ICOP 2009 - International Conference on Optics and Photonics
Chandigarh, India, 30 Oct. - 1 Nov. 2009

SIMULATION OF $In_xGa_{1-x}N$ BASED p-i-n SOLAR CELLS

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Abstract: The InGaN alloy system offers a unique opportunity to develop high efficiency solar cells. In this study, p-i-n solar cells consisting of $In_xGa_{1-x}N$ are successfully simulated, with Indium fraction varying from x = 0.07 to 0.25. The key properties of $In_xGa_{1-x}N$ were simulated by employing PC-1D software, including I-V characteristic, efficiency, band structure, built-in electric field, quantum efficiency etc. The results of the simulation were compared with the results of other fabricated solar cell published in the literature and analyzed the causes of the differences among these results. This work may help the progress in the preparation of the InGaN-based high efficiency solar cells.

1. INTRODUCTION

The III-nitride technology is well established for optoelectronic applications such as light emitting diodes and laser diodes [1], recent developments confirm its substantial potential in photovoltaic applications [2].

Recently, indium gallium nitride ($In_xGa_{1-x}N$) alloys are becoming familiar in electronics, they have energy gaps lying between 0.7 and 4.2 eV [3]. So it can be used for photovoltaic applications. The goal of achieving photovoltaic conversion efficiencies of 50% or higher not only attributes as a scientific achievement and aids specialized applications, but can also reduce the cost of large-scale solar electric generation. Detailed balance modeling indicate that in order to achieve practical terrestrial photovoltaic efficiencies of greater than 50%, materials with band gaps greater than 2.4 eV are required [4]. In addition to the wide band gap range, the nitrides also demonstrate favorable photovoltaic properties such as low effective mass of carriers, high mobilities, high peak and saturation velocities, high absorption coefficients, and radiation tolerance [5].

In order to evaluate the possibilities of these alloys, we tried, to model and simulate the p-i-n solar cell structures by varying the fraction of Indium in $In_xGa_{1-x}N$ and the thickness of the intrinsic region. The calculations here were done for AM1.5 illumination.

2. SIMULATION

The different layers of the p-i-n solar cell structures were simulated with the help of PC1D software. The top layer consisted of p-type Gallium Nitride (GaN) of thickness 0.1 µm and having doping concentration of 5e17 cm^{-3} and the bottom layer consist of n-GaN of thickness 0.2 µm with the doping concentration of 5e18 cm^{-3}. The middle layer consists of intrinsic $In_xGa_{1-x}N$ layer with a concentration of 1e11 cm^{-3}. The indium fraction was varied from 7% to 25% . Figure.1 shows the p-i-n structure considered for simulation.

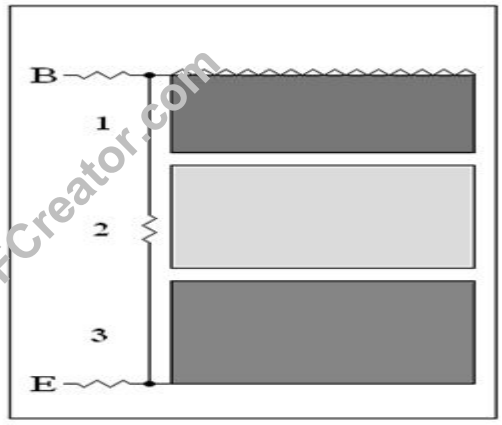

Fig. 1. p-i-n structure.

The p-i-n solar cell structures were simulated by changing the thickness of the intrinsic layer. Figure. 2. shows the short circuit current obtained for different layers of varying thickness and indium concentrations. It is observed from the figure that the short circuit current increases almost linearly.

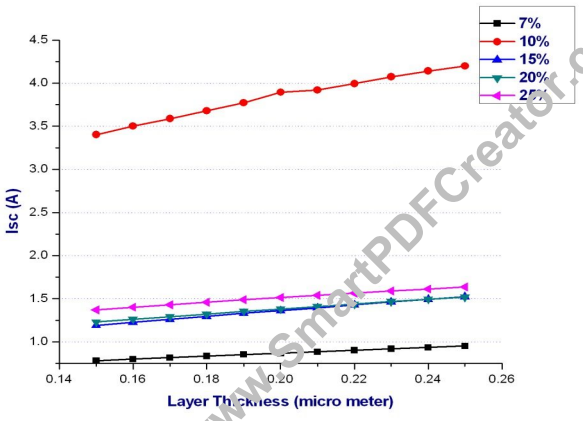

Fig. 2. Short circuit current vs intrinsic layer thickness.

The device size of 10 cm x 10 cm p-i-n structure was considered for simulation. After simulation the short circuit current obtained was (Isc) 3.893 A with an open-circuit voltage (Voc) of 2.395 V. The device was excited by one sun exc file in the transient mode. The maximum power obtained was 5.853 W . The calculated fill factor of the device was 62.77% and the calculated efficiency of the cell was 58.53% for the layer thickness of 0.20 µm.

Table.1. comparison of efficiency of $In_xGa_{1-x}N$ layer with different layer thickness and different Indium fraction

Layer thickness µm	Efficiency (%)				
	In (7%)	In (10%)	In (15%)	In (20%)	In (25%)
0.15	3.053	49.36	7.083	7.543	9.443
0.16	3.195	51.44	7.525	7.947	9.868
0.17	3.332	53.23	7.934	8.332	10.26
0.18	3.476	55.11	8.383	8.734	10.67
0.19	3.628	57.06	8.869	9.154	11.08
0.20	3.755	58.53	9.254	9.516	11.44
0.21	3.904	60.14	9.711	9.915	11.82
0.22	4.054	61.69	10.19	10.31	12.19
0.23	4.213	63.30	10.67	10.73	12.57
0.24	4.366	64.71	11.13	11.12	12.93
0.25	4.512	65.94	11.58	11.50	13.26

Table.1. shows the comparison of efficiency of p-i-n solar cell for different Indium fraction of InGaN and different thickness. The thickness of InGaN was varied from 0.15 µm to 0.25 µm. The maximum efficiency was observed with indium fraction of 10% in InGaN. Figure.3 shows the efficiency for different layer thickness with different indium fraction. We can notice that efficiency increases linearly with increase in layer thickness for different indium fraction.

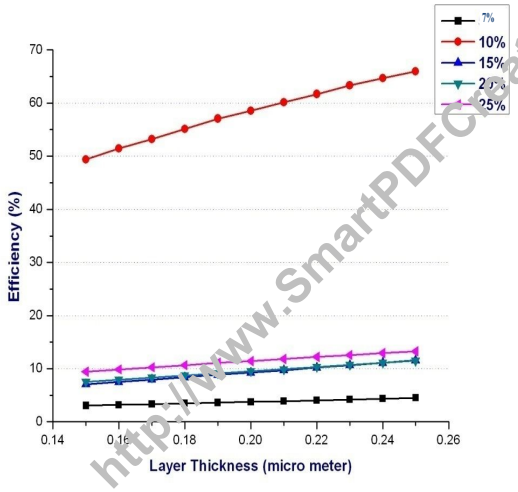

Fig. 3. Efficiency vs intrinsic layer thickness

3. CONCLUSION

The Voc and the fill factor obtained in the simulation is comparable with the p-i-n solar structure fabricated by Omkar Jani et al [6] for the indium fraction of 20%.

ACKNOWLEDEMENT

The author would like to thank the Director, CEERI for his encouragement and all the members of the optoelectronic devices group for their support.

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