TBP を用いたプラネタリーMOVPE 装置による InGaP 太陽電池の開発
Development of InGaP solar cells grown in planetary MOVPE reactor using TBP

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1 Introduction

The past few decades have witnessed the tremendous progress on III-V semiconductor solar cells owing to the development of fabrication technologies, including the crystal growth by MOVPE method. Even tough extensive researches regarding MOVPE growth have been carried out up to the present, there is no notable report on the growth of InGaP solar cells in a planetary MOVPE reactor using tertiarybutylphosphine (TBP) which has a relatively lower intrinsic toxicity than PH_3. According to few available references, InGaP solar cells grown with TBP generally fall behind PH_3 samples in terms of quality and performance [1]. In this work, we develop and optimize growth conditions of InGaP solar cells in a planetary MOVPE using TBP and their structures to address this quality issue. With regard to our previous report on the growth of InGa(AsP) solar cells on InP, the rector temperature is the most important factor to realize high quality epitaxial layers and solar cells in our planetary MOVPE [2]. Hence, we will first study the effects of growth temperature on the properties of InGaP layers and solar cells. The influences of device structure will be subsequently investigated.

2 Experimental details, results and discussion

The experiment was carried out in a planetary MOVPE reactor (AIXTRON 2000HT) equipped with Laytec Epicurve DA IR T. The reactor pressure during the growth was kept at 100 mbar. First, double-hetero samples comprising of 1-µm thick InGaP sandwiched between InAlGaP cladding layers were grown with various growth (surface) temperatures from 560 to 590 °C. In contrast to the InGaP grown with PH_3 in a horizontal reactor previously reported by our group [3], the carrier lifetime in InGaP shortened with an increase in surface temperature. The reasons can relate to the depletion of TBP and parasitic gas-phase reactions at high growth temperature [2]. However, with temperatures less than 560 °C, the carrier lifetime terribly degraded due to high background impurity concentration. With the optimized surface temperature of 560 °C, InGaP solar cells with different structures including standard n-p (NP), rear junction (RJ) and rear hetero junction (RHJ) were fabricated. As shown in Fig. 1(a), the NP sample exhibited poor carrier collection efficiency plausibly due to inferior quality of p-InGaP base layer. This hypothesis was supported by the low carrier mobility in p-doped InGaP evaluated by Hall Effect measurement and the degradation of long wavelength EQE spectra in Fig. 1(b). With the RJ structure utilizing the thick n-InGaP base layer, the performance of this sample was notably improved with good I-V and EQE properties. The RHJ was expected to show the best result, particularly V_{oc}, because the depletion region partially presented in the wide-gap p-InAlGaP BSF where the SRH loss should be reduced. However, existing in the depletion region, the interface between p-InAlGaP BSF and n-InGaP base layers probably introduced carrier recombination leading to a lower V_{oc} shown in Fig 1(a). The bandgap discontinuity at hetero-interface had no significant effect on the carrier collection of this cell (Fig. 1(b)).

3 Summary

With the optimized growth conditions and the use of thick n-InGaP absorber layer, high quality InGaP solar cells could be successfully fabricated in the planetary MOVPE using TBP. Further study should focus on the improvement of material quality and the hetero-interface.

[1] I. Garcia et al., JCG 310, 5209 (2008).
[2] H. Sodabanlu et al, JJAP 57, 08RD09 (2018).
[3] H. Sodabanlu et al, J. Photovolt. 10, 480 (2020).

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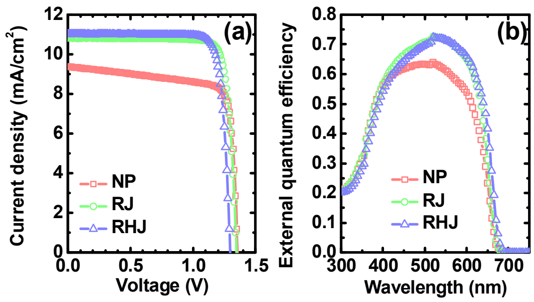

Fig. 1 (a) I-V characteristics under AM1.5G and (b) EQE spectrum of InGaP solar cells with different device structures