Extended Abstracts of the 2002 International Conference on Solid State Devices and Materials, Nagoya, 2002, pp. 444-445

P3-13

A New Microwave-Excited Plasma Etching Equipment separated Plasma Excited Region from Etching Process Region

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Introduction

A damage-free dry etching with high-etching rate, high selectivety, and excellent uniformity are required. Furthermore, in order to expand a process condition margin, the substrate pattern and material dependences over large-diameter wafers should be suppressed. However, in conventional dry etching equipments such as Dipole-Ring Magnet (DRM) etcher(1) or Balanced Electron Drift (BED) etcher(2), optimizations of process conditions for each substrate patterns, substrate materials and self-bias conditions are required because the plasmas in these equipments are generated mainly by secondary electron emission from wafer, which is set at cathode, due to ion bombardment to wafer. This problem is becoming serious for not only realizing single chamber/multi processes in step-by-step investment flexible production line but also damage-free contact etching which can suppress hole deactivations with carbon-rich fluorocarbon film depositing bottom surfaces of contact holes (Source/Drain region) using two self-bias voltage (Vdc) conditions of Vdc=-500~-600V and Vdc=-150V(2).

The plasma source using the RLSA, which has been developed for gate oxidation/nitridation(3), is one of promissing candidates to solve these difficulties. Also, using heavy norble gasses of Kr or Xe with large atomic diameters, this plasma source of quite low-electron temperature compared with conventional ones has a potential to realize both damage-free and high-speed ething. In this report, we present first results of applying the RLSA plasma source to etching system by introducing a new gas-supply structure of a metal gas shower head in the low-electron temperature (<~1eV) diffusion plasma region.

Experimental Apparatus

Figure 1 shows the new plasma etching system for 200mm wafer. Microwave with 2.45GHz radiated from the RLSA is used to excite the plasma. In order to uniformly introduce plasma excitation gas, 16 holes with 1.8mm diameters are opened at the sidewall of the chamber in a circle. The shower head, which is set at 30mm position below the bottom of the dielectric plate, consists of several stainless tubes, and many small gas injection holes (number of 172) with 0.2mm diameter are opened on the wafer side of these tubes as shown in Fig. 2. Such small-diameter holes prevent plasma from flowing into the inside of the tubes and also realize uniform gas injection over wafer. In order to generate self-bias, a wafer stage is connected to a RF power supply with 13.56MHz through a blocking capacitar and a maching box.

Results and Discussions

The microwave cannot penetrate into such a high-density plasma ($>10^{12}$cm^{-3}) due to cut-off mode (cut off density is 7.5×10^{10}cm^{-3} for 2.45GHz). Thus, plasma excitation region is limited to the region around the skin depth (~5mm) surface just below the bottom of the dielectric plate. Electron temperature is plotted as a function of distance z from the dielectric plate in Fig. 3 for the chamber of the RLSA plasma source(4). It is clearly seen that electrons are accelerated by microwave mainly in the plasma excitation region, and the plasma at a distance >~10mm from the dielectric plate is only down-flow and diffusion plasma of quite low electron temperature (<~1eV). Since the shower head is installed in such a plasma condition as indicated in Fig. 3, metal contamination due to sputter is suppressed. The shower head plays quite important roles on etching process. Firstly, etching selectivity to both Si and resist is improved because etching gasses are fed in low-electron temperature region and excess decomposition of etching gas is prevented. Next, the plasma potential can be kept low although the RF power is applied to wafer because the metal shower head contributes to be a electrical ground plate for the RF bias, which can realize metal-contamination-free processes. Finally, plasma excitation condition can be controlled without influence of the RF bias because RF current does not flow to plasma excitation region due to the metal shower head. This enables us to realize etching processes without dependences on substrate patterns and materials.

Figure 4 shows the ion current density to wafer in the etching equipment as a function of microwave power P_{μ} for each working pressures. It is found that plasma attenuation effect due to the shower head is small and enough ion currents for practical etching application can be obtained. When RF power is applied to the wafer stage, |Vdc| increases with increase in RF power as shown in Fig. 5. On the other hand, ion corrent density does not drastically change with increase in RF power as shown in Fig. 6. These results show that plasma excitation condition depends only on the microwave power, and plasma excitation region is completely separated from the process region. Figure 7 shows SiO_2 etch rate using C_5F_8 as a function of C_5F_8 flow rate in case that |Vdc| is about 200V. Practical etch rate is obtained, and etch rate is expected to increase with increase in |Vdc|. Figure 8 shows cross sectional SEM image of SiO_2 contact hole. Contact hole is successfully etched.

Conclusion

A new plasma etching equipment with the RLSA has been developed. In this equipment, a etching process region is completely separated from a plasma excited region by installing a new metal shower head in the diffusion plasma region. Thus, the plasma excitation condition and self-bias condition can be individually controlled. Contact hole is succsessfully etched using C_5F_8 gas. It is expected that cost of etchng process in manufacturing line is drastically reduced because of realization of the process without dependences on substrate patterns, substrate materials and self-bias conditions.

References

[1] M. Sekine, et al., Jpn. J. Appl. Phys. Vol. 34 Part1, No. 11, (1995) pp6274-6278

[2] R. Kaihara, et al., The Ninth International Symposium on Semiconductor Manufacturing, Proceeding of ISSM2000, (2000) pp.102-105

[3] K. Sekine, et al., IEEE TRANSACTION ON Electron Devices, Vol. 48, No. 8, (2001) pp1550-1555

[4] M. Hirayama, Doctral Thesis, Chap. 4 (1997)

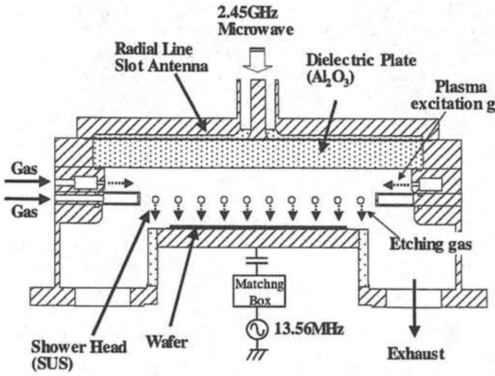

Fig. 1 Schematic of the new etching system. Etching gassed are supplied by a shower head installed in diffusion plasma region.

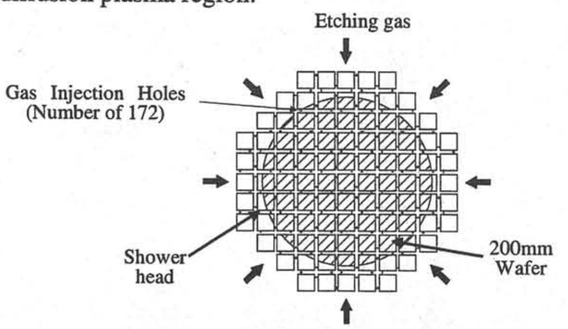

Fig. 2 Top view of the shower head. Etching gasses are uniformly supplied over 200mm wafer by gas injection holes (number of 172).

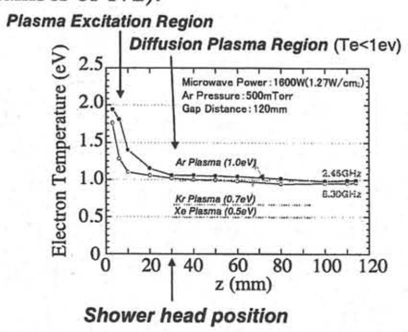

Fig. 3 Electron temperature as a function of distance z from the dielectric plate. Plasma excitation region is limited to a region just below the bottom of the dielectric plate. The shower head is installed at z=30mm of the diffusion plasma region.

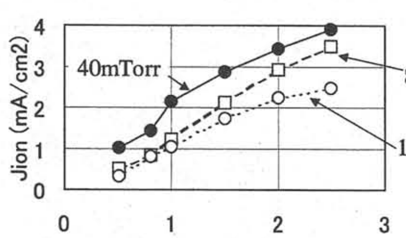

Fig. 4 Ion current density to wafer as a function of microwave power P_μ in case of each working pressures. Enough ion currents are obtained in spite of the insertion of the shower plate.

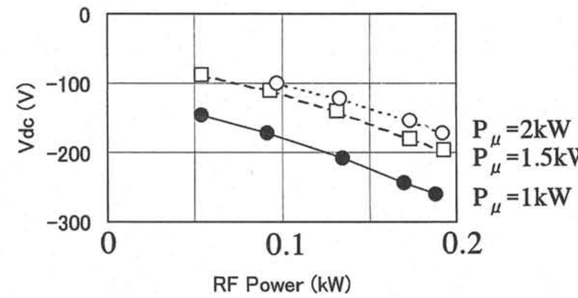

Fig. 5 Self-bias voltages Vdc as a function of RF power in case that P_μ=1kW, 1.5kW and 2kW, respectively.

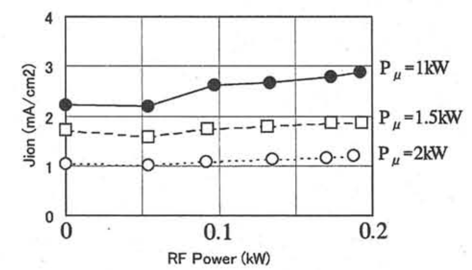

Fig. 6 Ion current density to the wafer as a function of RF power in case that P_μ=1kW, 1.5kW and 2kW, respectively. Ion currents, which are mainly determined by P_μ, are not influenced by RF power.

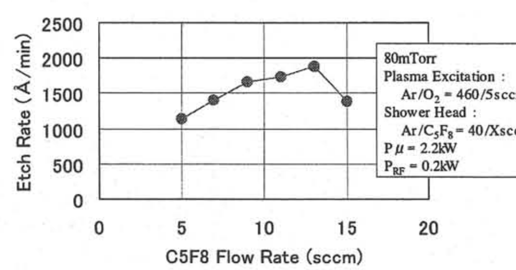

Fig. 7 Etch rage of SiO_2 as a function of C_5F_8 flow rate in case that |Vdc| is about 200V.

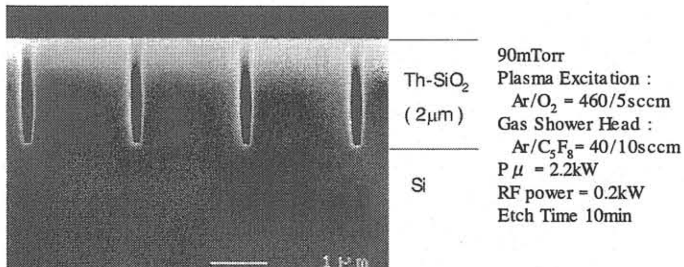

Fig. 8 Cross sectional SEM image of SiO_2 contact hole. Contact hole is successfully etched.