Epitaxial Growth of InGaN Nanowire Arrays for Light Emitting Diodes

*Christopher Hahn, Zhaoyu Zhang, Anthony Fu, Cheng Hao Wu, Yun Jeong Hwang, Daniel J. Gargas and Peidong Yang**

Department of Chemistry, University of California, Berkeley, California 94720, and Materials Sciences Division, Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley California 94720

*Address correspondence to p_yang@berkeley.edu

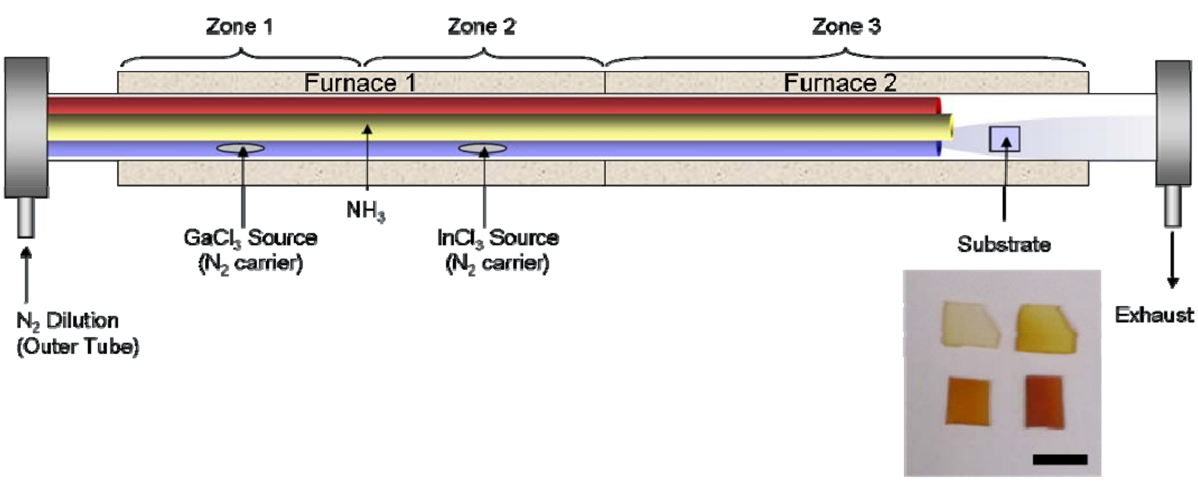

Figure S1. Schematic of the three-zone HCVD system. This system has three 1/4-inch quartz tubes housed in a 1-inch quartz tube situated within two furnaces equipped with three independently controlled thermocouples (zones 1-3). The system supplies $GaCl_3$ (N_2 carrier), $InCl_3$ (N_2 carrier), and

NH_3 precursors through two inner tubes (blue, yellow). $GaCl_3$ and $InCl_3$ were placed in the same inner tube and spaced apart such that the vapor pressures of each precursor could be independently controlled in zone 1 ($GaCl_3$) and zone 2 ($InCl_3$). N_2 gas also flows through the outer tube during the reaction. The photograph in the inset shows four homogeneous samples of different indium compositions. Scale bar = 6 mm.

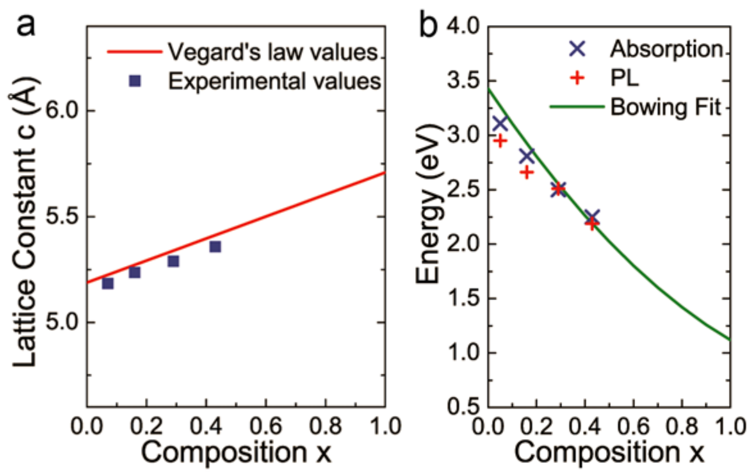

Figure S2. Vegard's law and energy correlations for $In_xGa_{1-x}N$ nanowire arrays. (a) The (002) wurtzite peak of the XRD patterns was analyzed to obtain the lattice constant *c* and was correlated to its EDS composition. The straight line represents the Vegard's law correlation between GaN (c = 5.188 Å) and InN (c = 5.709 Å). (b) The square of absorption plots was linearly extrapolated to determine the bandgap energy of different compositions. The black bowing line represents the fitting equation used by Kuykendall *et al.* Corresponding PL peak energies show a slight Stokes shift in emission from the band gap.

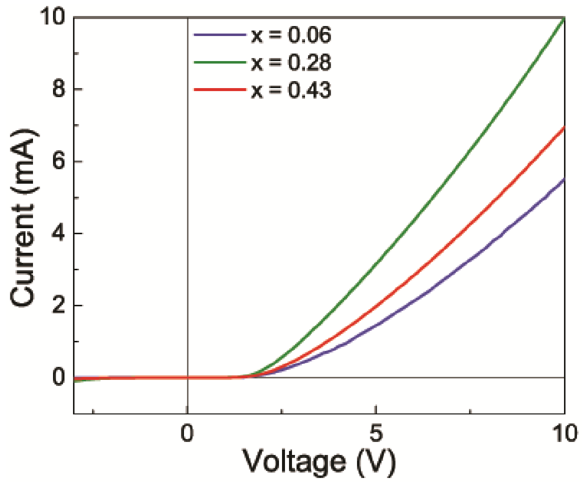

Figure S3. Overlaid I-V curves for x = 0.06, x = 0.28, and x = 0.43 showing rectification.

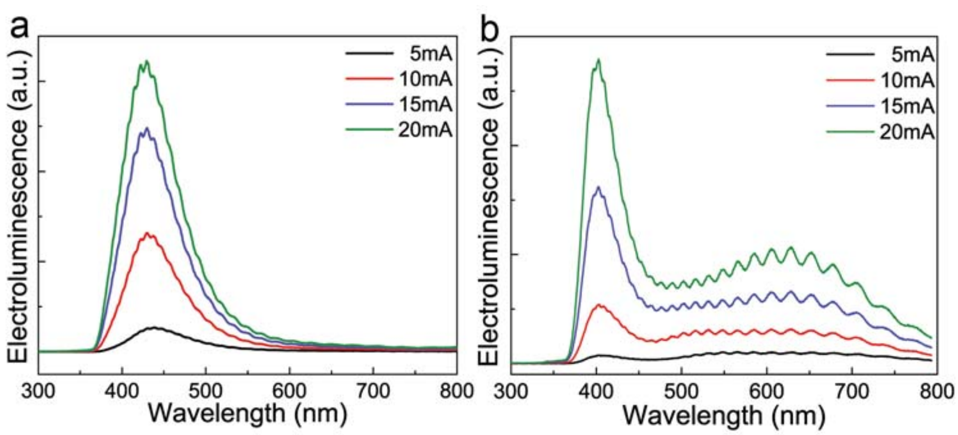

Figure S4. The emission's dependence on current for the (a) x = 0.06 and (b) x = 0.43 LED devices. (a) The spectra for the x = 0.06 device show an 8 nm blue shift with increasing injection current. (b) The spectra for the x = 0.43 device show no noticeable blue shift with increasing injection current.

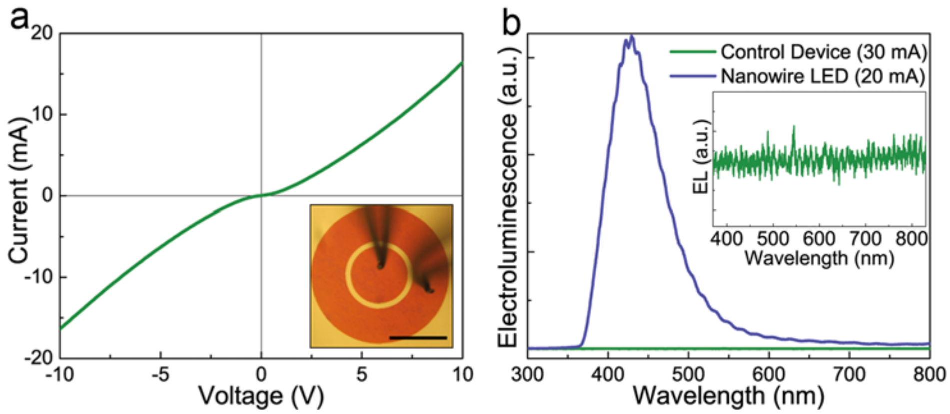

Figure S5. Control device showing no emission from the substrate. Ni/Au (20 nm / 20 nm) contacts were deposited on the p-GaN substrate in a geometry that mimicked the current injection geometry used in the LED devices. (a) I-V curve of the control device. Inset: Photograph of the measured device. Scale bar = 250 µm. (b) Corresponding spectrum (green) of the device sourced with 30 mA of injection current showing no emission from the p-GaN/undoped-GaN junction. For comparison, the EL spectrum (blue) from the forward-biased x = 0.06 LED device is shown with the control device's spectrum. Inset is a close-up view of the control device's spectrum showing only background noise.