Different branched carbon nanotubes prepared by pyrolysis method

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Abstract

Some kinds of branched carbon nanotubes (CNTs) were prepared in the products of ordinary carbon nanotubes prepared by the catalystically pyrolysis method. The ordinary carbon nanotubes have straight morphology, and the average diameter was about 50 ~ 80 nm. The branched carbon nanotubes included single-branched, double-branched, cross-branched and multi-branched carbon nanotubes.

Introduction

Carbon nanotube (CNT), as one of the most important nano-materials, has achieved a great progress in preparation, while most of the research attentions focused on multi-walled CNTs, double-walled CNTs and single-walled CNTs. With the development of nowadays microelectronics industry, the preparation of the branched CNTs (BCNTs) now attracts more attentions and BCNTs are considered as one of the most promising candidates of micro- and nano- electronic devices due to their mechanical or electrical properties. In 1995, Zhou et al [1] prepared the “L”, “Y” and “T” branches CNTs by the arc discharging method. From then on, some researchers tried to fabricate the CNTs with many kinds of branches by various methods, such as arc-discharge, alumina template, catalytic hydrocarbon decomposition, hot-filament CVD and self-seeded catalysts method [2 ~6], etc. The morphologies of branched CNTs have “L”, “Y”, “T” and multi-branched, etc.

In this work, some kinds of branches CNTs, such as “Y”, crossed and multi-branched, were prepared by catalytical pyrolysis method. The microstructure and morphology of the branched CNTs are characterized by TEM.

Experimental

CNTs were produced by catalytical pyrolysis method using a vertical furnace [7]. Benzene was used as carbon source and ferrocene as catalyst precursor with thiophene. The reaction temperature was between 1160 to 1170 ^{o}C. The flow rates of nitrogen and hydrogen are 1.46 L/min and 5.4 L/min, respectively.

The morphologies and microstructures of the products were characterized by transmission electron microscope (TEM) with an accelerating voltage of 200 kV.

Results and discussion

Figure 1 shows the typical TEM image of the main products prepared at that condition. As can be seen, the main products are straight CNTs with the diameter about 40 ~ 80 nm. The products are very pure, and only very few particles exist.

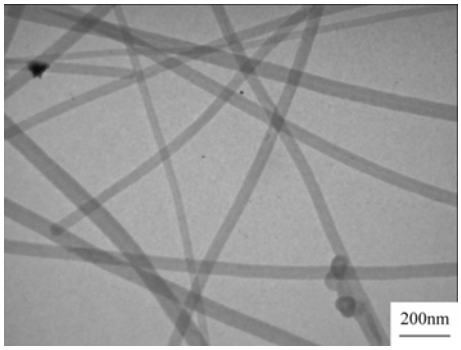
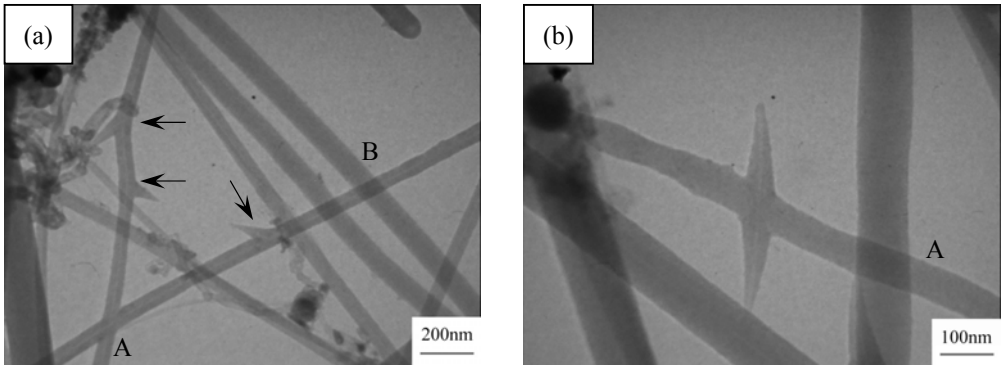


Figure 1 TEM images of the main products

The TEM images of the branched CNTs are showed in Figure 2. From Figure 2(a), we can see one "X"- branched CNT. Two branched CNTs cross at the point "A". The point "A" is different from the point "B" that was the point of one CNT lap over another one, which suggest that that CNT is really one "X" branched CNT. The diameter of the two branches is about 60 nm. As showed by black arrows in Figure 2(a), the branched CNTs also have others short branched CNTs with cone-shaped morphology that are about 150 nm long, which shows the asymmetric "Y" type morphology. Figure 2(b) shows one cross-branched CNT that is like an asymmetric "+". The main branched CNT is very long with diameter of about 70 nm. The secondary branched CNT has the cone-shaped morphology with length of about 450 nm. The point "A" also shows the cross morphology, but that is the overlapping point of two separate CNTs. Figure 2(c) is a typical TEM image of multi-branched CNTs. This kind of branched CNT has one main-bone CNT that are entirely coated on the outer surface by a lot of CNTs. The diameters of those branched CNTs are about 15 ~ 50 nm, which are smaller than that of the ordinary CNTs. This may be caused by the smaller Fe catalyst particles. The growth mechanism of the multi-branched CNTs is that the main-bone CNT is the catalyst support for the other branched CNTs to grow. After the main CNT has formed, many pyrolytic Fe deposited on the surface and agglomerated into new catalyst nano-particles. Those new Fe catalyst nucleated new CNTs which formed as the branches of the original CNTs. In Figure 2, some other kinds of branched CNTs were discovered, such as "Y"- (point "A" and "B"), "T"- (point "C") and "X"- (point "D") type.



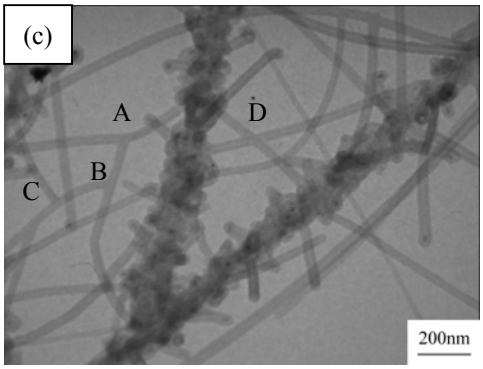


Figure 2 TEM images of different branched CNTs

Conclusion

In summary, some kinds of branched CNTs, such as “Y”-, “T”-, “X”- type and multi-branched CNTs, were discovered in the products prepared by catalytical pyrolysis method using a vertical furnace.

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