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A Flat-Head Plasma Absorption Probe for Measurement of Plasma Density

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Abstract:
In this study, a flat-head plasma absorption probe(FHPAP) is developed for plasma density measurement in low density high pressure plasmas. The probe structure consists of a monopole antenna formed by a short section of the centre conductor of a semi-rigid coaxial cable, copper plate tight fit with the tip, and a glass enclosure. The characteristics of the probe is investigated by employing three dimensional electromagnetic numerical simulation analysis (HFSS, ANSYS Corp) where the plasma is treated as a dielectric with dielectric constant determined by plasma density, microwave frequency and collision frequency of electrons. In the simulation, the resonance frequency is extracted from the reflection spectrum. Simulation analysis reveals that the coupling of the resonator is shifted toward critical coupling as a result of the flat head antenna, and thus giving rise to a higher resonant peak in the microwave reflection spectrum.

1. Introduction

Low temperature non-equilibrium plasma discharges are widely applied ranging from micro/nano fabrication to bio/medical treatments. The plasma density is one of the key parameters controlling the characteristics of plasma based processes. Thus, a non-invasive sensor, e.g., microwave-based ones, for monitoring, or even feedback control of the plasma density of plasma tools is highly desirable. One popular approach is the resonant-type microwave sensors[1-3], where a resonant structure is often employed and the plasma density is determined by the shift of the resonance frequency. In our previous work, we have demonstrated a dielectric-loaded plasma absorption probe (DLPAP)[4] to extend the operation regime to lower density and higher gas pressures. In this study, FHPAP is proposed. The structure of the probe and the measurement system are illustrated in Fig. 1. The probe is constructed by a semi-rigid coaxial cable with a flat head antenna structure. The characteristics of the probe have been investigated by numerical analysis using High Frequency Structure Simulator (HFSS).

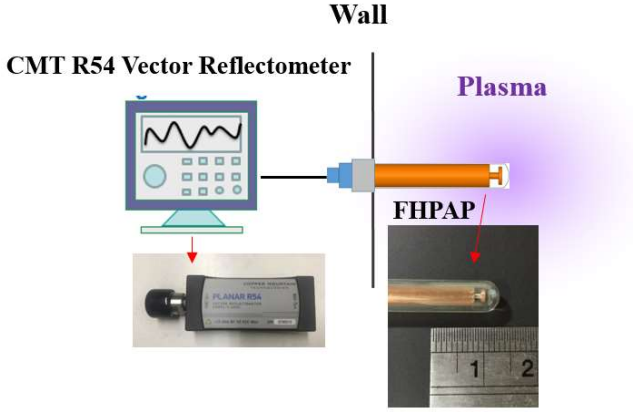
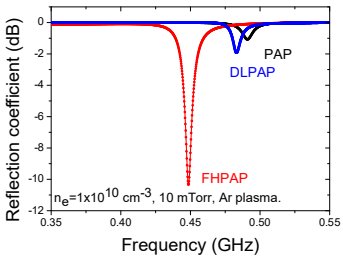


Fig. 1. Schematic of FHPAP and experimental setup.

2. Simulation result

Figure. 2. (a) shows the microwave reflection spectra for different resonant probes. Figure. 2. (b) is the corresponding Smith chart. Simulation result exhibits that the antenna structure governs the coupling between the plasma and the probe. Coupling is shifted toward critical coupling as a result of the flat-head antenna. Figure. 3. shows the relation between resonance frequency and plasma density. A monotonic increase of the resonance frequencies with the plasma densities, as expected. The detailed results of simulation analysis and experimental measurements will be presented.

(a)



(b)

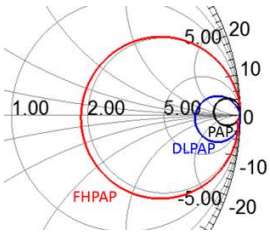


Fig. 2. (a) microwave reflection spectra for different probes, and (b) corresponding Smith chart.

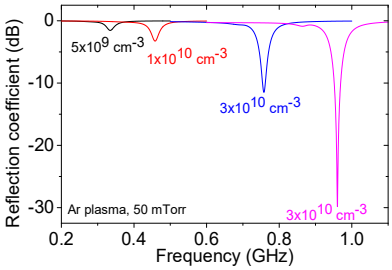


Fig. 3. Relation between resonance frequency and plasma density.

3. References

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