

Formation of ZnTe:Cu/Ti Contacts at High Temperature for CdS/CdTe Devices

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Acknowledgements
Alan Fahrenbruch (ALF)

Research supported by United States Department of Energy -
Contract No. DE-AC36-99GO10337

NREL/PR-520-39845

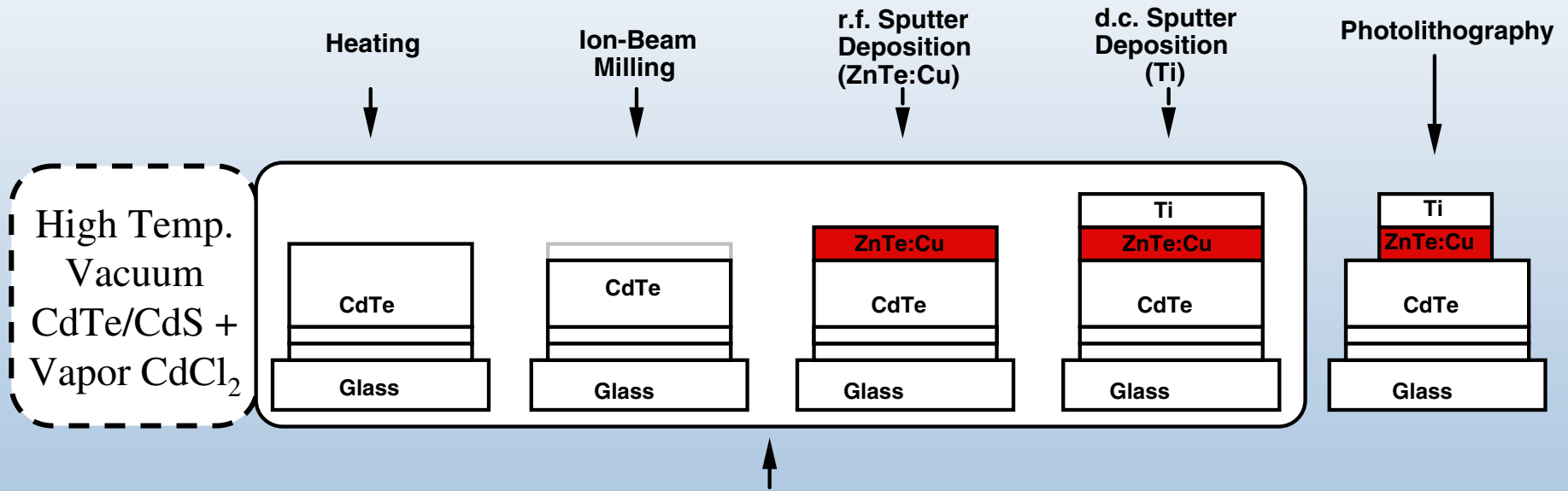
Presented at the 2006 IEEE 4th World Conference on Photovoltaic Energy Conversion (WCPEC-4) held May 7-12, 2006 in Waikoloa, Hawaii.

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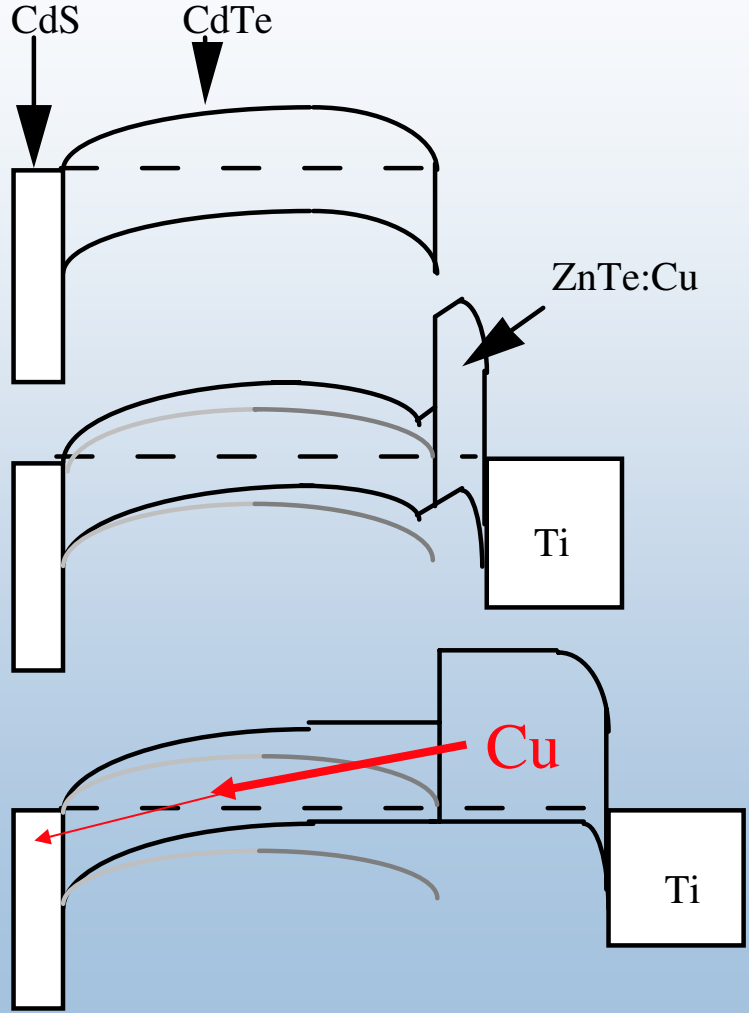
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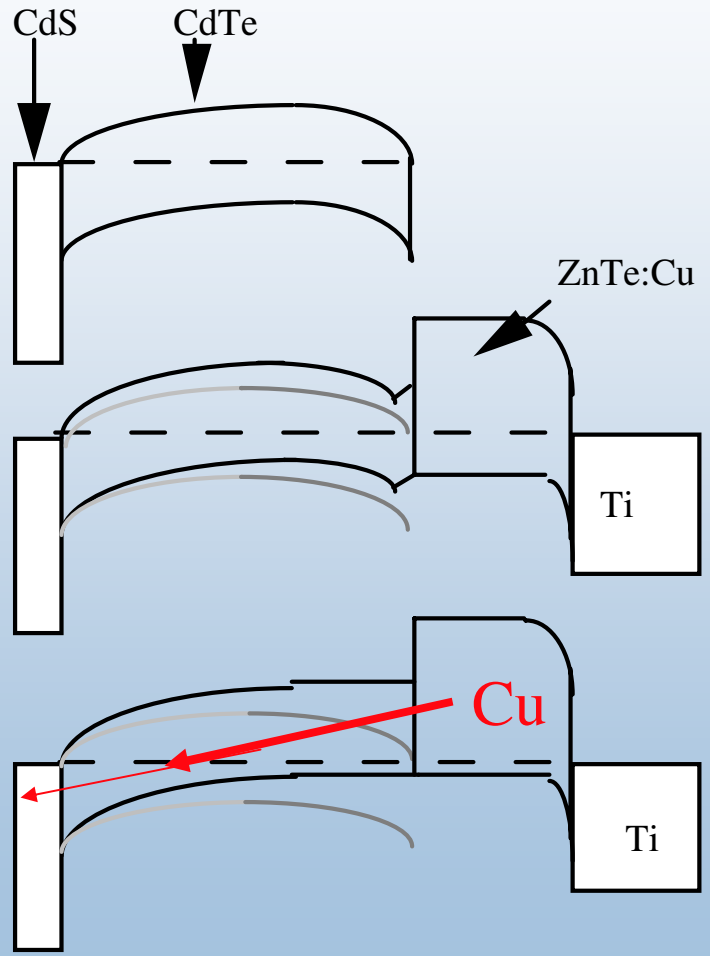
ZnTe:Cu/Ti Contact Process (All-Dry, High-Temperature [300°C])



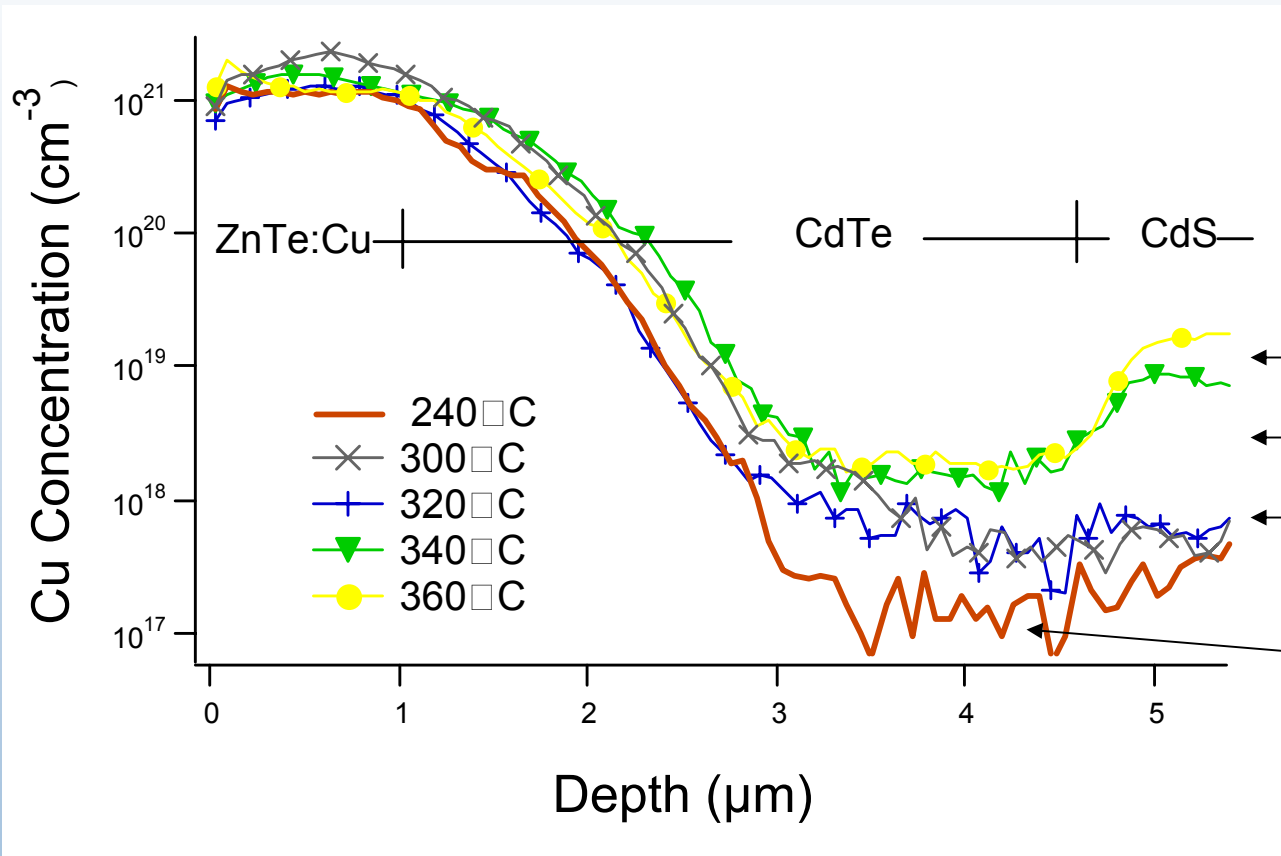
Constant Temperature $\sim 300^{\circ}\text{C}$
Vary ZnTe:Cu Thickness



Constant Thickness $\sim 0.5 \mu\text{m}$
Vary ZnTe:Cu Temperature



SIMS Analysis of Temperature Dependence



← Too Much Cu?

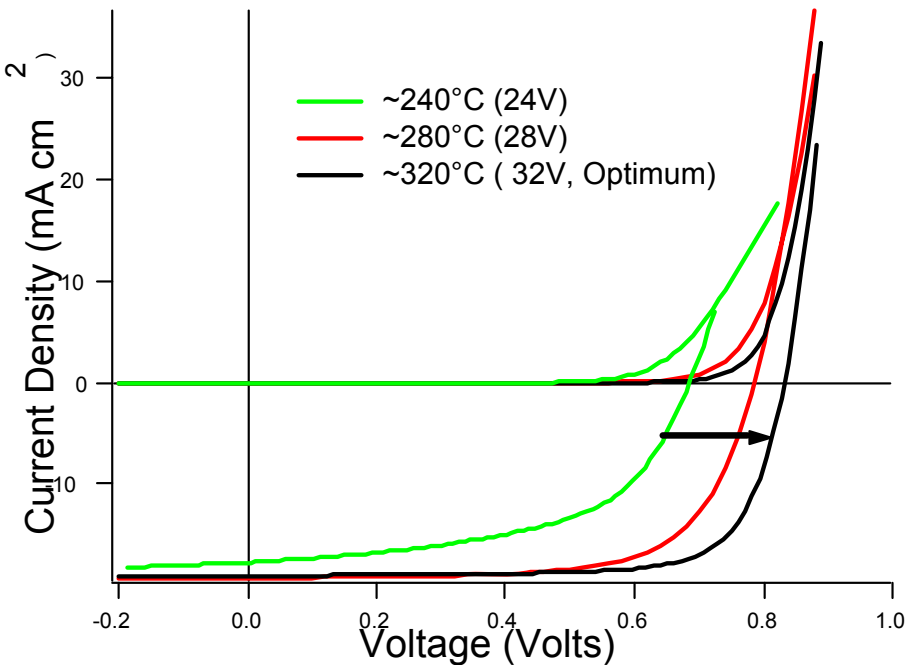
← ??

← Just Right Cu?

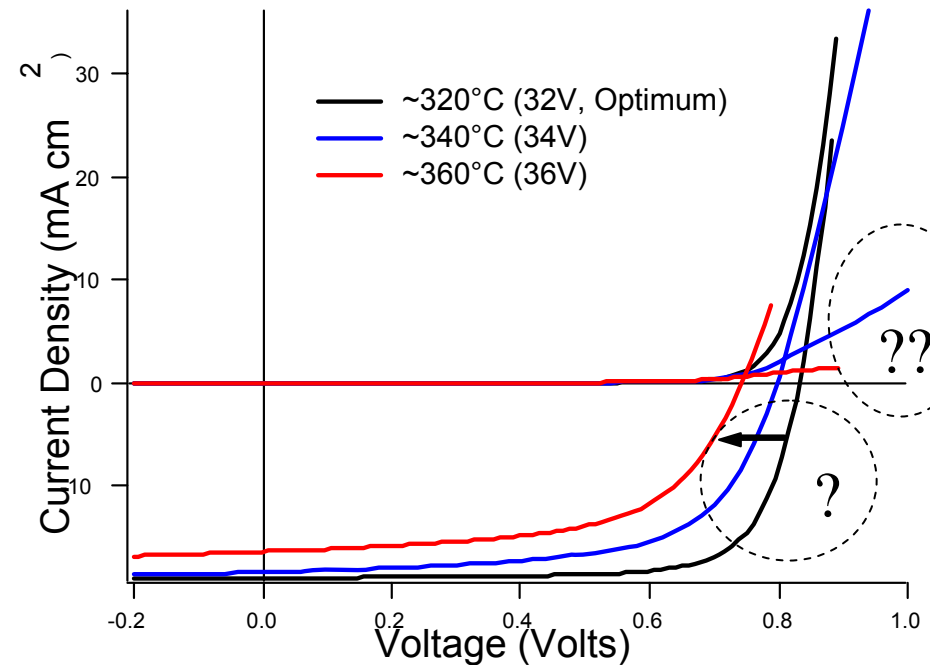
← Too Little Cu?

Insight from Temperature Dependent Studies (ZnTe:Cu Contact Temperature)

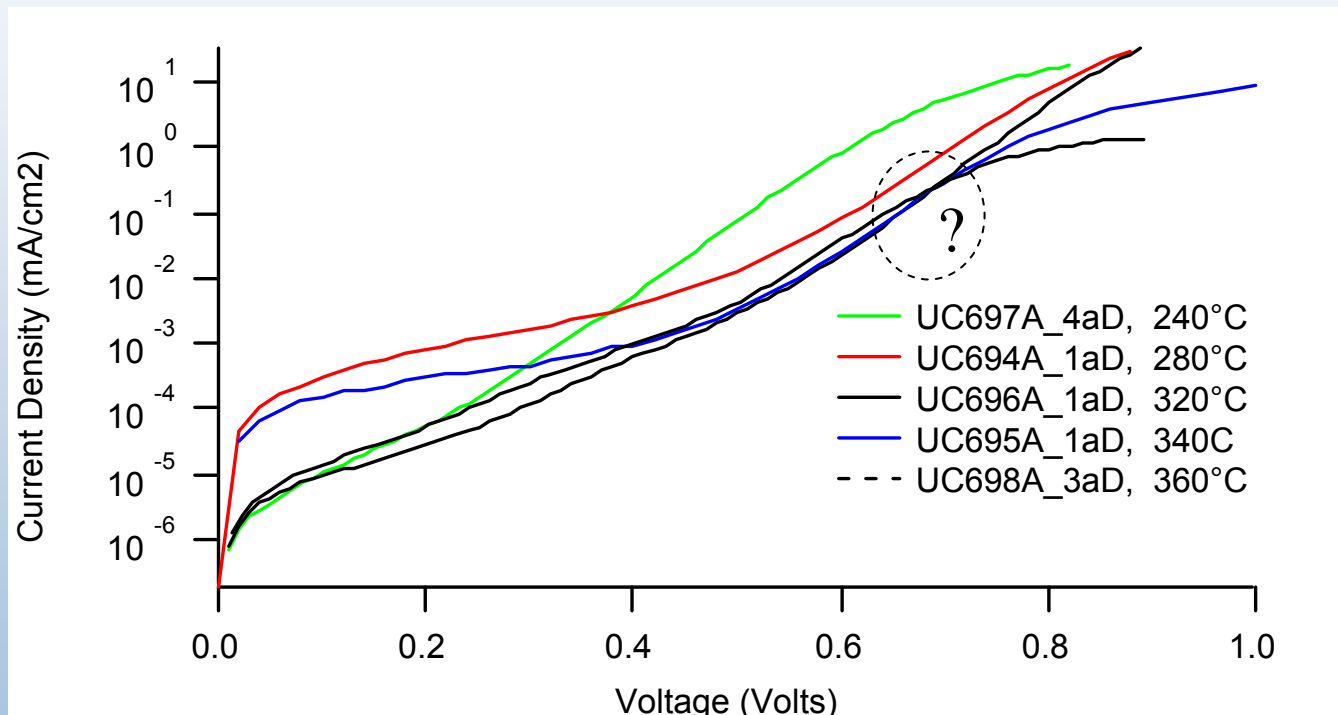
Cu Diffusion Less Than Optimum

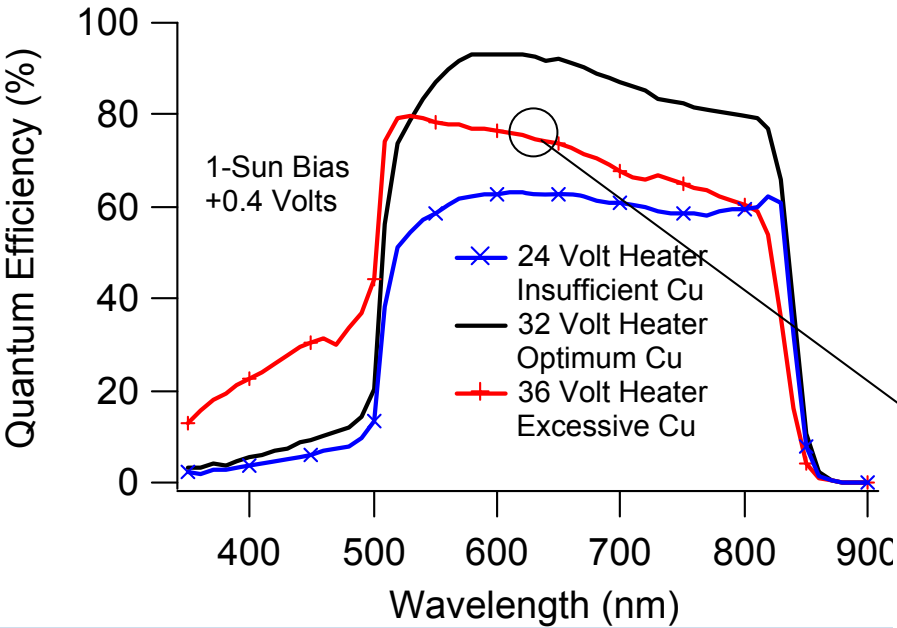


Cu Diffusion Greater Than Optimum



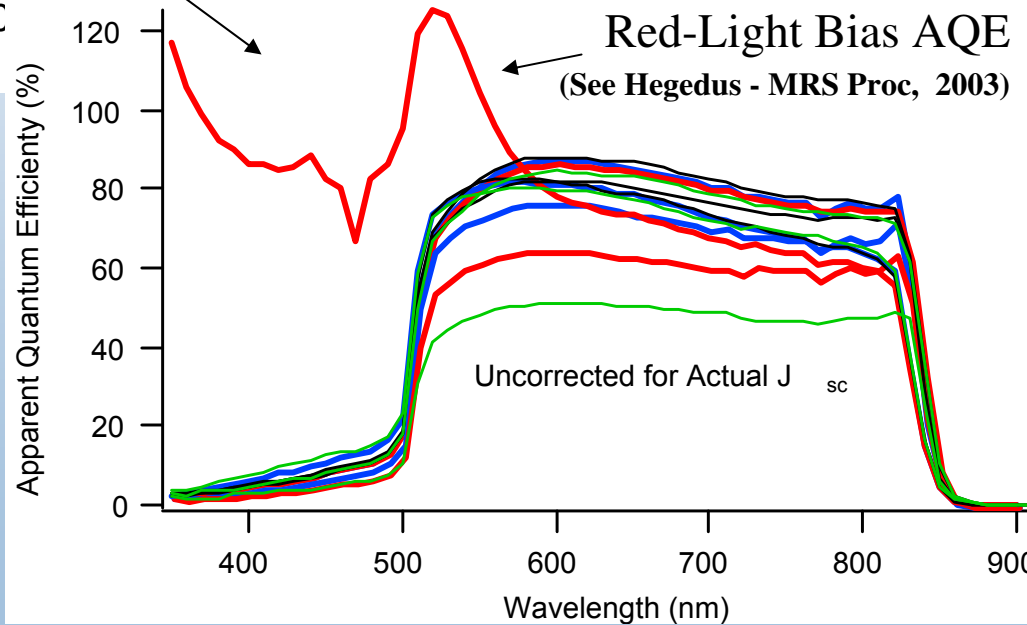
Dark IV Analysis of Temperature Dependence (Low J_0 and Increase in R_s at Higher Contact Temperature)





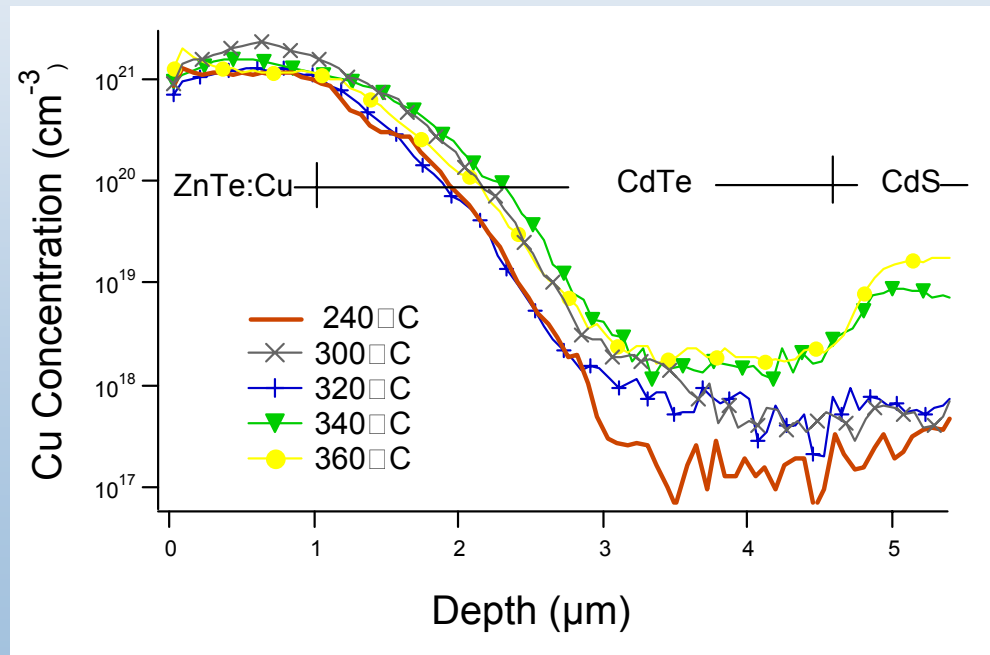
Red-Light Bias QE Confirms
Photoconductive CdS
For Excessive Cu Devices

QE Comparison Suggests
Narrow Junction
for Excessive Cu Devices



Some Resulting Questions

- Is Cu diffusion from the contact always “good” in CdTe and always “bad” in CdS?
- Is there a maximum Cu concentrations that can be tolerated?
- If Cu in the CdS can be minimized, does the V_{oc} increase?
- Can the Cu diffusion from contact be *controlled advantageously*

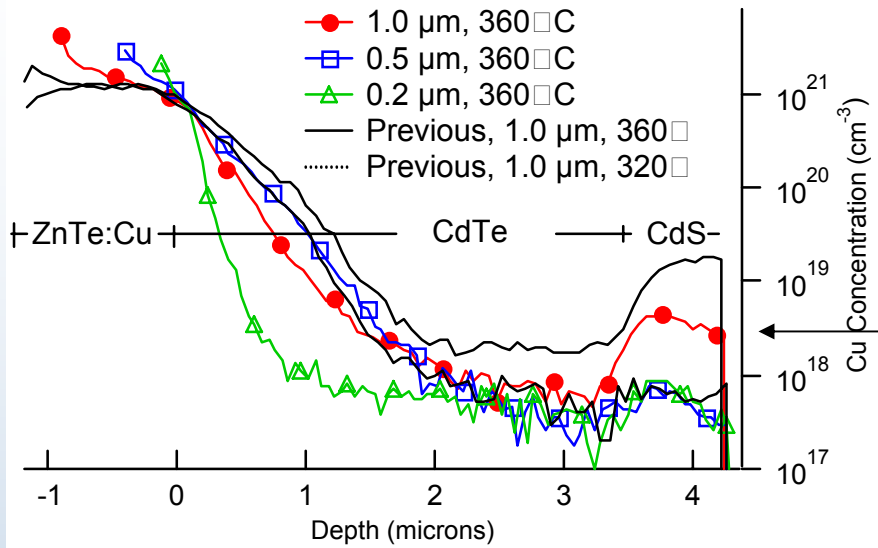


ZnTe:Cu Contact Parameters - This Study

- Ion Beam Mill Depth 1000 Å
- Cu Concentration in ZnTe 9 atomic percent
- ZnTe:Cu Thickness (0.5 μm ~Optimum)
 - Vary: 0.04-1.0 μm
- ZnTe:Cu Deposition Temperature (300°C ~Optimum)
 - Increase: 360°C (Too High!)
- Outer Metallization Ti, 0.5 μm, 185°C

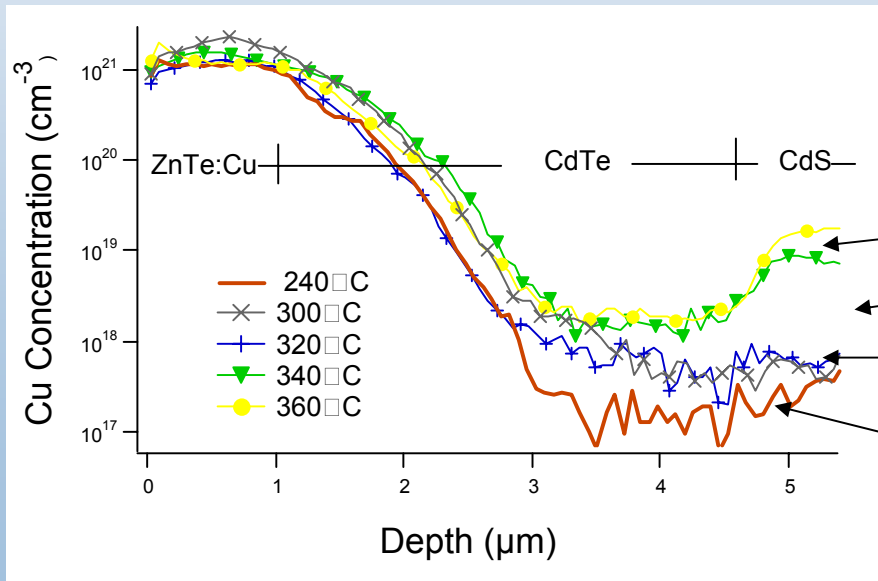
Device Performance ([This Study](#), VTD Production Material)

- V_{oc} ~800 mV
- J_{sc} ~19 mA/cm²
- FF ~71%
- Efficiency ~11%



This Study
 Maximum Cu
 Midway Between
 Past Studies

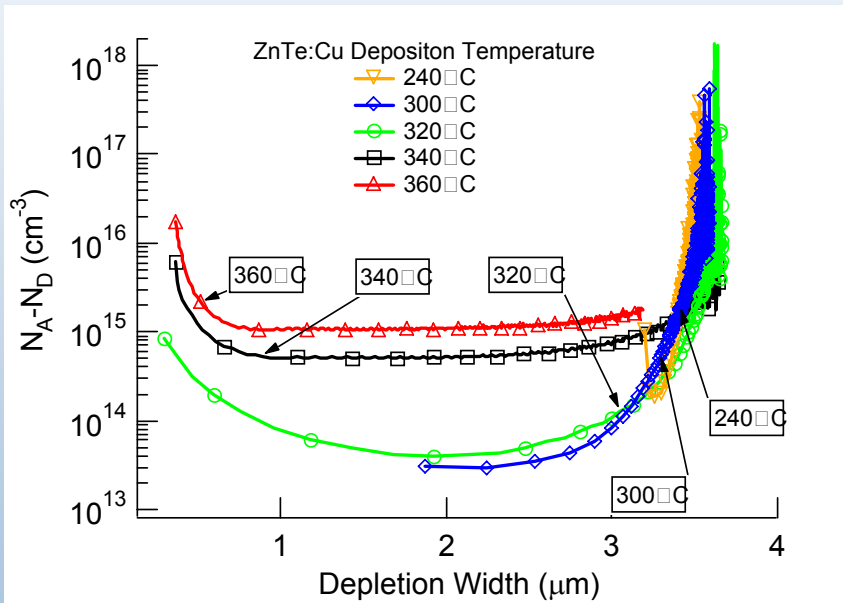
Key Result:
 Extent of Cu Diffusion
 Limited by
 ZnTe:Cu Thickness
 at High Contact
 Temperature



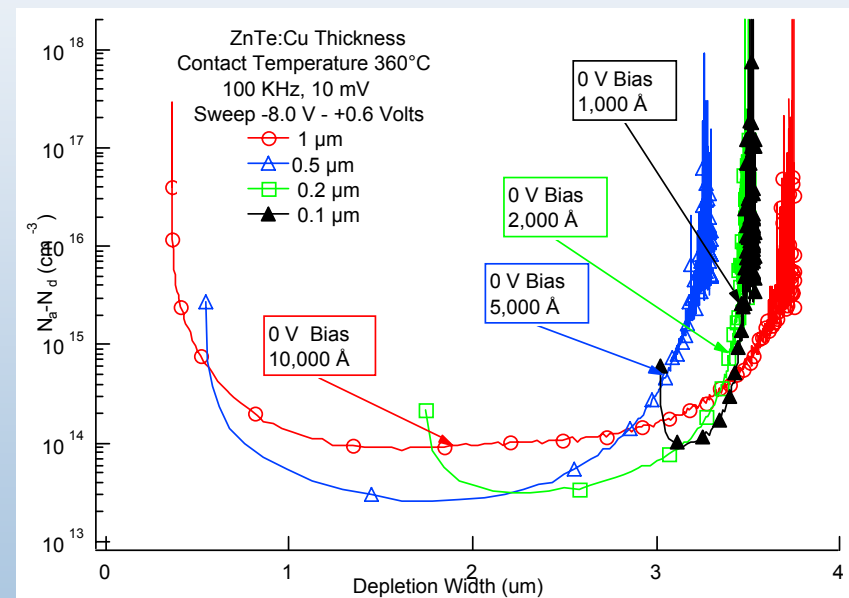
Previous Studies
 Too Much Cu?
 ??
 Just Right Cu?
 Too Little Cu?

Comparison of Previous and Present C-V Analysis

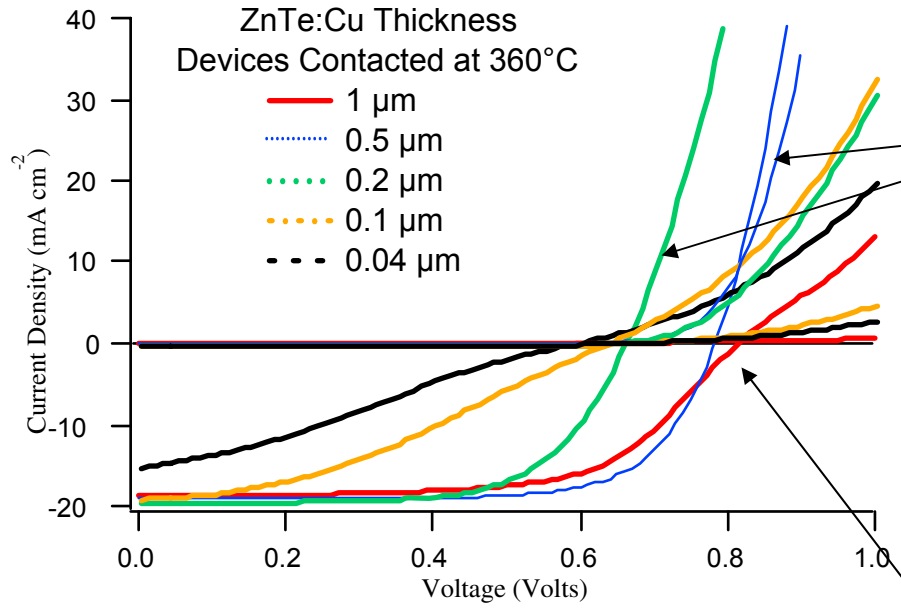
Previous Data - Contact Temperature



New Study - ZnTe:Cu Thickness

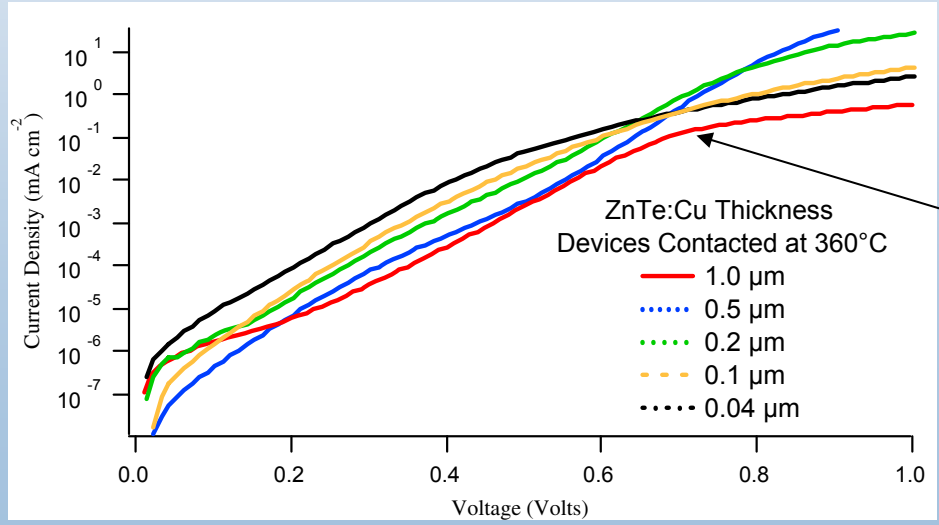


(100 kHz, 10 mV, -8.0 to +0.6 Sweep)



0.2 μm ZnTe:Cu Insufficient
- Even at 360°C

Key Result:
High Contact Temperature
Cannot Compensate for
Insufficient Cu from Contact

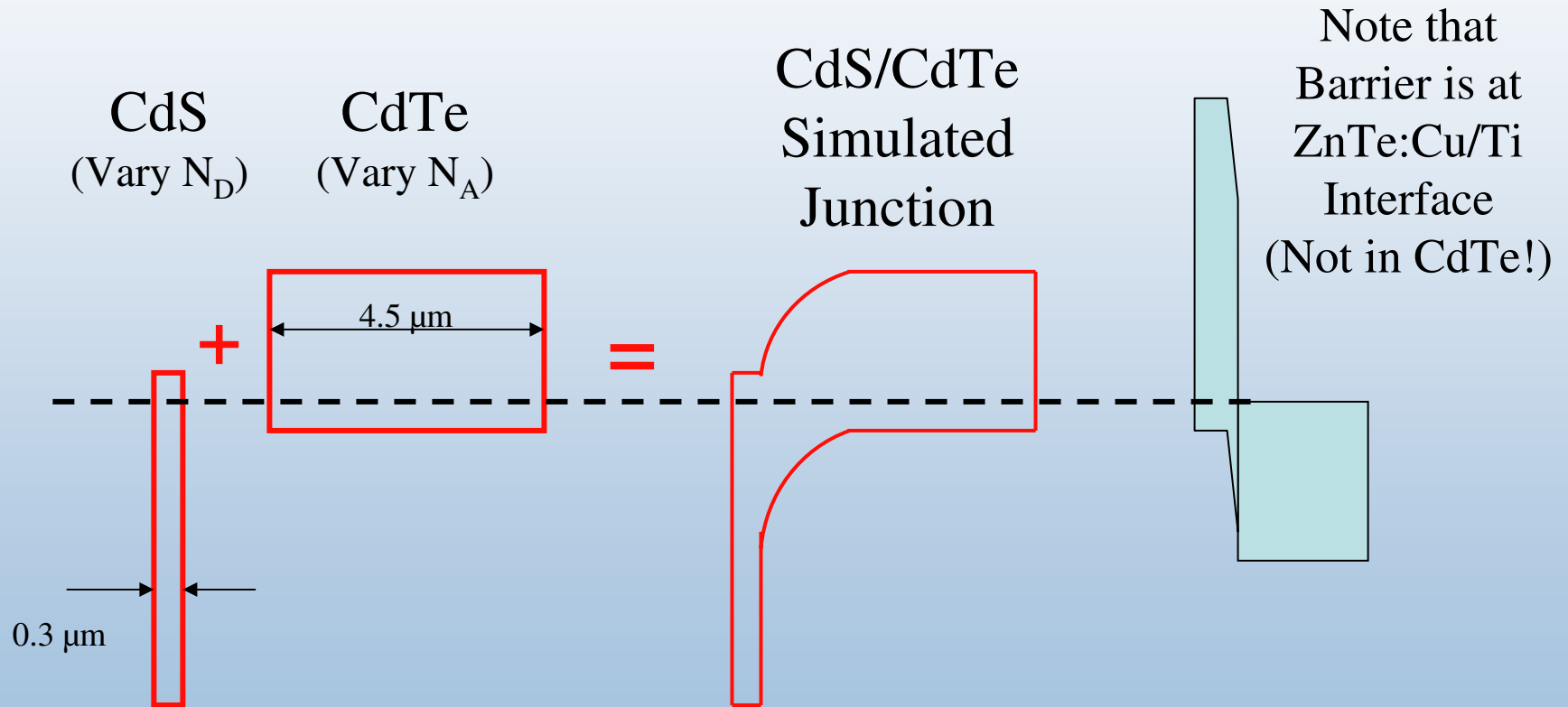


Unlike Previous Study
 V_{oc} Increases to
1 μm ZnTe:Cu

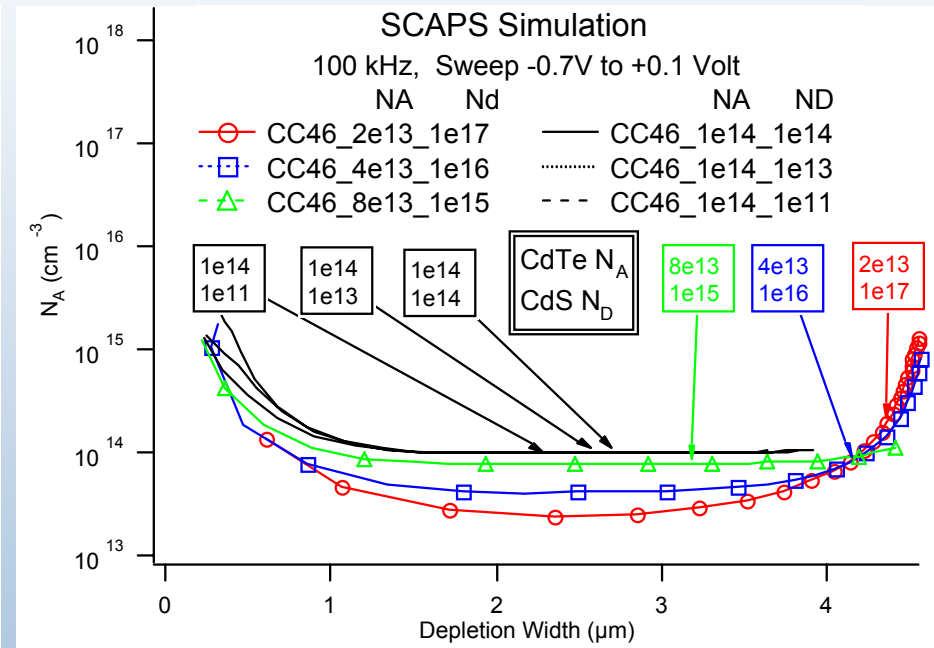
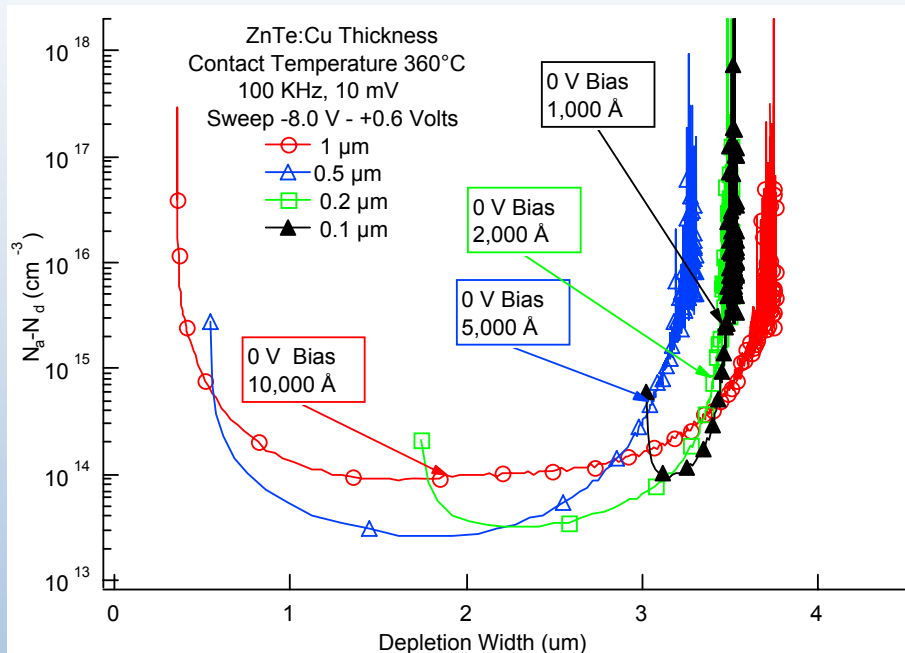
But still high apparent R_s

SCAPS-1D Simulation Model Device

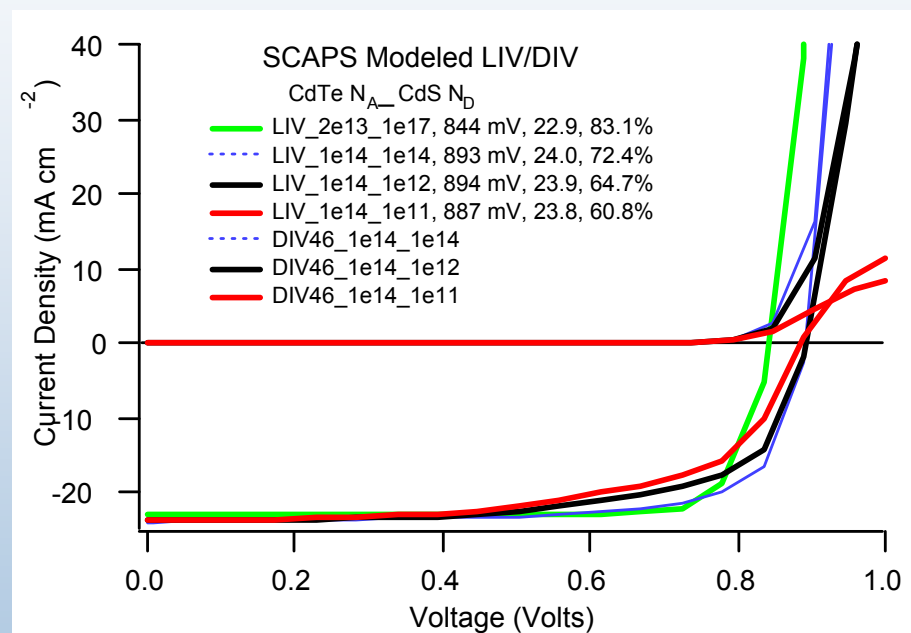
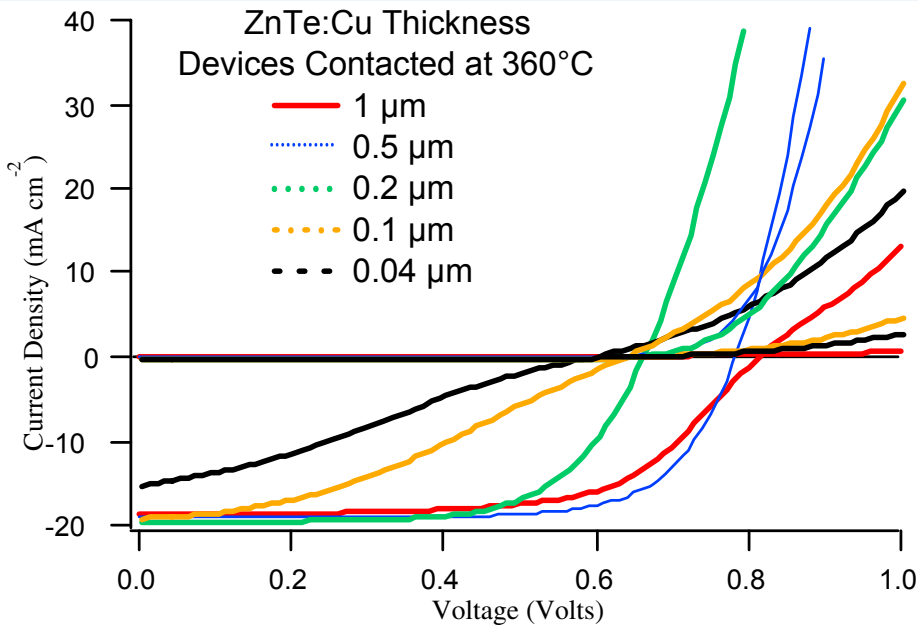
(Vary Shallow CdS N_D and CdTe N_A Only - No Deep Defect Considered)



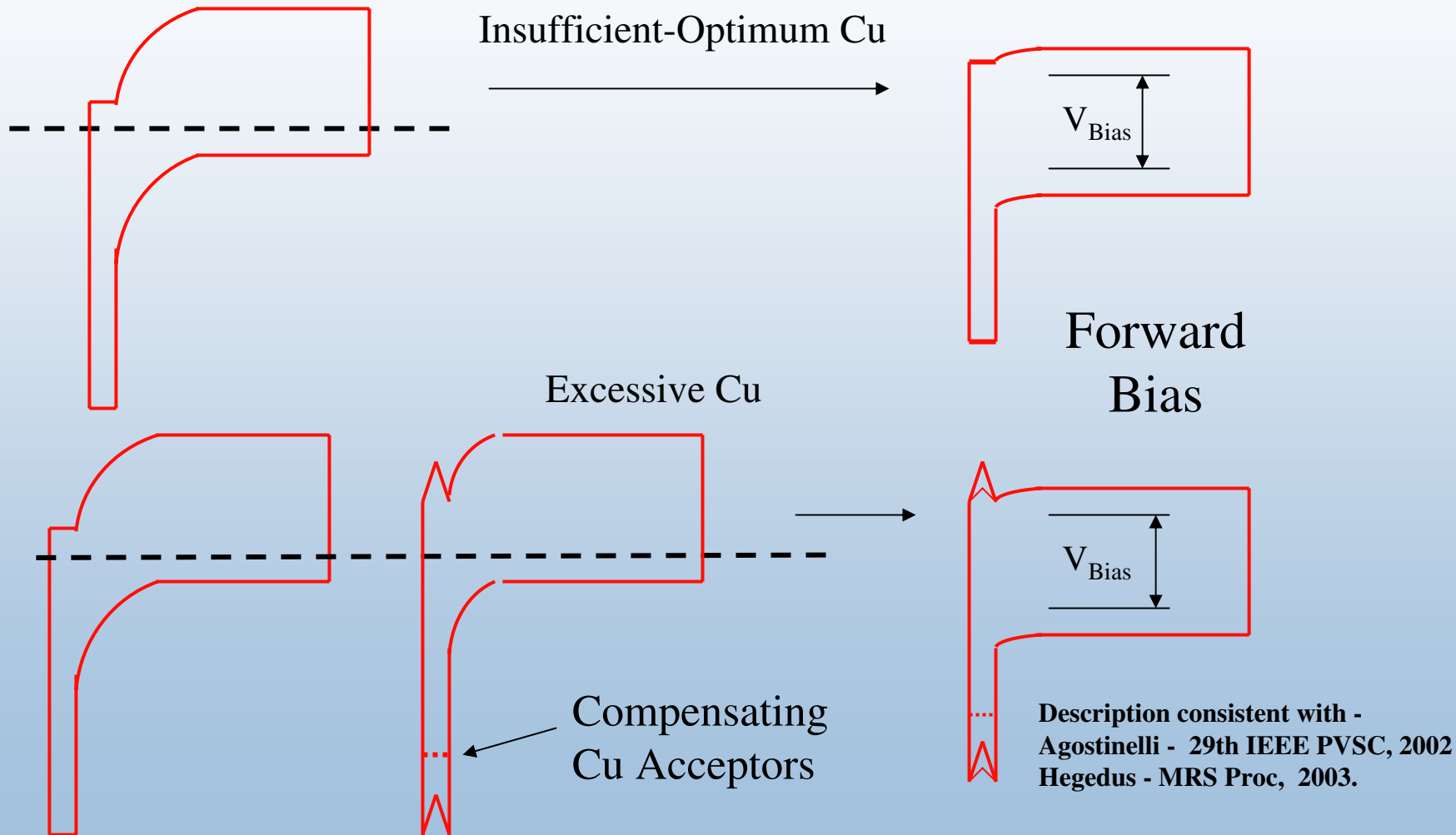
Comparison of C-V Measurement and SCAPS-1D C-V Simulation



Comparison of LIV/DIV Measurement and SCAPS-1D Simulation



Probable Cause of Apparent Series Resistance For CdS/CdTe Devices with High Cu Concentration in CdS



Conclusions

- Cu diffusion from a ZnTe:Cu contact causes good and bad things:

- **The Good (Cu in CdS $< \text{low } 10^{18} \text{ cm}^{-3}$)**

- Increase in CdTe $N_A - N_D$ that leads to V_{oc} and FF improvement

- **The Bad (Cu in CdS $> \text{low } 10^{18} \text{ cm}^{-3}$)**

- Possibly decreased of shunt resistance (?)

- Depletion width in CdTe can become too narrow for optimum current collection at J_{MPP}

- Donor reduction in CdS (*Significant* FF loss in LIV)

- Excessive Cu diffusion into CdS readily observed by **red-light bias** QE

- Next Question - Can we get the **Good** without the **Bad**?

$N_A - N_D$?