A-O9 AAPPS-DPP2019

3rd Asia-Pacific Conference on Plasma Physics, 4-8,11.2019, Hefei, China

Continuous synthesis of graphene nano-flakes by non-thermal plasma with a magnetically rotating arc at atmospheric pressure

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Thermal and non-thermal plasma processes have been considered as potential methods for continuous gas synthesis of graphene in recent years. A novel approach for the preparation of few-layer graphene nano-flakes (GNFs) is presented in this work. The GNFs are continuously synthesized by non-thermal decomposition of hydrocarbons using a magnetically rotating arc at atmospheric pressure. The products are characterized by transmission electron microscopy (TEM), Raman spectrum, BET measurements and X-ray photoelectron spectroscopy (XPS). The effects of arc current, feedstock gas type, feedstock gas flow rate, C/H mole ratio and buffer gas type on the morphologies and microstructures of pyrolysis products are investigated and discussed.

Results show that low power, low carbon concentration and high hydrogen concentration are considered the essential condition for the formation of GNFs. The synthesized GNFs are agglomerative flakes, where each flake is between 50 and 300 nm. Material analyses indicate that the GNFs have excellent properties such as a good crystalline structure, a high purity, a low number of layers, and a large specific surface area. Such characteristics suggest that the GNFs could be applied in fuel cells and energy storages. Building on the above results, a possible nucleation mechanism of graphene is proposed. On the one hand, low concentration of graphene nucleating precursor-polycyclic aromatic hydrocarbons (PAHs), is a necessary condition for the formation of GNFs. A process of slow rate of nucleation and rapid surface growth may occur during the GNFs formation[1]. On the other hand, low C/H mole ratio can form mass activated hydrogen atoms which terminate dangling bonds at edge of graphene and prevent the bending of carbon, that promotes the formation of GNFs[2].

Compared with GNFs prepared in other non-thermal plasmas, this method has a lower energy cost (<0.3 kWh/g) and no pollution while guaranteeing the quality of GNFs. It is anticipated that the method developed in this paper will be highly advantageous for the mass and continuous productions of GNFs. Additionally, the morphologies and microstructures of final products can be adjusted easily by controlling the operating parameters.

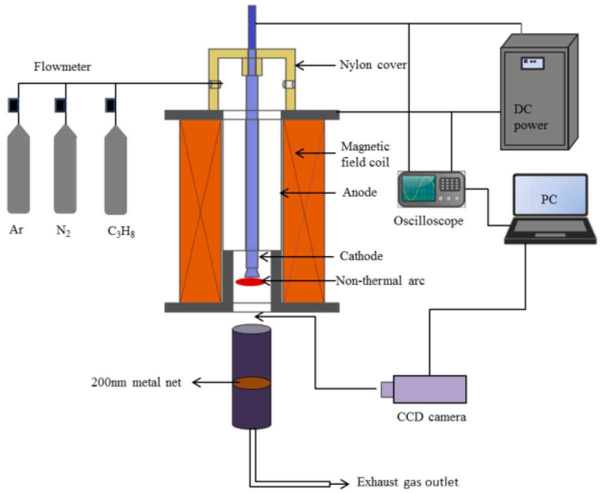

Figure 1 Schematic diagram of the experimental apparatus

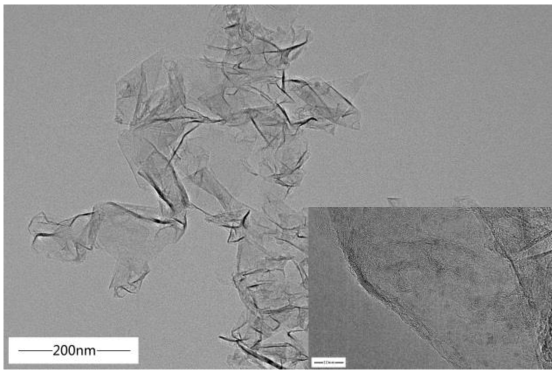

Figure 2 Typical TEM and HRTEM image of GNFs

Reference:
[1] A. Dato and M. Frenklach, "Substrate-free microwave synthesis of graphene: experimental conditions and hydrocarbon precursors," New Journal of Physics, vol. 12, no. 12, p. 125013, 2010.
[2] D. Zhang et al., "Controllable synthesis of carbon nanomaterials by direct current arc discharge from the inner wall of the chamber," Carbon, vol. 142, pp. 278-284, 2019.

Acknowledgement: The program is supported by NSFC (No. 11675177) and Hefei Carbon Art S&T Ltd.