties. For example, graphene nanosheets which are exfoliated from graphite or synthesized using a chemical solution have shown the potential applications as an electrode, catalysts, and electrochemical sensors. In addition to graphene, various kinds of materials such as MoS₂, MnO₂, and MgO nanosheets have been studied extensively. This work demonstrates that atomic layer deposition (ALD) is a facile but effective technique for fabrication of metal oxide nanosheets precisely controlling thickness and chemical composition. We spin-coated a substrate with polymer such as PMMA, PVA, and PAA as a sacrificial layer, then coated the polymer with TiO₂ or ZnO ALD. We made small cuts through the metal oxide/polymer film, and then dissolved the polymer in solvent to release nanosheets from the substrate. We successfully attained two dimensional TiO₂ nanosheets with several hundred μm in lateral size and less than 10 nm in thickness. In addition to single material nanosheets, we can effectively form heterogeneous nanosheets with two metal oxides such as TiO₂/ZnO, where each layer thickness is individually controlled. We confirmed the thickness with AFM and compositions with EDX. We are exploring possible applications for these materials, and available results will be presented and discussed.

NS-TuP6 Nanoscale Surface Patterning for Controllable Metal Deposition, G. Smith, C.L. Berrie, University of Kansas

Nanoscale patterning techniques using an atomic force microscope on self-assembled monolayers (SAMs) are used to controllably form metal nanostructures on gold and silicon surfaces. Nanoetching and nanografting are done on methyl-terminated SAMs to pattern in molecules with carboxyl termination. Oxidative lithography is used to electrochemically oxidize

nanopatterns into methyl-terminated SAMs to achieve similar results. These nanopatterns are then treated with an electroless metal plating solution to form metal nanostructures selectively on the patterns. The patterns and features are characterized with atomic force microscopy. Controllable metal nanostructure formation has implications in nanoelectronics and nanodevice construction.

NS-TuP7 Probing the Size-Induced Electronic Structures of CdSe Quantum Dots, P. Nachimuthu, A.S. Karakoti, S.P. Sanghavi, P. Yang, V. Shutthanandan, L.J. Terminello, S. Thevuthasan, Pacific Northwest National Laboratory

The CdSe quantum dots have been studied for various applications ranging from biomedical imaging and sensing to hybrid solar cells. When the size of the nanocrystals reduces below the exciton Bohr's radius, the energy levels become discrete (quantized). Consequently, the band gap of quantum dots increases with decreasing the size of the dots. This is inherently reflected in the electronic structures of these quantum dots. In addition, these CdSe quantum dots are known to exhibit a phase transition from a stable hexagonal phase in larger dots to a metastable cubic phase at smaller dot sizes during their synthesis. As the size of quantum dot decreases, the number of surface atoms and the energy associated with the surface increase leading to creation of vacancies, which results in the non-stoichiometric CdSe. However, the mechanism is not clear at atomic level. Therefore, we took a systematic approach to study the size-induced structural and electronic properties of CdSe quantum dots in toluene and drop-casted on Si by various in-situ and ex-situ imaging, spectroscopy and diffraction techniques to obtain the correlation between the quantum confinement and the corresponding stoichiometry, crystalline phases and the effect of surface ligands. The CdSe quantum dots capped with trioctylphosphine oxide (TOPO) or hexadecylamine (HDA) in toluene exhibit predominantly wurtzite crystal structure, which undergoes a phase transformation to zinc blende crystal structure following drop casting on Si and this phase transition increases with decreasing the size of the CdSe quantum dots. A systematic increase in the core level binding energies of Cd 3d and Se 3d, the band gap and the Cd/Se ratio is found as the size of the quantum dots decreases from 6.6nm to 2.1nm. This is attributed to the quantum confinement of CdSe crystallites by the capping ligands in toluene which increases with decreasing the size of the quantum dots thereby increasing the Se vacancies. However, drop-casting of CdSe quantum dots on Si alters the arrangement of capping ligands on the quantum dots which facilitates significant phase transformation. To gain further insights in understanding these transitions we are seeking first principles investigation on model CdSe particles using density functional theory (DFT). The relative stability between the two phases as a function of particle sizes will be reported.

NS-TuP8 Plasmon-Enhanced Emission With GLAD-Functionalized ZnO Nanowires, D.C. Mayo, A.T. Mayo, A. Ueda, Z. Pan, R. Mu, Fisk University

ZnO has increasingly been the focus for optical emission studies due to both its wide band gap of 3.37 eV and high thermal stability. In this research, vertically oriented ZnO nanowires (NWs) are grown upon silicon substrates using a novel, modified vapor-solid method within a vertical furnace. Electron-beam evaporation is then used with glancing angle deposition (GLAD) to functionalize the sides of the ZnO NWs with both Ag and MgO:Ag. Comparative characterization is then performed using photoluminescence measurements at varying angles to examine both surface-plasmon-enhanced emissions and to study the underlying coupling mechanisms responsible for the enhancements. This research may serve as the foundation for applications which range from high-efficiency LEDs to optoelectronic plasmon waveguides.

NS-TuP9 Fabrication of High-Performance Carbon Nanotube Field-Effect Transistors with Semiconductors as the Source/Drain Contact Material, Z. Xiao, Alabama A&M University, F.E. Camino, Brookhaven National Laboratory

We report fabrication of high-performance single-walled carbon nanotube field-effect transistors (CNTFETs) using semiconductors as the source/drain contact material and defining submicron-meter gate within the source and drain, without overlapping the source and drain. Common problems in the fabrication of carbon nanotube field effect transistors (CNTFETs) include the positioning of tubes across electrodes and poor device electrical performance due to the presence of metallic nanotubes intermixed with semiconducting ones. To circumvent these problems, dielectrophoresis (DEP) will be used for tube alignment, while semiconducting electrodes such as Sb₂Te₃ and Bi₂Te_{3-x}Se_x, instead of metal electrodes in CNTFETs will be employed to selectively turn off metallic nanotubes resulting in improved device electrical characteristics. The submicron-meter gates within the source and drain in the fabrication of CNTFETs will be fabricated using the ion beam assisted deposition capability of the dual

electron/ion beam system. The electrical measurements on the CNTFETs will be performed and the measurement results will be reported.

NS-TuP11 Preparation of Triethylamine Stabilized Silver Nanoparticles for Low-Temperature Sintering, S.L.C. Hsu, J.T. Wu, National Cheng-Kung University, Taiwan, R.O.C.

In this research, silver nanoparticles were synthesized by chemical reduction from silver nitrate using triethylamine as the protecting and reducing agents simultaneously. The average size of the silver nanoparticles was less than 5 nm, which allowed low-temperature sintering of the metal. X-ray diffraction (XRD), thermogravimetric analysis (TGA), and energy dispersive spectrometric (EDS) analysis results indicate that silver nitrate has been converted to silver nanoparticles completely. Using a 20 wt% silver nanoparticles suspension with thermal treatment at 150 °C, silver films with a resistivity of 8.09 x 10⁻⁵ W cm have been produced, which is close to the resistivity of bulk silver.

NS-TuP12 Selective Growth and Characterization of a SnO₂ Nano-Wire by Employing DNA-templated Gold Nanoparticle Chains, J.H. Heo, Korea Institute of Materials Science, South Korea, H.J. Kim, Sungkyunkwan University, South Korea

Recently, the Tin-oxide(SnO₂) has been widely used in the fabrication of various gas(O₂, CO, NO_x) detecting sensor. Basically, the SnO₂ is n-type semiconductor which has a wide band gap, about 3.99eV. Also, thin film of SnO₂ has been known as a transparent electrode and it is applicable for a various electronic parts. Nowadays, research on SnO₂ nano-wire characterization is very actively performed because it is able to realize a micro-sensor array with conventional Silicon processing. However, it isn't easy to align a single SnO₂ nano-wire on the specific site for the fabrication of integrated gas sensor device. To achieve a high-performance gas-sensor with SnO₂, we need to make integrated single SnO₂ nano-wire 2 electrode devices. In this study, we employed DNA-templated alignment using a combination of molecular combing and surface-patterning techniques to form a Au nanoparticle chain as a catalyst. It is possible to obtain parallel and latticed nanostructures consisting of DNA molecules and thus DNA-templated Au nano-wires aligned at 400nm intervals.[1,2] After that, a single SnO₂ nano-wire which had been synthesized on the Au nanoparticle by a thermal process.[3,4] By using the AFM probing technique, a Rh coated conducting cantilever can approach a single SnO₂ nano-wire in nano scale and get the I-V curves with sweeping applied voltage between Au electrode and cantilever with a controlled concentration of Oxygen in measuring chamber to change the ionosorption rate. From the results of such experiments, we selectively grow SnO₂ nano-wires and verified Oxygen detecting ability which would be necessary for the realization of micro-sensor array.

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