Decoding Growth Conditions: Spatial Temperature Mapping in Carbon-Rich Plasma Flows via NO-LIF

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Abstract

Understanding the synthesis of high-quality graphene from gaseous hydrocarbons via microwave plasma reactors at atmospheric pressure is a key milestone on the path to industrial applications of this 2D material. While plasma-based processes offer a high-throughput route, the formation, quality and morphology of the resulting graphene framework are expected to be sensitive to the local gas-phase temperature and thermal gradients within the post-plasma zone. However, obtaining precise temperature data via optical *in situ* diagnostics in plasma environments is a major challenge due to interference from laser-heated particles.

In this study, we implement multi-line nitric oxide laser-induced fluorescence (NO LIF)[1] as a non-intrusive diagnostic tool to investigate the temperature distribution in a carbon-particle-laden post-plasma flow. Our methodology exploits the rotational temperature distribution of the NO molecule excited in the γ-band (226 nm) by effectively isolating the molecular fluorescence signal from competing laser-induced incandescence (LII) and scattering effects of nucleated carbonaceous material via excitation-wavelength scanning.

We present the diagnostics setup alongside preliminary spatially resolved temperature maps. These maps showcase the capability of the multi-line NO-LIF thermometry approach to resolve the temperature distribution of the post-plasma flow. By illustrating the spatial distribution of the temperature field, we demonstrate how this framework can be used to identify the specific regions where nucleation and growth of graphene are expected to occur [2]. This diagnostics approach lays the groundwork for a more fundamental understanding of the plasma-chemical conditions required for the formation and growth of graphene and could support the future optimization of reactor geometry and flow parameters. Ultimately, this work contributes to a diagnostics framework designed to facilitate the transition from empirical synthesis toward a more knowledge-based and controlled growth of this 2D material in scalable plasma systems.

References

[1] Bessler, W., Schulz, C., Lee, T. et al. *Appl Phys B* 75 (2002), 97–102
[2] Li, N., Li, D., Zhen, Z et al. *Mater Today Comm* 36 (2023), 106568