Investigation of the RF power transfer efficiency of a planar ICP operated in Hydrogen

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RF coupling efficiencies were investigated for low pressure low temperature hydrogen plasmas generated in a planar ICP. The measurements revealed that the power transfer efficiency η, defined by the ratio of RF power delivered by the generator to the power absorbed by the plasma, exhibits a peak for varying pressure and increases with higher power. Furthermore, η improves when the thickness of the dielectric window between the RF solenoid and the discharge chamber is reduced.

1. Introduction

An important task for optimizing low pressure processing ICPs is improving the transfer of the RF power from the RF circuit to the plasma. The power transfer (or coupling) efficiency η is defined as the ratio of the power delivered by the generator $P_{delivered}$ to the power actually absorbed by the plasma P_{plasma}. Two kinds of losses are imposed on P_{del} lowering η: losses due to ohmic heating in the RF network conductors and losses due to eddy currents that are induced e.g. in metallic parts of the vacuum system. In addition, operational parameters such as gas pressure, RF power and frequency but also the setup geometry influence the coupling efficiency [1].

Most investigations up to now focussed on rare gas plasmas but in many processing discharges, molecular gases are applied. Therefore, the investigations presented in this contribution were carried out in low pressure hydrogen discharges at pressures between 1 and 10 Pa.

2. Experimental setup and diagnostic methods

The experimental setup consists of a cylindrical discharge chamber with a height of 10 cm and a diameter of 15 cm. The planar solenoid which is connected to the RF generator (2 MHz, P_{max} = 2 kW) via a matching network is placed on top of the vessel. It is separated from the discharge by a quartz plate serving as dielectric window. Two different quartz plates can be installed: the first one has a thickness of 20 mm in order to withstand atmospheric pressure. This allows operating the solenoid in ambient air what is the standard setup of planar ICP's. In the second setup, the thickness of the quartz plate is reduced to 3 mm. As this plate cannot withstand atmospheric pressure, the coil is placed in an additional vacuum chamber.

Plasma parameters are obtained from a movable Langmuir probe and optical emission spectroscopy. The RF power delivered by the generator to the load is determined with an in-line V-I probe. An RF current transformer measures the RF current running through the plasma coil. With these quantities, the coupling efficiency η can be calculated [2]. It should be noted that impedance matching of the load to 50 Ω is always perfectly achieved for the presented measurements (i.e. $P_{reflected}$ = 0 W) by adjusting the variable capacitors in the matching unit.

3. Results and discussion

The measurements show that the RF coupling efficiency increases in general with higher RF power. At varying pressure, η exhibits a broad maximum between 3 and 5 Pa. These relative behaviours are also typical for ICPs operated with rare gases and can be explained with the variation of the electron density due to the change of RF power and with the change of the effective collision frequency of the plasma electrons at varying gas pressure [1, 2].

Installing the thin quartz plate increases the coupling efficiency significantly from around 45% to 70% at 5 Pa. The RF field magnitude drops rapidly with increasing distance from the coil. Therefore, much higher RF fields reach the plasma with a thin dielectric window what is beneficial for the coupling. In a next step, the influence of the RF frequency on η is going to be investigated.

Acknowledgements

The authors would like to thank the Deutsche Forschungsgemeinschaft (DFG) for their support within the project BR 4904/1-1.

References

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