**Full Subgap Defect Density of States in p- and n-type Metal Oxide Transistors**

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Recent developments in the Ultrabroadband Photoconductive Density of States (UP-DoS) method enable the acquisition of full subgap DoS on metal oxide thin-film transistors (TFTs), including InGaZnOx, SnO and Cu2O channel materials.[1,2] To achieve full valence-to-conduction band edge coverage, we continuously scan the incident laser photon energy from hn = 0.1 to 3.6 eV, yielding an integrated trap density, Ntot(hn), that increases stepwise as each subsequent subgap defect state is ionized. The identity of each defect peak is assigned by comparing the derivative UP-DoS spectra, dNtot/dhn, to both DFT+U simulations and experimental defect recombination lifetimes.[1,2]

For p-type channel TFTs, UP-DoS spectra of SnO and Cu2O reveal metal vacancy peaks near the valence band maximum that determine the TFT equilibrium hole concentration and Fermi level energy. Due to its measured small bandgap of 0.7 eV, unipolar p-type transistor behavior in SnO is achieved only when the defect DoS near the conduction band minimum, attributed to oxygen interstitials, is sufficiently large to suppress n-type conduction. For Cu2O TFTs, UP-DoS reveals the presence of a minority phase of CuO existing at a heavily oxidized semiconductor-dielectric interface. This oxidized minority phase explains the large discrepancy between the measured Hall mobility (μHall = 20 cm2V-1s-1) and field effect mobility (μFE = 0.2 cm2V-1s-1) for Cu2O thin-films.[1]

In contrast to p-type materials, n-type amorphous InGaZnOx is dominated by oxygen vacancies with different neighboring metal coordinations. Near the conduction band edge, UP-DoS reveals the presence of a broad Gaussian electron trap state centered at 0.4 eV. Using a 10K atom DFT+U simulation, this defect state is further assigned as a (In In In Ga) coordinated oxygen vacancy. For 15 different TFT processing conditions, UP-DoS measures the trap density of this In-rich electron trap state to show an inverse correlation with both TFT mobility and subthreshold swing. This correlation is validated using a first-principles DoS mobility model that shows the tail-state condunctivity requires the inclusion of this broad shallow donor peak to reasonably simulate a-InGaZnOx TFT transfer curves.

Finally, we reconfigure our UP-DoS microscopy method to use high-power femtosecond lasers that selectively ionize specific defects while also annealing the amorphous InGaZnOx lattice. The end result suggests a fundamental transformation of the active-channel material that boosts field-effect mobility >10x, with minimal impact on TFT reliability.

[1] Mattsson, M. J., Niang, K. M., Parker, J., Meeth, D. J., Wager, J. F., Flewitt, A. J., & Graham, M. W. (2025). [Defect Density of States of Tin Oxide and Copper Oxide p‐type Thin‐film Transistors](https://advanced.onlinelibrary.wiley.com/doi/10.1002/aelm.202400929). *Advanced Electronic Materials*, 2400929.

[2] Mattson, G. W., Vogt, K. T., Wager, J. F., & Graham, M. W. (2023). [Illuminating trap density trends in amorphous oxide semiconductors with ultrabroadband photoconduction](https://advanced.onlinelibrary.wiley.com/doi/abs/10.1002/adfm.202300742). *Advanced Functional Materials*, *33*(25), 2300742.