

Metamorphic 1.7 eV InGaP front- and rear-junction solar cells with high open- circuit voltage

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Abstract—We present a materials and device study on metamorphic 1.7 eV $\text{In}_{0.63}\text{Ga}_{0.37}\text{P}$ (MM InGaP) grown by molecular beam epitaxy (MBE). Rapid thermal annealing (RTA) greatly enhanced time-resolved photoluminescence lifetimes (τ_{TRPL}) of both MM p- and n-InGaP double heterostructures (DHs), suggesting the potential for high-performance MM 1.7 eV InGaP solar cells. MM InGaP front-junction (FJ) cells show high peak internal quantum efficiency (IQE), while MM rear-heterojunction (RHJ) InGaP cells show low $W_{\text{OC}} = E_g/q \cdot V_{\text{OC}}$ values.

Keywords—MM materials, 1.7 eV InGaP, RTA, TRPL lifetime, MM RHJ cells

MM III-V junctions are highly promising for integration in high-efficiency multijunction solar cells, which currently have an efficiency record exceeding 47%. [1] MM materials are also important for tandem solar cells with internally lattice-matched 1.7 eV MM InGaP and 1.15 eV MM $\text{In}_{0.15}\text{Ga}_{0.85}\text{As}$ junctions, which have the potential for 37% efficiency under the AM1.5G spectrum due to nearly optimal spectral matching. [2] In addition, such a tandem could be lifted off as a flexible, spectrally matched tandem cell, and could even allow the possibility of reusing both the bulk GaAs substrate and $\text{In}_x\text{Ga}_{1-x}\text{As}$ graded buffer (InGaAs GB).

MBE-grown InGaP materials show relatively poor device performance compared with metal-organic vapor phase epitaxy (MOVPE)-grown materials due to a higher concentration of point defects caused by lower growth temperature (460-500°C for MBE vs >600°C for MOVPE). Our previous work showed improvement of MBE-grown materials by eliminating the point defects through RTA. [3, 4]

In this work, we grew MM p- and n-InGaP DHs on optimized InGaAs GBs, which achieved low threading dislocation density (TDD) comparable to the best-reported values. [5] We describe RTA effects on τ_{TRPL} of MM InGaP DHs. They showed a strong improvement of τ_{TRPL} by RTA, and we observed longer τ_{TRPL} compared with lattice-matched (LM) InGaP DHs grown by MBE with the same doping and thickness, indicating great promise for high V_{OC} . [3] We designed and grew MM FJ InGaP cells with a lightly doped MM p-InGaP base as shown in Fig. 1 (a). Lastly, we present MM RHJ InGaP cells with MM n-InGaP emitter (Fig. 1 (b)). LIV parameters of both

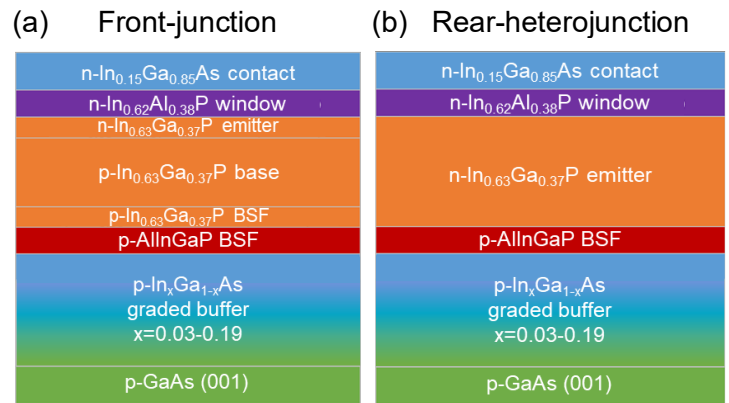


Fig. 1. Schematics of growth structures for (a) 1.7 eV InGaP FJ cells and (b) 1.7 eV InGaP RHJ cells

FJ and RHJ cells were improved after RTA. MM FJ cells have better carrier collection due to greater diffusion length compared to MM RHJ cells. However, MM FJ cells have higher W_{OC} than MM RHJ cells due to stronger non-radiative recombination. With further optimization, both FJ and RHJ MM InGaP cells are promising for high-efficiency spectrally matched tandem solar cells.

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