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Instantaneous generation of many flaked particles caused by micro-arc discharge in mass production plasma etching equipment

プラズマエッチング装置における異常放電発生時の剥離パーティクルの多量発生

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The relationship between the instantaneous generation of flaked particles and micro-arc discharge is investigated in mass-production plasma etching equipment. To elucidate the mechanism of such particle generation, we simultaneously detect particle generation from deposited films on a ground electrode and occurrence of micro-arc discharge under mass-production conditions. The results indicate that the deposited films are severely damaged and flake off as numerous particles when micro-arc discharge occurs. The rapid changes in floating potential on the films due to the arcing cause electric field stress working as an impulsive force. Many particles are generated not from the melting of chamber parts by micro-arc discharge but from the flaking of deposited films by the impulsive force.

1. Introduction

Particle contamination in plasma etching equipment is among the most serious problems in volume manufacture of LSI because the particles can short-circuit LSI and significantly lower production yields. Development of particle-free processes and equipment is crucially important.

In plasma etching for mass production of LSI, etching reaction products adhere to the inner chamber walls, gradually forming films as wafers are processed. During the etching process, a few particles are constantly generated by flaking of the deposited films due to electric field stress that acts boundary between the inner wall and the film [1]. Serious contamination caused by many particles sometimes suddenly occurs, resulting in a number of defective LSI devices and significantly decreasing the production yield. Micro-arc discharge is considered a possible cause of the sudden generation in light of the situation of damages in process chambers in mass-production equipment.

In this study, we investigate the relationship between the instantaneous generation of flaked particles and micro-arc discharge by under mass-production conditions.

2. Experimental methods

The experimental apparatus shown in Fig. 1 is the same mass-production reactive ion etching (RIE) equipment as that described in Ref. 2. The equipment features a capacitive rf (13.56MHz) discharge with a parallel plane geometry. The etching process sequence and equipment parameters are the same as those used in actual manufacturing facilities. This study uses a titanium etching process that often causes significant particle contamination. The etching gas consists of SF_6 with a flow rate of 100 sccm and O_2 with a flow rate of 6 sccm at a pressure of about 18 Pa. The distance between the ground electrode and the rf electrode is 60mm. The rf power is 1000 or 1600W.

The in situ particle monitoring system is described in detail in Ref. 2. In the system, a sheet-shaped laser beam is introduced in a plane parallel to the wafer in the processing chamber at a distance of 4 mm from the ground electrode. The light scattered by particles is measured using an image-intensified charge-coupled device (CCD) camera. The viewing port style plasma probe (VP-Probe) can detect a transient change in the floating potential formed on the inner surface of the viewing port [3]. Because the inner wall of the RIE equipment is insulated, the change in the floating potential formed on the wall can also be detected by the probe. Signal from the probe is monitored with the status signals of rf power and CCD camera using a digital oscilloscope, with a sampling frequency of 1 MHz.

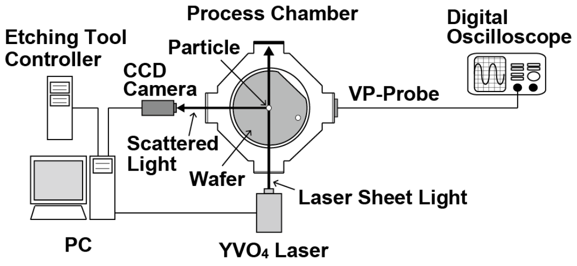

Fig.1. Schematic top views of the experimental setup.

3. Results and discussion

Figure 2(a) shows the relationship between the number of particles and the rf power status signal while processing a wafer. Figure 2(b) shows the VP-Probe response signal recorded during plasma processing. Many particles are detected along with the abrupt increase in the VP-Probe amplitude at 7.3 s. Immediately after the probe detects these signals, the etching process is forcibly stopped by the operation of a protection circuit in the electrostatic chuck (ESC) power supply owing to overleak current at 7.5 s. Hence, significant changes in the probe signal arise from the micro-arc discharge occurring at backside of the wafer. Figure 3 shows an image of laser light scattered by particles captured at 7.3 s on the horizontal axis in Fig. 2(a). Many particles flaking off from the ground electrode are observed. The arcing at the wafer and many particles from the ground electrode occur simultaneously, despite in different parts of the chamber. The large and rapid changes in the inner wall potential, detected by the VP-Probe, can make the electric field stress acting on the deposited film work as an impulsive force [4]. Consequently, numerous particles are instantaneously generated. These results, therefore, clearly demonstrate that micro-arc discharge gives rise to the instantaneous generation of numerous flaked particles, not the melting particles from the location of arcing.

4. Conclusion

We have investigated the relationship between instantaneous generation of flaked particles and micro-arc discharge under mass-production plasma etching conditions. Experimental results show that the floating potential on the deposited films at the inner chamber wall changes rapidly and markedly when micro-arc discharge occurs, which causes many particles. The films can be strongly damaged because of the impulsive force of electric field stress. The particles are generated not from melting of chamber parts by micro-arc discharge, but from flaking of deposited films. This mechanism can occur on both the ground electrode and the chamber walls, and cause serious contamination.

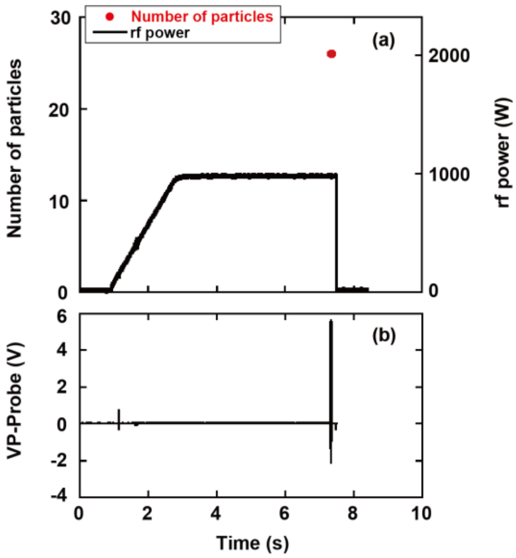

Fig.2. (a) Number of particles and rf power status signal while processing one wafer. (b) VP-Probe signal recorded during etching processing.

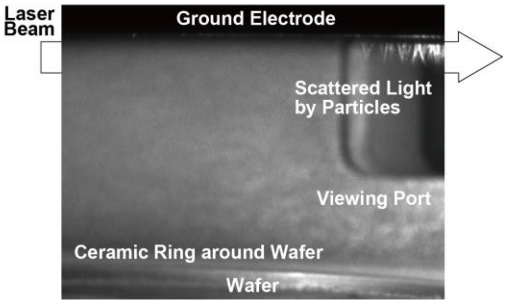

Fig.3. Image of laser light scattered by particles captured at 7.3 s on horizontal axis in Fig. 2(a).

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