Light trapping in GaAs microcrystals on silicon for tandem solar cells

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ABSTRACT

In the active field of silicon based tandem solar cells, the integration of III-V materials has long been a very attractive option but with technical obstacles due to heterogeneous material integration. An emerging technology in this field is that of epitaxial lateral overgrowth, in which growth is initiated on Si in shallow holes of diameter some tens of nanometres created in a nanometric surface silicon oxide interlayer. Growth proceeds in a three dimensional mode, with lateral growth over the oxide interlayer, without exceeding the Matthews-Blakeslee limit for strain relaxation. The resulting crystals are therefore free of defects. The structure presents an interesting theoretical problem given that the top cell is a three dimensional object of just a few microns in size with feature scales ranging from nanometres to microns, and complex optical and electrical spatial variations across these scales. The facets of the crystal, which may be rectangular or hexagonal depending on growth parameters, act as a built-in light refracting array which can provide light trapping. Furthermore, the crystals possess slightly different crystal orientations and are not able to constitute a uniform conformal layer, but consist of an array of separate cells, connected at their front surface by a conformal transparent conducting layer acting as the front contact. The efficiency of the resulting tandem is a complex problem which is a function of crystal geometry, density, and light trapping propeties, and the resulting impacts on the lower gap silicon solar cell. This paper presents two dimensional numerical modelling of the tandem structure, focussing on an AlGaAs/GaAs top gap cell. We present studies of efficiency focussing on the microcrystalline top cell. This includes optical intensity maps in the structure as a function of micro-crystal geometry ranging from rectangular to hexagonal shapes, and impact of micro-crystal density on efficiency and as a function of III-V material composition and bandgap. We conclude by drawing design rules for III-V micro-crystal on silicon tandem solar cells.

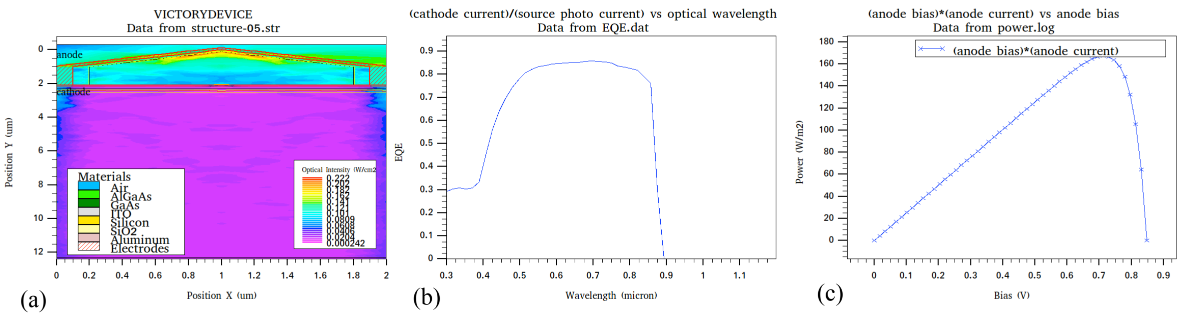

Figure 1(a) structure of the GaAs on Si tandem showing a single crystal and the light intensity distribution and silicon restricted to 10µm for illustrative purposes (b) quantum efficiency of the GaAs top cell and (b) efficiency of 16.7% for this un-optimised structure suffering from short wavelength losses due to the lack of AR coat and thick AlGaAs emitter.