Effect of piezoelectric field on carrier dynamics in InGaN-based solar cells

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1. Introduction

InGaN alloys are thought to be one of the most promising materials as solar cells becuase its bandgap covers almost all the solar spectrum. For the design of the device structure, development of reliable nitride-based solar cell simulator is esential because nitrides show a strong piezoelectricity which should affect the device performance. A simple InGaN structure was simulated to compare the experimental results [1]. As a consequence, we obtained considerably similar results (Table 1) and IV characteristics (Fig. 1) with this simulator. This means that our simulatin model is reliable. Especially, an interesting thing is that staircase like IV characteristics were shown in the both cases.

Table 1 Comparison of the experimental results with the simulated results.

	Experiment	Simulation
Open circuit voltage (V)	2.23	2.52
Short circuit current density (mA/cm²)	1.59	1.69
Conversion efficiency (%)	1.41	1.68
Fill factor (%)	61	59

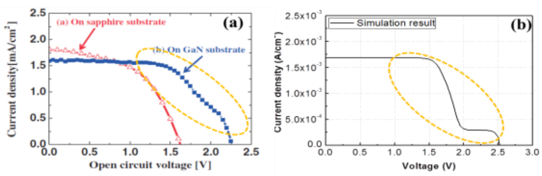

Fig. 1 IV characteristics of InGaN solar cell ((a) experimental results, (b)simulated results)

2. Effect of piezoelectric filed

To vary the amount of piezoelectric fields, three different $In_xGa_{1-x}N$ layer (x = 0.05, 0.1, 0.2) using GaN substrate were designed and simulated in this study. For $In_{0.05}Ga_{0.95}N$ sample, recombination rate is increased by increasing the vias voltage like a general case, because the piezoelectric fields did not affect the band diagram (see Fig. 2(a)). However, band diagram for $In_{0.10}Ga_{0.90}N$ sample shows slightly tilted energy band (see Fig. 2(b)), which is due to an increase of piezoelectric fields. As a result, the energy band is completly flatten at much lower vias (around 1.4 V) as contrast with the $In_{0.05}Ga_{0.95}N$ sample's one, so the recombination rate also bacome increasing at the lower vias. Furthermore, the current is almost constant(see black line in Fig. 2(d)) at around 2-2.4V region by decreasing the recombimation rate, because electron and hole wave function are separated by increasing the vias voltage. For the $In_{0.20}Ga_{0.80}N$ sample (see Fig. 2(c)), energy band are tilted significantly because the piezoelectric field is too strong. Therefore even at the 0 vias voltage, band diagram showed separated electron and hole wave function due to the formation of the valleys on each n and p side region. This behaviour is quite similar to that of the $In_{0.10}Ga_{0.90}N$ at around 2-2.4V. Additionally, nonpolar and semipolar $In_xGa_{1-x}N$(x=0.1, 0.2, 0.3) structures which can eliminate or reduce the field effect were also simulated as shown in Fig. 2(e). Understandably we could see that conversion efficiencies are significantly improved especially if In-composition is equal to or higher than 0.2 by using nonpolar or semipolar plane.

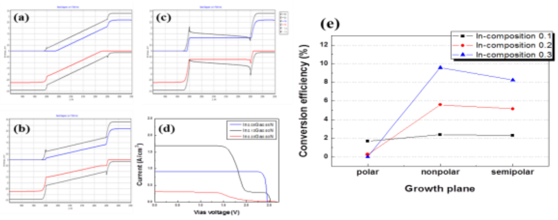

Fig. 2 Band diagrams of three differnent $In_xGa_{1-x}N$ samples ((a)x=0.05, (b)0.10, (c)0.20) and (d) their IV characteristics. (e) Conversion efficiency in relation to growth plane with variation of In-composition.

Reference

[1] Y. Kuwahara, *et al.*, Appl. Phys. Exp. **3,** 111001 (2010).