Four Junction Dilute Nitride Solar Cells for Next Generation CPV-systems

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1. Introduction

Next generation concentrated photovoltaic (CPV) power plants need cost-effective solar cells with higher efficiency than commercially available today. For efficient cell production and system integration, improved monolithic III-V multijunction cells are prime choices due to straight forward production. In this paper, we report on the progress in development of monolithic lattice matched four junction cells. The structure incorporates two dilute nitride bottom junctions with band gaps of 0.9 eV and 1.2 eV. The studied four junction cell has a realistic potential to exhibit over 47% efficiency at high concentrations.

2. Experiments and results

Monolithic four junction and triple junction solar cells were grown by molecular beam epitaxy, details on the growth can be found elsewhere [1]. The cells were antireflection coated and processed into 1 mm^2 sizes. Current–voltage characteristics were measured using an OAI TriSOL solar simulator. The solar simulator spectral match for the sub-cells was carefully analyzed. We used AM1.5D 1000 W/m^2 ASTM G 173-03 spectrum as a reference. The performance of the sub-cells was also estimated by performing external quantum efficiency measurements. In addition, for the analysis of the current generation by sub-cells we used single junction and isolation-type cells. We also selected top-cell limited high efficiency GaInP/GaAs/GaInNAsSb cell with 1 eV bottom junction as a reference for the four junction cell. The triple junction cell has short circuit current density (J_{sc}) of ~12 mA/cm^2 at AM1.5D conditions. Similarly, the four junction cell was designed to have a J_{sc} of 12 mA/cm^2.

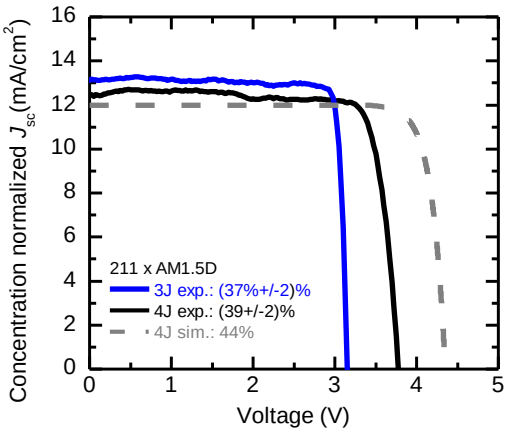

Figure 1. Performance of dilute nitride 3J reference cell, 4J experiment, and performance projection for optimized 4J cell at ~200x.

For the four junction cell we achieved a conversion efficiency of 39% at 211 suns illumination, as seen from Fig. 1. The voltage increase for the four junction cell compared to the triple junction cell was 0.45 V. At the same concentration, the reference triple junction cell exhibited an efficiency of 37%. With higher top cell current, the triple junction cell could reach efficiency as high as 42%. The simulation of current generation in the four junction cell, based on diode modelling [2], matches well with the actual cell performance, revealing a potential efficiency of 44% at 211 suns. Further increase in efficiency up to 47% is expected with higher light concentration, optimization of antireflection coating and improved current matching.

References

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[2] A. Aho, A. Tukiainen, V. Polojärvi and M. Guina, Nanoscale Research Letters, vol. 9, pp. 1-7, 2014.