GaAs 太陽電池における極性の影響

Polarity dependence of the properties of GaAs solar cells

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1 Introduction

It is well known that arsenic antisite defects (As_{Ge}) are the dominant native defect in MOVPE-grown, As-rich, p-type GaAs due to their low formation energy. One method to improve the material quality of p-GaAs is to use low V/III ratios during growth [1], but this approach has a limitation when using TBA as the As source because the V/III ratio is already low due to the high pyrolysis efficiency of TBA. Besides, the incorporation of background carbon can also be a problem at low V/III ratios. A thermodynamic analysis of native point defects in GaAs showed that the concentration of the deep level (EL2) As_{Ge} defects decreases to zero when the n-type doping is greater than 2×10^{17} cm^{-3} [2]. Therefore, it is promising that GaAs solar cells with an n-type base layer may have higher performance than traditional cells with a p-type base. This work will explore and compare the properties of GaAs solar cells with different polarities: n-on-p (NP) and p-on-n (PN).

2 Experimental details, results and discussion

The traditional NP solar cell consisted of an n-GaAs emitter layer (2×10^{18} cm^{-3}) and a p-GaAs base layer (5×10^{16} cm^{-3}) on a p-GaAs substrate, while the PN device had a p-GaAs emitter layer (2×10^{18} cm^{-3}) and an n-GaAs base layer (2×10^{17} cm^{-3}) on an n-GaAs substrate. The thickness of the base layers was 2.0 µm. Highly doped InGaP layers were used for the BSF and window layers according to the cell structures. The solar cells, with an area of 0.25 cm^2, were evaluated without an anti-reflection coating.

The illuminated and dark I-V curves are shown in Figs. 1(a) and 1(b), respectively. Firstly, the short-circuit current density (J_{sc}) of the PN cell was slightly larger than that of the NP device. The IQE spectra indicated a better short wavelength response in the PN sample, probably due to better carrier extraction in the p-GaAs emitter compared to the n-GaAs emitter of the NP cell. The quality of the n-GaAs was superior, so the degradation in minority hole collection was not observed in this 2.0 µm thick layer. The PN sample clearly had a larger open-circuit voltage (V_{oc}) than the NP cell, attributed to lower SRH recombination. This was revealed by the dark I-V measurement, which showed that the PN cell had smaller J_{01} and J_{02} components than the NP cell. The ideality factor being greater than 3 for the NP solar cell might indicate the presence of deep levels in the bandgap.

3 Summary

The GaAs p-on-n solar cell exhibited a higher V_{oc} and efficiency due to the decrease in defect density in the n-GaAs base layer compared to the n-on-p device. It is worthwhile to further investigate and optimize p-on-n solar cells, as well as to conduct a feasibility study on multi-junction solar cells based on the p-on-n polarity.

[1] H. Sodabanlu et al, in 36th EU-PVSEC, 689-92 (2019).
[2] D. T. J. Hurle, JAP 85, 6957 (1999).

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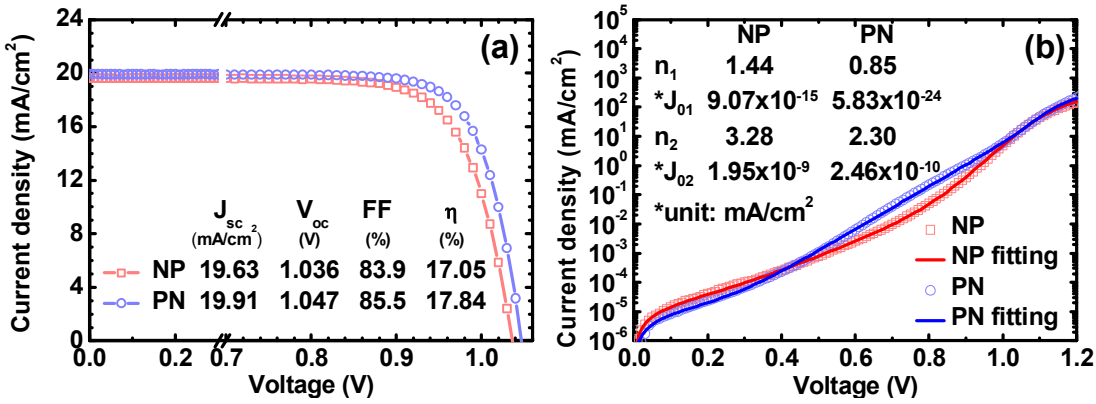

Fig. 1 (a) I-V characteristics under AM1.5G (100mW/cm^2) and (b) dark I-V curves of the GaAs n-on-p and p-on-n solar cells.