Inductively Coupled Plasma Etching of $Pb(Zr_XTi_{1-X})O_3$ Thin Films in Cl_2/C_2F_6 and HBr plasmas

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Many researches for PZT and PLZT (La-doped PZT) ferroelectric films as a dielectric material for storage capacitors of highly integrated memory devices (e.g., DRAM and FeRAM) have been carrying out since these films have a high dielectric constant and remanant polarization. Various etching processes including reactive ion etching (RIE) (1,2) have been applied to define the patterns on ferroelectric materials. In order to overcome the poor selectivity to photoresist mask in conventional RIE, the high density plasma system such as inductively coupled plasma (ICP) was employed in this study (3).

$Pb(Zr_XTi_{1-X})O_3$ thin films of 2500 Å in thickness were deposited on Pt coated $Ti/SiO_2/Si$ substrates by sol-gel process. Using Cl_2/Ar, C_2F_6/Ar, $Cl_2/C_2F_6/Ar$ and HBr/Ar gas chemistry, dry etching of PZT films was studied by varying the etching parameters including coil RF power, dc-bias voltage to substrate and gas pressure. The gases containing chlorine and fluorine are very effective in making the volatile compounds with PZT films, depending on the etching conditions.

The etch rates of PZT films by using C_2F_6/Ar and Cl_2/Ar gases are shown in Fig. 1. As the concentration of each gas increases, the etch rates also increase but decrease with further increasing concentration. It indicates that the etching of PZT films with these gases exhibits a characteristic of reactive ion etching and the excess etch gas inhibits the sputtering of ions to the film surface, resulting in slow etch rate. Fig. 2 shows the SEM photographs of PZT films etched by C_2F_6/Ar and Cl_2/Ar gases. In the case of C_2F_6/Ar gas, thick polymer along the pattern was observed. However, clean etch profile was obtained with Cl_2/Ar gas but the selectivity to photoresist mask was poor. One can see the etched sidewall of the pattern (Fig. 2(b)), otherwise it should be protected by a photoresist mask. The mixture of Cl_2 and C_2F_6 gases was attempted to utilize only the advantages of Cl_2/Ar and C_2F_6/Ar gases, and HBr/Ar gas was also investigated as an alternative gas (Fig. 3). It is expected that HBr gas can make volatile etch products and give high selectivity to photoresist mask. Fig. 3 shows the same trend in etch rate with respect to gas concentration for both gases. The etch rate of $Cl_2/C_2F_6/Ar$ gas was faster than that of HBr/Ar gas. The etch profiles for these gases were shown in Fig. 4. The SEM photographs show clean etch profiles for both gases, which were obtained under the optimized etch conditions. The sidewall slopes of the etched PZT films were similar and these were much stiffer than those by either Cl_2/Ar or C_2F_6/Ar gas.

Chlorine-containing gases in PZT etching were more effective than fluorine-containing gases. The etching process for PZT thin films was developed to obtain the high etch rate (1000~1500 Å/min) and reasonable selectivity without redeposits and residues. The sidewall angle of etched PZT films was in the range of 50~80°. The electrical properties of PZT capacitors etched by $Cl_2/C_2F_6/Ar$ and HBr/Ar gases are being investigated.

REFERENCES

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Fig. 4 Etch profiles of PZT films etched in (a) $Cl_2/C_2F_6/Ar$ and (b) HBr/Ar gases.

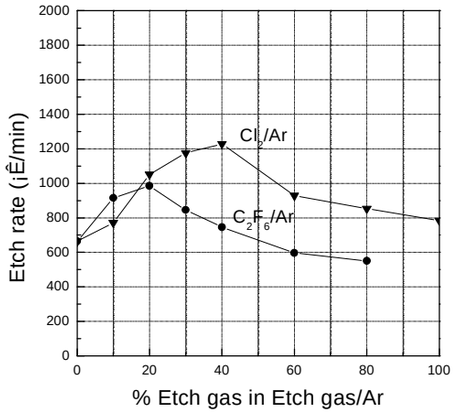

Fig. 1 Etch rates of PZT films as a function of etch gas concentration.

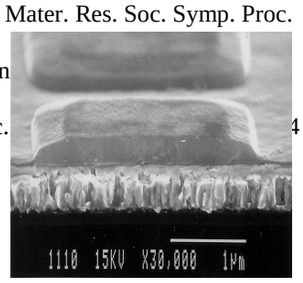

Fig. 2 Etch profiles of PZT films etched in (a) C_2F_6/Ar and (b) Cl_2/Ar gases.

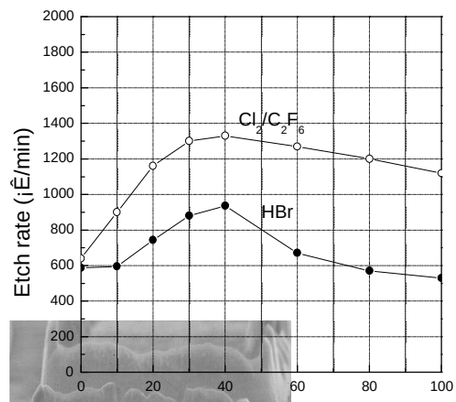

Fig. 3 Etch rates of PZT films as a function of etch gas concentration.