Comparison between boron atoms density measured by OES, LIF and resonance absorption techniques in a $H_2/CH_4/B_2H_6$ micro-wave plasma

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1. Introduction

This study focuses on the determination of atomic boron density in a $H_2/CH_4/B_2H_6$ microwave plasma. The microwave reactor for diamond film deposition is a water-cooled stainless steel nearly resonant cavity operating at high pressure (100 – 300 mbar) and high MW power (0.6 – 3.5 kW). The discharge, produced by a 2.45 GHz microwave generator, sparks off the activation of the gas mixture (0 - 1% CH_4 ; 0 – 66 ppm B_2H_6) leading to the formation of an approximate hemispheric plasma on the 5 cm diameter substrate holder supporting a crystal diamond substrate.

2. Results

2.1. OES

The absolute boron density in its doublet ground state ($^2P_{1/2,\,3/2}$) is deduced from the intensity ratio of the 2497/8 Å doublet [1,2]. Due to the 2 times higher density in the ($^2P_{3/2}$) state compared to ($^2P_{1/2}$) one at high density the resonant re-absorption can lead to an intensity ratio of the doublet different than the theoretical value 1. The density is deduced from this intensities ratio. The light emitted by the plasma is collected through a lens with a focal of 500 mm and then is focused on an optical fiber with a second lens. The other side of the optical fiber is connected to a spectrograph (500 mm focal length with a 2400 gr/mm grating blazed at 250 nm) backed by an ICCD detector. The collecting system is mounted on a motorized plate allowing measurements from 1 to 39 mm above the substrate. Results are represented on the figure 1 and show that the boron density seems independent of the radial position. The calculated density from the ~0.82 intensity ratio is about 2 10^{13} cm^{-3}.

2.2. LIF

The boron density profile is recorded by LIF on the 2089/90 Å doublet. A dye laser pumped by a Nd:YAG laser is used for photon flux generation around 2090 Å (5 - 40 µJ/pulse). The laser wavelength is calibrated using an I_2 reference cell [3]. The fluorescence signal is collected with a photomultiplier tube through a 210 nm filter. The excitation beam and the collection system are mounted on motorized plates allowing measurements from 1 – 30 mm above the substrate. The fluorescence signal is represented on the figure 1 for the transition at 2089 Å. Contrary to the results obtained by OES, the fluorescence signal is not constant and shows 2 minima.

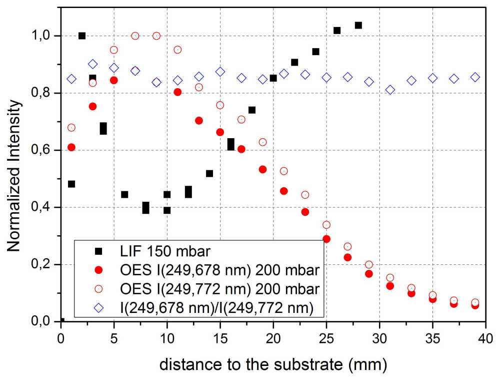

Fig. 1: Ratio of the emission intensities of the 2497/8 Å boron doublet compared to the 2089 Å fluorescence measured by LIF for close pressure conditions

2.3. Resonance absorption technique

The method that uses the intensity ratio of the resonance doublet of boron states on the main assumptions that the plasma is homogeneous and that the spectral profiles of emission and absorption lines are identical. In our experimental conditions, the LIF results obtained for several conditions of gas mixture, pressure and micro-wave power arise questions about these assumptions. In order to understand the difference observed using these techniques, we will use resonance absorption with external lamp [4] and self-absorption [5] techniques.

References

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