Topic number: 6

A Spiral Microstrip-line Microwave Resonant Probe-for Measurement of Plasma Density

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In this study, a microwave probe (spiral probe, SP) based on a spiral shaped resonant structure is developed for plasma density measurement. The probe structure is a shorted microstrip transmission line operated at half-wavelength resonance. 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 functions determined by plasma density, microwave frequency and collision frequency of electrons. In the simulation, the resonance frequency is extracted from the reflection spectrum. Simulation results show that a monotonic increase of the resonant frequency with the plasma density.

1. Introduction

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, where a resonant structure is often employed and the plasma density is determined by the shift of the resonance frequency[1-3]. In our previous work, we have demonstrated a microstrip line microwave interferometer for monitoring of plasma density in plasma tools. In this study, a plasma density probe based on a spiral shaped microstrip microwave resonator, spiral probe (SP), is proposed. The structure of the probe and the measurement system are illustrated in Fig. 1. The probe is constructed by a shorted micro-strip transmission line operated at the half-wavelength resonance.[4] The characteristics of the probe have been investigated by numerical analysis using the High Frequency Structure Simulator (HFSS)[5].

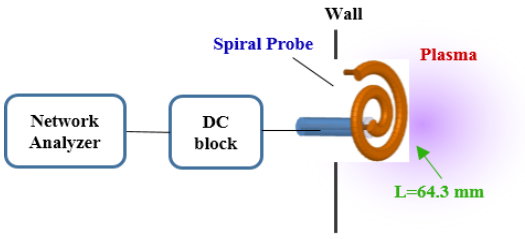

Fig. 1. Structure of Spiral-probe and experimental setup.

2. Simulation result

Figure. 2. shows the electric field distribution at the resonance for plasma density of $5x10^{10}$ cm^{-3}, illustrating the characteristics of half-wave resonance. Figure 3 depicts the microwave reflection spectra for different plasma densities, along with the dependence of the resonance frequencies on the plasma densities, showing a monotonic increase of the resonance frequencies with the plasma densities, as expected.

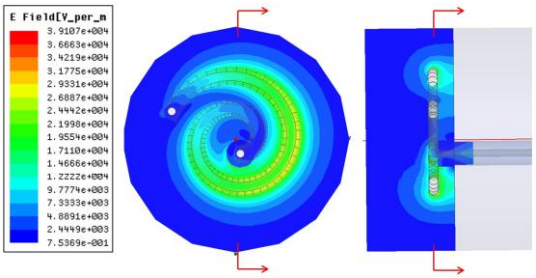

Fig. 2. The electric field distribution at resonance (2.71 GHz) for plasma density of $5x10^{10}$ cm^{-3}.

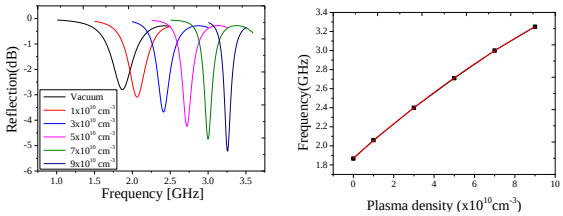

Fig. 3. HFSS simulation results: (a) microwave reflection spectra for different plasma densities, and (b) resonance frequency v.s. plasma density.

3. References

[1] M. Lapke, *et al.*, *Plasma Sources Sci. Technol.*, vol. 20, 2011.
[2] R. B. Piejak, *et al.*, *Appl. Phys.* vol. 95, 2004.
[3] T. Shirakawa and H. Sugai, " *Japan. J. Phys* 32, pp. 5129, 1993.
[4] A. Pandey, *et al.*, *Appl. Phys.* vol. 104, 2014.
[5] C. H. Hsieh, *et al.*, *Plasma Sources Sci. Technol.* vol. 24, 2015.