Insights into Phosphorus-Doped Diamond Layers via Optical Emission Spectroscopy of $PH_3/CH_4/H_2$ Microwave Plasmas

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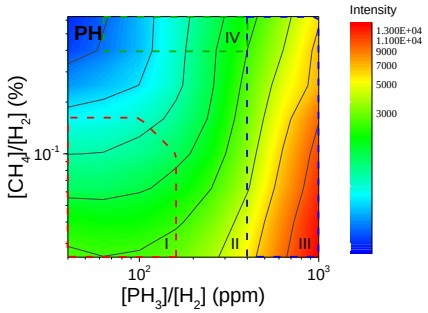
The synthesis of n-type phosphorus-doped diamond layer is considered a crucial factor in the development of high-power electronic devices. However, challenges persist in improving phosphorus concentration due to low phosphorus incorporation efficiency, crystalline imperfections, phosphorus contamination in the chamber, and the passivation of phosphorus dopants by hydrogen atoms in phosphorus-doped diamond layers. Recently, Lobaev et al. revealed a proportional relationship between phosphorous concentration and the intensity of PH radical emissions1, offering a new approach to characterizing layer properties through plasma chemistry analysis.

In this presentation, optical emission spectroscopy (OES) was used to comprehend the plasma chemistry of $PH_3/CH_4/H_2$ in a NIRIM-type microwave plasma enhanced chemical vapor deposition (MWPECVD) system. The behaviour of PH and CH radicals in the plasma was explored as a function of PH_3 and CH_4 concentrations. The intensity of PH radical emissions is reduced as the concentration of CH_4 increases due to strong reaction between phosphorus and carbon-containing molecules. Polycrystalline phosphorus-doped diamond layers were grown using both static and dynamic CH4 gas flow methods to understand the relationship between OES results and layer properties. Phosphorus incorporation efficiency and Raman spectra of the layers were further examined based on plasma chemistry and phosphorus concentrations. The OES results indicated that phosphorus contamination in the reaction chamber plays an important role in the amount of PH radicals in the plasma and the phosphorus concentration in phosphorus-doped diamond layers. These findings offer insights for precise control of phosphorus concentration, optimization of growth conditions, and understanding the limitations of improving phosphorus concentration in the layer.



OES intensity mappings of PH radical emissions

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References

1. M.A. Lobaev, *et al. Phys. Status Solidi A.* **216** (2019), 1900234.