# Supporting Information

# Effect of Solution Temperature on Solution-Processed High Performance Metal Oxide Thin Film Transistors

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**Figure S1.** Experimental setup for controlling the metal oxide precursor solution temperature. With this setup, it is possible to synthesize a metal oxide precursor solution and maintain it at a specific temperature.

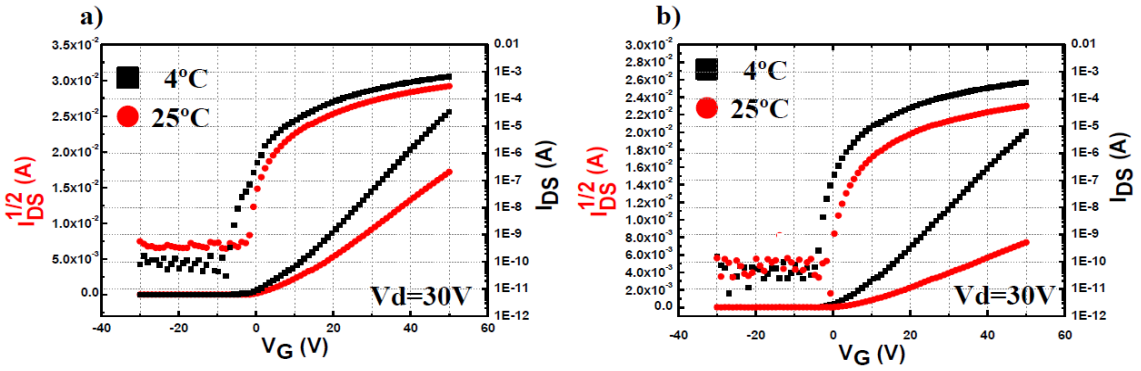


**Figure S2.** Transfer characteristics of metal oxide TFTs deposited at the indicated solution temperatures. Transfer curves of (a) IGO and (b) IGZO. All of the thin films were annealed at 350 °C.

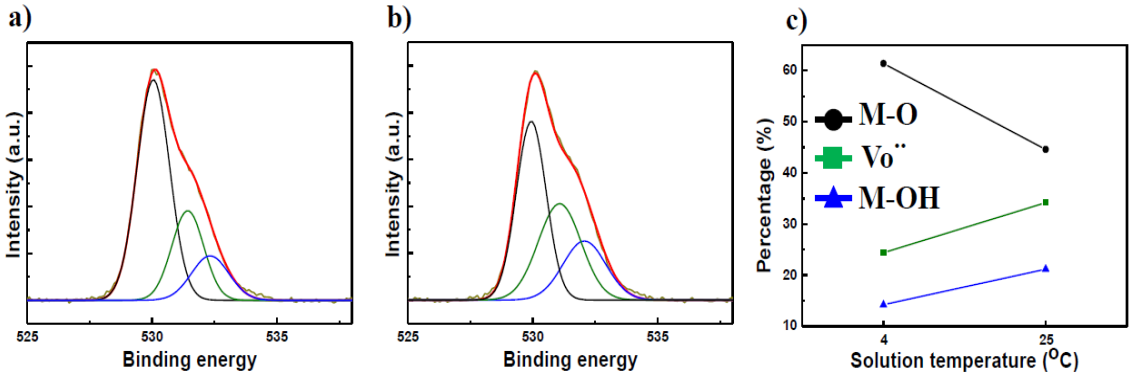


**Figure S3.** O1s XPS spectra for the IGO thin films annealed at 350 °C deposited from (a) 4S and (b) 25S. (c) Percentages of the oxide lattices, lattice with oxygen vacancies, and oxygen in hydroxide. The percentages were calculated based on the area integration of each O 1s peak. The colored lines indicate the peaks that are from the oxide lattices without oxygen vacancies (~529.9 eV), the oxide lattices with oxygen vacancies (~531.4 eV), and the hydroxide (~531.7 eV).[1]

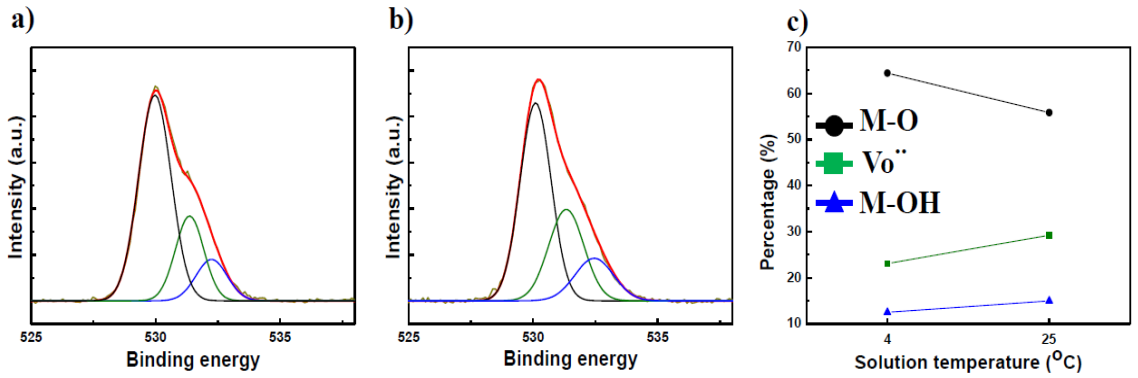


**Figure S4.** O 1s XPS spectra for the IGZO thin films annealed at 350 °C deposited from (a) 4S (b) 25S. (c) Percentages of the oxide lattices, lattice with oxygen vacancies, and oxygen in hydroxide. The percentages were calculated based on the area integration of each O1s peak. The colored lines indicate peaks that are from the oxide lattices without oxygen vacancies (~529.9 eV), the oxide lattices with oxygen vacancies (~531.4 eV), and the hydroxide (~531.7 eV).[2.]

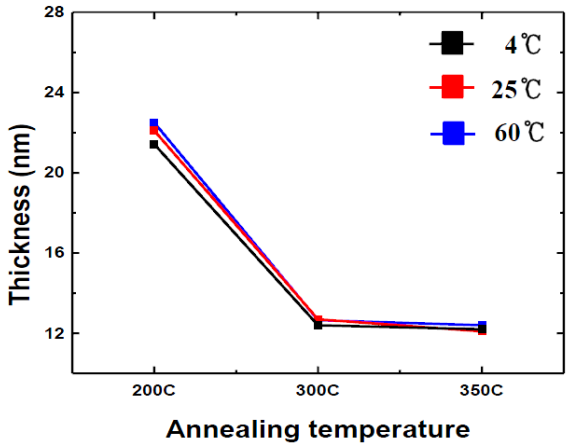


**Figure S5.** Dependence of the thickness of IZO thin films deposited at the indicated solution temperatures on annealing temperature from 200 to 350 °C.

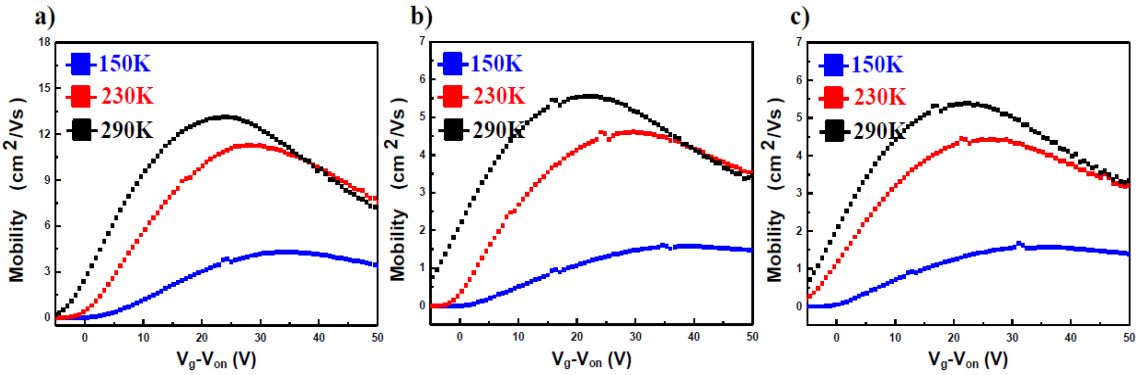


**Figure S6.** Plots of mobility vs. $V_g$-$V_{on}$ for IZO TFTs deposited from (a) 4S, (b) 25S, and (c) 60S measured at different temperatures.

**Electrical characterization of the GIO and GIZO TFTs**

The synthesis of the GIO and GIZO solutions is described in the section below. Here, we discuss the assessment of the electrical performance of the GIO and GIZO TFTs fabricated from the metal precursor solutions at 4 and 25 °C. In particular the electrical performance was assessed by analyzing the field-effect mobility, threshold voltage and drain current on-off ratio. Figures S2a and S2b show the transfer curves of the GIO and GIZO TFTs fabricated from 4S and 25S. It can be observed that these TFTs had high on-currents and field-effect mobility at $30V_{DS}$ because of their large quantities of oxide lattices and small percentages of oxygen vacancies in the GIO and GIZO thin films (see Figures S3 and S4). In addition, as the solution temperature was increased, the threshold voltage of the GIO and GIZO TFTs increased. Details of the electrical performance of the IGO and GIZO TFTs deposited from 4S and 25S are summarized in Table S1.

**Preparation of the metal oxide precursor solutions: GIO, GIZO and ZTO**

Precursor solutions for the IGO and IGZO thin films were synthesized by dissolving a mixture of indium nitrate hydrate [$In(NO_3)_3 \cdot xH_2O$], gallium nitrate hydrate [$Ga(NO_3)_3 \cdot xH_2O$]

and zinc nitrate hexahydrate [$Zn(NO_3)_2 \cdot 6H_2O$] in 2-methoxyethaol and maintaining the solutions at various temperatures (4 and 25 °C) using a chiller. The metal precursor ratios were as follows: In : Ga = 7 : 3 and In : Ga : Zn = 2 : 1 : 2 for IGO and GIZO, respectively. The precursor solution for ZTO was synthesized by dissolving a mixture of zinc chloride [$ZnCl_2$] and tin chloride [$SnCl_2$] in 2-methoxyethanol with a few drops of water and maintaining the solution at 4 or 25 °C using a chiller. For the ZTO precursor, a 1:1 ratio of Zn : Sn was achieved. These clear precursor solutions for IGO, GIZO, and ZTO were stirred for 12 h at various temperatures before the spin-coating. Then, the GIO, GIZO, and ZTO solutions were spin-coated on 200 nm-thick-$SiO_2$/P++ Si substrates at 4000rpm for 30s. The obtained GIO, GIZO, and ZTO thin films were annealed at 350 °C for 2 h on a hot plate in air with low humidity (~20%).

**Film characterization**

The chemical and electronic structures of the IGO, IGZO, and ZTO thin films were examined by performing X-ray photoelectron spectroscopy (XPS; Thermo VG, U.K.). The surface XPS data were collected using monochromatic Al Kα radiation (1486.6eV) in a ultrahigh-vacuum system with a base pressure of ~ $10^{-10}$ mb. The binding energy shift was corrected using the C1s peak (284.8eV).

## REFERENCES


(1) Jeong, S.; Lee, J.; Lee, S. S.; Choi, Y.; Ryu, B. *J. Phys. Chem. C* **2011**, *115*, 11773-11780.

(2) Jeong, S.; Ha, Y. G.; Moon, J.; Facchetti,; A.; Marks, T. J. *Adv. Mater.* **2010**, *22*, 1346-1350.