Synthesis of Graphene Nanoflakes by Methane Pyrolysis in Thermal Plasma

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Abstract: This study explores the synthesis of graphene nanoflakes (GNFs) through methane pyrolysis in a thermal plasma system, emphasizing the influence of hydrogen (H_2) addition on their quality. The findings indicate that varying H_2 flow rates significantly affect the properties of GNFs. The results underline the importance of optimizing H_2 flow conditions to achieve high-quality GNFs.

1. Introduction

With its sp^2 crystal structure and hexagonal shape, graphene is a two-dimensional nanomaterial with excellent physical, chemical, and mechanical properties. It is highly versatile and promising for mass production potential and various applications [1].

According to the experiments of C. Wang *et al.*, it was revealed that high gas temperature and H atoms are essential for the formation of graphene nanoflakes (GNFs) [2]. Thermal plasma provides a high-temperature region; Y. H. Lee *et al.* also showed that triple thermal plasma enhances methane pyrolysis [3]. We concluded that this method suits graphene synthesis. Therefore, this study aims to explore the optimal conditions for synthesizing GNFs through a methane pyrolysis system in a triple thermal plasma and evaluate its characteristics.

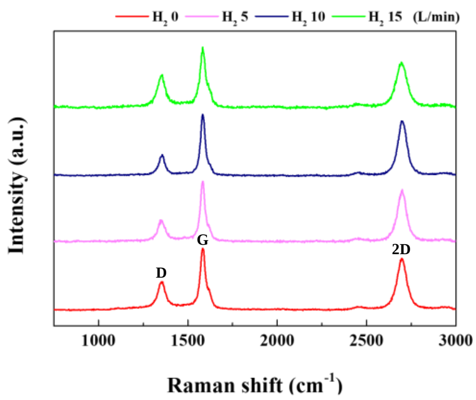

Fig. 1. Raman spectra of the products under different H_2 flow rates.

2. Methods

The system consists of three non-transferred DC plasma torches, a pyrolysis reactor, graphite tubes, gas injections, and power supplies. Nitrogen (N_2) was used as the plasma-forming gas, and the flow rate per single torch was fixed at 15L/min. To investigate the effect of hydrogen (H_2), the experiment was conducted by fixing the flow rate of CH_4 and changing only the flow rate of H_2.

3. Results and Discussion

Raman spectrum analysis showed a spectrum and crystallinity like GNFs; the results are shown in Fig. 1. The D band is associated with structural defects and impurities in the graphitic structure. In contrast, the G band represents the vibrational mode of well-ordered sp2 carbon atoms in the graphitic lattice. The ratio of the D band to the G band intensity (I_D/I_G) indicates the sample's crystallinity. The ratio of the 2D band intensity to the G band intensity (I_{2D}/I_G) estimates the thickness of the sample. A lower I_D/I_G value indicates a material with higher crystallinity. As the H_2 flow rate was varied, the following I_D/I_G and I_{2D}/I_G ratios were observed: at 0 L/min H_2, $I_D/I_G = 0.46$ and $I_{2D}/I_G = 0.82$; at 5 L/min, $I_D/I_G = 0.35$ and $I_{2D}/I_G = 0.85$; at 10 L/min, $I_D/I_G = 0.31$ and $I_{2D}/I_G = 0.89$; and at 15 L/min, $I_D/I_G = 0.52$ and $I_{2D}/I_G = 0.75$. SEM and TEM image analyses confirmed the product's multi-layered, sheet-like structure. This morphology was like that of typical GNFs. The crystallinity tends to increase as the H_2 flow rate increases. However, it decreases under the condition of 15 L/min H_2 flow rate, which suggests that rapid cooling may have caused a decrease in crystallinity.

4. Conclusion

The synthesis of GNFs by methane pyrolysis in triple thermal plasma was investigated. The experiment was performed by changing the flow rate of H_2, and the effect of H_2 on the properties of the synthesized GNFs was analyzed. It was confirmed that the GNFs generated under H_2 10 L/min among the experimental conditions showed the best characteristics.

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References

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