21PA-044

Production and Control of Large-Diameter Microwave Plasmas Using an Antenna Cavity with In-situ Adjusting Mechanism of Radiation Profile of Electric Fields
放射電界のその場可変機構を持つマイクロ波アンテナキャビティを用いた大口径プラズマの生成と分布制御に関する研究

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We performed generation experiment of large diameter plasmas for next generation 450 mm wafers and generated those plasmas by using a cylindrical microwave plasma generator using the MSP antenna with an inserted metal plate.
Then, we investigated uniformity and controllability of the plasma distribution of the radial and the azimuthal direction.

1. Introduction

In a semiconductor manufacturing, we widely use a plasma process like surface etching/deposition, and so it is an essential technique in supporting modern IT society. Generation of the plasma with a large area, high uniformity and low electron temperature is demanded in the plasma process. In late years we widely use a microwave plasma because it has the advantages for high density, low electron temperature, and the plasma process such as no electrode. They, in a field of the microwave plasma, reported that highly uniform large-diameter plasmas can be formed by various devices [1]. On the other hand, the quality difference between the edge and the center has been a problem due to increase in size of wafers. So it is necessary to control the plasma density distribution along the radial direction of the processing substrate.

In this work we generate the large-diameter microwave plasma which can be applied to processing silicon wafers of the next-generation 450 mm size. So we use a cylindrical microwave plasma generator with MSP (Multi-Slotted Planar) antenna and the inserted metal plate (VRMP: Variable Radius Metal circular Plate). The radius of this can be changed by outside operation in the antenna cavity. Under the condition that a microwave electric field is radiated from outer radii, we generate the highly uniform plasma of the radial direction, and investigate the azimuthal distribution of the plasma.

2. Experiment

2.1 Experimental setup

We show the cylindrical microwave plasma generator used in this study in Fig. 1. This device is comprised of the microwave source, the circularly polarized wave converter, a pair of three-stub tuners, the MSP antennas, VRMP, a dielectric window (quartz glass) and an electric discharge container.
The microwave source's frequency is 2.45 GHz and its maximum power is 3.0 kW. The radius of the MSP antenna is 250 mm, the thickness is 1mm and it has approximately 1,000 slots except the outside and center. This antenna can radiate an electric field formed in an antenna cavity in a container through the quartz glass [2]. VRMP is comprised of five pieces of fan-shaped metal plate of thickness 0.5 mm and can change the radius R from 17.5 cm to 20 cm. The radius of the chambers is 650 mm to be designed for a silicon wafer of next-generation 450 mm. The microwave propagates in waveguides to the antenna cavity, where standing waves are formed in the r-direction and propagating waves are formed in the θ-direction. The microwave is radiated from the MSP antenna to plasma，and the plasmas are produced. Ar gas is used to produce plasmas, the pressure in the chamber p_{Ar} is kept constant. The distribution of the plasmas is measured by a Langmuir probe and a charge-coupled device (CCD) camera. The Langmuir probe is used to measure r- and θ-directional distribution (r = 0~22.5 cm) of the ion saturation current density, J_{is}. The CCD camera is used to monitor the brightness pattern of the plasmas. In the past study, we showed that the peak of r-directional distribution of plasmas generated by a cylindrical microwave plasma generator tended to be at the center (r = 0 cm).

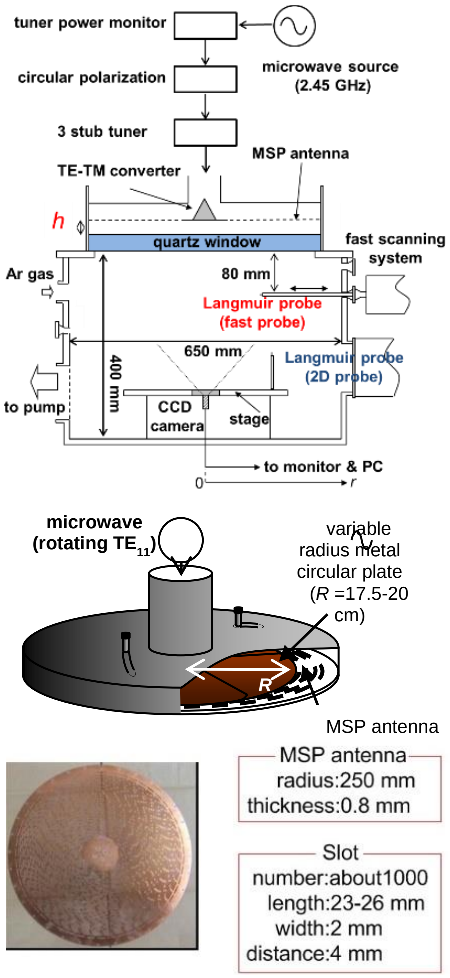

Fig. 1 The experimental setup.

2.2 Evaluation index

We use G to evaluate J_{is} distribution. G is calculated by

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

In Equation 1, evaluation range is r = 0～22.5 cm, it is calculated in increments of 0.25 cm, so n is 90, and J_{is} (k) represents the value of J_{is} at that point. G shows that a degree of leaning of J_{is}.

3. Results

Figure.2 shows the radial distribution of J_{is} when VRMP is inserted in the antenna cavity. Ar gas pressure is p_{Ar} = 20 mTorr. The peak of J_{is} distribution is center (r = 0) for VRMP radius of 18.5 cm. Figure 3 shows dependence of the G on the VRMP radius. The G increases with larger radius of VRMP. As a result, we show that the antenna cavity with inserted VRMP is the effective means for controlling the r-directional distribution of plasmas.

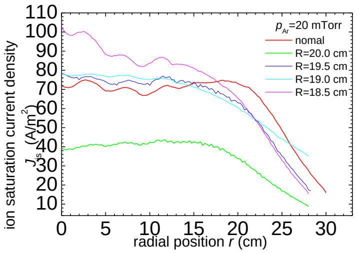

Fig. 2 Radial distribution of *Jis* for various *R* of VRMP.

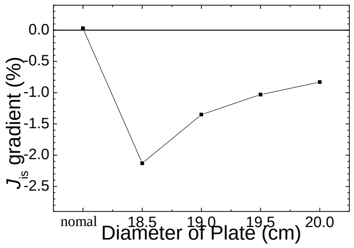

Fig. 3 G versus *R*

Figure.4 shows a contour plot of G in the radial direction for R=0, 18.5～20 cm and p_{Ar}=10 ~ 100 mTorr. An uniform plasma whose G is less than ±0.3 % is can be generated for p_{Ar}=10~40 mTorr. It was not possible to create the uniform plasma for p_{Ar}=100 mTorr, this is because the plasma distribution is not stabilized. The azimuth distribution of J_{is} is showed at the poster.

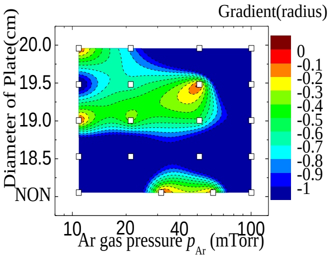

Fig. 4 Contour plot of the dependence of G on R and p_{Ar}.

4. Conclusion

In cylindrical microwave plasma generator using the MSP antenna, we conducted our experiments plasma generation of 450mm wafer of the next generation. By inserting a metal plate (VRMP), we radiated the microwave electric field from the outside diameter, and generated a stable and uniform plasma in the radial direction. As a result, we found that a uniform plasma can be generated in and the radial direction at 10 ~ 40 mTorr. We are planning to adjust the distribution of the azimuthal direction in the future.

References

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