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Buckypaper

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Abstract

As most promising reinforcement materials for use in high performance composite, the extraordinary high modulus and strength, carbon nanotubes are considered by many researchers. Due to potential applications like in safety, artificial muscles, material science, aerospace and electronics, a thin nano material composed of cylindrical carbon nanotubes called as buckypaper is gaining interest in scientific community. In this paper we will see the structure of carbon nanotubes, synthesis of buckypaper from those carbon nanaotubes and the applications of buckypaper. Because of their phenomenal strength, lightness, as well as electrical and thermal conductivity, the carbon nantubes can solve some of the words greatest problems. Also according to Dynamic mechanic analysis (DMA) nanotube had strong influence on composites damping properties. The research result show that proposed buckypaper/resin infiltration approach can be used for fabricating nanocomposites with controllable nano structure and high SWNT loading. These SWNT are important for developing high performance nanotube-based composites.

Keywords: *Carbon nanotubes, buckypaper, nano-structures, thermal and electrical conductivity*

1. Introduction

Buckypaper is a macroscopic aggregate of carbon nanotubes (CNT), or “buckytubes”. It owes its name to the buckminsterfullerene, which is 60 carbon fullerene (an allotrope of carbon with similar bonding). Depending on the type of nanotube which is defined by its diameter, length and chirality, nanotubes have very broad range of electronic, thermal and structural properties. Carbon nanotube can be thought of as being a sheet of graphite, which is rolled into a cylinder and closed at either end with caps containing pentagonal rings. There are two different classes of nanotubes, they are small diameter, single wall-nanotubes (SWNTs, ~1nm) and large diameter, multi –wall nanotubes (MWNTs, ~10nm). SWNTs are the fundamental cylindrical structure, and can be used as building blocks for both multi-wall nanotubes and the ordered arrays of single- wall nanotubes called ropes. In multi-wall nanotubes, as per the name there are several concentric tubes of carbon, which are nested inside each other.

Carbon nanotubes naturally tends to entangle themselves in to disordered ropes and bundles and thus the principal on which buckypapers is based is the mechanical entanglements of these ropes and bundles which are held together by Van der Waals forces [1]. Also by using Raman Spectroscopy, the buckypaper and nanotubes were characterized. By using phase shift microscope and an atomic force microscope the physical characteristics of multi-wall and single-wall buckypaper were obtained.

2. Literature review

Sumio Lijima discovered carbon nanotube in 1991, at NCE Corporation in Tokyo, Japan. After few years, Richard Smally, a Nobel-Laurete form Rice University, synthesized the first carbon nanotube buckypaper. The thickness of typical buckypaper is of 25 µm. The thermal, mechanical and electrical properties of carbon nanotube buckypaper have been studied extensively. The buckypaper is made from

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carbon nanotubes which are 10 times lighter than steel, and are 250 times stronger than steel. And have electrical conductivity similar to silicon and copper, and also have thermal conductivity higher than that of diamond. But there has yet to be developed an inexpensive and efficient method of mass producing CNTs to make buckypaper. At current position the High Performance Material Institute (HPMI) at Florida State University is leading in optimizing the properties of buckypaper and maximizing the efficiency of buckypaper synthesis process [2].

3. Structure and Properties

The structure of carbon nanotubes affects the properties of buckypaper as a whole, as buckypaper comprises of nanotubes. CNTs are made up of carbon atom, in the form of graphene. In the structure of nanotube, sp2 orbital hybridization is displayed by each carbon atom which accounts for the tensile strength of CNTs.

3.1 Structure of SWNT's

The structure of carbon nanotube can differ. Thus the structures are given in the form of vector: v=$n \times a1 + m \times a2$, in which n and m are integers. And a1 and a2 are unit vectors. Here the integers (n, m) defined a structure of CNTs. In fig: For example if atom at (0,0) was superimposed on the atom at (5,5), we will get a armchair structure, when (0,0) the starting atom superimposed on (9,0), the structure is called as zig-zag structure and if neither of these two cases are their then most commonly seen structure called as chiral structure, occurs, as shown in fig: 2(c)[3].

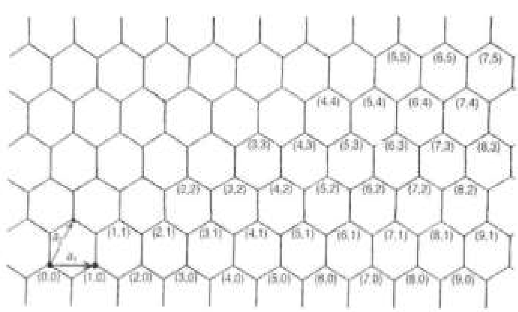

figure: 1

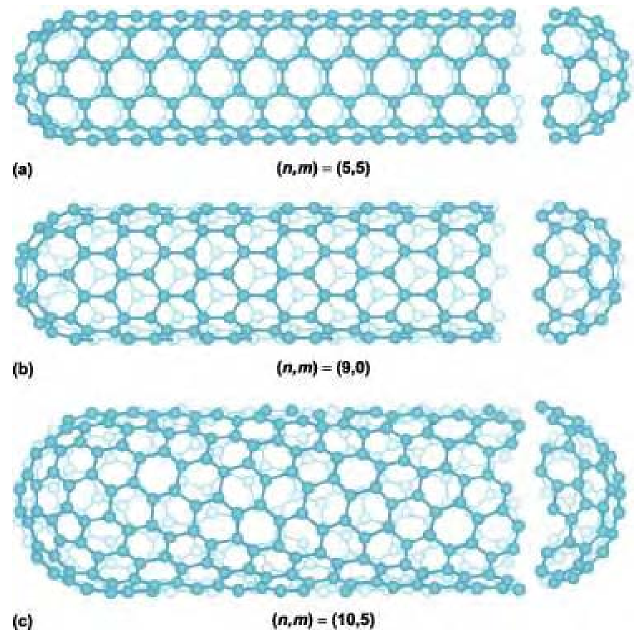

Figure 2: (a) armchair structure (b) zig-zag structure (c) chiral structure

3.2 Structure of MWNT's

As implied by name, multiwall nanotubes have multiple walls. The structure Described above can be used as individual tubes that make up MWNT's. Also there are two ways in which the individual tubes can be oriented, the grapheme sheet wrapped around it and the concentric tubes having different diameters [4].

Table 1: Comparing the elastic modulus and tensile Strength of SWNTs and MWNTs with other Materials [5].

Material	Tensile Strength (GPa)	Young's modulus (GPa)
Single wall nanotube	150.000	1054.000
Multiwall nanotube	150.000	1200.000
epoxy	0.005	3.500
Wood	0.008	16.000
steel	0.400	208.000

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4. Properties of carbon nanotubes:

4.1 Young's Modulus and Tensile Strength

A carbon nanotube is a six-membered, aromatic carbon ring, where each carbon atom in the structure contains a double bond and two single bonds. Therefore sp2 hybridization is present in each carbon atom. These covalent sp2 bonds are responsible for the phenomenal tensile strength of CNTs, because carbon-carbon double bond (146 KJ/mol) has greater bond energy than that of carbon-carbon single bond (83 KJ/mol). Tensile strength can be defined as the maximum stress a substance can withhold without stretching or breaking. Young's Modulus is a measure of stiffness. It is also known as elastic Modulus, and CNTs have a significantly higher Young's Modulus than other materials [6].

4.2 Thermal and Electrical conductivity:

The carbon atoms have sp2 hybridization orbitals. Hence Π bonds form. Electrons in the aromatic carbon ring are able to move freely because of the resonance structures in the aromatic carbon ring. SWNTs can be classified as either semiconductors or metals depending on their defining integers (n, m).If n=m (armchair structures), the nanotube acts as a metal. CNTs which are having other structures behave as a semiconductor.

For semiconductors to conduct electricity, it is necessary to excite electrons from valance band in to conduction band. Band gap is nothing but the amount of energy required to make that electron jump to conductive band. If n-m is multiple of 3, then carbon nanotube acts as a semiconductor with small band gap, else SWNT will be a moderate semiconductor.

CNTs are also good thermal conductors, when conductivity of SWNT is compared with conductivity of copper, a known thermal conductor with conductivity of 385 W/mk, it is found that SWNT are noteworthy thermal conductors with conductivity equal to almost 3500 W/mk [7].

Table 2:

	SWCNT Buckypaper	MWCNT Buckypaper
Volume fraction of CNTs in the Buckypaper	16.5%	8.9 %
Mean Diameter	68 ± 25 nm (Bundles)	30 ± 5 nm
Buckypaper thickness	67 ± 4 lm	72 ± 4 lm

5. Applications

1) Buckypaper are composed of tube shaped carbon molecules, which are 50,000 times thinner than human hair. Because of its unique properties, it is envisioned as a wondrous new material for energy efficient aircraft, automobiles and light, improved TV screens, powerful computers and many other products.
2) Buckypaper is potentially 500 times stronger than steel but yet 10 times lighter, when sheets of it are pressed and stacked together to form a composite. It can also disperse heat like steel or brass and conducts electricity like copper or silicon.
3) Airplane manufacturers, at present use a network of copper or aluminum foils for covering the wings and fuselage to provide Protection from lightning strikes. But here the main Drawback is of copper, its weight. While Buckypaper weighs only 15% as much as copper, hence buckypaper can replace copper for great savings in weight.
4) As a filter membrane we can use buckypaper to trap micro particles in fluid or in air. Since the nanotubes in buckypaper are insoluble and can be used for variety of functional groups, they can act as a sensor or can selectively remove compounds.
5) Buckypaper can be used as electrode material for fuel cell applications.

6. Conclusion and future scope:

Buckypaper Due to Its unique properties is envisioned as a new material for more powerful computers, energy efficient aircraft and automobile, improved TV screens and many more. Buckypaper is 250 times stronger than steel yet 10 times lighter. Discovery of this has lead revolution in the field of Material science and chemistry. Buckypaper produced with multiple filtration and dispersion steps have relatively uniform porous structure and ropes size. This buckypaper can also be functionalized or electrified to encourage growth of specific types of cells and can be used to grow biological tissue, such as nerve cells.

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