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Chemical Shift and Surface Characteristics of Al-Doped ZnO Thin Film on SiOC Dielectrics

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Aluminum doped zinc oxide (AZO) films were fabricated on SiOC/p-Si wafer and SiOC film was prepared on a *p*-type Si substrate with the SiC target at oxygen ambient with the gas flow rate of 5–30 sccm by a RF magnetron sputter. *C–V* curve of SiOC/Si wafer was measured to observe the relationship between the polarity of SiOC dielectrics and the change of capacitance depending on oxygen gas flow rate. The SiOC film could be controlled to be polar or nonpolar, and their surface energy was changed depending on the polarity. Smooth surface is essential to improve the TFT performance. AZO-TFTs used smooth SiOC film with low polarity as a gate insulator was observed to show low leakage current (IL) and low subthreshold voltage swing. It is proposed that SiOC film with high degree amorphous structure as a gate insulator between AZO and Si wafer could solve problems of the mismatched interfaces, which was originated from the electron scattering due to the grain boundary.

Keywords: AZO, Reflectance, SiOC, Capacitance, TFT.

RESEARCH ARTICLE

1. INTRODUCTION

Wide band gap semiconductors have attracted considerable interest. Al doped ZnO (AZO) films have attractive much attention because of their comparative high optical transmittance, high reflection constant, large piezoelectric constant and ultraviolet emission properties and low electrical resistivity with respect to other TCOs widely used such as Tin-doped Indium Oxide (ITO) films. Mobility of AZO TFTs can be associated with both gate dielectric materials and generation of majority carriers in the AZO films and interface.[1,2] Effects of gate insulators in oxide TFTs were researched. There was used high-*k* or low-*k* materials as a gate insulator for oxide TFTs.[3] It has been known that SiCO low-*k* with low leakage current. SiOC film has low-*k* dielectric constant by lowering the polarization or porosity in the film. Materials instead of SiO_2 film has the dielectric constant about 2.1 and good insulator properties In view of mechanical properties, low-polar SiOC film is superior to pourous SiOC.[3] In this study, AZO on SiOC film was prepared by RF sputter in order to investigate the AZO growth and the effect of polarity of substrate. SiOC film was deposited with various oxygen flow rates by RF magnetron sputtering to have various polarities.

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2. EXPERIMENTS AND RESULTS

The SiOC film was prepared on *p*-type Si substrate at room temperature by RF magnetron sputtering with a 2 inch diameter ceramic target (SiO:C, 97%:3% wt.) targets supplied by LTS Research Laboratories, Inc., U.S.A. The distance from the target to the substrate was kept at 100 mm and the base pressure was 4.5×10^{-5} Pa. The flow rate of the oxygen (99.9999%) was controlled by a mass flow controller (MFC) from 10 to 30 sccm, and the sputtering RF power was at 300 W. AZO thin film was also deposited using the AZO targets (99.99% purity) by RF magnetron sputter at a pressure of 0.01 Torr in argon atmosphere at room temperature. The chemical-optical analyses of the film were performed using UV-visible spectrometer (UV-SOLUTIONS-U-40-01) and Fourier transform infrared spectroscopy (Galaxy 7020A). The *C–V* was measured using MIS (metal/SiOCfilm/Si) structure and mask pattern with diameter of 200 μm. Aluminum was used as the electrode source. To observe the characteristic of AZO TFT and SiOC as a gate insulator, the channel width and length was 1200 μm and 0.25 μm, respectively.

Figure 1 shows the FTIR spectra of the SiOC thin films grown at the room temperature by RF magnetron sputtering. The FTIR spectra[3] of SiOC film consists of the main bond of 950~1250 cm^{-1} and sub bond under 950 cm^{-1}. There is no change of the FTIR spectra of all the samples

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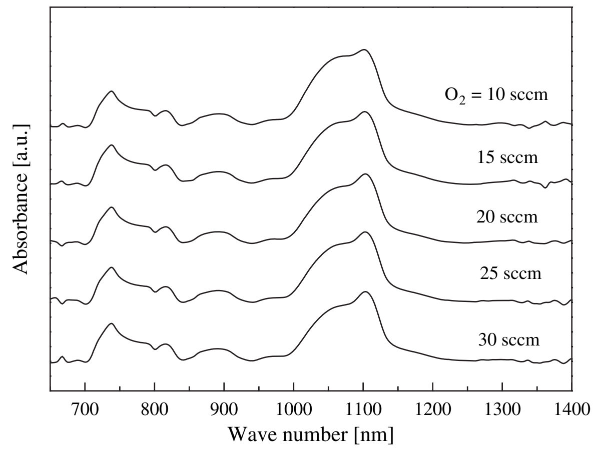

Fig. 1. FTIR spectra of the SiOC thin films on *p* type Si wafer deposited with various oxygen.

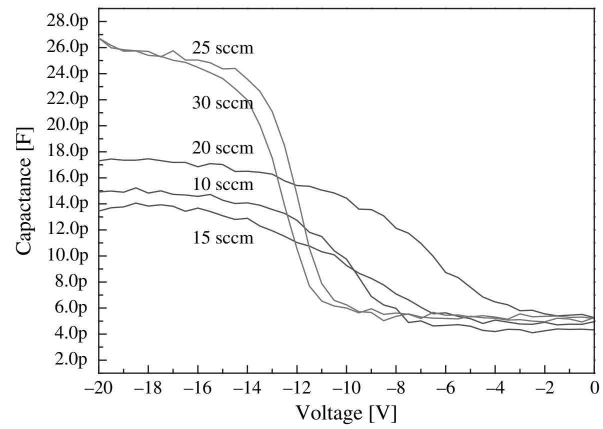

Fig. 3. Capacitance of SiOC films with various O_2 gas flow rates.

regardless of the oxygen gas flow rates. Consider this, the appearance of no significant change in FTIR spectra nevertheless various deposition condition indicates a stability of the process in sputtering system to make the low-*k* SiOC film with various properties, as it would be shown later.

Figure 2 is the reflectance of SiOC film by sputter and the samples of 20, 25 and 30 sccm as O_2 gas flow are similar results. So this result indicates that the optical-chemical properties of these films originate from the same reason in the bonding structure generation. Samples of 20, 25 and 30 sccm as O_2 gas flow show the uniformity in the visual range in spite of various swing figures at samples 10 and 15 sccm.

Figure 3 is the electrical properties were measured by MIS structure. The capacitance increased at samples 30 and 25 sccm. Capacitance was divided into two types such as high and low values. Sample of 20 sccm in middle range including samples with 15, 10 and 20 sccm showed the low capacitance in spite of similar reflectance of samples 20, 25 and 30 sccm as shown in Figure 2. However, samples of 25 and 30 sccm were high capacitance and the trend with increasing near −10 V was similar. These two types of electrical properties depended on the polarity according to the characteristic of SiOC film. Therefore, sample 20 sccm of middle properties was the lowest polarity as non polar. Considering this, opto-electrical properties of sample 20 sccm was attributed to deficient polar sites in the interaction between alkyl and hydroxyl group due to the CH and OH.

Figure 4 is I_d–V_g curve of electrical characteristics of AZO with SiOC as a gate insulator. AZO/SiOC film with $O_2 = 20$ sccm as non-polarity showed lower leakage current than that of AZO on SiOC with 30 sccm, moreover, the threshold voltage was also lower as shown in the inset. Inset was transfer characteristics of I_g–V_g curve and the I_g–V_g curve of AZO/SiOC film with $O_2 = 20$ sccm and $O_2 = 30$ sccm, related with the threshold voltage. The threshold voltage shift also originated from the charge trap within gate insulator and interface charge trap. It is known that

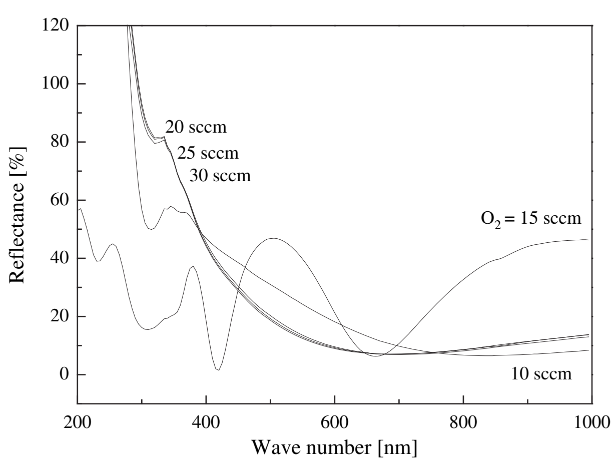

Fig. 2. Reflectance of SiOC film with various O_2 gas flow rates deposited by RF magnetron sputtering.

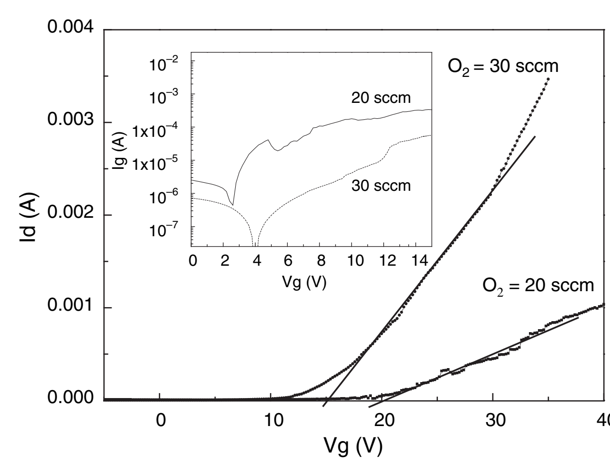

Fig. 4. I_d–V_g curves of AZO/SiOC film with polar ($O_2 = 30$ sccm) and non polar ($O_2 = 20$ sccm).

the threshold voltage and sub-threshold swing are related to the interface trap density and the number of deep state.[3] The threshold voltage in AZO TFT on SiOC film of $O_2 =$ 30 sccm is higher than that of AZO TFT on SiOC at $O_2 = 20$ sccm. The initial trapped charge at the dielectric interface will influence the threshold voltage, and the threshold voltage shift is easily observed as numbers of traps exist at the dielectric interface by forward/reverse voltage sweep. SiOC film with $O_2 = 20$ sccm as a gate insulator suppressed the threshold voltage shift because of effects of lowering the trap charge, low polarization and low capacitance due to electron deficient sites. The better subthreshold swing is attributed to the decrement of dielectric interface trap density and the number of deep state. Effect of lowering the polarity in SiOC film made flat surface and then the crystallinity of AZO grown on SiOC film also improved. The V_{th} of AZO TFT on SiOC film with $O_2 = 30$ sccm in compared with that of $O_2 =$ 20 sccm was positively shifted by about 4 V, but the on-off characteristic of TFT used SiOC film with $O_2 = 30$ sccm was superior due to the electron rich effects. To control the threshold voltage of ZnO related oxide thin film, SiOC film was observed good performance such as low dielectric constant, low threshold voltage and flot surface for gate insulators in TFT.

3. CONCLUSION

To develop the low temperature process for semiconductor devices, AZO/SiOC film was prepared by rf magnetron sputter, and the transistor characteristic was researched to define the effect of polarity at substrate materials. SiOC film involved the properties from non-polarity to polarity due to the chemical reaction of the hydroxyl and alkyl group. The V_{th} shift was occurred when the substrate has the polarity, and this polarity became unstability in TFT characteristic. However, the enhancement of threshold voltage was due to the decrement of dielectric interface trap density of SiOC film as gate insulator and the low polarity and electron deficient sites in SiOC/Si substrate improved the characteristics of threshold voltage in TFT.

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References and Notes

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