Smart Stacked InGaP/GaAs/GaAs//Si Quadruple-Junction Solar Cells Grown using Molecular Beam Epitaxy

Takeyoshi Sugaya[1], Takashi Nakamoto[2], Kikuo Makita[1], Taketo Aihara[1], Takeshi Tayagaki[1], Ryuji Oshima[1], Hidenori Mizuno[1], and Yoshinobu Okano[2]

[1] *National Institute of Advanced Industrial Science and Technology (AIST), 1-1-1 Umezono, Tsukuba, Ibaraki 305-8568, Japan*

[2] *Tokyo City University, 1-28-1 Tamazutsumi, Setagaya, Tokyo 158-8557, Japan*

InGaP(1.9 eV)/GaAs(1.42 eV) on Si(1.1 eV) multijunction solar cells have been studied to realize low-cost and high-efficiency solar cells [1]. However, the current matching is not appropriate in this material system because the current generated in a Si subcell is smaller than that generated in InGaP and GaAs subcells. Therefore, a triple-junction top cell on a Si bottom cell configuration is suitable for obtaining the current matching among connected subcells. Although we demonstrated InGaAsP and AlGaAs second (1.7 eV) cells in the triple-junction top cells, InGaAsP cells were difficult to grow and AlGaAs cells exhibited poor performance when they were grown using molecular beam epitaxy (MBE) [2]. In this paper, we demonstrated an InGaP/GaAs/GaAs triple-junction solar cell grown using MBE to use as a top cell in a Si-based quadruple-junction solar cell.

The sample structure is shown in Fig. 1. A MBE-grown InGaP/GaAs/GaAs top cell was stacked to a Si bottom cell by smart stack technology which is a new semiconductor bonding technique using conductive nanoparticle alignments [3]. Figure 2 shows a *J-V* curve of a quadruple-junction solar cell. An efficiency of 18.5% with a high V_{oc} of 3.3V was obtained in InGaP/GaAs/GaAs//Si multijunction solar cells. External quantum efficiency (EQE) spectra of the solar cell are shown in Fig. 3. The highest and lowest current densities were generated by the first InGaP and second GaAs cells, respectively. The J_{sc} of 7.4 mA/cm^2 shown in Fig. 2 was in good agreement with the value estimated from the EQE measurements, which was limited by the second GaAs cell. This can be improved by reducing the absorption layer thickness of the first InGaP cell. In the presentation, we will discuss the role of substrate miscut on the properties of InGaP top cells.

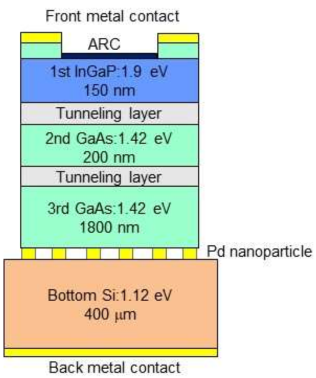

Fig. 1 Structure of a quadruple-junction solar cell

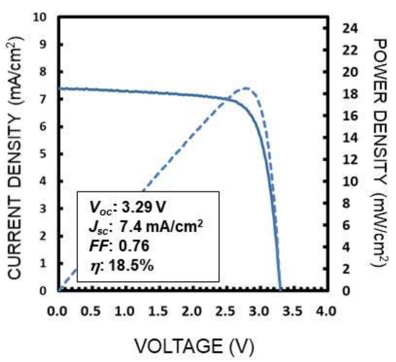

Fig. 2 *J-V* curve of a solar cell.

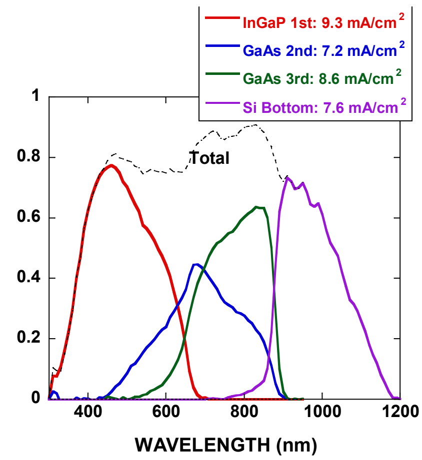

Fig.3 EQE spectra of a solar cell.

[1] R. Cariou *et al.*, IEEE J. Photovoltaics 7, 367 (2017). [2] T. Sugaya *et al.*, J. Vac. Sci. Technol. B 35, 02B103 (2017). [3] H. Mizuno *et al.*, Appl. Phys. Lett. 101, 191111(2012).

+ Author for correspondence: t.sugaya@aist.go.jp