

## XPS and TEM Studies of Co-Mo Catalysts on Quartz Substrates for Growth of SWNTs

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Bimetallic Co-Mo catalysts<sup>1</sup> with a stoichiometry of 1.3–1.6 and a nominal thickness of a few monolayers were prepared on quartz substrates from metal acetate solutions with a dip-coating method. Critical evidences of catalyst chemical state and morphology during calcination and reduction were discovered to understand the mechanism of high selectivity of catalysts exhibited in the growth of high-quality SWNTs<sup>2</sup> during the alcohol catalytic chemical vapor deposition process.

The results<sup>3</sup> showed that the calcination in air at 400 °C decomposes metal acetates to metal oxide species. The excess CoO exists as nano-sized wetting particles either dispersed on or attached to CoMoO<sub>x</sub> underlayers/boundaries. After treatment in hydrogen up to 800 °C, CoO is reduced to metallic Co which forms well-dispersed partially de-wetting Co particles with a number density of  $\sim 1.3 \times 10^{17} / \text{m}^2$  and a diameter of 1–2 nm, as shown in Fig. 1. It is proposed that CoMoO<sub>x</sub> underlayers are formed at catalyst/SiO<sub>2</sub> interfaces, which stabilize these nano-sized metallic Co particles from agglomeration into large ones by limiting their mobility. These well-dispersed nano-sized Co particles directly confirmed in TEM image correlate well with the selective growth of high-quality SWNTs with diameters of 1.1–1.7 nm.

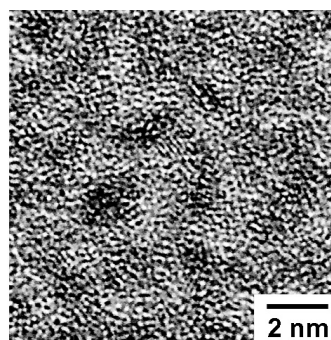


Fig. 1. TEM image of reduced Co-Mo catalysts

This study reveals that the stable existence of well-dispersed nano-sized catalytic metal particles is indispensable for the highly selective growth of high-quality SWNTs in CVD process.

[1] Y. Murakami, Y. Miyauchi, S. Chiashi and S. Maruyama, Chem. Phys. Lett., **79**, 377 (2003)

[2] Y. Murakami, S. Chiashi, Y. Miyauchi, M. Hu, M. Ogura, T. Okubo and S. Maruyama, submitted to Nature Mater.

[3] M. Hu, Y. Murakami, M. Ogura, S. Maruyama and T. Okubo, submitted to J. Phys. Chem. B.

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