Short communication

Room temperature fabrication Oxide TFT with $Y_2O_3$ as a gate oxide and Mo contact

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1. Introduction

The ease in forming of oxide in amorphous form which exhibits the bulk and crystalline band gap is an advantage of OTFT. The high mobility between 10 and 40 cm$^2$ (V s)$^{-1}$ which is higher than a-Si by the several magnitudes, an important factor that has attracted the attention of researchers. In addition, the transparent nature of these oxides is useful for transparent optoelectronics. Various gate oxides have also been employed to improve the gate leakage current. The focus of the most of the studies has been to improve the field effect mobility along with lowering fabrication temperature. The field effect mobility values from various sources are provided in Table 1. In most of the studies, the RF sputter deposition method has been utilized to deposit a-IGZO and gate oxide. The gate insulator TiSiO$_2$ of thickness 132 nm sandwiched between SiO$_2$ layers has been used by Na et al. [2]. Aluminum has been used as contact metal, while the substrate of n-type Si has been used. The room temperature fabrication of TFT on glass substrate with a-IGZO as an active layer and Y$_2$O$_3$ gate oxide has been reported by Yabuta et al. [3]. The bottom contact structure has been fabricated with Au/Ti contact. Further, the effective parameters for TFT with a-IGZO and SiO$_2$ gate oxide deposited by PECVD at 330 °C exhibits highest field effect mobility. The mobility has been reported around 35.8 cm$^2$ (V s)$^{-1}$, on/off current ratio of the order of $10^4$ with threshold voltage and subthreshold swing 5.9 V and 0.59 V/dec, respectively [6]. Thus, the TFT with Y$_2$O$_3$ gate oxide with reasonably high field effect mobility along with Mo contact has not been reported so far. Forming contact is essential step to prevent any more disintegration of contact metal which can lead to increase in resistance of contact materials. It has been observed that the resistance of molybdenum contact increases on device processing. In addition, it has also been evident that the plasma damages the gate contact while depositing Y$_2$O$_3$; an additional factor leading to increase in resistance. In light of exiting literature, good performance of OTFT with Y$_2$O$_3$ as a gate dielectric with molybdenum contact still to be obtained. In this article, we have demonstrated the TFT with Y$_2$O$_3$ gate oxide with Mo contact.

2. Experimental

The a-IGZO was deposited using RF sputter at 40 W power and Ar + O$_2$ ambient in the ratio of 9:1. The metal contacts were formed of molybdenum deposited by DC sputter. The gate oxide Y$_2$O$_3$ was deposited by RF sputter at power of 120 W and Ar + O$_2$ ambient in the ratio of 1:1. The optimized deposition parameters were taken from the literature [7]. The fabrication of device was carried out in class 100 clean room. The glass substrate was cleaned in deionized water, acetone and methanol for 10 min at each step in an
ultrasonic bath. The molybdenum of 100 nm thick was deposited on glass and the gate was patterned out using lithographic process followed by gate oxide Y2O3 of 135 nm layer deposition. The IGZO of 50 nm was deposited and was patterned to form active channel region followed molybdenum deposition and molybdenum liftoff process to form source and drain contact. The device was annealed in N2 +5 %H2 ambient for 2 h at 400°C. Electrical characteristic was measured by Agilent main frame semiconductor analyzer 4572B.

3. Results and discussion

The device structure and schematic are provided in Fig. 1 and the transfer curve for the device with ratio of channel width (W = 40 μm) to channel length (L = 50 μm) 0.8 and the dielectric constant for MIM structure as an inset are presented in Fig. 2.

The off current for all the devices have been observed of the order of 10^-11 A, which is bit on higher side compare to the literature. The on current for all the devices have been measured to be 10^-7 A. Thus the on/off current ratio of the order of 10^4 has been obtained for all the devices. The threshold voltage and saturation mobility for the devices have been extracted using square law equation as

\[ I_{ds} = \mu \frac{W}{L} \left( V_{gs} - V_{th} \right) \left( V_{gs} - V_{th} \right) \]

where \( V_{th} \) is threshold voltage, \( \mu \), \( W \), \( L \), \( \epsilon_0 \), \( \epsilon_r \), \( 5.1–5.4 \); average dielectric constant has been used for mobility calculation, \( W \) and \( L \) are field mobility, permittivity of free space, permittivity of Y2O3, channel width and channel length respectively. The capacitance of the gate dielectric in a processed device has also been measured to determine the dielectric behavior of the Y2O3. The dielectric constant which has been used to determine the mobility is an average value measured on five different devices. The leakage current density for as-deposited Y2O3 has been reported to be 10^-9 A/cm² for 100 nm thick layer [8]. The observed gate leakage current density on the deterioration of Y2O3 is higher by the 10^3 order of magnitude compare to the MIM structure. The low conduction band offset between IGZO and Y2O3 is one of the reasons for high leakage current.

The dielectric behavior of gate oxide under such a hostile condition has also been probed. It is essential to determine the correct value of mobility and threshold voltage. Thus the dielectric constant at different frequencies and applied bias from -5 to 5 has been measured and is provided in Fig. 2 as an

![Fig. 1. Oxide TFT: (a) schematic and (b) representative fabricated bottom gate device.](image)

![Fig. 2. Transfer curve for the OTFT with W/L = 0.8; dielectric constant of MIM structure as an inset.](image)

Table 1

<table>
<thead>
<tr>
<th>Field effect mobility (cm²/V s)</th>
<th>a-IGZO (nm)</th>
<th>Gate oxide (thickness, nm)</th>
<th>Deposition method</th>
<th>Threshold</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>30</td>
<td>Y2O3 (200)</td>
<td>RF</td>
<td>2.1</td>
<td>[1]^a</td>
</tr>
<tr>
<td>11.4</td>
<td>50</td>
<td>TiSiO2 (132)</td>
<td>RF</td>
<td>1.18</td>
<td>[2]^b</td>
</tr>
<tr>
<td>12</td>
<td>50</td>
<td>Y2O3 (140)</td>
<td>RF</td>
<td>1.4</td>
<td>[3]^c</td>
</tr>
<tr>
<td>6–9</td>
<td>30</td>
<td>Y2O3 (140)</td>
<td>RF</td>
<td>1.6</td>
<td>[4]^d</td>
</tr>
<tr>
<td>10</td>
<td>50</td>
<td>Y2O3 (140)</td>
<td>PLD</td>
<td>1.4</td>
<td>[5]^e</td>
</tr>
<tr>
<td>11.3</td>
<td>50</td>
<td>135–140 nm</td>
<td>RF</td>
<td>3.4</td>
<td>This work</td>
</tr>
</tbody>
</table>

^a PET substrate. ^b Si substrate. ^c Glass substrate.
inset. The maximum mobility that has been extracted in this investigation is 11.3 cm²/V s, while the lowest value of $V_{th}$ has been observed to be 1.7 V.

The operational voltage for the transistor has been obtained as low as 5 V. The $I_d$–$V_{ds}$ characteristic for the transistor with $W/L$ (40 μm/50 μm) = 0.8 is shown in Fig. 3. The $I_d$–$V_{ds}$ curve exhibits very distinct behavior and formation pinch off region. However, it is to be emphasized that the substrate injection resulting into overall low drain current.

The effect of $W/L$ ratio on the threshold ($V_{th}$) and mobility is provided in Fig. 4. It has been observed that the change in channel length from 20 to 50 μm leads to the mobility improvement by the magnitude of 9–10 depending on the drain bias while the as the width of channel region change from 20 to 40 μm keeping channel length constant, the mobility shows further enhancement. For the device with channel length of 50 μm and channel width of 40 μm, mobility has been observed to be 11.3 cm²/V s.

The saturation mobility exhibits an exponentially increasing behavior with drain bias, while $V_{th}$ is almost constant. The mobility dependence on the drain bias hints to emission of captured charges as drain bias increases. The behavior exhibits saturation of mobility as a function of drain bias which also supports a conclusion.

4. Conclusions

In this work, the Oxide TFT with Mo contact and $Y_2O_3$ gate oxide has been demonstrated. The saturation mobility of 11.3 cm²/V s using $Y_2O_3$ as a gate oxide and the applicability of gate oxide in a hostile annealing condition has been determined. Although, the saturation mobility has been observed to be reasonable, the substrate injection due to small difference in conduction band offset is going to play big role in determining the leakage current.

Acknowledgements

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References