Multilevel intermediate-band solar cells based on III-Nitrides

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The concept of intermediate-band solar cells (IBSC) is promising to overcome the intrinsic Shockley-Queisser limit via IB optical transitions. In 1997, Luque and Marti predicated a 63% conversion efficiency in IBSCs relative to 41% for conventional single-junction cells under full concentration. An IB solar cell consists of an IB material sandwiched between two orinary *n*- and *p*-type semiconductors, in which the sub-bandgap-energy photons are absorbed through the transitions from the valance band to the IB, adding up to the photovoltaic current, while maintaining a high voltage. Encouraging results have been demonstrated for IBSCs using InAs/GaAs quantum dots (QDs), highly mismatched alloys, or impurities. ***However***, all these IBSCs exhibit the single-IB absorption, a low open-circuit voltage (V_{oc}), and a small coverage of the solar spectrum. Superior to conventional photovoltaic materials, III-Nitride semiconductor $In_xGa_{1-x}N$ is the only system that can provide the perfect match to the solar spectrum due to a wide adjustable direct bandgaps. Nevertheless, poor-quality and difficulty in *p*-type doping for In-rich InGaN hinders the development of InGaN-based solar cells.[1]

In this article, we report ***the first demonstration of*** the ***multilevel IBSC*** by using III-Nitride semiconductors. A strain-modulated quantum structure is proposed as the IB materials embedded inside one *p*-*n* junction. The absorption wavelength is extended from ultraviolet approaching as long as near-infrared region, covering almost all the strong luminescence in the solar spectrum. The IBs transitions are experimentally demonstrated by external quantum efficiency (EQE) and cathodoluminescence (CL) measurements, and further confirmed using a two-photon excitation process (TPE) at room temperature.

This novel device concept avoids the difficulties in the In-rich $In_xGa_{1-x}N$ film. Instead, the unique wide bandgaps are utilized as the host material. More importantly, the experimental demonstration for the first time of the multilevel IBs opens up an interesting opportunity for the development of IBSCs in the photovoltaic field.

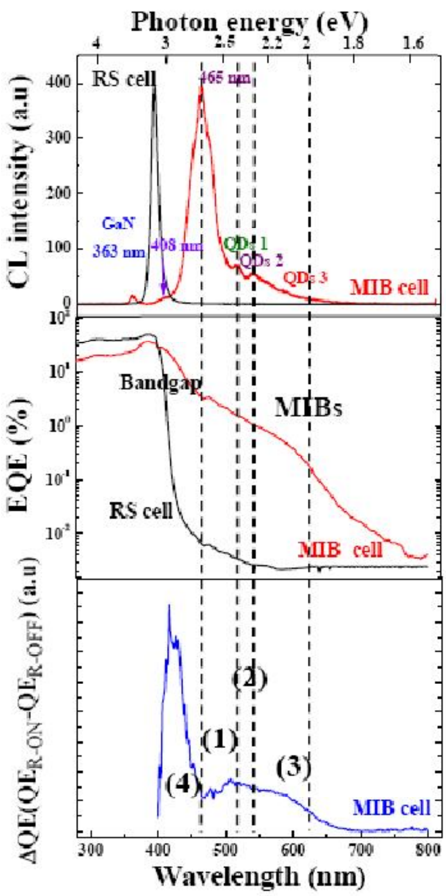

Figure. CL spectra, EQE, and TPE spectra for the MIB cell and reference cell.

References

1. Sang, et al. *Appl. Phys. Lett.* **99**, 161109 (2011)