Nanotubes: Science and Applications Topical Conference
Room: Exhibit Hall B2 - Session NT-TuP

Poster Session

NT-TuP1 Vertically Aligned Carbon Nanotubulated Fibers Grown by Microwave Plasma-Enhanced Chemical Vapor Deposition, *M. Hiramatsu,* ***K. Ito****, K. Kato,* Meijo University, Japan*, C.H. Lau, J.S. Foord*, University of Oxford, UK

Carbon nanotubes have attracted attention for several applications because of their unique properties such as high field electron emission capability and capacity for the storage of large amount of hydrogen. Carbon nanotubes with different structure and morphology can now be fabricated with several techniques. In the present work, carbon nanotubulated fibers were grown by microwave plasma-enhanced chemical vapor deposition (MWPCVD). These carbon nanotubulated fibers were in the form of the bundles of carbon nanotubes and were aligned perpendicular to the substrate. A mixture of methane and hydrogen was used as a carbon source gas. The applied microwave power and the pressure during the growth were 400-500 W and 25-30 Torr, respectively. The growth experiments were carried out for 5 - 15 min at a substrate temperature of 600 °C or less. The vertically aligned carbon nanotubulated fibers were grown selectively on a patterned Ni thin layer as a metal catalyst prepared on the silicon (100) substrate by electron beam evaporation. The diameters of the grown nanotubulated fibers were approximately 100 nm. Raman spectra for the carbon nanotubulated fibers fabricated were recorded, and the graphitised structure was clearly confirmed from the sharp G-line peak located at 1600 cm^{-1}. The field electron emission characteristics for the vertically aligned carbon nanotubulated fibers were investigated. The onset field of the field electron emission for the carbon nanotubulated fibers was 10 V/µm.

NT-TuP2 STM Investigation of Oxygen Adsorption on Carbon Nanotubes, ***S. Santucci****, L. Lozzi, M. Simeoni, M. Passacantando,* INFM and University of L'Aquila, Italy*, L. Valentini, I. Armentani, J.M. Kenny,* University of Perugia, Italy

Carbon nanotubes, thanks to their electronic and structural properties, are studied for many important applications. One recently interesting application is the gas sensing. In fact it has been shown that the electrical conductance of single-walled carbon nanotubes (SWNTs) can be drammaticaly changed upon exposure to gaseous molecules such as NO2, NH3[1]or O2.[2] These molecules can be adsorbed both at the nanotube surface or can be accepted inside the nanotube.[3] In this work we will present STM/STS data acquired onto multi-walled carbon nanotubes (MWNTs) during the exposure to O2 molecules. The MWNT films have been deposited by plasma enhanced chemical vapor deposition (PECVD) using Ni as catalyst particles on silicon. These samples have been exposed to O2, keeping the sample at different temperatures, in order to simulate the gas sensing processes (adsorption/desorption). The adsorption of O2 determines the variation of STS curves, showing the presence of new states, both filled and empty ones, which can be assigned to the interaction between molecules and MWNTs. These states also depend on the sample temperature, in particular the empty ones. The desorption process has been also followed, showing the missing of the oxygen-MWNT states when oxygen is removed from the STM chamber.

[1] J.Kong, N.R. Franklin, C. Zhou, M.G. Chapline, S. Peng, K. Cho, H. Dai, Science 287 (2000) 622.
[2] P.G. Collins, K. Bradley, M. Ishigami, A. Zettl, Science 287 (2000) 1801.
[3] A. Fujiwara, K. Ishii, H. suematsu, H. Kataura, Y. Maniwa, S. Sizuki, Y. Achiba, Chem. Phys. Lett. 336 (2001) 205. .

NT-TuP3 Synthesis of Single-walled Carbon Nanotubes on Thin Film Catalysts via Chemical Vapor Deposition, ***Y.J. Yoon****, J.C. Bae, H.K. Baik,* Yonsei University, Korea*, S.J. Lee,* Kyungsung University, Korea, *K.M. Song*, Konkuk University, Korea

Synthesis of single-walled carbon nanotubes (SWNTs) via chemical vapor deposition (CVD) has attracted notable attentions due to its low reaction temperature, compared to other processes. It enables SWNTs to be easily applied to electronic devices such as transistors, and chemical sensors. Recently, many researchers have been reported the synthesis of SWNTs on powder supports via CVD. However, synthetic method of SWNTs on flat Si substrates via CVD is not fully established due to the difficulty of catalyst control. The main issue of SWNT synthesis via CVD is the optimization of catalyst preparation. In this paper, to improve a yield and selectivity of SWNTs on patterned Si substrate, the optimization of catalyst was progressed by thermodynamic approaching. Catalysts were prepared by thin film deposition (Co, Ni, Fe, Mo and their alloys) on silicon substrate using D.C. magnetron sputtering system with an accurate thickness controller in angstrom scale. SWNTs were grown by catalytic decomposition of methane and hydrogen gas at the temperature range between 700°C and 1000°C. In order to investigate the formation mechanism of SWNTs, the characterization of nanoparticles and SWNTs by SEM, TEM, and Raman was performed. The nucleation and growth step for SWNTs on various catalysts will be presented by thermodynamic approaching.

NT-TuP4 Experimental and Theoretical Studies on the Gas Adsorption of Multi Walled Carbon Nanotubes Thin Films, ***S. Picozzi****, L. Lozzi, S. Santucci,* INFM, Univ. L'Aquila, Italy*, L. Valentini, I. Armentano, J.M. Kenny,* Univ. Perugia, Italy*, A. Pecchia, A. Di Carlo, P. Lugli,* Univ. Tor Vergata, Italy*, B. Delley*, Paul Scherrer Institut, Switzerland

The special geometry and unique properties of carbon nanotubes (CNT) offer relevant potential applications.[1] In particular, the effects of environment gases (such as O2, NO2, NH3) on the electronic and transport properties of carbon nanotubes have recently attracted great interests.[2,3] To date, the reported theoretical gas sensing studies have been based either on isolated single wall carbon nanotubes (SWNTs) or on SWNT mats. In the present work multi-wall carbon nanotubes (MWNTs) deposited by plasma enhanced chemical vapor deposition have been investigated as resistive gas sensors towards NO2. Experimental findings revealed the chemisorption of oxidizer gas upon the surface of the MWNTs, suggesting that p-type semiconductor behavior is present. The possibility of modulating the electronic properties of nanotubes using adsorption of gas molecules is investigated using first-principles density functional calculations. Transport characteristics are calculated using non-equilibrium Green's functions. The simulations account for the reaction dynamics between the CNT and the adsorbing gas,thus allowing the determination of the preferred adsorption site as well as the calculation of the current flowing along the nanotube as a function of time. The charge transport is dominated by the hopping mechanism across a bundle of several nanotubes. For this reason the influence that the adsorbed molecules have on the hopping rate between adjacent nanotubes has been also investigated. The results elucidate the mechanisms of adsorption and doping of CNTs and its influence on their conduction properties.

[1] M.S.Dresselhaus, G. Dresselhaus and P.C.Eklund, "Science of Fullerenes and Carbon Nanotubes" (Academic, New York, 1996).
[2] J. Kong, N.R. Franklin, C. Zhou, M.G.Chapline, S. Peng, K. Cho and H. Dai, Science 287, 622 (2000).
[3] P.G. Collins, K. Bradley, M. Ishigami and A. Zettl, Science 287, 1801 (2000).

NT-TuP5 Synthesis of Single-walled Carbon Nanotubes without Metal Catalysts by Arc Discharge, ***J.C. Bae****, Y.J. Yoon, H.K. Baik*, Yonsei University, Korea

Since single-walled carbon nanotubes (SWNTs) were discovered, great effort to control the nucleation and growth of SWNTs by selecting the metal catalysts, working pressure, ambient temperature, and feeding methods of carbons. Models proposed for nucleation and growth of SWNTs usually start from the carbon-metal gas phase or carbon-metal cluster. In other words, metal catalysts were believed to be necessary for the formation of SWNTs. In recent, new the technique for the formation SWNTs was reported. This technique did not require a metal catalyst and use as precursor amorphous carbon nano-sized particles generated by laser-induced chemical vapor deposition. In other words, the proper precursors are necessary for the formation of SWNTs, and metal catalysts are not. In arc discharge method, hemispherical fullerenes, which play a role in nucleation of carbon nanotubes, were easily formed in inert ambient. In addition, in case of CVD method flux control of carbon is key factor to determine which type of carbon nanotubes are formed. It indicates that SWNTs can be synthesized without metal catalysts by flux control of carbon in arc discharge. In this work, three types carbon anode were used to control the carbon flux. One was graphite rod (6mm diameter, 70 mm length), another was graphite rod (6mm diameter, 70 mm length) in which a hole (3 mm diameter, 50 mm deep) is drilled, and third was graphite rod (6mm diameter, 70 mm length) in which a hole (3 mm diameter, 50 mm deep) is drilled and filled with pure graphite powders. SWNTs were collected from round the cathode.

NT-TuP6 Field Emission Properties of Nanostructures Based on Molybdenum Ternary Compounds versus Carbon Single Wall Nanotubes, ***M. Zumer****, V. Nemanic, B. Zajec*, Institute of Surface Engineering and Optoelectronics (ITPO), Slovenia*, M. Remskar, A. Mrzel, D. Mihailovic*, Jozef Stefan Institute, Slovenia

As the single wall carbon nanotubes (SWCNT) were recognized as stable emitters for various electron devices, the performance of any new material is well introduced when tested in comparison to them. From several reports on field emission (FE) measurements, it is difficult to eliminate all the experimental parameters that may influence the results. On a short term time scale, the characterization may be presented by the Fowler - Nordheim plot, while the long term behavior can only be presented by real measuring results. We have investigated the FE properties of quasi one-dimensional molybdenum ternary compounds. They were synthesized by a catalytic transport reaction and characterized by conventional microscopic methods. The results of FE measurements were compared to those obtained on commercially available purified SWCNT at identical experimental conditions. All FE measurements were performed in an UHV system at 10^{-9} mbar base pressure. The samples were mounted on the top of metal pins positioned some mm from the aluminized luminescent screen biased as the anode. Current - voltage (I-V) measurements were performed under continuous bias conditions up to 4.5 kV where the resulting macroscopic field reached approx. 0.9 V μm^{-1}. The emission current from a few sites reached a value of some ten micro amps in both cases. The current variation with time was related to onset and disappearance of emission spots of various shapes. The average current initially dropped, but became relatively stable even on the time scale of a few hundred hours for both FE materials studied.

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