

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

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Hydrogen incorporation in III-nitride semiconductors is a powerful tool for precise tuning of their electronic and optical properties.¹ Among III-nitride semiconductors, InN is receiving considerable attention due to its narrow bandgap and high electron mobility, making it suitable for use in optoelectronic devices. In this work, we present reversible bandgap engineering in Mg-doped InN nanowires (NWs) through the combined use of low-energy hydrogen ion irradiation and annealing. Hydrogen incorporation produces a photoluminescence (PL) peak shift of ~ 0.4 eV, due to bandfilling effects and bandgap opening, through the formation of hydrogen-related complexes as previously shown Young Innovation in epilayers.² Subsequent thermal or laser annealing enables partial or total hydrogen removal, providing reversible control over the NW optical properties.

To investigate and optimize this bandgap engineering strategy, pristine Mg-doped InN NWs grown on Si are subjected to varying hydrogenation doses and temperatures. μ -PL measurements as a function of excitation wavelengths and temperature are performed on single NWs to directly probe the hydrogen depth profile and bandgap changes. μ -PL with excitation wavelengths of different penetration depths provides an optical and non-destructive method to estimate the hydrogen depth profile in InN NWs.³ NWs hydrogenated at the same hydrogen dose but at different temperatures exhibit different hydrogen depth profiles. Hydrogenation at low temperatures produces a steep hydrogen concentration profile, whereas hydrogenation at high temperatures gives a broad hydrogen profile. The steep hydrogen profile achieved at lower hydrogenation temperatures is particularly attractive for realizing quantum-confined structures through local bandgap modulation, as previously obtained in GaAsN⁴ and never attempted in InN.

These results demonstrate that the combination of post-growth hydrogenation and post-hydrogenation annealing provides a versatile platform for reversible bandgap engineering in InN NWs and a novel methodology for probing purely optically the hydrogen diffusion properties, opening new opportunities for quantum-confined nanostructures and wavelength-tunable optoelectronic devices.

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2. Pettinari, G. *et al.* Genesis of 'solitary Cations' Induced by Atomic Hydrogen. *Adv. Funct. Mater.* **25**, 5353–5359 (2015).
3. Tahir, M. *et al.* Investigation of hydrogen diffusion in InN Nanowires through bandgap variation. in preparation.
4. Trotta, R. *et al.* Hydrogen diffusion in GaAs_{1-x}N_x. *Phys. Rev. B Condens. Matter Mater. Phys.* **80**, (2009).