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Structural Variations in Boron-Doped Single Wall Carbon Nanotubes

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The possibility of substitutional doping in carbon nanotubes (CNT) to manipulate their electronic properties for use in molecular electronics and sensors has created considerable interest [1-3]. Doped CNTs offer the opportunity to understanding dopant-iduced perturbations on physical properties in one-dimensional materials, and to exploiting their unique properties in these nanotechnologies. The feasibility of tailoring structural and electronic properties of CNTs by using boron and nitrogen have been reported [1-3]. Boron and nitrogen dopants are of particular interest because of these expected modifications of the electronic properties of CNTs. Controlling the concentration of nitrogen atoms in the carbon lattice can be useful to tune the conducting properties of single wall carbon nanotubes (SWCNTs) by *in situ* doping. The substitution of boron in the carbon lattice is expected to increase the hole-type charge carrier concentration, thus influencing the conductivity.

We have carried out a systematic study to dope single wall carbon nanotubes (SWCNTs) with varying amounts of boron using the pulsed laser vaporization technique. Targets containing boron concentrations, varying from 0.5 to 10 at % boron, were prepared by mixing elemental boron with carbon paste and Co-Ni catalysts. The products were examined by atomic resolution electron microscopy, nano-electron energy loss spectroscopy (nano-EELS), thermoelectric power (TEP) measurements and Raman scattering experiments. Electron microscopy and Raman studies have revealed that the concentration of boron in the targets greatly affects the type of product. SWCNTs were found in the products prepared from targets containing up to 3 at % boron. While there is no clear evidence of B in SWCNT lattice using electron spectroscopy measurements (within the detection limit of 0.05-0.1 at %B), the sign reversal in TEP (figure 1) and Raman spectra indicate changes to the electronic structure in the presence of boron. At higher boron concentrations (3.5 at % and higher), there are significant changes in the nanostructure, with the formation of a small concentration of double wall carbon nanotubes (DWCNT) (figure 2) and graphite layers. The absence of SWCNTs at these higher amounts of boron may be attributed to the poisoning of the catalyst particles by boron. With the higher B levels in the target material, B appears to play a catalytic role in the formation of DWCNTs. We have achieved the direct growth of DWCNTs without a Co-Ni catalyst, enabling us to control the nanostructural evolution in doped SWCNTs, using B as the variable.

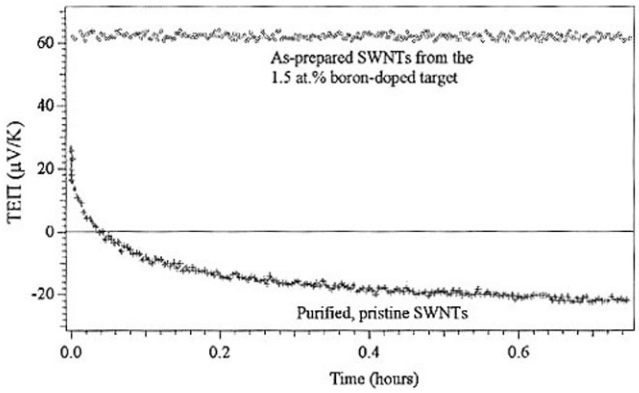

Fig. 1. Comparison of thermopower data for the purified, pristine SWCNTs and the SWCNTs produced from the nominal 1.5 at % boron-doped target. The samples were held in vacuum at 500K.

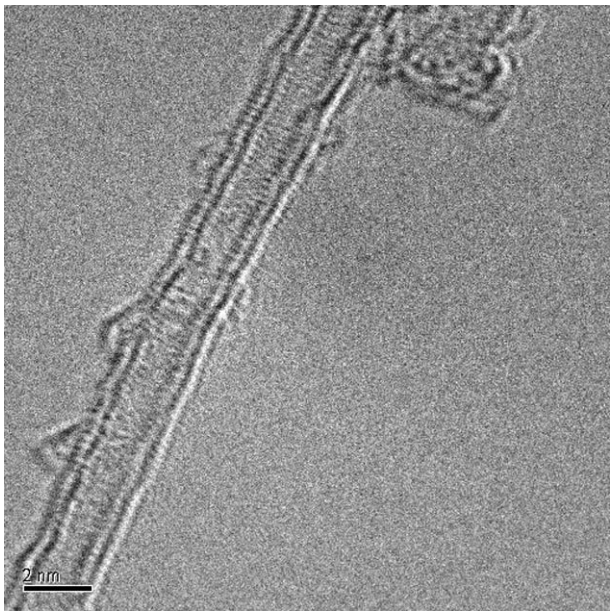

Fig.2. High resolution TEM image of DWCNT in samples produced from more than 3.5 at % boron-doped target. The image also reveals the lattice in the core region.

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