Dilute Nitrides

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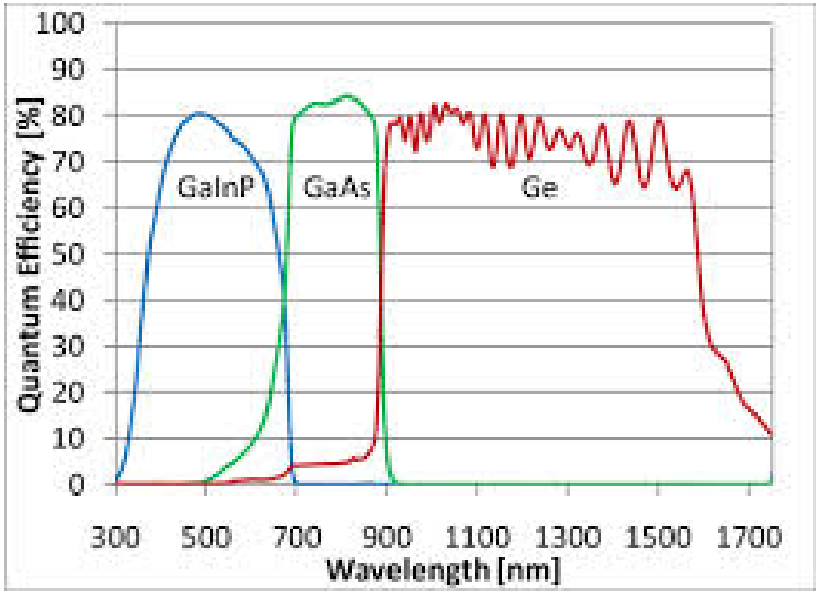
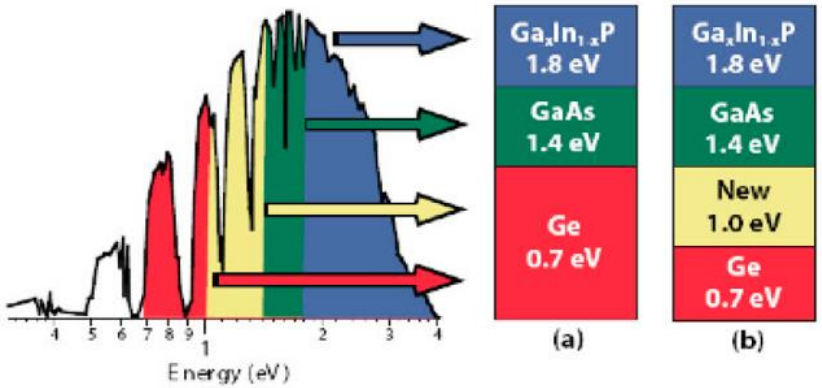
Gallium Indium Nitride Arsenide (GaInNAs)

- Use as 4th layer in multi-junction cells
  - Absorb a wider range in the spectrum
- Problems with defect formation
- Solution introduction of hydrogen and rapid thermal annealing (RTA)
- Hydrogen passivates nitrogen defects
- Rapid Thermal Annealing (RTA) improves material quality



http://www.pvmeasurements.com/

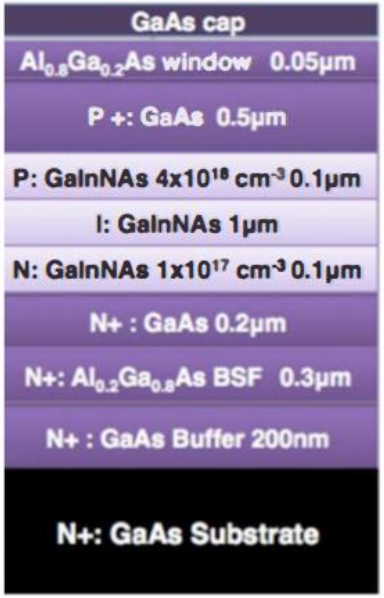


J.F. Geisz and D.J.Freidman, Semiconductor Science and Technology 17, 769 (2002)

GaInNAs Study Samples

- Vu470 and Vu467 made by Sheffield University
  - Reference quantum wells
  - Vu470 single layer quantum well
  - Vu467 3 layer quantum well

- S677 made by Miwa Fukuda, a previous Graduate student
  - Bulk nitride solar cells
  - The higher quality of 3 bulk samples made
  - Previously studied reference bulk sample w Collin

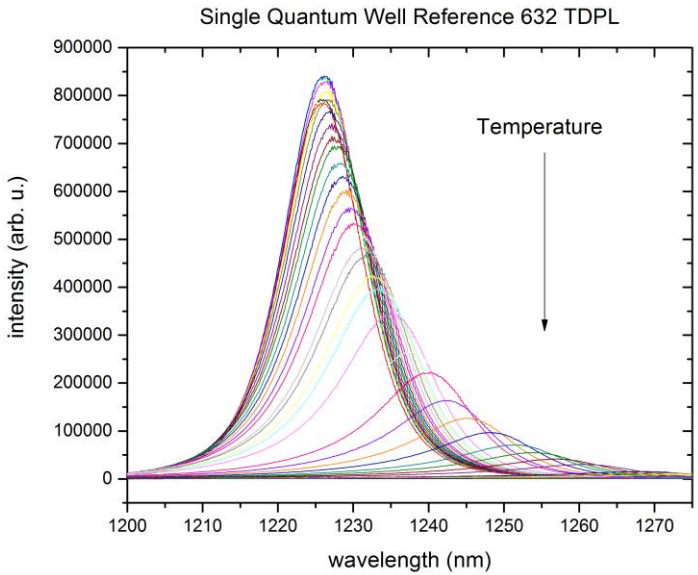


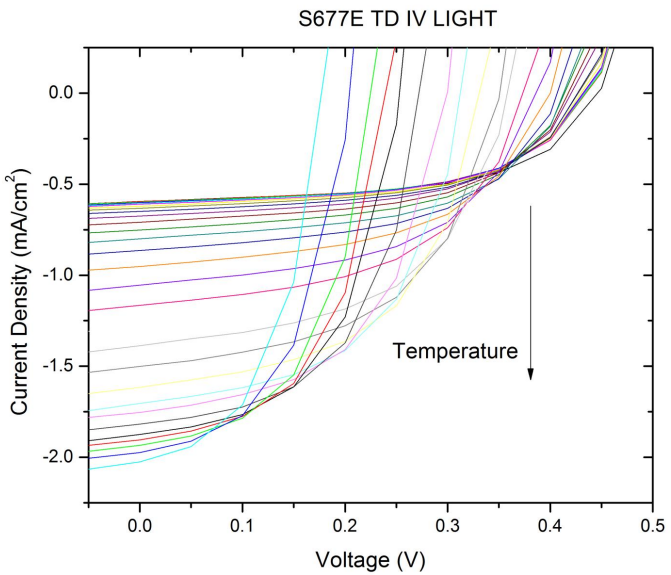
M. Fukuda IEEE 2015

- All samples were passivated with hydrogen at Amethyst Research Inc.

Experimental Procedures

- Photoluminescence (PL)
  - Power and temperature dependence
  - Energy of the band gap
- Current Voltage (IV)
  - Temperature dependence
  - Voc, Jsc, Pmax

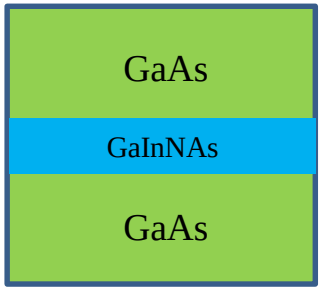




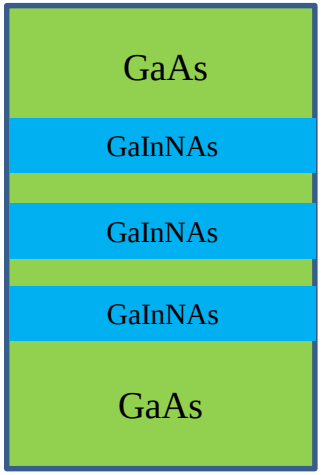
Photoluminescence

- Vu470: single quantum well
- Vu467: 3 layer quantum wells

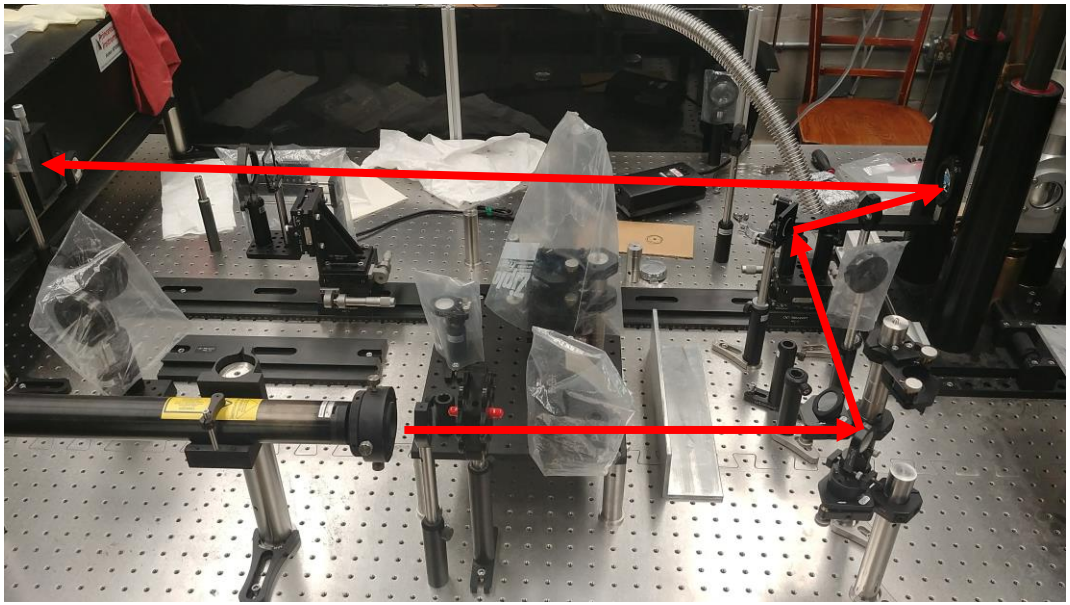
SQW



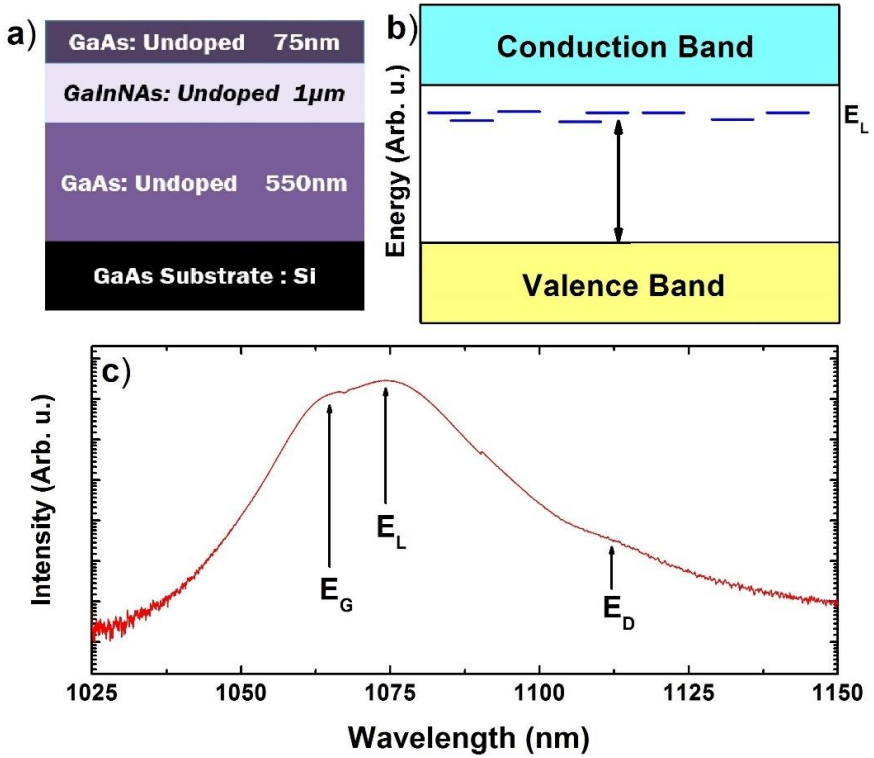
3QW



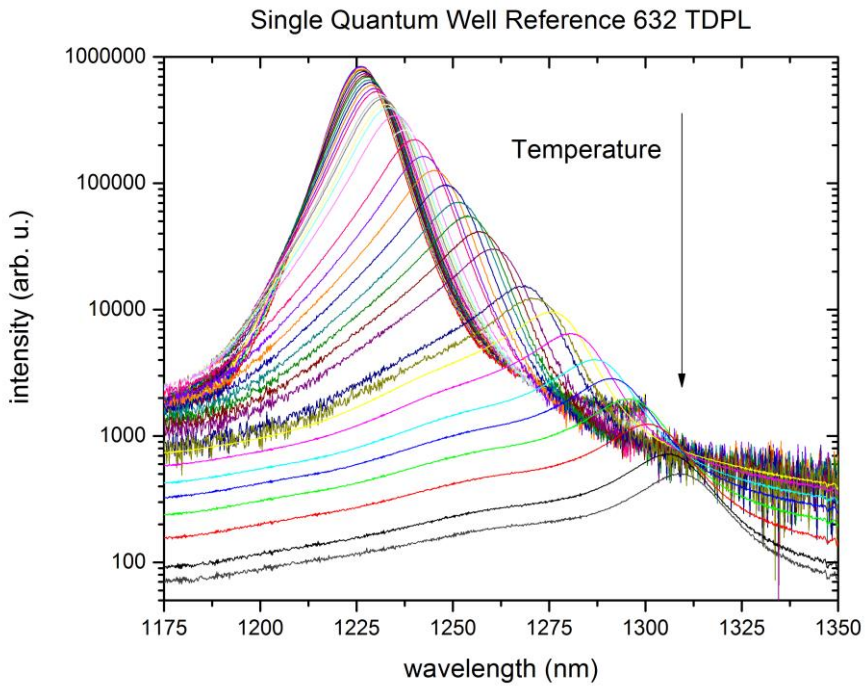
Photoluminescent Set up



Temperature Dependent Photoluminescence Single Quantum Well Reference

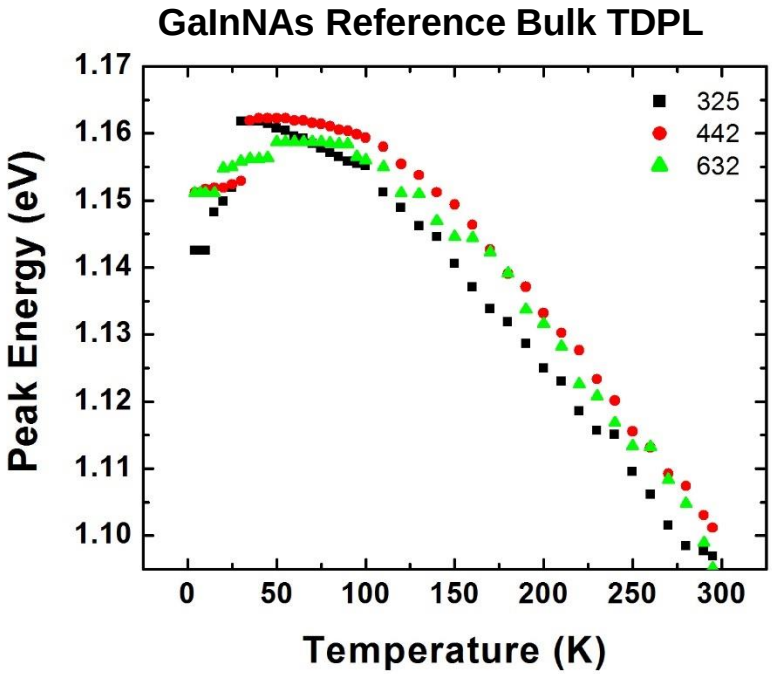


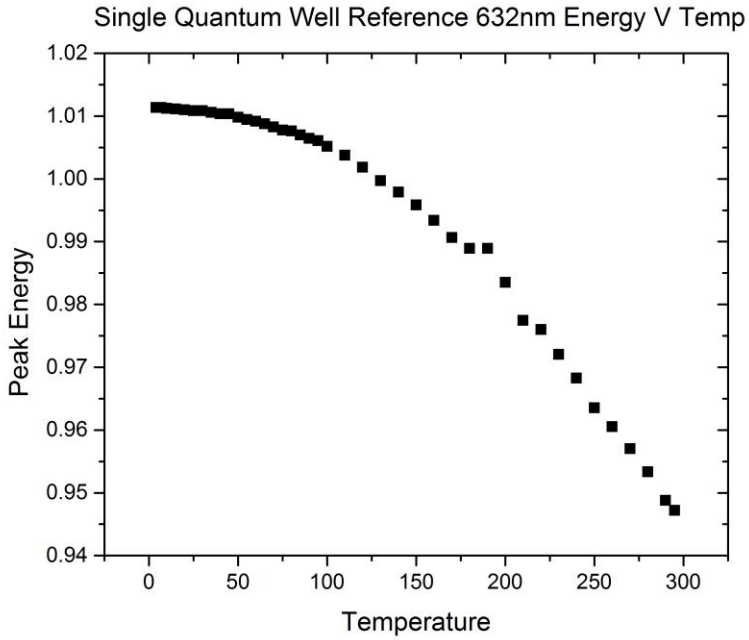
C. R. Brown Royal Society of Chemistry 2017



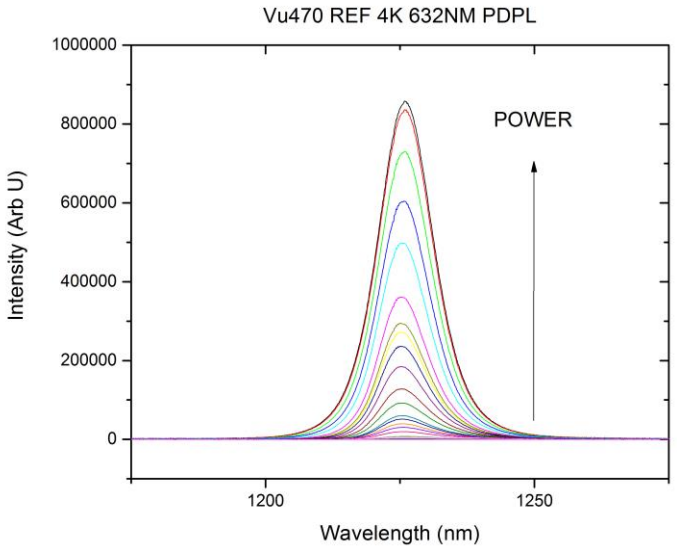
Photoluminescence
Effects of Hydrogenation

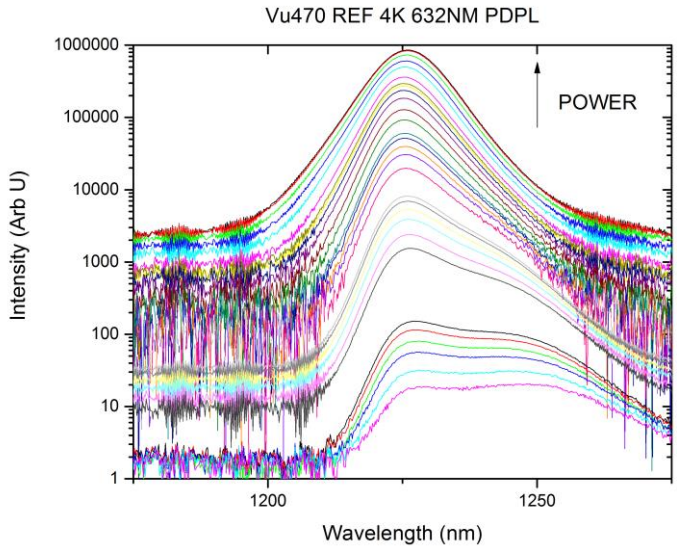
- Localization due to impurities at low temperatures in low quality samples

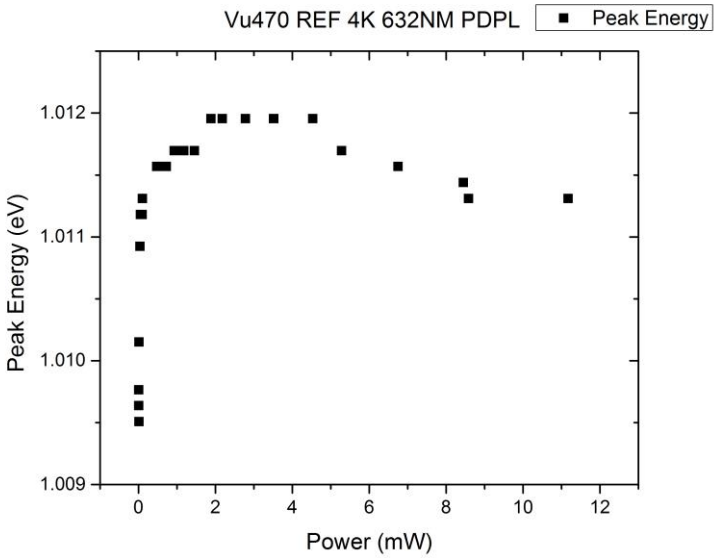


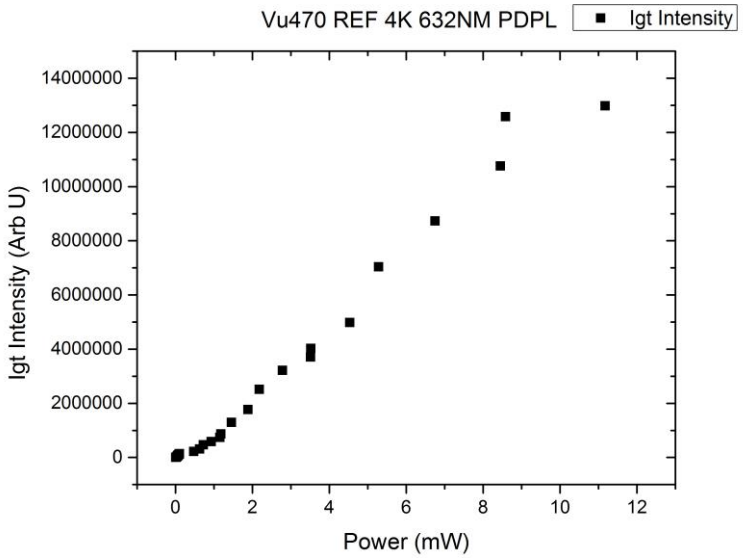


Power Dependent Photoluminescence Single Quantum Well Reference at 4K

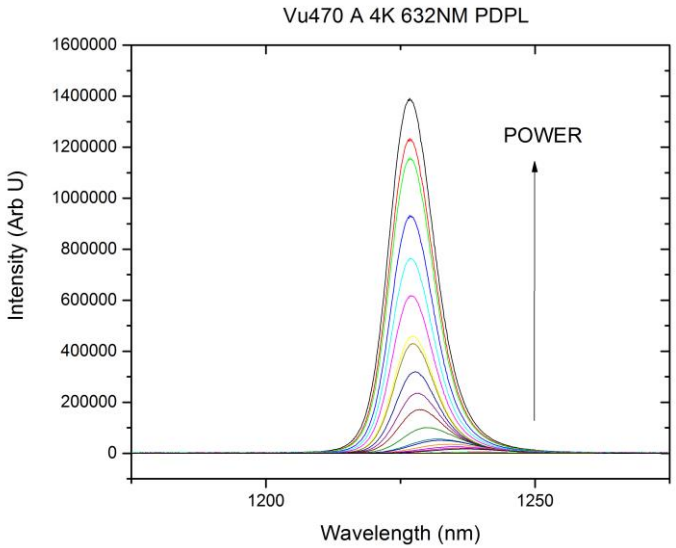


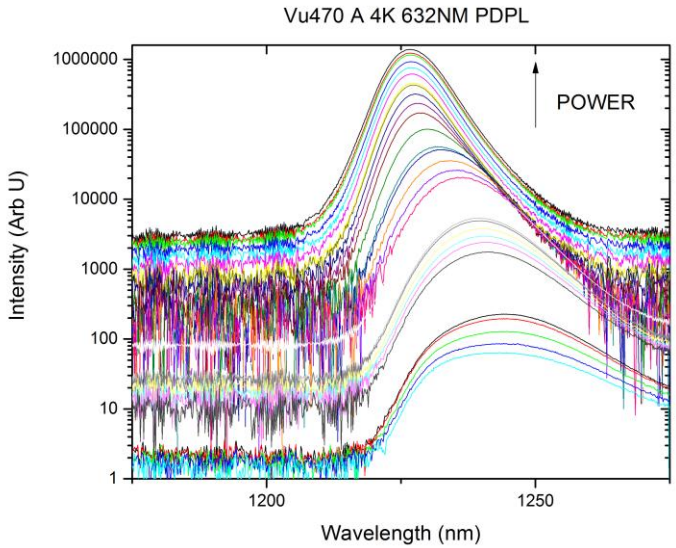


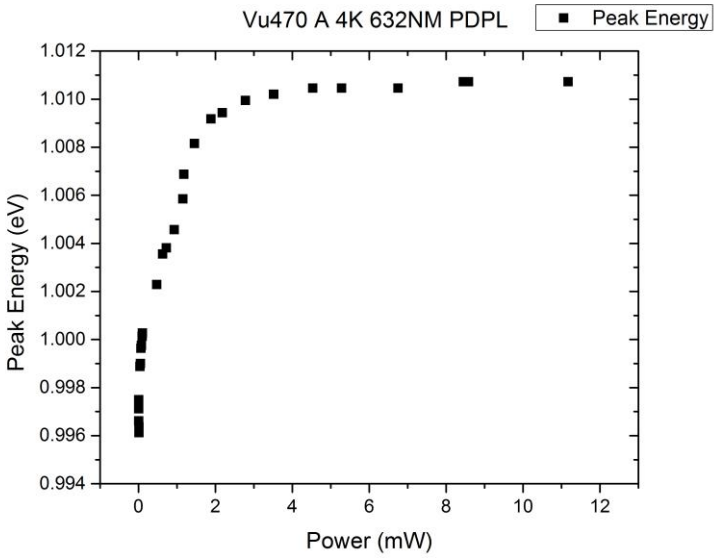


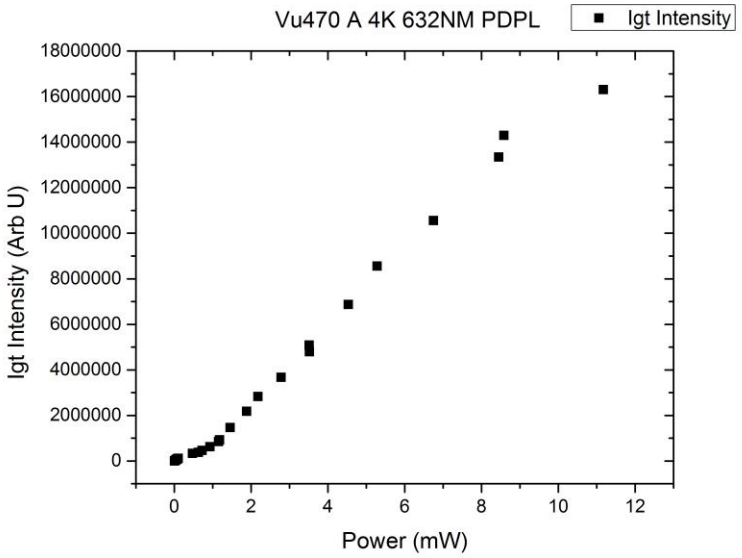


Power Dependent Photoluminescence
Single Quantum Well Highest Hydrogenation at 4K

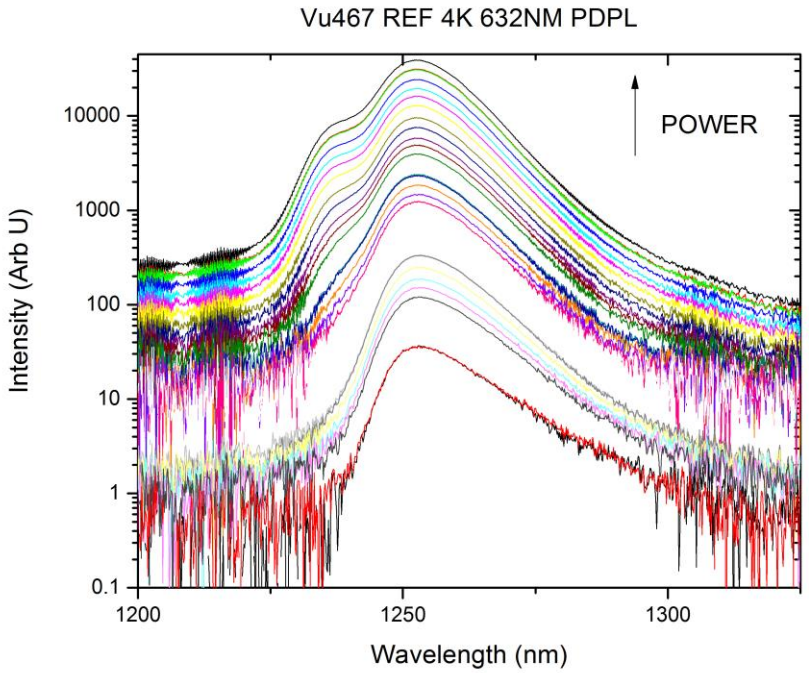


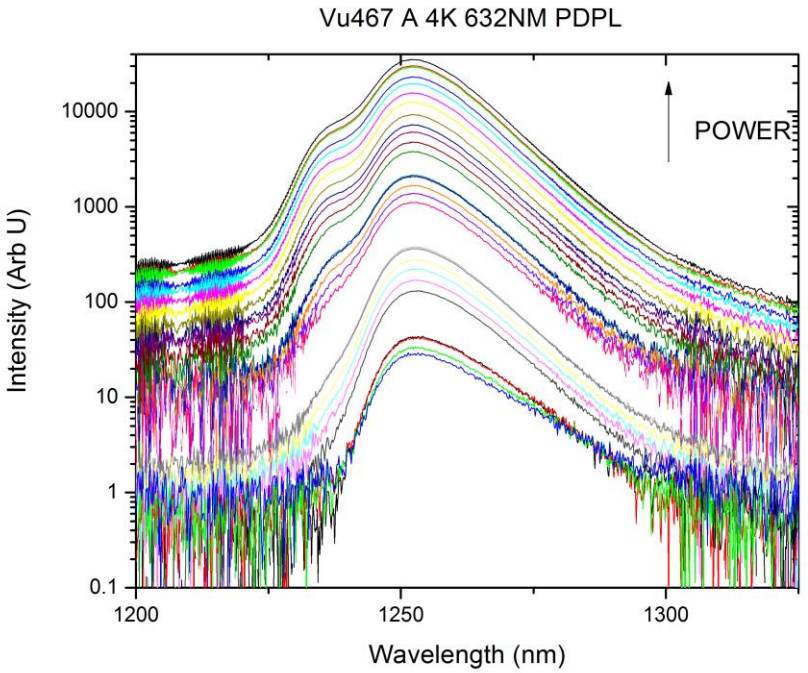






Power Dependent Photoluminescence 3 Layer Quantum Well at 4K

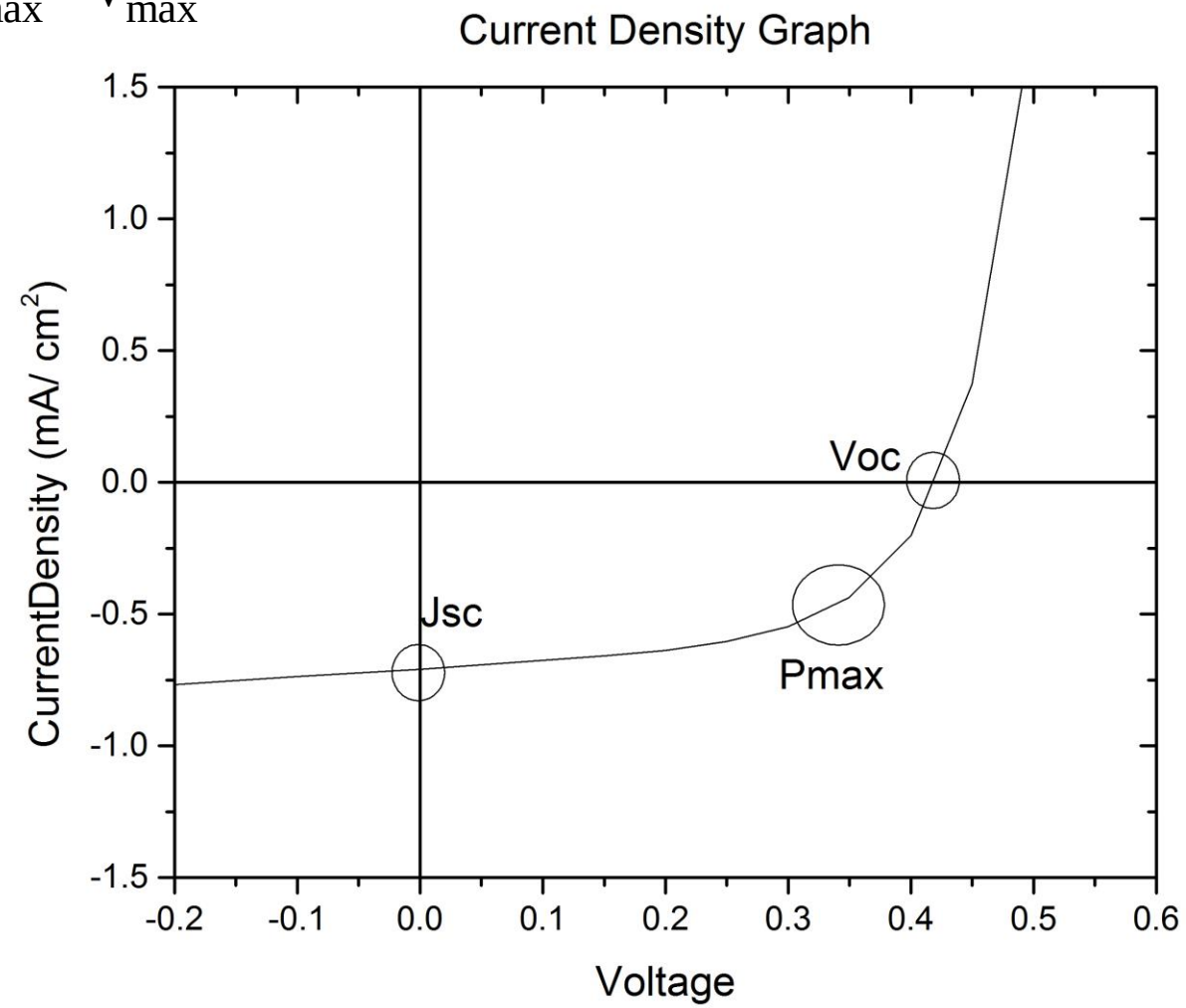




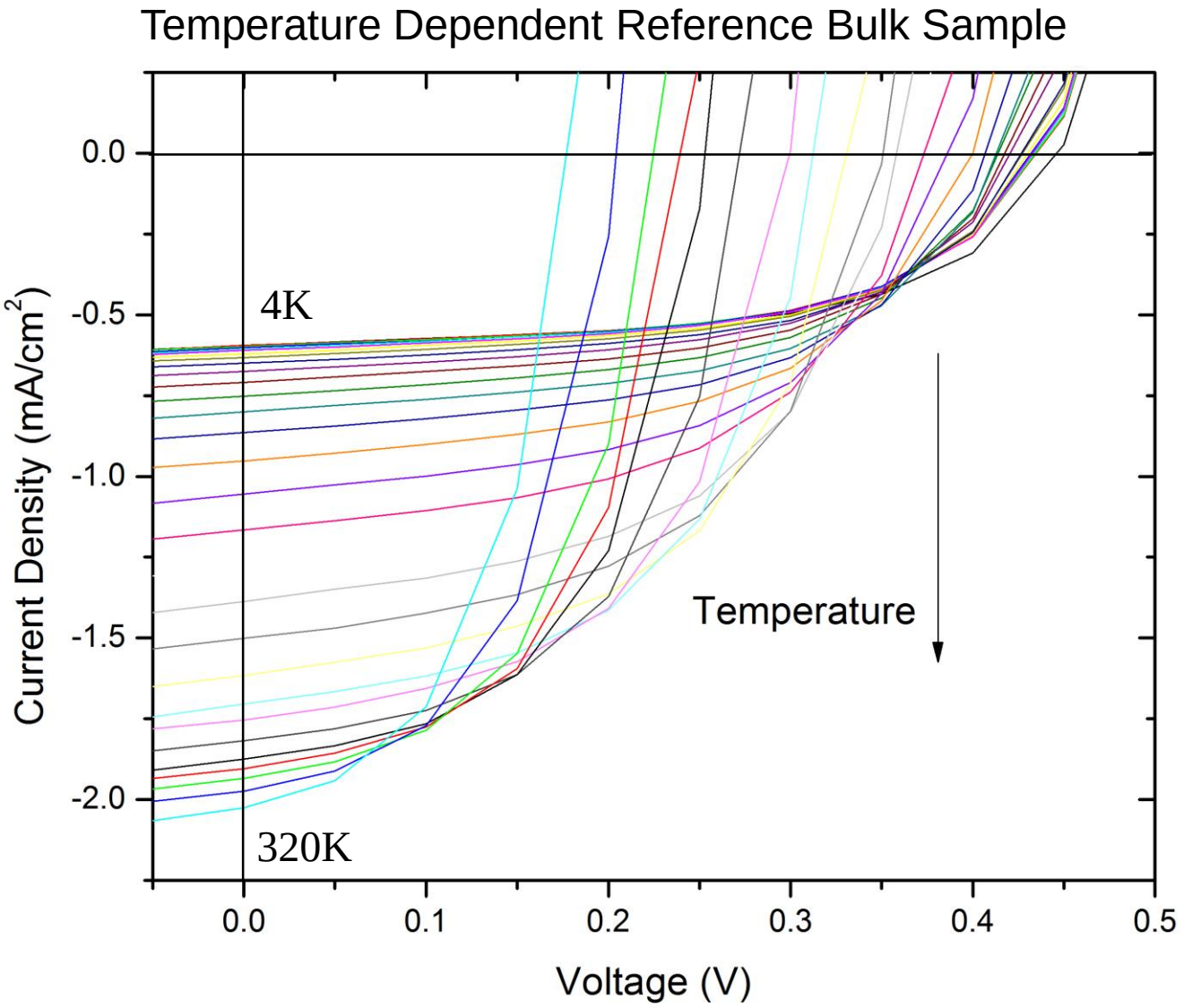
- Effects of hydrogenation are very small
- Hydrogen concentration is high enough to not completely remove the nitrogen

Analysis of Bulk Solar Cells

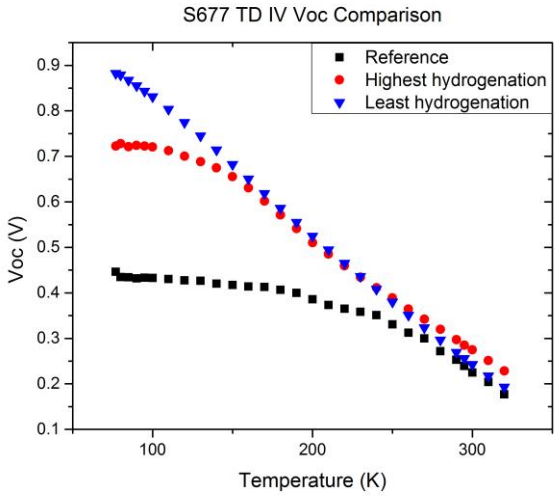
- V_{oc} = Voltage at open circuit (I = 0)
- J_{sc} = Current density at short circuit (V = 0)
- $P_{max} = J_{max} * V_{max}$

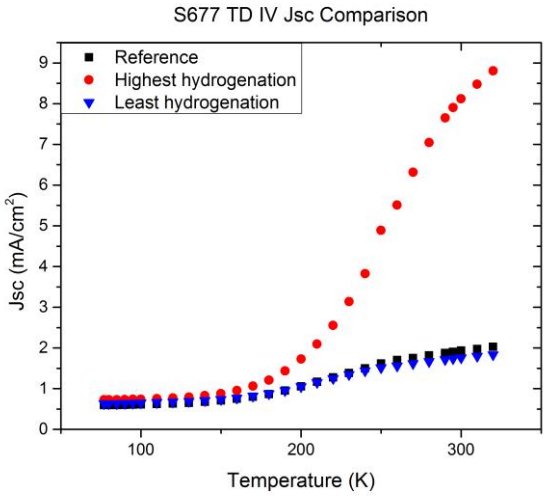


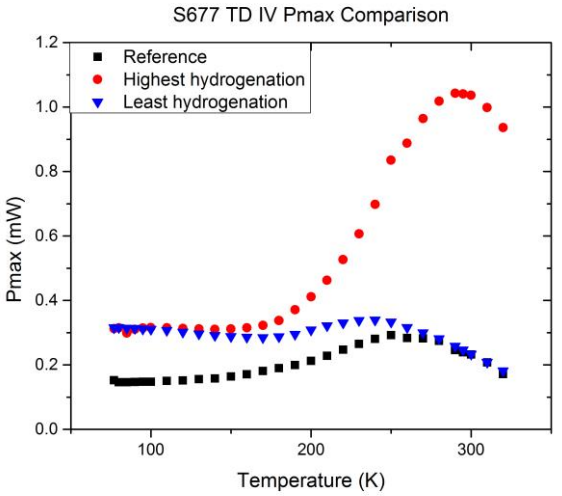
Analysis of Bulk Solar Cells



Analysis of Bulk Solar Cells







- Data follows expected results in highest concentration around operating temp
- Still studying lower temperature

Conclusion

- Photoluminescence of quantum wells
  - High quality samples
  - Little effect of hydrogenation at low power
- Current-Voltage of solar cells
  - Followed expected trends
  - Still analyzing
- Small portion of other measurements done along side Collin
- Continue analyzing data
- Comparing to other samples

Acknowledgements

- DFT calculations performed at OSCER at the University of Oklahoma

OCAST
Oklahoma Center for the Advancement of Science and Technology

cRHEA

ARI
AMETHYST RESEARCH INCORPORATED

NASA

NSF