

Time resolved in-situ TEM observations of Carbon Nanotube growth

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Carbon nanotubes have a unique place in electron microscopy since their discovery by Iijima. They are typically produced by three methods, laser ablation, the arc and by chemical vapour deposition (CVD), usually involving a transition metal catalyst. CVD is most important because it used for industrial scale production, and also on surfaces, for making nanotubes for electronic devices [1]. However, the growth process is not well understood at an atomic level. We have studied the catalyst activation and nucleation of carbon nanotubes using in-situ time resolved transmission electron microscopy, using realistic catalysts and realistic growth conditions and pressures [2]. The catalyst activation is found to consist of a de-wetting of thin layer metal from an oxide support to form nano-crystallites. The catalyst is found to be solid and metallic under our conditions. Nucleation occurs by the formation of a carbon layer cap above the nano-particle which then grows into a nanotube. In CVD typically, one tube grows from each nano-particle. The nanotube walls grow tangentially to the catalyst surface. For multiwall nanotubes, the catalyst particle undergoes severe distortions during growth due to stress, but remains solid. Supplementary in-situ XPS studies confirm that the catalyst is in metallic rather than oxide or carbide state [3].

1. J Robertson, *Materials Today* 10 p36 (Jan 2007)
2. S Hofmann et al, *Nanoletters* 7 602 (2007)
3. C Mattevi, S Hofmann, et al, *J Phys Chem C* (accepted)

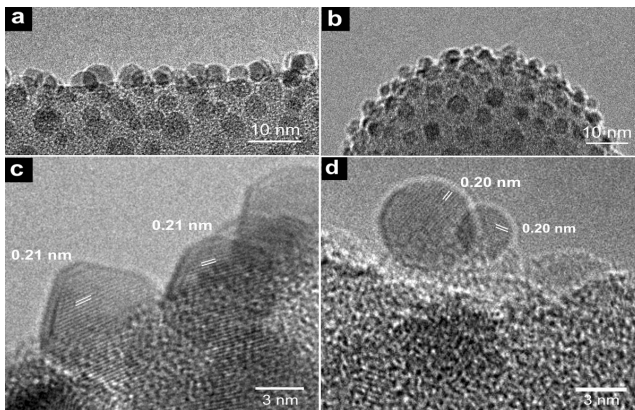


Figure 1. The catalyst restructures into a series of nano-particles in order to be active in growth.

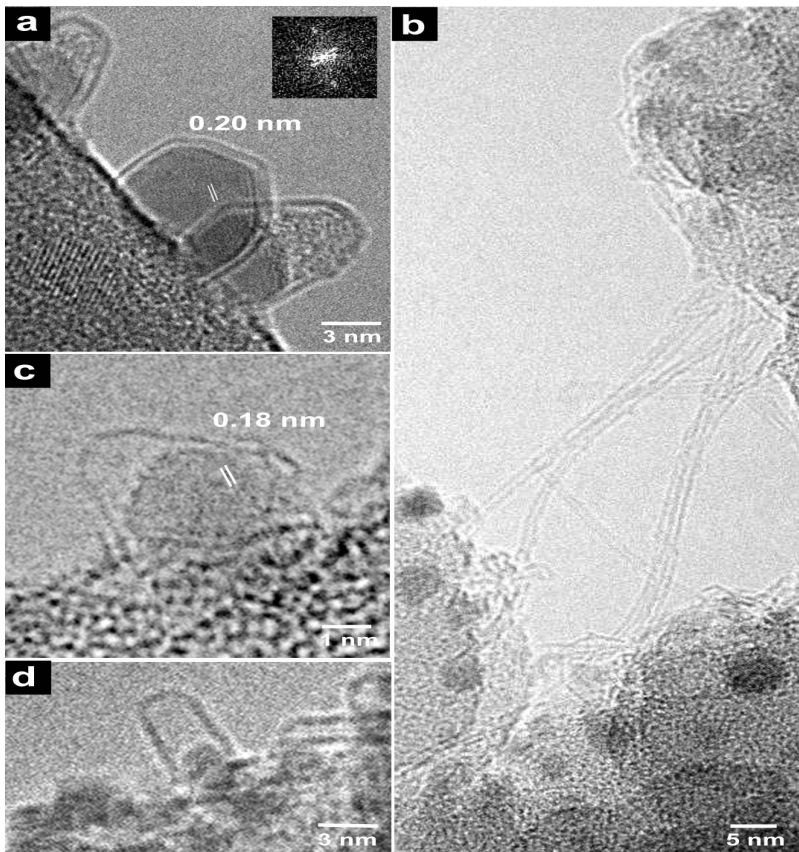


Figure 2. In-situ TEM of nucleating and growing carbon nanotubes.