Low-temperature deposition of IGZO using high-power impulse magnetron sputtering

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Amorphous Indium Gallium Zinc Oxide (a-IGZO), invented by the Hosono group in 2004, has been widely used as a channel material for thin-film transistors (TFTs) in display backplanes due to its high electron mobility (~10 $cm^2/V\cdot s$), low leakage current (~10^{-10} A), low subthreshold voltage, and high optical transparency in the visible range [1][2]. Recently, Low-Temperature Polycrystalline Silicon and Oxide (LTPO) technology has been used, employing oxide TFTs as switching transistors. However, low-temperature polycrystalline silicon (LTPS) is still required for driving transistors because of its higher mobility (~80 $cm^2/V\cdot s$). Therefore, it is required that the mobility of oxide TFTs can be further improved while maintaining low leakage current.

It has been reported that an increase in the film density of IGZO improves the mobility, resulting in 90.4 $cm^2/V\cdot s$ [3][4]. In addition, C-axis aligned crystalline IGZO (CAAC-IGZO) shows extremely low leakage current (< 10^{-12} A) [3] and high film density of about 6.3 g/cm^3 [5][6]. The stability of the transfer characteristics was improved by using CAAC-IGZO for TFTs. However, the crystallization of IGZO films was required to thermal treatment temperature as high as 450 °C [7].

High-power impulse magnetron sputtering (HiPIMS) is an ionized sputtering method that applies high-voltage pulses with a short pulse width of several tens of microseconds to the target, generating a high-density plasma (10^{12}-10^{13} cm^{-3}). The high-density plasma promotes the ionization of species in the gas phase and the ion bombardment effect is expected to enhance the crystallization of IGZO thin films. In addition, the pulse duty ratio is below 1 % in our experimental conditions, which enables low-temperature deposition.

In this study, we aimed to enhance crystallization and film density at low temperature using HiPIMS.

A 2-inch IGZO target (In:Ga:Zn:O = 1:1:1:4) was applied to a pulsed voltage with a pulse frequency of 500 Hz and a pulse width of 9 μs. A mixed gas of argon and oxygen was used at a total gas flow rate of 6 sccm and an oxygen gas flow ratio (O_2 / (Ar + O_2)) of 2%. The sputtering pressure was 1.5 Pa, the distance between the target and the substrate was 50 mm, and the deposition time was 30 minutes.

Figure 1 shows the temporal variation of the substrate temperature. The substrate temperature was approximately 59 °C at 30 min. The IGZO film was deposited at low temperature since the average power of 2.3 W/ cm^2 was very low at low duty ratio of 0.45 %, although the peak power density was as high as 1 kW/cm^2.

Figure 2. shows the XRD pattern of the IGZO thin film. The crystalline peaks attributed to IGZO(220) and IGZO(440) were observed at 2θ = 29° and 60°, respectively. This result indicates that the spinel structure of IGZO was deposited by using HiPIMS below the substrate temperature of 59 °C. The ion bombardment during a very short pulse width promoted the crystallization of IGZO at low substrate temperature.

References
[1] K. Nomura et al., Nature, 432, 488 (2004).
[2] T. Kamiya et al., Sci. Technol. Adv. Mater., 11, 044305 (2010).
[3] H. Y. Liu et al., IEEE. Trans. Elec. Dev., 67, 3016633 (2020).
[4] H. Ide et al., Jpn. J. Appl. Phys., 56, 03BB03 (2017).
[5] S. Yamazaki et al., SID Symp. Dig., 46 (2015).
[6] J. Koezuka et al., SID Symp. Dig., 723 (2013).
[7] S. Yamazaki, et al., Jpn. J. Appl. Phys., 53, 04ED18 (2014).

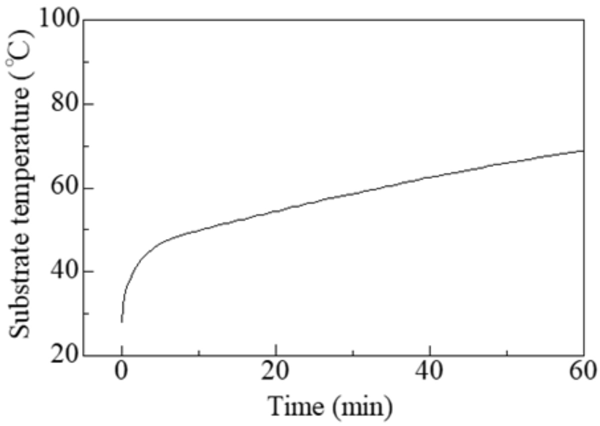

Figure 1. Temporal variation of substrate temperature.

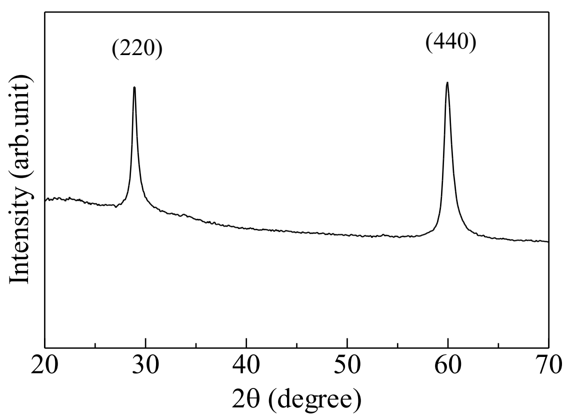

Figure 2. XRD pattern of IGZO film.