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Diamond growth perturbed by high TMB partial pressures

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Introduction The chemistry that supports diamond boron doping by microwave plasma-activated chemical vapor deposition (MPCVD) is complex, but its understanding is required for the sake of reproducible sample preparations. In many studies, diborane (B_2H_6) or trimethylboron ($B(CH_3)_3$, TMB) diluted in hydrogen (H_2) are used as boron source, and methane (CH_4) as carbon source. Therefore, boron precursors are converted into active species typ. BH_x (x = 0–3) by the plasma. Some of those BH_x accommodate into the growing diamond film by mean of surface reactions [1]. In the particular diamond growth with a CH_4 partial pressure below 2 % and the admixture of TMB, we found some differences in the relative density of active species from models [2]. In this study, the transition from growth to etching has been revealed when more than 0.5 % of TMB were introduced in the plasma.

Experiment Optical emission spectroscopy (OES) aimed to characterize electronically excited atoms and molecules that compose the plasma.

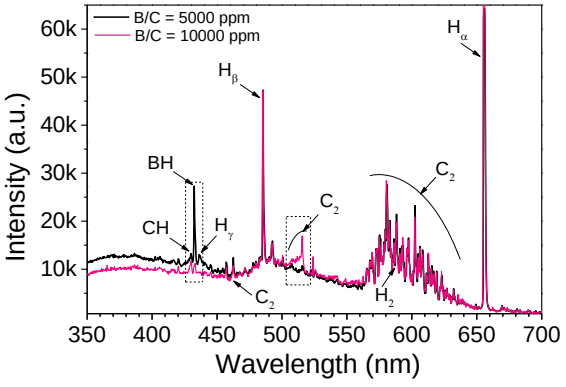

Figure 1. Two superimposed optical emission spectrums of TMB/CH_4/H_2 plasma mixtures where B/C = 5000 ppm and 10000 ppm (resp. thick and thin line). Microwave power, gas pressure, and CH_4/H_2 ratio were constant at resp. 80 Watt, 60 Torr, and 1 %.

Here, OES has been used to monitor in-situ the deviation of relative densities of BH, H, and C_2 radicals close to the diamond surface as functions of process conditions. Microwave power, pressure, and substrate temperature were constant, resp.: 80 Watts, 60 Torr, and 830–840 °C. OES data were combined with the process gas mass spectroscopy. Boron incorporation efficiency has been estimated by cathodoluminescence, and by SIMS.

Results &discussion In the example presented in Fig. 1, the plasma containing 1 % of CH_4 and B/C = 5000 ppm provided a diamond layer doped at 5×10^{19}cm^{-3}. Its OES showed a large peak attributed to BH species. That BH peak intensity increased as much as boron was incorporated in the diamond layer. At the opposite, the BH peak dropped by a factor five when the TMB concentration in the gas phase doubled; B/C = 10000 ppm. As result, the diamond sample exhibited no boron layer, but an etched surface instead. We presumed that TMB was not efficiently decomposed by the plasma at concentration larger than 0.5 %. The production of larger amount of BH species was investigated by increasing microwave power, gas pressure and under several CH_4/H_2 ratio. Those effects on the plasma chemistry were monitored by OES in order to find the signature of optimized doping growth conditions.

References

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