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Controlled Synthesis of Single-Walled Carbon Nanotubes

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Single-walled carbon nanotubes (SWNTs) have been considered as a promising candidate for next-generation electronics due to its extraordinary electrical properties associated with one-dimensional structure. Since diversity in electronic structure depends on geometrical features, the major concern has been focused on obtaining the diameter, chirality, and density controlled SWNTs. Despite huge efforts, the controlled synthesis of SWNTs has not been achieved. There have been various approaches to synthesize controlled SWNTs by preparation of homogeneously sized catalyst because the SWNTs diameter highly depends on catalyst nanoparticles size.

In this study, geometrically controlled SWNTs were synthesized using designed catalytic layers: (a) morphologically modified Al2O3 supporting layer (Fe/Al2O3/Si), (b) Mo capping layer (Mo/Fe/Al/Si), and (c) heat-driven diffusion and subsequent evaporation process of Fe catalytic nanoparticles (Al2O3/Fe/Al2O3/Si). These results clearly revealed that (a) the grain diameter and RMS roughness of Al2O3 supporting layer play a key role as a diffusion barrier for obtaining Fe nanoparticles with a uniform and small size, (b) a density and diameter of SWNTs can be simultaneously controlled by adjusting a thickness of Mo capping layer on Fe catalytic layer, and (c) SWNTs diameter was successfully controlled within a few Å scale even with its fine distribution. This precise control results in bandgap manipulation of the semiconducting SWNTs, determined by direct comparison of Raman spectra and theory of extended tight binding Kataura plot. We suggest that these results provide a simple and possible way for the direct growth of diameter, density, and bandgap controlled SWNTs by precise controlling the formation of catalytic films, which will be in demand for future electronic applications.

Keywords: Single-walled carbon nanotubes