SIZE CONTROLLABILITY IN SYNTHESIZING CARBON SPHERES

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Abstract

In the present contribution, uniform carbon spheres were synthesized by "arc in liquid" method with the aromatic hydrocarbons as the medium for arc discharge. Transmission electron microscopy, field-emission scanning electron microscopy, and X-ray diffraction were employed to study the morphologies and microstructures of the samples.

Keywords: carbon spheres, transmission electron microscopy, scanning electron microscopy

Introduction

Carbon materials have been applied in various areas, including catalyst support, separation system, water purification, and hydrogen-storage materials. It is well known that the properties of materials are strongly dependent on the particles shape, size and size distribution. The creation of novel carbon spheres has in recent years developed into an increasingly important research area at frontier of advanced materials due to its excellent chemical, mechanical, and thermal stability. However it is very difficult to control the particle size and dispersion of carbon spheres, which may act as the key role in the application area. "Arc in liquid" method, which does not require vacuum facilities, is recently reported as a cost-effective technique to synthesize carbon nanostructures. Many novel carbon nanostructures such as carbon nanotubes (CNTs), carbon nanohorns (CNHs), carbon onions (COs) and metal-included carbon nanocapsules (CNCs) have be synthesized by this method. Based on the above information it is expected that carbon spheres could be formed in liquid.

In this work, carbon spheres with uniform diameters were successfully synthesized by arc discharge in aromatic hydrocarbons. Transmission electron microscopy (TEM), field-emission scanning electron microscopy (FESEM), and X-ray diffraction (XRD) were employed to study the morphologies and microstructures of the samples

Experimental

In the experiment, uniform carbon spheres were fabricated by applying arc discharge in aromatic hydrocarbons in an open vessel. The discharge apparatus consisted of two graphite electrodes, an open vessel (2L) and a direct current power supply. The graphite cathode (20 mm in diameter) and anode (6 mm in diameter) were submerged in liquid toluene and aligned horizontally. The whole procedure took place at the depth of 3 cm below the liquid surface. The optimized discharge current was 30, 40, 60A. The arc discharge in toluene was found stable and could run for 20 s by adjusting the cathode–anode gap to be approximately 1 mm. The products are characterized by HRTEM (JEOL JEM 2010) and SEM (JEOL JSM- 6700F). X-ray diffraction (XRD) measurements were carried out on a D/max-3C X-ray diffractometer using CuKα radiation (1.5405 Å) to characterize the structure of the as-synthesized carbon spheres.

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Results and Discussion

The SEM image of the carbon spheres is shown in Fig. 1. Aggregates of carbon structures with globular morphology were observed from this image. Tubular structures were not found in the fine powders. It can be seen that the carbon spheres are monodispersed with an average diameter less than 1μm. The sizes are about 200nm, 50nm and 400nm. It is experimentally found that the current was main factor, affected the morphologies and size of carbon spheres directly. By a series of comparisons, different sizes of carbon spheres were obtained. In other words, the particle size and dispersion of carbon spheres are controled by discharge current.

As can be seen from Fig.2, the products consisted mainly of homogeneous carbon spheres appeared condensed with each other sized about 50 nm. Obviously, the surfaces of the carbon spherules are very smooth, different from the rough surface of mesocarbon microbeads (MCMB) or spongy carbon nanobeads. The microstructure of the particles was further determined to have relatively low crystallization degrees by TEM and XRD.

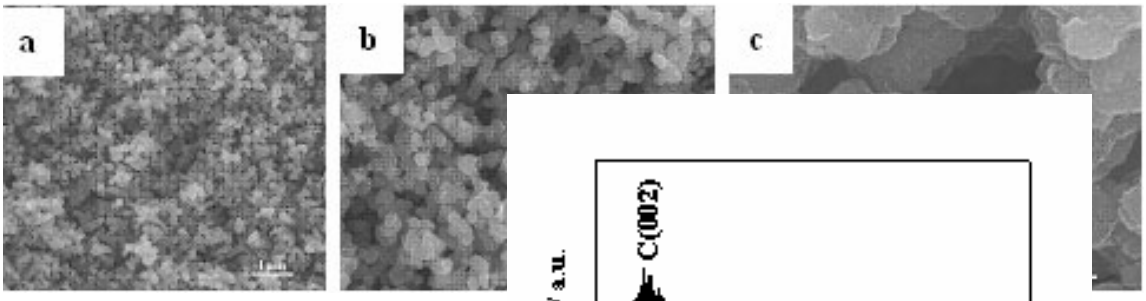
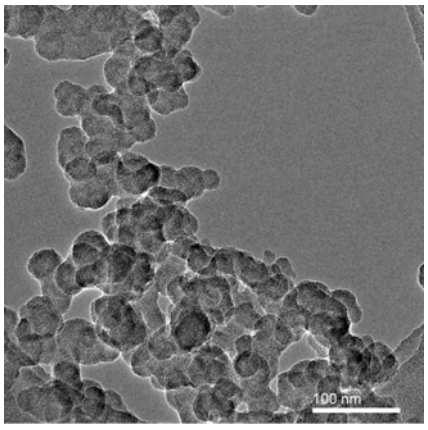


Fig.1. SEM images of the products

The powder XRD pattern of the carbon sph t 24° corresponds to the structure factor peaks of gra llow diffraction peak reveals the non-graphitic structure



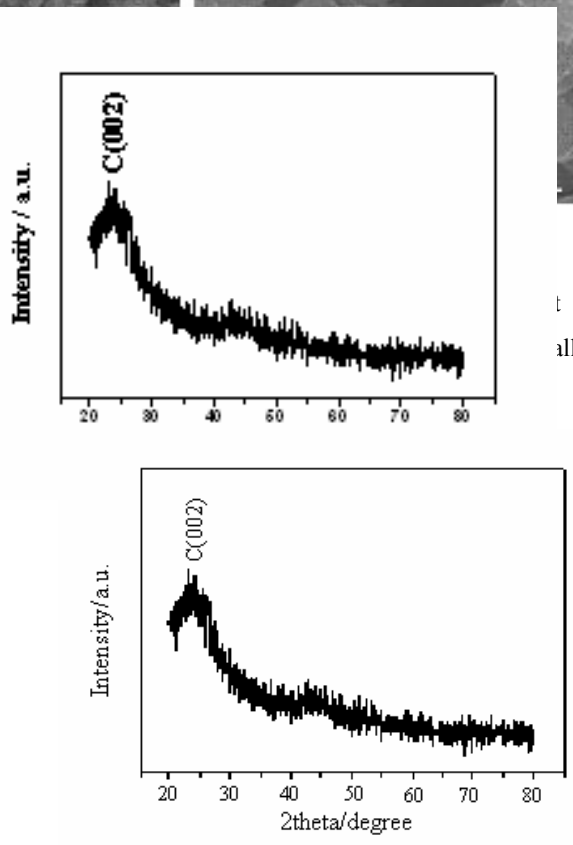


Fig.2 a) High magnification and b) XRD spectrum showing details of the carbon spheres at 40A.

When the arc was performed, the high-temperature cracking of the aromatic hydrocarbons is expected to occur. It can be inferred that the carbon source for the carbon spheres in the present condition is mainly aromatic hydrocarbons according to the mass balance. The rapid solidification of the vaporized carbon caused by the

sharp temperature gradient in the reaction zoon was determined to play an important role for the formation of carbon spheres.

It is known toluene will decompose to benzyl and phenyl at high-temperatures (>1200 K). Furthermore, a part of hexagonal carbon structures can be decomposed into small fragments and atoms at the centre zone of the arc (>4000K). The bubbles at the arc spot should contain high concentration of organic species including hexagonal carbon structures (toluene, benzyl, and phenyl) and dissociated carbonaceous clusters. Due to rapid quenching by the surrounding liquid, these organic species evolve into more stable carbon nanoparticles. These nanoparticles with different size in this study are reasonably generated under the different local conditions coexisting in the bubbles. In addition, liquid toluene provides less efficient cooling than does the deionized water because the strong evaporation of liquid toluene doesn't allow a good thermal exchange between the synthesized material and its surroundings. Therefore the carbon nanoparticles produced in liquid toluene exhibit a degraded structure compared with that produced in water.

Conclusions

In summary, uniform carbon spheres were successfully produced by applying arc discharge in liquid toluene. The particle size and dispersion of carbon spheres could be controlled by discharge current. It was indicated that aromatic hydrocarbons were the most suitable medium for the production of carbon spheres when the arc was performed in liquid toluene.

Acknowledgements

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