High Efficiency Lattice Matched Four-Junction Solar Cells on GaAs

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Next generation concentrated photovoltaic power plants need cost-effective solar cells with higher efficiencies than what is commercially available today. To this end, advanced monolithic III-V multijunction cells are prime choices owing to high process yield and straightforward production compared to the other III-V solar cell technologies, such as solar cells based on inverted methamorphic growth and wafer-bonding. Currently the best demonstrator cells have exhibited 46% efficiency [1]. In this paper, we report the progress in the development of monolithic lattice matched four-junction (4J) solar cells based on GaInP, AlGaAs, GaAs and GaInNAsSb heterostructures. The general architecture of the device developed is shown in Fig. 1, which reveals the use of two lattice-matched dilute nitride bottom junctions with bandgaps of 0.9 eV and 1.2 eV. The exploitation of such dilute nitride hetersotrctures at below 1 eV bandgap has been enabled by the possibility to tailor the MBE process, and avoid issues related to unintentional C background doping and unwanted phase separation present in MOCVD.

The structures were grown using a Veeco GEN20 MBE system equipped with standard Veeco solid sources and a Veeco UNI-Bulb RF plasma source for N incorporation. The performance of the 4J cell was evaluated by using a solar simulator calibrated for AM1.5D (1000 W/m^2) ASTM G173-03 spectrum. For the excitation, we used 100 suns intensity. For comparison, a MBE grown triple junction (3J) cell was also measured with the same system. The current–voltage (*I–V*) characteristics of the solar cells are presented in Fig. 1.

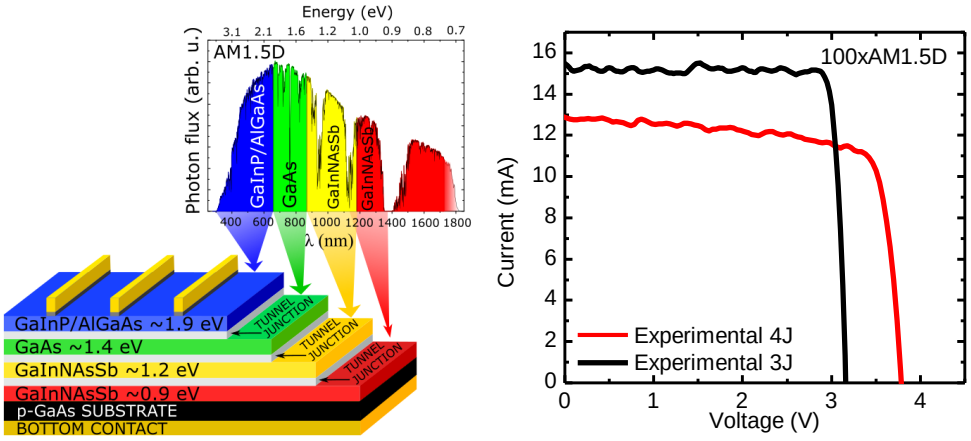

Figure 1. *Schematic illustration of the processed four-junction solar cell structure (left). I–V characteristics of 3J and 4J cells fabricated on GaAs by MBE (right). The 3J cell is fabricated without the 3rd junction of the 4J design. The I–V curves were measured at continuous 100 suns illumination.*

Both cells exhibit an efficiency of 37%. Although we do expect higher performance for 4J cell, the parameters obtained are rather good given the early stage of 4J development. The 4J cell shows 0.6 V higher open-circuit voltage than the 3J reference. Owing to this increase, results obtained for the component cells of the 4J and a simulation model with component cell characteristics, we estimate that an optimized 4J cell could exhibit efficiency as high as 44% at 100 suns [2]. Moreover, at 1000 suns concentration an efficiency of 47% is realistic. The optimization steps towards these targets will be discussed.

[1] M.A. Green et al. Progress in Photovoltaics, Vol. 25, No. 7, pp. 668-676. (2017)
[2] A. Aho et al. Accepted to Progress in Photovoltaics (2018)