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Efficiency Improvement by Transparent Contact Layer in InGaN-Based *p-i-n* Solar Cells

J. P. Shim[1], S. R. Jeon[2], D. S. Lee[1]

[1]*School of Information and communications, Gwangju Institute of Science and Technology (GIST), Gwangju, Korea*
[2]*Korea Photonics Technology Institute (KOPTI), Gwangju, Korea*

Abstract. InGaN/GaN p-i-n solar cells with 10.8% indium composition were fabricated with different current spreading layers and metal-grid electrodes. Ni/Au (5nm/5nm) and ITO (150 nm) were used as a spreading layer for comparison. The solar cell with the ITO current spreading layer showed better results than Ni/Au, a 79.5% fill factor and 1% conversion efficiency. Optimization of the metal-gird electrodes also affected on solar cell efficiency.

Keywords: InGaN solar cell, spreading layer, ITO
PACS: 88.40.hj

INTRODUCTION

InGaN is a promising material for solar cells due to its tunable bandgap energy from 0.7eV for InN to 3.4eV for GaN, covering the entire solar spectrum [1]. It is very important to enhance the transmission of the sun light and extraction of the generated carriers. For this reason some InGaN solar cells use Ni/Au semitransparent layers for Ohmic contact to p-GaN. However, the transmittance of Ni/Au layers represents less than 60% in 350~400nm wavelength regions [2], [3]. We used indium tin oxide (ITO) as a transparent *p*-contact material and compared with Ni/Au layers. We also carried out experiments to optimize metal electrode design such as the number of metal grids, grid spacing, and so on.

EXPERIMENT

InGaN/GaN *p-i-n* structures were grown using metal organic chemical vapor deposition (MOCVD) with 10.8% indium composition. Two sets of 2.5 mm × 2.5 mm solar cell devices with different spreading layers were fabricated. Fabricated solar cell structure is shown in FIGURE 1. They were etched down to *n*-GaN by Inductive Coupled Plasma (ICP) to form *n*-contact pads. Then, Ni/Au (5nm/5nm) and ITO (150nm) was deposited on *p*-GaN, respectively. Grid type Ni/Au (30nm/ 500nm) *p*-contact pads were formed on each spreading layer. Ti/Al/Ti/Au (30 nm/80 nm/20 nm/500 nm) *n*-contact pad was formed in the order. Two cells were annealed at 500˚ C for 1 min under ambient condition. Three additional sets of samples with ITO spreading layers were fabricated in the same way with various number of *p*-contact pads. External Quantum Efficiency (EQE), fill factor (F.F.), open circuit voltage (V_{oc}), short circuit current (J_{sc}) and conversion efficiency were measured under 1.5 AM condition.

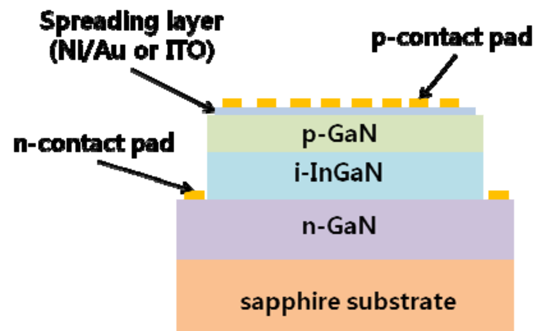

FIGURE 1 Fabricated InGaN based p-i-n structure

RESULT AND CONCLUSIONS

As shown in FIGURE 2, spreading layers largely affect to short circuit current density (J_{sc}) and the solar cell with ITO spreading layer shows better results than

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Ni/Au.

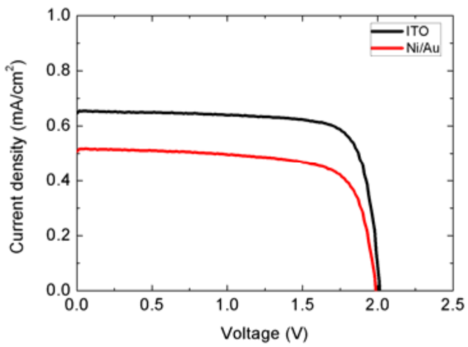

FIGURE 2 I-V characteristics of the InGaN-based *p-i-n* solar cells with ITO and Ni/Au spreading layer under AM 1.5 condition.

Although a high fill factor (> 70%) and a high open circuit voltage (~ 2V) were obtained for two samples, conversion efficiencies were different due to different J_{sc} values. The solar cell with the ITO spreading layer shows higher J_{sc} than Ni/Au resulting in 1% conversion efficiency.

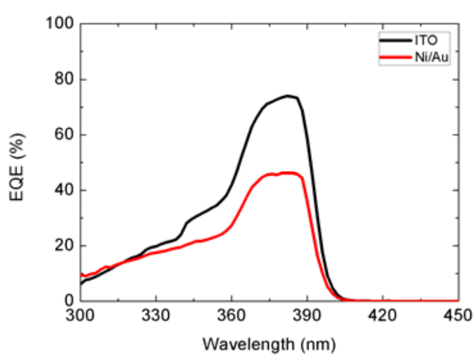

FIGURE 3 EQE of the InGaN based *p-i-n* solar cells with ITO and Ni/Au spreading layers. ITO shows higher EQE.

To investigate the J_{sc} difference according to spreading layers, EQE was measured from 300 nm to 450 nm. As in FIGURE 3, the solar cell with the ITO spreading layer shows higher EQE mostly due to better carrier extraction than Ni/Au. Over 90% transmittance of ITO in this wavelength range also contributes to the enhanced sunlight absorption considering only 60% transmittance of Ni/Au. [2], [3].

The effects of number of grid metals in solar cell device are shown in FIGURE 4. While J_{sc} decreases with increasing number of grid metals due to the increased shading area, V_{oc} was slightly increased. ITO-1-(2) sample having 9 metal grids with 180um grid spacing showed the highest conversion efficiency of 1%.

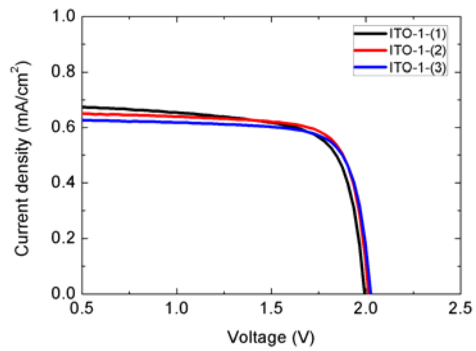

FIGURE 4 I-V characteristics of the InGaN-based *p-i-n* solar cells with various number of grid metals under AM 1.5 condition.

Although we obtained a little enhancement in J_{sc} by increasing the number of grid metal lines, further optimization is needed in various factors including current movement path and resistivity that affect to current extraction.

InGaN-based *p-i-n* solar cells with various current spreading layers were fabricated and the solar cell with the ITO current spreading layer showed better results, a 79.5% fill factor and 1% conversion efficiency, than Ni/Au layer.

ACKNOWLEDGMENTS

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