Optical Study of Hydrogen Diffusion and Hydrogenation-Driven Bandgap Engineering in InN Nanowires

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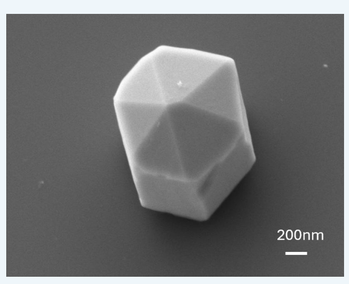
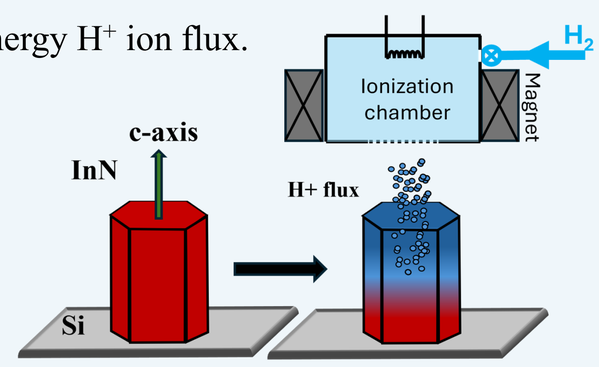
Introduction

- Indium nitride (InN) is a narrow-bandgap (~ 0.65 eV) III-nitride semiconductor promising for infrared optoelectronics.
- Post-growth hydrogenation provides an effective method for modifying the electronic structure and tuning the bandgap of InN.
- In this work, InN nanowires are investigated using micro-photoluminescence (μ-PL) spectroscopy.
- Particular emphasis is placed on understanding hydrogen diffusion and bandgap engineering in InN nanowires.

Growth and Hydrogenation

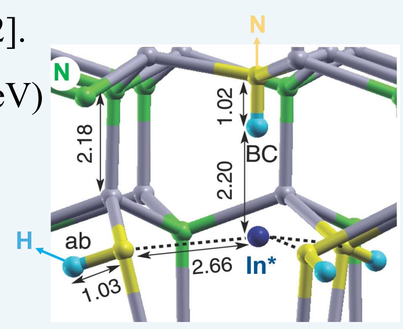
- InN nanowires grown on Si(111) along wurtzite c-axis [1].
- Hydrogenation using low-energy H^+ ion flux.

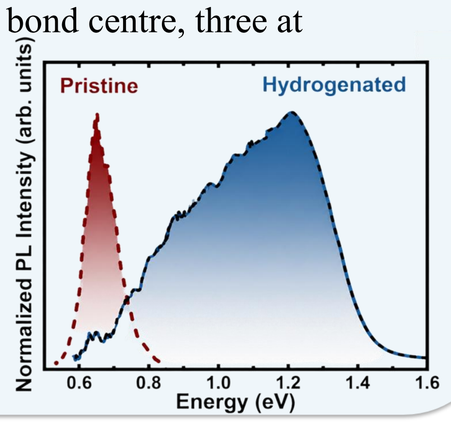




Effect of Hydrogenation

- In^* complex in InN with four H atoms (one at the bond centre, three at antibonding sites) [2].
- PL blue shift (~0.5 eV)
- Bandgap opening.
- Band filling.

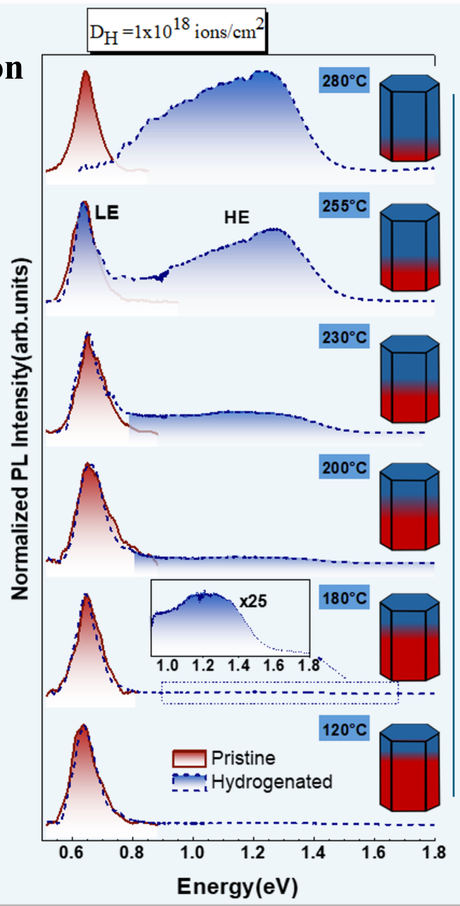




Hydrogen Diffusion study

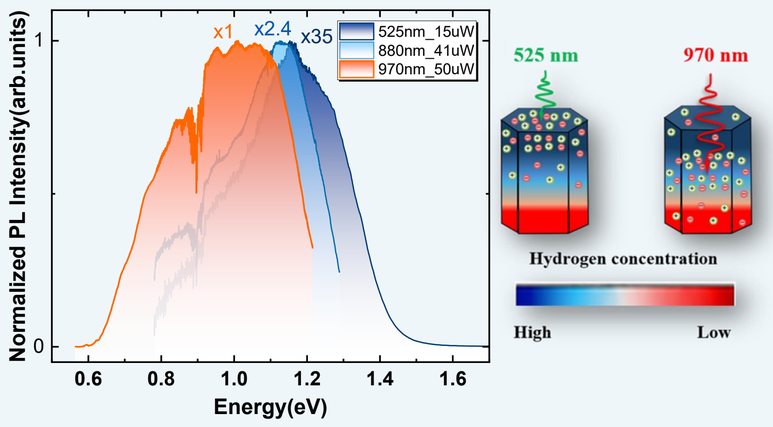
Influence of Hydrogenation Temperature

- Increasing hydrogenation temperature enhances hydrogen incorporation and diffusion [3].
- A progressive increase of the high-energy peak PL intensity is observed with increasing temperature.



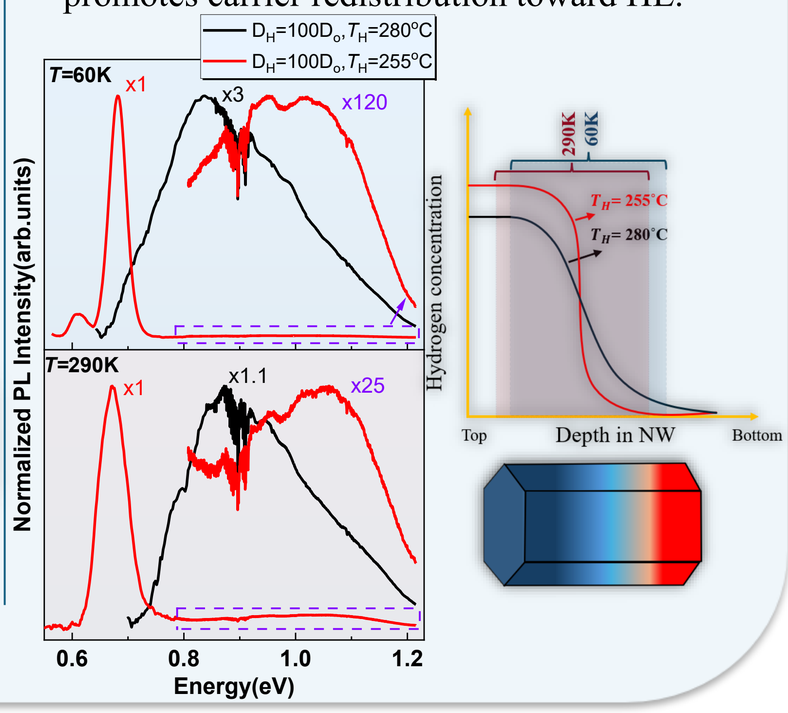
Excitation-Wavelength-Dependent μ-PL

- PL shifts to lower energy with increasing excitation wavelength.
- Longer wavelengths probe deeper, H-poor regions of the nanowire, revealing the depth-dependent hydrogen distribution in the nanowire.



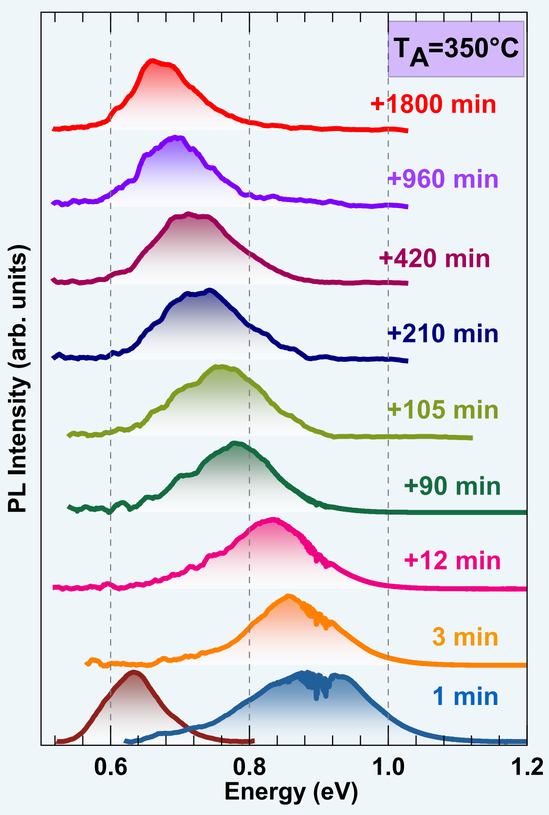
Temperature-dependent μ-PL

- Increasing temperature reduces PL intensity and promotes carrier redistribution toward HE.

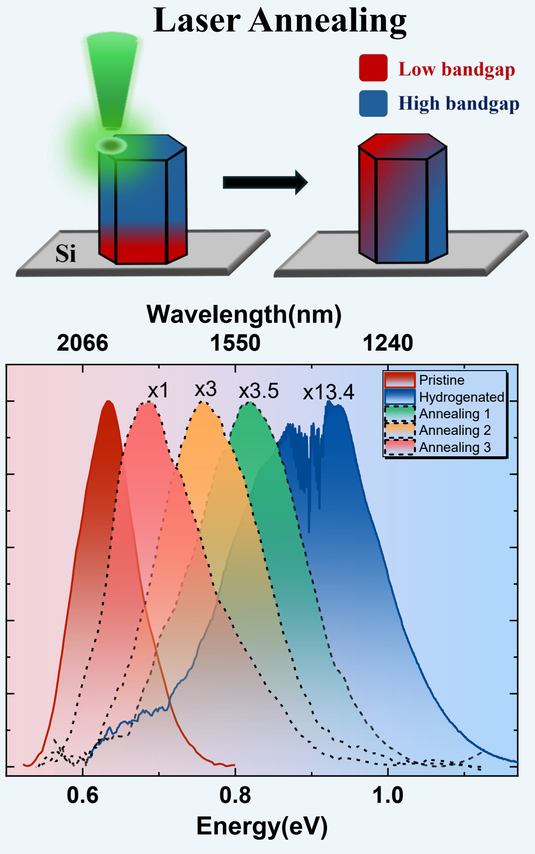


Post-hydrogenation Annealing

Thermal Annealing



Laser Annealing



Conclusions

- Hydrogenation increases the bandgap of InN nanowires through band anticrossing and can be partially reversed by thermal/laser annealing.
- PL excitation wavelength controls the probed region, revealing the hydrogen distribution along the nanowire.
- Temperature-dependent PL studies demonstrate carrier diffusion and localization in regions with different hydrogen concentrations.
- These results demonstrate precise and reversible bandgap engineering in InN nanowires, providing a promising approach for nanoscale optoelectronic and quantum applications.

References

[1] S. Zhao et al., Nano Letters, 12 (2012).

[2] G. Pettinari et al., Adv. Funct. Mater., 25, (2015).

[3] Tahir, M. *et al*. in preparation.

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