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Diameter-Controlled Synthesis of Discrete and Uniform-sized Single-Walled Carbon Nanotubes using Monodisperse Iron Oxide Nanoparticles Embedded in Zirconia Nanoparticle Array as Catalysts

*Sangjin Han, Taekyung Yu, Jongnam Park, Bonil Koo, Jin Joo, and Taeghwan Hyeon**

National Creative Research Initiative Center for Oxide Nanocrystalline Materials and School of Chemical Engineering, Seoul National University, Seoul 151-744 (Korea)

Single-walled carbon nanotubes (SWCNT) have been intensively investigated for their possible applications in nanoscale electronic devices such as single electron transistors and light emitting diodes. For these applications, synthesis of discrete and uniform SWCNTs is critical because their electronic properties depend on diameters and helicity.

Here we would like to report on the synthesis of discrete SWCNTs with uniform diameters of 3.0 nm and 1.8 nm using binary arrays composed of monodisperse 2.0 nm zirconia nanoparticles and monodisperse iron oxide nanoparticles with particle sizes of 3.3 nm and 1.8 nm, as catalysts for methane CVD. The agglomeration of iron oxide nanoparticles during the SWCNT growth was prevented by embedding the active catalyst nanoparticles in inactive zirconia nanoparticle matrix.

The overall synthetic procedure is described in Scheme 1. Monolayer array composed of iron oxide and zirconia nanoparticles on oxidized silicon wafer was generated using Langmuir-Blodgett (LB) trough. Fig. 1 exhibited the TEM image of the mixture of nanoparticles of iron oxide and zirconia deposited on a silica-coated molybdenum grid after the CVD process. It was clearly observed that iron oxide nanoparticles were well separated and scattered among zirconia nanoparticles, and the size uniformity of iron oxide nanoparticles was preserved even after the CVD process. Fig. 2 shows AFM image of AFM images of SWCNTs grown on binary arrays consisting of 3.3 nm iron oxide and 2.0 nm zirconia nanoparticles deposited on SiO_2/Si wafer. When we deposited iron nanoparticles on SiO_2/Si wafer via simple spin coating, extensive agglomeration of iron oxide nanoparticles occurred, resulting in CNTs with broad diameter distribution. Fig. 4a showed the AFM image of SWCNTs grown on 1.8nm iron oxide deposited on SiO_2/Si wafer via spin coating exhibiting abundant SWCNT well-grown on SiO2/Si wafer. However, the resulting diameter distribution (Fig. 4b) had much broader (4.0 ± 1.3nm) and disagreed with the size of used iron oxide nanoparticle. These results demonstrated that our idea is very effective for preventing the agglomeration of iron oxide nanoparticle resulting in narrow diameter distribution of SWCNT.

Reference

1. Sangjin Han, Taekyung Yu, Jongnam Park, Bonil Koo, Jin Joo, and Taeghwan Hyeon* *J. Phys. Chem. B* **2004,** *in press*

Scheme 1. Schematic representation of the synthetic procedure. (1) LB deposition of binary nanoparticle array, (2) Calcination to remove surfactant, (3) CH_4 CVD process.

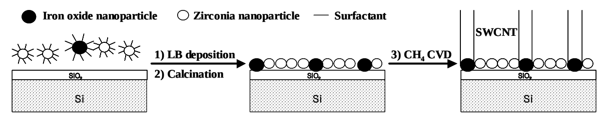

Figure 1. TEM image of binary array consisting of 3.3 nm iron oxide and 2.0 nm zirconia nanoparticles deposited on SiO_2/Mo grid after CH_4 CVD.

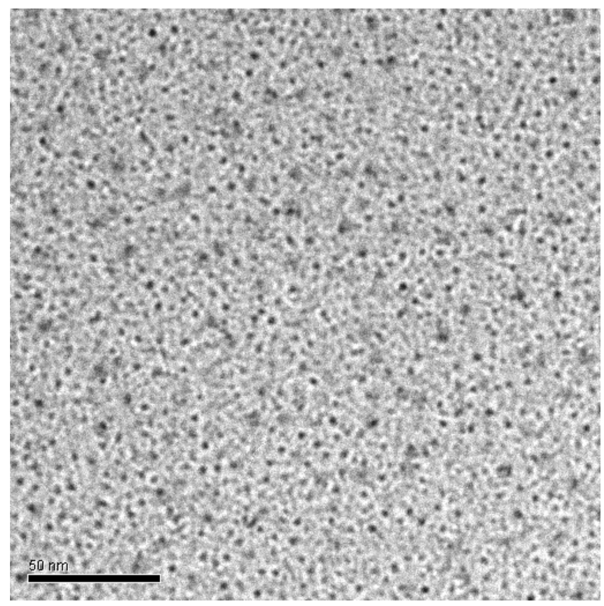

Figure 2. AFM images of SWCNTs grown on binary arrays consisting of 3.3 nm iron oxide and 2.0 nm zirconia nanoparticles deposited on SiO_2/Si wafer.