SiGeSn as a 1.0eV component sub-cell in III-V multi-junction solar cells

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Motivation

To achieve a highly efficient four-junction solar cell, a 1.0 eV sub-cell is required. Alloying Ge with both Si and Sn results in a ternary SiGeSn alloy covering this energy gap range, and allows the alloy to be lattice-matched to Ge. A SiGeSn sub-cell in a InGaP/InGaAs/SiGeSn/Ge solar cell (see Figure 1) allows an all lattice-matched four-junction (4J) cell to be produced, eliminating the need for an expensive wafer-bonding process required for lattice mis-matched 4J cells [1]. Modelling indicates such a 4J SiGeSn cell could reach 48% efficiency [2]. The 1.0 eV sub-cell could also be used in a tandem cell with e.g. GaAsP, giving a combination of band gaps close to the detailed balance optimum for a two-junction cell [3].

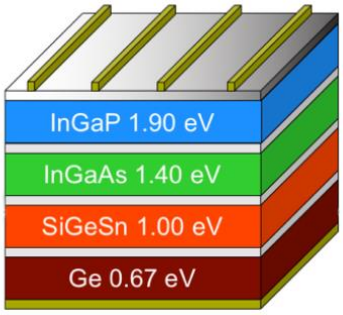

Figure 1: architecture of a four-junction solar cell using SiGeSn. From [2].

Purpose of the work

There is a lack of data regarding this relatively new alloy. SiGeSn was characterized using both optical and electrical techniques. A single SiGeSn junction and triple junction InGaP/InGaAs/SiGeSn cell were fabricated to show the feasibility of utilising SiGeSn in multi-junction solar cells [4]. In addition, optical characterisation of unprocessed SiGeSn samples contributes to understanding of the material properties, aiding further growth optimisation for improved device performance.

Scientific approach

The work comprises characterization of single and triple junction solar cells containing SiGeSn, including external quantum efficiency (EQE) and current-voltage (I-V) measurements. In addition, spectroscopic analysis of SiGeSn samples grown on Ge will be presented, specifically steady-state and time-resolved photoluminescence (PL) measurements and optical constants extracted from ellipsometric data.

Results and conclusions

The feasibility of using SiGeSn as a sub-cell in a multi-junction solar cell was demonstrated. Maximum EQEs in the SiGeSn sub-cell of 80% and 70% at 850nm were observed in the 1J and 3J cell respectively. The open-circuit voltage was lower than expected in the 3J cell, possibly due to high bulk and surface recombination and sub-1.0 eV indirect absorption in the SiGeSn [4]. Optical characterisation using photoluminescence and spectroscopic ellipsometry indicates a blue-shift of the band-gap energy with increasing Si fractions and improved radiative efficiency in p-type SiGeSn.

References

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