Fabrication of Nanoscale Columnar Diodes by Glancing Angle Deposition

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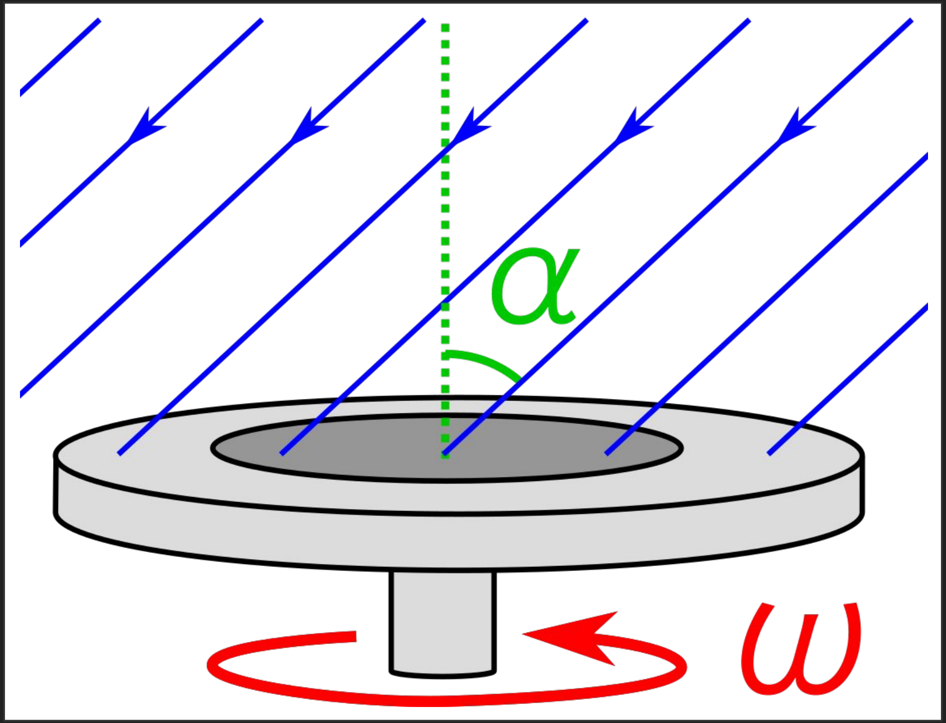
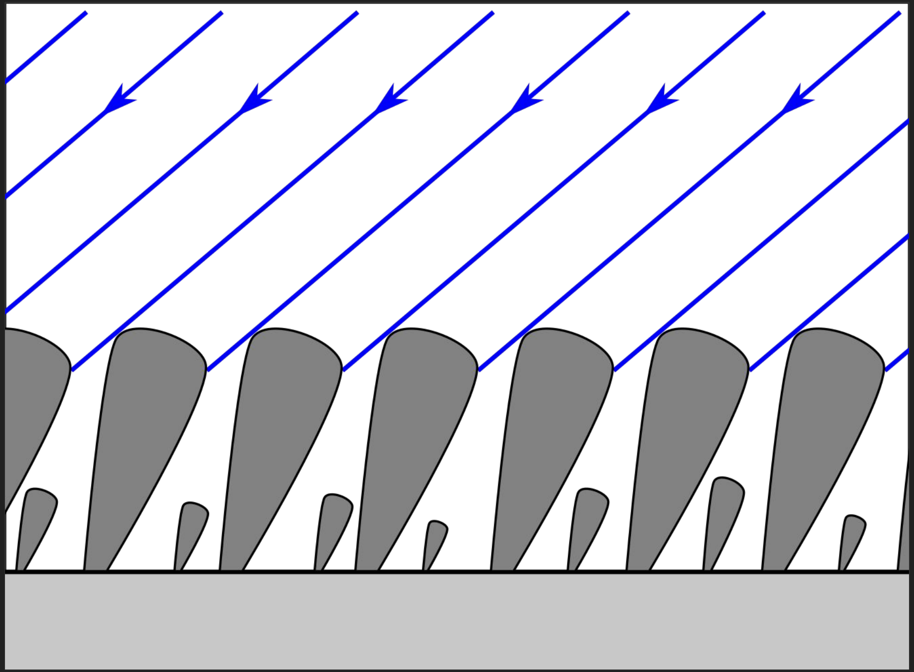
What is Glancing Angle Deposition (GLAD)?



- Vapor mean free path > target-substrate separation
- Vapor obliquely incident on substrate
- Substrate rotation precisely controlled

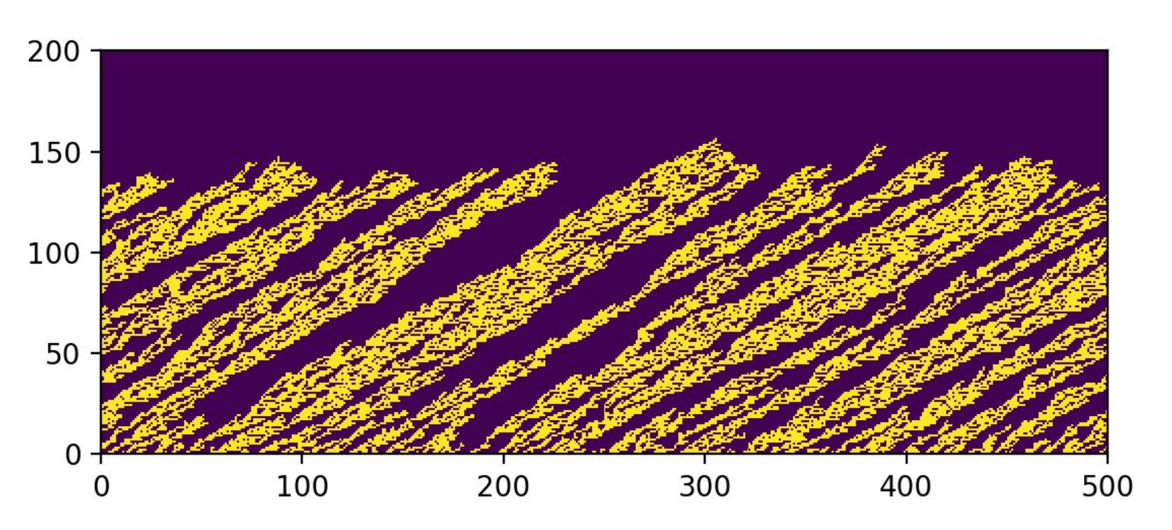
Why would we do that?

- Vapor follows “line of sight”
- Surface features “cast shadows”
- “Shadowed” areas stop growing
- Competitive growth!

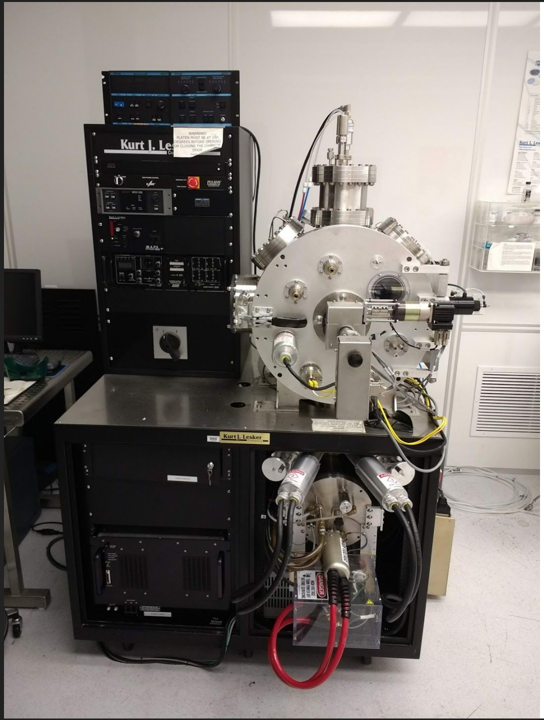


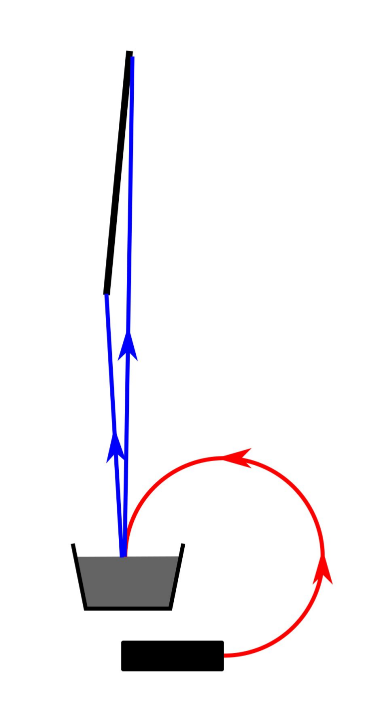
A simple model of GLAD

- Vapor incident at angle α
- Where it hits, it sticks
- Periodic boundary conditions
- Tilted columns!



Let’s get GLAD

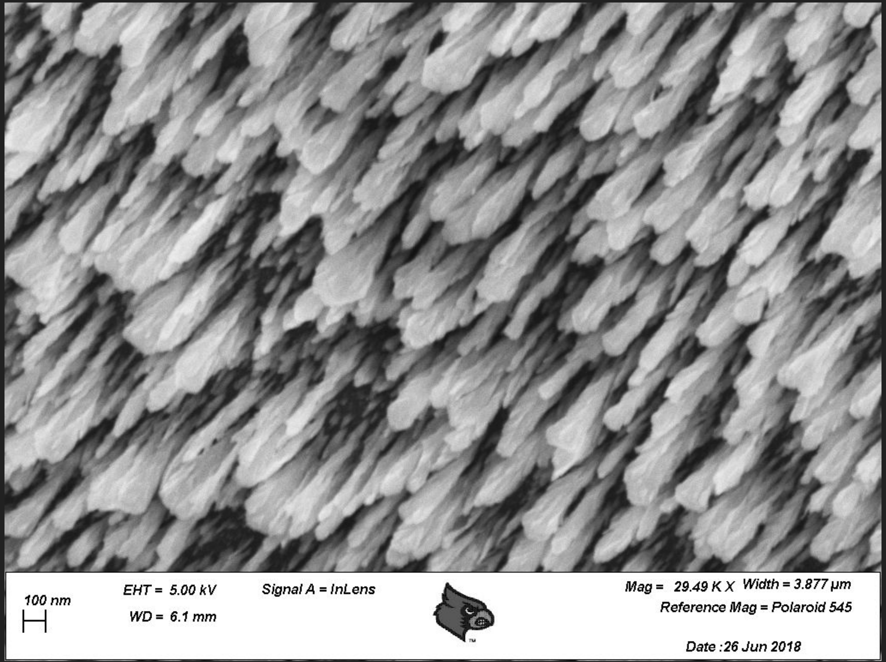


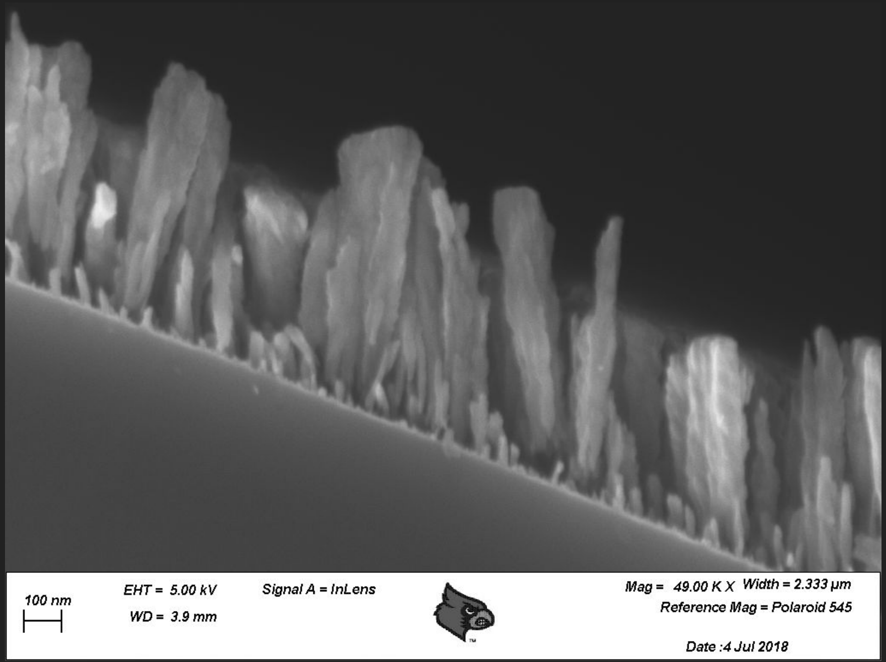


- We use ebeam
- MFP > target substrate separation
- Controllable α and ω

Some real GLAD films

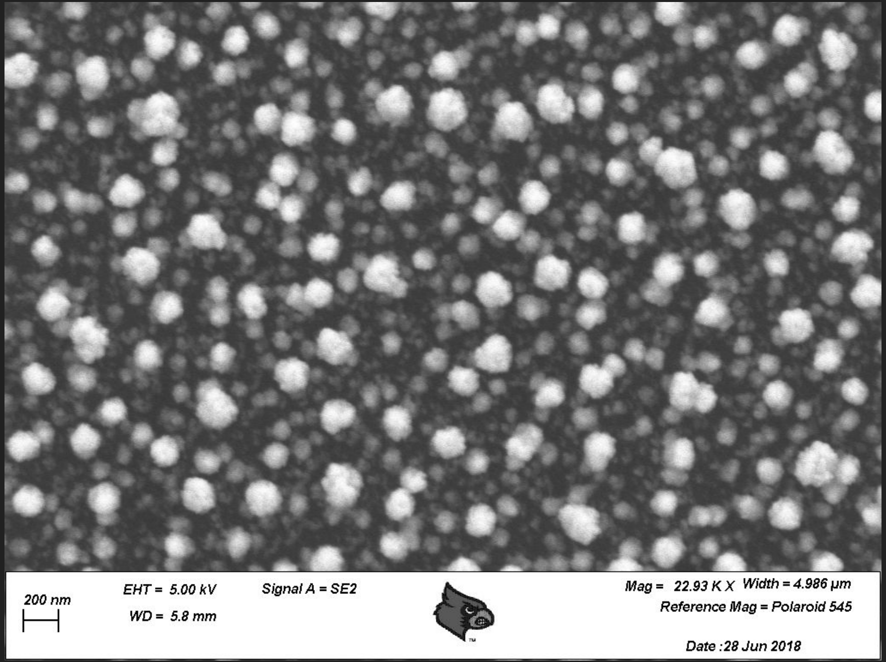
α = 84º, ω = 0 RPM, dep time = 30 minutes, rotations = 0 rev

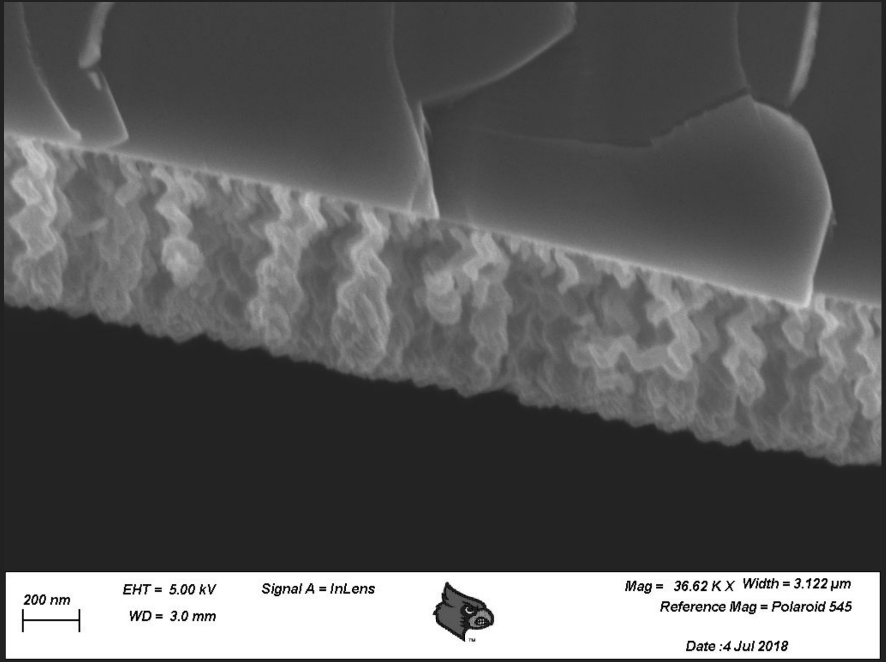




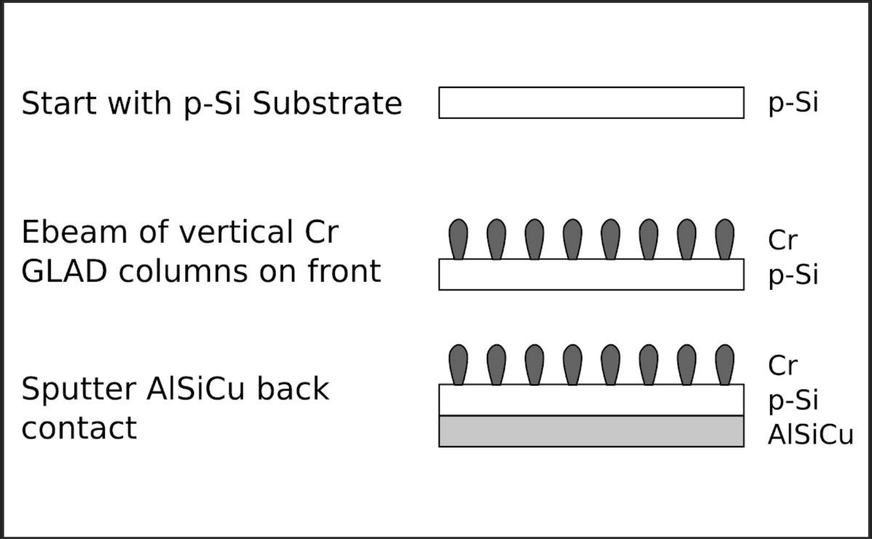
Some (more) real GLAD films

α = 84º, ω = 0.1 RPM, dep time = 40 minutes, rotations = 4 rev





What’s the simplest device we could possibly make?

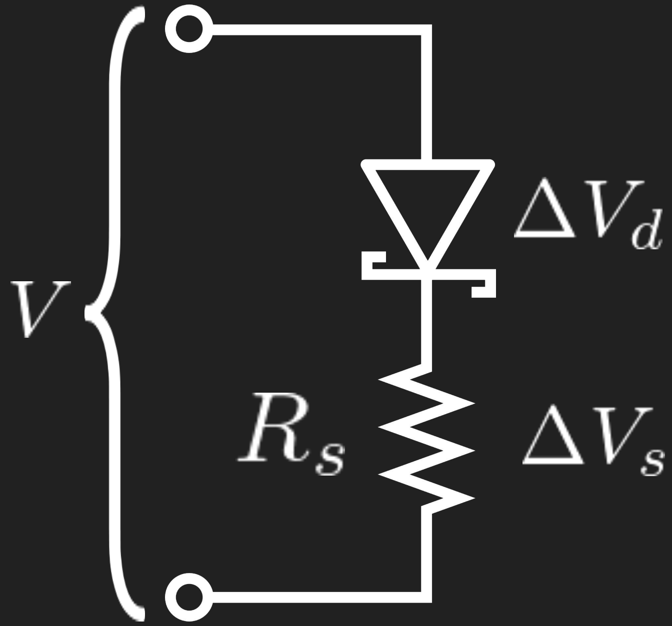


- Schottky Diodes!
  - Metal/Semiconductor junction

$$I = I_s \left(e^{\frac{V}{\eta V_T}} - 1 \right)$$

- Just add a back contact!

Modeling the device:

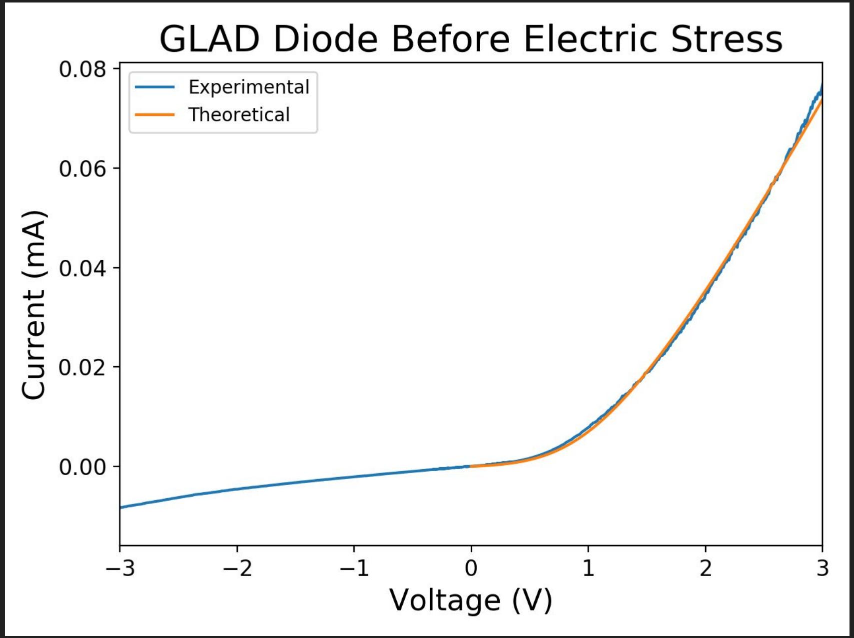


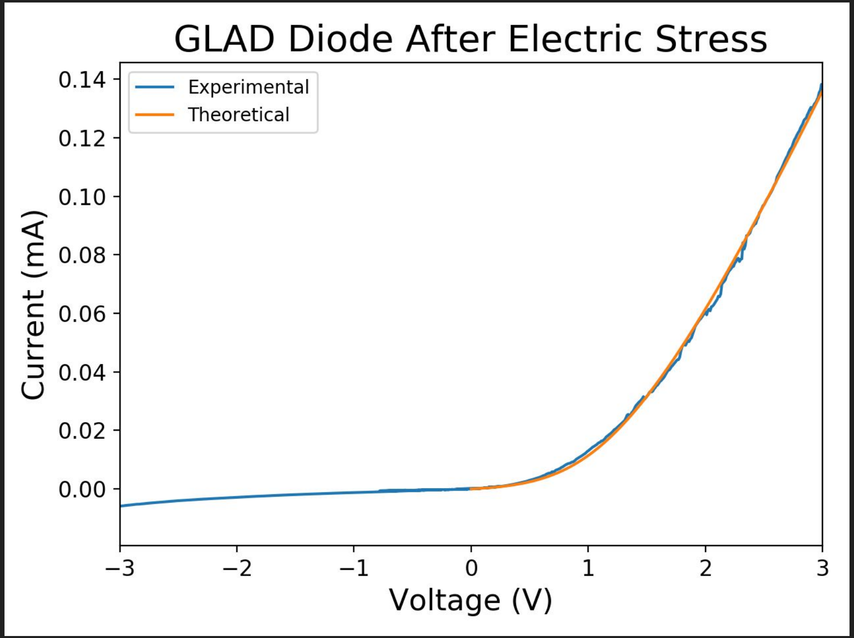
Model diode in forward bias using Shockley diode equation with ideality factor:

$$I = I_s \left(e^{\frac{\Delta V_d}{\eta V_T}} - 1 \right)$$

I(V) can only be expressed implicitly, so we solve it numerically.

I-V Characteristics and Curve Fits (GLAD diode)



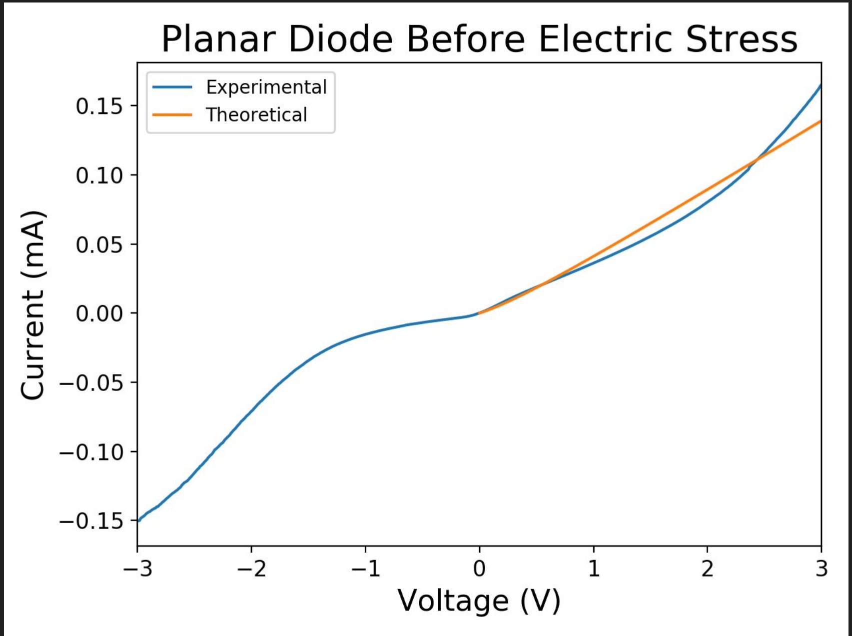


I_s=2.4×10^{-7} A, η=9.65, R_s=21200 Ω

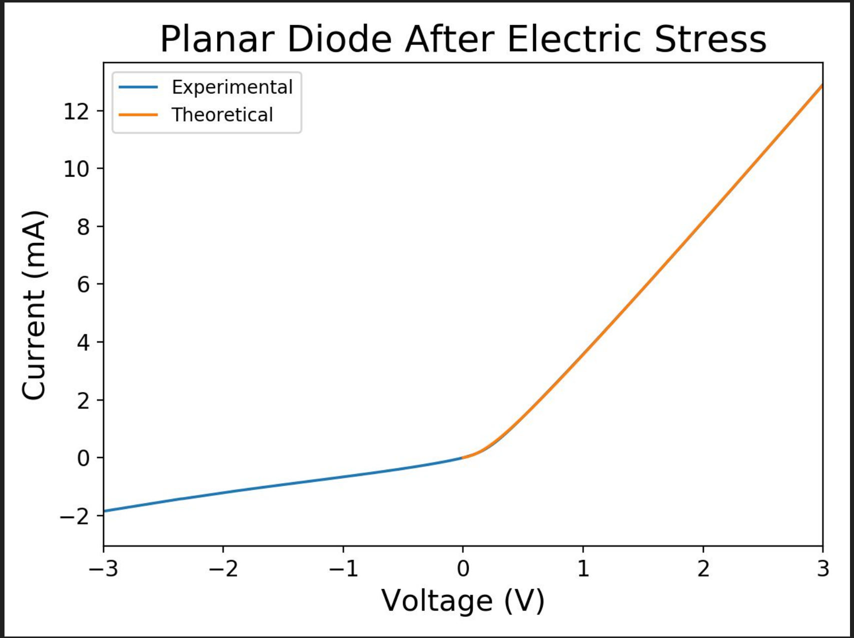
I_s=1.8×10^{-7} A, η=8.6, R_s=11300 Ω

Electrical stress: -75V to 75V at 60 Hz

I-V Characteristics and Curve Fits (planar diode)



I_s=5.0×10^{-7} A, η=3.6, R_s=19300 Ω



I_s=6.1×10^{-6} A, η=2.53, R_s=206 Ω

Electrical stress: -75V to 75V at 60 Hz

Conclusions

- We successfully made GLAD diodes!
- Ideality factors were higher (bad)
- Series resistances were higher (bad)
- Difficult to interpret difference in currents
- Electrical stress had smaller effect on GLAD diodes
- GLAD diodes better fit the model before electrical stress