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Light Weight High Efficiency III-V Solar Cells using Epitaxial Lift Off (ELO)

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1. Abstract

GaAs and InP based solar cells were fabricated using epitaxial lift-off (ELO) across 4-inch based substrates. 1 cm^2 GaAs solar cells have been fabricated with a yield >80% across full 4" ELO wafers. The efficiency of a dual junction GaAs solar cell (ELO) was 22%. Single junction InP ELO solar cell was demonstrated on a 4-inch InP substrate with an efficiency of 11%. Transmission electron microscopy studies of ELO solar cells indicated no evidence of threading dislocations, voids or delaminating at the semiconductor–metal interface. The ELO technology was applied to both GaAs and InP based materials over the entire substrate area with excellent success. ELO can be used to realize ultra light high efficiency solar cells for both space and terrestrial applications. The ELO process also provides the ability to reuse the substrate numerous times. This provides tremendous benefits in the utilization of raw materials to realize a greener and cleaner environment.

2. Introduction

There is an increasing need to further lower the weight of solar cells for space applications to improve the power/weight performance. Presently, the weight of space-based solar cells is dominated by the substrate. The highest efficiency solar cell used for space application is based on GaAs multijunction (MJ) technology. [1,2].The active layer accounts for less than 5% of the total weight.

This paper presents a novel processing technology that can completely remove the substrate from the active layer while preserving the quality of the active layers across the entire substrate surface area. ELO, also known as peeled film technology, was initially developed in the late 1970's [3]. It makes use of a thin layer of AlGaAs as a detachable release layer, which permits an epitaxial stack grown on top of the AlGaAs layer to be removed from the substrate without damaging either the stack or the substrate. The basic principle of ELO is to use an etch solution which has a large selectivity between the substrate and stack and the release layer.

The focus of this work was to achieve a large reduction in solar cell weight by employing wafer-scale epitaxial lift off (ELO) to remove solar cells from the substrate on which they are grown and transfer them onto lightweight carriers such as metal film or a polymeric insulator film.

3. Experimental

GaAs and InP solar cells were grown by metalorganic chemical vapor deposition (MOCVD) at low pressure using Arsine (AsH_3), Phosphine (PH_3), Trimethylindium (TMI) and Trimethylgallium (TMG), and trimethylaluminum (TMAl) as precursors. Si, Te were used as n-type dopants and C and Zn were used as p-type dopants. The inverted solar cell device structure was grown on top of a high Al composition (>80%) AlGaAs release layer. The 4" ELO wafer was processed to form 1.0 cm^2 solar cells with emitter electrodes suitable for both multi-sun and single sun illumination. The devices were analyzed using I-V and QE analysis. Transmission electron microscopy and scanning electron microscopy were used to study the microscopic and macroscopic defects in the ELO layers and no defects were detected.

4. Results

Figure 1 shows a typical process flow for ELO solar cells. The process starts with growth of an AlGaAs release layer followed by the growth of the solar cells. The solar cell layers were grown in an inverted configuration in order to be consistent with the ELO process. After the epitaxial growth, a handle layer is deposited on top of the device structure and the whole wafer is immersed in etch solution which etches away the release layer. A full 4” GaAs ELO wafer is shown in Figure 2.

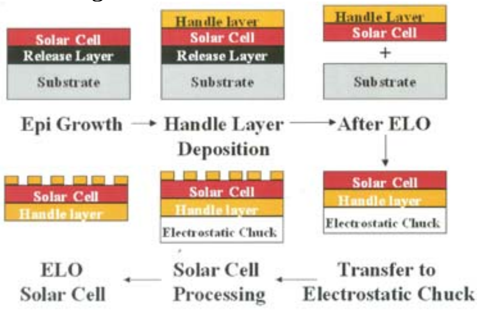

Figure 1: The ELO solar cell process flow.

Figure 2: A full 4” GaAs ELO wafer is shown.

From Figure 2 it is clear that the ELO wafers are flexible and can be bent without breaking. After release, the wafer returns to its original configuration. The wafers are also light: typical 4” ELO wafer weighed 1.6 g. Device characteristics of dual junction GaAs based ELO solar cells are shown in Fig. 3. The results of the GaAs dual junction ELO solar are nearly identical to a standard dual junction solar cell. A higher efficiency can be realized by optimizing the dual junction structure.

Fig. 4 shows a 4-inch InP ELO solar that has been fully processed into solar cells. The process that was established for GaAs lift-off can be transferred to InP based materials using a similar approach. The average efficiency of the InP solar cell at 1-sun AM1.5 was 11%. Jsc was 16.6 mA/cm^2 with a FF of 77%. This is the first report of a 4-inch lifted off InP solar cell.

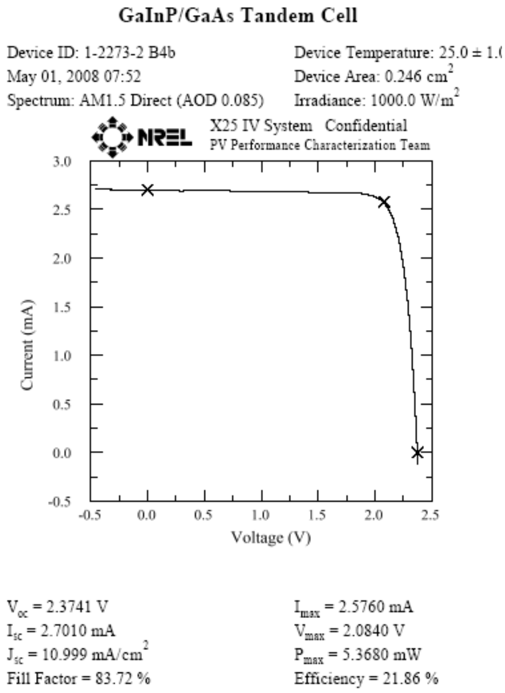

Figure 3: I-V characteristics of dual junction GaAs solar cell is shown.

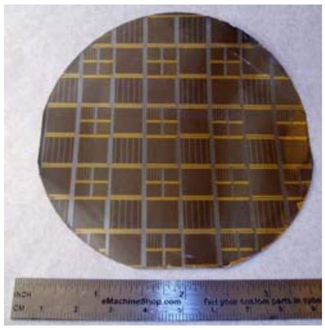

Figure 4: 4-inch InP ELO processed is shown.

5. Summary

GaAs and InP ELO solar cell devices across the entire substrate areas were demonstrated with high yield. The efficiency of the ELO solar cells is comparable to standard solar cells. The ELO process is scalable to high volume production. The advantage of weight reduction was clearly demonstrated in the ELO solar cells. The ability to reuse the substrates provides significant benefits in raw materials utilization.

References

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