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Quinary indium gallium zinc aluminum oxide films and thin-film transistors

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Recently, thin-film transistors (TFTs) used as switching and driving devices have been widely applied in liquid-crystal displays (LCDs), flexible electronics, smart cards, etc. Several transparent conducting oxide (TCO) films are being investigated to obtain channel layers, owing to their wider energy bandgap and lack of absorption of visible light. In view of their wider energy bandgap, higher transmittance, and reasonably high electron mobility, quaternary indium gallium zinc oxide (IGZO) films have been widely used as the channel layer of TFTs in displays with larger frame size and high pixel resolution. However, IGZO TFTs still face the problem of long-term instability induced by oxygen vacancies in IGZO film. In the previously reports, Al has been incorporated into ZnO-based films to stabilize oxygen and improve their stability, because of its higher bonding energy with oxygen. Consequently, the stability of oxygen in the quinary indium gallium zinc aluminum oxide (IGZAO) films could be improved by the Al-O bonds. Furthermore, the 3s orbital of Al cation can provide an extra transport pathway and widen the conduction-band bottom to increase the electron mobility. In this work, high-quality and highly stable IGZAO films were deposited using vapor cooling condensation method to form the channel layer of highly stable TFTs.

To investigate the effect of Al, both IGZO and IGZAO films were deposited on sapphire substrates by vapor cooling condensation system. In the system, Al metal and IGZO powder were loaded into respective tungsten boats. During deposition, sublimated IGZO vapor was condensed and deposited on sapphire substrate attached to a stainless-steel holder with liquid nitrogen cooling system. Besides, IGZAO films were deposited from IGZO powder heated at 1033oC and Al metal heated at 1254oC, simultaneously. The channel width (W) and the channel length (L) of the resulting TFTs were 100 um and 10 um, respectively.

It was found that the electron mobility and electron concentration of the IGZAO films were 7.2 cm2/V-s and 9.94E15 cm-3, respectively. The maximum iDS of the IGZO and IGZAO TFTs when operated at gate−source voltage (vGS) of 5 V was 12.1 uA and 20.8 uA, respectively. Compared with the gm of 3.73E-6 S for the IGZO TFTs, the IGZAO TFTs exhibited a better gm of 7.63E-6 S. Consequently, the corresponding field-effect mobility uFE of 23.3 cm2/V-s of the IGZAO TFTs was better than that of 11.3 cm2/V-s of the IGZO TFTs. Compared with the S value of 223 mV/dec of the IGZO TFTs, the S value of the IGZAO TFTs was improved to 168 mV/dec. The threshold voltage of the IGZO and IGZAO TFTs changed by 0.51 V and 0.34 V, respectively, as the temperature was changed from 225 K to 300 K.

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