

GaInNAsSb-based Four Junction Solar Cells on GaAs and Ge Substrates

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1. Introduction

Solar cells with four or more junctions have potential to reach a conversion efficiency level beyond 46% [1]. To this end, multijunction solar cells incorporating dilute nitride junctions (i.e. GaInNAsSb) have emerged as a promising lattice-matched technology approach. We report on the progress in the development of four junction (4J) cells incorporating GaInNAsSb absorbers grown on GaAs and Ge substrates. The cells are fabricated by molecular beam epitaxy (MBE). The two designs target either high current (4J_{HC}) or high voltage (4J_{HV}) optimization strategy. Ideally, they should have similar efficiency peaking at over 47% under high concentration.

2. Experiments and results

The band gaps for sub-cells corresponding to the 4J_{HC} design on Ge are 0.7 eV, 1.1 eV, 1.4 eV and 1.9 eV. The corresponding band gaps for the 4J_{HV} design on GaAs substrate are 0.9 eV, 1.2 eV, 1.4 eV and 1.9 eV. The calculated short circuit current density values (J_{sc}) for sharing the photons equally between each sub-cell are ~ 14 mA/cm² and ~ 13 mA/cm², respectively at AM1.5D (1000 W/m²) one sun. Fundamentally, the 4J_{HV} approach provides 0.3 V higher open circuit voltage (V_{oc}) when compared to 4J_{HC}. On the other hand, the Ge-based design generates more current (~ 1 mA/cm² at one sun). The design J_{sc} values were 13 mA/cm² and 12 mA/cm² for the 4J cells, respectively. This design ensures current over-generation for bottom cells, and effectively a higher fill factor and power than equal photon sharing between the junctions would give.

The experimental cells were first assessed under AM1.5D one sun illumination, for which they exhibited J_{sc} values of 10.9 mA/cm² for 4J_{HC} and 10.6 mA/cm² for 4J_{HV}. For both approaches, the J_{sc} was limited by the bottom junctions, which also explains the fill factors being lower than ideal (see Fig. 1). Fig. 1 reveals also the characteristics for 100 suns concentrated illumination (AM1.5D, 1000 W/m²). A linear dependence of the J_{sc} vs. concentration is observed for all the cells. The 4J_{HC} shows only marginal improvement of V_{oc} when compared to a reference 3J cell with Ge bottom junction, while the 4J_{HV} shows larger increase of V_{oc} (0.6 V). The 4J_{HV} solar cell exhibits an efficiency of 38%, while the 4J_{HC} has clearly lower efficiency peaking at 22%. We note that Ge-based cells are in much early optimization stage compared to GaAs-based devices. The reasons for the performance degradation compared to ideal scenario and future prospects will be discussed.

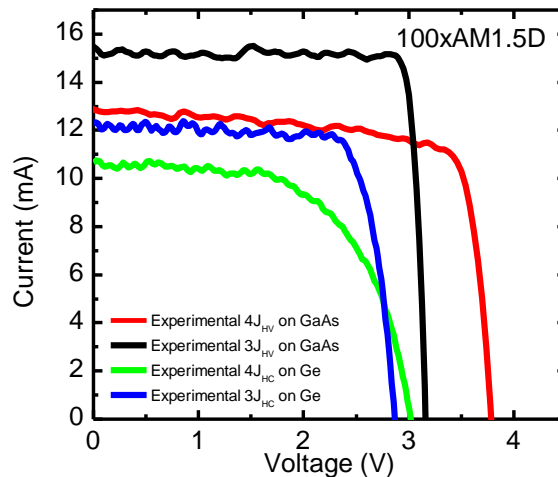


Figure 1. IV-characteristics of 3J and 4J cells fabricated on GaAs and Ge substrates by MBE. The 3J cells are fabricated without the 3rd junction of the corresponding 4J design. The IV-measurements were biased using continuous 100 suns illumination. The cell size was 1 mm².

References

- [1] A. Luque, Will we exceed 50% efficiency in photovoltaics?, J. Appl. Phys., 110 (2011), p. 031301