Measuring Material Diffusion And Performance Changes in Semiconductor Diodes

Daniel Abreu, Electrical Engineering

Mentor: Nicholas Rolston, Assistant Professor

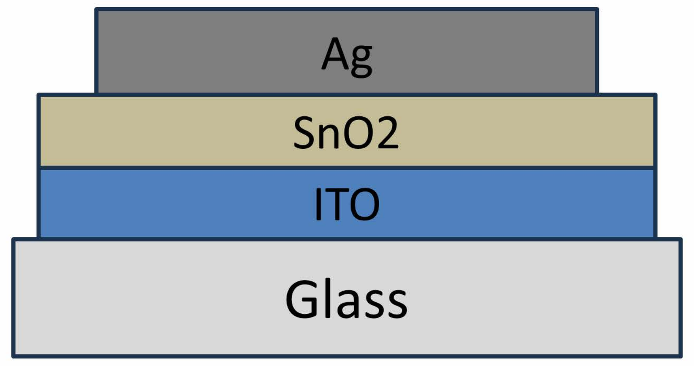
School of Electrical, Computer and Energy Engineering

Research question: How do defects (intentional dopants and unintentional materials) and metal diffusion change in semiconductor materials when heated, and to what effect do they have on the performance/reliability of semiconductor devices, such as diodes?

Sample Prep and Testing:

- SnO_2 was coated on slides of ITO via spin coater
- Samples were annealed at 300 Celsius at various time durations to test aging

Beginning Sample Cross Section

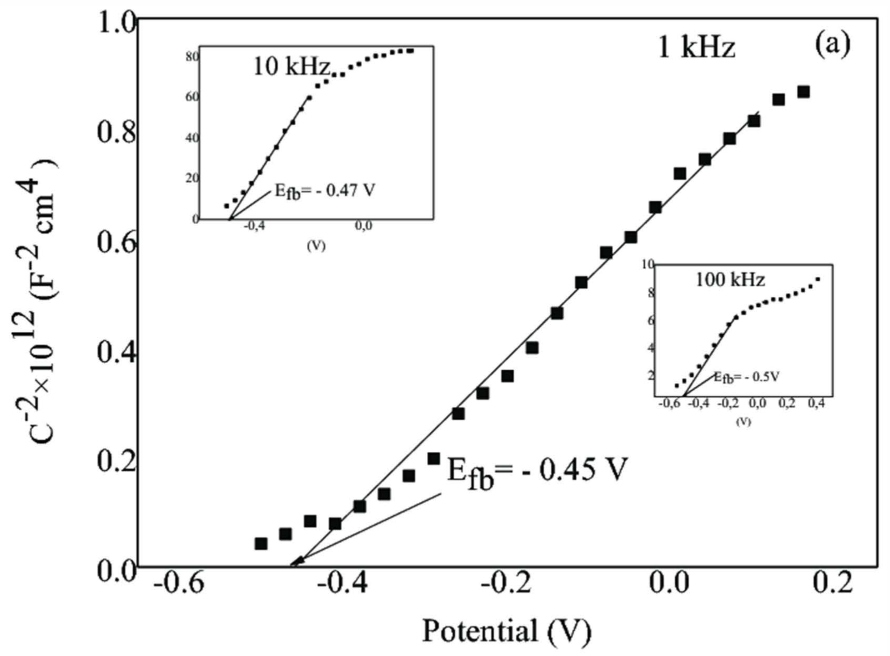


Mott-Schottky Equation:

A = 50nm

$\varepsilon = 10\,\varepsilon_0$

$$C^{-2} = \frac{2}{qA^2 \varepsilon N_D}(V + V_{\mathrm{bi}})$$

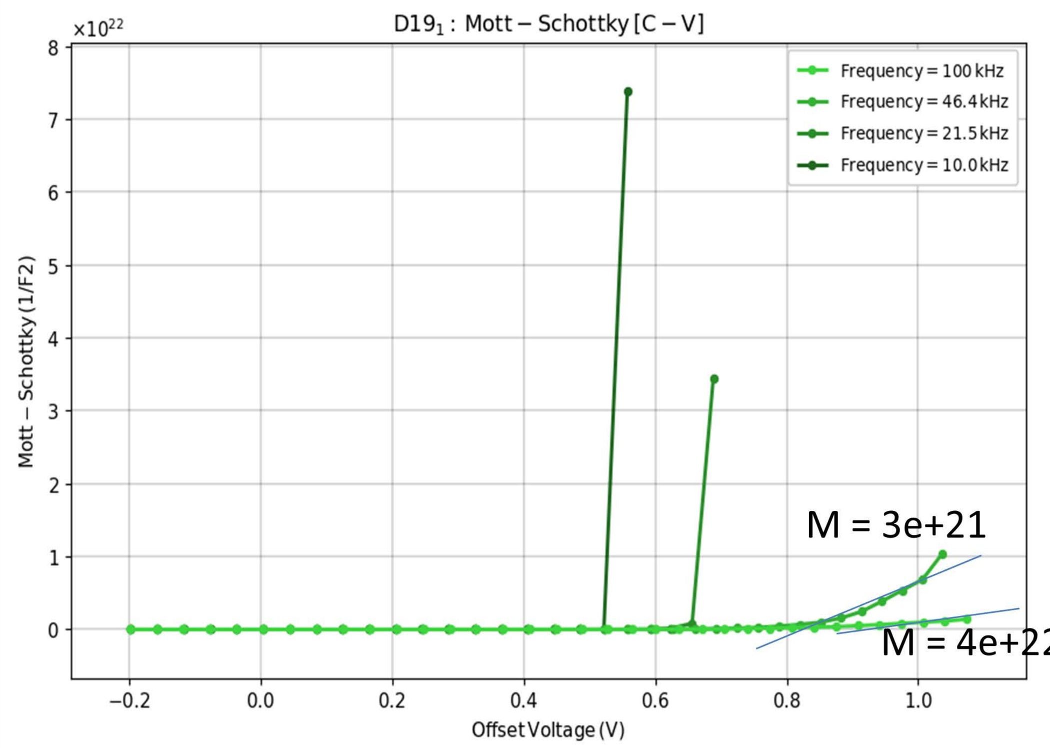


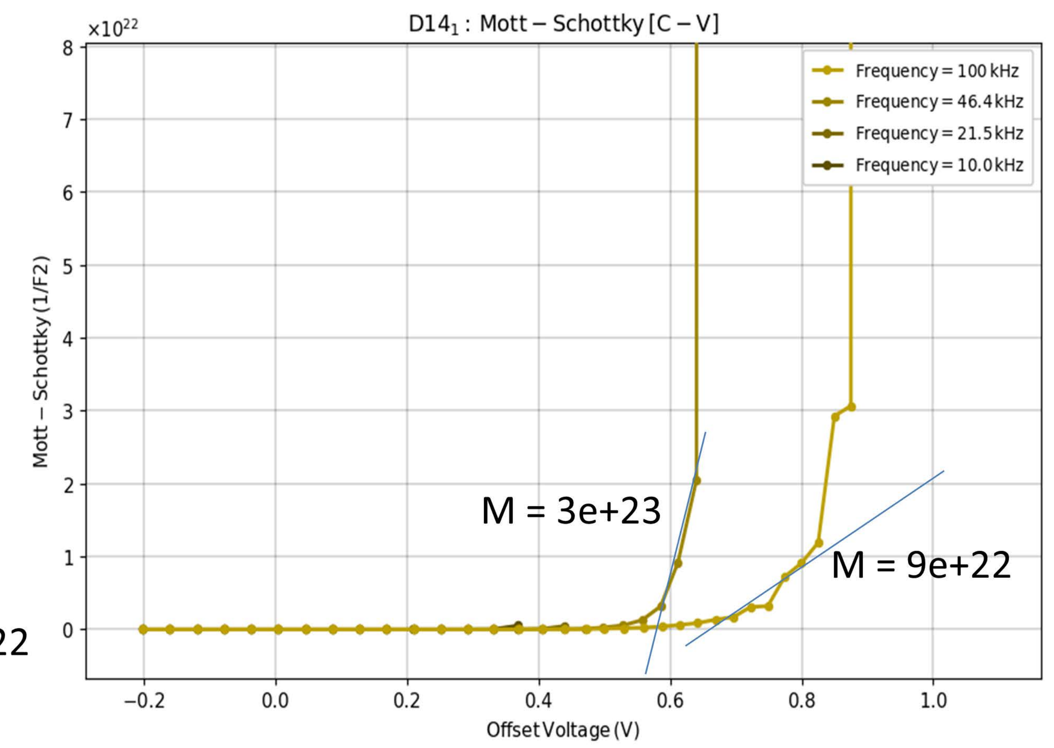
Example of what a more ideal Mott-Schottky graph should look like (left). Future experiments will aim to create a more linear fitting region where donor density can be more accurately taken.

Introduction: The purpose of this research is to find a correlation between aging semiconductor diodes, the before and after performance, and the metal distribution through the diode. The purpose is to find a new way to characterize semiconductor materials and degradation.

Sample Results: Both graphs are Mott-Schottky graphs taken via post processing of c-v measurements. Mott-Schottky is essential because the slope can be used to estimate donor density via the equation.

Sample annealed at 300 C for 1 minute (left graph)





Sample annealed at 300 C for 60 minutes (Right graph)

Donor Density (#/cm³): Anneal Time 1min.	Donor Density (#/cm³): Anneal Time 60 mins.
@100kHz: N_D = 1.88e+22	@100kHz: N_D = 6.27e+20
@46.4 kHz: N_D = 1.41e+21	@46.4kHz: N_D = 1.88e+20

Conclusion: Despite the fact that the Mott-Schottky graphs weren't as linear as originally hoped, the slopes obtained show a significant change in the diffusion of the material. The data shows that when comparing respective frequencies, donor density changes throughout the material and even reduces in the sample. Further research shows that, in higher concentrations of Indium, as seen in this experiment, the device will be p-type as opposed to n-type, which explains the reduction in donor density. For the future, improving the sample prep will help find a more accurate relation, and see if results, or relationships found, are repeatable. The data gathered so far point to diffusion of materials increasing as aging increases.

Next Steps:

- Improve sample prep procedures as to improve the consistency of results
  - Hopefully obtain more linear graphs for Mott-Schottky
- Experiment with different ways of aging/producing samples
- Test other semiconductor materials
- Model Distribution using GD-OES (Glow Discharge – Optical Emission Spectrometer)

References:

- Image: Kaizra, Salima & Bellal, B. & Louafi, Yamina & Trari, M.. (2017). Improved activity of SnO for the photocatalytic oxygen evolution. Journal of Saudi Chemical Society. 22. 10.1016/j.jscs.2017.07.005.
- Equation(s): Wikipedia contributors. (2023, June 5). Mott–Schottky plot. In Wikipedia, The Free Encyclopedia. Retrieved 05:11, April 11, 2024, from https://en.wikipedia.org/w/index.php?title=Mott%E2%80%93Schottky_plot&oldid=1158721088

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Ira A. Fulton Schools of Engineering, Arizona State University