Parametric Study of Degree of Dissociation in a Low Pressure ECR based Hydrogen Plasma Source

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Knowledge of atomic Hydrogen (H) concentrations in a partially ionized hydrogen plasmas is essential for various applications such as cleaning and reduction of oxidation from the metal surface, passivation of silicon surface, growth of diamond film, negative hydrogen ion production etc. [1,2]. The dissociation of the feed gas H_2 by electron impact is the primary source of H atoms in a low pressure hydrogen plasma source. The Degree of Dissociation (DoD) refers to the ratio of the numbr densities of the dissociated molecules to the total number of molecules.

In this work parametric study of DoD of hydrogen plasma in a microwave (2.45 GHz) electron cyclotron resonance (ECR) source is reported. Gas pressure was varied from 2 – 10 mTorr while the input microwave power was maintained in the range of 300- 600 W. Two ECR field topologies were used to investigate its effect on dissociation. The basic experimental set up is shown in Fig. 1(a). In first configuration the ECR source [3] as shown in the extreme left is encapsulated by three permanent ring magnets (NdFeB) that provide the required field (875 G) for the resonance heating to take place. In the second configuration only one ring magnet is used which allow to have two ECR surfaces inside the source compared to former where the back ECR layer lied in atmosphere behind the quartz plate [Fig 1(b),(c)], thus did not attribute to heating. Plasma was produced in the source and expanded into an adjoining cylindrical chamber of length 55 cm and diameter 15cm.

The line intensity ratio method was used to determine the DoD [4]. For this purpose the Balmer-α and Balmer-β lines were captured using an optical emission spectrometer which was integrated with the vacuum chamber through a lens and multimode fiber.

The DoD was found to be always higher in the single-ring configuration. At 2 mTorr pressure and 600 W power 9% DoD was obtained for this configuration compared to 7% in the three-ring configuration. However, at higher operating pressure dissociation became lowered. Similar trend was observed when the input power is reduced [Fig 1(d), (e)]. To investigate further the experimental results were compared with that obtained from a volume averaged global model of a low pressure hydrogen plasma. The model results showed reasonable agreement with the experimental results.

References

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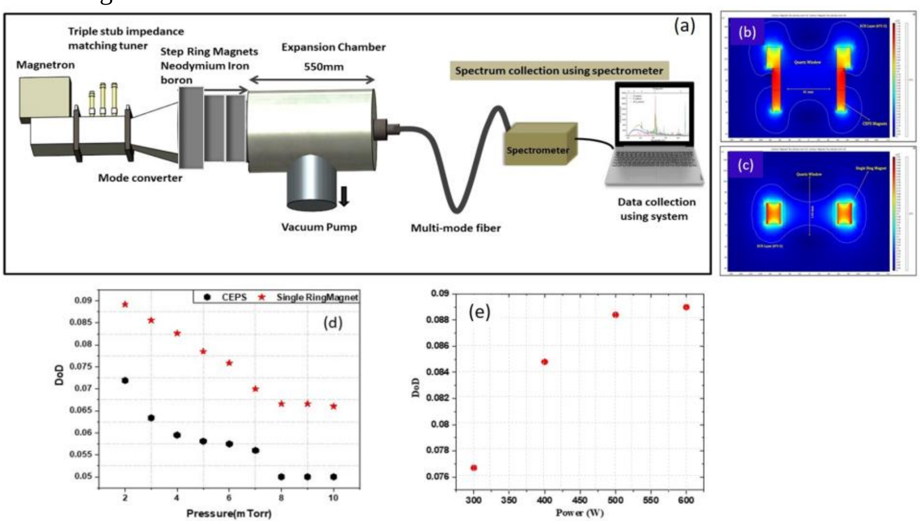

Figure 1. (a) Schematic of the experimental set up with three-ring magnets (b) Magnetic field simulation of three-ring magnets and (c) single ring magnet. COMSOL Multiphysics tool is used. (d) Plot of DoD with pressure for both the experimental set up; Power: 600 W (e) Variation of DoD with input power in the single ring experimental set up; pressure: 2 mTorr.