Selective Passivation of Nitrogen Defects in GaInNAs Solar Cells

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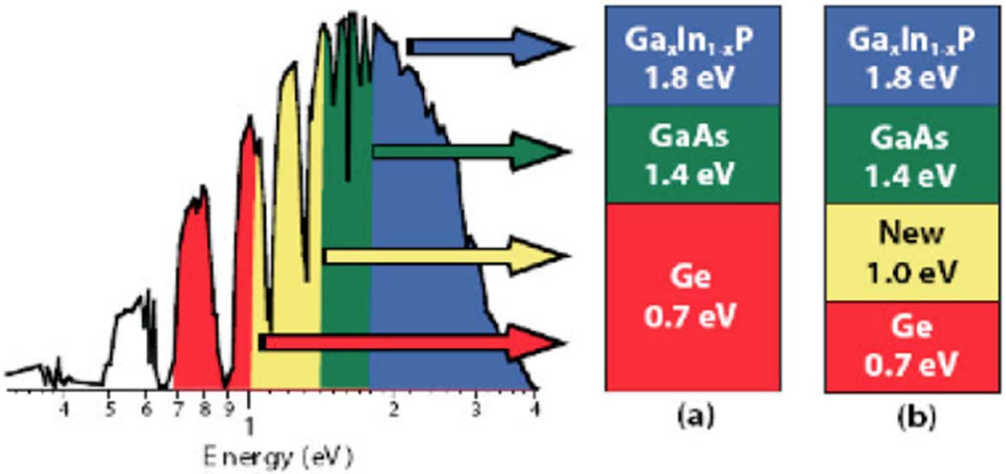
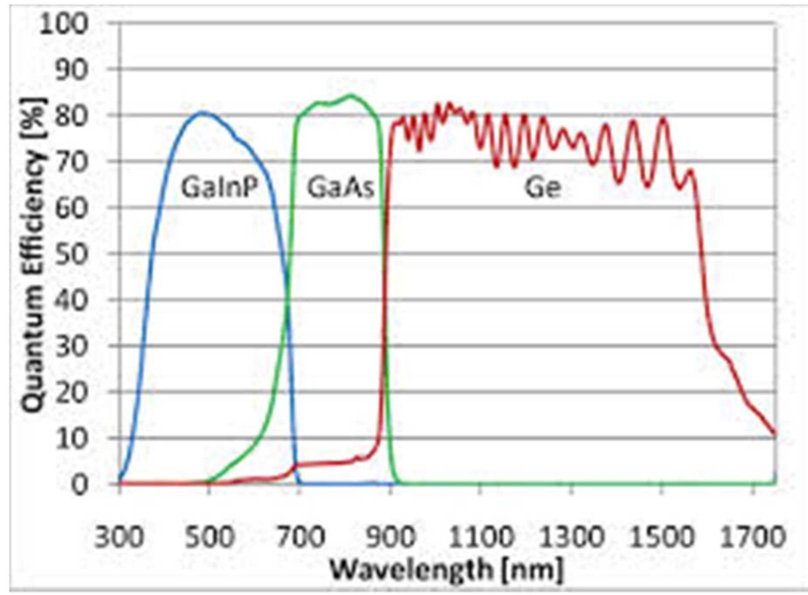
Photovoltaics Materials & Device Group, University of Oklahoma: http://www.nhn.ou.edu/~sellers/group/index.html

Multijunction Solar Cells: Divide and Conquer



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

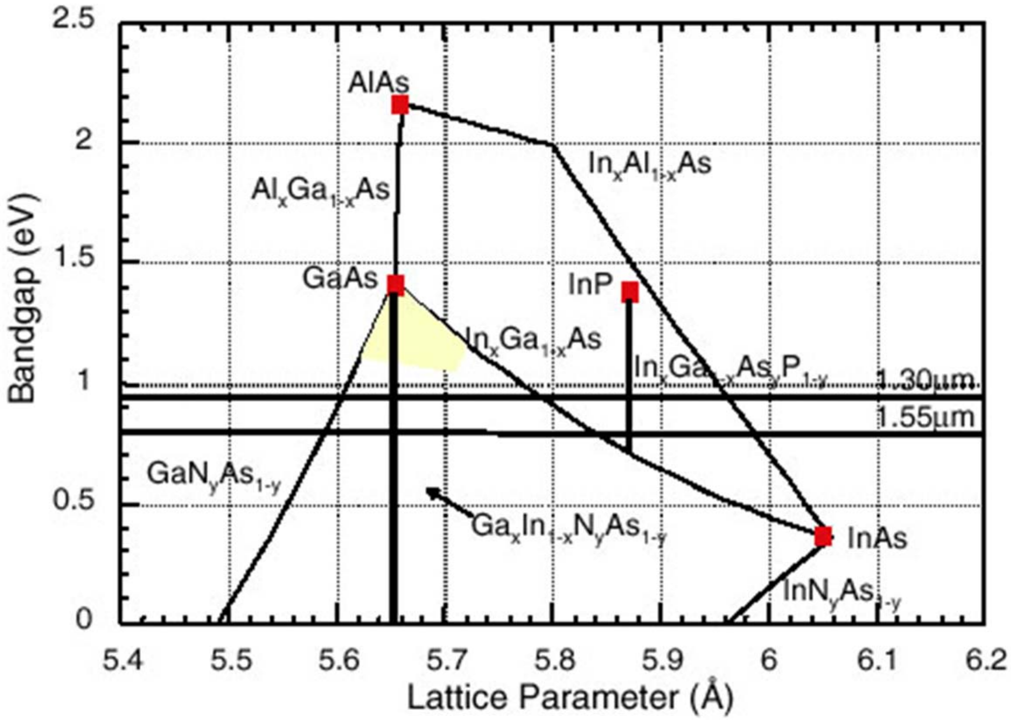


http://www.pvmeasurements.com/

- Three junctions: 44% efficient
- Four junctions: Up to 52% efficient
- Power wasted by Ge due to poor current matching

We need a material with 1eV bandgap, correct lattice spacing

GaInNAs is a Promising but Problematic Candidate for the Fourth Junction



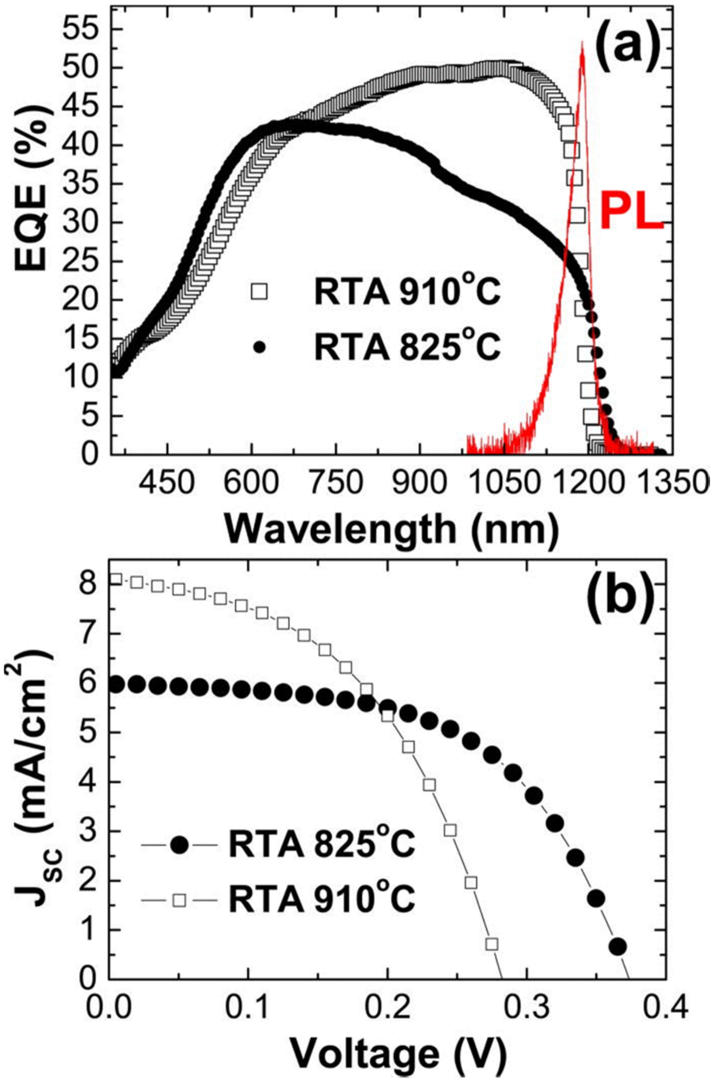
J. S. Harris, Semicond. Sci. Technol. 17, 880 (2002)

Growth Problems:

- High temperature--phase separation, clustering
- Low temperature--defect formation, low nitrogen inclusion

Regardless of sample quality, substitutional N is locally different electrically than As, causing low diffusion lengths.

Annealing (RTA) Reduces Problems Associated with Growth Temperature



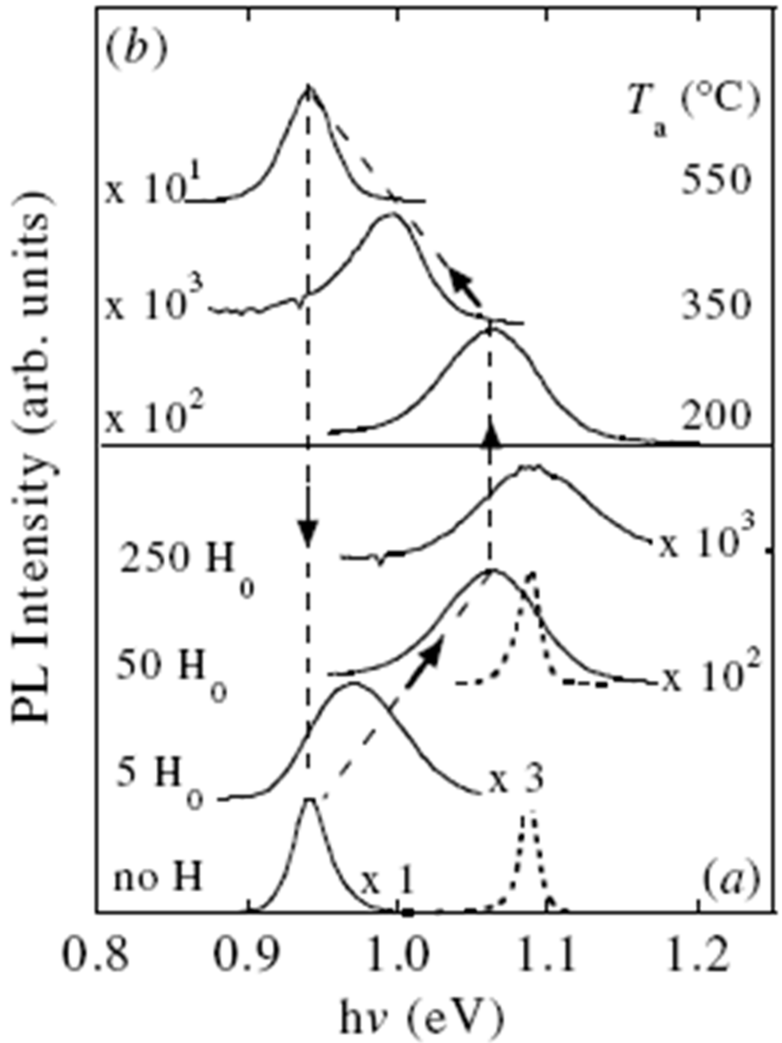
Sellers et al. Appl. Phys. Lett. 99, 151111 (2011)

- More ideal quantum efficiency in solar cell structures
- Reduced recombination losses
- Breaking up of N-N clusters

Dilute nitride MJSCs have seen efficiencies in excess of 43%

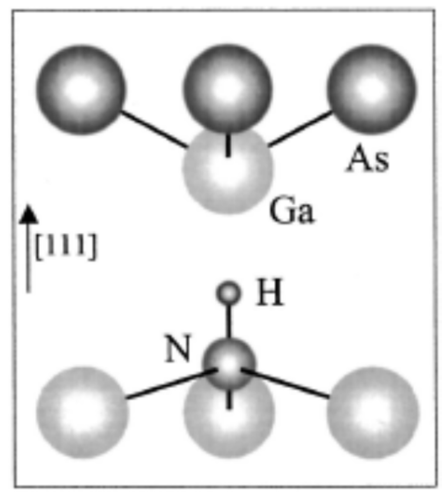
M. Wiemer, V. Sabnis, H. Yuen, *Proc. SPIE*, 2011, **8108**, 810804.

Hydrogenation Has Shown Passivation of Substitutional Nitrogen



Polimeni *et a*l. Semi. Sci Tech. **797,** (2002)

- Restoration of original band gap
- Process reversible through RTA
- Favorable due to small, electronegative nitrogen



Bissiri *et al*. Phys. Rev. B. **65**, 235210 (2002)

Samples Used

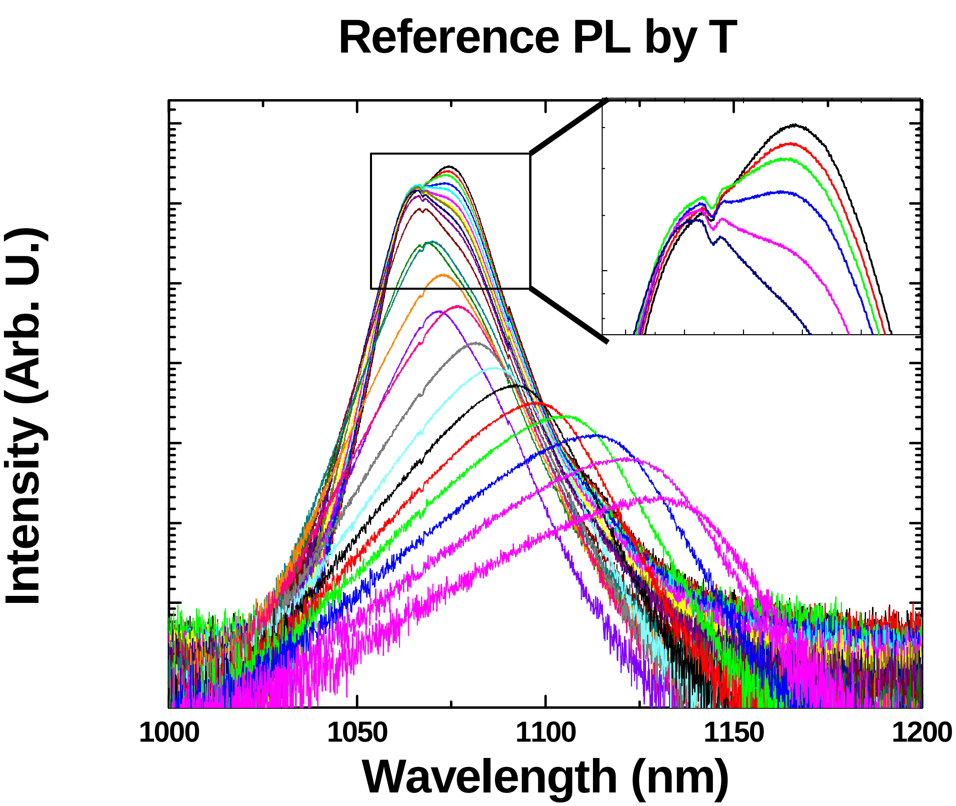
Bulk $Ga_{0.91}In_{0.09}N_{0.028}As_{0.972}$ annealed at 800°C

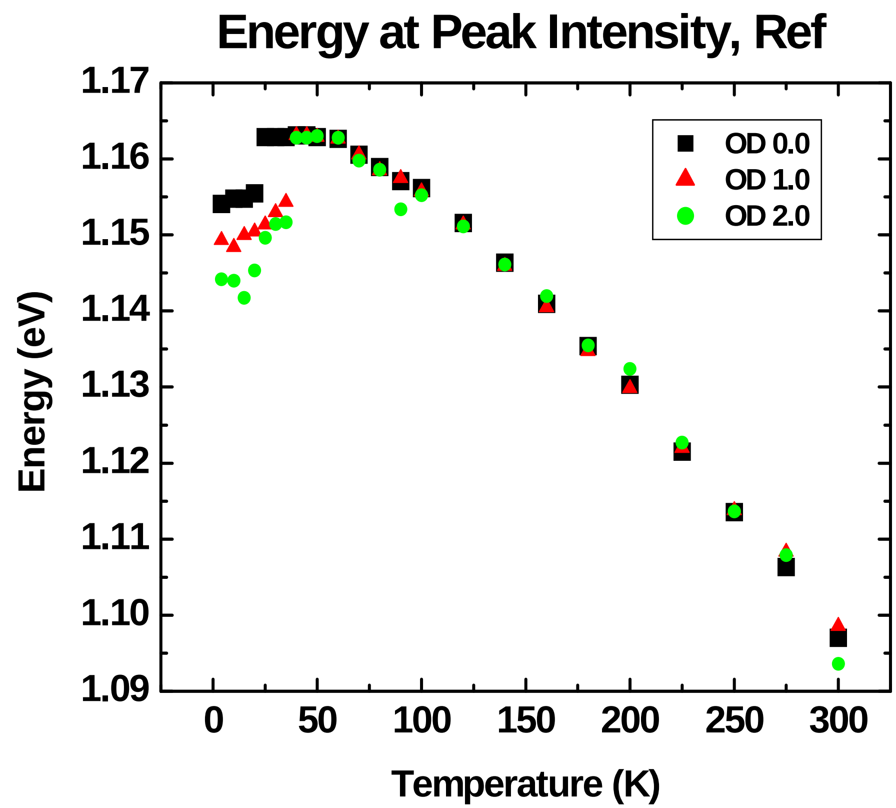
UV-Activated hydrogenation, 2 μm penetration

Three samples:

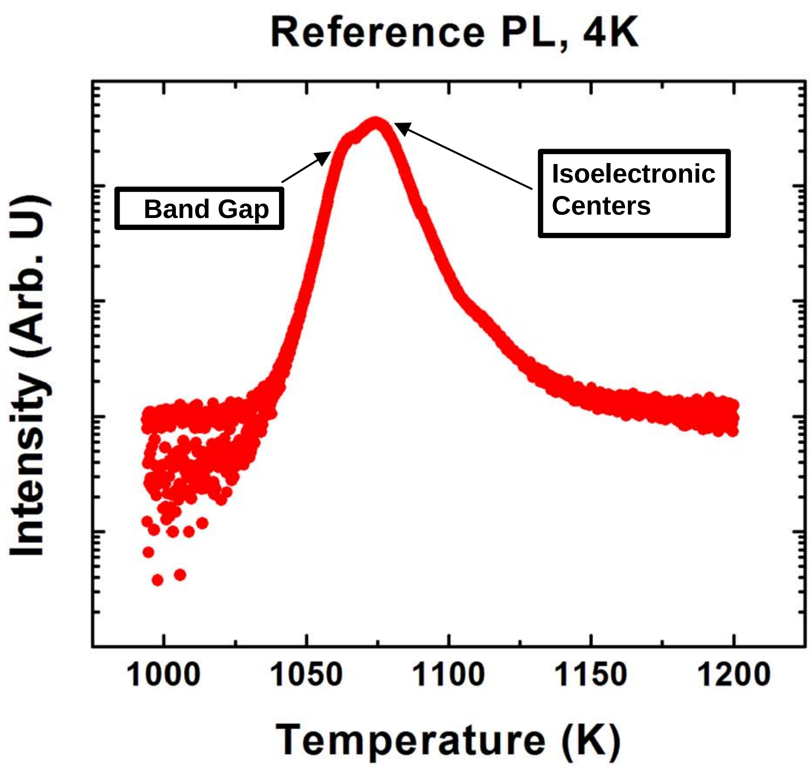
- Reference – Unhydrogenated
- #9 – Intermediate hydrogenation
- #8 – High hydrogenation

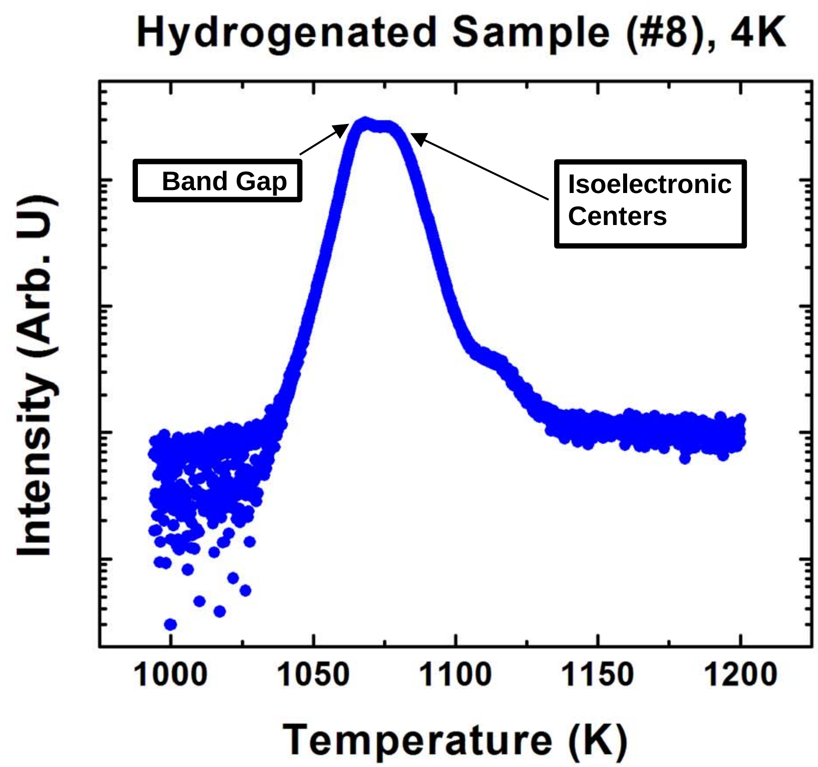
Isoelectronic Effects Remain After Annealing in Reference





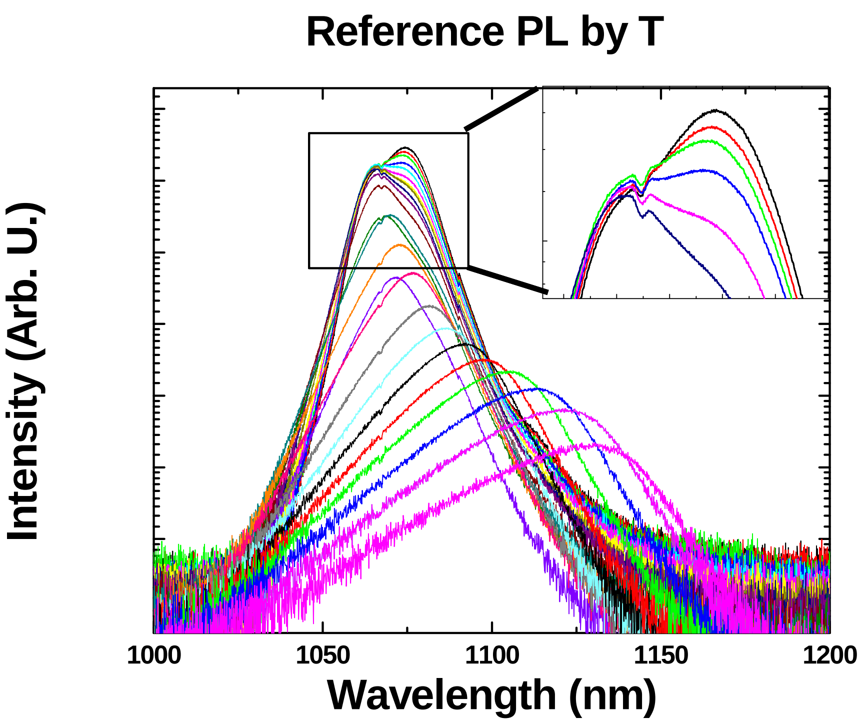
Hydrogenation of GaInNAs Mitigates Isoelectronic Effects, Retains Band Gap

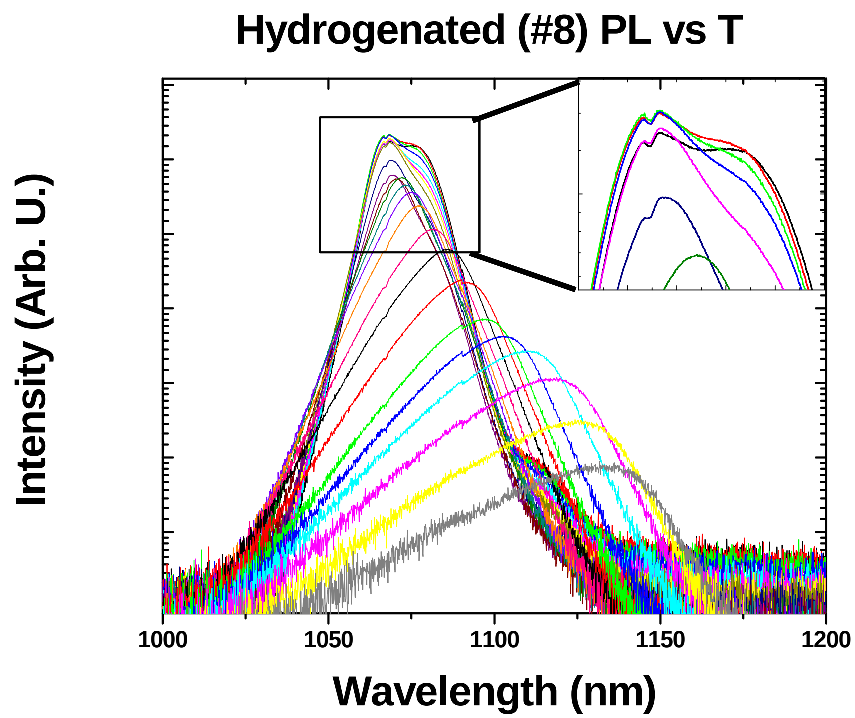




Reduction in intensity of low-energy “shoulder”

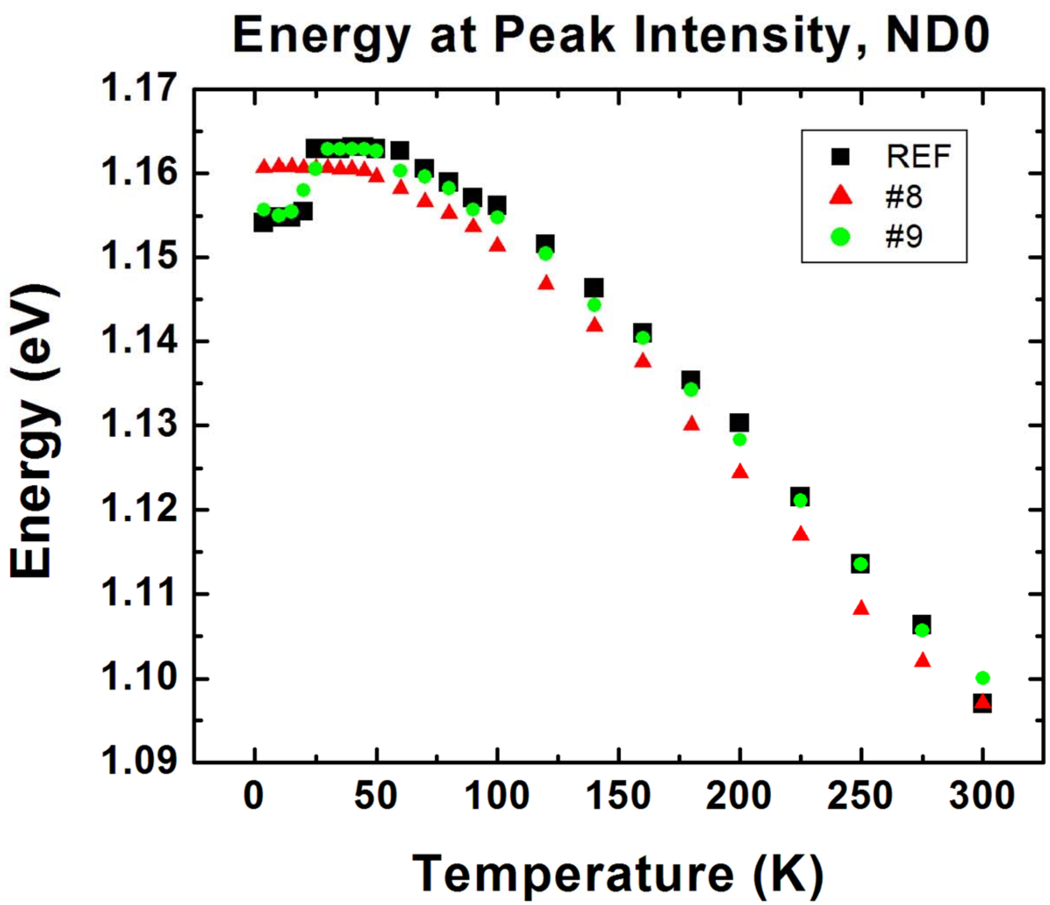
Hydrogenation of GaInNAs Mitigates Isoelectronic Effects, Retains Band Gap





Peak now has reduced 's-shape' with temperature

Hydrogenation of GaInNAs Mitigates Isoelectronic Effects, Retains Band Gap



- Samples correlate well at high temp
- Isoelectronic states quenched under high light intensity

Summary

- The hydrogenated samples exhibit lessened effects of isoelectronic centers while retaining substitutional nitrogen
- Further studies will be conducted to verify which N-H complexes are forming and to analyze their effect on the band structure and carriers.

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