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Fabrication of GaAs/GaInNAs Heterojunction Solar Cells Applicable To High-Efficiency Multi-junction Tandem Structures

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1. Introduction

The GaInNAs alloys are currently investigated for wide applications ranging from long-wavelength optical fiber communication lasers [1] to high-efficiency multi-junction tandem solar cells [2]. In particular, GaInNAs with an energy bandgap of ~ 1eV is of great importance for use in lattice-matched GaInP/GaAs/GaInNAs/Ge 4-junction solar cells in order to achieve energy conversion efficiencies in excess of 40%.

However, both the optical and electrical properties of GaInNAs thin-films become increasingly degraded with increasing N composition [3]. The mechanism for the degradation is still not fully understood, though N-related deep-level defects are known to be responsible for the reduction of minority carrier lifetimes and diffusion lengths [4]. As a result, photocurrents generated in GaInNAs subcells have not reached sufficiently high values. One way to increase the current generation in GaInNAs subcells is to employ a *p-i-n* structure with a wide, intrinsic base layer (*i*-layer) inserted in the *pn* junction. In this work, we characterized *p*-GaAs/*i*-*n*-GaInNAs heterojunction solar cells fabricated by atomic-H assisted RF-molecular beam epitaxy (RF-MBE) [5] for the first time. The dependence of *i*-layer thickness on photoresponse was also investigated.

2. Results

Figure 1 shows the measured external quantum efficiencies (EQEs) of *p*-GaAs/*i*-*n*-GaInNAs heterojunction solar cells with varying *i*-layer thickness *d* = 0, 300, 600, and 1000nm, respectively. The photoresponse above the wavelength of 870nm, which is the bandedge of GaAs, would correspond to current generation solely in the GaInNAs material. It can be observed that, (1) the insertion of *i*-layer results in the overall improvements of EQE both in the short-wavelength region < 870nm and the long wavelength region up to ~ 1000nm. This is because the built-in field across this wider depletion layer can sweep the minority carriers away from the junction fast enough

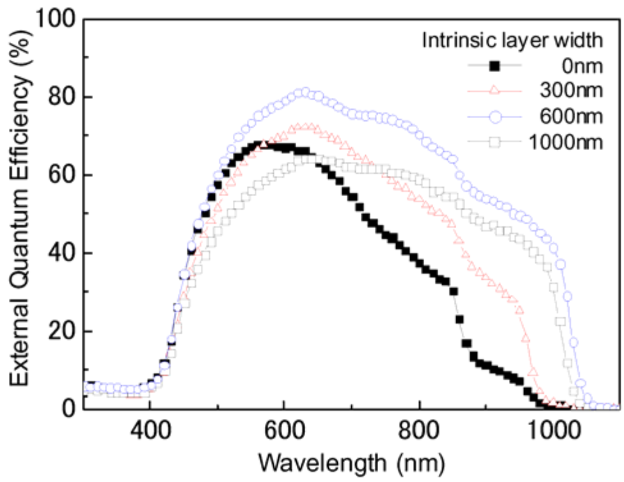

Fig. 1. External quantum efficiencies (EQEs) of *p*-GaAs/*i*-*n*-GaInNAs heterojunction solar cells with varying intrinsic layer widths of 0, 300, 600, and 1000nm, respectively.

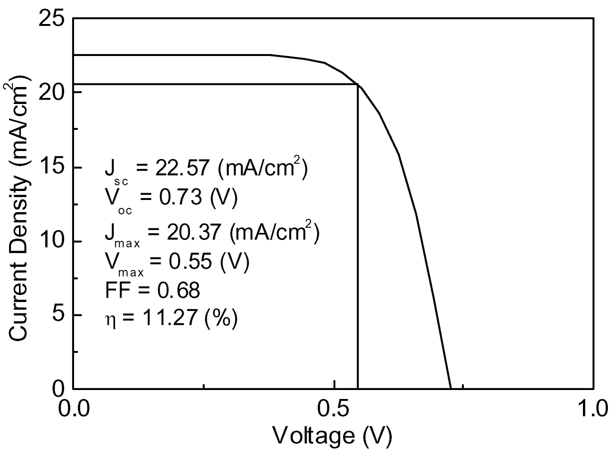

Fig. 2. Projected photovoltaic response for with d = 600nm sample. Maximum efficiency of 11.27% is obtained at AM1.5.

that the recombination loss can be reduced. As a result, the effective minority carrier diffusion length in GaInNAs layer is thought to be improved from less than 100nm to 600nm by the insertion of *i*-layer. (2) By adding a little more N in GaInNAs alloy causes a large reduction in the bandgap energy by ~ 80nm as can be clearly seen in d = 600 and 1000nm samples. However, the sample with d = 1000nm shows a degraded response compared to 600nm sample. Thus sample with d = 600nm shows the best and optimum performance among the samples tested in this study.

The projected photovoltaic response for with d = 600nm sample has been determined using the EQE and dark I-V curves; short-circuit current density I_{sc} = 22.57 mA/cm^2, open-circuit voltage V_{oc} = 0.73 V, fill-factor FF = 0.68 resulting in a high efficiency of 11.27 % (AM1.5) as shown in Fig. 2. The results are promising for applications to future 4-junction tandem solar cells using GaInNAs material.

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References

[1] M. Kondow *et al*, Jpn. J. Appl. Phys. **35** (1996) 5711.
[2] M. Yamaguchi, Physica E **14** (2002) 84.
[3] D. J. Friedman *et al*, J. Crystal Growth **195** (1998) 409.
[4] A. J. Ptak *et al*, J. Crystal Growth **251** (2003) 392.
[5] Y. Shimizu *et al*, J. Crystal Growth **278** (2005) 553.