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TCAD Simulation of IGZO TFTs

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Introduction

Technology Computer-Aided Design (TCAD) tools allow for simulation of electronic devices at a physical level. Having been a great asset in the past for the development of silicon technologies, its expected that a similar root can be taken for maturing oxide electronics [1] allowing for an understanding on how to further improve device performance and stability as required to meet the technology's full potential [2]. By giving insight on mechanisms behind device operation and allowing to explore different device configurations (geometries/materials) these tools can lead to a viable process and device development. Currently, TCAD is already enabling us to investigate aspects such as short-channel effects, trap-related instability mechanisms and carrier distribution for single/double gate devices.

TCAD Physical Simulation

Disadvantages

- Higher complexity than empirical models
- Requires incorporation of physics into the device simulator

Advantages

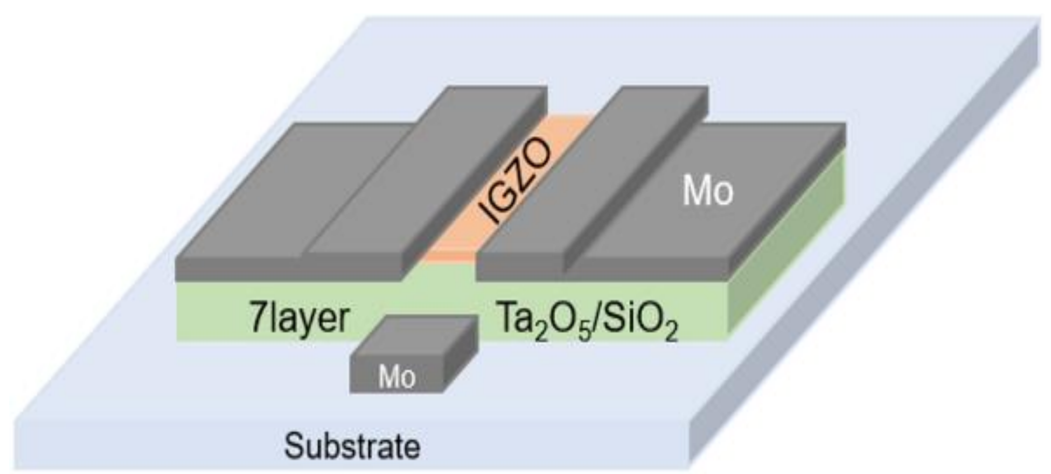
- Provides insight on device operation
- Predictive capabilities – extrapolation
- Visualization of theoretical knowledge

Simulation of IGZO TFTs

The Silvaco's 2D ATLAS™ tool is used for simulation of IGZO TFTs, as fabricated at CENIMAT|i3N (physical or solution processing routes).

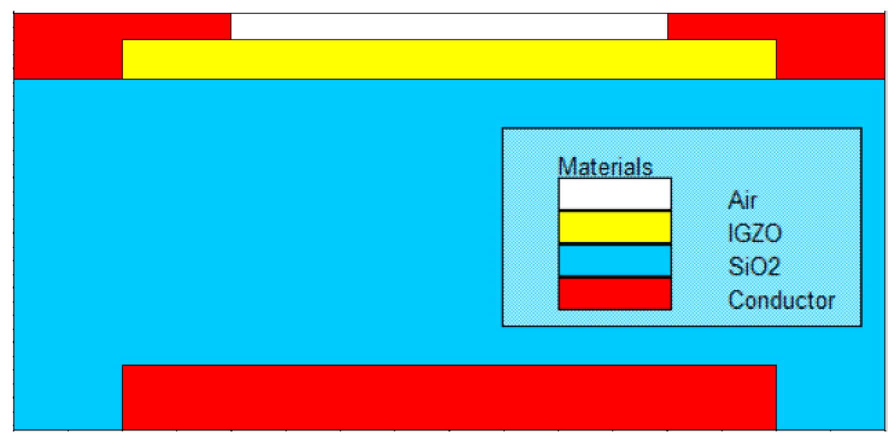
- Physical parameters extracted from the fabricated devices are inputted into the simulation.

Fabricated IGZO TFTs



Device Parameters	
μ (cm^2 $(Vs)^{-1}$)	16
I_{On}/I_{Off} @V_{DS} = 0.1 V	≈10^6
Off current	≈10fA
n_{conc} (cm^{-3})	10^{16}

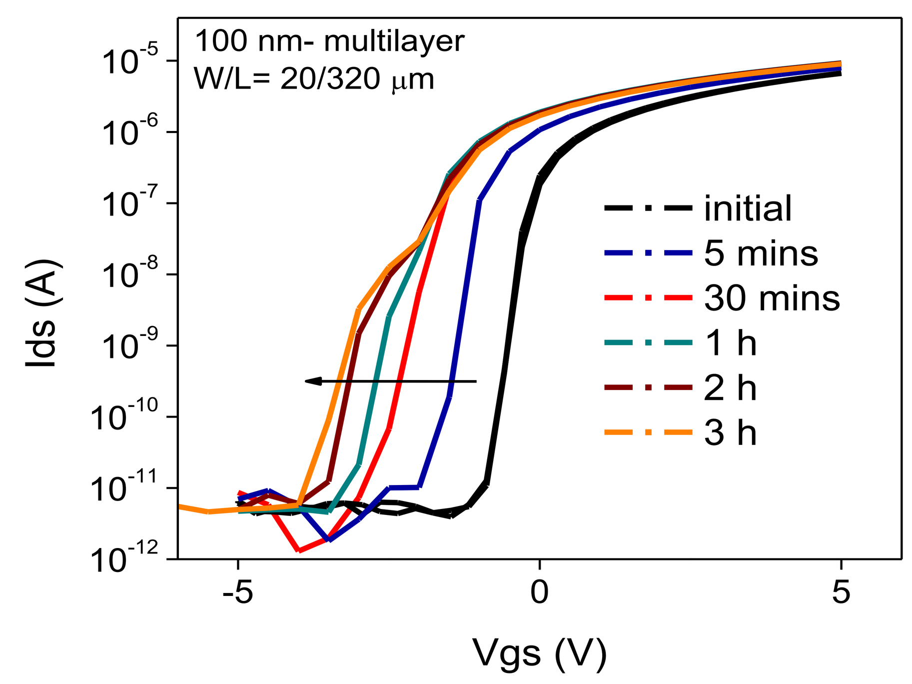
Simulated IGZO TFTs.



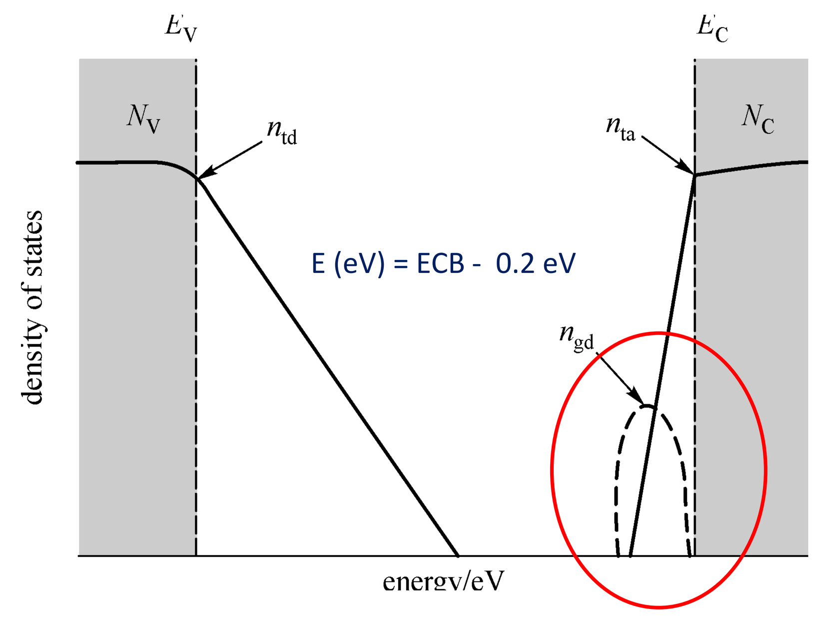
Material properties

Varying the density of states in the IGZO band-gap: simulations with increasing shallow donor-like states show the appearance of a "hump"-like behaviour in the transfer characteristics, as seen after PGBS in fabricated devices.

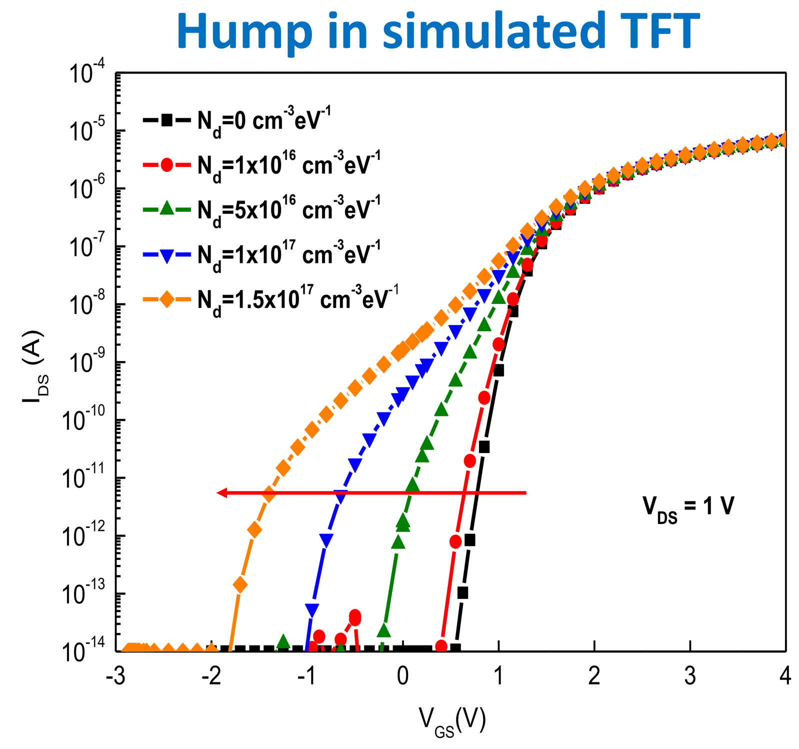
Fabricated TFT



DOS in simulation



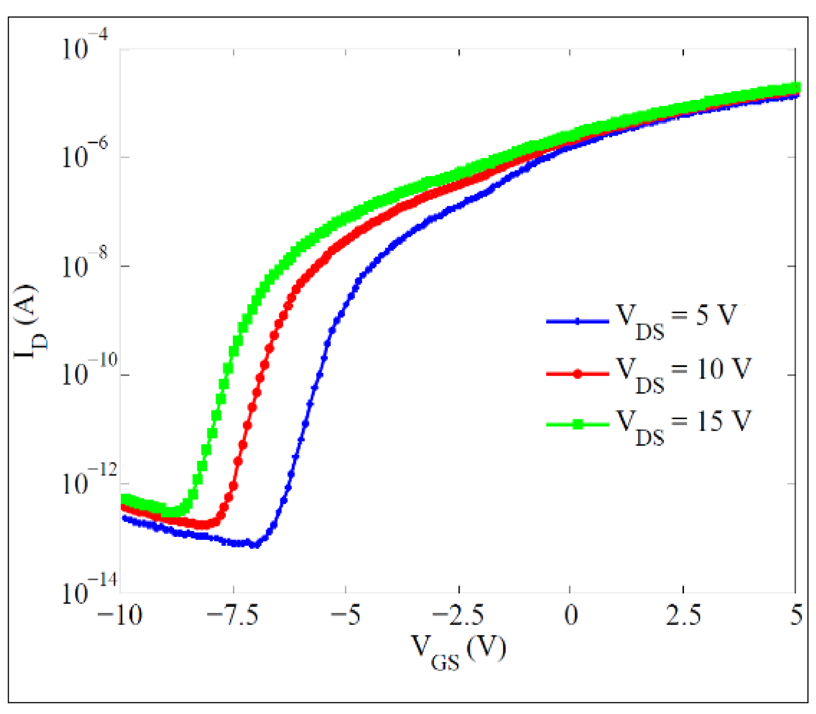
Hump in simulated TFT



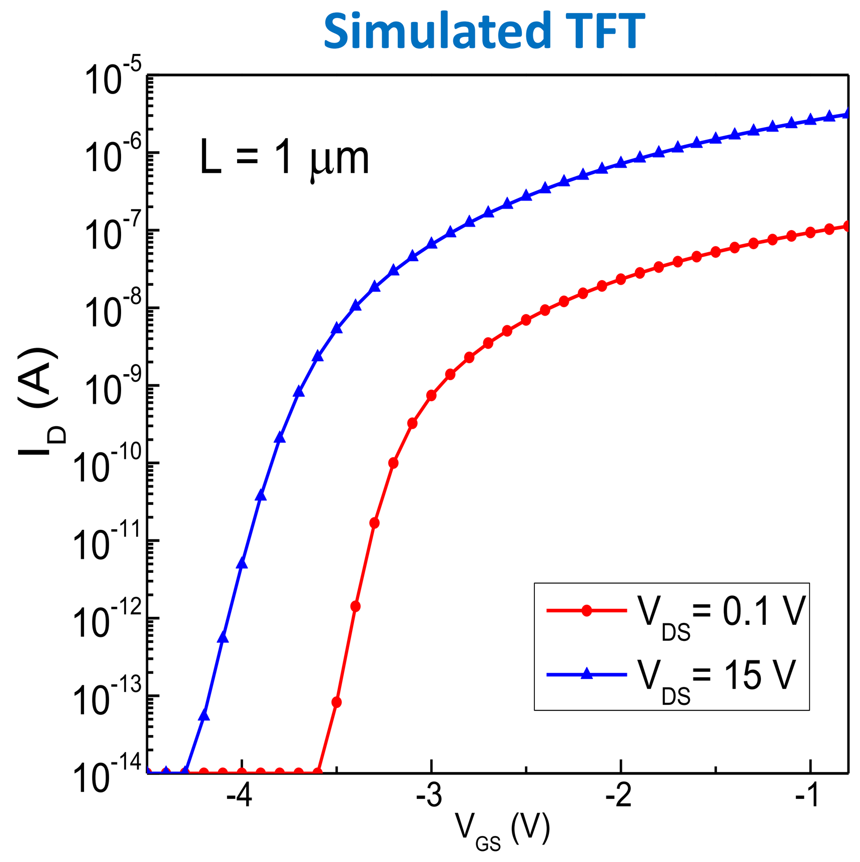
Device architecture

With the scaling down of the TFT dimensions, short-channel effects can be observed in both fabricated and simulated TFTs (lower V_{Th} for higher V_{DS} due to DIBL).

Fabricated TFT

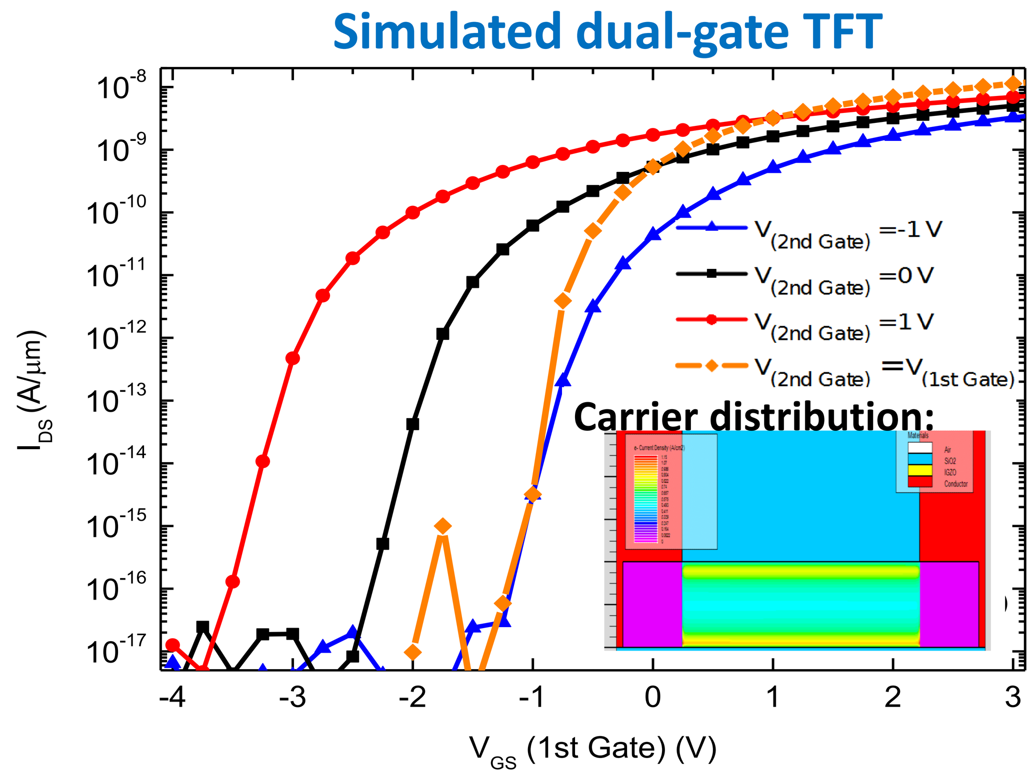


Simulated TFT



Simulation of a dual-gate TFT showing the effect of different biasing conditions for the second-gate.

Simulated dual-gate TFT



References

[1] H. Hsieh, T. Kamiya, K. Nomura, H. Hosono and C. Wu, Appl. Phys. Lett. 92, 133503 (2008).

[2] J. Martins, P. Barquinha, and J. Goes, "TCAD Simulation of Amorphous Indium-Gallium-Zinc Oxide Thin-Film Transistors," in *Proceedings of 7th IFIP WG 5.5/SOCOLNET, DoCEIS 2016,* Springer International Publishing, 551-557 (2016).

Conclusions

- TCAD tools can help in oxide TFT technology improvement.
- "Hump" might be related to donor-state creation.
- IGZO-TFTs showed Short Channel Effects for few μm L.
- Dual-gate TFTs – V_{th} modulation and improve TFT performance.

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