MOVPE-grown pseudomorphic GaAsP/(100)GaAs heterostructures for fabrication of 1.7 eV top junction in 4-terminal tandem III-V/Si solar cells

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Multi-junction (tandem) solar cells in the form of monolithically stacked cells, each absorbing a different interval of the solar spectrum allow to reach external quantum efficiencies well beyond the Shockley-Queisser limit for single-junction solar cells [1]. Tandem solar cells based on a crystalline Silicon (Si) bottom junction are very attractive due to the relative low cost of Si; a dual-junction cell with a 1.7 eV top junction based on III-V semiconductors (e.g. GaAsP) and a Si (1.12 eV) bottom cell raises the theoretical conversion efficiency of the tandem cell up to ~38%. However, structural constrains limit the monolithic growth of III-V compounds on Si and performances of such tandem cells remain far from theoretical figures.

Recently, four-terminal tandem cells composed of a thin GaAs cell mechanically stacked onto an interdigitated back contact Si cell with a glass interlayer have shown efficiency up to 32.6% [2]. The advantage of such approach is that the high-quality III-V cell could be monolithically grown on GaAs. Although using GaAs wafers in the epitaxy of the III-V top cell increases production costs, chemical lift-off of the cell from the underlying substrate and multiple re-utilization of the latter have been demonstrated in the literature [3], as a viable strategy to keep production costs low.

We report on metalorganic vapor phase epitaxy (MOVPE) and structural/optical properties of pseudomorphic GaAsP-based heterostructures on (100)GaAs, with the aim to fabricate a high efficiency 1.7 eV top cell for utilization within a stacked 4-terminal tandem III-V/Si solar cell. Despite GaAsP epilayers grown by MOVPE are commonly used in the fabrication of (In)GaAs-based solar cells and laser diodes, not so much has been reported to date on the growth and structural (strain, plastic relaxation), radiative (photoluminescence, PL) properties of tensile-strained GaAsP epilayers on GaAs. P incorporation into the GaAsP alloys has been determined along with the solid-vapor distribution curve as function of growth temperature by employing tertiarybutyl-arsine and tertiarybutyl-phosphine as As and P precursors respectively, in combination with trimethyl-gallium. Analysis of as-grown samples by high-resolution X-ray diffraction allowed to estimate the elastic strain state of the material and evidenced the onset of plastic deformation, which turned out to agree well with People-Bean relaxation model (values of critical thickness turned out to range within few-hundreds nanometer) [4]. Low temperature PL spectra further showed a dominant near band-edge emission for most GaAsP samples. Examples of high quality step-graded GaAsP buffer layers on (100)GaAs and lift-off through introduction of an AlAs sacrificial layer are also reported.

References

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