Nitrogen and Boron Doping Effects in Carbon Nanospheres

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Abstract

Carbon nanospheres (CSs) are attracting more attention worldwide due to their excellent performance in various fields such as drug delivery, heterogeneous catalysis and encapsulation of support materials. Carbon atoms in CSs can be replaced with other atoms in the carbon matrix which alters the physical and chemical properties of the spheres. Typical elements that are used as dopants are N, B, S and P. These heteroatom dopants in carbon materials provide improved and controllable electronic features and rich surface chemistry, thus play an increasingly important role in nanocarbon-enabled advanced functional materials, e.g. sensors[1], energy storage materials[2] and heterogeneous catalysts[3]. Heteroatom doped CSs can be solid, hollow or core-shell in morphology. Different methods have been used to synthesize CSs, and some require a catalyst, a soft or hard template. Of the available methods for the synthesis of solid and hollow CSs, the chemical vapour deposition (CVD) route seems the most viable due to its simplicity and low-temperature of operation; and for the fabrication of hollow CSs it is better than hard templating routes, since the extra steps and use of harsh etching agents (typically HF) to remove hard templates make processing tedious. Herein we report a simple method for the growth of nitrogen doped carbon spheres (N-CSs) and boron-doped hollow carbon spheres (B-HCSs) without using a catalyst or a template. N-CSs were synthesized via a CVD method at 900 °C using C_2H_2 as the carbon precursor and CH_3CN as a C and N source. For the B-HCSs growth, a similar set-up to N-CSs synthesis was used, and C_2H_2 was used as the carbon precursor and $B(OCH_3)_3$ as a C and B source. The N-CSs and B-HCSs were synthesized using vertical furnace and the properties of the produced materials were compared to CSs synthesized using C_2H_2 as a C source. The morphology, structural features and the composition of the CSs, N-CSs and B-HCSs were ascertained by TEM, HAADF-STEM, TGA and XPS. Fig. 1 shows the TEM image of B-HCSs. Compared to TEM images of CSs and N-CSs (not shown here), which appeared solid, the morphology of the B-HCSs was hollow while some had core-shell morphology. TGA analysis confirmed the presence of the B_2O_3 (25-35%) in the crude product and this B_2O_3 could be removed by boiling water. HAADF-STEM (not shown here) analysis confirmed the presence of B_2O_3 in the centre of the core-shell boron doped carbon spheres. Using XPS analysis, the N content in the N-CSs was found to be 3.10%. The level of boron content in the B-HCSs was found to be 3.92 % (mainly B_2O_3). The final residual B found in B-HCSs was associated with B doping. The B_2O_3 acted as a template for the formation of the B-HCS structures and a mechanism for the B-HCS formation is proposed.

References

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Figures

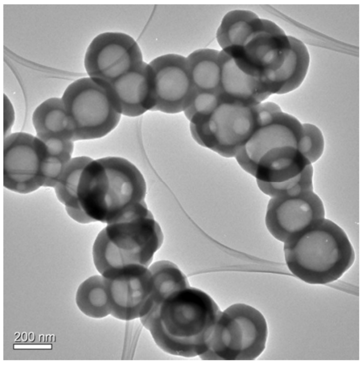

Figure 1. TEM image of B-HCSs