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ORIGINAL PAPER

Efficient synthesis of carbon nanotubes with improved surface area by low-temperature solvothermal route from dichlorobenzene

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The synthesis of well-aggregated carbon nanotubes in the form of bundles was achieved by the catalytic reduction of 1,2-dichlorobenzene by a solvothermal approach. The use of 1,2-dichlorobenzene as a carbon source yielded a comparably good percentage of carbon nanotubes in the range of 60–70 %, at a low reaction temperature of 200 °C. The products obtained were analysed by X-ray diffraction, Raman spectroscopy, scanning electron microscopy, and transmission electron microscopy techniques. The X-ray diffraction studies implied the presence of pure, crystalline, and well-ordered carbon nanotubes. The scanning electron and transmission electron microscopic images revealed the surface morphology, dimensions and the bundled form of the tubes. These micrographs showed the presence of multi-walled carbon nanotubes with an outer diameter of 30–55 nm, inner diameter of 15–30 nm, and lengths of several hundreds of nanometers. Brunauer–Emmett–Teller-based N_2 gas adsorption studies were performed to determine the surface area and pore volume of the carbon nanotubes. These carbon nanotubes exhibit a better surface area of 385.30 $m^2\ g^{-1}$. In addition, the effects of heating temperature, heating time, amount of catalyst and amount of carbon source on the product yield were investigated.

Keywords: solvothermal process, 1,2-dichlorobenzene, low-temperature synthesis, CNTs bundles

Introduction

Carbon nanotubes (CNTs) have attracted a great deal of interest since their discovery by Iijima (1991), as more and more special properties are disclosed. They are materials formed on a nanoscale by sp^2 hybridised carbon atoms with interesting structural designs such as cylinder-shaped macromolecules with a radius of only a few nanometers. Much research has been directed towards the efficient synthesis of this material because of its unique morphology, nano-scale, physico–chemical properties, and their versatile applications in electrochemical devices (Baughman et al., 1999), hydrogen storage (Liu et al., 1999; Zubizarreta et al., 2009), field emission devices (Shim et al., 2001), chemical sensors (Kong et al., 2000), biomedical applications (Wu et al., 2010), and as nano-tweezers (Kim & Lieber, 1999). Although many techniques are available for the synthesis of CNTs, progress is slow in challenging issues like synthesising them at a greater yield, cost-effectiveness, etc. Arc discharge (Bethune et al., 1993; Kim & Kim, 2007; Jian et al., 2008), laser ablation (Scott et al., 2001), and catalytic decomposition (Benito et al., 1998) are the most common techniques for the synthesis of CNTs; these follow the basic principle of evaporation and condensation of the carbon source on a graphite target in an inert atmosphere. In recent years, other possible methods for the synthesis of carbon nanotubes have been reported. They are: laser evaporation of a metal graphite composite target (Dai et al., 1996) carbon monoxide disproportionation on a metal catalyst (Herreyre & Gadelle, 1995), and hydrocarbon pyrolysis using a metal catalyst (Rodriguez, 1993; Mahanandia et al., 2008).

Although the above methods produce high quality materials with good yields, the requirement of a large amount of energy to achieve the high temperature (1000–3700 °C) and the use of lasers and inert atmo-

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