Area: III-V Compound Semiconductor and Concentrator Space PV Technologies.

GAAS SINGLE JUNCTION CELLS ON SI SUBSTRATES FABRICATED BY SURFACE ACTIVATED BONDING AND ETCHING OF SACRIFICIAL LAYERS

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III-V-on-Si hybrid multijunction solar cells are a promising candidate for realizing high-efficiency and low-cost photovoltaics (PV). The present authors previously reported on InGaP/GaAs/Si hybrid triple junction cells [1]. The triple-junction cells were fabricated by the surface activated bonding (SAB) of InGaP/GaAs heterostructures grown on GaAs substrates to Si-based bottom cells, removing GaAs substrates by using the selective wet etching, and employing the conventional device process sequences. It is noteworthy that GaAs substrates, which should compose the major part of the cell costs, are consumed in such processes. In this work, we examined the possibility for the process for fabricating hybrid solar cells in which GaAs substrates are recycled [2]. We prepared a GaAs epi wafer with an AlAs sacrificial layer inserted between a GaAs single junction cell structure and a GaAs substrate. We fabricated a GaAs cell after the SAB of the GaAs epi wafer to an n^+-Si substrate and separating the GaAs substrate by etching the sacrificial layer. The surface of the separated GaAs substrate was examined by an atomic force microscopy (AFM) observation. In addition, the performances of the fabricated GaAs cell were measured.

We fabricated a GaAs-on-Si multilayer structure composed of a GaAs substrate/a buffer layer/an AlAs sacrificial layer/an n-on-p GaAs single-junction PV layer bonded to an n^+-Si substrate. The thickness of the AlAs layer was 15 nm. The area of the bonded III-V layer was 1.2 cm^2 (1 cm by 1.2 cm). The samples were not heated during the SAB process. The multilayer structure was annealed at 300 °C for 1 hour so as to achieve a bonding interface with an enough strength. A mechanical load was applied to a side of the GaAs substrate while the multilayer structure was placed in an HF solution. A schematic cross section of the multilayer structure is shown in Figure 1. The applied mechanical load was also shown in this figure. The GaAs substrate was successfully separated after a ~30-hour dipping in the HF solution. A ~80-mm^2 GaAs PV layer, or a ~70% of the initially bonded area, remained bonded to the Si substrate after separating the GaAs substrate.

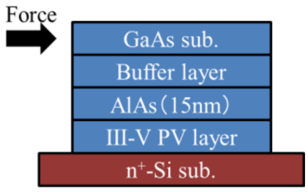

Figure 1: Layer structure after bonding.

An AFM image of the surface of the separated GaAs substrate is shown in Figure 2. The averaged roughness of the surface was 0.25 nm, which was similar to that of epi-ready GaAs substrates.

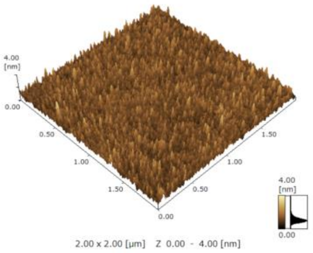

Figure 2: AFM image of the GaAs substrate.

A 4-mm^2 (2 mm by 2 mm) GaAs single junction cell was fabricated by the mesa etching and the formation of the emitter and base contacts. It is noteworthy that an n+-GaAs contact layer was placed at the top of the cell. Figure 3 shows current-voltage (I-V) characteristics of the cell under the solar irradiance of air mass 1.5G and one sun. The short circuit current density, open circuit voltage, fill factor, and conversion efficiency were 5.1mA/cm^2, 0.77V, 0.71, and 2.8%, respectively. The observed short circuit current was limited by the absorption in the contact layer, which was experimentally confirmed by the spectral response measurement (not shown). The obtained results suggest that III-V-on-Si hybrid multijunction cells can be fabricated while GaAs substrates are recycled by combining the SAB and the sacrificial layer etching.

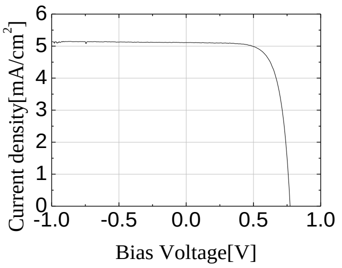

Figure 3: I-V characteristics of GaAs single junction cell.

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Reference

[1]N.Shigekawa, et al. Jpn. J. Appl. Phys. 54 08KE03 (2015).
[2]Kyusang Lee et al J. Appl. Phys. 111, 033527(2012).