S6-04

Application - Thermal Plasmas: Synthesis of Carbon-Related Nanomaterials by Thermal Plasma

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1. Introduction

The possible hybrids (*sp*, *sp*^{2} and *sp*^{3}) of carbon atoms provide different carbon allotropes, such as amorphous carbon, graphite, and diamond. The discovery of fullerenes (C_{60}) has inspired considerable research interest of new carbon allotropes, and the subsequent discoveries of carbon nanotubes (CNTs) and graphene opened up a new era in carbon nanomaterials and nanotechnology. Over the past few decades, carbon nanomaterials have attracted increasing attention due to their excellent physical and chemical properties, and they have been considered as the most promising materials for energy conversion (i.e., solar cells and fuel cells) and storage (i.e., supercapacitors and batteries).

Thermal plasma technology has attracted more and more attention due to high efficiency and the huge potential for commercial producing carbon nanomaterials. In this research, arc discharge is used to synthesize carbon nanomaterials, and the formation mechanism is investigated.

2. Experimental setup

A homemade arc discharge apparatus, in which two graphite electrodes were installed vertically, was used to prepare carbon nanomaterials. The buffer gas was injected into the reaction chamber after evacuating the air from the chamber, including argon, nitrogen, and hydrogen gases at 70 kPa. The arc was generated at the current of 200 A and the voltage was maintained around 25-30 V when it was monitored by oscilloscope. After the anode graphite was evaporated, samples were deposited to the inner wall of the reaction chamber to obtain carbon nanomaterials. Synthesized nanomaterials were characterized by Raman, SEM, and TEM.

3. Results and discussion

Figure 1 shows TEM images of samples prepared under Ar, N_2, and H_2 atmosphere. The diameter of spherical carbon nanoparticles (SCNs) were found to be about 30-80 nm, and these SCNs had amorphous structure in Figure 1(a). Figure 1(b) shows the typical 'dahlia-like' carbon nanohorns (CNHs) whose basal plane lattice has no perfect periodicity in the cone region, represented by a conical shape with a cone angle of 20º. The cone-like termination is due to a well-ordered *sp*^{2} structure terminated on the tip. As shown in Figure 1(c), the surfaces of few-layers graphene (FLG) sheets with 2-5 layers are transparent and have folded layers with wrinkles over the surface.

Figure 2 shows schematic illustration of formation mechanism of these carbon nanomaterials. In Ar, it was impossible for the argon atom to bond with the carbon cluster, leading to carbon precursors combining into amorphous SCNs. In N_2, the nitrogen atoms quickly bonded with the carbon atoms to form C-N bonds. C-N bonds led to the bending of the graphite sheets, and thereby reduced energy barrier to form carbon pentagons and heptagon, facilitating the generation of CNHs. Hydrogen inhibited the rolling and closing of graphene sheets by terminating the dangling carbon bonds [1].

4. Conclusions

Amorphous SCNs, 'dahlia-like' CNHs, and FLG were successfully synthesized by arc discharge. The formation mechanism of these carbon nanomaterials by arc thermal plasma was deduced.

References

[1] D. Zhang *et al.*, Carbon, **142**, 278-284, (2019).

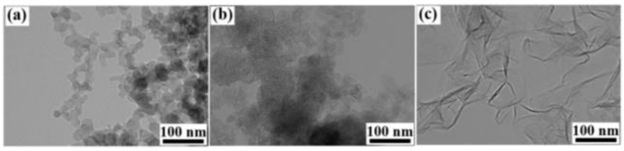

Fig. 1 TEM images of carbon nanomaterials synthesized under different buffer gases: (a) Ar, (b) N_2, and (c) H_2.

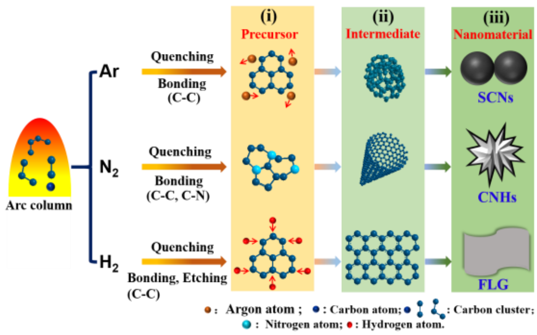

Fig. 2 Schematic illustration of formation mechanism of carbon nanomaterials from inner wall of chamber using different gases by arc discharge.