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# Electronic Supplementary Information

# The Structural, Optical and Electrical Characterization of High-Performance, Low-Temperature and Solution-Processed Alkali Metal-Doped ZnO TFTs

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We modified equation of optical absorption coefficient as follows,[1]

$$T_{ZnO/glass} = e^{-(\alpha_{ZnO} d_{ZnO})} \cdot e^{-(\alpha_g \cdot d_g)}, \quad T_g = e^{-\alpha_g \cdot d_g}$$

$$T_{relativeZnO} = \frac{T_{ZnO/glass}}{T_{glass}} = e^{-\alpha_{ZnO} d_{ZnO}}$$

$$-\frac{1}{d} \ln T_{relativeZnO} \cong \alpha$$

We estimated the optical bandgap from the intersection of the linear extrapolated line with the horizontal axis,[2]

$$(\alpha h\nu)^n = A(h\nu - E_{opt}) \quad (1)$$

The value of n in equation (1) was obtained the best straight line fit to the experimental data for n=2 when α was plotted against *hν*. The measured optical bandgap ($E_{opt}$) was defined as follows,

$$E_{opt} = E_g - \Delta E \quad (2)$$

The Burstein-Moss shift, ΔE, could be expressed as,

$$\Delta E = \frac{h^2 E_b}{8\pi^{\frac{2}{3}}}, \quad E_b = \frac{N^{\frac{2}{3}}}{m_e^*} \tag{3}$$

Thus, equation (2) could be written as follow.

$$E_{opt} = E_g + \frac{h^3 N^{\frac{2}{3}}}{8 m_e^* \pi^{\frac{2}{3}}} \tag{4}$$

N is carrier concentration. Assuming the effective mass $m_e^*$ to be independent of doping concentration, we could determine the optical bandgap of pristine ZnO film and the average value of $m_e^*$ from the UV transmittance plot.[3] To calculate the optical bandgap, the linear data region of pristine ZnO film was selected. Generally, the band gap of intrinsic ZnO is ~ 3.3eV, however, the calculated optical bandgap of pristine ZnO film which we selected was 3.24eV. Under the same linear data region (3.5eV~3.64eV) of $(\alpha h\nu)^2$ *vs.* photon energy plot, the $E_{opt}$ of Li-doped ZnO films (1mol%~ 15mol%) was calculated respectively.

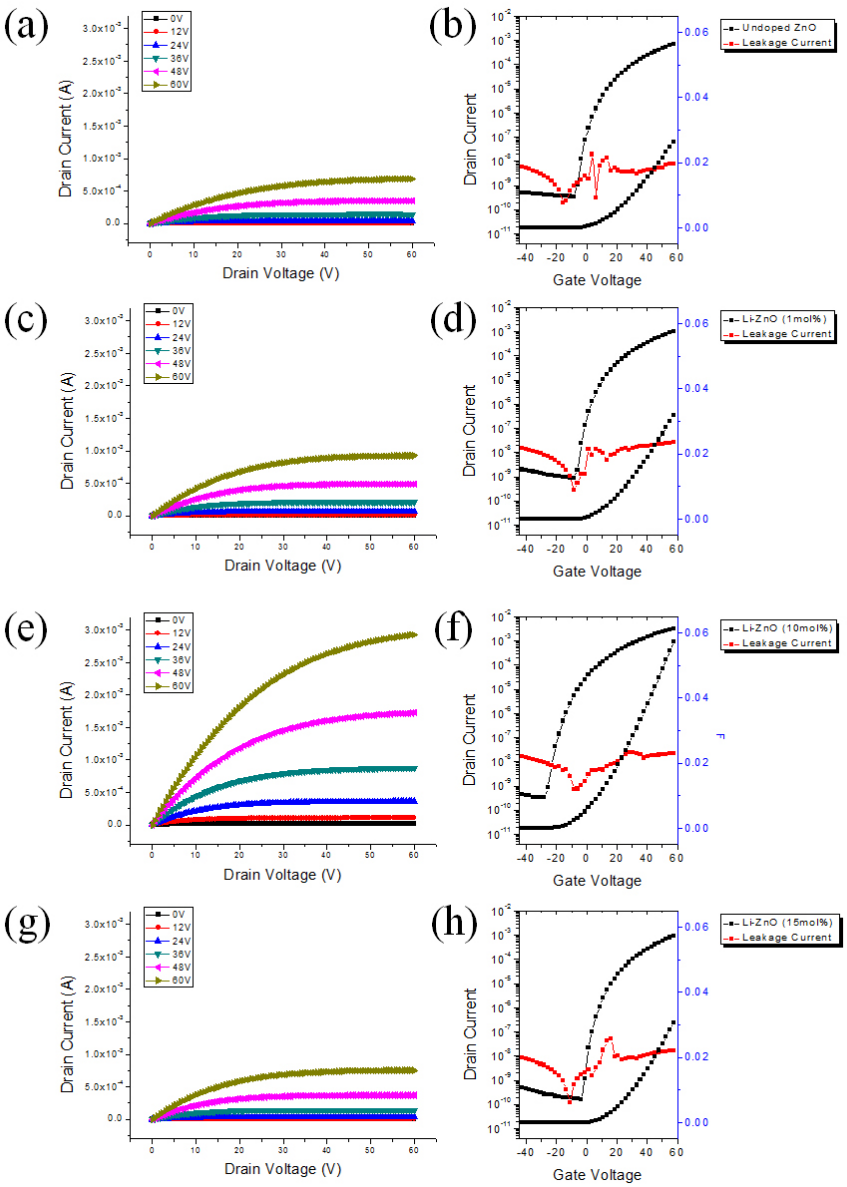



**Figure S1**. Output curves and transfer curves of ZnO TFTs. (a) and (b) pristine ZnO. (c) and (d) Li- ZnO (Li 1mol%). (e) and (f) Li-ZnO (Li 10mol%). (g) and (h) Li-ZnO (Li 15mol%). The gate voltage was varied between 0 V and 60 V in steps of 12 V. The channel length and width were 50 and 1000 μm, respectively.

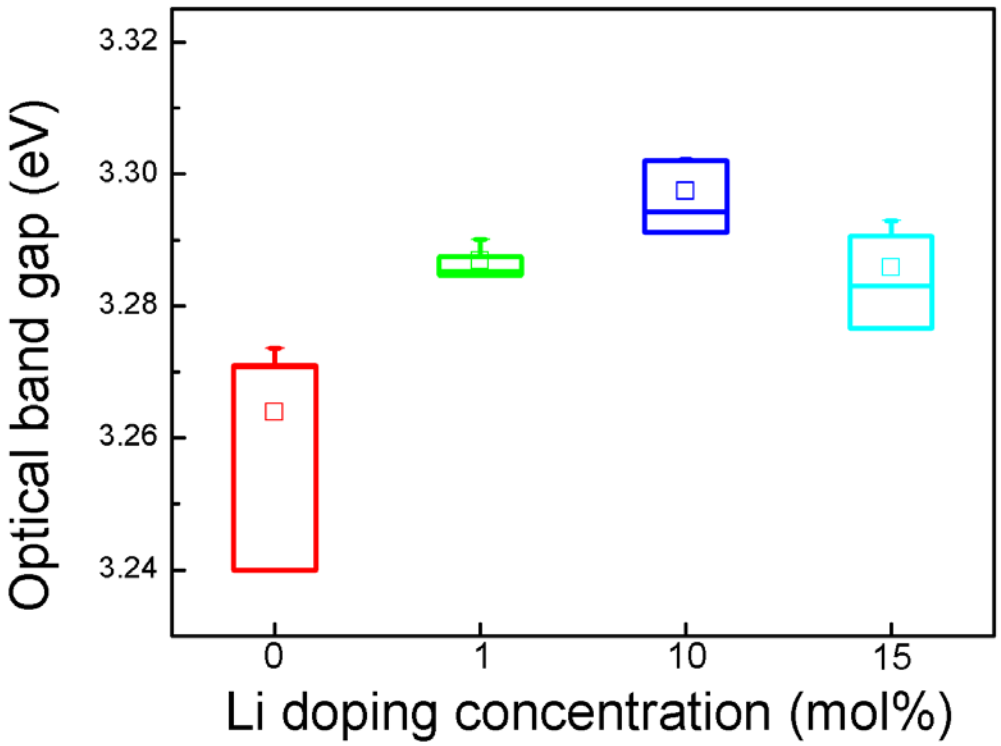



**Figure S2.** The box chart of optical band gap *vs.* Li doping concentration.

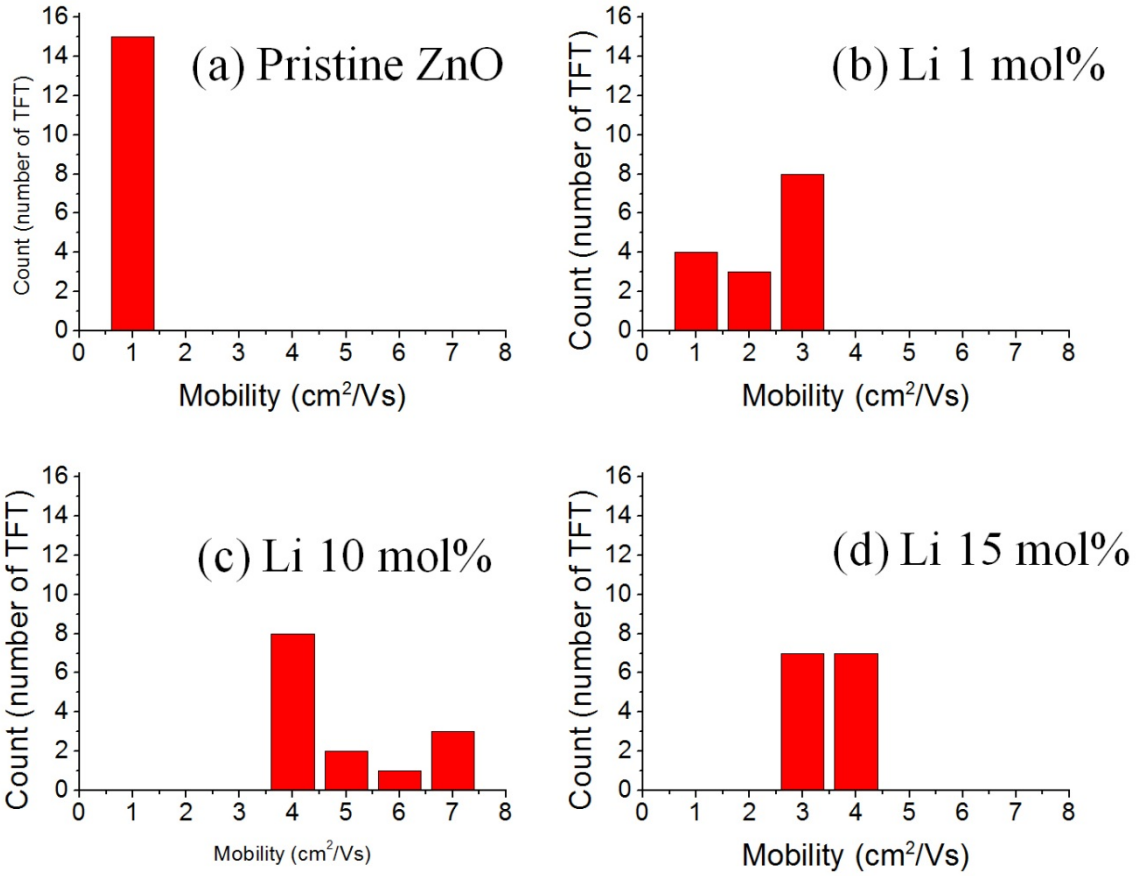



**Figure S3.** The average field effect mobility of Li-doped ZnO TFTs as one run at 300°C. (a) pristine ZnO. (b) Li-doped ZnO (1mol%). (c) Li-doped ZnO (10mol%). (d) Li-doped ZnO (15mol%).

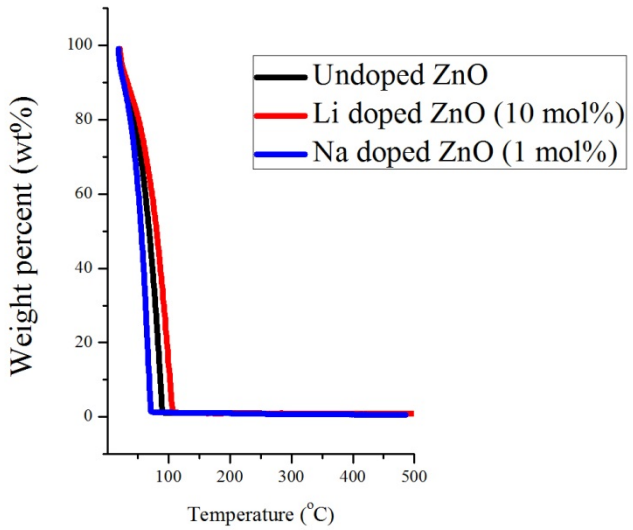
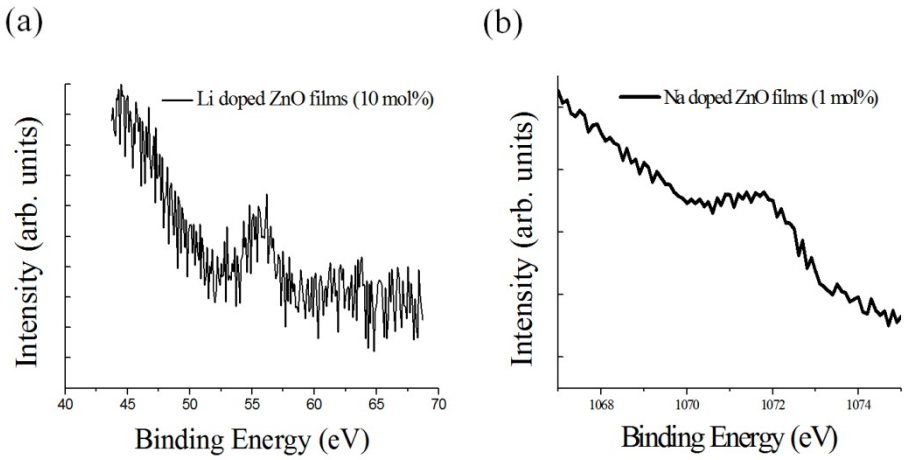



**Figure S4**. The TGA data of various alkali metal-doped ZnO films.




**Figrue S5.** XPS spectra of alkali metals doped ZnO films. (a) Li peaks at 55.7eV in Li-doped ZnO films (10 mol%). (b) Na peaks at 55.7eV in Na-doped ZnO films (1 mol%).

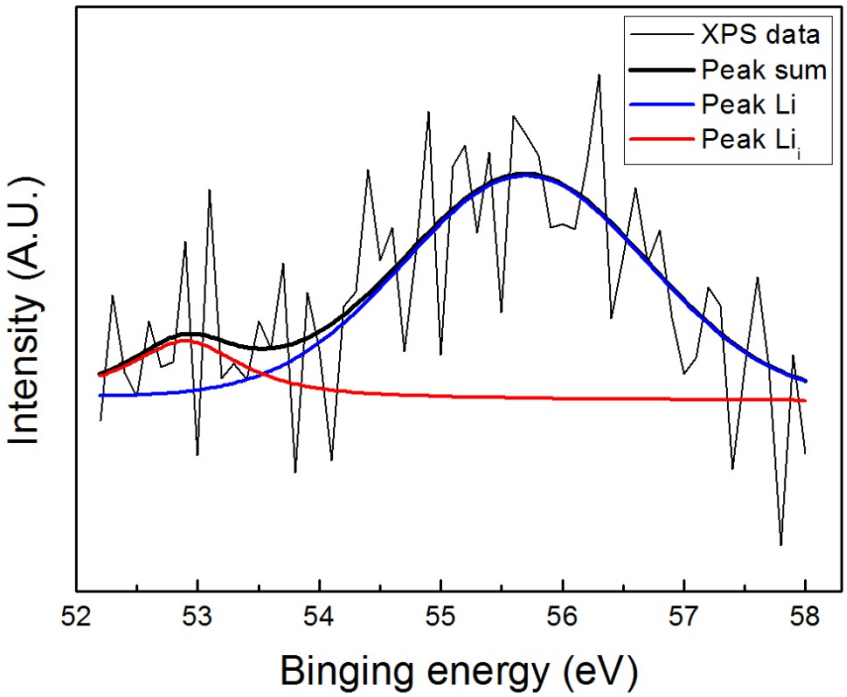



Figure S6. XPS spectra of Li 1s for Li-doped ZnO film (10 mol%).

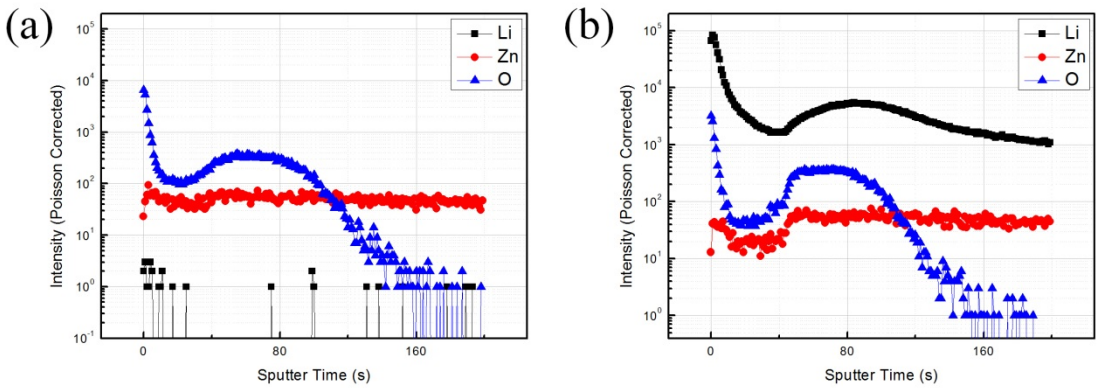



Figure S7. TOF-SIMS results of (a) pristine and (b) Li-doped ZnO (Li 10 mol%) film. Etching rate and analysis area was 0.4 Å/s and 100 x 100 μm, respectively.

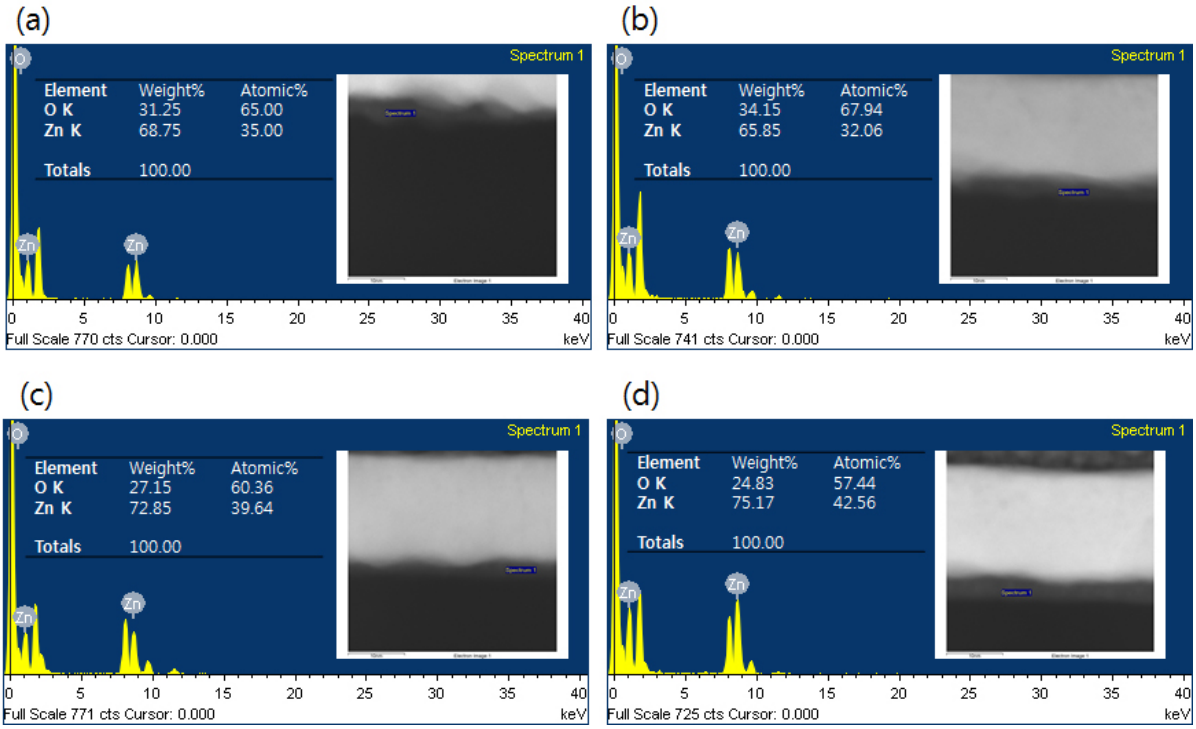



**Figure S8.** EDS results of (a) pristine and (b) Li-doped ZnO (Li 1 mol%) films. (c) Li-doped ZnO (Li 10 mol%) films. (d) Li-doped ZnO (Li 15 mol%) films. Note that nitrogen doping was not observed in the ZnO films. All films were annealed at 300 ˚C for 1 hour.

## Reference

1. K. H. Kim, K. C. Park and D. Y. Ma, J. Appl. Phys., 1997, **81**, 7764-7772.

2. A. Sarkar, S. Ghosh, S. Chaudhuri and A. K. Pal, Thin Solid Films., 1991, **204**, 255-264.

3. S. Karamat, S. Mahmood, J. J. Lin, Z. Y. Pan, P. Lee, T. L. Tan, S. V. Springham, R. V. Ramanujan and R. S. Rawat, Appl. Surf. Sci., 2008, **254**, 7285-7289.