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A Brief Review on Recent Development of Carbon Nanotubes by Chemical Vapor Deposition

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Abstract

Development of carbon nanotubes was done by several methods like arc discharge, laser ablation, silane solution, flame synthesis method but the standard or famous technique using chemical vapor deposition (CVD). CVD is one of the approaches to develop CNT, due to easy control of the reaction course and high purity of the obtained materials. Various type of CVD present like thermal CVD, plasma enhanced CVD, or microwave plasma CVD. These kinds of types give the different advantage and drawbacks to the production of CNT and its preparations.

1. Introduction

Carbon nanotube (CNT) is new development material in 1991 by Iijima [1] it is allotropes of carbon with cylindrical nanostructure which is have a diameter in nanometer scale. It was made up from purely carbon and in tube shaped material. CNT have prodigious properties that can cope with various applications. It was alleged high thermal and electrical conductivity. Besides that, it was noticed in previous research for mechanical properties resulting that have high Young Modulus as it is strong double bond. The bending strength of nanotubes is 14 GPa [2].

CNT does not have rigid type, it can be produce in different types which is single wall carbon nanotube (SWCNT) and multi wall carbon nanotube (MWCNT) that drive to a different properties and ways to produce its. The highlighted divergence between these two types is SWCNT is a single layer of graphene while MWCNT is multiple layer of graphene. The illustration of the graphene sheet was in Figure 1.

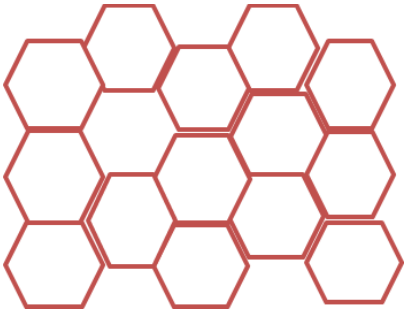

Figure 1: Sheet of graphene.

SWCNT required catalyst for synthesis and not for MWCNT, bulk synthesis was difficult to produce for SWCNT and easy for MWCNT, the purity of SWCNT was poor while high in MWCNT. SWCNT is less accumulation in body while for MWCNT is more accumulation in body. In fact, it was easy to twist for SWCNT and more pliable compared to MWCNT, it cannot be easily twisted. SWCNT was synthesis to growth narrow chirality distribution and large scale production of it's by adding the catalysts [3]. For the clear different in structure between SWCNT and MWCNT was revealed in Figure 2.

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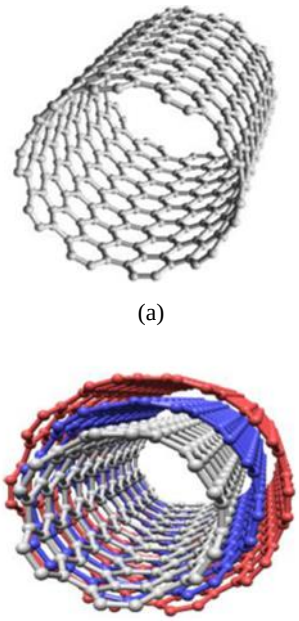

(a)

(b)

Figure 2: Illustrations of (a) SWCNT and (b) MWCNT [4]

2. Properties and Application

MWCNT is suitable use for nano to macro scale application and free standing macroscopic morphologies. Thus, it suitable in application such as fabrication of MWCNT reinforced polymer and ceramic matrix composite [5]. MWCNT shows the unique electrical and mechanical properties. Other potential applications of MWCNT are in field emitter, gas storage and separation, nanoprobes, chemical sensors and high strength composites [6].

CNT have great characteristic like magnetic properties, high thermal and electrical conductivity, low atomic number and high aspect ratio (defined by the ratio of the length to the radius) [7]. According to Cadek et al. [8] and Eder & Eder [9], mechanical properties of CNT due to its strong double bond that resulting the large Young Modulus, double carbon bonds (C=C) are one of the strongest bonds in nature and this CNT composed of perfect arrangement of these bonds.

The small dimensions, high strength, and the remarkable physical properties of its structures make them a very unique material [10]. Highest strength to weight ratio, helps in creating light weight space crafts. Easily penetrate membranes such as cell walls which help in cancer treatment. Electrical resistance changes significantly when other molecules attach themselves to the carbon atoms due widely use in developing sensors which can detect chemical vapours.

Other than that, CNT has expected elongation to failure of 20-30% combine with stiffness and their tensile strength was above 100 Gpa [9]. Strong impact electronic properties of CNT are primarily determined by their chirality [11]. High electrical conductivity and the high aspect ratio leads to optimum geometrical field enhancement and remarkable thermal stability [12].

3. Processing

CVD is the process that base on thermal reaction. Thermal reaction is the process where the thermal energy was relied and reaction of the hot zone. CVD technique was done in the presence of catalyst primarily Fe, Ni, and Co. The selection of catalyst was elected from transition metals. The role of catalyst in CVD route is decomposition of carbon source. The carbon source for CVD process was choose from hydrocarbon like methane, ethane, xylene, or acetylene. CVD is widely use in material processing technology. CVD is the method to synthesis the growth of CNT effectively. This method also is most affordable way [13] [10]. The quality of CVD grown CNT depends on the nature of the catalyst and is the most promising for large scale production [14].

It is known as effective method for synthesis CNT, and paramount quality. This technique also use low temperature between 800-1000ºC [4]. This CVD method was selected because it is the great mode to synthesis compared with others because embrace the decomposition of gaseous or volatile carbon compound and wise controlling morphology and structure in nanotubes production [15]. This method is the best way of synthesis compared with other methods because of their equipment requirements and high amount of energy used sort less favourable for nanotube productions [15].

The use of methane gas in furnace and as gas decomposes it frees up carbon atoms, which recombine in the form of nanotube. CVD is easiest to scale to industrial production and long length of its uses. Nanotubes that are usually formed are MWCNT and often riddled with defects. The typically temperatures used in process of CVD was around the range of 200 to 1600ºC [16].

Figure 3 shows the schematic diagram of furnace tube in CVD processing technique. These two processes in CVD which is first, catalyst are deposited on substrate so that the nucleation of catalyst is carried out via chemical etching or thermal annealing, and the metal catalyst is used. Then, source of carbon is placed in the reaction chamber in gas phase. Molecule of carbon converts to atomic level by energy source like heating or plasma.

Mechanism of CVD is dissociation of hydrocarbon molecules catalyzed by transition metal and saturation of carbon atoms in metal nanoparticle. Hence, tubular carbon solids in sp^2 structure which is graphene from the precipitation of carbon from the metal particle.

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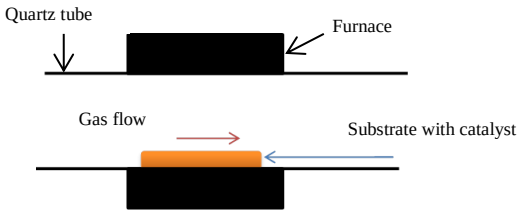

Figure 3: Schematic diagram of tube furnace.

The advantages of this method compared with other are high yields, easy scalability, long tubes, alignment and pattern growth and high purity. According to this advantages, there are some inconvenient by this method are the cost in purchasing the materials, and then the set-up of furnace with gases quite complex and need serious handling.

CVD give the controlling of morphology and structure in production of nanotubes [15]. Besides, CVD will give the comparable thickness of the film produces, it can deposited variety of materials with high in purity and then high deposition rate but not required high vacuum [16].

4. Materials

Materials used are aluminium powder in composition of (0.38 mol, 99 % purity), nickel nitrate hexahydrate salts ($Ni(NO_3)_2.6H_2O$), distilled water and sodium hydroxide (NaOH) for the preparation of catalyst . This type of nickel was choosing because of its properties that gives the significant effect on the particles size of nickel oxide (NiO), and meet high dispersion and abundant surface area of held nickel oxide [17].

Aluminium powder was chose to become metal catalyst because of its properties that have high temperature resistance and retain high hardness. Besides that, this element has been deposited using CVD, so that it's worth it to apply in this method. The used of the quartz tube in furnace for gases flow [18]. The production of the high yield also influence by numbers of quartz tube used [19].

NaOH solution was indicating in this experiment to acts as alkaline treatment for the sample become more stable. Strong acid solution of hydrochloric acid (HCl) was used in purification method for this experiment. The chosen of this acid because it does not effecting the carbon species [9].

5. Challenges

In view of the production of CNT using CVD method might involve several challenges that will affect this kind of product processing because it was involve in consumption of methane gas provide in tube furnace. The quartz type of glasses needed in this process that involve high purchase and need a care in handle this to prevent it from fragile.

Besides that, the characterizations of this study might cause special equipment like high resolution transmission electron microscope (HRTEM) to observe morphology of the CNT growth and then, the use of scanning electron microscope (SEM) to investigate the distribution of the CNT. This equipment required high in costs and well experience handling.

5. Conclusion

In this study, it can be conclude that the best method to produce or synthesis CNT was proven using CVD that will give a better results or high yields in production or growth of CNT. In fact, developments of CVD resulting in large scale production of high purity CNT.

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