# BASE PRESSURE CONTROLLED FABRICATION OF HIGH-MOBILITY $In_2O_3$ THIN FILM TRANSISTORS

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Transparent amorphous oxide semiconductors (TAOSs) have been extensively studied as active channel layers of thin-film transistors (TFTs) for next-generation flat-panel displays. Among TAOSs, amorphous In–Ga–Zn–O (a-IGZO) TFTs have now become the backplane standard for active-matrix liquid-crystal displays and active-matrix organic light-emitting diode displays because of their reasonable field-effect mobility ($\mu_{FE}$) of over 10 $cm^2$ $V^{-1}$ $s^{-1}$, extremely low leakage current, low process temperature (<350 °C), and large-area scalability [1]. Although the $\mu_{FE}$ value of a-IGZO TFTs is more than ten times higher than that of a-Si:H TFTs (<1 $cm^2$ $V^{-1}$ $s^{-1}$), the further improvement of $\mu_{FE}$ values is required to expand their range of applications as alternatives to poly-Si TFTs (50–100 $cm^2$ $V^{-1}$ $s^{-1}$). Recently, we reported a $\mu_{FE}$ value of 139.2 $cm^2$ $V^{-1}$ $s^{-1}$ for a TFT obtained using hydrogenated polycrystalline $In_2O_3$ ($In_2O_3$:H) formed via solid-phase crystallization at 300 °C [2]. The hydrogen introduced during sputter deposition plays an important role in enlarging the grain size and decreasing the subgap defects in $In_2O_3$:H. Although $In_2O_3$:H TFTs show extremely high $\mu_{FE}$, another method of introducing hydrogen into $In_2O_3$ films might be more suitable for practical application. Nomura *et al*. reported that the a-IGZO films contained hydrogens at the high densities of $\sim 10^{20}$ $cm^{-3}$ due to the residual H-containing species in the deposition chamber [3].

In this study, we investigated the effects of base pressure (BP) on $In_2O_3$ film quality and TFT properties. $In_2O_3$ films were deposited on alkali-free glass substrates (Corning® EAGLE XG®) by pulsed laser deposition (PLD) without substrate heating from a ceramic $In_2O_3$ target. The oxygen pressure and laser fluence were maintained at 3 Pa and ~1.5 J $cm^{-2}$ $pulse^{-1}$, respectively. The BP was varied from $7.5 \times 10^{-5}$ to $1.0 \times 10^{-3}$ Pa.

Figures depict the electron backscattering diffraction (EBSD) images for the 200 °C annealed $In_2O_3$ films deposited under BP of (a) $7.5 \times 10^{-5}$ Pa, (b) $1.0 \times 10^{-3}$ Pa. The grain size of the films significantly increased from 0.5 to over 1 µm with increasing BP and the resultant film showed high Hall mobility of 112.5 $cm^2$ $V^{-1}$ $s^{-1}$. This result indicates that hydrogen was incorporated into the film by increasing BP. Figure c show typical transfer characteristics of the TFTs with $In_2O_3$ channel deposited under different BP. The $In_2O_3$ TFT deposited under BP of $1.0 \times 10^{-3}$ Pa exhibited a switching with a high $\mu_{FE}$ of 79 $cm^2$ $V^{-1}$ $s^{-1}$, a subthreshold swing of 0.11 V $dec.^{-1}$, a threshold voltage of −1.4 V. The proposed method has great potential for future electronics applications.

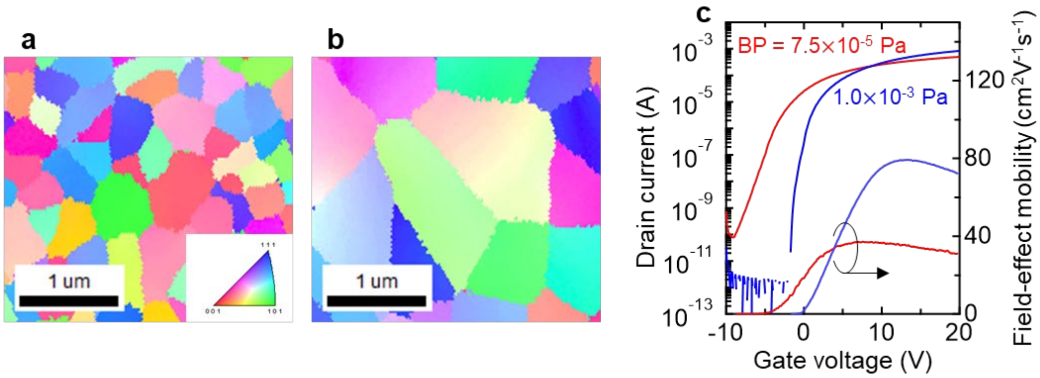

*Figure – EBSD images of the 200 °C annealed $In_2O_3$ films deposited under BP of (a) $7.5 \times 10^{-5}$ Pa, (b) $1.0 \times 10^{-3}$ Pa. (c) Transfer characteristics of the polycrystalline $In_2O_3$ TFTs with channels deposited under different BP.*

[1] K. Nomura et al., Nature 432, 488 (2004).
[2] Y. Magari et al., Nat. Commun. 13, 1078 (2022).
[3] K. Nomura et al., ECS J Solid State Sci Technol 2, 1 (2013).