Diamond Chain-like Nanowires

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One-dimensional structures with nanometer diameters, such as nanotubes and nanowires, have attracted extensive interest in recent years because of their unusual quantum properties and potential applications as nanoconnectors and nanoscale devices. Since the discovery of carbon nanotubes in 1991, various one-dimensional materials have been fabricated. However, until now there has been no report on the synthesis of diamond with nanometer scale one-dimensional structure. Here we report the preparation of diamond nanowires consist of chain-like diamond structure, produced by using hydrogen plasma treatment of carbon nanotubes.

The purified carbon nanotubes were dispersed onto silicon substrates and then were placed into the radio- frequency plasma-enhanced chemical vapor deposition reaction chamber. After the samples were heated to a temperature of about 1000 K, hydrogen was fed into the chamber at a gas flow rate of 50 sccm to maintain the reactant pressure at 150 Pa and plasma with a power density of 0.5 W/cm^2 was initiated simultaneously. After reaction for several hours, the specimens were cooled down in vacuum.

Fig.1a shows the TEM image of the diamond chain-like nanowires (similar to silicon chain-like nanowires) from the carbon nanotube specimen after treatment in hydrogen plasma at temperature of 1000 K for 10 hours. Instead of ordered concentric graphite sheets of MWCNTs, many nanoparticles were formed on the original carbon nanotube walls after hydrogen plasma treatment. The nanotube hollow structure is reserved to some extent, indicated by two rows of nanoparticle array formed along the carbon nanotube precursor. The ring pattern in the inset of Fig.1a from electron diffraction confirmed the diamond structure of nanocrystallines.

The microstructure of diamond chain-like nanowires was further confirmed by HRTEM observation. Fig.1b gives a lattice image of a nanowire, in which the core-shell structure is clearly visible. The crystalline core is wrapped in an amorphous outer layer with an atomically sharp interface. The spacing between the parallel fringes of the crystalline core was measured to be about 0.21nm, which is equal to the spacing of {111} planes of crystalline diamond. These nanocrystals are connected by an ultrathin amorphous carbon layer. If the nanowires form a closely aligned network on a substrate, we can simply estimate that a nucleation density above 10^{11} nuclei/cm^2 is achievable. To the best of our knowledge, current nucleation density achieved is about 10^{10} nuclei/cm^2, which is one order of magnitude lower than our current nucleation density. High-density and large area diamond nucleation is the basis for growing high quality diamond films. The present method of hydrogen plasma treatment has great potentials for the preparation of high quality diamond films in a more controllable way. In addition, combining diamond negative electron affinity, high nucleation site density and nanosize effect, this kind of chain-like diamond nanowires is expected to possess more excellent properties than other nanowires for numerous important applications, especially in field emission.

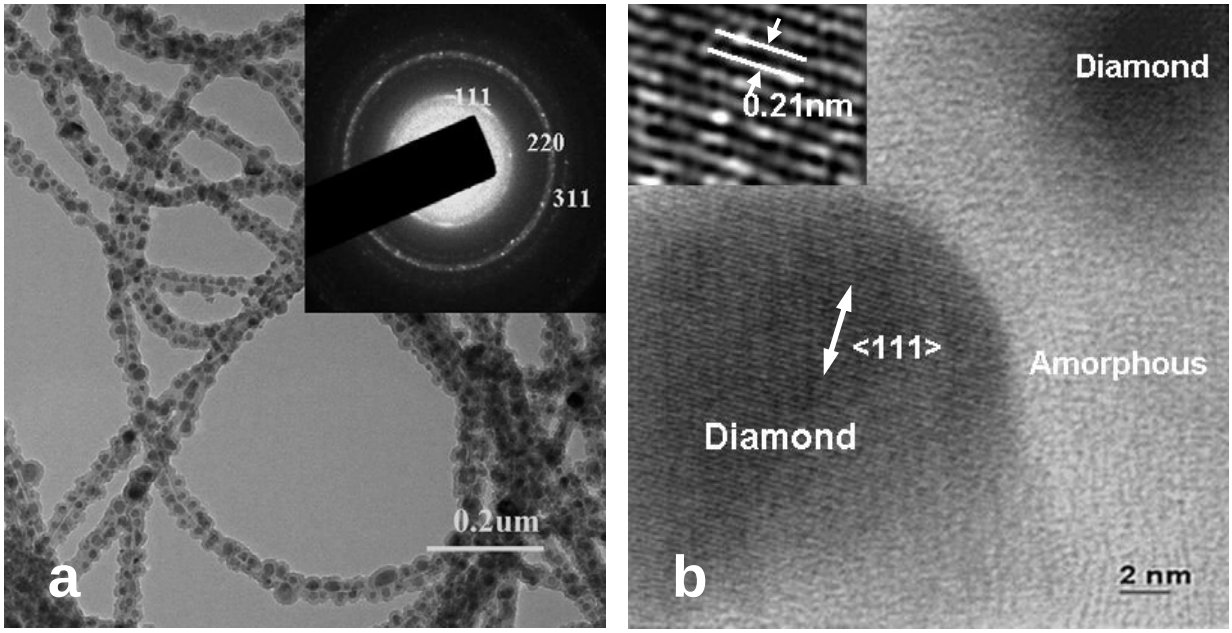

Figure 1 TEM image of hydrogen plasma treated MWCNTs. (a), Low magnification image shows the diamond crystallites embedded in amorphous carbon clusters and partial reservation of CNT hollow structure. (b), HRTEM image shows the diamond (111) lattice planes with a d-spacing of 0.21 nm. The inset in is the simulated image of the nanocrystals after image filter processing by Fourier transform.