Modeling of the Density of States in Field-effect Zinc Oxide Semiconductor Devices Fabricated by Ultrasonic Spray Pyrolysis on Plastic Substrates †

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Abstract.

In this work, using a physically based simulator, the modeling of the density of states (DOS) through the fitting of the electrical characteristic in field-effect devices is presented. The transfer characteristics are fitted in Zinc Oxide thin-film transistors (ZnO TFTs), along with the capacitance - voltage curves in Metal-Insulator-Semiconductor (MIS) capacitors using ZnO as active layer. The ZnO semiconductor devices were fabricated by Ultrasonic Spray Pyrolysis at high frequency on polyethylene terephthalate plastic substrates. Different aspects were considered and discussed to model the interfaces such as additional contributions.

Simulation

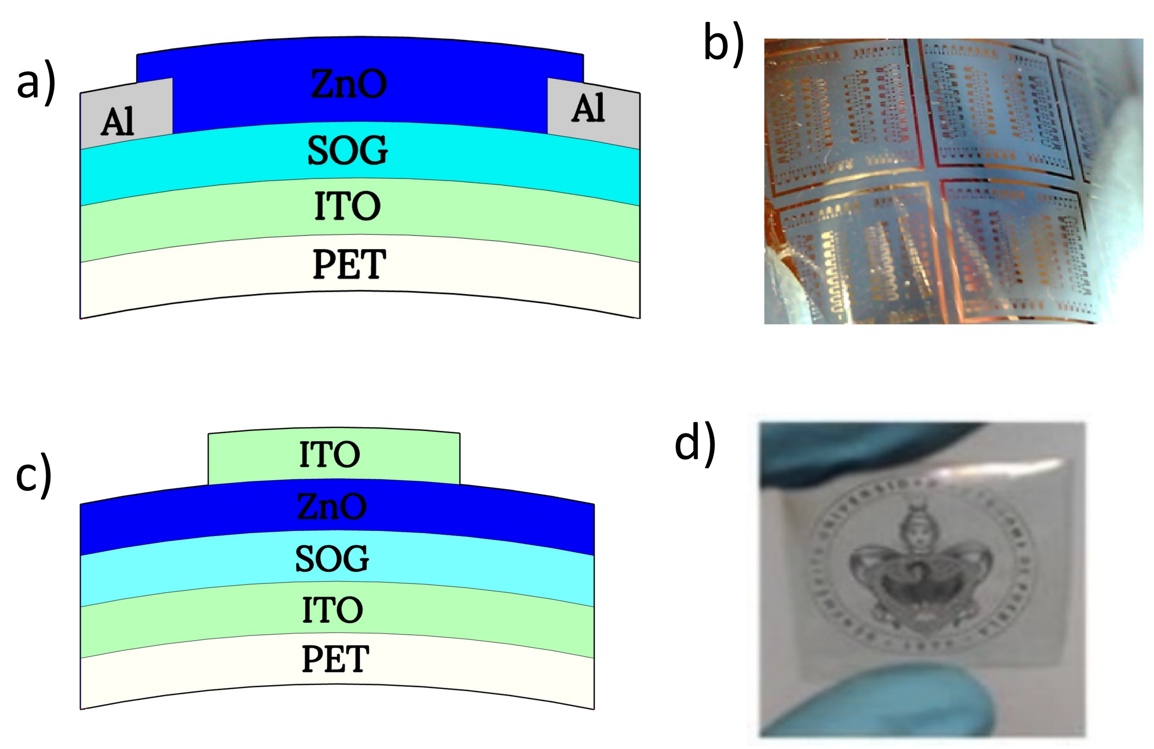

Figure 1. (a) Schematic cross-sectional view of the structure of bottom-gate coplanar structure of the TFT (b) Photograph of ZnO TFTs fabricated on PET plastic substrates. (c) Schematic cross-sectional view of the structure of MIS capacitor, (d) Photograph of MIS capacitor fabricated on PET plastic substrates.

Numerical approximation of the DOS distribution $g(E)$ is given by[1]:

$$g(E) = N_{TA} \exp\left(\frac{E-E_C}{W_{TA}}\right) + N_{TD} \exp\left(\frac{E_v-E}{W_{TD}}\right) + N_{GA} \exp\left(\frac{E_{GA}-E}{W_{GA}}\right) + N_{GD} \exp\left(\frac{E-E_{GD}}{W_{GD}}\right) \quad (1)$$

Table 1. Main parameters used in the simulation.

Parameters	ZnO	Description
Eg (eV)	3.05	Energy gap
NTA (cm-3eV-1)	3.5x1020	Density of tail-acceptor states
NTD (cm-3eV-1)	4.0x1020	Density of tail-donor states
WTD (eV)	0.05	Decay energy of tail-donor states
WTA (eV)	0.025	Decay energy of tail-acceptor states
NGA (cm-3eV-1)	1.0x1017	Density of deep-acceptor states
NGD (cm-3eV-1)	1.5x1019	Density of deep-donor states
WGD (eV)	0.1	Decay energy of deep-donor states
WGA (eV)	0.05	Decay energy of deep-acceptor states
EGD (eV)	0.1	Peak energy of deep-donor states
EGA (eV)	0.35	Peak energy of deep-acceptor states
μ_n (cm-2/V-s)	15	Electron band mobility
μ_p (cm-2/V-s)	0.1	Hole band mobility

Results

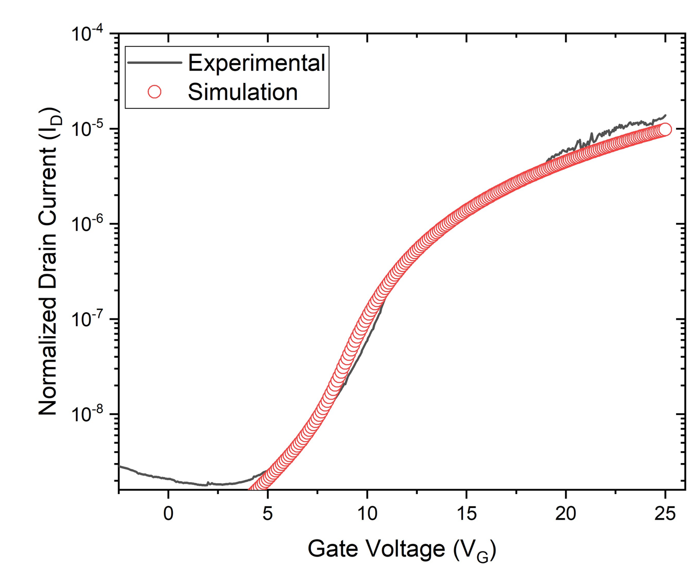

Figure 2. Experimental and simulated transfer characteristics of ZnO TFTs fabricated by Ultrasonic Spray Pyrolysis at high frequency on plastic substrates.

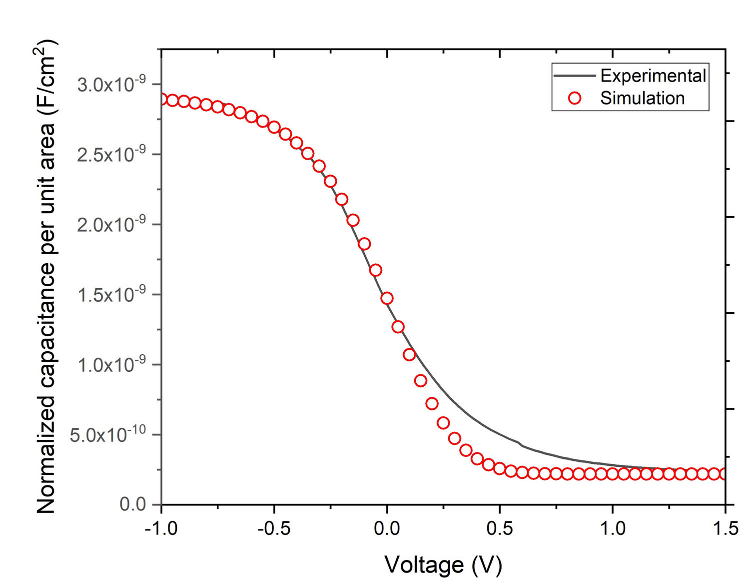

Figure 3. Experimental and simulated C-V characteristics of MIS capacitor fabricated by Ultrasonic Spray Pyrolysis at high frequency on plastic substrates.

Conclusion

In summary, the DOS was modeled to successfully reproduce the experimental electrical characteristics of ZnO TFTs and MIS capacitors. An accurate estimation of the DOS was also obtained by fitting the electrical characteristics in both TFTs and MIS capacitors. The advantage of using physically-based simulations is that the DOS of Oxide semiconductor films in field-effect devices can be modeled separating the contribution of the different interfaces in the device.

References.

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