Contribution of individual process steps on particle contamination during plasma CVD operation

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Particles generated in plasma-assisted processes for semiconductor manufacturing can degrade the quality of the products. Particle contamination may occur under plasma operation or in the postplasma.[1)] However, the occurrence time and level of contamination from individual steps has never been investigated. Information about them would be very useful for controlling particle contamination. This work presents the experimental results of characterization of the occurrence time and level of contamination from individual process steps during plasma operation. Moreover, the residual particle charge in the postplasma is estimated.

The experiments were performed in a parallel plate reactor. Plasma was derived from nitrogen gas at a pressure of 4 Torr by a 13.56 MHz rf power source. Monodisperse silica particles of 0.6 μm in size were introduced from the outside. The particle behavior was observed using LLS technique (Fig. 1). The occurrence time and level of contamination were determined by making use of the capability of thermophoresis to shield the wafer from particle deposition. They were determined by comparing the number of particles deposited on the wafer at the conditions of with and without applying thermophoresis in the postplasma.

Fig. 2 shows the dependence of number of particles deposited on the wafer on particle trap modes at a rf power of 100 W. The particle trap modes during plasma operation can be found elsewhere.[2)] The gas flow rate is 50, 200, and 400 sccm for the lumping, winding, and escaping modes, respectively. The lowest level of particle contamination is obtained for the winding mode. The particle contamination occurs during postplasma for the lumping and winding modes, whereas it occurs during plasma operation in the escaping mode.

Fig. 3 shows number of particles deposited on the wafer for different dc bias voltage during postplasma. Particle deposition cannot be observed for negative dc bias. For positive dc bias, the number of particles deposited is increased over unbiased voltage by approximately three times. These suggest that most particles retained their negative charge in the postplasma.

Fig. 4 shows the cloud front displacement as a function of time. The terminal settling velocity for the cases of unbiased and positive dc bias determined from the plot is 13.2 mm/s and 15.3 mm/s, respectively. The residual particle charge, derived from the force balance on particle for the unbiased and positive bias cases, can be estimated from

$$p=3\pi\mu d_p(v-v')/(C_c eE), \qquad (1)$$

where v and v' are the terminal velocity for the unbiased and positive dc bias, respectively. The number of charges per particle in the postplasma estimated from eq. (1) is 11.4 electron charges that are about 1% of their charges during plasma.

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References

1) Selwyn et al., *J. Vac. Sci. Technol. A* **77**, 2758 (1989).
2) Setyawan et al., *J. Appl. Phys.* **92**, 5525 (2002).

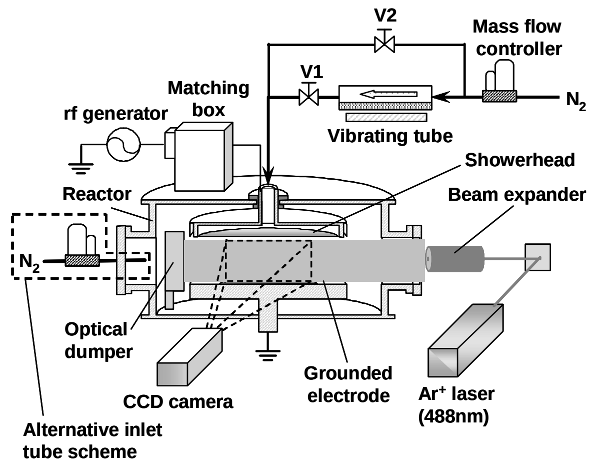

Fig. 1. Schematic diagram of the experimental set up.

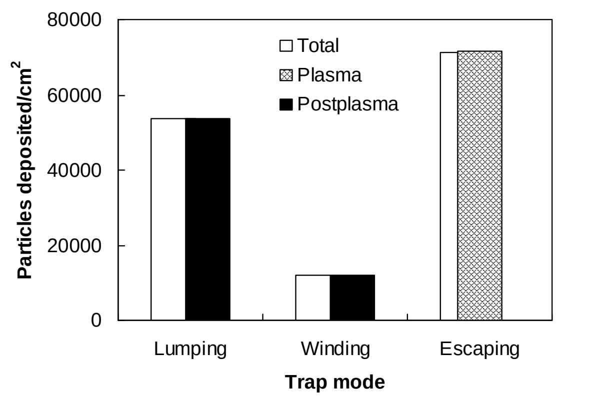

Fig. 2. Dependence of number of particles deposited on the wafer on particle trap mode.

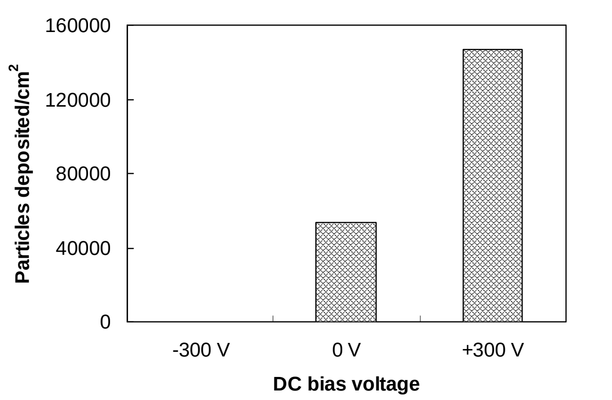

Fig. 3. Dependence of number of particles deposited on the wafer on the applied bias voltage for the lumping mode.

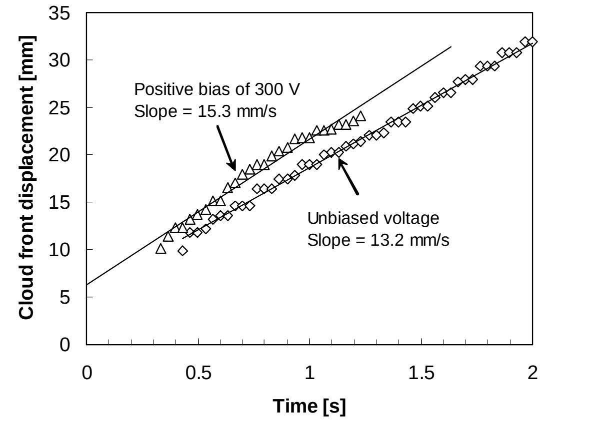

Fig. 4. Particle cloud displacement after extinguishing the plasma for the cases of unbiased and positive bias of 300 V for the lumping mode.