Importance of excess oxygen on growth and carrier transport of amorphous In-Ga-Zn-O with impurity hydrogen

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Amorphous oxide semiconductors represented by amorphous In-Ga-Zn-O (a-IGZO) are promising materials for thin-film transistors (TFTs) due to their large field-effect mobilities (>10 $cm^2(V \cdot s)^{-1}$) and small subthreshold voltage swings (<0.2 $V \cdot decade^{-1}$).[1] It has been reported a-IGZO films contain impurity hydrogens and its concentration is varied by the base pressure (P_{base}) of a deposition chamber, which leads to different film structures, densities, and electrical properties[2,3] and has clarified some hydrogen species work to passivate defects in a-IGZO.[4] Besides, the roles of hydrogen on subgap states are not understood well. In this work, we fabricated a-IGZO films using two sputtering systems with different P_{base} (denoted STD and UHV sputtering for P_{base} ~10^{-4} Pa and ~10^{-7} Pa, respectively) and extensively investigated the hydrogen effects by optical absorption coefficient (α), hard X-ray photoemission spectroscopy (HAXPES), Hall effect measurement, etc.

Figure 1 shows the α spectra of STD and UHV a-IGZO films deposited with various oxygen pressures (P_{O2}). It is seen that the STD film deposited without O_2 (P_{O2} = 0 %) has a long tail subgap absorption extending from the optical band gap (E_g ~3.0 eV) to 0.5 eV, while the UHV films do not show such high-density defect states even though deposited without O_2. The STD film deposited at P_{O2} = 3 %, which is the optimal condition for TFTs, shows the minimum subgap absorption; while, a similar α spectrum with the small subgap absorption is obtained at P_{O2} = 1 % for the UHV a-IGZO. This result quantitatively supports the idea that ~2 % of excess oxygen is required to compensate subgap defects and donors induced by the impurity hydrogens. Figure 2 shows the conductivity as a function of P_{O2} for STD and UHV films, further supporting this conclusion. Further, HAXPES spectra clarified that the long tail subgap absorption in the P_{O2} = 0 % STD film comes from segregation of metallic In. More details including growth dynamics will be presented at the conference.

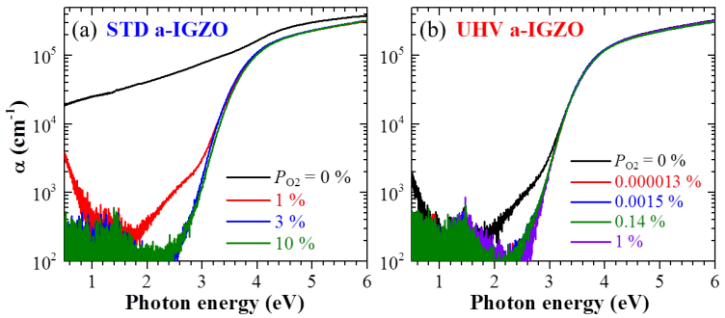

Fig. 1. Absorption spectra of (a) STD and (b) UHV a-IGZO films deposited at various P_{O2}.

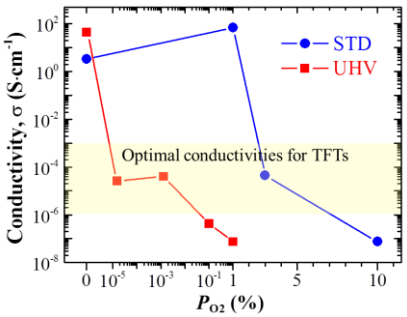

Fig. 2. Conductivity as a function of P_{O2} for the STD and UHV films.

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