PROJECT FACTS

UNIVERSITY OF KENTUCKY
CENTER FOR APPLIED ENERGY RESEARCH

Morphological Control of Tapered and Multi-Junctioned Nano-Tubular Carbon Structures

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Carbon nano-structures are very promising for potential catalyst applications and the synthesis methods for carbon tubes with larger inner diameters are of enormous interest. We developed a method to engineer different hollow carbon structures, which have interconnected nanostructures to be used for catalysis and nano/micro-fluidics, especially aimed at fuel cells. These new morphologies are shown in the figures below and correspond to varying tapering angles at various lengths of the same tube thus providing new junctions within the same structure. Specifically, the tapering angle could be varied from 0 degrees (straight tube) to approximately 58 degrees with large inner diameters. The coalescence of carbon structures during growth into one structure is quite possible and results in multiple tube junctions.

The experiments are conducted in an ASTeX 5010 microwave plasma reactor on a variety of substrates (molybdenum, graphite and titanium). A thin film of gallium was always applied as catalyst onto the substrates followed by sprinkling of molybdenum powder (3-7 microns) on the gallium film (exposed to 18% H_2/CH_4 plasma at 1100 watts and 40 torr reactor pressure for one hour).

There is a mechanism for varying tapering angle of the carbon tube in-situ: The presence of molybdenum promotes nucleation of carbon at the gallium droplet-molybdenum interface and thus assists in the formation of carbon 'tube' around the gallium droplet. As the carbon tube grows in length, the gallium-carbon interface lifts the gallium droplet by setting up a steady contact angle between the meniscus and the growing carbon wall, thus setting the tapering angle of the overall structure. This process is further advanced by using gallium "nanoweb-precursors." The meniscus angle and the conical angle of the resulting carbon tube are related by the following relationship:

$$\phi = 2\theta - 180^0$$

where ϕ is the conical angle and θ is the contact angle between gallium and the developing interface (Figure 1). The diameter of the tubes is between 200-300 nm (Figure 1). Similar results can be obtained with nitrogen dosing experiments. Oxygen helps control and alter the morphology of the structures during the growth process. The physical impingement of two or more growing carbon tubular structures with gallium at the tips results in spontaneous coalescence of gallium droplets into one bigger droplet, due to strong cohesive forces associated with gallium, forming seamless Y-junctions (Figure 2) with open channelways as shown in HR-TEM (Figure 3).

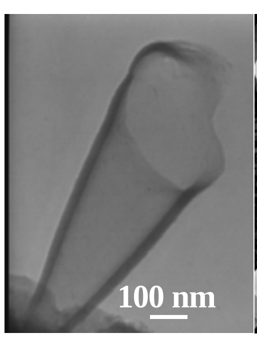

Figure 1

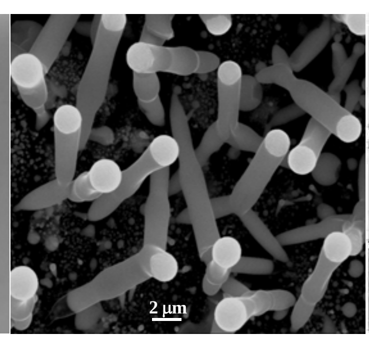

Figure 2

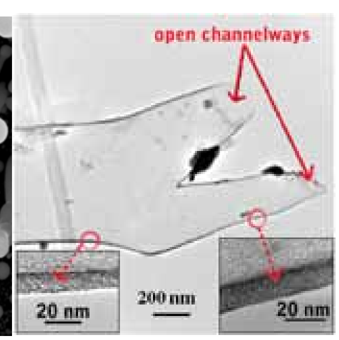

Figure 3