Enhancing the Electrochemical Properties and Processing Techniques of Carbon Nanotubes for Bio pharmacological Applications: A Research Perspective

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Abstract. Compared with other biopharmaceutical technologies, carbon nanotubes not only have unique structure, but also have strong electrochemical properties, which occupy an important position in the fields of chemistry, physics, biopharmaceutics and materials science, and have played an active role in promoting the development of biopharmaceutics and chemical industry in China. Carbon nanotubes (CNTs) are mainly used in the field of biopharmacology for the determination of small biological molecules and drug molecules, the determination of dopamine and thrombin, the determination of high concentrations of ascorbic acid, and the detection of drug formulations. Although carbon nanotubes (CNTs) have many advantages in the field of biopharmaceutics, there are certain limitations that limit the scope of application of carbon tubes, which are mainly the following: one is the high cost of the carbon nanotube material itself and the high technical difficulty of its preparation; the other is that the smooth surface of the material is not conducive to the loading of other particles; finally, although the carbon nanotubes are modified with different groups after treatment, the structure of the material itself is damaged. Finally, although carbon nanotubes are modified with different groups after treatment, their own material structure is destroyed, which reduces their conduction performance. Although the above defects can affect the performance of carbon nanotubes, they can be solved by optimizing the structure of carbon nanotubes, enhancing the plastic mechanical properties of carbon nanotubes and corrosion resistance, in order to give full play to the role of carbon nanotubes in the field of biopharmaceuticals. In this regard, the author briefly analyzes the electrochemical properties of carbon nanotubes in biopharmacology and the application of treatment methods based on relevant literature and work experience, hoping to provide reference value for related scholars and researchers.

Keywords: Biopharmacology, Carbon nanotubes, Electrochemical properties, Processing methods, Preparation and growth mechanism.

1. Introduction

"Carbon fibers" were discovered in 1991 by Iijma, a specialist from NEC, Japan, who also confirmed that carbon fibers have strong mechanical, electrical, magnetic, and thermodynamic properties, in agreement with the findings of other experts. "Carbon nanotubes (CNTs) are essentially composed of carbon fibers with extremely small radial dimensions. Carbon fibers have excellent mechanical, electrical, magnetic and thermodynamic properties, so the formed carbon nanotubes (CNTs) have strong electrocatalytic activity, which can promote electron transfer from electroactive substances and electrodes, thus effectively increase the electrocatalytic activity, which can meet the needs of various applications and has great application value and application prospects [1-2].

In recent years, China's social economy, science and technology have been developed rapidly, and many advanced technologies have been derived, among which "carbon nanotubes" are the most widely used and influential, and have been applied in the field of biopharmaceutics with great effect, accelerating the development of the field of biopharmaceutics. "Carbon nanotubes", known as "Carbon nanotubes" or "CNTs" for short, are a kind of biopharmaceutical material that has emerged in recent years. With the development of social economy and science and technology, the yield of carbon nanotubes (CNTs) has been gradually increased, and the types of CNTs have been diversified, including not only bifurcated CNTs, but also different types of CNTs such as metal-filled, unfilled and graphene by adjusting the discharge atmosphere. The types, capacities and yields of carbon nanotubes (CNTs) with different raw materials and catalysts are also different. Carbon nanotubes (CNTs) have a special structure and are one-dimensional quantum materials, with radial dimensions of CNTs reaching the nanoscale, axial dimensions of microns, and sealing at both ends [1]. Therefore, compared with other materials of the same function, carbon nanotubes are stronger, more ductile, and more structurally robust. Moreover, the preparation and application of carbon nanotubes (CNTs) have also made breakthroughs in recent years, so it is very necessary and important to deeply study the electrochemical properties and processing methods of carbon nanotubes in bio pharmacology, which deserves attention and attention [2]. Based on this, a brief overview of carbon nanotubes (CNTs) is given in the first part; the structure, electrochemical properties and processing methods of CNTs are briefly analyzed in the second part; the applications of CNTs in biopharmaceuticals are analyzed in the third part; and the preparation techniques and growth mechanisms of CNTs are analyzed in the fourth part.

2. Carbon nanotubes (CNTs)

Carbon nanotubes (CNTs) are tubular materials made of carbon atomic layers that can be interconnected cooperating carbon fibers curled together, with a special and complex structure, and with diameters up to the nanometer level and length units mostly in centimeters, with specific advantages such as small size, high strength, strong chemical properties, strong physical properties, strong electrical properties and thermodynamic properties. Therefore, products composed of carbon nanotubes (CNTs) have high strength and structural stability, and are able to cope with various external stresses and have a long service life [2-3].

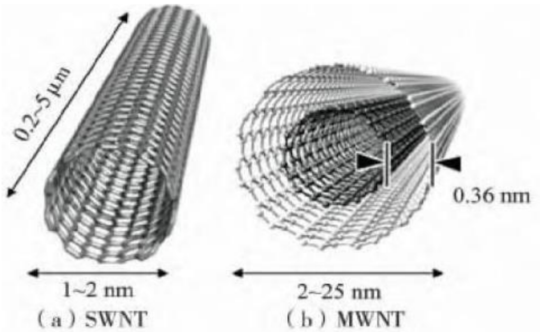

Figure 1. Schematic diagram of carbon nanotubes (CNTs) [4]

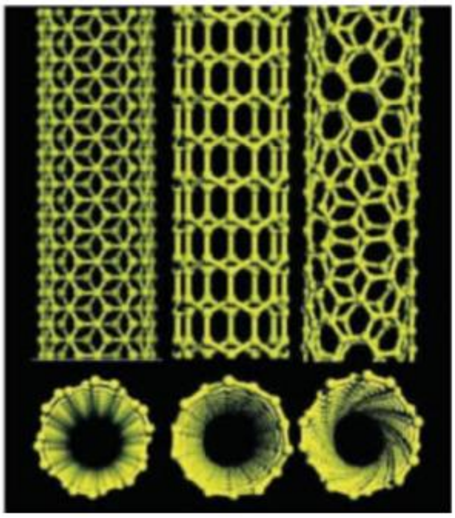

Figure 2. Structure diagram of different types of single-walled carbon nanotubes (SWNTs) [4]

3. Structure, properties and processing of carbon nanotubes (CNTs)

3.1. Structure of CNTs

Carbon nanotubes (CNTs) can be divided into two types of nanotubes, single-walled carbon and multi-walled carbon, according to the number of layers that make up the walls of carbon nanotubes, where single-walled carbon nanotubes are divided into armchair, sawtooth, and symmetrical single-walled carbon nanotubes according to their structure (see Figure 1-a, Figure 2-a, b, c); multi-walled carbon nanotubes are composed of several or dozens of single-walled carbon nanotubes, Figure 1-b shows multi-walled carbon nanotubes.

In 1991, Sumio Iijima S. (Japan) used high-resolution transmission electron microscopy to observe carbon nanotubes [4] (CNTs), and the observations showed that carbon nanotubes (CNTs) are composed of multiple tubular carbon monomers (including tubular carbon fibers and layers of carbon atoms). The unique electrical and chemical properties of carbon nanotubes (CNTs) can facilitate its reaction with other chemical elements, resulting in structurally stable novel materials. Most carbon nanotubes (CNTs) have nanoscale tubular structures, such as single-walled carbon nanotubes and multi-walled carbon nanotubes, which are not only very robust nanoscale tubular structures, but also have very small cylinder diameters and consist of several independent regions with different physical and chemical properties, so that multi-walled carbon nanotubes are composed of one to several hundred or even several thousand coaxial carbon shells with each shell spacing of about 0.34 nm[3].

3.2. CNTs performance

3.2.1. Electrical Properties

The electrical properties of carbon nanotubes (CNTs) are determined by the graphite sheet curl angle and carbon tube diameter, and the electrical properties of carbon nanotubes (CNTs) are different for different ink sheet curl angles and carbon tube diameters. The graphite sheet curl angle and carbon tube diameter are negatively correlated with the electrical properties of CNTs, i.e., the larger the graphite sheet curl angle and the larger the carbon tube diameter, the smaller the electrical properties of CNTs, because the larger the graphite sheet curl angle and carbon tube diameter, the weaker the influence between graphite layers, and the less the current input to CNTs, which in turn reduces the metallic properties of CNTs. CNTs) metallicity, ballistic transport properties [3][5].

3.2.2. Chemical Properties

Compared to other materials of the same function, carbon nanotubes (CNTs) have a more stable structure, but because they have strong chemical properties of their own, mainly in terms of their surface characteristics and pore structure properties. During the growth of carbon nanotubes, many structural defect sites are formed, and these structural defects are easily opened by oxidants or atmosphere oxidation, and also different functional groups can be formed on them [4]. Therefore, they are also more prone to chemical reactions [5], such as oxidation reactions. Oxidation reactions increase the structural density of the tube ends of carbon nanotubes (CNTs) and are more reactive than the column part, so to ensure that carbon nanotubes (CNTs) are not oxidized during use, the average loading density of the graphite plane of the five-membered carbon ring at the tube ends needs to be minimized with the help of other chemicals to reduce the problems such as decrease in structural robustness occurring after oxidation reaction [6].

3.3. Processing method

For the prepared carbon nanotubes (CNTs), in addition to the treatment of impurities such as metal catalyst particles and amorphous carbon, they need to be treated with acid by chemicals such as concentrated sulfuric acid and nitric acid to quickly remove other chemicals from the surface of carbon nanotubes (CNTs), reduce the incidence of oxidation reaction of carbon nanotubes (CNTs), and also high carbon nanotubes (CNTs). CNTs) corrosion resistance. The specific treatment methods are as follows: ① Determine the specifications and dosage of concentrated sulfuric acid and nitric acid according to the length, diameter and internal structure of carbon nanotubes (CNTs), and then fill the concentrated sulfuric acid and nitric acid into a 100 mL test tube according to the ratio of 3:1, such as when taking 30 mL of concentrated sulfuric acid, 10 mL of nitric acid should be added, and then make a mixture [6-7]. (ii) After the mixture is prepared, the pure carbon nanotubes (CNTs) will be immersed in the mixture and put into a water bath at 35-40°C along with the test tube for sonication for 24 h [7]. (③After sonication, a suspension will be obtained, at which time it needs to be treated with 200 mL of water for dilution and rinsed with 10 mmol/L NaOH solution.

4. Carbon nanotubes (CNTs) preparation method and growth mechanism

4.1. Carbon nanotubes (CNTs) preparation method

4.1.1. Electric arc discharge method

The arc discharge method uses graphite rods containing catalyst as the anode and pure graphite rods as the cathode in a low-pressure arc chamber filled with certain inert gas, hydrogen or other gases to generate a continuous arc above 3,000°C between the electrodes, which causes complete vaporization and evaporation of graphite and catalyst to generate carbon nanotubes [8].

Single-walled carbon nanotubes have been prepared by using the DC arc discharge method using Fe-S as the catalyst and maintaining the low-pressure air pressure in the arc chamber between 6 and 12 kPa [8]. The carbon nanotubes (CNTs) prepared by this method have the advantages of clear wall lines, structural integrity, less impurities and high crystallinity.

4.1.2. Chemical Vapor Deposition (full process, CVD)

Chemical vapor deposition (CVD), which usually involves cracking a carbon-containing gas or liquid carbon source under the action of a catalyst at a certain temperature to generate carbon nanotubes, is also known as catalytic cracking, and has the advantages of simple equipment, low cost, and high yield, with the disadvantages of low graphitization and many impurities. The catalysts are generally transition metals (e.g., Fe, Co, Ni, Pd, etc.) and the carbon source can be carbon containing gases such as methane, CO, ethylene, or liquids such as benzene and toluene [9-10]. Some researchers have prepared carbon nanotubes and Y-type carbon nanotubes by catalytic decomposition of liquid dimethyl sulfide through the catalytic effect of Co/MgO [10]. The carbon nanotubes prepared by this method have a relatively regular morphology and nanoscale outer diameter (60-70 nm) and inner diameter (30-40 nm), as well as high purity and metallic conductivity. In the preparation of carbon nanotubes (CNTs), besides selecting the catalyst type and controlling the amount of catalyst used in accordance with the requirements and standards, it is also necessary to control the temperature during the preparation process, because either too high or too low temperature is not conducive to the reaction, and the appropriate temperature can ensure the quality of carbon nanotubes (CNTs).

4.1.3. Laser evaporation method

Laser evaporation is a method to prepare carbon nanotubes by bombarding the surface of graphite targets doped with transition metals such as Fe, Co, and Ni with laser light under the protection of inert gas (He) at a reaction temperature of 1200°C. The advantage of this method is the high purity of the prepared carbon nanotubes, but the high energy consumption, complex experimental equipment and high preparation cost [10-11]. For example, carbon black powder and micron nickel powder were mixed thoroughly in a 1:1 weight ratio and hydrostatically molded into the target material. The laser ablation parameters used were pulse width 0.6 ms, frequency 20 Hz, laser power density 1.28×107W/cm2, and single pulse energy about 2.4 J. The carbon nanotubes were prepared by laser ablation of the target material for 1 h.

4.1.4. Template Method

The template method is a method to obtain carbon nanotubes by using a porous material with nanometer to micrometer pore size as a template and combining techniques such as electrochemical, precipitation, sol-gel and vapor phase precipitation methods to precipitate material atoms or ions on the pore wall of the intrinsic template [11]. For example, anodic aluminum oxide templates (AAO) are produced by the secondary anodic oxidation method, and highly directionally grown amorphous carbon nanotubes with controllable wall thickness are prepared by cracking ethylene or acetylene with CVD heat and optimizing the synthesis temperature and time.

In addition to the above-mentioned preparation methods, carbon nanotubes (CNTs) can also be prepared by flame method, solar method, electrolytic alkali metal halide method, etc.

4.2. Growth mechanism of carbon nanotubes (CNTs)

The four growth mechanisms include "gas-liquid-solid (VLS), gas-solid-solid (VSS), gas-phase nucleation (VPN) and stepwise", see Figure 3.

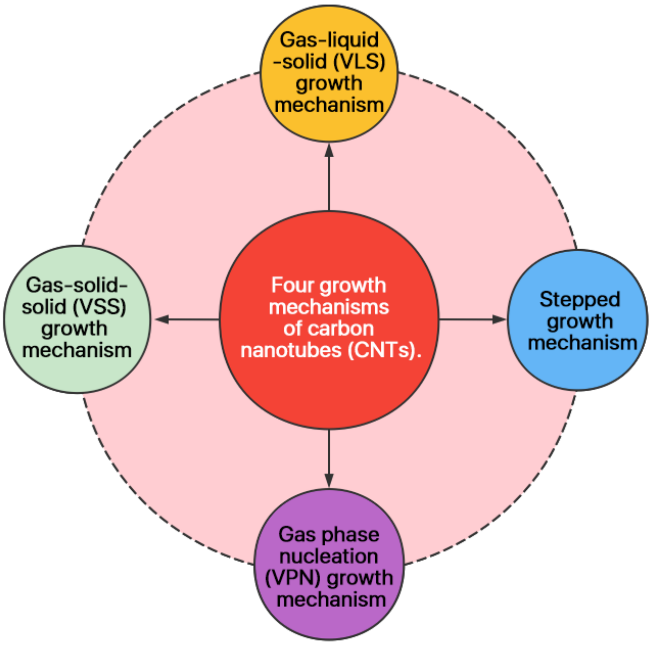

Figure 3. Four growth mechanisms of carbon nanotubes (CNTs)

The steps and principles differ for different growth mechanisms, as follows:

4.2.1. The "gas-liquid-solid" growth mechanism

The mechanism of VLS is as follows: the gaseous carbon source adsorbs on the surface of the catalyst particles and cleaves to form carbon containing species such as Cl and C2; the carbon containing species dissolve in the catalyst and diffuse inside the catalyst; when the carbon species reach supersaturation in the catalyst, the solid carbon precipitates on the other side of the nanocatalyst particles to form carbon nanotubes [11-12]. In this mechanism, the diffusion of carbon species inside the catalyst particles is the rate-controlling step.

4.2.2. "Gas-solid-solid" growth mechanism

The VSS mechanism is based on the decomposition of a gaseous source of carbon on the surface of the catalyst particles, followed by the formation of carbon nanotubes directly on the surface [12]. This mechanism is based on the decomposition of a gaseous carbon source on the surface of a solid catalyst particle, followed by the formation of carbon nanotubes directly on its surface [12].

4.2.3. "Gas-phase nucleation" growth mechanism

The specific process of this mechanism, referred to as "VPN", is as follows: the precursor of the metal catalyst decomposes in the first stage of the furnace to form metal atoms and then aggregates to form nanometallic particles; the catalytic atoms from the decomposition of the gaseous co-catalyst dissolve in the nanometallic particles (nucleation of catalyst particles); the carbon atoms from the cracking of the gaseous carbon source dissolve in the nanometallic particles containing the catalytic atoms and reach a supersaturated state; the supersaturated carbon atoms precipitate on the surface of the nanometallic particles and form single-walled carbon nanotubes; carbon deposition occurs on the surface of the single-walled carbon nanotubes and transforms into multi-walled carbon nanotubes [13].

4.2.4. "Stepwise" growth mechanism

The existing "bottom growth" and "top growth" models are applicable to spherical and cylindrical catalyst particles with regular shapes. The "stepped" growth model compensates the existing "bottom growth" and "top growth" models, which are applicable to regular shaped catalyst particles, for the generation of different terminal carbon nanotubes. The "stepped" growth model is not sufficient to explain the causes of different terminal carbon nanotubes [14].

5. Application scope

Carbon nanotubes (CNTs) not only have a unique structure, but also have strong electrochemical properties and have a wider range of applications in various fields. In the electronics field, they are expected to replace silicon as the material for manufacturing next-generation higher performance and lower energy consumption electronic components. In the medical field, carbon nanotubes may be used as the main component of the new carbon skeleton in the future to help regenerate injured or diseased tissues; secondly, carbon nanotube arrays may be used to develop a bendable and wearable portable terahertz scanner in the future for nondestructive device detection, such as surgery, imaging and other medical monitoring fields; in addition to this, magnetron carbon nanotubes are expected to be used to treat drug-resistant glioblastoma In addition, it is expected to use magnetron carbon nanotubes to treat drug-resistant glioblastoma, providing new ideas for the treatment of drug-resistant glioblastoma. In the field of optics, it is expected to be used in the manufacture of high-end lasers. In the military field, it can be used for future biochemical protective clothing, explosive detectors, etc. Carbon nanotubes may be used in future composite materials to produce lighter and more resistant composites. At present, the research on carbon nanotubes has made remarkable achievements, and it is believed that in the near future, the applications of carbon nanotubes will be more diversified and extended to more fields.

6. Summary

Carbon nanotubes (CNTs) are the product of new era development, and they are widely used in various fields. They have strong chemical, physical, mechanical, electrical, magnetic and thermodynamic properties, and their structure is very special and solid, so they have high strength. With the development of social economy and science and technology, the yield of carbon nanotubes (CNTs) has been gradually increased, and the types of carbon nanotubes (CNTs) have been diversified, not only the bifurcated carbon nanotubes (CNTs), but also different types of carbon nanotubes (CNTs) such as metal-filled, unfilled and graphene can be obtained by adjusting the discharge atmosphere, and the carbon nanotubes (CNTs) with different raw materials and different catalysts The types, capacities and yields of CNTs vary with different raw materials and catalysts. In the process of preparing CNTs, besides selecting the catalyst type and controlling the amount of catalyst used in strict accordance with the requirements and standards, it is also necessary to control the temperature during the preparation process, because either too high or too low temperature is not conducive to the reaction, and a suitable temperature is necessary to ensure the quality of CNTs.

In this paper, we first describe the structure of carbon nanotubes (CNTs), including single-walled carbon nanotubes (SWNTs) and multi-walled carbon nanotubes (MWNTs). The electrical and chemical properties of carbon nanotubes (CNTs) with different structures are different, but they all have strong ballistic transport properties and high loading density, so their strength is 3~4 times stronger than other materials with the same function. Carbon nanotubes (CNTs) can be treated by acid treatment method. Next, the preparation methods of carbon nanotubes (CNTs) including arc discharge method, chemical vapor deposition (CVD) method, laser evaporation method and template method are described. The growth mechanism of CNTs can be classified into "gas-liquid-solid (VLS), gas-solid-solid (VSS), gas-phase nucleation (VPN) and stepwise growth". Finally, it is described that CNTs can be combined with other nanomaterials to develop new biopharmaceutical materials, such as nano-gold and nano-selenium to produce highly sensitive and high-strength biopharmaceutical molecular materials, and therefore have a good prospect of application in the field of biomedicine, with very broad application prospects and development space.

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