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Study on a Production Control of Microwave-Excited Plasmas by an Antenna-Cavity with the Specific Structure

構造を有するアンテナキャビティを用いたマイクロ波励起プラズマの生成制御に関する研究

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The purpose of this research is to control the distribution of plasmas produced by a cylindrical microwave-excited plasma device with a multi-slotted planar (MSP) antenna.From the past research, it is known that modes of an electric fields in the plasma chamber is similar to ones in a cavity which is part of the antenna on the space. Therefor, it is comparatively easy to control the plasma distribution by changing the cavity structure. In this study, we developed an antenna-cavity with the specific structure,and revealed that the cavity with a metal circular plate may be able to control the plasma distribution and generate the plasma with good uniformity.

1. Introduction

Plasma processing is used in various stage of semiconductor manufacturing process.A microwave -excited plasma is one source used for plasma processing. Microwave-excited plasmas sustained by surface waves have a long history, and a large stock of knowledge has accumulated. The spatial resonance arises under a certain condition of the device structure and the electron density, and it is known to cause mode jumps and hysteresis behavior, so it is not easy to control the microwave-excited plasmas. On the other hand, the plasma resonance is a field enhancement phenomenon at the position of a certain electron density in nonuniform plasmas. To improve control, it is desirable to suppress the spatial resonance and to actively use the plasma resonance, and have to create such conditions. To achieve the above purposes, we create plasmas by the cylindrical microwave-excited plasma device with the MSP antenna. The distribution of the electric fields in the plasma chamber is similar to ones in the antenna-cavity. Consequently, it is considered that we comparatively easy to control the plasma distribution by changing the cavity structure. In this paper, we present some experimental results and view the availability of the antenna-cavity with the specific structure we developed .

2. Experimental detail

Figure 1 shows the schematic illustration of the experimental setup. The setup consists of the microwave source, the directional coupler, the power monitor, the circular polarization converter, the three-stub auto tuner, the TE-TM converter, the antenna cavity, the metal circular plate, the MSP antenna, the quartz the window and the plasma chamber. Making the plasma from argon gas. We use two types of Langmuir probes, which one moves in radial direction, the other in azimuthal direction to investigate the distribution of plasmas and evaluate the uniformity of plasmas.

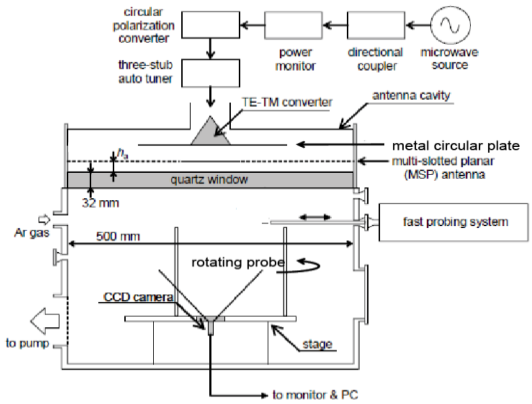

Fig.1. Schematic illustration of the experimental setup

3. Results and Discussion

Figure 2 shows the azimuthal distribution of plasmas produced in (a) 10 mTorr and (b)100 mTorr. The plasma production conditions are that the power is 1.0 kW, the antenna position h_a is 55 mm, and the metal circular plate is 200 mm in radius.The left figures of Fig.2 shows the ratio of the azimuthal

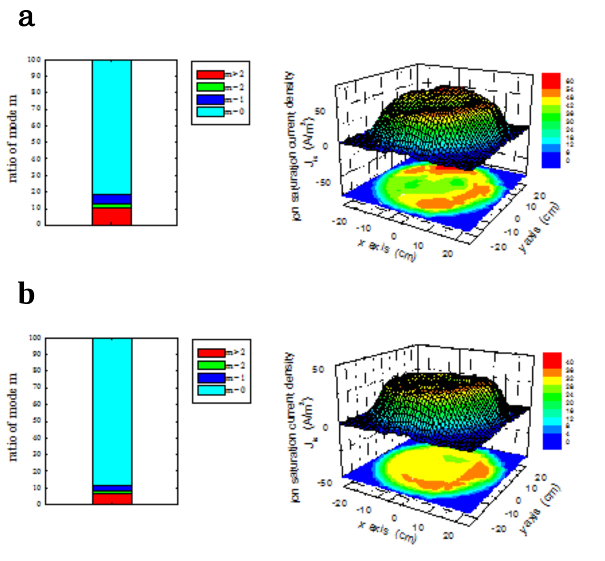

Fig.2. The azimuthal distribution of plasmas; (a) Ar gas pressure: 10 mTorr, (b) Ar gas pressure: 100 mTorr

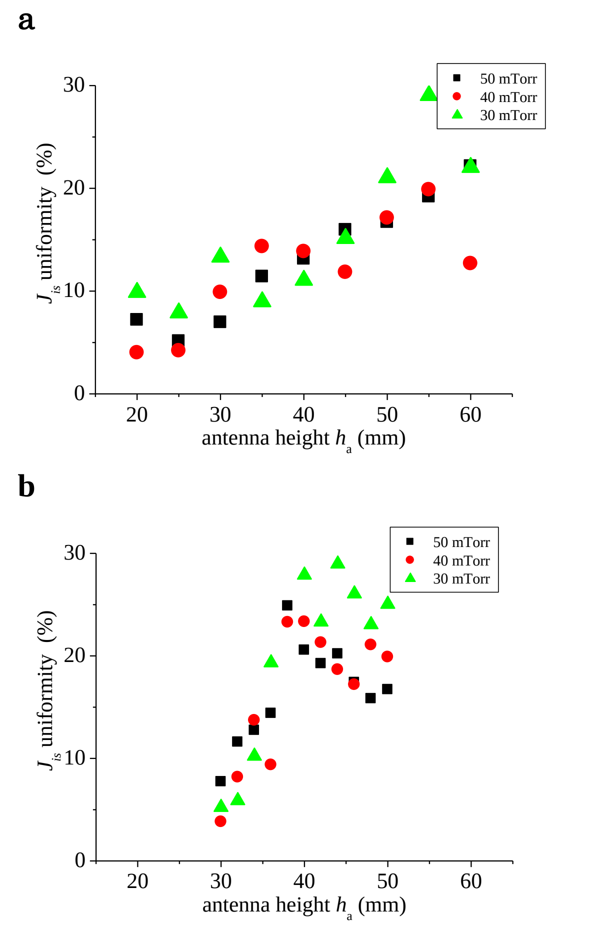

Fig.3. The dependence of the plasma uniformity in the radial direction on the antenna position ha;The metal circular plate is (a) 200 mm, (b) 210 mm in radius.

mode number m. The percentage of the m components is calculated by function expansions. As a sample for the explanation, function expansions for $a(r, \theta)$ are explained below.

The Fourier expansion, which is used as the transform in the azimuthal direction, is written as follow:

$$a(r,\theta) = \sum_m f(m,r) e^{im\theta} \qquad (1)$$

$f(m, r)$ is calculated by the Fourier transform:

$$f(m,r) = \frac{1}{2\pi} \int_{-\pi}^{\pi} a(r,\theta) e^{-im\theta}\, d\theta \qquad (2)$$

The ratio of the $m = 0$ component is more than 80 percent in either case. The $m = 0$ component is the uniform component in the azimuthal direction. In brief, the plasma with relatively good uniformity in the azimuthal direction can be produced in wide gas pressure range. The right figures of Fig.2 show the 2D distribution of the ion saturation current density J_{is}. The peak of J_{is} appears circularly in either case. The aim of the metal circular plate is to adjust the radial distribution of the electric fields, so these results reflect the effect of the metal circular plate.

Figure 3 shows the dependence of the plasma uniformity under the radius of 150 mm in the radial direction on the antenna position h_a. The metal circular plate is (a) 200 mm, and (b) 210 mm in radius. The uniformity is calculated by $(n_{max} - n_{min}) = (2n_{ave}) \times 100$ %, where n_{max}, n_{min}, and n_{ave} represent the maximum, minimum, and average values, respectively. The plasma production conditions are that the power is 1.2 kW and Ar gas pressure is 30 or 40 or 50 mTorr. It is found that the radial plasma uniformity depends on the radius of the metal circular plate. Additionally, as the antenna position h_a changes, good uniformity point ($\leq$5.0 %) moves. In summary, the radial plasma distribution can be changed, and plasmas with good uniformity in the radial direction can be produced by changing the cavity structure.

4. Conclusions

Using the cavity with the metal circular plate which takes a part as the physical boundary and adjust the radial distribution of the electric fields can improve the plasma uniformity in the radial direction. And then, the cavity is available in wide gas pressure range. They show that the plasma with good uniformity can be produced in various conditions by the antenna-cavity we developed, and the plasma distribution can be controlled by changing the radius of the metal circular plate and adjusting the antenna position h_a.