Researchers discover two early stages of carbon nanotube growth

October 3 2011

Boston College researchers have discovered two early-stage phases of carbon nanotube growth during plasma enhanced chemical vapor deposition, finding a disorderly tangle of tube growth that ultimately yields to orderly rows of the nanoscopic tubes, according to a report in the latest edition of the journal *Nanotechnology*.

By using a thin layer of catalyst, Professor of Physics Zhifeng Ren and researcher Dr. Hengzhi Wang discovered two previously overlooked stages of carbon nanotube growth, they report. The method yields a first stage where budding tubes appear randomly entangled, then a second stage of partially aligned tubes, then a third and final stage of tubes in full alignment, which is the standard used by researchers who produce carbon nanotubes for use in a range of materials and biomedical research .

"These growth phases are controlled by the thickness of the catalyst in use," said Wang. "Each stage, it turns out, has its own merit. Each stage has its own purpose."

In plasma enhanced chemical vapor deposition, carbon nanotubes are grown through the repeated accumulation of carbon atoms from the decomposition of gasses upon a catalyst particle, which creates multilayered carbon material on a substrate. Researchers have sought to create neatly aligned rows of millions of carbon nanotubes upon the substrates.

"We didn't know why we were seeing these nanotube configurations," said Ren, among the pioneers in the development of aligned carbon nanotubes. "This is really why you are a scientist. You see a new phenomenon and then you try to understand it."

Ren and Wang say that in the process of achieving the third stage of nanotube growth, the two earlier phases of growth have gone overlooked as each stage is etched away by the next application of plasma. Further masking these early-stage carbon nanotubes is the fact that they are not present when a thick catalyst is used, according to their findings.

The first stage tubes, produced in zero to four minutes, are described as a tangle of random large and small diameter carbon nanotubes. The second stage tubes, created in four to ten minutes, are generally smaller in diameter, but taller and only partially aligned.

Wang says that while these nanotubes are not in neat, orderly rows, they do have the advantage of offer a larger volumetric density and create a larger surface area, which could be an important development in the use of carbon nanotubes in heat transfer in thermal management. A potential application could involve in applying a thin coating of carbon nanotubes to an integrated circuit in order to draw away heat and efficiently cool the device.

After ten minutes of plasma etching, the early stage nanotubes have been washed away and the third stage tubes begin to emerge in tall, ordered rows upon the substrate. At this stage, the tubes themselves are shielded by makeshift "helmets" of catalyst particles, which effectively protect them during the last part of the growth process. Eventually, these last bits of catalyst are etched away as well.

Provided by Boston College