Area3, III-V Compound Semiconductor and Concentrator and Space PV Technologies

**STEP-TUNNEL InGaAs/GaAsP QUANTUM WELL SUPERLATTICE FOR 1.15-eV MIDDLE CELL IN 4-JUNCTION SOLAR CELL**

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As a structure to realize 50% efficiency, 4-junction cell has been proposed with the subcell bandgaps of 1.99/1.51/1.15/0.66 eV from the top to the bottom [1]. The top two cells consisting of AlInGaP and AlGaAs bulk, respectively, can be grown epitaxially on a Ge bottom cell, whereas the 3rd cell with 1.15 eV bandgap is the bottleneck for the realization of the lattice-matched 4-junction cell. The fabrication of lattice-matched cell is expected to be easier than the case of preceding 4-junction cells by wafer bonding [2] and inverse metamorphic (IMM) growth [3]. Using InGaAsP alloys which can be grown with metal-organic vapor-phase epitaxy (MOVPE) with high quality and productivity, strain-balanced InGaAs/GaAsP quantum well superlattice has been implemented in a GaAs middle cell and the absorption edge was extended to 1.2 eV to serve as the 2nd cell of a 3-junction cell [4]. Further extension of the absorption edge to 1.15 eV was also successful using an InGaAs/GaAsP quantum well with graded-content interlayers [5]. This structure, having a period of 33.2 nm, becomes too thick if it is implemented up to 100 periods and internal electric field is insufficient for carrier collection at operation-point voltage.

We here attempted to improve the step-tunnel structure [4], which is mostly current-matching for a 3-junction cell, and obtained a 1.15-eV cell with superior carrier collection and much reduced thickness than the previous structure [5]. In order to obtain an effective bandgap of 1.15 eV, the In₀.₃GaAs well was widened from 3.5 to 6.3 nm, a similar well thickness to the previous structure [5], which necessitated stronger strain compensation. We therefore modified the interlayer from GaAs to GaAsF₀.₀₈ so that the tensile strain in both the interlayer and the GaAsP₀.₄ barrier can compensate the compressive strain of the well. A period in the new structure is 22.3 nm, which is 2/3 of the previous structure [5]. Especially, the thin barrier facilitated tunneling-assisted carrier transport and improved carrier collection efficiency. As a result, with the same 70 wells implemented in a GaAs single-junction cell, significant current enhancement was obtained for the new structure under a 800-nm filter which mimics the situation under the 2nd subcell. Further improvement in the management of hetero-interfaces during MOVPE process will enhance fill factor and will open a way to the realization of quantum-well-enhanced 4 junction cells.

Reference

![Figure 1: Band alignment in (a) the previous composition-graded quantum wells and (b) the step-tunnel superlattice.](image)

![Figure 2: Performance of the GaAs single-junction cells with the quantum well superlattice structures in Fig. 1.](image)