FABRICATION OF CARBON NANOTUBES

FABRICATION

The most common method used to fabricate carbon nanotubes is electric-arc discharge. An electric arc is an electrical breakdown of a gas which produces an ongoing plasma discharge, similar to the instant spark, resulting from a current flowing through normally nonconductive material such as air. The arc occurs in the gas-filled space between two conductive electrodes (often made of carbon) and it results in a very high temperature, capable of melting or vaporizing just about anything. So this process takes place like this: 1) a current is run through an anode, or a positively charged piece of carbon, 2) then this current jumps through a certain type of plasma material to a cathode, or a negatively charged piece of carbon, where there is an evaporation and deposition of carbon particles in through the plasma, 3) finally an outer hard-shell region made of decomposed graphite is formed and an inner core region with loosely packed columns which consist of straight, stiff multishell carbon nanotubes and closed polyhedral particles (also known as carbon nanoparticles). These columns grow at a rate of approximately 1mm per minute on the cathode surface. The best result of carbon nanotubes and nanoparticles from the anode that can be obtained is about 25%. The average temperature in the plasma where the nanotubes are formed is very high at 4000 K (about 6740 degrees F).

To obtain single-shell carbon nanotubes, a catalyst must be added to the evaporated carbon. This catalyst is commonly a metal such as cobalt, nickel, or a mixture of certain other metals. This metal catalyst along with graphite powder is added in a hole drilled through the anode contact (we will see later that this catalyst addition adds to the impurities on the nanotubes). During the arc-discharge, web-like structures are formed around the cooler parts of the electrodes. Within these structures, bundles of 10-100 single shell nanotubes are formed. This particular method is normally very inefficient, but the use of a nickel-yttrium catalyst has improved the efficiency and overall production of single shell nanotubes.

PURIFICATION

Well, the process does not end here; there must be a purification process. This is because about 33% of the carbon clusters produced in the electric-arc discharge do not contain nanotubes with the desired tube-like structure. It has been shown that the tips of these nanotubes are easily destroyed through oxidation, or the addition of oxygen. This occurs because the tips act like nanoparticles which are easily destroyed in higher temperatures (700^{o}C) whereas the tubes are not. This method only gives about less than 1% of pure carbon nanotubes; however, there is a method that gives just less than 40% pure carbon nanotubes. This method is carried out by allowing the oxidation to occur in a solution which slows down the reaction and makes it more uniform.

In the single shell nanotubes, the catalyst materials act as impurities, therefore just raising the temperature and relying on oxidation alone does not work mainly because it destroys the single shell nanotubes. These impurities also function to end the growth of the nanotubes. Therefore there must be several steps of solution-based purification.

GROWTH MECHANISMS

Most of the formation and growth of carbon nanotubes is still theoretical, but the question must be asked, what causes the tubes to stop forming during the electric-arc discharge? The question is still mostly unanswered, therefore scientists are still researching the mechanisms which allow the carbon to form the way it does and how these nanotubes interact with each other during these formations.

REFERENCES

P. M. Ajayan, T. W. Ebbesen, 1997, "Nanometre-size tubes of carbon," Rep. Prog. Phys., Volume 60, pp. 1034-1040.