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High Rate and Low Radiation Damage Film Deposition by Copmressed Magnetic Field (CMF) Magnetron Sputtering

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Introduction We have developed a novel low temperature high rate sputtering techniques. [1)] In this technique c-axis highly aligned ZnO piezoelectric films were fabricated with a very high deposition rate (~15 µm/h). In this paper it is shown that these films deposited in this technique have less radiation damages to the substrates and deposited films than other sputtering techniques.

Description of New Equipment In the conventional magnetron sputtering techniques, a magnet is fixed to the back of the target to produce a leakage flux on the target surface. In our system another solenoid coil is placed around a cylindrical bell jar to push away the leakage fluxes to the target surface. These two magnetic fluxes play an important role in this system. Moreover, as shown in Fig. 1, setting outer pole piece of the magnet behind the target to the outside of the target diameter, its utilization efficiency was greatly improved. Figure 2 shows how the magnetic field is compressed to the target surface. The parallel components to the target surface are effective to trap electrons and ionized particles.

Novel points of the system are :

1) The target utilization efficiency is higher than 80%. (Conventional magnetron: 30 %)

2) The minimum target-substrate distance is 1 cm or less in order to be outside the plasma region because the plasma is compressed to the target surface and a disklike doughnut. (Conventional magnetron: 4 - 5 cm)

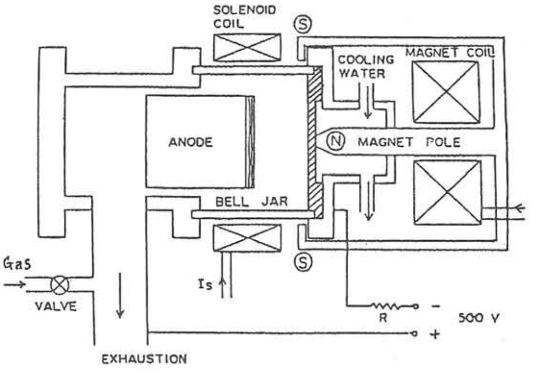

Fig. 1 CMF-magnetron sputtering system.

Experiments C-V characteristics of Al-ZnO-SiO_2-Si [2)] (MZOS) structure were observed and shown in Fig. 3. A 1000Å thermally oxidized SiO_2 was grown on the n-Si wafers ($N_D = 2 \times 10^{15}/ cm^3$). An Al gate diameter was 0.5 mm. The surface-state charge density was estimated as $Q_{ss}/q = 3.1 \times 10^{11}/cm^2$. ZnO films were deposited by our CMF-magnetron sputtering (Ⓐ in Fig.3) and conventional dc reactive sputtering (Ⓑ in Fig. 3). As this figure shows no increase in fast-surface states were observed in Curve Ⓐ though it was observed in Curve Ⓑ. It is reported in the literature that a large hysteresis and large shift of V_{FB} are observed in this MZOS structure. [3,4)] But this stable C-V characteristics were independent of film deposition rate

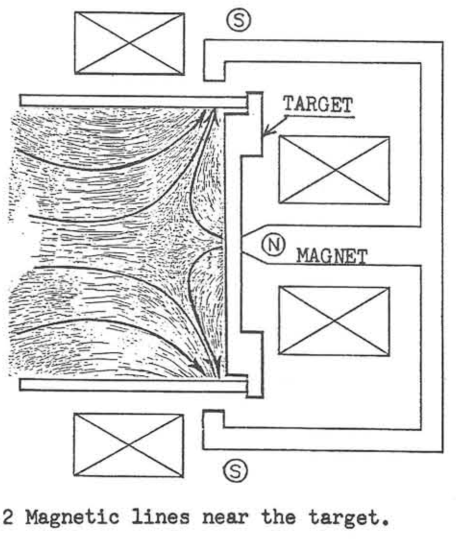

Fig.2 Magnetic lines near the target.

and scanning speed of C-V characteristics.

Next, ZnO films were etched off from MZOS structure, and C-V characteristics of the etch-back MOS structure were observed and shown in Fig. 4(a) and (b). Dashed lines in the figure are C-V characteristics of original MOS structure at 1 MHz. Fig. 4(a) is for the etch-back MOS of Curve Ⓐ in Fig. 3. These curves are same as those of original MOS structure, but they shift 0.8 V toward positive direction. It shows that negative charges are trapped in the SiO_2.

On the other hand, Fig. 4(b) is for the etch-back MOS of Curve Ⓑ in Fig. 3. This figure shows that fast surface states are induced in SiO_2-Si interface and ionized charges are trapped in the SiO_2. From these experimental results we can conclude that the CMF-magnetron sputtering technique can deposit films with low radiation damages and high deposition rate.

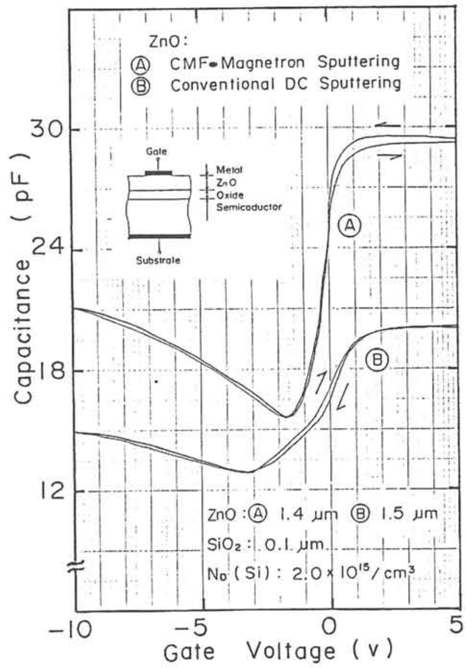

Fig. 3 C-V characteristics of MZOS structure at 1MHz.

Conclusion Radiation damages of films deposited by the CMF-magnetron sputtering techniques were clarified. The sputtering conditions of ZnO are tabulated in Table 1. We believe that this techniques will permit a great success to deposit SiO_2 and Si_3N_4 films for VLSI process. As the deposition temperature is low enough to deposit on plastics, we have deposited optical TiO_2 films on PMMA and it is possible to use He as a sputtering gas instead of Ar gas because of high deposition rate.

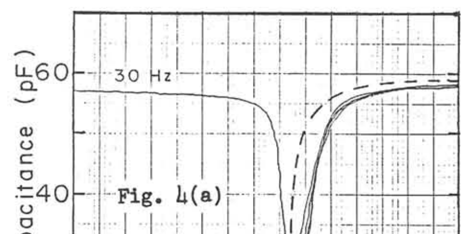

Fig. 4 C-V characterristics of etch-back MOS structure.
(a) CMF-magnetron sputtering
(b) Conventional dc sputtering

References

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Table 1. Sputtering condition of ZnO

	CMF-Magnetron	Conventional diode
Target	Zn	Zn
Gas	Ar : O_2 = 1 : 1	Ar : O_2 = 1 : 1
Pressure	0.2 Torr	0. 15 Torr
Current	400 mA	20 mA
Voltage	360 V	750 V
Deposition rate	10 μ/h	1500 Å/h