Characterization and numerical analysis of III-Sb tandem solar cells

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The best solar conversion efficiencies are currently achieved with multijunction solar cells made of III-V semiconducting materials.[1] Their good performances result from the distribution of the solar spectrum between the subcells with bandgaps optimized specifically to maximize the harvesting of the solar light. Nonetheless, one of the major concerns encountered in the field of multijunction solar cell is the lack of narrow band gap materials hindering the harnessing of the higher wavelengths and being lattice-matched to the conventional substrates (GaAs, InP). This concern may be overcome with a use of III-Sb quaternary alloys, i.e. AlGaAsSb, InGaAsSb and AlInAsSb, providing the bandgap coverage of 0.3-1.65 eV. Their composition can be tuned in order to achieve an alloy with a desired value of bandgap, which can be monolithically grown on GaSb substrate.

In this work, the behavior of two tandem solar cells containing III-Sb quaternary alloys as active layer is studied. The cells are composed of GaSb (0.73 eV) bottom subcell and $Al_{0.75}In_{0.25}As_{0.26}Sb_{0.74}$ (1.33 eV) top subcell grown by Molecular Beam Epitaxy on GaSb (001) substrate.[2] Experimental details on the growth, fabrication and architecture of the solar cells will be described. The characterization of the structural and optical properties of the AlInAsSb layers will also be presented. The behavior of the cells was characterized with a use of dark and 1 sun J-V measurements, as well as the Spectral Response. The experimental data was then analyzed with a use of 1D numerical simulations and interpreted in terms of the solar cells architecture. The model used for this purpose is a MATLAB code specifically developed for the accurate simulation of the multijunction solar cells. The model solved the continuity and Poisson equations in 1 dimension. In order to provide the most realistic analysis possible, some of the input data, such as mobilities or the optical parameters (n,k) of the quaternary alloy were determined empirically prior to the modeling. The results of those simulations allowed us to identify the factors responsible for the weak performances of those tandem cells and proceed towards their optimization.

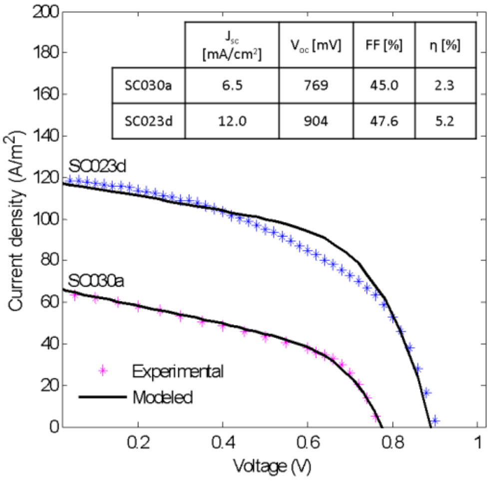

Fig. 1. Experimental and modeled 1-sun J-V characteristic of both tandem cells along with their key figures of merit

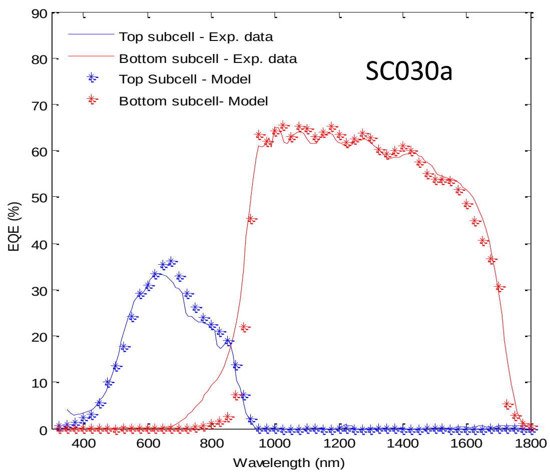

Fig. 2. EQE measurements of both subcells of SC030a sample fitted with 1D model

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[2] J. Tournet, Y. Rouillard, E. Tournié, Growth and characterization of AlInAsSb layers lattice-matched to GaSb, Journal of Crystal Growth. 477 (2017) 72–76. doi:10.1016/j.jcrysgro.2017.04.001.