A

Seminar report

On

Carbon Nanotubes

Submitted in partial fulfillment of the requirement for the award of degree of Mechanical

SUBMITTED TO: **SUBMITTED BY:**

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Preface

I have made this report file on the topic **Carbon Nanotubes** , I have tried my best to elucidate all the relevant detail to the topic to be included in the report. While in the beginning I have tried to give a general view about this topic.

My efforts and wholehearted co-corporation of each and everyone has ended on a successful note. I express my sincere gratitude to …………..who assisting me throughout the prepration of this topic. I thank him for providing me the reinforcement, confidence and most importantly the track for the topic whenever I needed it.

Introduction

Over the past several decades there has been an explosive growth in research and development related to nano materials. Among these one material, carbon Nanotubes, has led the way in terms of its fascinating structure as well as its ability to provide function-specific applications ranging from electronics, to energy and biotechnology Carbon nanotubes (CNTs) can be viewed as carbon whiskers, which are tubules of nanometer dimensions with properties close to that of an ideal graphite fiber. Due to their distinctive structures they can be considered as matter in one-dimension (1D).

In other words, a carbon nanotube is a honeycomb lattice rolled on to itself, with diameters of the order of nanometers and lengths of up to several micrometers. Generally, two distinct types of CNTs exist depending whether the tubes are made of more than one graphene sheet (multi walled carbon nanotube, MWNT) or only one graphene sheet (single walled carbon nanotube, SWNT). For a detailed description on CNTs please refer to the article by Prof. M. Endo.

What are Carbon Nanotubes ?

Carbon nanotubes are fullerene-related structures which consist of graphene cylinders closed at either end with caps containing pentagonal rings.

History

- 1952 L. V. Radushkevich and V. M. Lukyanovich
  - 50 nm MWCNT Published in Soviet Journal of Physical Chemistry
  - Cold War hurt impact of discovery
  - Some work done before 1991 but not a “hot” topic
- 1991-1992 The Watershed
  - Iijima discovers MWCNT in arc burned rods Mintmire, Dunlap, and White‘s predict amazing electronic and physical properties
- 1993 Bethune and Iijima independently discover SWCNT
  - Add Transition metal to Arc Discharge method (same method as Bucky Balls)

Applications

Today, carbon nanotubes find application in many different products, and researchers continue to explore creative new applications.

Current applications include:

- Bicycle components
- Wind turbines
- Flat panel displays
- Scanning probe microscopes
- Sensing devices
- Marine paints
- Sports equipment, such as skis, baseball bats, hockey sticks, archery arrows, and surfboards
- Electrical circuitry
- Batteries with longer lifetime
- Electronics

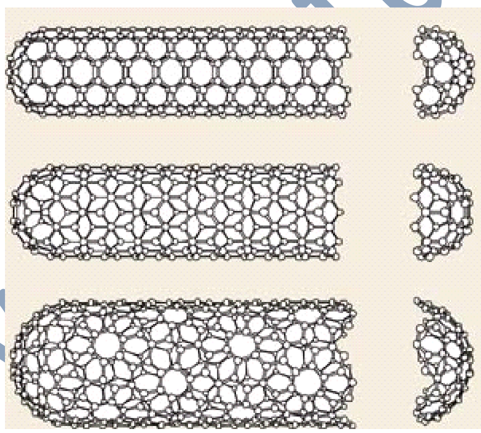
Uses

Future uses of carbon nanotubes may include:

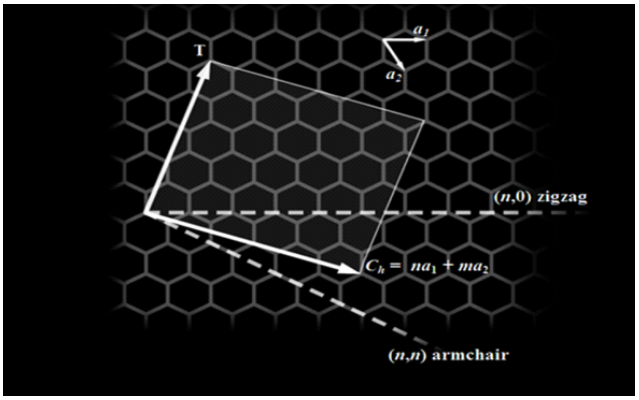
- Clothing (stab proof and bulletproof)
- Semiconductor materials
- Spacecraft
- Space elevators
- Solar panels
- Cancer treatment
- Touch screens
- Energy storage
- Optics
- Radar
- Biofuel
- LCDs
- Submicroscopic test tubes

STRUCTURE

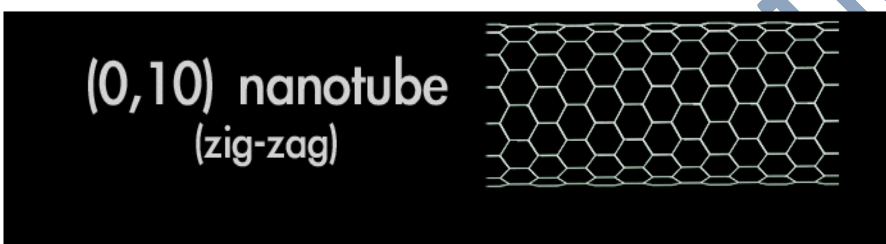
- Folded version of two dimensional graphite sheets
- Depending on the dimension of the graphite sheet and type of folding, different types can be created
- Sidewalls consist of only hexagonal carbon rings
- End caps are made of pentagons and hexagons of fullerenes



Method to roll the graphite sheet is defined by helicity vector Cn and angle of the helicity.



- Helicity vector Cn=OA=na+mb
- Also called roll up or chiral vector
- (0,n) co-ordination pattern



- One third of this exhibits metallic nature others are semiconducting

Synthesis Methods for Carbon Nanotubes

Arc-Evaporation

Arc-evaporation synthesis, also known as electric arc discharge, has long been known as the best method for synthesizing fullerenes, and it also generates the highest quality carbon nanotubes.

Arc-evaporation apparatus consists of two graphite electrodes under helium. A current of around 50A is passed between the electrodes, causing some of the graphite from the anode to evaporate and condense on the cathode - this deposit contains the carbon nanotubes.

Arc-evaporation with pure graphite electrodes produces mainly multi-wall nanotubes, although single-wall nanotubes can be made by this method by doping the anode with a metal catalyst such as cobalt or nickel.

Whilst the nanotubes produced by arc discharge are of a very high quality, they are mixed with a large amount of amorphous carbon, which makes this technique difficult to scale up.

Laser Vaporization

The laser vaporization (or laser ablation) method was developed in 1995. A pulsed laser is fired at a graphite target in an inert environment, at high temperature and pressure. The target is usually placed at one end of a 50cm quartz tube - the nanotubes are collected at the opposite end.

The shape and structure of the nanotubes produced by laser vaporization are more easily controllable, as they are only affected by a small number of parameters. The yield of carbon nanotubes is also much higher, with very little amorphous carbon produced, but the overall amount generated is very small. This combined with the high operating temperature and pressure make this method highly inefficient for producing large amounts of carbon nanotubes.

Chemical Vapour Deposition (CVD)

Chemical vapour deposition is the method with the most promise for mass production of carbon nanotubes. It operates at much lower temperatures, and produces nanotubes in greater quantities than arc discharge or laser vaporization.

CVD uses a carbon-rich gas feedstock, such as acetylene or ethylene (IUPAC ethyne, ethene). The gas is passed over a metal nanoparticle catalyst (typically iron, nickel, or molybdenum) which has been deposited on a porous substrate (e.g. silica, alumina). Carbon atoms dissociate from the gas molecules as they pass over the catalyst, rearranging on the surface to form nanotubes and fullerenes. This allows nanotubes to be synthesized continuously, making the technique ideal for scaling up to large manufacturing volumes.

The choice of catalyst used for CVD is crucial. Changing the catalyst can entirely alter the quality and yield of the nanotubes produced. The diameter of the carbon nanotubes also depends directly on the catalyst particle size used, as the particles nucleate the growth of the nanotubes.

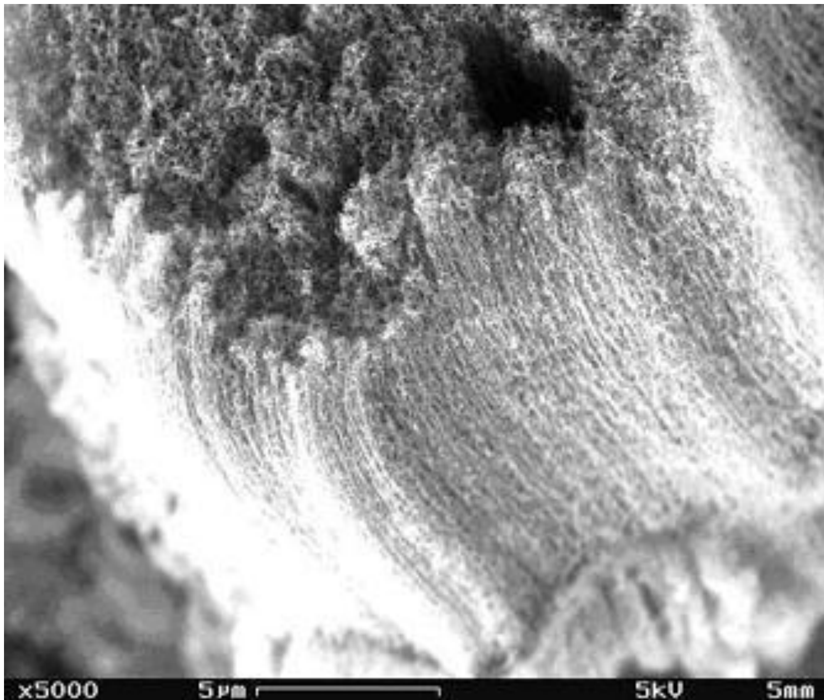
The properties of the substrate used are also important. The substrate material should be able to retain a high surface area and pore volume at high temperatures - carbon nanotubes grow significantly faster on a porous surface, as carbon atoms can move through the substrate to join growing structures.

Optimizing Chemical Vapour Deposition

Of the well-established methods, CVD shows the most promise for larger-scale synthesis of carbon nanotubes. Much research effort has gone into improving the efficiency of the process.

The main problems which this research is attempting to solve are the poisoning of the catalyst surface by the build-up of amorphous carbon, preventing further nanotube growth, and the number of costly and complicated processes which must take place before and after the synthesis step.

- **Water Assisted "Supergrowth" by CVD** can produce high purity, vertically aligned single-walled nanotubes, with lengths up to the millimetre range. This is achieved by mixing a small amount of water vapour into the hydrocarbon gas feedstock. It is thought that this cleans the amorphous carbon away from the substrate, keeping the surface clean and allowing unrestricted growth of nanotubes.
- **Catalytic Pyrolysis** is chemically very similar to CVD, but the preparation and purification steps are significantly simplified. Catalyst particles, or organometallic precursors, are injected into the hydrocarbon (often benzene, toluene, or hexane) stream. The nanotube growth occurs on the reactor wall, or on a specific substrate, which is usually quartz. This generates pure, aligned nanotubes in one step, without the need for separate catalyst/substrate preparation.



Other Synthetic Methods

Several other methods for producing carbon nanotubes have been reported, which are mostly at an early stage of research. Some of these may have the potential to be good mass-production methods, with further development.

- **Diffusion flame synthesis**, with a variety of metal and metal oxide catalysts and support geometries
- **Electrolysis of graphite** in molten lithium chloride under an inert atmosphere
- **Ball milling and annealing of graphite**, catalyzed by iron contamination from the steel milling balls
- **Heat treatment of polyesters** formed from citric acid and ethylene glycol, at 400C in air
- **Hydrothermal treatment of polyethylene** with a nickel catalyst under high pressure
- **Explosive decomposition of picric acid**, in the presence of cobalt acetate and paraffin, produces a high yield of relatively homogeneous, "bamboo-shaped" carbon nanotubes.

Purification of Carbon Nanotubes

Carbon nanotubes are most often produced in combination with a range of fullerenes and amorphous carbon - separating the desirable nanotubes from this other matter can be problematic. Most synthesis methods also produce a range of nanotube sizes and structures. Whilst synthetic methods can be optimized to reduce the degree of purification needed, for demanding applications nanotubes will always need to be cleaned and sorted effectively.

The most common purification methods can recover about 90% of the nanotube yield, and consist of:

- **Dispersion** - sonification of the crude sample along with a detergent
- **Acid reflux** - this step uses large quantities of acid over a very long period of time, usually around 10 hours
- **Micro-filtration** - using a PTFE membrane, usually performed in several steps to achieve the required purity.

Advantages

- Extremely small and lightweight, making them excellent replacements for metallic wires
- Resources required to produce them are plentiful, and many can be made with only a small amount of material
- Are resistant to temperature changes, meaning they function almost just as well in extreme cold as they do in extreme heat
- Have been in the R&D phase for a long time now, meaning most of the kinks have been worked out
- As a new technology, investors have been piling into these R&D companies, which will boost the economy

Disadvantages

- Despite all the research, scientists still don't understand exactly how they work
- Extremely small, so are difficult to work with
- Currently, the process is relatively expensive to produce the nanotubes
- Would be expensive to implement this new technology in and replace the older technology in all the places that we could
- At the rate our technology has been becoming obsolete, it may be a gamble to bet on this technology

Conclusion

Carbon nanotubes are the next step in miniaturizing electronic circuits, replacing silicon transistors and diodes, which are fast reaching the theoretical limits of size and speed of operation. Using CNTs, nanochips can be made with entire circuits on it. Ideal diodes can be made from CNTs, resulting in highly efficient electronic circuits.

References

www.studymafia.org

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