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Innovation for Our Energy Future

Effects of Cu Diffusion From ZnTe:Cu/Ti Contacts on Carrier Lifetime of CdS/CdTe Thin Film Solar Cells

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National Renewable Energy Laboratory

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The ZnTe:Cu/Ti Contact Process

(All-Dry, High-Temperature [~300°C])

High Temp. Vacuum CdTe/CdS + Vapor $CdCl_2$

Heating

Ion-Beam Milling

r.f. Sputter Deposition (ZnTe:Cu)

d.c. Sputter Deposition (Ti)

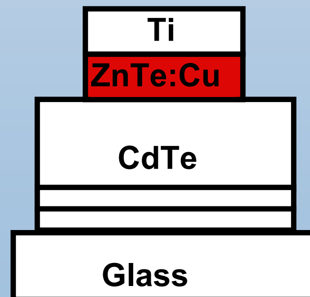
CdTe
Glass

CdTe
Glass

ZnTe:Cu
CdTe
Glass

Ti
ZnTe:Cu
CdTe
Glass

Photolithography



Some Research Advantages

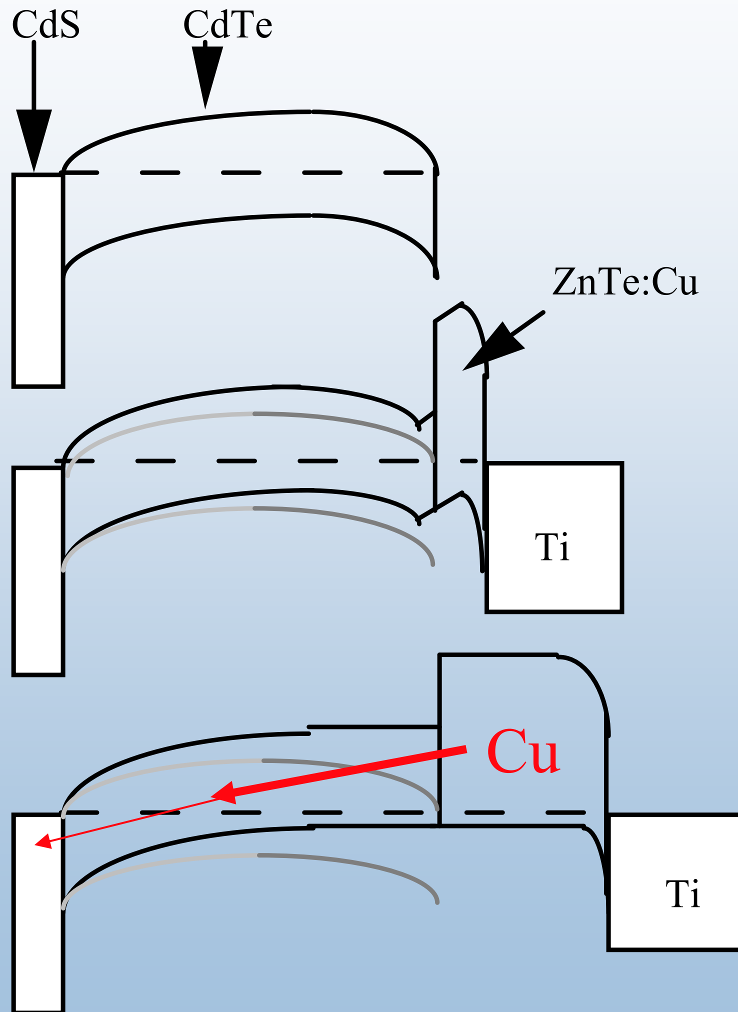
Precise control of junction performance

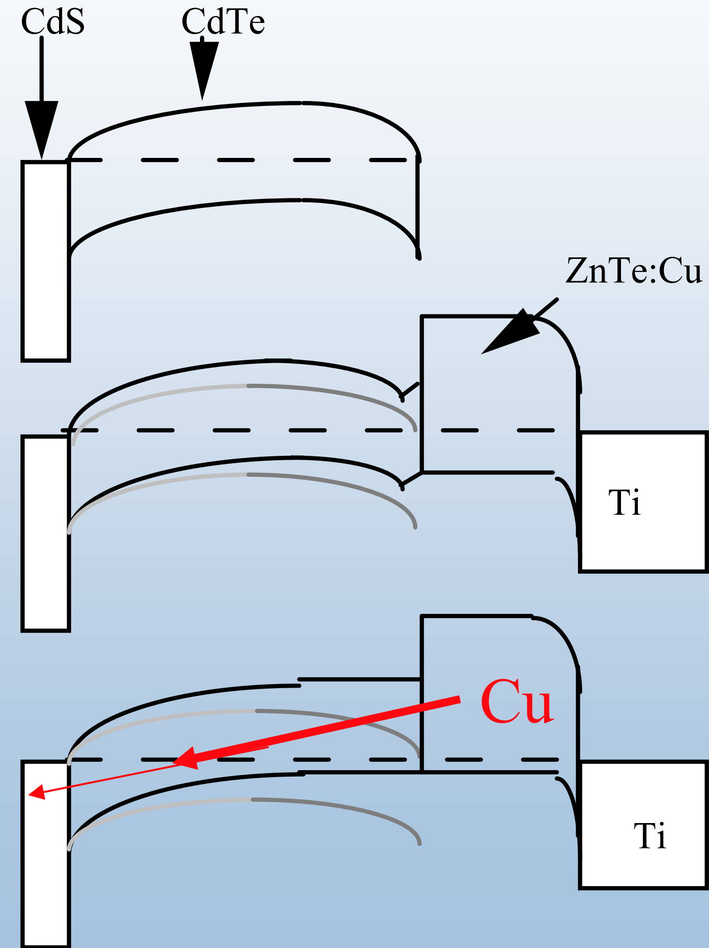
High device stability

Can achieve very low Cu incorporation

Easy to make large, identical sample sets

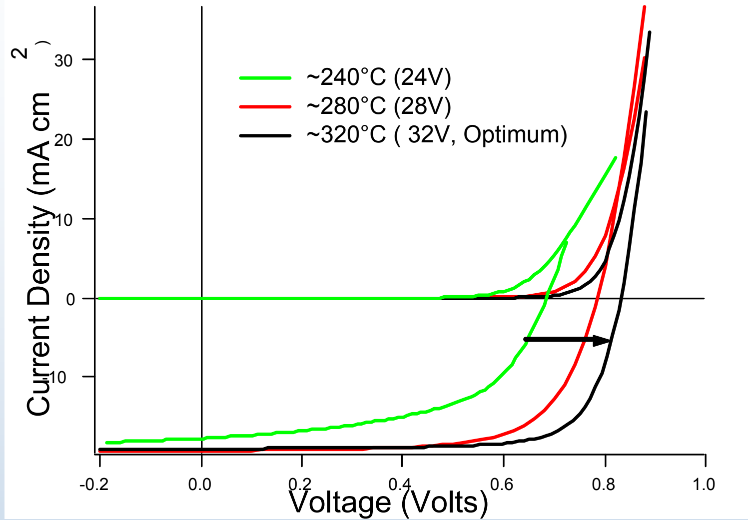
Past Studies



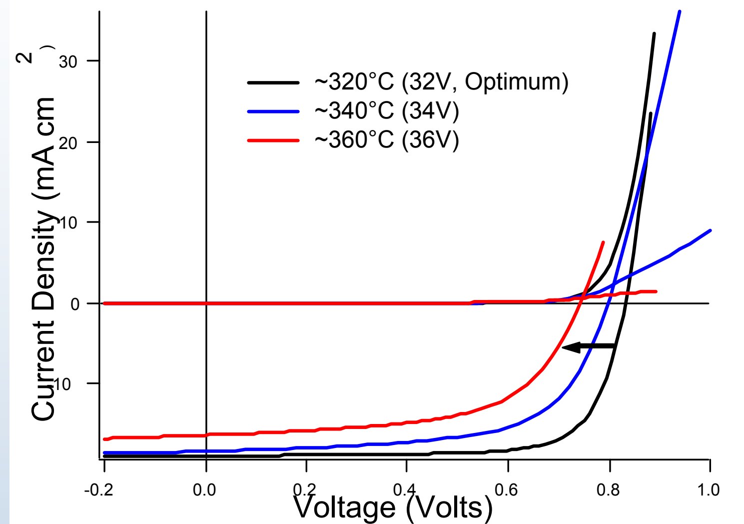


Some Insight from Past Studies

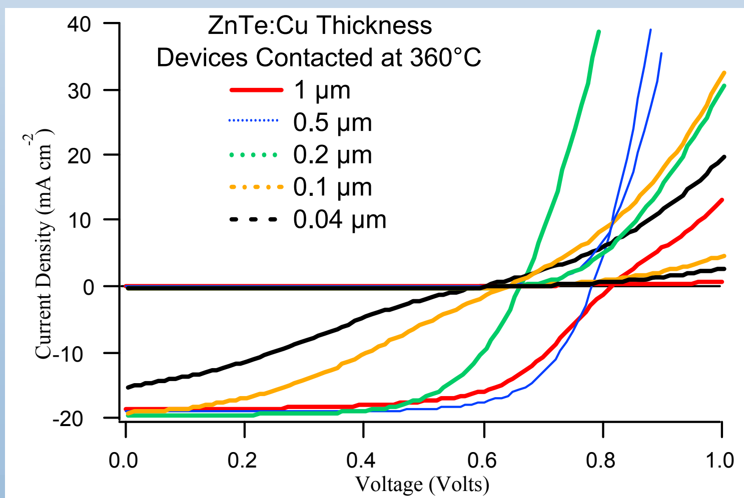
Cu Diffusion Less Than Optimum



Cu Diffusion Greater Than Optimum



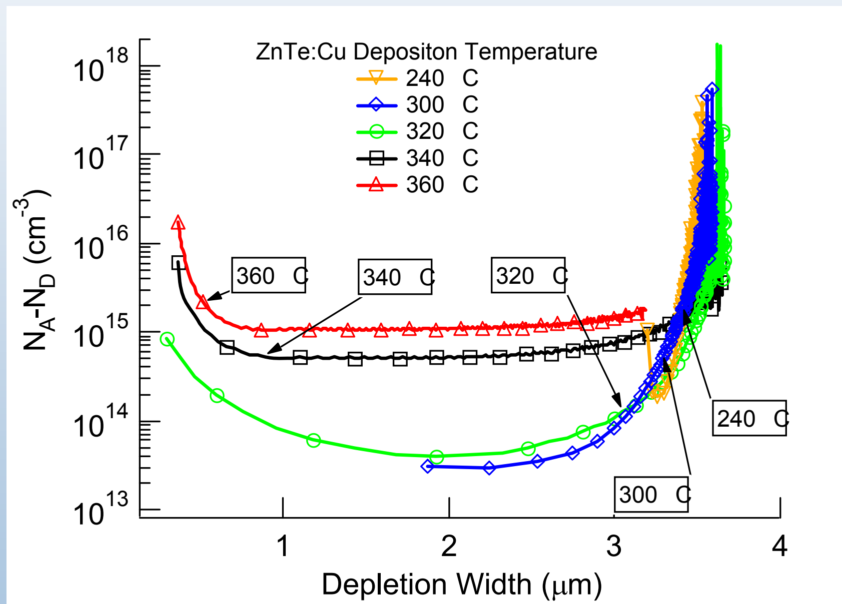
Effect of Contacting Temperature



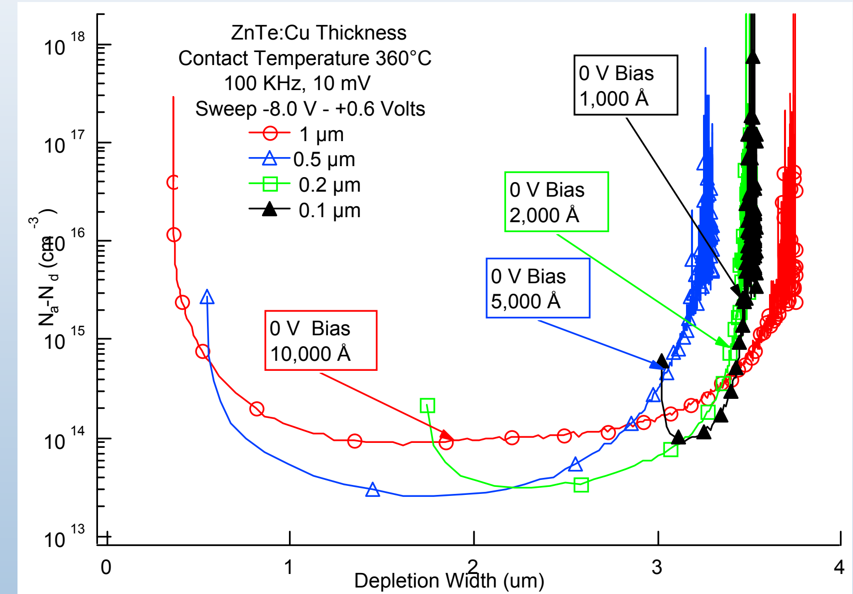
Effect of ZnTe:Cu Thickness

Comparison of Previous and Present C-V Analysis

Vary Contact Temperature

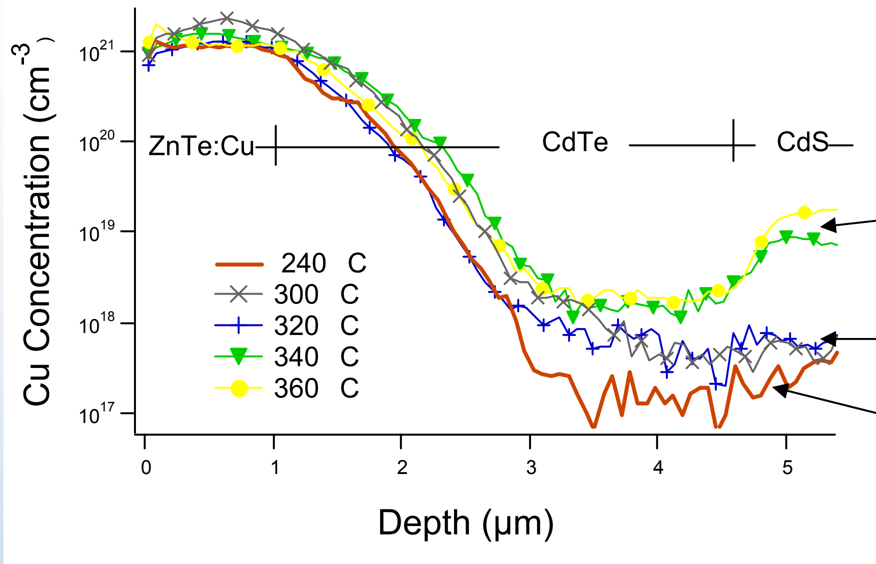


Vary ZnTe:Cu Thickness



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

Compositional Analysis



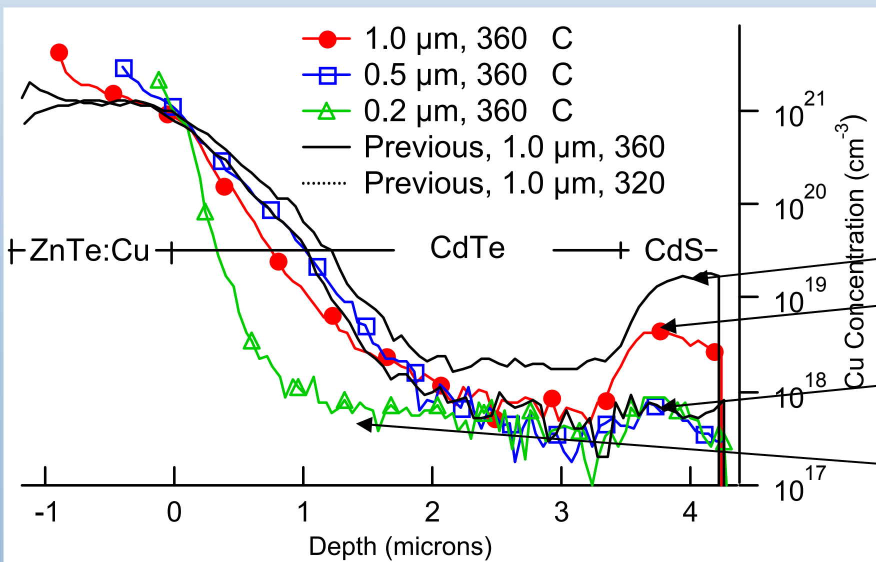
Contact Temperature

Excessive Cu

Optimum Cu

Insufficient Cu

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



Contact Temperature

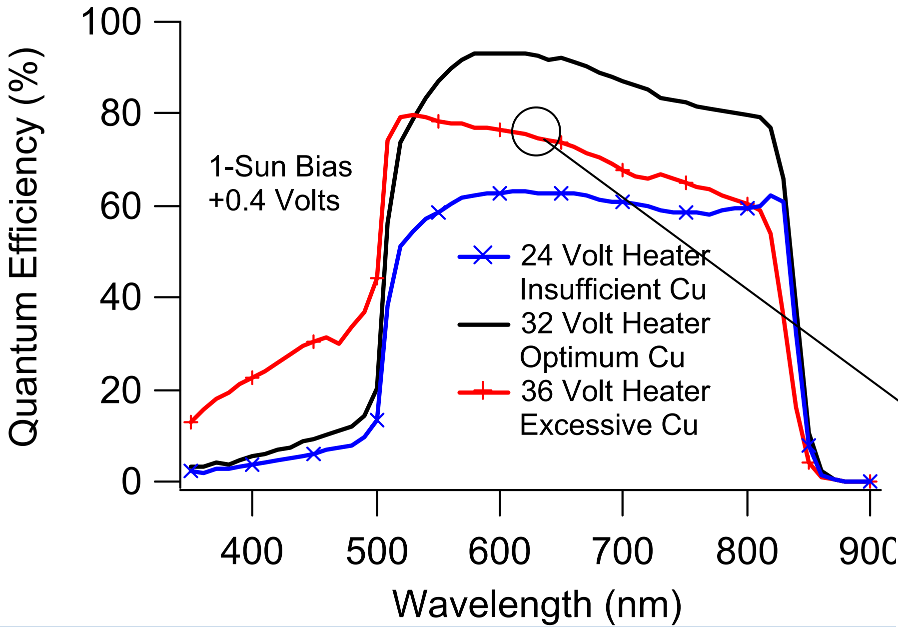
Excessive Cu

??

Optimum Cu

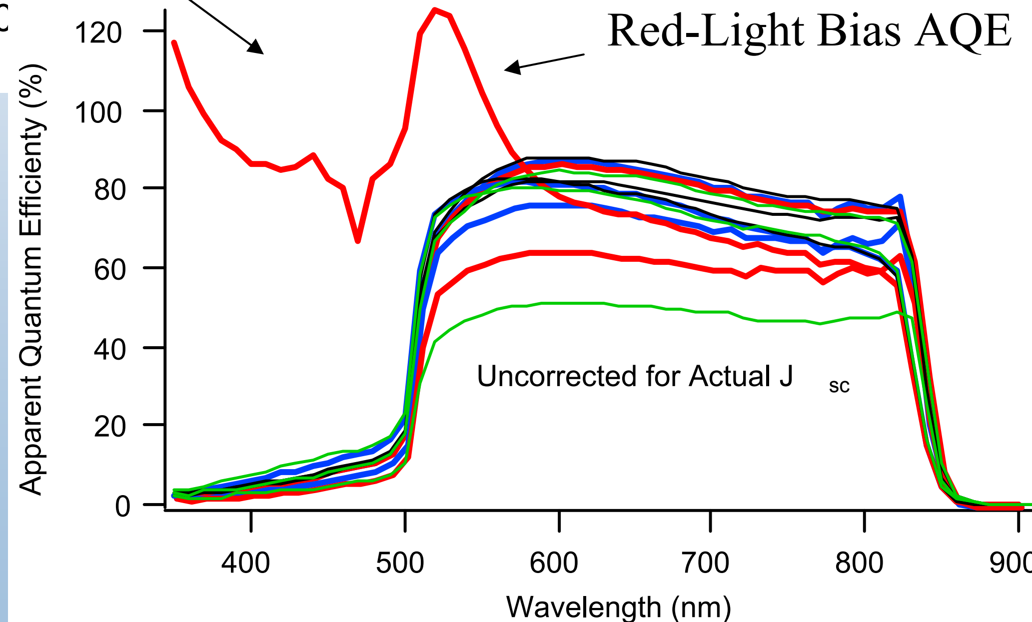
Insufficient Cu

Light and Voltage-Dependent Quantum Efficiency

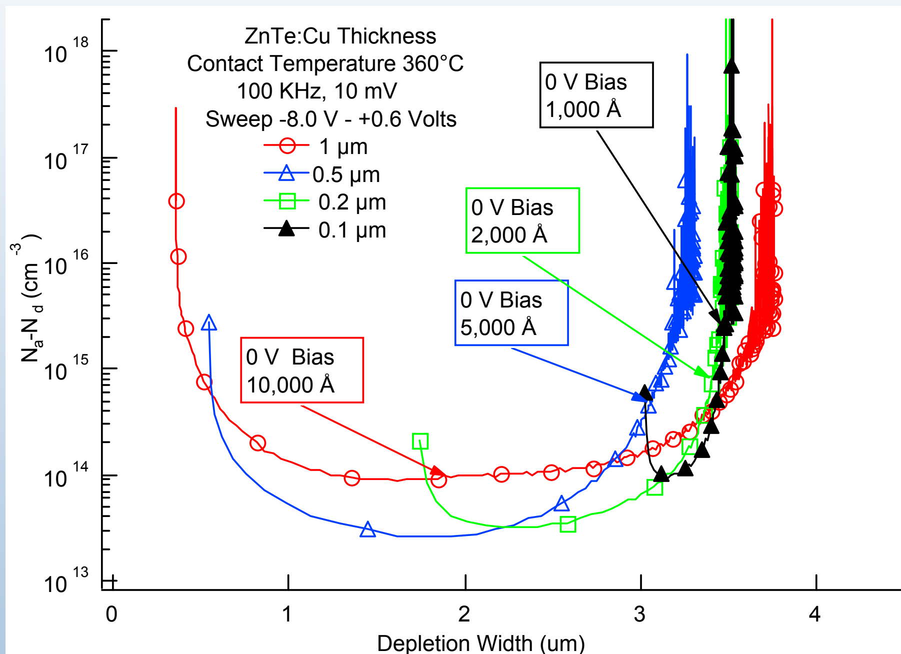


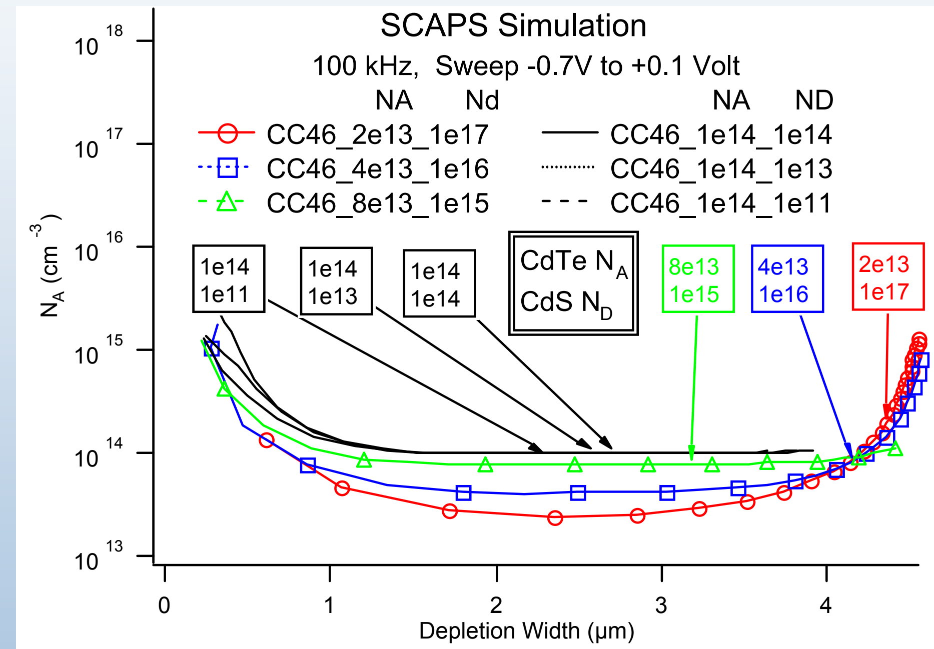
Red-Light Bias QE Confirms
Photoconductive CdS
Only For "Excessive" Cu Devices

QE Comparison Suggests
Narrowing Junction
for Excessive Cu Devices



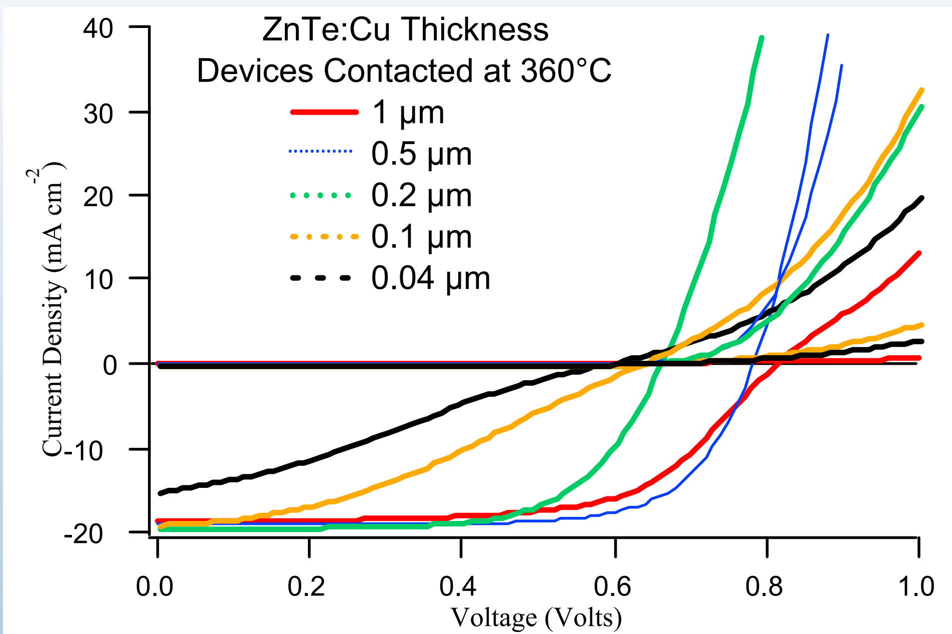
Comparison of C-V Measurement and SCAPS-1D C-V Simulation

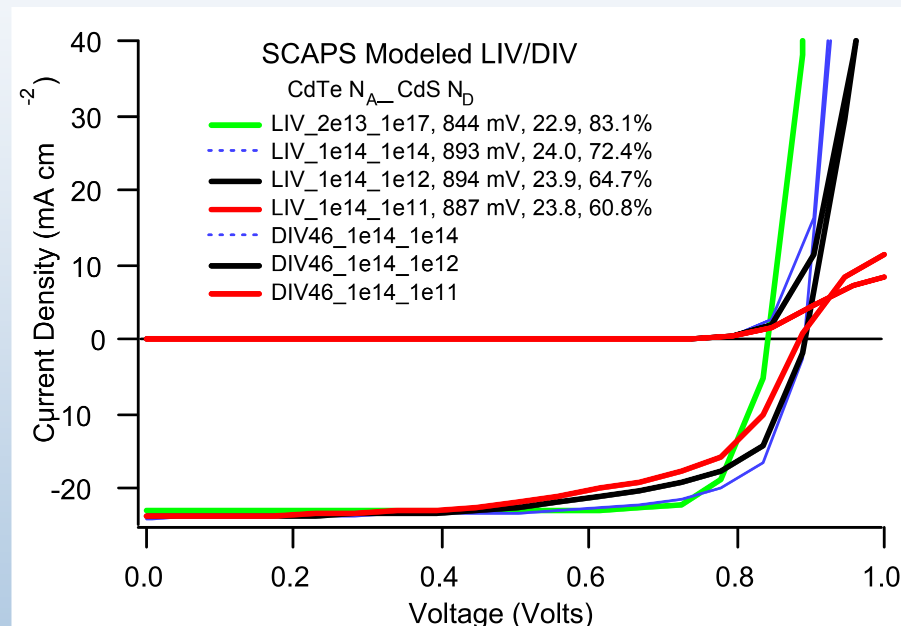




Gessert, et. al, 4th World Conf. PV Energy Conversion, pp.432-435

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



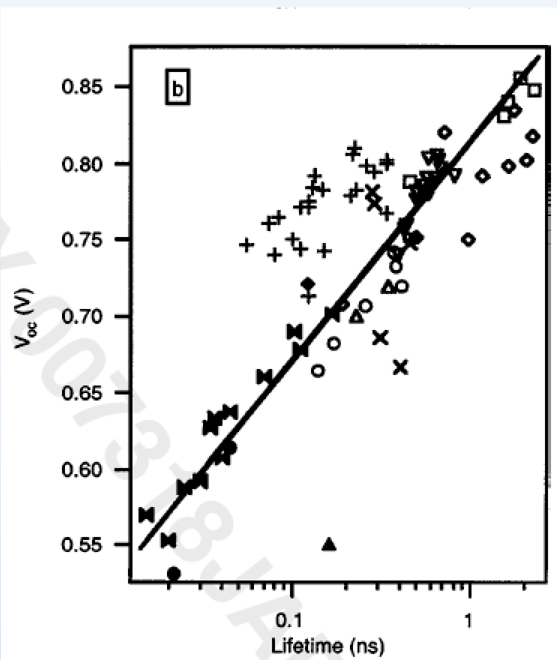


Gessert, et. al, 4th World Conf. PV Energy Conversion, pp.432-435

But…

Modeling Assumes Minority Carrier Lifetime Does Not Change

Previous TRPL studies indicates minority carrier lifetime decreases with Cu



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TIFF (LZW) decompressor
are needed to see this picture.

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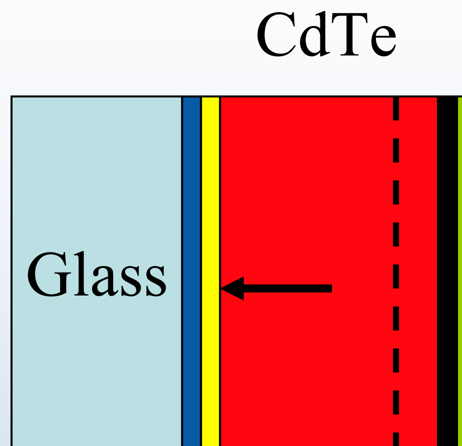
Metzger, Albin, Levi, Sheldon, Li, Keyes, Ahrenkeil, JAP 94(6) (2003)

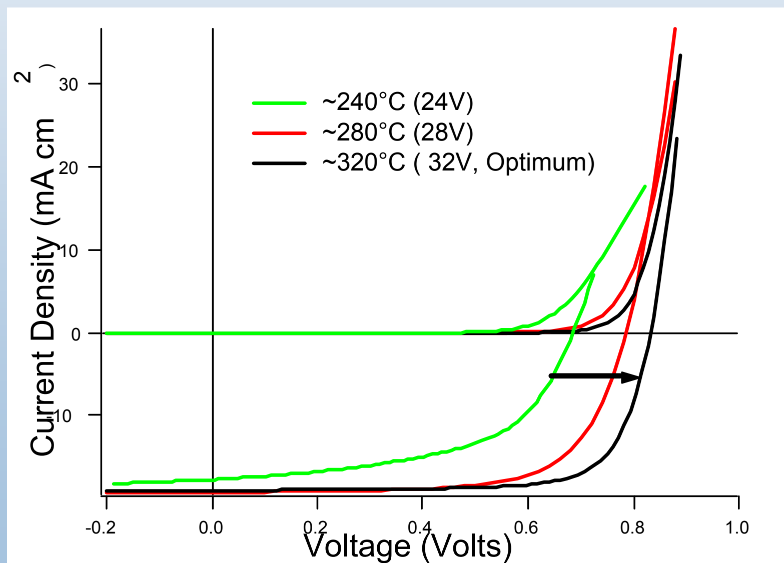
Wu, Zhou, Duda, Yan, Teeter, Asher, Metzger, Demtsu, Wei, Noufi, TSF, 515, 5798 (2007)

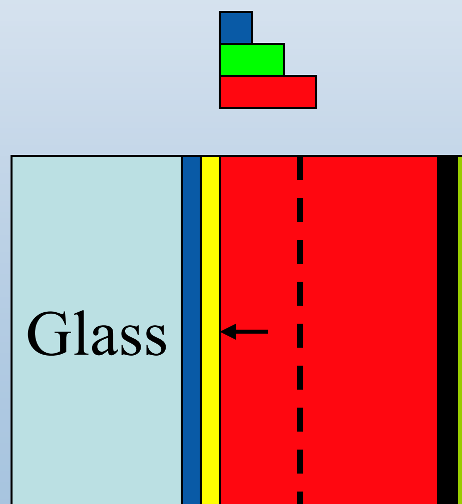
Demtsu, Albin, Sites, Metzger, Duda, TSF, 516 p. 2251 (2008)

Quandary

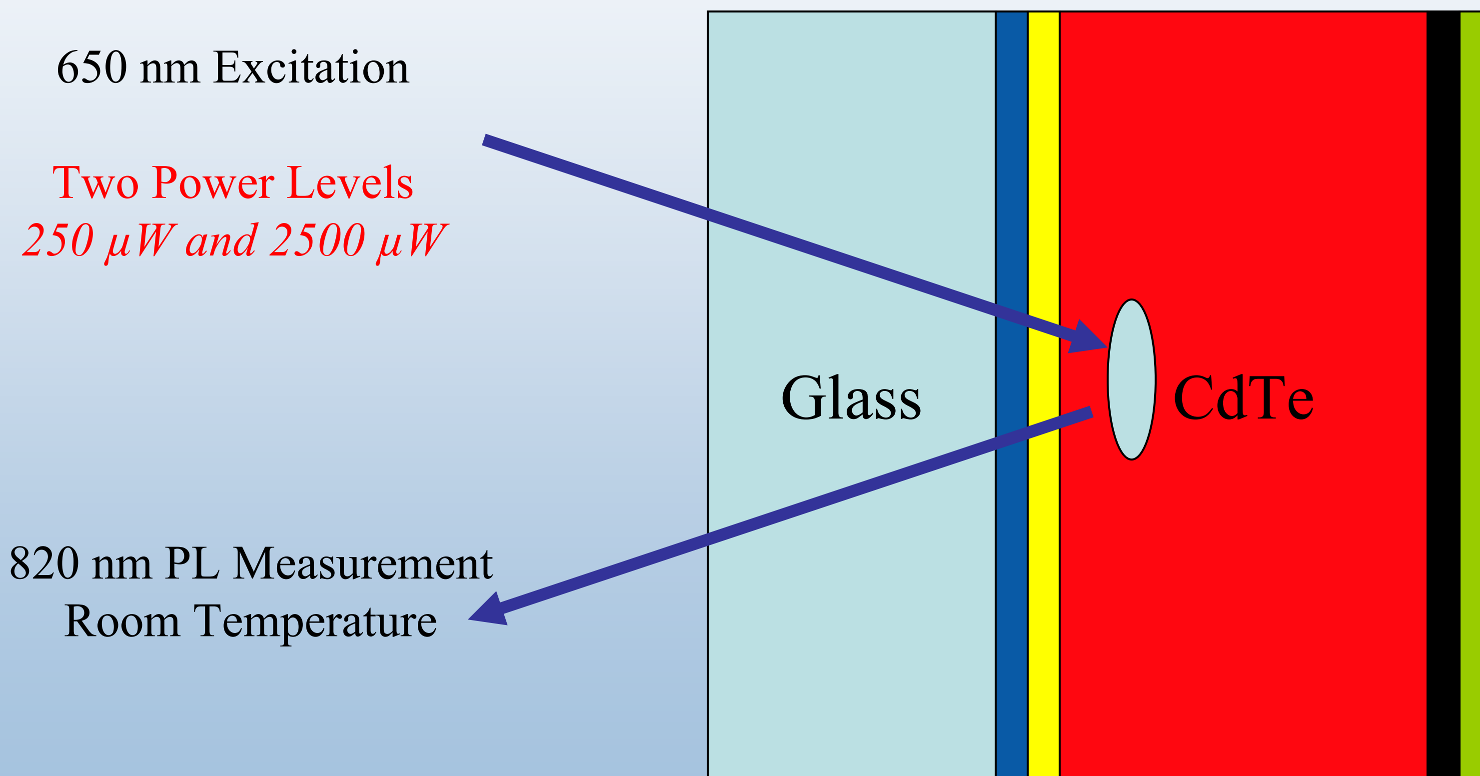
If both carrier lifetime and space charge width decreases with Cu incorporation, why does voltage-dependant collection decrease?





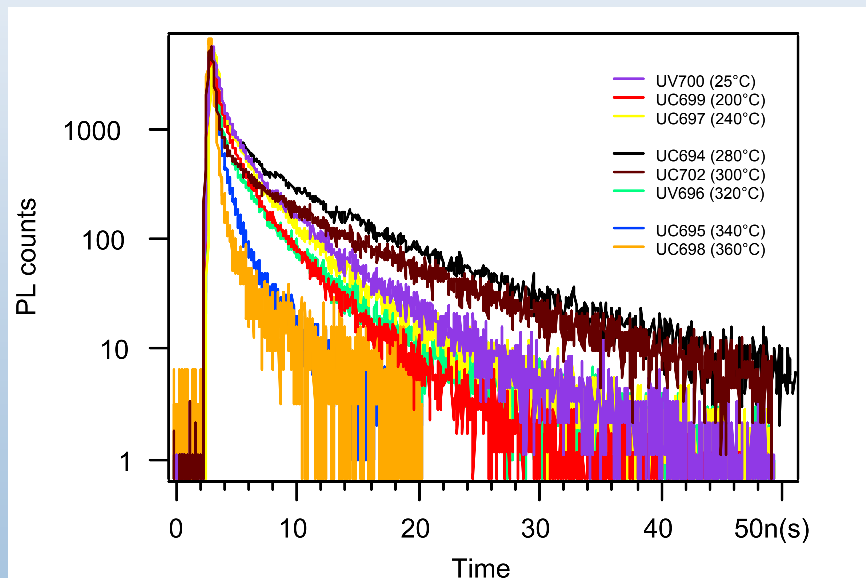


Time Resolved Photoluinescence (TRPL)

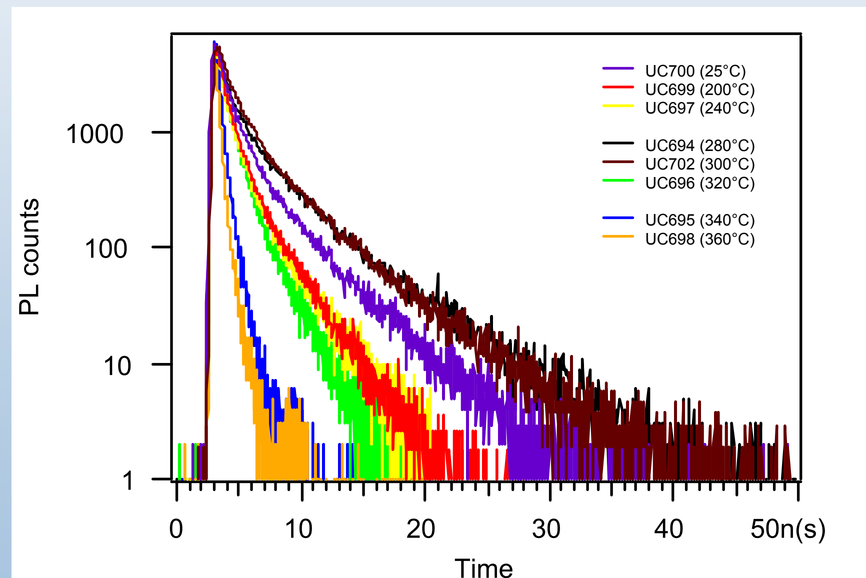


TRPL Study of Cu Diffusion and Contact Temperature

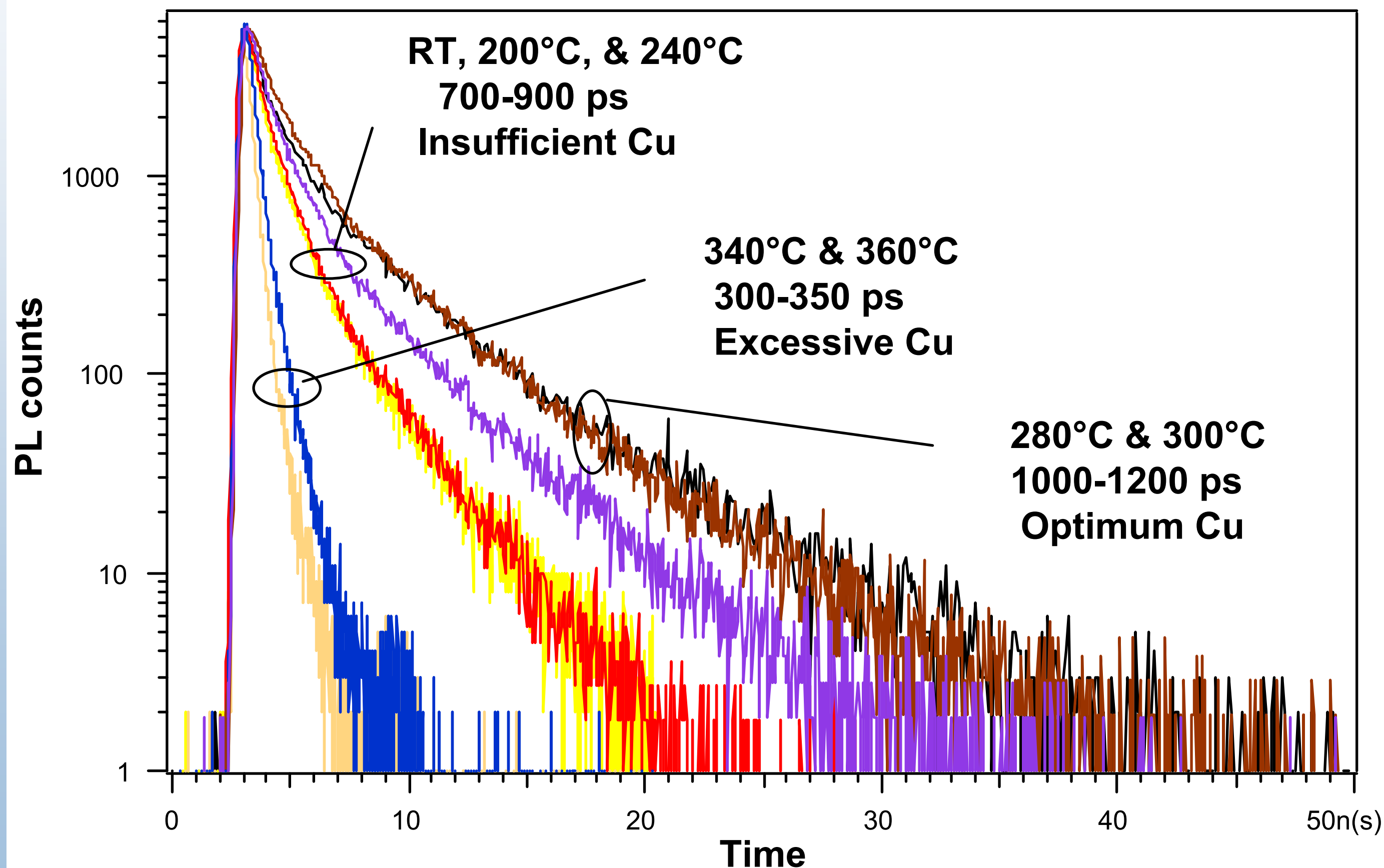
250 μW Power



2500 μW Power



TRPL Study of Cu Diffusion and Contact Temperature (2500 µm Power)



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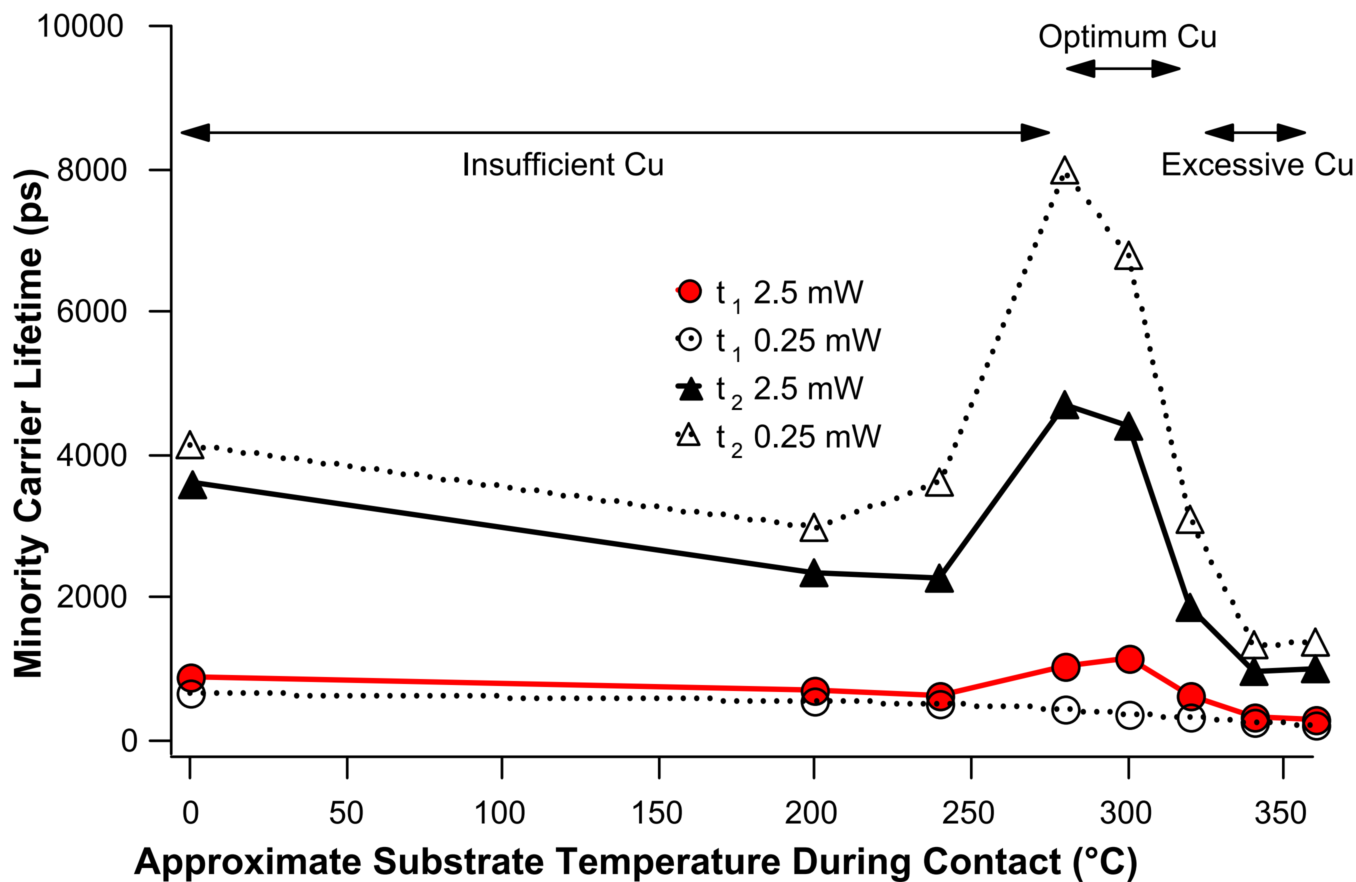

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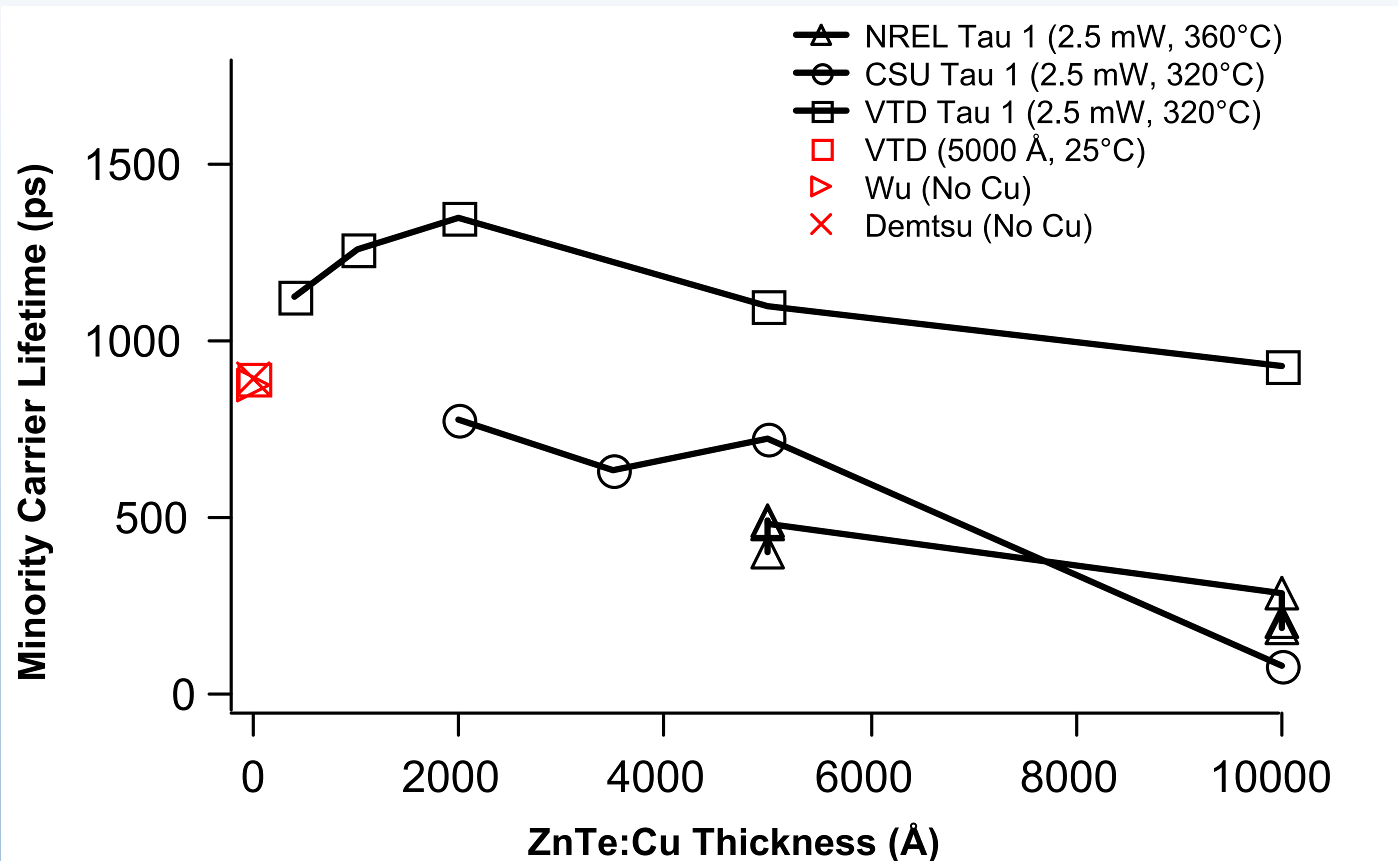

Conclusions

- Minority carrier lifetime can decrease or increase during contacting
    - Depends on temperature during Cu diffusion
    - Depends on amount of Cu diffused
- For the ZnTe:Cu/Ti contact, the longest lifetimes occur at contact temperature of ~280-320°C
    - This may explain why other contact processes are often optimized within this this temperature range
- Strategy for optimization of Cu-containing contacts:
    - Examine effect of temperature on lifetime
    - Adjust Cu amount of Cu in contact to maximize net acceptor density to maximize V_{oc}, optimize depletion width, and limit Cu diffusion into CdS

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