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InGaN/GaN Nanostructures for High Efficiency Solar Cells

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The InGaN/GaN material system is a promising candidate for the growth of highly efficient solar cells. With direct nanowire growth on silicon, superior light trapping properties at low costs are possible. With the introduction of quantum well superlattices, intermediate states well below the bandgap of GaN enable the absorption of lower energy photons that would otherwise pass through the structure. In this work, we investigate the potential of InGaN/GaN nanowire heterostructures as candidates for novel solar cell designs on silicon via a combination of optical/electrical characterization and computer-aided device simulation.

The InGaN/GaN nanowire heterostructures were grown via radio frequency plasma-assisted molecular beam epitaxy (MBE) on Si (111) [1]. Nanowires were grown as axially oriented p-i-n junctions with p-GaN and n-GaN regions as the emitter and base, respectively. Ten InGaN/GaN QD/s form the intrinsic region.

The device is modelled as a bulk structure with ten quantum wells as the nanowire dimensions approach 100 nm. The large diameter of the QDs (˜50 nm) permits the treatment of the quantum dots as quantum wells, since confinement is primarily along the growth axis. Confined states are solved via the Schrödinger equation for ten coupled quantum wells using Crosslight Apsys for various coupling regimes.

Current-voltage measurements, photoluminescence and electroluminescence spectroscopy of the nanowire solar cells were performed. External quantum efficiency (EQE) was measured as a function of increasing beam intensity and wavelength. The presence of non-negligible current generated at wavelengths below the bandgap of GaN, suggest photons are sequentially absorbed in the InGaN QDs and into the GaN conduction band for collection. This fulfills one of the requirements of an intermediate band solar cell. Future directions and design possibilities are discussed.

Author: CHERITON, Ross (University of Ottawa)

Co-authors: Dr HINZER, Karin (University of Ottawa); Mr SADAF, Sharif (McGill University); Dr MI, Zetian (McGill Unversity)

Presenter: CHERITON, Ross (University of Ottawa)

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