



Preparation of carbon nanotube macroscopic body by finite field self-assembly assisted high temperature connection

He Lamei, Jiang Qi*, Chen Jiankang, Sun Meng, Yuan Shuai, Han Dengquan, Lu Xiaoying, Zhao Yong

Key Laboratory of Advanced Technologies of Materials (Ministry of Education of China) and Superconductivity and New Energy R&D Centre, Southwest Jiaotong University, Chengdu 610031, PR China

ARTICLE INFO

Article history:

Received 22 March 2014

Accepted 12 July 2014

Available online 19 July 2014

Keywords:

Carbon nanotube

Structural

ABSTRACT

A carbon nanotube macroscopic body (CNT-MB) is prepared by finite field self-assembly assisted high temperature connection. Using the solvation effect of the organic solvent under the high-intensive and long-time ultrasound treatment, the carbon nanotube (CNT) powder was uniformly dispersed in n-hexane and then the dispersed CNT began to self-assemble in the less and less finite field with the n-hexane volatilization above the inorganic solvent. Then, by growing new CNT between the close or adjacent pristine CNTs at high temperature, the CNT-MB with three-dimension network structure was prepared without adhesive. The obtained CNT-MB has 2 times electrical and 8 times mechanical properties than that of the CNT-MB precursor (without new CNT growing), indicating excellent application prospects in many fields.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

Carbon nanotube (CNT) is known as one of the stiffest and strongest materials in the world [1,2]. Since CNT was discovered in 1991 [3], many research results have been reported about CNT novel physical and mechanical properties: superior mechanical properties, resilience, low density and high electrical conductivity [4,5]. All these make CNT a potential nano-scale reinforcement material to improve materials electrical and mechanical properties. However in fact, CNT is a powder, which would hinder its applications as a macroscopic body material. Usually, there are two ways to transform the CNT powder into macroscopic body material: adding adhesive or without adhesive. Of course, adding adhesive is an easy way, but it inevitably introduces impurity, which is harmful to the material. In this paper, we introduce a new method to prepare carbon nanotube macroscopic body (CNT-MB) without adhesives, named as finite field self-assembly assisted high temperature connection, which is different from the reported macroscopic bulk prepared from aligned single walled CNT using the zipping effect of liquids to draw the tubes together [6]. First, CNT powder is dispersed into the volatile organic solvent, which is located above an inorganic solvent, and the single CNT is allowed to self-assemble in the continuously narrowing organic solvent

(finite field) with the organic solvent volatilizing. Then the CNT-MB precursor is obtained and floated on the surface of the inorganic solvent after the organic solvent volatilizing process is over. After that, new CNT is grown to connect close or adjacent CNTs at high temperature by adding CNT catalyst on the CNT-MB. Thus, the CNT-MB with real connection points is prepared by removing the CNT catalyst. The obtained CNT-MB not only has three-dimensional network structure but also has better electrical and mechanical properties than the CNT-MB precursor.

2. Experimental procedure

Preparation of materials: The CNT used in this paper was provided by our research group [7]. Nitric acid treatment was employed to remove the catalyst particles. Purified CNT was dispersed in n-hexane solution by ultrasonic treatment for 1 h at 150 W (the temperature was kept at about 25 °C). The obtained CNT dispersion liquid was added into DI water dropwise. After 24 h of standing at ambient temperature, CNT-MB precursor was obtained on the surface of the DI water.

The connection CNT catalyst was prepared with AR grade citric acid and nickel nitrate (molar ratio 2:1). The catalyst addition on CNT-MB precursor was carried out by the impregnation method. The CNT-MB precursor with catalyst was placed in a quartz boat and placed in a horizontal quartz glass tube of a resistance furnace. The temperature was heated up to 800 °C from ambient temperature at

* Corresponding author. Tel./fax: +86 28 87603544.

E-mail addresses: jiangqi66@163.com, jiangqi@swjtu.cn (J. Qi).

a rate of $10\text{ }^{\circ}\text{C min}^{-1}$ with Ar gas flowing (50 mL min^{-1}) through the quartz tube. Once the temperature reached $800\text{ }^{\circ}\text{C}$, it was held at that temperature for 30 min with H_2 gas (25 mL min^{-1}) flowing through the tube instead of Ar gas. After that, the temperature was lowered to $700\text{ }^{\circ}\text{C}$ with Ar gas (50 mL min^{-1} flowing rate), and then the temperature was held for 10 min with a $200\text{ mL min}^{-1}\text{C}_2\text{H}_2/\text{Ar}$ mixture gas flowing rate ($V_{\text{C}_2\text{H}_2}: V_{\text{Ar}}=1: 9$). Finally, the reactor cooled to the ambient temperature with Ar gas (25 mL min^{-1}) flowing through the tube. The operation was very similar to the CNT growing operation in Ref. [7], only the CNT growing time was shortened from 60 min to 10 min. The obtained sample was purified by $80\text{ }^{\circ}\text{C}$ concentrated nitric acid for 2 h and washed by DI water, then the CNT-MB was obtained by vacuum drying at $105\text{ }^{\circ}\text{C}$ for 24 h.

Characterization: Transmission electron microscopy (TEM, JEOL JEM-100CX), scanning electron microscopy (SEM, JEOL JSM-7001 F) and digital camera were used to characterize the obtained samples' morphology. The obtained samples were gold spray treated for SEM testing. And the obtained purified CNT was dispersed in water and dropped on the copper grid for TEM testing. The mechanical properties were characterized by a universal mechanical testing machine (Instron, 5567). The samples were cut into rectangle shapes (the length and width were 1 cm and 2 cm, respectively; the height was the pristine thickness of the obtained macroscopic body samples, about 0.3 cm). Some hot melt adhesive was applied on both ends in width (about 0.5 cm long, two sides) of the rectangle samples, which is convenient to connect clips of the test machine. The electric conductivities of the samples were measured on the electric conductivity tester (RTS-9) by the four-point probe method.

3. Results and discussion

Fig. 1 is the TEM image of the used CNT (a) and the digital photos of the preparation process (b, CNT dispersed in n-hexane; c, n-hexane (with dispersed CNT)/water; d, CNT-MB precursor). From Fig. 1a, we can see that the obtained CNT is multi-walled CNT, randomly entangled and a good hollow structure. It is about 20 nm in diameter and very long. Fig. 1b shows the digital photo of the result of purified CNT dispersing in the n-hexane. As seen from Fig. 1b, the purified CNT can be well dispersed into n-hexane organic solution by ultrasonic treatment as the experimental operation mentioned above. We consider that the n-hexane acted as not only the solvent but also as the solvation effect of the CNT dispersion [8]. The solvation effect was produced with the CNT and n-hexane with the high-intensive and long-time ultrasound treatment. The purified CNT treated by ultrasound might have some kind of electric charge [9], which makes it work as the ion in the solvation effect. Thus the n-hexane molecule accumulates around the purified CNT affected by the electric charge with the help of ultrasound treatment. As a result, there are lots of n-hexane organic molecules covering the surface of the dispersed CNT; then, the solvated CNT can work as an organic molecule and can be uniformly dispersed into n-hexane organic solvent (named as solution A). Of course, the obtained CNT dispersion liquid is only a CNT suspension for CNT and is a kind of super-molecule. Fig. 1c is the digital photo of the result of solution A dropping into the water. From Fig. 1c, it can be seen that there is obviously a two-layered structure (named as solution B, where the upper layer is black and the lower layer is colorless). We

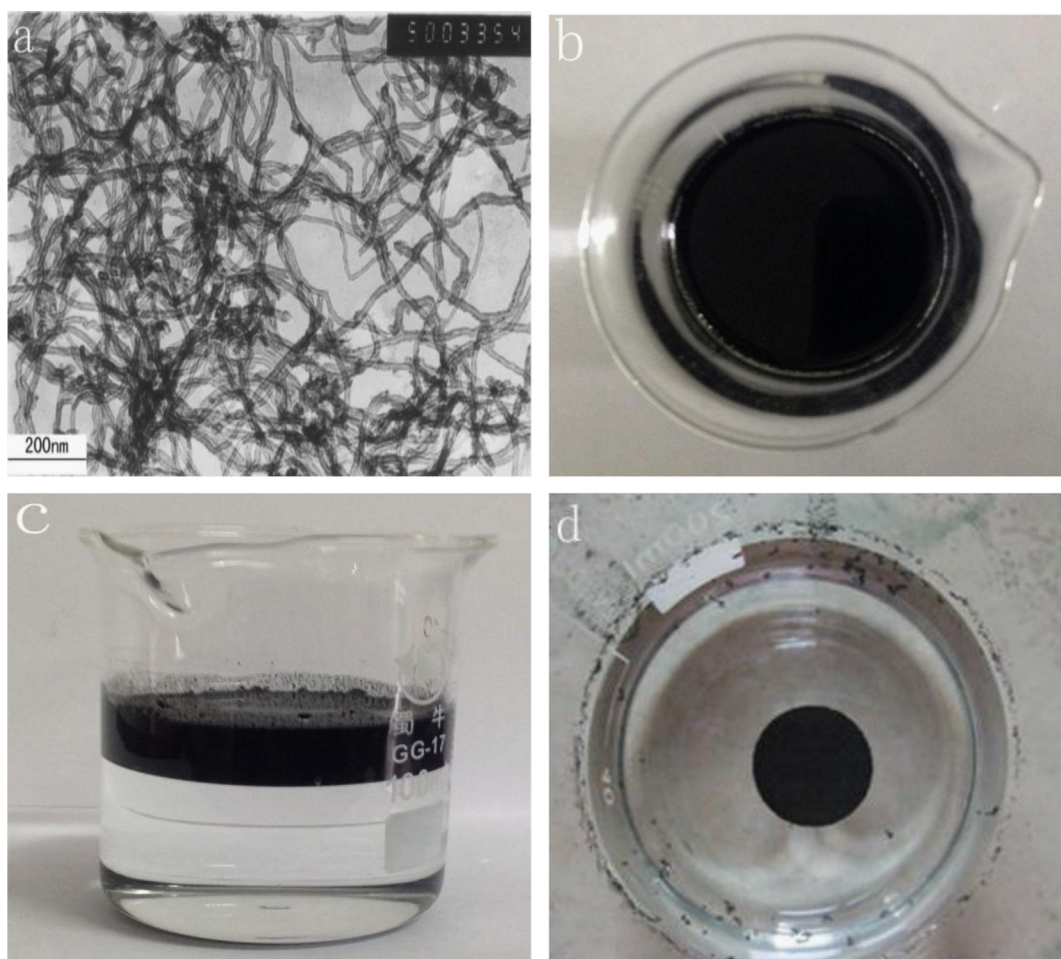


Fig. 1. TEM image of the used CNT (a) and the digital photos of the preparation process (b, CNT dispersed in n-hexane; c, n-hexane (with dispersed CNT)/water; d, CNT-MB precursor).

Download English Version:

<https://daneshyari.com/en/article/8019644>

Download Persian Version:

<https://daneshyari.com/article/8019644>

[Daneshyari.com](https://daneshyari.com)