Tuesday Afternoon Poster Sessions, November 16, 2004

Nanometer-scale Science and Technology
Room Exhibit Hall B - Session NS-TuP

Poster Session

NS-TuP1 Electrostatic Potential and Charge Domain Mapping of Samples by a Large Range Scanning Probe Microscope., ***Y.D. Park,*** Seoul National University, South Korea, Korea*; J. Lee, S. Lee, Y.S. Cho, H. Shin, Y. Kuk,* Seoul National University, South Korea

A large range scanning probe microscope was constructed, with a new beam reflection structure. Z scanner was separated from X-Y scanner for fast scanning of massive samples. A high precision (~100 nm) X-Y stepper was used to scan samples over a large area. Double reflection mirrors are used to avoid z positional errors caused by laser beam path. The nanowires and carbon nanotubes are imaged without any distortion on electrode-patterned Si wafer. The scanning range can be varied from tens of nanometer to tens of micrometer with this microscope. The electrostatic potential mapping over many nanowires and the surface charge domain of ferroelectric samples will be given for examples.

NS-TuP2 Fabrication of High Performance NSOM Probe For Optical Trapping, *S.S. Choi, D.W. Kim, C.K. Chun,* ***M.S. Song,*** SunMoon University, Korea*; M.J. Park,* Korean Military Academy, Korea

There have been tremendous interests about the optical trapping of the biomolecule in the microdevice with optical spectroscopic capablities. For microdevice application purposes, the optical trapping with nearfield optical probe array seems quite promising. Though, the weak nearfield intensity has been major obstacle for its application. The nearfield optical intensity through the nanosize aperture is dependent upon the aperture size, the grain size of the deposited metallic film, and other factors influencing the surface plasmon excitation. The surface plasmon excitation can be accomplished with periodic texturing of the metal surface around the nanoszie aperture. The enhancement of the nearfield optical intensity can be utilized for the nearfield optical trapping. In this report, the two adjacent metal aperture was fabricated using microfabrication technique including stress-dependent oxidation, isotropic wet etching of silicon oxide and bulk etching of Si, and bimetallic metal deposition. The adjacent nanosize metal aperture with distance less than the input wavelength can improve the output optical intensity. The bimetallic deposition of Ti/Al layer has been performed in order to provide better uniformity of the coated metal film. The buffer layer of Ti thin film would reduce grain size during the reflow process. The reduced grain size of the deposited thin film is supposed to improve throughput of nearfield optical intensity. The fabricated probe array will be utilized for near field optical trapping of the biomolecule. The optical characterization of the fabricated nearfield probe array will be investigated and the biomolecule trapping be tested.

NS-TuP3 Visualization of Two-Dimensional Doping Profile in Si for the Fabrication of Resistive AFM Probe, ***H. Shin,*** *B. Lee,* Kookmin University, Korea

In recent, scanning resistive probe microscopy (SRPM)@footnote 1@, as a variant of SPM-based techniques, which has a semiconductor resistor at the apex of the tip and can observe surface charges directly, was newly proposed and demonstrated. Spatial resolution of SRPM is dependent upon the size of the prepared resistor at the apex. The size of the resistor can be determined by width of the SiO2 implant mask, where both sides of the mask were open and implanted with As+ ions, and the diffusion length of the ions underneath. Using Kelvin Force Microscopy (KFM), we investigated the area of the resistor or equivalently underneath of the mask and determined the diffusion length of implanted As+ ions. For the first time, the depletion regions in the graded junction between implanted n+ and p-type Si substrate were observed. Furthermore, we proposed the mechanism of the SRPM by the observation of the overlapping depletion regions in the narrow resistor, which results the lowering barrier height for charge carriers. @FootnoteText@ @footnote 1@ H. Park, J. Jung, D.-K. Min, S. Kim, S. Hong, and H. Shin, Scanning Resistive Probe Microscopy: Imaging Ferroelectric Domains, Appl. Phys. Lett., 84, 1734-1736 (2004).

NS-TuP4 Nanoscale Current Mapping of Indium Zinc Oxide Thin Films Investigated by Conducting Atomic Force Microscopy, ***C.Y. Su,*** National Science Council, Taiwan*; H.C. Pan,* National Science Council, Taiwan, Taiwan, ROC*; M.H. Shiao,* National Science Council, Taiwan*; C.N. Hsiao,* National Science Council, Taiwan, R.O.C.

Transparent conducting oxide (TCO) films such as impurity-doped indium oxide systems have been widely applied for opto-electronic devices. Recently, several advantages of ZnO doped indium oxide (IZO) thin film has been reported. Since the photon emissive layer thickness of a device is typically in the range around 100 nm, understanding of the microscopic evidences for improving device performance is required. We have used the technique of conducting atomic force microscopy (CAFM) to investigate the relations between local surface electrical properties and morphologies of IZO thin films treated by different cleaning methods. The conducting regions are attributed to zinc oxide distributed randomly in the average size of 35 nm. Microscopic current mapping indicates ultraviolet-ozone (UV-ozone) treatment is contributed to produce nonconductive region due to generation of stable oxide as reported previously. By applying a tip bias of over -9 V on the nonconducting region, UV-ozone treated sample showed resistance against decomposition while the others failed. This stable oxide acts as a hole transport layer between the photon emissive layer and IZO thin film, which improves stability of devices by decreasing degradation rate of device performance. The surface oxide layer is generally attributed to increasing the work function after UV-ozone treatment, and higher efficiency is achieved as a result of reduction in energy barrier by improving interfacial conditions. Similarly, an additional ultra-thin SiO@sub 2@ layer deposited over IZO thin film would optimize electrical properties for improvement of device performance.

NS-TuP5 A Combined Vapor and Electrochemical Deposition Approach to the Controlled Growth of Nanoscale Metal Dendritic Islands, Beaded Wires, and Continuous Wires, ***C.E. Cross,*** *J.C. Hemminger, R.M. Penner,* University of California Irvine

Under conditions of careful control of the experimental parameters of substrate temperature and metal atom flux, conventional vapor deposition can be used to grow a variety of useful metal nanostructures. We use this approach to grow dendritic islands as well as beaded nanowires of gold on graphite substrates. Combining this approach with electrochemical deposition allows us to convert beaded nanowires into continuous nanowires (diameters as small as 20nm) that are many microns in length. Low flux vapor deposition of sub-monolayer amounts of gold on a graphite substrate that is held at or near room temperature generates dendritic islands of gold. The islands are fairly monodispersed in lateral dimensions (~100nm across). If the graphite substrate is held at higher temperature (@>=@300°C) "beaded wires" can be grown by decorating the graphite steps. The "beaded wires" are composed of gold "dots" that are 10-20nm diameter. Once again the "beaded wires" consist of gold dots that are highly monodispersed. The "beaded wires" provide excellent nuclei for electrochemical growth of very narrow, long, continuous wires of gold on graphite, where the wires are several microns in length. Each of these classes of structures have potentially interesting uses. The dendritic islands of gold are of interest in studies of the catalytic properties of gold nanostructures. The theoretically expected one dimensional electronic structure and optical properties of linear chains of gold dots that are tens of nanometers in diameter spaced by 10nm are of interest and the long nanometer scale continuous wires of gold are under development for sensor applications.

NS-TuP6 Electrochemically Grown Single Nanowires for Gas and Biochemical Detection, ***C. Lee,*** *M. Yun, R.P. Vasquez,* Jet Propulsion Laboratory (JPL)*; N.V. Myung,* University of California at Riverside*; E. Menke, R.M. Penner,* University of California at Irvine

We have developed an electrochemical nanowire growth technique which allows the use of a wide variety of sensing materials such as metals, alloys, metal oxides, semiconductors, and conducting polymers. Using this technique, we have grown single 3 micron long Pd nanowires with a diameter of 75 nm. We have also grown single polypyrrole nanowires of 500 nm diameter. The Pd nanowires grown by this technique have been used to sense hydrogen gas and the polypyrrole nanowires have been used as a pH sensor. The Pd nanowire hydrogen sensor operates under ultra low power (~ 25 nW) conditions and exhibits a fast response (<300 ms) due to the small sensor volume. Our hydrogen sensors can detect hydrogen over a wide range of concentrations from 0.02 % hydrogen gas to 10 % hydrongen gas and can be used for monitoring explosive concentrations of hydrogen gas. In the case of single nanowire pH sensor, the current change observed

upon the change in the conductivity of polypyrrole is 2 nA when 1 microliter of buffered solution at pH 12.45 is placed on top of the single polypyrrole nanowire sensor.

NS-TuP7 Phase Transformation of Copper Oxide Nanowires, *H.-Y. Chen,* National Tsing Hua University, Taiwan*; S. Han,* National Taichung Institute of Technology, Taiwan*;* ***Y.-B. Chu,*** National Chung Hsing University, Taiwan*; H.C. Shih,* National Tsing Hua University, Taiwan

The phase transformation of Cu@sub 2@O to CuO nanowires has been investigated by x-ray diffraction, transmission electron microscopy, and field emission electron microscopy. The Cu nanowires were firstly electrodeposited into anodic aluminum oxide templates with the pore size of 100 nm. After that, the specimens were annealed in air at 250°C to 900°C. The Cu completely transformed into Cu@sub 2@O above 250°C, meanwhile the CuO phase appeared above 350°C. The CuO phase increased with temperatures, whereas Cu@sub 2@O decreased significantly with annealing temperature increasing. Additionally, the Cu@sub 2@O phase completely transformed into CuO while the specimen annealed at 900°C. The phase transformation is accounted for the changes of Gibbs free energy with temperatures, and the consideration of thermodynamics is further discussed.

NS-TuP8 Polyaniline Nanofiber Chemical Sensors, ***S. Virji,*** *J. Huang, R.B. Kaner,* University of California, Los Angeles*; B.H. Weiller,* The Aerospace Corporation

Using a new interfacial polymerization method for the synthesis of conducting polyaniline nanofibers, we have developed nanofiber sensors and compared them to conventional polyaniline sensors. Polyaniline nanofiber films give high sensitivity and fast time responses due to their large surface area that allow for easy diffusion of gases into and out of the film. Conventional polyaniline thin films, chemically synthesized by oxidative polymerization and cast from organic solvents, exhibit strong but relatively slow, diffusion-controlled, doping characteristics when exposed to acid or base. In addition to doping and dedoping, polyaniline can also be reduced in the presence of a reducing gas such as hydrazine and swelling effects occur in the presence of organic solvents. This latter process can involve vapor-induced chain alignment of polyaniline in the presence of small alcohols. With a large range of detection capabilities, high sensitivity and time response, polyaniline nanofibers are a promising sensor material.

NS-TuP9 Growth of CNT and Tungsten Nanowires Deposited in HFCVD System, ***M. Passacantando,*** *L. Lozzi, R. Rastelli, S. Santucci,* University of L'Aquila, Italy

Oplay an important role in testing and understanding fundamental physical concepts, for example, the role of dimensionality and size in optical, electrical, and magnetic properties, but also hold considerable technological promise for new nanodevices applications. Furthermore the growth of these nanostructured materials directly on silicon, silicon oxide and other thin films now used in the microlectronics production process opens new possibilities for a quick application as nanodevices. Multiwalled carbon nanotubes and tungsten nanowires have been directly deposited in a hot filament chemical vapour deposition (HFCVD) system using acetylen (C@sub 2@H@sub 2@) on 3 nm of Nickel film deposited on Pt-Si@sub 3@N@sub 4@ patterned substrate. The CNT have been grown only on Si@sub 3@N@sub 4@ site, with a presence of tungsten wires on the Pt pattern. The as-synthesized products were characterized using X-ray diffraction (XRD), scanning electron microscopy (SEM) and X-ray Photoelectron Spectroscopy (XPS) techniques. The tungsten wires, after the extraction from the deposition apparatus showed a partially oxidised status (WO@sub x@, x=1-2), smooth surface with no amorphous sheath, and a sharp-tip end with diameters in the range of 10-100 nm. The proposed growth method can be easily scaled up for the real applications.

NS-TuP10 Numerical Simulation of Nanostructure Growth, ***H.H. Hwang,*** NASA Ames Research Center*; D. Bose,* Ames Center for Nanotechnology*; T.R. Govindan, M. Meyyappan,* NASA Ames Research Center

Nanoscale structures, such as nanowires and carbon nanotubes (CNTs), are often grown in gaseous or plasma environments. Successful growth of these structures is defined by achieving a specified crystallanity or chirality, size or diameter, alignment, etc., which in turn depend on gas mixture ratios, pressure, flow rate, substrate temperature, and other operating conditions. To date, there has not been a rigorous growth model that addresses the specific concerns of crystalline nanowire growth, while demonstrating the correct trends of the processing conditions on growth rates. Most crystal growth models are based on the Burton, Cabrera, and Frank (BCF) method, where adatoms are incorporated into a growing crystal at surface steps or spirals. When the supersaturation of the vapor is high, islands nucleate to form steps, and these steps subsequently spread (grow). The overall bulk growth rate is determined by solving for the evolving motion of the steps. Our approach is to use a phase field model to simulate the growth of finite sized nanowire crystals, linking the free energy equation with the diffusion equation of the adatoms. The phase field method solves for an order parameter that defines the evolving steps in a concentration field. This eliminates the need for explicit front tracking/location, or complicated shadowing routines, both of which can be computationally expensive, particularly in higher dimensions. We will present results demonstrating the effect of process conditions, such as substrate temperature, vapor supersaturation, etc. on the evolving morphologies and overall growth rates of the nanostructures.

NS-TuP11 Metal Catalyzed Carbon Nanotube Synthesis by Chemical Vapor Deposition: A First Principles Study of CNT Nucleation and Growth, ***S.H. Lee,*** *G.S. Hwang,* The University of Texas at Austin

Carbon nanotubes (CNTs) have numerous potential applications ranging from chemical and biological sensors to future electronic devices. Their shape, atomic configuration, and chemical composition could be tailored by tuning process parameters such as temperature and feed gas composition. Such atomic scale control is essential for the development of viable novel chemical, biological and electronic devices. However, still very little is known about underlying growth mechanisms, due largely to a difficulty in direct measurement of complex physical and chemical phenomena occurring during actual CVD processing. While current experimental techniques are still limited to providing complementary real space information, the interplay between experiment and theory will contribute to uncovering complex CNT growth mechanisms and subsequently achieving precise control of their physical and chemical properties. Using density functional theory calculations, we have investigated the initial stage of Ni-catalyzed CNT growth with a feed gas of C2H2/NH3. In this talk, we will present i) decomposition of C2H2 and NH3 which is a strong function of the surface facet of catalysts, ii) hydrogen etching of carbon, iii) diffusion dynamics of decomposed carbon atoms, and iv) formation mechanisms of ring structures from small hydrocarbon species. We will also discuss when the atomic configuration of CNTs will be determined, such as zigzag and armchair structures.

NS-TuP12 Evolution of Single-wall Carbon Nanotubes under Atomic and Molecular Deuterium Treatments, ***E.G. Keim,*** University of Twente, MESA+ Institute, The Netherlands*; W. Lisowski,* Polish Academy of Sciences, Poland*; A.H.J. Van den Berg, M.A. Smithers,* University of Twente, MESA+ Institute, The Netherlands

Relatively little experimental activity has been devoted to the interaction of atomic hydrogen with single-walled carbon nanotubes (SWNTs). Here we present SEM, TEM and XPS data dealing with the question of how the SWNTs are affected by prolonged interaction with a gas mixture of atomic (D) and molecular deuterium (D@sub 2@) at various temperatures. The material, HiPco, was first dispersed in isopropanol in an ultrasonic bath and was subsequently deposited on Si(100). Both the heating of SWNTs and their interaction with deuterium were performed in situ in a quartz cell, part of a separate UHV glass system@footnote 1@, and maintained at 78 or 273 K. The SWNT samples were exposed to the gas mixture, produced by the thermal dissociation of D@sub 2@ on a hot W filament, its temperature, T@sub f@, being kept at 1020 and 1550 K for a deuterium pressure of 0.005 and 0.5 Torr, respectively. All gas-solid interactions were monitored in situ by Thermal Desorption Mass Spectrometry (TDMS). See Ref.@footnote 2@ for a description. The spectroscopic and microscopic examinations were performed ex situ. Prolonged interaction of the (D + D@sub 2@) gas mixture produced at T@sub f@ = 1020 K leads to a coalescence of bundles of SWNTs forming large diameter carbon ropes of square and triangular cross-section covered by nano-aggregates of graphite material. Both the coalescence of single SWNTs and a massive reconstruction of bundles of SWNTs into multi-walled nanotubes were found to occur after prolonged exposure of the SWNTs to the gas mixture produced at T@sub f@ = 1550 K. Similar evolution phenomena were observed earlier@footnote 3@, however, after annealing the SWNTs under Ar flow above 2000 K. @FootnoteText@ @footnote 1@ W. Lisowski, Vacuum 53, 13 (1999).,@footnote 2@ W. Lisowski, E.G. Keim and M.A. Smithers, J. Vac. Sci. Technol. A21, 545 (2003).,@footnote 3@ K. Méténier, S. Bonnamy, F. Béguin, C. Journet, P. Bernier, M. Lamy de La Chapelle, O. Chauvet, S. Lefrant, Carbon 40, 1765 (2002).

NS-TuP15 Theoretical and Experimental Studies on the Adsorption of Oxidizing Gas on Carbon Nanotubes Thin Films, ***L. Lozzi,*** University of L'Aquila, Italy*; L. Valentini,* University of Perugia, Italy*; S. Picozzi, C. Cantalini, S. Santucci,* University of L'Aquila, Italy

In this work a combined theoretical and experimental study on CNT-based system for gas sensing applications is reported. Carbon nanotubes thin films have been deposited by chemical vapor deposition on Si3N4/Si substrates provided with Pt electrodes. Microstructural features as determined by SEM, TEM and Raman spectroscopy highlight the growth of defective tubular carbon structures. The electrical resistivity of the CNT film shows a temperature dependence semiconducting-like and a p-type response with decreasing electrical resistance upon exposure to NO2 gas and O3. No response has been found by exposing the film to CO gas, while some other concomitan gases may have an interfering behavior [1]. In order to obtain a theoretical validation of the experimental results, the equilibrium position, charge transfer and density of states are calculated from first principles for the CNT+CO and CNT+NO2 and CNT+O3 systems. Our density functional calculations show that Both CO and NO2 and O3 molecules adsorb weakly on a defect free tube wall, with essentially no charge transfer between the tube and the molecules. The electronic properties of CNTs are sensitive to the adsorption of NO2 and O3 due to an acceptor-like peak close to the tube valence band maximum, while they are insensitive to the CO adsorption. According to the experimental findings, our theoretical results suggest that gas-induced modification of the density of states close to the Fermi level might significantly affect the transport properties of nanotubes. The role of the defects on the wall of CNT is also discussed and related to the experimental results. In particular the anomalous adsorption of O3 that produces a consumption of the CNT film also at low temperatures is explained as the effect of the chemisorption of this gas onto defective sites. [1] C.Cantalini, L.Valentini, I.Armentano, L.Lozzi, J.M.Kenny and S.Santucci. Sensors and Actuators B 95, 195 (2003).

NS-TuP16 Oxygen Functionalized MWNT as Active Layer for Gas Sensing: Detection of NO@sub 2@ and NH@sub 3@, *A. Felten,* LISE, Belgium*; R. Ionescu, E. Sotter, E. Llobet, X. Vilanova, X. Correig,* Universitat Rovira i Virgili, Spain*; C. Bittencourt,* ***J.-J. Pireaux,*** LISE, Belgium

Due to their large surface area, Carbon Nanotubes (CNTs) show the potential to be applied as the active material of gas sensors. However, the presence of a thick graphite-like layer at the surface of the nanotubes can rule out the sensing potentiality of this material. In this work we use inductive RF oxygen plasma to functionalize the surface of nanotubes. The influence of different plasma conditions (power, treatment time and pressure) on the functionalization of the CNT surface was studied by XPS. The analyses showed that when a too high power is applied, a chemical etching occurs at the surface and the metallic precursors used in the CNT syntheseis are exposed. On the other hand, for an optimized range of the parameters, functional groups (hydroxide, carbonyl, carboxyl) are attached to the CNT while a reduction in the amount of graphite at the CNT surface is observed. After characterization, functionalized MWNTs (Nanocyl Â®) were used to form the sensitive layer of micro-hotplate gas sensors, prepared by the drop coating method. Detection of NO@sub 2@ and NH@sub 3@ concentrations as low as 500 ppb and 200 ppm, respectively, was found to be possible at ambient temperature. Plasma treatment showed to improve the sensing potentiality of CNTs by reducing the thickness of the graphite-like layer at their surface. The presence of the residual metallic catalysts at the CNTs surface proved to play an important role in sensitivity.

NS-TuP17 Synthesis and Property of Carbon Nanosheets at Different Deposition Temperatures, ***M.Y. Zhu****, J.J. Wang, X. Zhao, R.A. Outlaw, D.M. Manos, B.C. Holloway,*** College of William and Mary

Carbon nanosheets, a novel form of free-standing graphite sheets with thickness less than 1 nanometer, were synthesized by radio-frequency (13.56MHz) plasma enhanced chemical vapor deposition (PECVD) on Silicon, quartz and tungsten foil. Carbon source, methane (CH@sub 4@), was diluted in hydrogen (H@sub 2@) to produce carbon nanosheets at various temperatures 650°C to 900°C. SEM images show that the surface morphology of carbon nanosheets varies a lot with deposition temperature. Lower deposition temperatures produce large, smooth nanosheets while higher temperatures produce small, corrugated nanosheets. Raman spectroscopy indicates that the crystallinity of nanosheets deteriorates with increasing substrate temperature. Diode I-V curves were acquired to study the field emission property of nanosheets grown at different temperatures, and yield a turn on field of as low as 4 V/µm.

NS-TuP18 Modeling, Fabrication and Characterization of Vertically Aligned Carbon Nanofiber (VACNF) Based Triode Field Emission Devices for Use in Massively Parallel Digital E-Beam Array Lithography (DEAL), ***X. Yang,*** University of Tennessee at Knoxville*; W.L. Gardner, L.R. Baylor, H. Cui, D.K. Hensley, R.J. Kasica, D.K. Thomas,* Oak Ridge National Laboratory*; M.A. Guillorn,* Cornell Nanofabrication Facility*; M.L. Simpson,* Oak Ridge National Laboratory

Field emission triodes have been fabricated for application in massively parallel Digital E-beam Array Lithography (DEAL) at Oak Ridge National Laboratory (ORNL)@footnote 1@. Vertically Aligned Carbon Nanofibers (VACNFs) were individually grown as the field emission cathode elements. Three electrodes are fabricated: the cathode, the extraction electrode and the focus electrode, separated from each other by 1µm SiO@sub 2@. We have demonstrated Fowler-Nordheim emission characteristics and electron beam focusing. The variation of beam diameter with focus aperture potential observed both optically and lithographically agrees well with electron beam simulations. Further modeling indicates that these devices will benefit from thicker (500 nm vs. 100 nm) electrodes in three ways: (1) improved focus effectiveness; (2) decreased optimal-beam size; and (3) increased depth of focus. The capability to realize thicker electrodes using a low-pressure chemical vapor deposition (LPCVD) tool is being implemented based on these results. Effects on beam shape and size due to electrode or field emitter offsets from coaxial geometry were also investigated with a 3D structure simulation. It was shown that a converged electron beam shape of 50nm or less in diameter is still obtained in the presence of small geometrical offsets. Preliminary 3x3 arrays of these devices have been fabricated and are being tested. While the extraction and focus electrodes are individually addressed the cathode is presently common to all devices. Individually addressed cathode designs, important for implementing DEAL with dose control circuits integrated into the device, are being investigated. Details of device modeling, fabrication, and characterization as well as device development to minimize offsets and realize individual cathode addressing will be presented. @FootnoteText@ @footnote 1@ ORNL is managed by UT-Battelle, LLC, for the U.S. Department of Energy under contract No. DE-AC05-00OR22725.

NS-TuP19 Microstructure Modeling of MOCVD Zirconium Oxide Deposition, ***M.O. Bloomfield,*** Rensselaer Polytechnic Institute*; Z. Song, B.R. Rogers,* Vanderbilt University*; T.S. Cale,* Rensselaer Polytechnic Institute

We use PLENTE, a software designed to study the formation and evolution of microstructure in thin films, to evaluate different models of growth for high vacuum MOCVD of zirconium oxide films on a selection of substrates. ZrO2 is a potentially important high-k dielectric material that can be deposited using zirconium tertbutoxide (ZTB). Cross sectional TEM and AFM of films in the early stages of growth show different wetting and island formation behavior as a function of deposition conditions, substrate selection, and history. Using PLENTE, TEM data and XRD data, we develop models of how islands grow during deposition and compare the evolving structures with experiment, primarily through trajectories of instantaneous void fraction measured experimentally via in situ spectroscopic ellipsometry. Models that include highly wetting islands and strong lateral growth show distinctly different voiding behavior from those with preferential growth non-parallel to the substrate, and in some cases, can be directly mapped to observed growth trajectories. Finally, we use the models developed to predict grain structural development for deposition onto rough and featured substrates, as demonstrations of possible use for integration of ZrO2 films into more complicated microelectronic structures.

NS-TuP20 Fabrication and Characterization of Carbon Nano-Cone Electron Emitters, ***K. He****, N. Badi, A. Bensaoula,*** University of Houston

R&D on effective field emitter arrays (FEAs) is now concentrated on nano-structured solid materials because of the significant local increase of the electric field on solid tips with a small radius of curvature. This paper reports on the electron field emission behavior from uncoated and boron nitride coated graphite nano-cones. Since nano-cones emit most of their current into a single narrow beam, it is expected that graphite nano-cones electron emitters will lead to a significant improvement in the performance of high-resolution electron-beam instruments as well as for high power microwave amplifiers. Fresh cleaved highly oriented pyrolytic graphite (HOPG) was surface treated with poly-l-lysine for adhesion purpose. By dipping the sample into a colloidal gold solution with particles with a nominal diameter in the range of 30-50 nm, naturally and uniformly dispersed gold nanoparticles are attached to the HOPG surface. These nanoparticles serve as a mask for a subsequent reactive ion etching process to form the graphite nano-cones. Higher etching rates under oxygen plasma were observed at a plasma power above 180 Watts. Depending on

the oxygen plasma etching parameters such as power and etching time, nano-cones with different shapes and sizes were fabricated. A sulfur doped boron nitride coating was deposited on the etched HOPG nano-cones using an ion assisted physical vapor deposition technique. Field emission characteristics from different coated and uncoated HOPG nano-cones will be presented along with their thermal and temporal stability measurements under different pressure environments. Acknowledgment: This material is based upon work supported by the National Science Foundation under Grant No. 0010100 and by NASA cooperative agreement to TcSAM. The authors would like to thank Dr. N. Medelci for his valuable help.

NS-TuP21 Epitaxial Growth of Nisi@sub 2@ on (001)Si Inside 50-200 Nm Openings Prepared by Scanning Probe Lithography, ***S.-Y. Chen,*** *S.D. Tzeng, S. Gwo,* National Tsing Hua University, Taiwan*; L.J. Chen,* National Tsing Hua University, Taiwan, Republic of China

Epitaxial growth of NiSi@sub2@ on (001)Si inside Si@sub3@N@sub4@ openings of 50-200 nm in size prepared by AFM tip-induced local oxidation has been investigated. From TEM and SEM observation, the size of the openings was found to influence significantly on the morphology of epitaxial NiSi@sub2@. As the dimension of the openings decreases, the shape transition of facetted NiSi@sub2@ from irregular polygons to inverse pyramids was found inside openings. NiSi@sub2@ facetted rods would appear as the size of the openings was further decreased. The results are attributed to the increased interface/volume ratio of silicides with decreasing size of openings and the non-uniform stress distribution within the miniature openings. As the thickness of Ni and annealing time are well-controlled, it is possible to obtain the identical NiSi2 pyramids of nano-scale even though the shape of openings is not identical.

NS-TuP22 Nanoscale Patterning by Pulsed Laser Irradiation and Nanoparticle Alignment, ***Y.F. Guan,*** *A.J. Pedraza,* The University of Tennessee, Knoxville

One- and two-dimensional nanostructure arrays have been generated in silicon by pulsed-laser irradiation, using a Lloyd's mirror configuration. The nanostructures consisted of periodic ripples and protrusions that could reach an amplitude of 20 nm and a height of 80 nm, respectively. The ripple nanostructure was used as a template for the alignment of gold nanoparticles. The gold was first sputter-deposited on the rippled surface at a grazing angle, and subsequently annealed at 700 °C. Atomic force and high resolution scanning electron microscopy studies revealed that the nanoprotrusions are preceded by the formation of extended ripples. The present experiments show that the Lloyd's mirror configuration strongly enhances the formation of ripples and that nanoprotrusions form at the intersection of two mutually orthogonal sets of ripples. On the other hand, when a Lloyd's mirror is not added only 1-D ripple formation was observed, with no protrusions. Interference of the incoming or refracted laser beam and the laser light scattered by the surface undulations has been long recognized as the cause of periodic ripple formation. It is concluded that the gradient of surface tension arising from a temperature gradient is responsible for the formation of the nanoripple structure, and the breakdown of the ripples into aligned nanoprotrusions is due to a second temperature modulation along the ripple lines. The intersection of two mutually perpendicular ripple structures and the very high reflectivity of the nanoprotrusion tips are the causes that promote this secondary laser light modulation.

NS-TuP23 Electronic and Ionic Processes in Local Oxidation of Titanium Nitride Thin Films, ***N. Farkas,*** *J.R. Comer, G. Zhang, E.A. Evans, R.D. Ramsier,* The University of Akron*; J.A. Dagata,* National Institute of Standards and Technology

We report an apparently unique property of titanium and titanium nitride thin films to undergo local oxidation or vaporization during scanning probe microscope (SPM)-based lithography. Nanometer-scale oxide dots or holes can be produced reliably depending on reversible SPM tip preparation. The presence of an electron-blocking tip oxide results in oxide growth on the substrate, while its absence leads to electronic breakdown. Both tip conditions can be obtained in a sequential and reversible manner. Electron emission is investigated using a variety of metallic and semiconducting SPM tips. Changing the nitrogen content of the deposition plasma over a wide range alters structural and electrical properties of the substrate materials and provides a basis for understanding the underlying processes, which we characterize by X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS), SPM roughness, and four-point probe measurements. This work contributes to a better understanding of the electronic and ionic components of the total current during SPM-assisted oxidation and demonstrates that this technique can be used to both modify and to characterize materials on the nanometer scale.

NS-TuP24 Synthesis and Characterization of Germanium Nanocrystals, ***H. Gerung,*** University of New Mexico*; S.D. Bunge, T.J. Boyle,* Sandia National Laboratories*; C.J. Brinker, J. Lee, M. Osinski, S.M. Han,* University of New Mexico

Semiconductor nanocrystals promise numerous potential applications, ranging from phosphors to biosensors. Herein, we focus on synthesis and characterization of Ge nanocrystals (NCs). Compared to group III-V or II-VI compound semiconductor NCs, the synthesis of Ge NCs in solution has been a challenge due to their covalent bond nature. Very few solution-phase syntheses have been reported, and the precursor preparation often involves a relatively high-pressure (>1 atm) process. We have developed a new method of synthesizing Ge NCs. The size of these crystals ranges from 3 to 10 nm. The control over shape and size dispersion of Ge NCs will be discussed in this presentation. We will present the effect of processing temperature and precursor concentration on the size. The synthesis relies on solution reduction of Ge@super 2+@ to Ge@super 0@ with commercially available precursors at relatively low temperature (300 °C) and at 1 atm of Ar ambient. This new synthetic route is scalable for mass production of Ge NCs. Photoluminescence spectra of Ge NCs show emission from 380 to 510 nm, and they demonstrate the quantum confinement effect of Ge NCs. However, ultraviolet-visible (UV-Vis) spectroscopy and attenuated-total-reflection Fourier transform infrared spectroscopy (ATR-FTIRS) show that Ge NCs are sensitive to air exposure, and they degrade over time in the absence of proper surface passivation. We therefore utilize different types of surfactants to encapsulate and stabilize the Ge NCs. The stabilized Ge NCs can be then incorporated into a silica matrix via sol-gel approach to form a self-assembled 3-dimensionally (3-D) ordered matrix.

NS-TuP25 Fabrication of SiGe Nanodot Array by Anodic Aluminum Oxide Templation, ***W.J. Huang,*** National Nano Devices Laboratories, Taiwan*; F.M. Pan, D.M. Chen,* National Chiao Tung University, Taiwan

Anodic aluminum oxide (AAO) has a highly ordered hexagonal pore array structure, and has been widely used as a template for nanostructured materials fabrication, such as carbon nanotubes and TiO@sub 2@ nanodots. Silicon germanium (SiGe) is an interesting semiconductor, which has a higher carrier mobility as compared with silicon, and has tunable bandgaps depending on the atomic composition of Ge. Moreover, SiGe is process-compatible with existing Si IC technologies. In conjunction with the AAO templation method and simple dry etching, we have prepared SiGe nanodot array with a dot size smaller than 50 nm. Si@sub 0.85@Ge@sub 0.15@ 50 nm in thickness was deposited on the Si wafer by ultrahigh vacuum chemical vapor deposition (UHV-CVD), followed by the sputter-deposition of TiN (20 nm). An Al film 4 μm in thickness was thermally evaporated on the TiN surface for the AAO preparation. The Al film was anodically oxidized in an oxalic acid electrolyte at room temperature, and the finished AAO pore array has a pore diameter about 60 nm. As the Al layer was completely oxidized, the underlying TiN layer was partially oxidized as well resulting in the formation of the TiO@sub 2@ nanostructure array with a pattern in compliance with the AAO pattern. The TiO@sub 2@ array was then used as the hardmask for dry-etching the remaining TiN and the SiGe bottom layer, and the SiGe nanodot array was thereby produced. Various analytical techniques, such as TEM, AFM and AES, have been employed to characterize the process steps of the SiGe nanodot array.

NS-TuP26 Site-selectivity of Chemical Reaction on a Biomimetic Super-hydrophobic/Super-hydrophilic Micropatterned Template, ***N. Saito,*** *Y. Wu, M. Kouno, Y. Inoue, O. Takai,* Nagoya University, Japan

Recently, the materials fabrication based on biomimetics attract the attention of many researchers due to their green process, high function and novel self-organized structure. In nature, there are super water-repellent plant leaves such as lotus and taro. These surfaces are covered with hydrophobic micropapilla. The presence of hydrophilic group on such a structure leads to ultra water-repellency. Water droplets would be formed on only super-hydrophilic regions when water was spilled over an artificial super-hydrophobic/super-hydrophilic micropattern on substrates. In this study, we focused on the fabrication and application of biomimetic super-hydrophobic/super-hydrophilic micro-pattern using the microwave plasma-enhanced chemical vapor deposition (MPECVD) and vacuum ultra violet (VUV) lithography. Silicon wafer was used as substrates. Raw materials in the MPECVD were trimethylmethoxysilane (TMMOS) and Ar. The super-hydrophobic/super-hydrophilic pattern was fabricated by VUV

irradiation thorough a TEM mesh. In order to confirm the pattern, surface water droplet was observed by environmental SEM. We successfully demonstrated site-selective electroless Cu plating on the pattern from the FE-SEM images.

NS-TuP27 Mechanical Property and Nano Texture of Alumina-Silica Ultra Water Repellent Films, ***M. Bekke***, *Y. Wu, N. Saito, M. Koga, Y. Inoue, O. Takai,* Nagoya University, Japan

Ultra water repellent (UWR) films have attracted significant attention due to both fundamental scientific interests and practical applications. It has been known that UWR film requires the surface with two factor, that is, adequate surface roughness and low surface energy. Wenzel and Cassie found a rule between surface roughness and water repellency. The surface roughness can be obtained using various fabrication methods such as sol-gel, plasma enhanced chemical vapor deposition (PECVD) and spray coating. Mechanical property of the film with large roughness is generally inferior to that of the smooth surface film. This is a crucial problem for an industrial application of UWR film. Therefore, it is necessary to improve the mechanical property of UWR film. In this research, we aim to prepare a UWR film with favorable mechanical properties using microwave plasma enhanced chemical vapor deposition (MPECVD). UWR film was fabricated on Si (100) substrate using the microwave plasma-enhanced chemical vapor deposition (MPECVD). Raw materials were trimethylmethoxysilane (TMMOS), CO@sub 2@ and Aluminum(III) diisoproxide ethylacetoacetate(ADE). The flux of the bubbling gas(CO@sub 2@) was changed and the quantity of the ADE was adjusted. The water-repellency of film was evaluated by water contact angle measurements. The surface morphology of UWR film was acquired by atomic force microscopy (AFM) and field emission scanning electron microscopy (FE-SEM). The chemical bonding states were characterized by Fourier transform infrared spectroscopy (FT-IR) and X-ray photoelectron spectroscopy (XPS). The mechanical properties of the film were evaluated by nanoindentation test.

NS-TuP28 Behavior of Water Microdroplets on Nano-textured Surfaces Fabricated by a Focused Ion Beam Technique, ***M. Kouno***, Nagoya University, Japan; *Y. Wu, N. Saito, M. Koga, Y. Inoue, O. Takai,* Nagoya University, Japan

Water repellency emerged on hydrophobic surfaces has attracted much attention due to fundamental and scientific interests. Surface nano-texture is a key factor for water repellency. Water repellency is generally evaluated by water contact angle. The water contact is usually evaluated in macrometer-scale. Environmental scanning electron microscopy (E-SEM) has the potential of the evaluation in micro-meter scale. In this study, we investigated the correlation between the surface structure and the water repellency based on the observation of water droplets in micro-scale using E-SEM. We prepared two types of samples with different nano-textured surface fabricated by a focused ion beam (FIB) technique. One was consisted of a fine array of concave structures with the center distances being 1 μm on Si(100) substrate. The other was composed of a similar array of convex structures. Their diameters were varied from 150 to 800 nm. All the sample surfaces were modified with the formation of a self-assembled monolayer from heptadecafuluoro-1,1,2,2-tetrahydro-decyl-1-trimethoxysilane [a type of fuloroalkylsilane, FAS, F@sub 3@C(CF@sub 2@)@sub 7@(CH@sub 2@)@sub 2@Si(OCH@sub 3@)@sub 3@] through chemical vapor deposition. These samples were observed by ESEM (Nikon, ESEM-2700). Water droplets were in situ formed on each sample surface by cooling the sample down to ca. 2.5 @super o@C, which is lower than the dew point under the condition of observation chamber. E-SEM images of the water droplets revealed that the water repellency of the sample depends on the shape and the array pattern on the surface in nanometer-scale.

NS-TuP29 Formation of Nanometer-scale Gap Electrodes Based on a Plasma Ashing Technique, *Y. Lee,* Sungkyunkwan University, Korea; ***Y. Roh***, Sungkyunkwan University, Korea, Republic of Korea; *K.-S. Kim,* Sungkyunkwan University, Korea

Realization of nano- and/or bio-electronic devices requires the formation of metal electrodes with a nanometer-scale gap. Recently the fabrications of metal electrodes with a nano gap dimension have been demonstrated by using advanced techniques such as electron-beam lithography, focused ion beam lithography, or advanced optical lithography. However, special techniques such as electromigration-induced break junction, shadow deposition, or electrochemical deposition have to carry out in order to reduce further the nanometer-scale gap between two metal electrodes formed by microlithography as above-mentioned. One of the proposed techniques to overcome a resolution limit of an optical lithography was a photoresist (PR) ashing technique, in which the minimum linewidth can be formed by ashing the PR pattern defined by the optical lithography. In this work, we proposed a noble and reproducible method to fabricate nanometer-scale gaps between two metal electrodes using PR ashing and lift-off techniques. Using this technique, we obtained metallic electrodes with a nano-gap of less than 10 nm. With this technique, the gaps between two electrodes could be easily controlled and reproduced.

NS-TuP30 Fabrication of MOS Structure with NiSi@sub 2@ Nanocrystals Embedded in Silicon Dioxide, ***P.-H. Yeh***, *C.H. Yu,* National Tsing Hua University, Taiwan; *L.J. Chen,* National Tsing Hua University, Taiwan, Republic of China; *H.H. Wu, T.-C. Chang,* National Sun Yat-Sen University, Taiwan; *P.T. Liu,* National Nano Device Laboratory, Taiwan

A metal-oxide-semiconductor (MOS) structure with NiSi@sub 2@ nanocrystals embedded in the SiO@sub 2@ layer has been fabricated. From the TEM micrograph and diffraction pattern, the nanocrystals were identified to be NiSi@sub 2@. The mean size and the aerial density of the NiSi@sub 2@ nanocrstals were estimated to be ~ 7.6 nm and 3.3 x 10@super 11@/cm@super 2@, respectively. A pronounced capacitance-voltage hysteresis is observed with a memory window of 1 V under the 2-V programming voltage. The process of the structure is compatible with the current manufacturing technology of semiconductor industry. The structure represents a viable candidate for low-power sub-100 nm nonvolatile memory devices.

NS-TuP31 The Formation of Au-nanowires Using DNA Molecule as a Template, ***H.-J. Kim***, *Y. Lee, I.-S. Yi,* Sungkyunkwan University, Korea; *Y. Roh,* Sungkyunkwan University, Korea, Republic of Korea; *B. Hong, H.-G. Jee, S.-B. Lee, M.-J. Shin, S.-G. Kim,* Sungkyunkwan University, Korea

The formation of metal nanowires via the conjugation of biomaterials (e.g., DNA molecules) and metal nanoparticles has been extensively investigated to obtain highly ordered electronic components for nanocircuitry and/or nanodevices. Metal nanowires were organized by the hybridization of nucleic-acid-functionalized metal or metallic nanoparticles with DNA molecule as a template. For example, Au-nanowires (AuNWs) were formed using the DNA molecules conjugated by aniline- and lysine-capped Au nanoparticles (AuNPs). In this work, we developed a simple technique to form Au-nanowires by the conjugation of 4-aminothiolphenol-capped gold nanoparticles (ATP-AuNPs) and the immobilized DNA molecules on 3-Aminopropyltriethoxysilane (APS) coated Si wafers. In this technique, a metallization process involves three steps: (1) DNA molecules were immobilized on the Si/APS substrate, (2) ATP-capped AuNPs were formed via strong chemical reaction between thiol (-SH) group of ATP and AuNPs, and (3) AuNWs were then formed by the interaction between DNA and ATP-AuNPs. In addition, we investigated the effects of the relative molar quantity (i.e., AuNPs/ATP) on the network formation of Au-nanowires. Our preliminary works indicate that the relative molar quantity may decide the structure of Au-nanowires. These results, as well as further interpretation of the data, will be presented at the conference.

NS-TuP32 Photoluminescent Emission Properties of Porous Nanostructured Y@sub 2@o@sub 3@:eu Thin Films, ***P.C.P. Hrudey***, *M. Taschuk, Y.Y. Tsui, R. Fedosejevs, M.J. Brett,* University of Alberta, Canada

Nanostructured photoluminescent thin films of europium-doped yttrium oxide (Y@sub 2@O@sub 3@:Eu), a well-known luminescent material, were grown using electron beam evaporation, in combination with the Glancing Angle Deposition (GLAD) technique. GLAD makes use of controlled substrate motion during extremely oblique physical vapour deposition (PVD) of a thin film resulting in a high degree of control over the nanostructure of the film. Films were deposited using pre-doped Y@sub 2@O@sub 3@:Eu source material. Scanning electron microscopy and x-ray diffraction were used to characterize film nanostructure, while the light emission properties of these films were characterized by photoluminescence measurements. In order to improve the photoluminescent response of the films a post-deposition annealing treatment was used. By annealing in air at 850°C, the film crystallinity improves leading to increases in the photoluminescent response by greater than three times that of the as-deposited samples. The emission properties of vertical posts, helices, and normally-incidence solid thin films were obtained and compared. In studying the effect of film structure on the emission properties vertical posts films were found to emit two times more light in the direction normal to the substrate surface than solid films that contained an equivalent mass of material. Additionally, optical filter devices incorporating Y@sub 2@O@sub3@:Eu were fabricated and studied for their effects on the emission properties.

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