21COE Programme: Mechanical Systems Innovation Open Seminar

21COE Programme: The Mechanical System Innovation Seventh Open Seminar 2006 will be held as follows. Participants from any departments will be welcome.

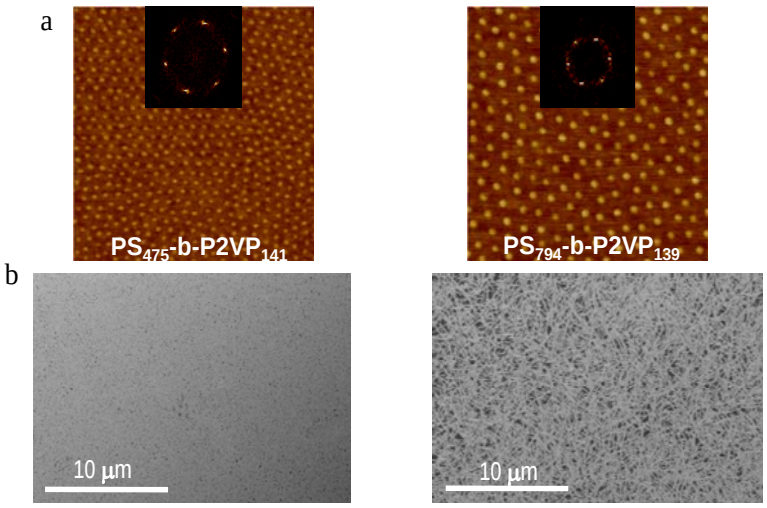
Invited Speaker : Dr. Jennifer Lu, Product development engineer, Microwave Technology Center, Agilent Technologies

Title : Catalytically Active Nanostructures Derived from Self-Assembled Block Copolymer Templates for Rationally Synthesizing Single-Walled Carbon Nanotubes and Understanding the Growth Mechanism

Date & Time: 2nd November 2006, 10:30am～12:00pm
Place: The University of Tokyo, Engineering Building II, 3rd Floor, #33B2 Electronic Engineering Meeting Room

Abstract: Nanostructures such as carbon nanotubes(CNTs) have demonstrated great technological promise. Burgeoning efforts in development of devices that utilize their remarkable properties have been sprouted. However, these efforts have achieved limited success to date largely due to the lack of precise control of properties and placement of CNTs. Developing robust synthesis methods to generate well-defined and defect-free CNTs is critical for understanding their physical properties and the key for bringing their highly touted properties into fruition. Employing self-assembled polymer templates, a variety of highly ordered catalytically active transition metal nanostructures, ranging from single metallic nanoparticles of Fe, Co, Ni, and bimetallic nanoparticles such as Ni/Fe and Co/Mo to Fe-rich silicon oxide nanodomains with uniform size and spacing have been successfully synthesized. These nanostructures have been demonstrated to be excellent catalyst systems for the synthesis of high-quality and single-walled CNTs with narrow size distribution. Because these catalytically active nanostructures are uniformly distributed and do not agglomerate at high growth temperatures, uniformly distributed CNTs have been obtained. In addition, the size and spacing of catalytically active nanostructures can be modified by tailoring the block length of the block copolymer templates. The density and diameter of CNTs can be adjusted accordingly as displayed in Figure 1. More significantly, these self-assembled catalyst-containing block copolymer systems are fully compatible with conventional photoresist patterning methods. Combining this bottom-up self-assembly of catalyst-containing block copolymers either in solution or thin film with the conventional top-down microfabrication processing, lithographically selective growth of CNTs on a surface or suspended across a trench has been attained. This facile method of

producing well-controlled catalyst-containing nanostructures greatly enhances the manufacturability of CNTs, thus facilitating the fabrication and commercialization of CNT-based devices. Examples of CNT-based devices for electronic and biological applications will be presented.The ability of this self-assembled block copolymer approach to control the catalyst-containing nanostructure at the nano-, micro- and macro-scales has enabled the study of the growth mechanism. It has been found that the growth condition for defect-free CNTs is sensitive to catalyst size. A specific sized catalyst has its own unique set of growth conditions for producing CNTs with a minimum amount of amorphous carbon. This finding points out the importance of uniform-sized catalyst-containing nanostructures for achieving consistent and high quality CNTs. It has also been discovered that the catalyst support plays an important role. The mean diameter and overall yield of CNTs vary greatly from substrate to substrate. Uniformly sized and highly ordered catalyst nanoparticles have been also used to investigate the effect of carbon stock feeding rate on the density and diameter of CNTs as shown in Figure 2. Establishing the correlation between CNT growth conditions such as carbon stock feed rate and catalyst size and understanding the effect of catalyst support will shed light on the CNT growth mechanism. This in turn will help to develop a rational synthesis method. If time permits, small-sized and uniform-diametered silicon nanowires synthesized from Au nanoparticles prepared by block copolymer surface micelle templates will be presented. Future research directions will be discribed during the presentation.



	Nanoparticle size (nm)	Nanoparticle Spacing (nm)	CNT diameter (nm)	G/D
PS_{475}-b-$P2VP_{141}$	2.2 (±0.2)	45	1.1(±0.4)	9
PS_{794}-b-$P2VP_{139}$	3.8 (±0.3)	71	1.7(±0.5)	16

Figure 1. (a) AFM height images of cobalt nanoparticles. (1 by 1 μm scan size, 10 nm in height); (b) SEM images of CNT mats; The inset is the summary table including cobalt nanoparticle size, spacing and CNT diameter obtained from AFM height analysis and

Raman analysis results of CNTs.

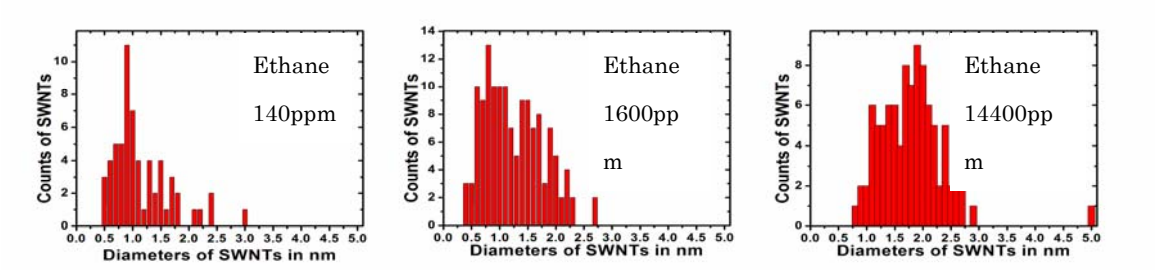


Figure 2. Histograms of diameters of single-walled CNTs grown at different ethane concentrations at 900°C (from left to right, mean diameter is 1.15nm, 1.25nm, 1.83nm, respectively).

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