Graphene Topical Conference
Room: Hall D - Session GR-TuP

Graphene Poster Session

GR-TuP1 Growth Mechanism of Carbon Nanowalls Synthesized by Irradiation of Independently Controlled Ar Ions and CF_X/H Radicals, *S. Kondo, O. Stepanovic,* Nagoya University, Japan, *K. Yamakawa, S. Den,* Katagiri Engineering Co., Ltd., Japan, *M. Hiramatsu,* Meijo University, Japan, *M. Hori,* Nagoya University, Japan

Carbon nanostructures such as carbon nanotubes, fullerenes, etc. are investigated intensively in the world. Among a nanocarbon family, we are focusing on carbon nanowalls (CNWs). The CNWs can be described as two-dimensional carbon nanostructures with edges comprising stacks of plane graphene sheets standing almost vertically on the substrate. The CNWs have several unique characteristics, e.g. high aspect ratio and large surface area. Hence, the CNWs attract great attentions for nanoscale electronic devices, storage materials for hydrogen gas, and fuel cells. Previously, we have fabricated CNWs using parallel-plate capacitively coupled plasma with hydrogen (H) radical injection. Considering the practical applications of CNWs, further investigations are required to clarify the growth mechanism for control of their morphologies and properties. In this study, two radical sources, inductively coupled plasmas (ICPs) using 13.56 MHz, and an ion source, a ICP using 13.56 MHz, were used in order to understand which radicals or ions contributed to the CNWs formation. The heated Si substrate was exposed to fluorocarbon (CF_X) and H radicals as well as Ar ions, of which densities were controlled in each source independently. The correlation between the characteristics of irradiated species, such as Ar ion energy and H radical density, and the CNWs morphologies was investigated employing a spectroscopic ellipsometry for in-situ observation on the substrate surface. It was found that CNWs were not formed with Ar ions of energies below 100 eV with CF_X and H radical injection. On the other hand, CNWs were successfully formed by Ar ions of energies between 100-200 eV, which were confirmed by SEM and Raman spectroscopy. The deposition rate of CNWs was proportional to the acceleration voltage of the Ar ions. As a result, not only fluorocarbon and hydrogen radicals but also high energy ions accelerated at energies of more than 100 eV were required for the nucleation of CNWs because higher energy ions created dangling bonds on the edge of CNWs, which will be a key for their growth. Furthermore, it was found out that the best value of hydrogen gas flow rate for the highest deposition rate and the better morphology of CNWs existed. The growth of high quality of CNWs with a high growth rate is determined by the balance of the ratio of H radicals to CF_X radicals. These results will be crucial to elucidate the mechanism of CNWs.

GR-TuP2 Enhanced Field Emission from Carbon Nanosheets by Thin Film Coatings, *M. Bagge-Hansen, R.A. Outlaw, M.Y. Zhu, **D.M. Manos***, The College of William and Mary

Carbon nanosheets (CNS) are a promising two-dimensional carbon allotrope for high current field emission cathodes and are grown by radio frequency (RF) plasma-enhanced chemical vapor deposition from a C_2H_2/H_2 gas blend at substrate temperatures of ~ 600 °C. The resulting film consists of vertically oriented, honeycomb sp^2 carbon arrays terminating in single graphene sheets that serve as field emission cathodes. Conditioned films have previously been shown to provide high emission current density (~ 2 mA/mm^2), and stable lifetime (less than 5% variation over >200 h). The Fowler-Nordheim equation predicts that the field emission current density is a strong function of the local effective work function, e.g., a reduction of 1 eV in work function results in an increase in emission current of up to two orders of magnitude. Since the work function of graphite, carbon nanotubes, and amorphous carbon is relatively high, 4 - 5 eV, selective thin film coatings can substantially lower the effective work function at active emission sites. Mo_2C and NbC films of ~1 nm have been grown on CNS by e-beam physical vapor deposition (PVD) in very high vacuum and subsequently characterized by Auger electron spectroscopy (AES) and x-ray photoelectron spectroscopy (XPS) in UHV. Comparison of the as-grown CNS to coated CNS show large increases in current density; for example, a 2 nm coating of Cr_2O_3/CNS gave an enhanced emission of a factor of 135. The emission shows a strong film thickness sensitivity that may be a consequence of band bending in the surface potential barrier. Coatings of ThO_2, Cr_2O_3 and NbO_x on CNS have also been similarly grown and demonstrate similar improvements in current density.

GR-TuP3 Thermal Desorption Study of Graphene Oxide, *D.A. Field, C.A. Ventrice,* Texas State University, *I. Jung, D. Yang, A. Velamakanni, R.D. Piner, R.S. Ruoff,* University of Texas

Graphene oxide is an electrical insulator that shows potential for use in nanoscale electronic devices. An understanding of the thermal stability of graphene oxide sheets is important since the electrical, chemical, and mechanical properties of graphene oxide will change as it is reduced at elevated temperatures. In this study, graphene oxide films were grown by deposition of an aqueous solution of graphene oxide onto oxygen plasma cleaned silicon nitride on silicon substrates. The thermal stability of these films was studied by temperature programmed desorption under ultra-high vacuum conditions. The primary decomposition components of the films are CO and CO_2. Analysis of the post-anneal chemical composition of the films was performed with x-ray photoelectron spectroscopy. Peaks associated with the C-C bond the C-OH, C=O, and C-O-OH functional groups are monitored at anneal temperatures up to 900 °C.

GR-TuP4 Photoemission-Assisteded Plasma Chemical Vapor Deposition Synthesis of Nano-Grain Graphene on Mica and Silicon, *T. Takami,* Tohoku University and CREST JST, Japan, *E. Ikenaga,* Japan Synchrotron Radiation Research Institute and CREST JST, *M. Nihei,* Fujitsu Limited and CREST JST, Japan, *Y. Takakuwa,* Tohoku University and CREST JST, Japan

Multilayer graphene with nano-scale grain size has been formed on mica and silicon (100) surface with a plasma chemical vapor deposition method at the temperatures lower than 700 C from the mixture gas of methane and argon. The plasma was assisted with an irradiation of ultraviolet light to the sample, induced photoelectric effect. The grown nanographene has been confirmed by transmission electron microscopy and core-level X-ray photoemission spectroscopy with synchrotron radiation. The lattice images with transmission electron microscope and the diffraction patterns indicated that nanographene was formed on the substrates. The peak position of C1S band and pai-pai* plasmon loss band on the X-ray photoemission spectra also revealed the growth of graphene.

GR-TuP5 Adsorption Kinetics of Alcohols on Single Wall Carbon Nanotubes, *J. Goering, M. Komarneni, **U. Burghaus***, North Dakota State University

Carbon nanotubes can be used as supports for applications such as direct liquid fuel cell catalysts. The adsorption kinetics of alkanes (butane, pentane, hexane, trimethylpentane) and alcohols (methanol, ethanol, propanol, 2-propanol, butanol, pentanol, and hexanol) on single wall carbon nanotubes (HiPco-CNTs) supported on silica has been studied by thermal desorption spectroscopy (TDS). Multi-mass TDS indicate molecular adsorption/desorption with low coverage binding energies increasing linearly with the size of the alcohols. The coverage dependence of the heat of adsorption has been determined by a Redhead analysis. The heat of sublimation, determined by a leading edge analysis, increases linearly with the size of the alcohols whereas the zero order pre-exponential factor is approx. independent of the molecular size. Coadsorption TDS of alcohol-alkane mixtures indicate adsorption of these molecules inside of the CNTs. Adsorption probabilities of alkanes measured by molecular beam scattering increase while opening the CNT tube ends by annealing fresh samples. First results on CoMoCAT CNTs are presented in order to address a possible structure activity relationship.

GR-TuP6 Fabrication, Structural Characterization, and Surface Modification of Carbon Nanoballs, *T. Ishizaki,* National Institute of Advanced Industrial Science and Technology, Japan, *N. Saito, O. Takai,* Nagoya University, Japan

Carbon related materials, eg, C60, CNT, diamond, and DLC, have attracted much attention and can be widely used in practical engineering fields. Synthesis of the carbon materials by chemical vapor deposition (CVD) have been considered as one of synthesis methods toward mass production. Carbon nanoballs (CNBs) can be also synthesized by the techniques that are normally used to produce carbon nanotube (CNT). CNBs have been expected to apply polymer composites and biological systems. In the case of application to the polymer composites, it is necessary to tailor the chemical property of the CNBs surface in order to covalently bind the polymer to the CNBs. In order to fabricate the CNBs-polymer composite, it is crucial to establish the surface modification method of the CNBs. In this study, we aimed to fabricate the CNBs by thermal CVD and to chemically introduce carboxylic acid groups to the CNBs surface. Fe-sputtered silicon wafer was used as a substrate. A target of Fe (99.99%) was used as received. A quartz tube in a ringed furnace was used as thermal CVD reactor. The substrate was placed on the center of the quartz tube. Reaction

temperatures were changed from 750 to 990ºC. The source gases were H_2 (100 sccm) and $CH_2=CH_2$ (25,75, 100, and 175 sccm). The samples obtained were characterized by FE-SEM, TEM, and Raman spectroscopy. The introduction of carboxyl groups to CNBs' surface were carried out by chemical wet process and vacuum ultra-violet (VUV) irradiation. The CNBs were successfully fabricated at the temperature of 850 and 990 ºC. Raman spectra showed that the CNBs had two peaks at around 1350 and 1590 cm^{-1}, which correspond to D and G bands, respectively. The carboxyl groups were introduced to the CNBs surface by chemical wet process. The COOH-terminated CNBs were uniformly dispersed in water, ethanol, and acetone.

GR-TuP7 Exposure of Epitaxial Graphene on SiC(0001) to Atomic Hydrogen, *N.P. Guisinger*, National Institute of Standards and Technology, *G.M. Rutter*, Georgia Institute of Technology, *J.N. Crain*, National Institute of Standards and Technology, *P.N. First*, Georgia Institute of Technology, *J.A. Stroscio*, National Institute of Standards and Technology

Graphene films on SiC exhibit coherent transport properties that suggest the potential for novel carbon-based nanoelectronics applications. Recent studies suggest that the role of the interface between single layer graphene and silicon-terminated SiC can strongly influence the electronic properties of the graphene overlayer. In this study, we have exposed the graphitized SiC to atomic hydrogen in an effort to passivate dangling bonds at the interface. We have used scanning tunneling microscopy to investigate the interface surface structure following exposure to atomic hydrogen for a range of sample temperatures. Initial results indicate that regions of clean SiC were successfully passivated with atomic hydrogen below 400 °C, while the underlying interface of the graphitized regions appear to be unchanged for all temperatures studied. The threshold temperature for passivating clean SiC suggest that the passivated dangling bonds are primarily from Si atoms that are present within the SiC surface reconstruction. Although the hydrogen does not appear to penetrate below the graphene layer, initial results suggest that it does adsorb to the graphene.
*This work was supported in part by NSF grant ECS-0404084.

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