研究快报

具有多向螺旋结构的碳纳米纤维

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关键词: 碳纤维 螺旋结构 化学气相沉积 多向螺旋结构
分类号: O614.81+1 O614.33

Carbon Nanofibers with Multi-directional Helical Structures

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The nanocarbonaceous material with helical structure is considered to be promising as nanocoils. Both left and right-handed helical structures normally coexist and are disordered. So far, there has been no report about double or multi-directional helical structures on an individual nanomaterial. In this paper, Multi-directional helical structures were observed in an individual carbon nanofiber during the pyrolysis of acetylene at a mixture of C_2H_2: H_2 = 2: 1. It is possible to control and prepare multi-directional helical nanomaterial, and it can be used into new application area.

Keywords: **carbon fibers** **helical structure** **CVD** **multi-directional helical structures**

0 Introduction

Carbon is the most versatile element in the periodic table, and it can build up 3-, 2-, 1- and 0-dimensionally structured substances with a broad variety of physical and properties[1]. As the old forms of carbon, such as diamond, graphite, carbon black, activated carbon and carbon, are formed either naturally or artificially, under thermodynamic control. They have been extensively used in many fields for a long time. The new forms of carbon, for example, the fullerenes and carbon nanotubes, have unique properties owing to their particular structure, and thus are of the probable constituents of future materials. Especially, the discovery of carbon nanotubes in 1991 by Iijima[2] has been stimulating intense experimental and theoretical studies of carbon nanomaterials and new microstructures[3~6].

Chemical vapor deposition (CVD) method for the synthesis of carbon nanofibers and carbon nanotubes has attracted lots of research interests in the recent years and is becoming one of the methods with the most

收稿日期:2003-07-10。收修改稿日期:2003-09-17。
国家自然科学基金资助项目(No. 29903003)。
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applicant future. It has been reported that the helical structure is found in the obtained nanocarbonaceous products. Chen observed the so-called super-elastic carbon micron-coils with high regular helical structure from the products obtained by pyrolysis of acetylene on a Ni catalyst[7] . Pan also succeeded in synthesizing carbon nanocoils at high yield using the conventional method of CVD on an iron and indium tin oxide catalyst[8].

The nanocarbonaceous material with helical structure is considered to be promising as the nanocoils. Its properties change with the helix angle, which may be useful on the study of the structure and the applications of the nanocarbonaceous material. Helical structures of all the reported nanocarbonaceous are at one direction, namely, either left-handed or right-handed. Nobody has reported that different kinds of chiral structure on an individual carbon nanofiber or carbon nanotube. In this communication, we report that different chiral structures can be observed on an individual carbonfiber. Only morphology study is shown in this letter. The physical properties and formation mechanism will be discussed later. This is to draw attention of researchers on physics, chemistry, electronics, and material science to the special property of the carbon nanocoils; and to extend the application area of the carbon nano materials.

1 Experimental

Carbon deposit was found on the tube wall of thermal couple during the synthesis of carbon nanotubes by pyrolysis of acetylene on an iron-lanthanum catalyst [9]. In this paper, the tube wall (Fe-Ni-Cr alloy) of thermal couple was used as the catalyst on the pyrolysis of acetylene at a mixture of C_2H_2: H_2 = 2: 1. The morphology of carbon deposit was characterized by the scanning electron microscopy (SEM, LEO 1530VP) and transmission electron microscopy (TEM, JEOL JEM-100CXII).

2 Results and Discussion

Fig. 1(1) shows the SEM picture of carbon deposit obtained at 973K. Carbon fibers cluster could be observed at the left down part of the picture, while some individual carbon fibers could be found at the right part of the picture. Fig. 1(2) shows the SEM picture of the carbon deposit obtained at 1073K. It is shown that besides the large diameter carbon fibers, some carbon coils with smaller diameter were also observed in the picture. The diameters of these carbon coils are between 80 nm and 150 nm, while the lengths are up to dozen micrometer. Fig. 1(3) and 1(4) show the SEM picture of an individual carbon coil. The double-directional helical structure is clearly shown in the picture. Point C is the turning point, the right-handed helix is formed along arrow A and the left-handed helix is formed along arrow B. A couple of reverse helical structures appeared in an individual carbon fiber. Fig. 1(5) shows the SEM picture of a carbon fiber with three-directional helical structures. Points C and E are turning points, the right-handed helix is formed along arrow A and D, and the left-handed helix is formed along arrow B. Fig. 1(6) shows the TEM picture of the carbon fiber with multi-directional helical structures. Points C, E, F, G are turning points, thus totally five-directional helical structures were observed.

Chiral structure generally exists in the universe, such as, on the spin of the elementary particles and electrons, parity nonconservation, turbulence, double helical structure on the DNA molecule and the optical isomer of organic compounds. In the microcosms, for example, the organic synthesis, both left and right-handed structures normally coexist and are disordered. The mixture shows external compensation. Chiral catalysis method can be used to obtain product with left or right-handed helix dominant products. Chiral also exists on the mesocosms (nanoworld), such as, semi conductive organic materials, nanowires, and nanotubes. The chiral is also disordered in those cases. Few researches have been done on controlling the chiral property during the synthesis of nanomaterial. Till now there is even no report on double or multi-directional helical structures on an individual nanomaterial.

The authors thereafter predict that it is possible to

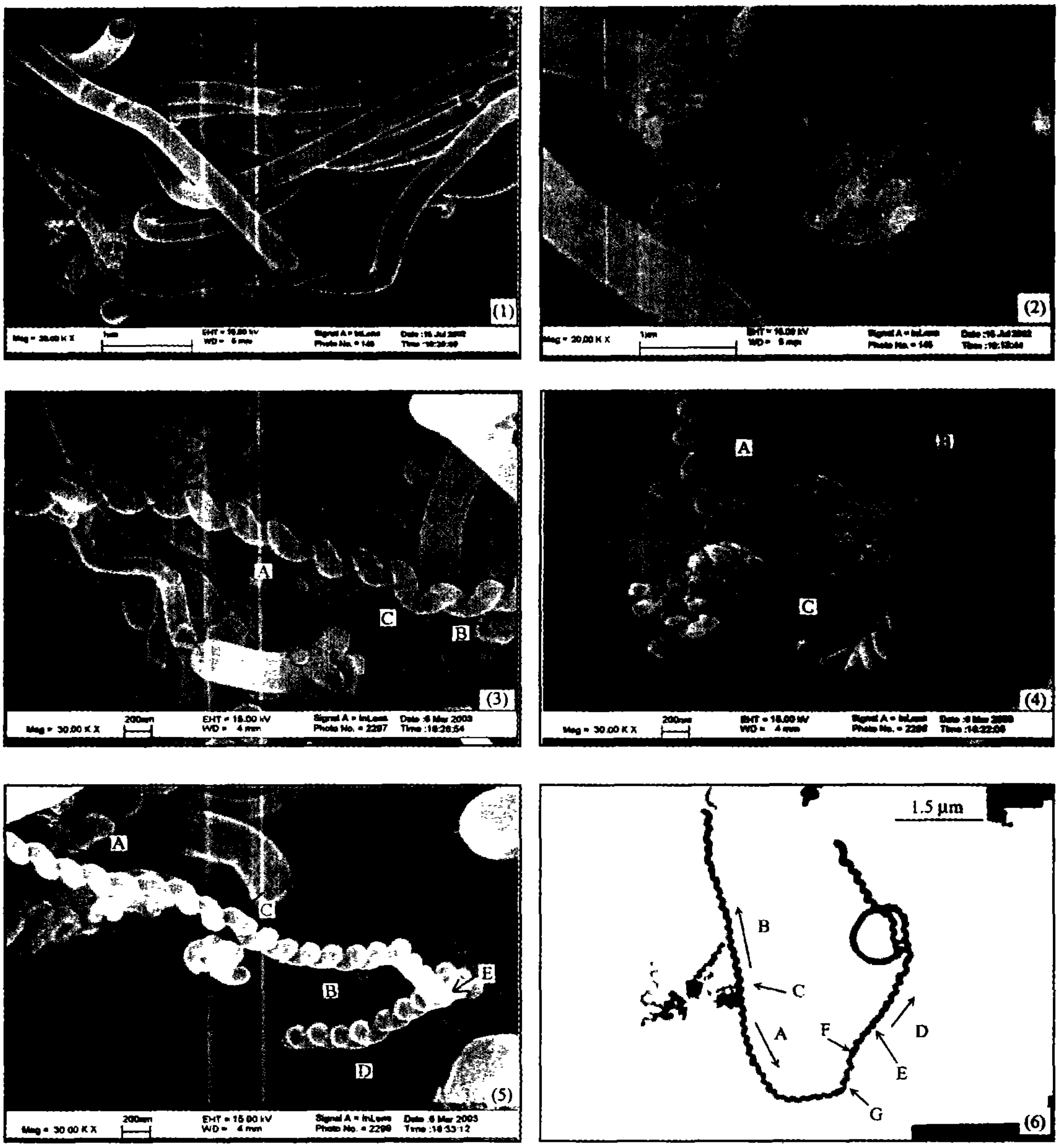

Fig. 1 Morphologies of carbon nanofibers: (1) ~ (5) SEM; (6) TEM

A, D: right-handed helix; B: left-handed helix; C, E, F: turning point

control and prepare the multi-directional helical nanomaterial, and that it can be used into new application area from the study on the formation of the multi-directional helical structures.

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