Effect of the catalyst deposition rates on the growth of carbon nanotubes

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Abstract : Single-walled carbon nanotubes (SWCNTs) were grown on a Si wafer by using thermal chemical vapor deposition (t-CVD). We investigated the effect of the catalyst deposition rate on the types of CNTs grown on the substrate. In general, smaller islands of catalyst occur by agglomeration of a catalyst layer upon annealing as the catalyst layer becomes thinner, which results in the growth of CNTs with smaller diameters. For the same thickness of catalyst, a slower deposition rate will cause a more uniformly thin catalyst layer, which will be agglomerated during annealing, producing smaller catalyst islands. Thus, we can expect that the smaller-diameter CNTs will grow on the catalyst deposited with a lower rate even for the same thickness of catalyst. The 0.5-nm-thick Fe served as a catalyst, underneath which Al was coated as a catalyst support as well as a diffusion barrier on the Si substrate. The catalyst layers were coated by using thermal evaporation. The deposition rates of the Al and Fe layers varied to be 90, 180 sec/nm and 70, 140 sec/nm, respectively. We prepared the four different combinations of the deposition rates of the Al and Fe layers. CNTs were synthesized for 10 min by flowing 60 sccm of Ar and 60 sccm of H_2 as a carrier gas and 20 sccm of C_2H_2 as a feedstock at 95 torr and 810 °C. The substrates were subject to annealing for 20 sec for every case to form small catalyst islands prior to CNT growth. As-grown CNTs were characterized by using field emission scanning electron microscopy, high resolution transmission electron microscopy, Raman spectroscopy, UV-Vis NIR spectroscopy, and atomic force microscopy. The fast deposition of both the Al and Fe layers gave rise to the growth of thin multiwalled CNTs with the height of ~680 μm for 10 min while the slow deposition caused the growth of ~800 μm high SWCNTs. Several radial breathing mode (RBM) peaks in the Raman spectra were observed at the Raman shifts of 113.3~281.3 cm^{-1}, implying the presence of SWCNTs (or double-walled CNTs) with the tube diameters 2.07~0.83 nm. The Raman spectra of the as-grown SWCNTs showed very low G/D peak intensity ratios, indicating their low defect concentrations.

Key Words : single-walled carbon nanotube (SWCNT), thermal chemical vapor deposition (CVD), catalyst, radial breathing mode (RBM)