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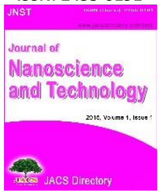

Synthesis and Characterization of Water Soluble Carbon Nanotubes

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ABSTRACT

Water-soluble carbon nanotubes (ws-CNTs) have been synthesized through oxidative treatment of dilute nitric acid with carbon soot obtained by burning mustard oil in insufficient supply of air. Crystallographic, morphological and topographic analyses of ws-CNTs have been studied using powder X-ray diffraction, transmission electron microscope and atomic force microscope respectively. Fourier transform infrared spectroscopy has been performed for confirmation of functional group.

1. Introduction

Carbon nanotubes are special nano-materials discovered by Iijima in 1991 [1]. They have better electrical conductivity than copper, exceptional mechanical strength [2] and high flexibility. These materials are used in chemical sensors, electronic IC circuits, hydrogen storage devices and temperature sensors. The strength of nano tubular materials can be increased by assembling them in the form of ropes of 20-30 nm diameter and several micrometers in length [3].

Initially, the arc discharge was employed to produce carbon nanotubes. This method was known enough and utilized for the synthesis of carbon filaments and fibers. Later on other techniques such as laser ablation or chemical vapor deposition (CVD) were examined in the production of carbon nanotubes. In fact, these are the three main production methods. Some efforts were also made to look for other possibilities to grow nanotubes but these had less success. The cause may be the expensive reaction apparatus, the state or the price of the catalyst material, the strange reaction conditions, e.g., high pressure, temperatures of liquid nitrogen. So, "the old technologies" were improved, adapted to new conditions more than to discover new technologies. Today, the arc discharge [4] and chemical vapor deposition methods [5] are widely applied for the formation of carbon nanotubes. Many studies were made to improve either the quality or the quantity of the produced material by optimizing the synthesis process. As a result some types of CVD method were discovered such as plasma-enhanced, microwave-enhanced, radiofrequency-enhanced CVD.

During the challenge of the wonderful world of carbon nanotubes theoretical studies were also carried out. Their argument is the growth mechanism [6-8] of carbon nanotubes and the possibility of the formation of other nanostructures. It is supposed that the growth mechanism varies slightly from one type of production method to another. It would be nice to discover the key parameters for their formation.

Recently, the research is focused on the application possibilities of carbon nanotubes. Gratefully to their peculiar properties the field of applications is broad and it is opened from electronics, electromagnetic devices, to composite materials and optics, to biomaterials and biomedical devices. Studies in biological and pharmaceutical fields were given where carbon nanotubes can act as a part of biosensors, drug and vaccine delivery vehicles [9-15].

Here in, we report a novel low-cost synthetic route to produce CNT by a simple and age-old method of burning of vegetable oil to prepare fresh carbon soot called 'kajal'. Synthesis of kajal is long known and its use is even mentioned in epics like the Ramayana and the Mahabharata. This kajal on oxidative treatment resulted in the synthesis of water-soluble carbon nanotube (ws-CNT) [16]. These ws-CNTs were structurally characterized by various techniques.

2. Experimental Methods

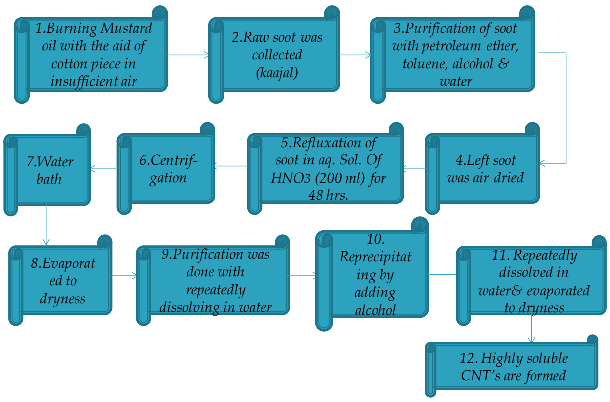

Fig. 1 Synthesis of ws-CNTs

Fig. 1 explains the synthesis of ws-CNTs. Synthesized sample of carbon nanotubes were characterized by powder X-ray diffraction (XRD) (Rigaku Japan, Miniflex 600), transmission electron microscope (TEM) [Hitachi (H-500)], atomic force microscopy (AFM) [Park XE 70] and Fourier transmission infrared spectroscopy (FTIR) [Perkin Elmer -Spectrum RX-IFTIR].

3. Results and Discussion

The recorded XRD spectrum of CNT's in Fig. 2 have full width half maximum (β = 0.1348 radians), average crystallite size calculated using Scherer formula (d = 1.04 nm). The structure of CNT's confirmed after comparing with JCDPS file is diamond cubic with lattice constant $a_{average}$= 6.119 Å.

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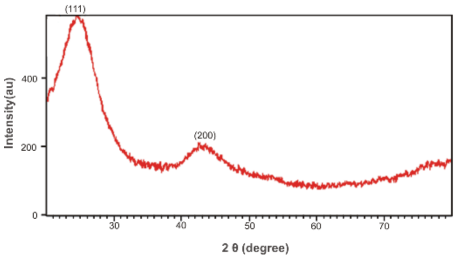

Fig. 2 XRD Spectrum of water-soluble CNT's

Morphology of ws-CNTs is shown by TEM micrographs in Fig. 3. Firstly sonication was performed by dispersing the CNT's into ethanol. After 1 hr sonication a pinch of sample was placed over carbon coated copper grid. Finally, air dried sample mounted on a carbon coated copper grids were loaded in TEM for analysis. It is clear from the recorded TEM micrographs that synthesized carbon nanotubes have some diameter and length. The accelerating voltage for TEM was 90 KV. The magnification power of TEM was 400000 x. The average diameter of water-soluble CNT's is 7.32 nm confirmed by TEM and average length is 85.67 nm.

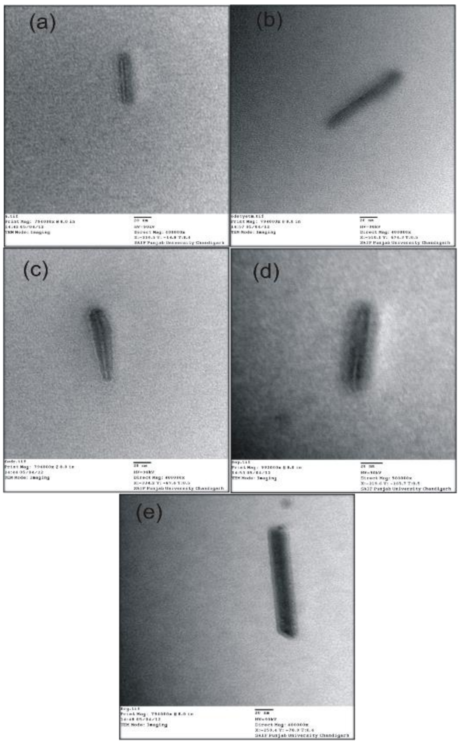

Fig. 3 TEM micrograph of ws-CNT's synthesized by using mustard soot

Table 1 Diameter and length of ws-CNTs from TEM micrographs

Fig. 3	Diameter (nm)	Length (nm)
a	0.72	11.25
b	8.33	108.3
c	4.9	93.3
d	9.33	83.9
e	13.328	131.61

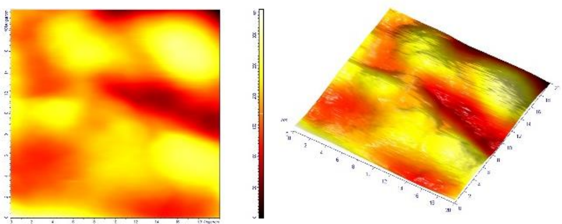

Fig. 4 a) 2D AFM micrograph of ws-CNTs; b) 3D AFM micrograph of ws-CNTs

Figs. 4a and b represent 2D and 3D AFM micrograph of ws-CNTs. The diameter and length of ws-CNTs from AFM micrograph matches with TEM micrograph. Sidewalls of the tube clearly show the presence of defects. These defects were expected because of the introduction of several carboxylic acid group functionalities on the surface of the graphene sheet of the CNT.

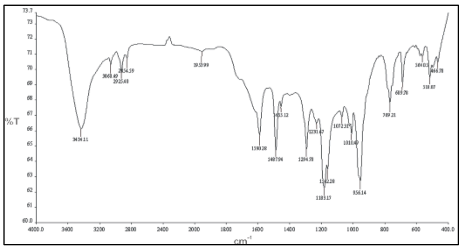

Fig. 5 FTIR Image of ws-CNT's synthesized by using mustard soot

FTIR studies confirm the presence of alcohol group in water-soluble CNT's. In Fig. 5 following peak positions show the presence of alcoholic group.

1. 3434.11 - O-H Stretch
2. 1231.67 - C-O Stretch
3. 1183.17 - C-O Stretch
4. 1162.28 - C-O Stretch
5. 1072.31 - C-O Stretch
6. 1010.49 - C-O Stretch

5. Conclusion

It can be able to show that 'kajal' made by burning mustard oil in a lamp actually contains CNT. The cause of its beneficial use for common eye ailments has not yet been known but may relate to its special structural property. Synthesis methods opted in the present investigation is very efficient method, as it gives high yield, high purity of the final product. This synthesis method is environment friendly; less expensive; less sophistication and very suitable method than other synthesis methods opted for the synthesis of water-soluble CNT's. XRD studies confirm that water-soluble CNT's have diamond cubic structure having average crystallite size 1.04 nm with lattice constant 6.119 Å. Topographic and Morphological analysis performed with AFM and TEM respectively confirm the formation of water-soluble CNT's with average diameter 7.32 nm and average length 85.67 nm. FTIR studies of water-soluble CNT's confirm the presence of alcohol.

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