Seminar

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Institute for Plasma Research

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Title: Investigation of Surface Microwave-Sustained Plasma in the Presence of Dielectric Beads and Magnetic Field

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Venue: Seminar Hall, IPR

Abstract

The present talk is based on the numerical investigation of the properties of a surface microwave (MW) - sustained plasma source in view of applications like the dissociation of CO_2 for clean energy and surface processing. The dissociation of CO_2 requires a non-equilibrium plasma source with a high value of plasma density (n_e) and low values of electron temperature (T_e), while surface processing applications require a controlled particle flux for the desired output. The present talk is based on a waveguide-based Microwave Plasma Source (MPS) capable of generating non-equilibrium plasma with a high ionization fraction and better efficiency. The effect of dielectric beads and an axial magnetic field (***B***-field) on the plasma properties of the source is also explored. The simulation of the source and other investigations have been carried out using finite element method (FEM) based, commercially available software, COMSOL Multiphysics®.

The MPS considered in the present study comprises a microwave source (2.45 GHz) followed by the waveguide assembly carrying a (quartz) plasma tube. The waveguide assembly is symmetric about the tube and consists of a straight section followed by the reduced height waveguide, which holds the plasma tube. The dimensions of the different components of the assembly determine its ***E***-field profile. Thus, the ***E***-field profile inside the waveguide assembly is investigated by solving the electromagnetic field equations under different sets of assembly dimensions. For an energy-efficient source, it is desired to have (i) a high local ***E***-field near the launcher and (ii) a minimum ***E***-field in the waveguide section lying on the other side of the tube. By observing the ***E***-field profiles in the waveguide assembly, an optimized set of assembly dimensions is obtained that fulfills the above two conditions. All further investigations are then carried out using this optimized geometry of the plasma source.

The plasma equations, considering Ar as the test gas, coupled with the electromagnetic field equations, are then solved in the plasma tube. The general feature of the plasma is found to be asymmetric along the tube with a maximum n_e and T_e to be $\sim 2.8 \times 10^{17}$ m^{-3} and ~ 2 eV respectively. These values are observed near the MW launcher, where the local ***E***-field attains its maximum value. At these positions, electrons can receive maximum energy from MWs, leading to ionization and plasma sustenance.

The effect of the presence of dielectric beads on the plasma properties is investigated next. For this, the inner surface of the plasma tube is filled with dielectric bead assembly (BA). The results suggest that the dielectric constant and the position of the BA inside the tube play a significant role in determining the plasma profile and, hence, the argon ion flux in the source. The metastables have been observed to influence the plasma profile significantly in the MPS, Furthermore, the influence of an externally applied ***B***-field on the plasma properties is examined. It is observed that if the maximum ***B***-field in the tube exceeds the value of the ***B***-field required for the electron cyclotron resonance, then the plasma follows the contour of resonance heating. Finally, a combined effect of ***B***-field and $BaTiO_3$ beads on the plasma properties is explored. The results are quite interesting and can be used to control the particle flux over a three-order magnitude span. With a suitable combination of external ***B***-field strength and the position of $BaTiO_3$ BA inside the plasma tube, the source can thus be exploited in material processing applications where the tuning of the particle flux is desirable.

Moreover, the results show that a higher ***E***-field in the MPS is efficiently being utilized to increase the ionization of the medium rather than increasing its T_e. The proposed MPS is thus capable of generating *non-equilibrium* plasma with higher values of n_e and, hence, is suitable for applications like dissociation of CO_2. The MPS has the potential to increase the ***E***-field further and can be exploited to increase the energy efficiency of the source for CO_2 conversion applications.
