

Society of Engineering Science 51st Annual Technical Meeting

1–3 October 2014

Purdue University, West Lafayette, Indiana, USA

Coherent antistokes Raman scattering diagnostics of plasma in synthesis of graphene-based materials

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ABSTRACT

Scalable production of carbon nanostructures to exploit their extraordinary properties and potential technological applications requires an improved understanding of the chemical environment responsible for their synthesis. In this study, the temperature and concentration of molecular hydrogen is measured using coherent antistokes Raman scattering (CARS) spectroscopy in the plasma of a Microwave Plasma Chemical Vapor Deposition reactor under parametrically controlled conditions. The reactor pressure is varied from 10 to 30 Torr and the plasma generator power from 300 to 700 W, simulating the conditions required for the synthesis of carbon nanotubes and graphene. Temperature measurements are conducted within the plasma sheath and 5–10 mm away from the sheath to elucidate the spatial distribution of temperature within and around the plasma region. The results of the CARS experiments indicate only a weak correlation between the rotational temperature of hydrogen and the distance away from the plasma sheath at 10 Torr. The temperature of hydrogen varies approximately from 700 K to 1000 K. However, a strong correlation at 30 Torr is apparent, in which the temperature increases from 1100 K to 1900 K at both 500 and 700W. The concentration measurements of molecular hydrogen imply that the degree of dissociation in the plasma is very low and that the rotational temperature of molecular hydrogen and the translational temperature of the heavy species in the plasma are equal to within experimental error. The spectroscopic techniques applied in this research may prove to be suitable in-situ monitoring methods for the scalable manufacturing of carbon nanomaterials.