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# Amorphous indium zinc oxide thin film transistors with ultra-high saturation mobility using $Sm_2O_3$ as gate insulator

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## 1. Introduction

In recent years, rare earth metal oxides (REO) have widely been used in metal-oxide-semiconductor structures [1], metal-insulator-metal capacitors [2], memory elements [3], optical devices [4]. REO materials have such potential application owing to their large band gap, high dielectric constant, and high thermodynamic stability. Such as $HfO_2$, and $TiO_2$ have been reported on electrical and chemical properties of many investigations [5]. Nevertheless, hafnium oxide easily forms oxygen vacancies to inducing leakage current, and $TiO_2$ has smaller band gap to not being barrier to conduction band. Thus, samarium oxide ($Sm_2O_3$) is an attractive REO with suitable dielectric constant and large conduction band offset. The excellent permittivity of that epitaxial samarium oxide thin film grown on $SrTiO_3$ substrate by pulsed laser deposition is 30.5 [6]. Jing-De Chen et al. demonstrated that metal-insulator-metal capacitor with $Sm_2O_3$ dielectric featuring low quadratic voltage coefficient of capacitance (VCC), high capacitance density and low leakage current [2,7]. Generally, the TFTs have great electric characteristics as that gate dielectric insulator have higher capacitance and lower leakage.

In this letter, we introduce IZO TFTs with samarium oxide as gate dielectric insulator. The high performance TFT devices have low-voltage operating region, small sub-threshold, and ultra-high mobility.

## 2. Experimental

The $Sm_2O_3$ films (80-85nm) were deposited on ITO glass by radio frequency reactive magnetron sputtering at room temperature. During the sputtering process, the chamber pressure was maintained at 20 mtorr and the sputtering power was 100W. The flowing ratio of argon to oxygen was kept 23.5/1.5 sccm through thin film growth. Finally, a 100 nm top aluminum layer was deposited by thermal coater and patterned by a shadow mask.

The ITO film that formed the gate electrode was patterned by conventional photolithography and etching process. And then, the 80nm $Sm_2O_3$ gate dielectric was deposited by RF reactive sputtering at room temperature. The 20nm IZO active layer was deposited by RF sputtering through shadow mask at room temperature. Drain and source electrodes were evaporated after that were patterned by photolithography and left-off process.

Those devices were measured by I-V and C-V in the dark box using E5270B semiconductor parameter analyzer and E4980A precision LCR meter, respectively.

## 3. Device characteristics

Fig. 1. shows the J-E characteristics of the Al/ $Sm_2O_3$/ITO capacitor. The leakage current density is $8\times10^{-8}$ (A/cm$^2$) at an electrical field of 1(MV/cm) and increases slightly as Al/ $Sm_2O_3$/ ITO capacitor was stressed positive bias. The phenomenon was believed that two electrodes have different work function to influence carrier injection into dielectric buck. In order to investigating current conduction mechanism for the Al/ $Sm_2O_3$/ITO capacitor, fitting the leakage curve from I-V measurement. Fig. 2. shows the $Ln(J)$ vs $E^{1/2}$ dependence. The slope of the curve at low electrical field is twice as at high electrical field. It is obtained the Schottky emission at low electrical field of 0.2(MV/cm)<E<1.3 (MV/cm) and the Poole-Frenkel emission at high electrical field of E>1.4(MV/cm). Fig. 3. shows C-V characteristics of the Al/ $Sm_2O_3$/ITO capacitor and the permittivity is 11 evaluated on V=0. The apparent asymmetric curves were believed to be due to different interface of Al/ $Sm_2O_3$ and $Sm_2O_3$/ITO. Fig. 4. shows AFM images of 80nm $Sm_2O_3$ insulator deposited on ITO glass, it indicates that the rms of $Sm_2O_3$ thin film is 3.620 nm.

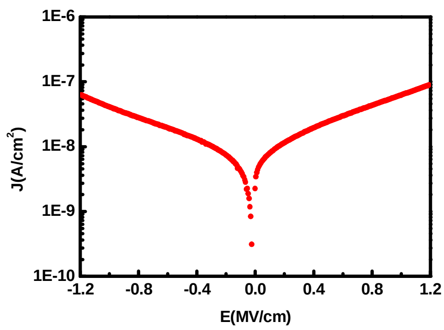


Fig. 1. J-E characteristics of the Al/ $Sm_2O_3$/ITO capacitor.

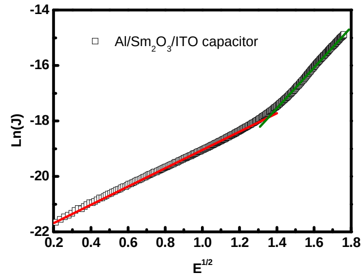


Fig. 2. Schottky emission (red line) and Poole- Frenkel emission (green line) plots of *Ln(J)* vs $E^{1/2}$ under positive bias.

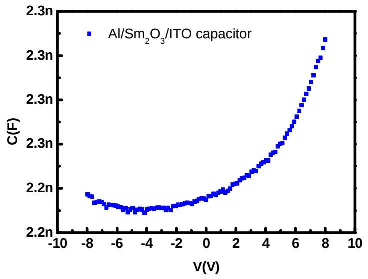


Fig. 3. C-V characteristics of the Al/ $Sm_2O_3$/ITO capacitor. The permittivity is 11 on V=0.

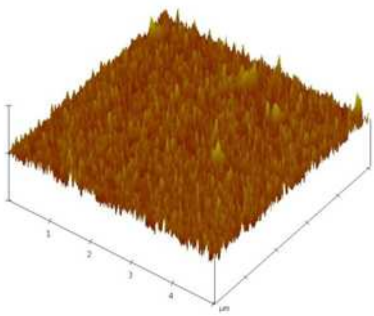

Fig. 4. AFM images of 80nm $Sm_2O_3$ insulator deposited on ITO glass.

The output $I_{DS}$-$V_{DS}$ characteristics of the IZO TFT are shown in Fig. 5. It clearly exhibits the typical transistor characteristics of current saturation and pinch off.

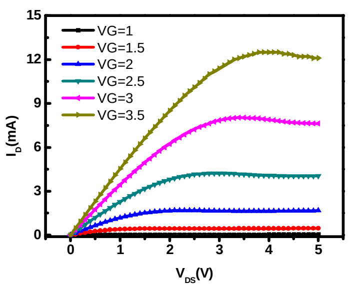


Fig. 5. Output characteristics of the IZO TFT with $Sm_2O_3$ gate insulator.

The Fig. 6. shows transfer characteristics of the IZO TFT, the on/off ratio is $2.28\times10^7$ , the threshold voltage is extracted from the square root of $I_{DS}$ is 1.29V, the sub-threshold swing is estimated to about 0.329 V/dec, and the excellent saturation mobility at $V_{DS}$=2.5V is 127.86 $cm^2$/Vs. In comparison with IGZO TFT and IZO TFT, the results suggest that IZO TFT has the higher saturation mobility, large on/off ratio, and smaller sub-threshold then IGZO TFT in our report.

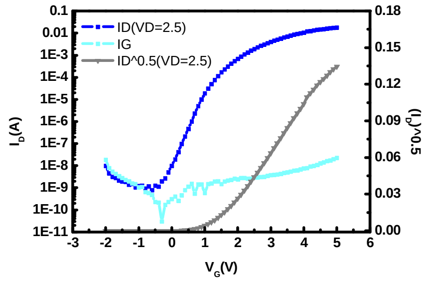


Fig. 6. Transfer characteristics of the IGZO TFT with $Sm_2O_3$ gate insulator.

## 4. Conclusions

In summary, we demonstrated MIM capacitor with samarium oxide as dielectric insulator on glass substrate. The Al/ $Sm_2O_3$/ITO capacitor exhibits small leakage current density (~$8\times10^{-8}$ A/$cm^2$) under 1MV/cm. When Al electrode was biased positive voltage, the carrier conduction mechanism was the Schottky emission at low electrical field of 0.2(MV/cm)<E<1.3 (MV/cm) and the Poole-Frenkel emission at high electrical field of E>1.4(MV/cm). In the meanwhile, we fabricated IZO TFT with samarium oxide as gate insulator. And the IZO TFT showed stabilized characteristics in the light of threshold voltage, on/off ratio, saturation mobility, sub-threshold were 1.29V, $2.28\times10^7$ , 127.86 $cm^2$/Vs, 0.329 V/dec, respectively.

## References


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