Carbon Nano Tubes and its Applications in the Field of Electronics and Computer Science

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Abstract— With rapid advancement of technology and unlimited quest in the intricate fields of science led man to confront nano tubes. It consists of C60 Fullerenes with tube like structures capped at both ends delivering extraordinary mechanical and electrical properties. It is hard to stress as extremely low turn on for fields and has high current densities. It is also the best emission field emitter for future field emission displays. Can be extensively used for fuel cells and field emission display. We throw a light on the research on nano tubes and it's general applications. In this paper we are focusing and questioning the field of research to ponder for the betterment off life to nano tube.

Key words: Nano tube, Single Electron Transistor, Carbon vapour deposition, Nano-electronics, Super capacitors, Nano probe and sensor

I. INTRODUCTION

Carbon nano tube (CNT) is a new carbon allotrope that was first discovered in 1991 by Dr. Sumio Iijima at NEC. CNT has closed tubular structures consisting of nested cylindrical graphite layers capped by fullerene-like ends with a hollow internal cavity. Carbon nano tube should not be confused with Carbon fibers: In CNTs walls are well graphitized and are parallel to the axis. We can imagine a sheet of graphite (carbon atoms disposed in a honeycomb lattice, graphene) rolling up to form a cylinder. These cylindrical structures are called Carbon Nano tubes. These elongated cylindrical structures ranges from one to several tens of nanometers in diameter and up to several micrometers in length. They can be looked at as single molecules, regarding their small size or as quasi- dimensional crystals with traditional periodicity along their tube axis.

Carbon nano tubes are formed from pure carbon bonds. Pure carbons only have two covalent bonds: sp^2 and sp^3, the former constitutes graphite and the latter constitutes diamond.

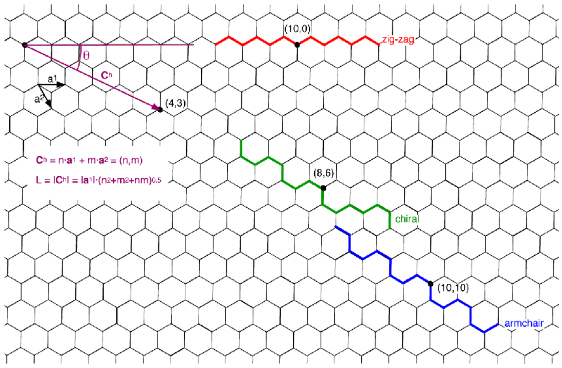


Figure: Structure of graphene sheet

Figure shows the structure of graphite and diamond.sp^2 is a strong bond within a plane but weak between planes. sp2 is composed of one s-orbital and two p-orbitals. When more sp^2 bonds come together, they form six-fold structures, like honeycomb pattern, which is the plane structure, the same structure as graphite. Graphite is stacked layer by layer so it's only stable for one single sheet. That's why graphite is used in pencils. Viewing these layers perpendicularly shows the honeycomb patterns of graphite. Wrapping these patterns back on top of themselves, joining the edges, and close one end while leave one end open, we form a tube of graphite, which is a Nano tube.

II. STRUCTURE OF CNT

In general the nano tubes could be specified in terms of the tube diameter (d) and the chiral angle (ø). The chiral vector (ch) is defined as a line connected from two crystallographic ally equivalent size on a two dimensional grapheme structure. The chiral vector can be defined in terms of the lattice translation indices (n, m) and the basic vectors a1 and a2 of the hexagonal lattice .i.e. ch = na1+ ma2

The chiral angle (ø) is measured as an angle between the chiral vector ch with respect to the zigzag direction (n, 0), where ø = 0° and the unit vectors of a1 and a2. The armchair nano tubes is defined as the ø= 30° and the translation is (n,n). All other types of nano tubes can be identified as pair of indices (n, m) where n≠m.

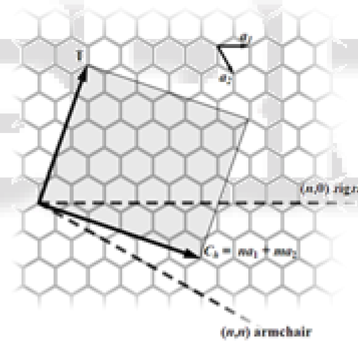


Figure: Vector notation of CNT

III. TYPES OF CARBON NANO TUBE

There are two types of nano tubes existing in nature: single-wall nano tube and multi-wall nano tube. Figure show the structure of single-wall nano tube and multi-wall nano tube. A tube made of a single graphite layer rolled up into a hollow cylinder is called a single-walled nano tube (SWNT); a tube comprising several concentric arranged cylinders is referred to as a Multiwall nano tube (MWNT). Multiwall nano tubes have similar lengths to single walled nano tubes, but much larger diameters. Their inner and outer diameters are around 5 and 100nm respectively corresponding to 30 coaxial tubes. Confinement effects are expected to be less dominant in MWNT than in SWNT because of larger circumference. Many of the properties of multiwall tubes are already quite close to graphite. While, the multiwall nano tubes have wide range of applications, they are less well defined from their structural and hence electronic properties due to many possible numbers of layers.

The properties of SWNT are more stable than MWNT so it is more favorable. SWNT have better defined shapes of cylinder than mwnt, thus mwnt has more possibilities of structure defects and its nanostructure is less stable. Hence, nano tubes are one-dimensional objects with a well-defined direction along the nano tube axis that is analogous to the in-plane directions of graphite Most researchers focus on SWNT and develop applications based on SWNT due the physical stability of SWNT.

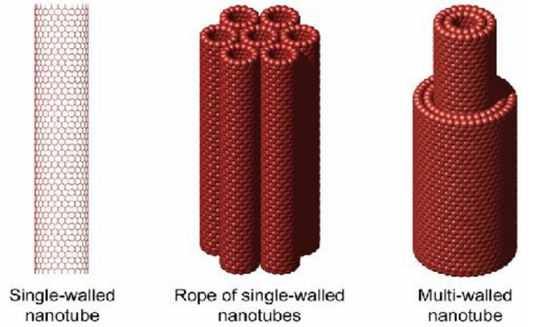


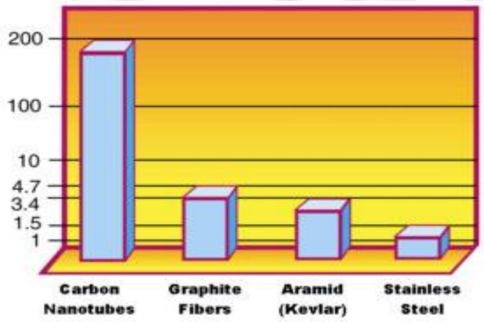
Fig.: Structure of SWNT and MWNT

IV. PROPERTIES OF NANO TUBES

Carbon nano tubes have attracted attention primarily because of their unique structure, and their exotic mechanical, thermal, chemical, and electronic properties

A. *Mechanical Properties*

Two mechanical properties are considered to be important, the stiffness or elastic strength and the tensile strength of the material. The reported value of Young's Modulus for CNTs goes up to 1.26TPa, which is 5 times greater than steel (230 GPa) and tensile strength up to 63Gpa. That means that materials made of nano tubes are lighter and more durable.



The chart compares the tensile strength of SWNT's to some common high-strength materials.

B. *Electronic Properties*

Carbon nano tubes have some distinct electrical properties. One of the important properties of carbon nano tube is that it can exhibit the characteristics of a metal or a semiconductor. Specially, the energy gap is determined by the rolling direction of nano tube. . There is a simple rule to determine if the nano tube acts as a metal or a semiconductor: if (n+m)/3 = integer, nano tube acts as a metal otherwise it acts as a semiconductor. Here chiral vector is denoted by a pair of integers (n, m).

C. *Thermal properties*

The thermal conductivity of carbon nano tubes is dependent on the temperature, current and vacancy concentration. The thermal conductivity of CNTs (2000W/mK) is five times greater than that of copper (400W/mK).

D. *Chemical properties*

Carbon nano tubes are very strong against acid and high temperature because of their perfect conjugated system. Acid and heat are often applied to purify carbon nano tubes. SWNTs are capable of adsorbing hydrogen at ambient temperature and pressure.

V. SYNTHESIS OF CNT

Primary synthesis for SWNT and MWNT include arc discharge, laser ablation etc. Along with gas phase catalytic growth, such as CVD offer greater potential for the scaling up of nano tube production. In electric arc discharge technique, the carbon arc provides a simple tool for generating the temp. needed for the vaporization of carbon atoms in a plasma (>3000°C, electrodes of 50-20 mm dia, 20-25 V across electrode and a DC of 50-120 amps flowing in between). Once the arc is in operation, the carbon deposits on the negative electrode. For MWNT, no catalyst is used while for SWNT, the electrodes are doped with a small amount of metallic catalyst impurity.

Laser ablation employs sequence laser pulses to vaporize a target containing graphite mixed with small amount of Co and Ni. Flowing Argon gas sweets the trapped nano tubes from high temperature zone to cooled collector. High yields with >70-90% were reported in the condensing of the heated flow tube.

A. *Limitations*

Scaling off cannot be done due to size of the carbon source (Anode in arc discharge and graphite target in laser ablation). It also requires subsequent purification steps to separate amorphous carbon and non-tubular substances. Due to them gas phase techniques such as chemical vapor deposition has been motivated. Gas phase growth of SWNT by using carbon monoxide finds highest yields at highest conditions (1200°C, 10 atm). At some places hydrocarbons, acting as carbon source, pyrolize readily on surfaces heated above 600-700°C. CVD methods have been successful to produce the vertically aligned CNTs in large quantities and at relatively low temperature. It occurs at 550°C on Ni coated Si substrate placed parallel to Pd plates as a dual catalyst and a tungsten wire filament. The CNT length increases with the increase in gas flow. Ni-C solid solution, which enables the carbon atoms to diffuse more easily even at low temperatures. The diameter and density of the aligned CNTs are determined by the thickness of the metal films while the length of the tubes can be controlled by varying the CVD reaction time. The CNTs were selectively deposited on the pattern Ni catalyst layer, which is sputtered on Si substrate. Morphology of the nano tubes is strongly influenced by the flow ratio of methane to hydrogen. Defect less nano tubes with small diameters are favorably produced under a small flow ratio.

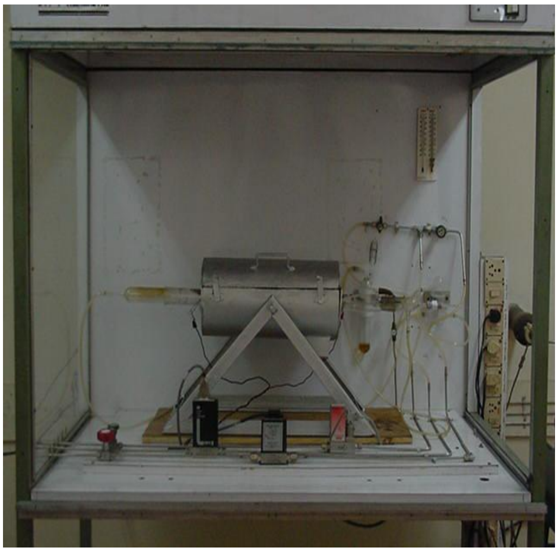


Image of CVD set-up (developed at SSPL.Delhi)

Carbon nano tubes have attracted interest due to there high mechanical strength, hydrogen storage and electron field emitting. In this context, the primary issue is the scale of synthesis and the control of carbon nanostructures

VI. APPLICATIONS

A. *Applications in Fuel Cell Technology:*

Carbon Nano tubes have been suggested for use in Fuel Cell applications,. Carbon nano tubes are anticipated to play a major role in next generation electronic components inclusive of fuel cells. They offer significant advantages over many existing materials due to their exceptional mechanical, electronic and chemical properties.. The efficiency of fuel cells is determined by the electron transfer rate at the carbon electrodes, which is the fastest on nano tubes

B. *Electrochemical Super Capacitors*

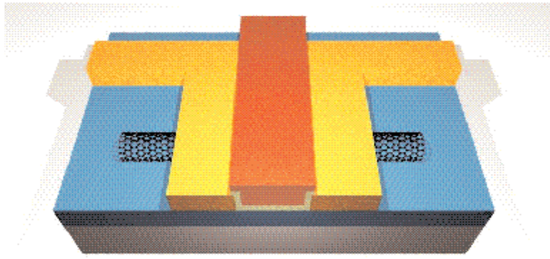
Super capacitors have a high capacitance and potentially applicable in electronic devices. Typically, they are comprised two electrodes separated by an insulating material that is ironically conducting in electrochemical devices. The capacity of an electrochemical super cap inversely depends on the separation between the charge on the electrode and the counter charge in the electrolyte. Because this separation is about a nano meter for nano tubes in electrodes, very large capacities result from the high nano tube surface area accessible to the electrolyte.

C. *Field emitting devices*

If a solid is subjected to a sufficiently high electric field, electrons near the Fermi level can be extracted from the solid by tunneling through the surface potential barrier. This emission current depends on the strength of the local electric field at the emission surface and its work function (which denotes the energy necessary to extract an electron from its highest bounded state into the vacuum level). The applied electric field must be very high in order to extract an electron. This condition is fulfilled for carbon nano tubes, because their elongated shape ensures very large field amplification. For technological applications, the emissive material should have a low threshold emission field and large stability at high current density. Furthermore, an ideal emitter is required to have a nanometer size diameter, a structural integrity, a high electrical conductivity, a small energy spread and a large chemical stability. Carbon nano tubes possess all these properties. However, a bottleneck in the use of nano tubes for applications is the dependence of the conductivity and emission stability of the nano tubes on the fabrication process and synthesis conditions.

D. *Transistors*

The field-effect transistor – a three-terminal switching device – can be constructed of only one semiconducting SWNT.



E. *Top-gated field effect transistor.*

By applying a voltage to a gate electrode, the nano tube can be switched from a conducting to an insulating state.73 A schematic representation of such a transistor is given in Figure 4-1. Such carbon nano tube transistors can be coupled together, working as a logical switch, which is the basic component of computers.

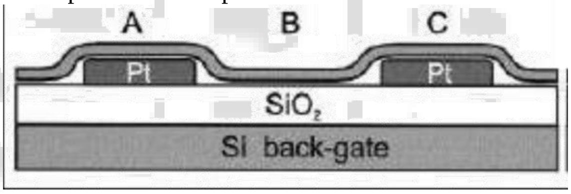


Fig.: A single semi-conducting nano tube is contacted by two electrodes. The Si substrate, which is covered by a layer of SiO2 300nmthick, acts as a back-gate.

F. *Single electron transistor:*

Due to the ability to define nano-scale regions of p or n material on a SWNT scientist have been able to make such a small quantum dot (QD). The properties of such a small doped region are influenced by the quantum mechanical effects of a single electron, The single-electron tunneling (SET) transistor consists of a gate electrode that electro statically influences electrons traveling between the source and drain electrodes. The electrons in the SET transistor need to cross two tunnel junctions that form an isolated conducting electrode called the island. Electrons passing through the island charge and discharge it, and the relative energies of systems containing 0 or 1 extra electrons depend on the gate voltage. At a low source drain voltage, a current will only flow through the SET transistor if these two charge configurations have the same energy

G. *Nano probes and sensors*

Because of their flexibility, nano tubes can also be used in scanning probe instruments. Since MWNT tips are conducting, they can be used in STM and AFM instruments. Advantages are the improved resolution in comparison with conventional Si or metal tips and the tips do not suffer from crashes with the surfaces because of their high elasticity. However, nano tube vibration, due to their large length, will remain an important issue until shorter nano tubes can be grown controllably. Nano tube tips can be modified chemically by attachment of functional groups. Because of this, nano tubes can be used as molecular probes, with potential applications in chemistry and biology.

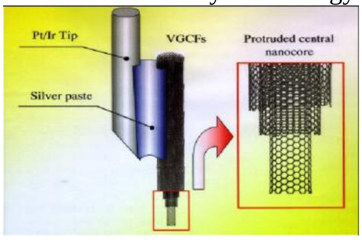


Fig.: Use of a MWNT as AFM tip. VGCF stands for Vapor Grown Carbon Fibre. At the centre of this fibre the MWNT forms the tip.

H. Computer Memory:

One of several revolutionary methods of building futuristic computers involves carbon nano tubes. At Harvard University, A small jolt of electric current bends the top of one nano tube down to meet another and a nano-switch is formed --a switch somewhere in the neighborhood of 100 times smaller than those in current state of the art computers. {The smallest features possible with today's photolithography are about 125 nanometers wide.} In principle-Arrays of these switches could be connected to form a logic circuit that would enable a computer to operate incredibly faster and more efficiently-combining ultra-fast computing power with extremely low electrical requirements. Basically all the information on your current hard drive, AND the computer itself could be compressed into a Dick Tracy style wrist watch. A billion bits of data storage on a chip slightly larger than a freckle.

VII. CONCLUSIONS

Carbon nano tubes have been utilized either individually or as an ensemble to build functional device prototypes, as has been demonstrated by many research groups. Ensembles of nano tubes have been used for field emission based flat panel displays, composite materials with improved mechanical and electromechanical actuators. Bulk quantities of nano tubes have also been suggested for high capacity hydrogen storage media. Individual nano tubes have also been used for field emission sources. Tips for scanning probe microscopy, nano tweezers and chemical sensors. Nano tubes are also promising as the central elements for future miniaturized electronic devices. The successes in nano tubes growth has led to the wide availability of nano tubes material, which is a main catalyst behind resent leaps and bounds in basic physics studies and applications of nano tubes.

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