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Production of Carbon Nanotube

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Abstract

Carbon nanotubes after their discovery in 1991 have become most important material for future applications. They have remarkable mechanical, chemical, thermal, optical, electrical properties hence attracting many researchers and industries. This paper describes methods of synthesis of carbon nanotubes namely arc discharge, Laser ablation and chemical vapor deposition (CVD).Here CVD is proposed as best method for production of carbon nanotubes from industrial point of view as it is relatively simple, energy efficient, inexpensive and gives large scale production of CNTs.

Keywords: *arc discharge, CNTs, CVD, laser ablation*

1 Introduction:

Carbon Nanotubes (CNTs) are nothing however allotropes of carbon with a nanostructure which will have a length-to-diameter quantitative relation bigger than 1,000,000.Due to their novel properties these cylindrical carbon molecules have great application in the field of nanotechnology. Formally derived from the graphene sheet, carbon nanotubes exhibit unusual mechanical properties such as high toughness and high elastic moduli. If we refer to their electronic structure, they exhibit semiconducting as well as metallic behavior and thus cover the full range of properties important from technology point of view .They exhibit extraordinary strength and distinctive electrical properties, and are economic conductors of heat. Carbon Nanotubes are categorized as single-walled carbon nanotubes and multiple walled carbon nanotubes. Their name is de-rived from their size, since the diameter of a nanotube is on the order of a few nanometers (approximately fifty thousand times smaller than the width of a human hair), whereas they will be up to many millimeters long. [1]. Although discovered so many years ago [2-4], first discovery of carbon nanotubes was made by Iijima [5] in 1991.He was working and he found layers of carbon (graphene) rolled into cylindrical structure in the soot of arc- discharge method. The nanotubes made up of many tens of graphitic shells (so known as multi-walled carbon nanotubes (MWCNT)) with adjacent shell separation of 0.34 nm, diameters of 1 nm and high length/diameter ratio. It was the invention of carbon nanotubes within the insoluble material of arc-burned carbon rod by Ilijima that greatly accelerated work on synthesis, production and properties of carbon nanotubes. After two years ijima and Ichihashi at NEC [6], and Bethune et al. [7] at IBM were succeeded in synthesizing Single walled carbon nanotubes (SWCNT) by addition of transition metal catalysts to carbon in an arc discharge in 1993.In 1995 Smalley and co-workers at Rice University synthesized bundles of aligned SWNT with small diameter distribution [8].Similarly catalytic growth of nanotubes by chemical vapor deposition was successfully done by Yacaman et al. [9]. These added significant contribution to the race for devising method of production of carbon nanotubes.

2 Methods of production of CNTs

There are various methods of production of carbon Nano-tubes such as production of nanotubes by laser ablation, arc- discharge, chemical vapour deposition, high pressure carbon monoxide (HiPco), flame synthesis, electrolysis, pyrolysis etc. But they will be mainly classified into following groups/teams.

A) Physical Processes

B) Chemical Processes

A. Physical Processes

1) Arc Discharge method

This is one of the oldest, easiest and most common methods of production of carbon nanotube. First utilized by Iijima [5] in 1991 at NEC's Fundamental Research Laboratory to produce new type of finite carbon structures having needle-like tubes. The needle like tubes was synthesized using an arc discharge evaporation method similar to that used for the fullerene synthesis. The carbon needles, ranging from 4 to 30 nm in diameter and up to 1 mm in length, were grown on the cathode of carbon using the direct current (DC) arc-discharge evaporation of carbon. These CNTs grew in argon atmosphere at 100 Torr. The arc was generated by running a DC current of two hundred ampere at20 V between the electrodes. Three components, namely argon, iron and methane, were critical for the synthesis of SWNT. Carbon soot created as results of arc-discharge settled and nanotubes grew on the iron catalysts contained in negative cathode. The Nano-tubes had diameters of 1 nm with a diameter distribution between 0.7 and 1.65 nm. In a similar method Bethune et al.Thin electrodes with bored holes were used as anodes, which were crammed with a mixture of pure powdered metals (Fe, Ni or Co) (catalysts) and graphite. The current of 95-100 A was running between the electrode and pressure was 100-500 Torr of Helium. SWNT were conjointly created by the variant of arc-technique by Journet et al. [10] as well. In his variant, the arc was generated between 2 carbon electrodes in an exceedingly reaction chamber below inert gas atmosphere (660 mbar). This method also produced large yield of carbon nanotubes. Ebbesen and Ajayan, [11] have reported large-scale synthesis of MWNT by a variant of the standard arc discharge technique also. Thus two kinds of synthesis can be achieved by the arc-discharge method: with or without catalyst to produce MWCNTs and SWCNTs, respectively (Journet and Bernler, 1998).Single-walled Nanotubes are produced when Co and Ni or some other metal is added to the anode. It has been known since the 1950s that carbon nanotubes can also be produced by passing a carbon-containing gas, such as a hydrocarbon, over a catalyst. The catalyst consists of Nano-sized particles of metal, usually Fe, Ni or Co. These particles catalyze the breakdown of the gaseous molecules into carbon, and a tube then begins to grow with a metal particle at the tip [12], [13].

2)Laser ablation

SWCNTs were firstly synthesized by the laser vaporization of a mixture of carbon (graphite) and transition metals located on a target by Guo et al. (1995). In a 1200oC furnace, a pulsed (Yudasaka et al., 1999; Eklund et al., 2002) or a continuous (Maser et al.,1998; Bolshakov et al., 2002) laser is used to vaporize a target which consist of a mixture of graphite and metal catalysts, such as cobalt or nickel, in the presence of 500 Torr (67 kPa) helium or argon gas. According to Scott et al. (2001) the mechanism can be understood as: when the target is vaporized, a cloud of C3, C2, C and catalyst vapours is formed rapidly. As soon as the cloud cools, the carbon species having a small molecular weight then combine to form larger molecules. The gasified catalysts condense slowly and cling to carbon clusters to stop their closing into cage structures. The growth of these molecules continues to form SWCNTs until either the catalyst clusters are too large or until the conditions have cooled (Scott et al., 2001). There are no reports of MWCNT synthesis by the laser-ablation technique. In the case of laser-ablation, the catalyst atoms play a critical role in the mechanism of the growth of SWCNTs. There will be no CNTs synthesized without the catalyst. Laser ablation and arc discharge are nearly same methods, because both use a metalimpregnated graphite target (anode) to make SWNTs, and both produce MWNT and fullerenes when pure graphite is used instead. However, the length of MWNT made through laser ablation is far shorter than that made by arc discharge methodology. Therefore, this methodology does not appear adequate for the synthesis of MWNT. Two new developments in this field are extremist quick Pulses from a free electron laser methodology the continuous wave laser-powder methodology.

B. Chemical method

1) Chemical vapor deposition (CVD)

In 1996 Chemical vapour deposition emerged out as elegant method for large scale production and synthesis of car-bon nanotubes. By using this method we can control growth direction on the substrate and can synthesize a high yield of carbon nanotubes [14]. Basically, chemical vapour deposition is the catalytic decomposition of hydrocarbon with the help of supported transition metal catalysts.

This process is carried out in two steps:-

• The supported Catalyst is deposited on substrate and then nucleation of catalyst is carried via chemical etching or thermal annealing. Ammonia is used as an etchant. Metal catalysts used are Ni, Fe or Co which can be deposited on substrates by means of electron beam evaporation, physical sputtering or solution deposition.

• Carbon supply is then placed in gas innovate reaction chamber. Then carbon molecule is regenerate to atomic level by exploitation energy supply like plasma or heated coil. This carbon can get subtle towards substrate, which is coated with catalyst and Nanotubes grow over this metal catalyst. Carbon supply used is methane, carbon monoxide or acetylene. Temperature used for synthesis of nanotube is in the range of 650 – 9000 C.

The use of the catalyst and preparation of the substrate is the most important factors in CVD, as this substrate will define the nature and type of carbon nanotubes formed. The substrate material can be silicon, glass or alumina. Catalyst particle size decides the nanotube diameter; therefore, the catalyst deposition technique should be chosen carefully to produce desired results. A variant of CVD called 'plasma power assisted CVD' could be a method within which a plasma is generated throughout the method. During plasma assisted CVD, it is possible to grow vertically grown carbon nanotubes by properly adjusting the geometry of reactor. Without plasma carbon nanotubes produced are usually random groups just like bowl of spaghetti. However, underneath sure rigorously controlled conditions even within the absence of plasma vertically aligned carbon nanotubes resembling that of carpet can be made. Currently at University of Califfornia, Berkeley [15] researchers have also reported the assembly of double walled carbon nanotubes from CVD. Success of such type has also been reported at University of California, San Diago [16]. CVD has proven itself as a favored method for the mass production of CNTs [17]. Various CVD techniques used for the production of CNTs include hot-wire (HWCVD), microwave plasma-enhanced (MWCVD), hot-filament (HFCVD), oxygen-assisted, liquid-injection (LICVD) and aerosol-assisted (ACVD)

3 Conclusion

From studies following points can be concluded:

1) Both arc discharge and laser ablation are energy extensive as well as expensive methods.

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2) Carbon nanotubes obtained by arc discharge and laser ablation require purification as they have unwanted form of carbon and catalyst.

3) CVD is inexpensive and gives large scale production.

4) For the production of 1D, 2D, and 3D carbon-based nanomaterial CVD is the most promising technique.

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