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Distribution Control of Microwave-Excited Plasma Using a Multi-Slotted Planar Antenna with Double Coaxial Feed System

二重同軸給電方式によるマルチスロット平板アンテナを用いたマイクロ波励起プラズマの分布制御

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Plasma process has been widely used in semiconductor manufacturing process. In this research, use is made of a cylindrical microwave-excited plasma device equipped with the Multi-Slotted Planar antenna. The circular antenna slot plate is divided into inner and outer radial sections and separately driven by two magnetron sources. In this paper, results of the plasma distribution control experiment by using two types of antenna are presented.

1. Introduction

In a semiconductor manufacturing process, a plasma process is used widely, and it becomes an essential technology in supporting modern ICT society. In late years, the improvement of the plasma technology is demanded because of becoming the larger diameter of the silicon wafer and further miniaturization of the processing. High uniformity, low electron temperature, and a large area are required to the plasma used for a process.

In the plasma process, the microwave-excited plasma is widely studied and used. It is reported that large-diameter and uniform plasma can be formed by various devices in the field of microwave-excited plasma.[1,2,3] However, due to the large diameter of the silicon wafer, the difference of quality occurs at the edge and center of the wafer, which becomes a problem. Therefore it is necessary to fine-tune the plasma distribution in the radial direction as needed.

In this study, using a cylindrical microwave plasma generator having the Multi-Slotted Planar (MSP) antenna, we control the plasma distribution in the radial direction and evaluate uniformity of the plasma.

2. Experiment

2.1.Experimental setup

Figure 1 shows the experimental setup used in this study for the microwave-excited plasma production by a dual coaxial waveguide. This device is comprised of two microwave power sources, two directional couplers, two power monitors, two three-stub tuners, a dual coaxial waveguide, an antenna cavity, the MSP antenna, dielectric window, and a vacuum chamber. The dual coaxial waveguide consists of inner and outer coaxial waveguide. Microwave fields at a frequency of 2.45 GHz propagate in a vacuum chamber, and plasma is formed.

The most significant characteristic of this device is that the coaxial waveguide has a dual structure, which is separated into the inner waveguide and the outer waveguide, and two microwave sources are connected to the waveguides. Microwave can be radiated with a different power inside and outside.

For measuring, this device has a CCD camera and Langmuir probes. CCD camera on the stage monitors light emission of the plasma. Two Langmuir probes are set up, one can measure a radial distribution of plasma, the other can measure the two-dimensional distribution.

We prepare two metal separators to select the inside and the outside microwave radiation area. Diameter of the total radiation area is 480 mm. The Antenna Type I has the separator with the diameter of 320 mm, and the Antenna Type II has 380 mm.

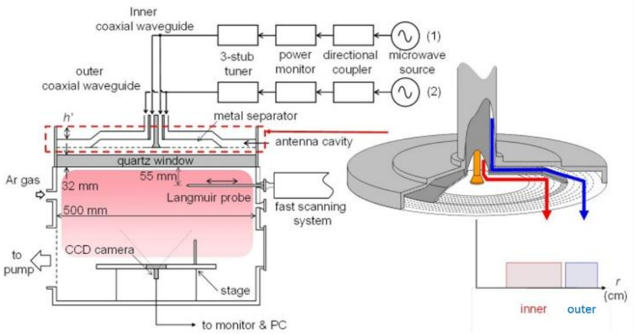

Fig. 1. The experimental setup.

2.2.Evaluation index

To evaluate the ion saturation current density (J_{is}) in the range of radial position r = 0 - 15 cm, we define the evaluation index: the Gradient (G).

$$G = \frac{n\sum_{k=1}^{n} r_k J_{is}(k) - \sum_{k=1}^{n} r_k \sum_{k=1}^{n} J_{is}(k)}{n\sum_{k=1}^{n} {r_k}^2 - \left(\sum_{k=1}^{n} r_k\right)^2} \times \frac{1}{J_{is}(\mathrm{ave})} \times 100[\%] \quad (1)$$

The Gradient evaluates a gradient of the plasma density. The Gradient shows that J_{is} distribution is a positive degree of leaning in the case of a positive value, J_{is} distribution is flat in the case of around 0, and J_{is} distribution is a negative degree of leaning in the case of a negative value.

3. Result

Figure 2 shows the radial distribution of J_{is} for Ar gas pressure p_{Ar} = 30 mTorr, when the power ratio of the inner and outer is varied, as the sum total power of 600 W inside and outside power, for (a) the Antenna Type I and (b) the Antenna Type II. The value of P_{in} is given in the figure. In the case of the Antenna Type I, when we vary P_{out}/P_{in}, the J_{is} distribution of the radial direction changed in r = 0 – 15 cm. It also shows that a peak of the distribution is tends to be outside even if the inside and outside power ratio is varied. Figure 2 (b) shows the case of the Antenna Type II, where J_{is} distribution changed mainly in the central part of r = 0 - 15 cm when P_{out}/P_{in} is varied. It can vary the gradient of the plasma density by controlling the inside and outside power ratio.

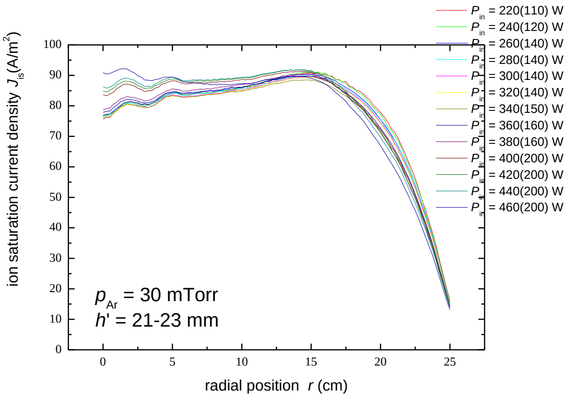

Fig. 2(a). Plasma distribution in the Antenna Type I.

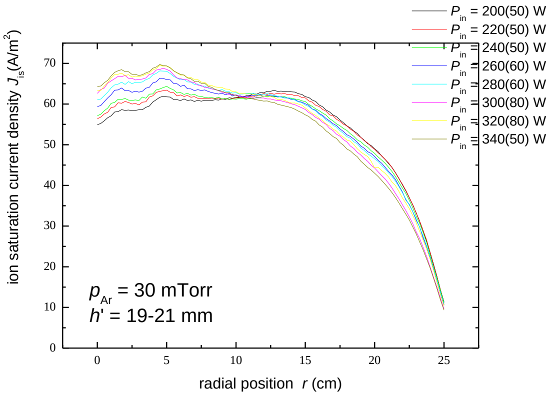

Fig. 2(b). Plasma distribution in the Antenna Type II.

Figure 3 shows the dependence of the Gradient on the inside and outside power ratio in p_{Ar} = 20 - 100 mTorr for (a) the Antenna Type I, and (b) the Antenna Type II. It is indicated in Fig. 3 (a) that the Gradient can be controlled to near 0 from the positive value, but it is difficult to be negative value if the power ratio is varied in the all pressure zone for the Antenna Type I. In the Antenna Type II, it is indicated that the Gradient is varied from negative to positive in a wide pressure range in Fig. 3 (b). It can be said from the above that the Antenna Type II is easy to control the Gradient of plasma density than the Antenna Type I. In addition, we found that the peak and the radius of the plasma distribution also can be controlled by varying the distance between the dielectric and the antenna in the Antenna Type II. We show it in the poster.

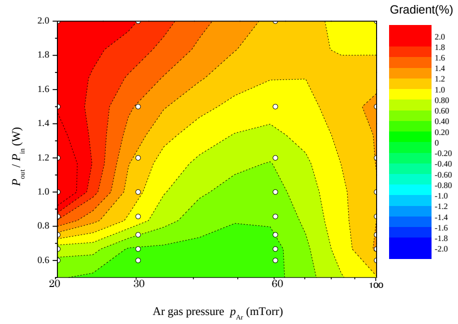

Fig. 3(a). Gradient dependence in the Antenna Type I.

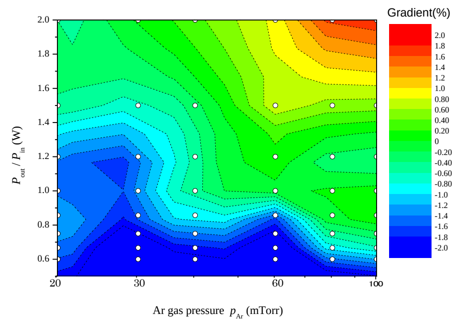

Fig. 3(b). Gradient dependence in the Antenna Type II.

4. Conclusion

Using microwave-excited plasma generator having the dual coaxial waveguide, experiments of controlling plasma distribution in the radial direction are performed. Two types of the antenna with different radius of the metal separators; small one (Antenna Type I) and large one (Antenna Type II) are compared. We show that the Antenna Type II is easy to control the Gradient of plasma density than the Antenna Type I.

Acknowledgements

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