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Low temperature deposition of metal oxide semiconductor materials by high-power impulse magnetron sputtering

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Amorphous Indium Gallium Zinc Oxide (IGZO) was invented by Hosono group in 2004 and has been used as a thin-film transistor (TFT) for displays due to higher electron mobility of approximately 10 cm²/Vs, low leakage current and low subthreshold voltage [1]. Nowadays, the low-temperature polycrystalline silicon and oxide (LTPO) technology, where switching transistors in the display backplane are replaced with oxide TFT has been used. The low leakage current characteristic of oxide semiconductors (OS) has been recognized as a key factor in low-power display technology, contributing to improved energy efficiency. The TFT with higher mobility is required for increasing the refresh rate of displays [2]. Since OS has lower mobility than low-temperature polycrystalline silicon (LTPS), LTPS is still required for driving transistors in LTPO. The domain size of polycrystalline IGZO or an increase in film density improves the mobility [3].

In this study, the low-temperature deposition of IGZO thin films was conducted by high-power impulse magnetron sputtering (HiPIMS) in order to enhance the migration of deposited atoms through high-density energetic ion bombardment.

IGZO thin films were deposited using a 2-inch IGZO target (In:Ga:Zn:O = 1:1:1:4) and a mixture gas of argon and oxygen. A pulsed voltage with a pulse width of 9 µs and a frequency of 500 Hz was applied to the IGZO target. The total flow rate of mixture gas was 10 sccm, the oxygen gas flow ratio (O_2/Ar+O_2) was 2 %, and the gas pressure was 3 Pa. After the deposition, post-annealing was performed at 400 °C in an oxygen atmosphere.

Figure 1 shows temporal variation of substrate temperature measured by using thermocouples for various peak power density. The peak power density was calculated from the multiplication of the peak target current density and the target voltage. The deposition times for each condition were within 10 min. The substrate temperature increased with increasing the peak power density and the substrate temperature at peak power density of 1.64 kW/cm^2 was below 60 °C. The crystal peak of IGZO (104) was observed at 1.64 kW/cm^2 from the XRD analysis. These results indicate that the low-temperature deposition of crystalline IGZO thin films was achieved by HiPIMS because the crystalline of IGZO films was, generally, required to thermal treatment temperature as high as 400 °C.

The optical band gaps, determined from the optical transparency of the IGZO films, was approximately 3.2 eV, which is equivalent to the conventional band gap energy of a-IGZO (3.2 eV).

Figure 2 shows the transfer characteristic of a top-contact bottom-gate TFT. The IGZO film as a channel layer was deposited on SiO_2/Si substrate at a peak power density of 0.96 kW/cm². The Ti were deposited for the source and drain electrodes by the ion beam evaporation. The transfer characteristics of TFTs fabricated using the IGZO films exhibited typical semiconductor-like behavior. A field-effect mobility of 22.4 cm²/Vs was obtained at a source-drain voltage of 8 V [4].

References
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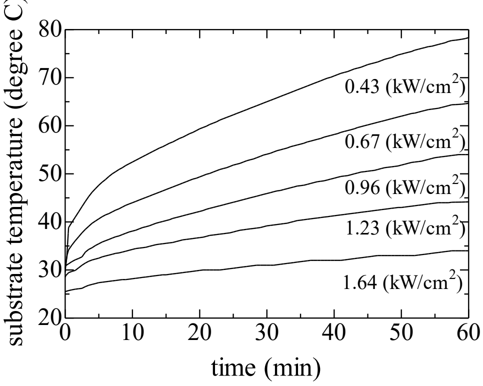

Figure 1 substrate temperature for various peak power density.

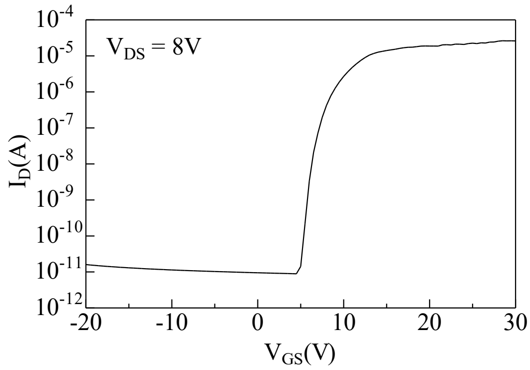

Figure 2 transfer characteristics of TFTs using IGZO film as a channel layer.