SUPPORTING INFORMATION

Axial p-n junction design and characterization for InP nanowire array solar cells

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1. Transmission electron microscopy

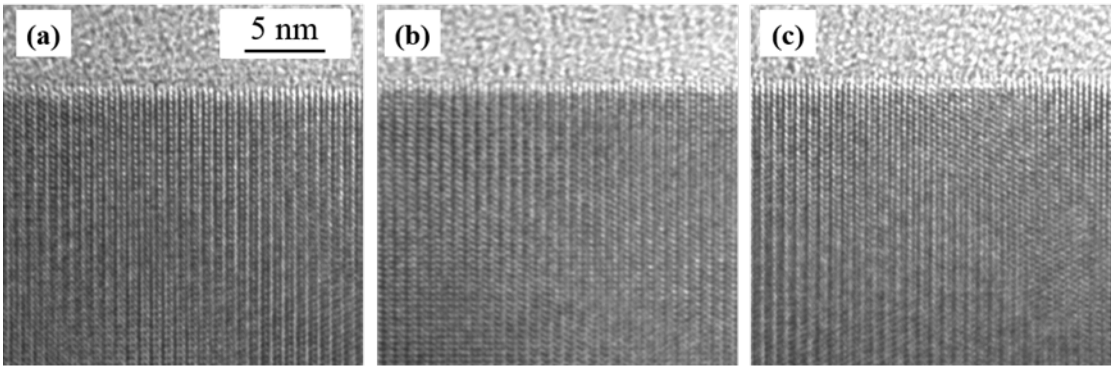

FIGURE S1 High-resolution TEM images taken along [-2110] zone axis from (a) p-doped, (b) undoped, (c) n-doped regions in a typical Sample II nanowire (NW).

Figure S1 shows three typical high-resolution TEM images from p-doped, undoped and n-doped regions in a typical Sample II NW. The NW has a pure wurtzite (WZ) crystal phase with no stacking faults being found along the NW. Pure WZ crystal phase has been confirmed for Sample I and Sample III as well.

2. Optical properties

2.1 Gaussian fitting for photoluminescence spectra

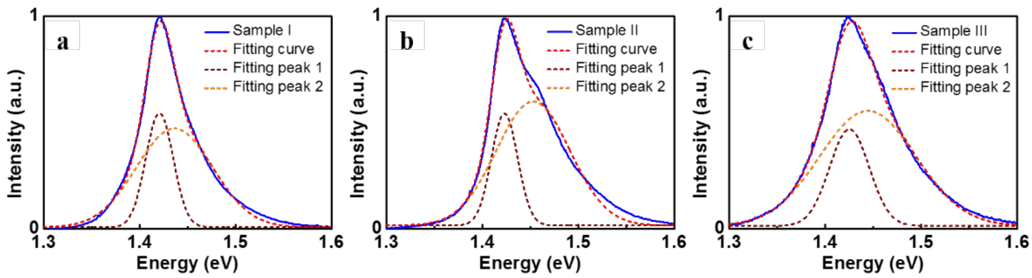

FIGURE S2 Normalized PL spectra and their fitting with two Gaussian curves from (a) Sample I, (b) Sample II and (c) Sample III.

2.2 Internal quantum efficiency

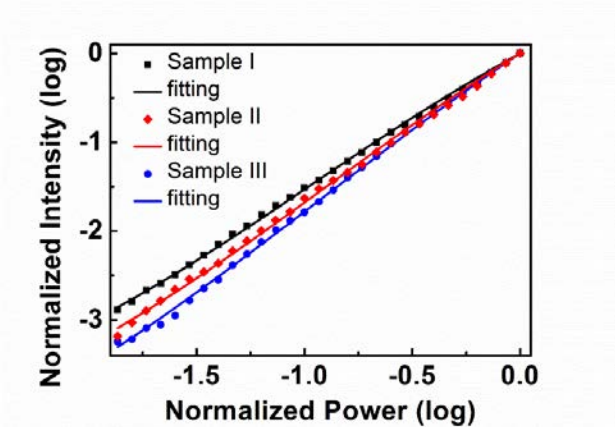

FIGURE S3 Integrated PL intensity as a function of excitation power from typical NWs of Sample I, II and III. The data points are experimental data and the curves are provided from fitting the experimental data using a simplified rate equation.

Figure S3 shows the integrated PL integrated intensity as a function of excitation power. By fitting these data using Equation S1,[1] the IQE can be extracted according to $\mathrm{IQE} = n_{rad}/n_o$, as shown in Figure 2C in the main text.

$$\mathrm{I(P)} \propto n_{rad} = \log\left(\frac{1+n_D}{n_0}\right) - \log\left(\frac{1+n_0+n_D}{n_0}\right) + n_0 \qquad \text{(S1)}$$

n_{rad} is the carrier density involved in radiative recombination, n_0 is the initial carrier density that is proportional to incident laser power and n_D is the doping density in unit of $1/\mathrm{B}\tau_{nr}$, where B is the radiative recombination rate constant and τ_{nr} is the nonradiative recombination lifetime.

3. Simulation

3.1 Casino simulation

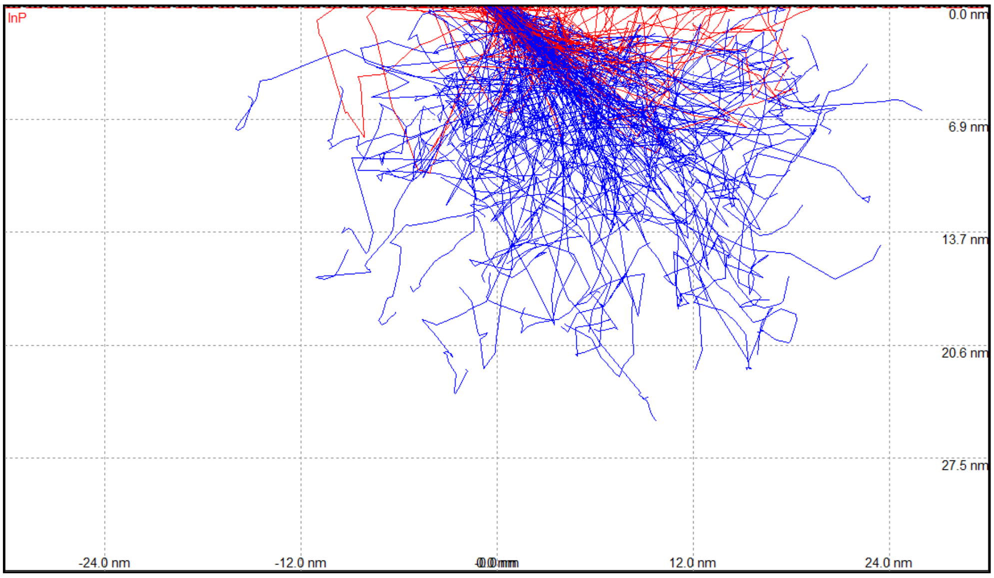

FIGURE S4 Scale drawing of electron trajectories in InP at 1 kV.

Figure S4 shows the simulated electron trajectories in InP using Casino simulation. The maximum penetration depth of electrons in the sample is calculated to be < 30 nm at 1 kV, indicating that the EBIC signal only originated from one single NW a time.

3.2 COMSOL simulation

The electrical modelling is based on drift-diffusion model and was conducted with COMSOL Multiphysics to simultaneously solve a Poisson's equation for the electric potential, and two continuity equations for electrons and holes, respectively. The solution of Poisson's equation determines the distribution of the electric field inside the NWs, and the continuity equations describe how carriers are transported in response to the field. The details of solar cell device simulation method can be found in Ref [2].

REFERENCES

[1] Wang F, Gao Q, Peng K, Li Z, Li Z, Guo Y, et al. Spatially Resolved Doping Concentration and Nonradiative Lifetime Profiles in Single Si-Doped InP Nanowires Using Photoluminescence Mapping. Nano Lett 2015;15:3017-23.

[2] Li Z, Wenas YC, Fu L, Mokkapati S, Tan HH, Jagadish C. Influence of Electrical Design on Core-Shell GaAs Nanowire Array Solar Cells. IEEE J Photovolt 2015;5:854-64.