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Novel Particle Reduction System in Chemical-Vapor-Deposition Process of Interlayer Dielectrics

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1. Introduction

Chemical-Vapor-Deposition (CVD) has been widely used for the interlayer dielectrics of ULSI interconnect. Especially, TEOS-CVD SiO_2 film is frequently used as contact-plug dielectric, hard-mask, low-k cap and interlayer dielectrics of upper layer of interconnect. However, the generation of particles in CVD chamber significantly reduces the yield of interconnect. The chamber cleaning and maintenance for reducing the particles take long time. If the particle generation is reduced, the fabrication and maintenance cost would be drastically reduced. Many researchers pointed out that the generation of particles are related to arc discharge (abnormal discharge) or sparks (local over- current flows)[1-5]. The arcs/ sparks are the local discharges that occurs between the chamber and plasma or between the wafer and plasma, which is typically energetic. The arcs/ sparks sometimes cause particles, device damage, and plasma instability, which reduce the yield and reliability of ULSIs, such as Fig. 1(a). Especially, the large RF power causes the arc discharge in parallel plate system of CVD chamber (Fig.1(b)). To reduce the generations of arcs/ sparks, we have to analyze and understand the generation mechanism of arcs/ sparks. One promising spark- monitoring candidate is the electromagnetic field sensing method that we proposed previously [4]. We have already clarified the generation and recovery mechanism of spark by using this method [5].

In this paper, we proposed the particle reduction system by combining the spark monitoring and RF power cut system. By stopping the RF power triggered by the spark signal, the generation of particles can be reduced successfully.

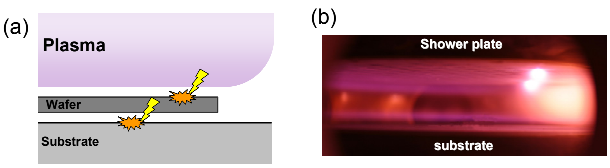

Fig.1 (a) Arc discharge in plasma process (b) Abnormal discharge (arc) in CVD chamber.

2. Experimental

We have already proposed an electromagnetic-field sensing method that detects spark signals pass out through the chamber's viewport, which means the process condition is not changed by the installation of a sensor [4, 5]. Successful sparking event detection is verified by a visible flush light seen from the viewing port and from damage observed on the wafer. We also reported that the sensor detects an electromagnetic field with frequencies of up to 6.5 GHz, which is the frequency for ESC-induced sparking, meaning that it has the required sensitivity to detect micro sparking. Furthermore, this sensor technology enables the detection of various kinds of anomalous discharge signals in addition to sparking.

We analyzed a commercialized TEOS-CVD chamber. Fig. 2 shows the particle reduction system. RF power cut was triggered by the EMS spark signal. The RF power recovered automatically after a while. First of all, we checked the relationship between the sparks and arcs by observing the optical emission from the plasma and the EMS output. Analyzing the results, we determined the power cut condition. Finally, we checked the ability of this particle reduction system by evaluating the reduction of arc discharge and counted particles on the wafer.

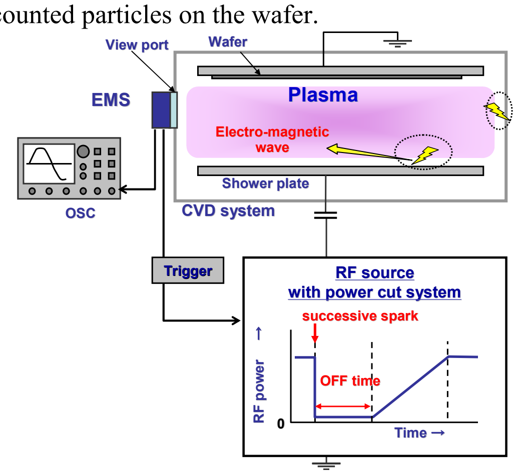

Fig.2 Particle reduction system by combining the EMS and RF power cut system.

3. Results and Discussion

Fig. 3 shows the measured results by electromagnetic sensor (EMS) and optical emissions in the CVD plasma. EMS detected a lot of sparks. Analyzing this observation, we found that the successive sparks began after the sparks of more than 5 μsec. Furthermore, we also found that the discharges shifted to the abnormal one after long-time sparks of more than 20 μsec. These phenomena means the local charge accumulation on the chamber wall, wafer surface, or substrate, cause the small sparks to solve the bias of charges. However, all charges cannot be cancelled, resulting in the shift to the arc discharge. According to these results, we determined the more than 5 -μsec successive spark as a trigger of stopping RF power (Fig. 4).

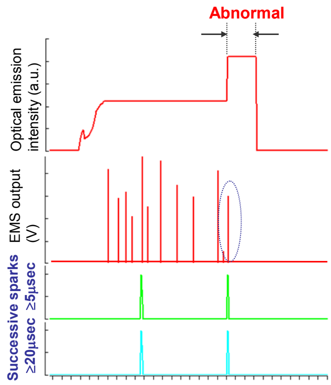

Fig.3 Time variation of optical emission intensity and EMS output in CVD plasma.

Fig. 5 shows the time variation of optical emission and EMS output in the case of (a) normal discharge and (b) CVD discharge with arc reduction system, such as Fig. 2 and Fig.4. In normal CVD discharge, the abnormal discharge occurred. We confirmed the shift to arc discharge occurred just after the long-time sparks. On the other hand, the shift to arc discharge could not observe by using the arc reduction system. In Fig. 5(b), we could observe a lot of sparks (EMS output); however, the arc generation was thought to be controlled by RF power cut. Fig. 6 shows the results of particle counting. Many particles could be observed in the normal CVD, while the number of particles was very few in the arc reduction system due to the reduction of arc generation.

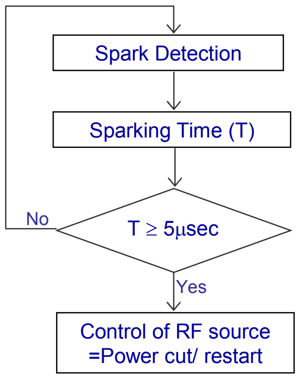

Fig.4 Sequence of arc reduction system

Finally we speculated the mechanism of generation of arc discharge to generate patricles(Fig.7). Accumulated charges flow to the chamber wall, which is observed as the sparks. It is considered that these sparks varies the plasma potential significantly. At that time, the locally focused electric field at the deposited by-products of shower plate results in the shift from the normal CVD discharge to the abnormal discharge (arc). Therefore, we found that the abnormal discharge can be eliminated by reducing the sparks.

4. Conclusions

We proposed the new particle reduction system in TEOS- CVD chamber. We reduced the abnormal discharge (arc) by RF power cut triggered by the spark signals of electromagnetic sensors, causing that the particles could be drastically reduced by this system. Consequently, we believe that this arc reduction system is very effective tools for stable production of TEOS-CVD SiO_2 dielectrics.

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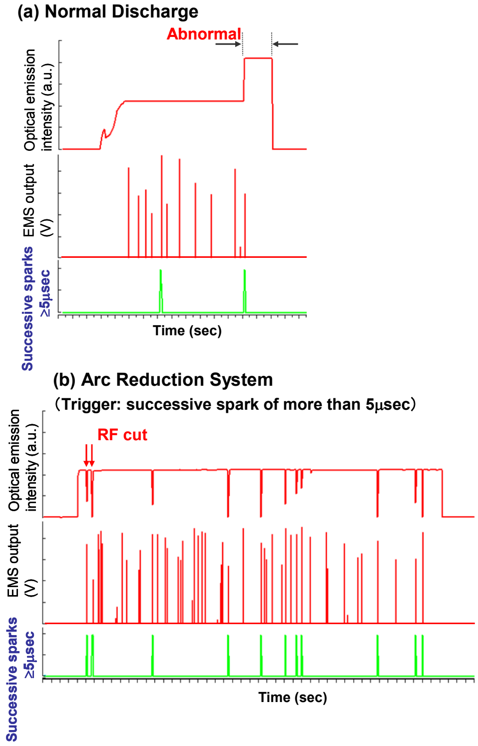

Fig.5 Effect of arc reduction system. Time variation of optical emission and EMS output (a) of the normal CVD discharge, (b) of arc reduction system.

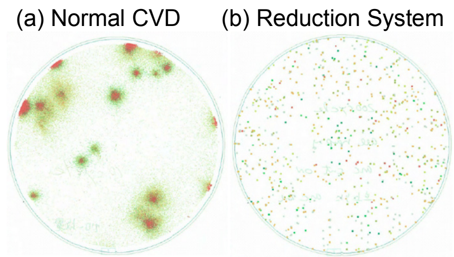

Fig.6 Results of particle inspection. (a) in the normal CVD process (b) in CVD process with arc reduction system.

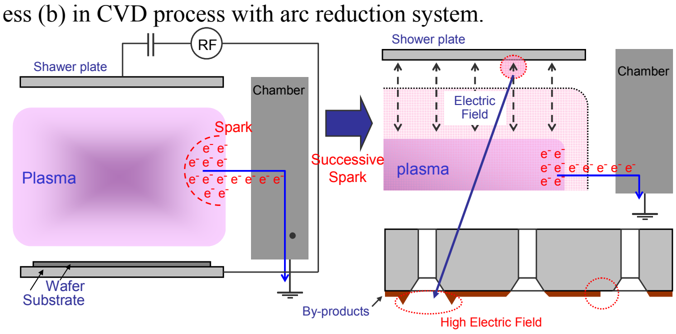

Fig.7 The mechanism of generation of arc discharge due to successive sparks.