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Cutting of multi walled carbon nanotubes

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Abstract

Multi walled carbon nanotubes (MCNT) synthesized by CVD method have been successfully cut into different lengths by controlling H_2SO_4/HNO_3 (5:3) oxidation time. During the cutting process H_2SO_4 and HNO_3 were added independently and the oxidation processes were carried out at a lower temperature to void excess weight loss and damage to MCNT. The resulting shorted MCNT (s-MCNT) formed stable dispersion state in the polar solvents without the help of surfactants that provided possibility for further functionalization and application. Moreover, NaOH solution was used to determine the total percentage of acidic sites and the total percentage of acidic sites are about 0.2–1%.

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Keywords: Multi walled carbon nanotubes (MCNT); Cutting; Titration; Scanning electron microscopy

1. Introduction

Since the discovery of carbon nanotubes by Iijima [1], fundamental research on carbon nanotubes and various potential applications [2–7] have been proposed. Recently, carbon nanotubes (CNT) with relatively short lengths have been attracting strong attention because such CNT are expected to provide connectors and components in molecular electronic devices [8] and have rich chemistry [9,10]. Therefore, different methods have been developed to cut CNT either physically or chemically. It is reported that the fluorination of purified CNT followed by pyrolysis of the fluorinated nanotubes at temperatures up to 1000 °C was found to have cut the nanotubes to a range of short lengths but the process is very complicated and energy consuming [11]. It is reported that STM and AFM were also successfully used to produce short CNT however these method were only used for individual CNT [12,13]. Recently, ball mills [14–18] has become an efficient method to cut CNT however it generally takes over 100 h to cut CNT to an average length of 200–300 nm. Moreover, sometimes carbon nanotubes were partially or completely

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damaged or carbon nanoparticles formed at the broken end of nanotubes.

Therefore, here we developed a facile, effective and controllable method to obtain shorted multi walled carbon nanotubes (s-MCNT) in a shorter time. The concentration of acidic sites introduced by mixture acid was decided by acid–base titration method. The characteristics of MCNT were investigated using scanning electron microscopy (SEM), X-ray diffraction (XRD) and the resulted functional groups were characterized using infrared spectroscopy (FTIR).

2. Experimental

As prepared MCNT synthesized by chemical vapor deposition (CVD) method contain many catalysts [19,20] therefore the as prepared MCNT were put into concentrated HCl with magnetic agitation for 5 h then filtered to eliminate these catalysts. The cutting experiments were carried out as follows: 250 mg pretreated MCNT was suspended in 300 ml of concentrated H_2SO_4 with magnetic agitation for 30 min at room temperature then added 180 ml of concentrated HNO_3. The mixture was heated at 60 °C for 4, 8 and 12 h, respectively. The s-MCNT were collected on a polytetrafluoroethylene (PTFE) filter with the pore size of 200 nm and washed with de-ionized water until the PH value reach neutral.

s-MCNT was ready for the titration experiment by heating at 100 °C for 1 h under vacuum to degas absorbed carbon dioxide and water. Then 100 mg of the s-MCNT was added in 0.03 M NaOH solution under vacuum for 50 h and stir was required to allow the s-MCNT equilibrate with NaOH solution. The mixture was then filtered through a filter with pore size of 200 nm and MCNT collected on the filter were washed with de-ionized water to remove all of the NaOH residues. The excess NaOH in the combined filtrated and washings were titrated with 0.03 M aqueous HCl to reach the neutral PH.

3. Results and discussion

Because carbon atom hexagons are more stable than pentagons and defect sites, these pentagons or defect sites of CNT are destroyed by mixture acid preferentially. As a result, the mass was reduced to relatively short and straight carbon nanotubes. The representative SEM images of s-MCNT are shown in Fig. 1. After mixture acid treatment for 4 h, purified

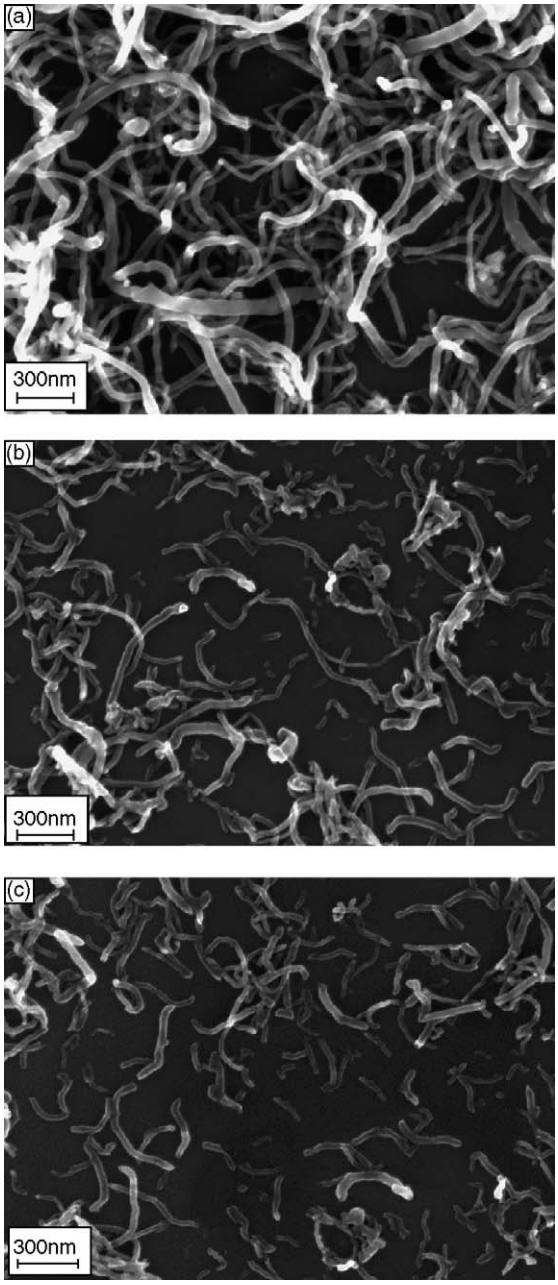

Fig. 1. SEM images of s-MCNT after mixture acid oxidation for (a) 4, (b) 8 and (c) 12 h.