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The influence of thickness variation on the efficiency of (InN/Si) and (GaN/Si) solar cells

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The (InN/Si) and (GaN/Si) solar cells was designed and investigated by using ISE TCAD simulation software under air mass 1.5 global irradiance spectrum. The doping levels of p-type and n-type were $1\times10^{19}cm^{-3}$ and $1\times10^{18}cm^{-3}$ respectively. The thickness of InN and GaN was changed several times as (0.2,0.4,0.6,0.8 and 1 μm). In this study , we present the effect of n- type layers thickness variation on the performance of InN and GaN solar cells structures. In this numerical study, all the processing conditions were kept constant except the thickness. The efficiency values were (29.15%) and (19.69%) for GaN and InN, respectively.

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Keywords: III-V nitride compounds, critical thickness, diffusion length, resistivity

1. Introduction

The effect of wafer thickness on the conversion efficiency of Sun Power's solar cell design was first described in 2003 [1]. The thickness of the cells affects its efficiency in a number of ways. Firstly, reducing of the thickness decreases the photo-generated current because there is no enough thickness to fully absorb the longer wavelength photons. However, in the Sun Power cell design, the light trapping features such as texture and a rear surface reflector increase the effective optical path length dramatically which minimizes the loss of the near band gap photons [2]. Secondly, decreasing the thickness increases the efficiency because the ratio of diffusion length to thickness increases and thus increasing collected efficiency of the minority carriers.

2. The properties of InN and GaN materials

The group III-V nitrides, such as indium nitride (InN), gallium nitride (GaN) and their alloys have actively been investigated for the past three decades or so for their promising semiconductor device applications in the electronics as well as optoelectronics operating in the blue and ultraviolet (UV) region of the light spectrum. The wavelength range of this continuous alloy system formed by the nitrides with direct band gaps which start from 0.77 eV for InN to 3.4 eV for GaN, thus covering the technologically important UV and visible spectral ranges [3]. GaN is also an attractive candidate for protective coatings due to its radiation hardness [4] and wide band gap makes it go to intrinsic concentration at a much higher temperature than materials like Ge, Si and GaAs, i.e. the intrinsic carrier concentration at any given temperature decreases exponentially with band gap. Therefore, GaN and similar wide band gap materials are attractive to high temperature applications. Moreover, the GaN is a direct and wide band gap semiconductor when compared to the more widely known (Si, GaAs and SiC). These properties have made InN and GaN a suitable semiconductor material for device applications in the high-temperature and caustic environment as well as in space applications. Consequently the InN and GaN have many attractive features like densities, higher mobilities and higher breakdown voltages [5,6].

3. Simulation results and discussion

In this study, we investigated the InN and GaN solar cell designs numerically by using ISE TCAD simulator as shown in Figs. (1, 2).

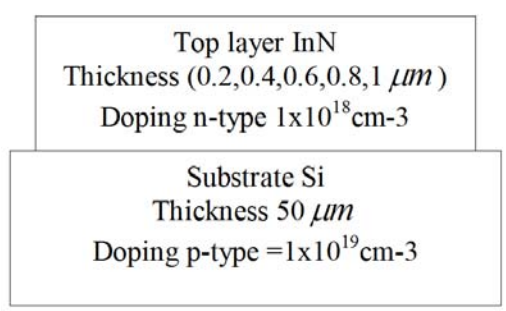

Fig. 1. InN/Si design.

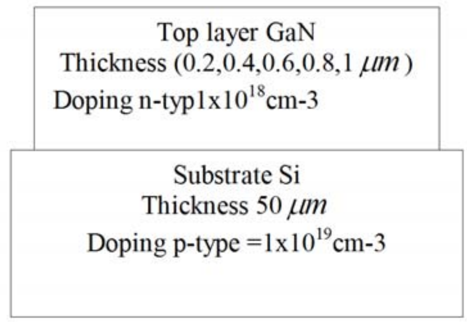

Fig. 2. GaN/Si design.

For a practical analysis of the solar cell performance, the dark and light I–V characteristics shown in Fig. 3.

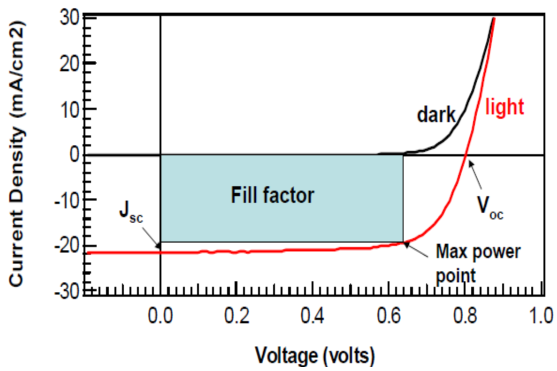

Fig. 3. Typical dark and illuminated solar cell.

Prominent parameters of the illuminated I–V characteristics include the open-circuit voltage V_{oc}, the short-circuit current density I_{sc}, the maximum power voltage V_{mp} and the current density for maximum power I_{mp}. The maximum power P_{mp} is given by the product V_{mp} Imp. The efficiency of the cell at the maximum power point is the ratio of the output power P_{mp} to the incident solar power P_{in} [7].

$$\eta = \frac{P_{mp}}{P_{in}} = \frac{V_{mp} I_{mp}}{P_{in}} = \frac{V_{oc} I_{sc} \eta_{fill}}{P_{in}} \qquad (7)$$

where η_{fill} is the fill factor

$$\eta_{fill} = \frac{I_{mp} V_{mp}}{I_{sc} V_{oc}} \qquad (8)$$

The I-V characteristics are very important parameters especially for the solar cells because the solar cell depends on V_{oc} and I_{sc} in order to obtain the fill factor (FF) and efficiency (η) values. From Tables (1, 2) observed that the optimum thickness was located in the range (0.2-1 μm) it was value (0.2 μm) for InN and GaN. Moreover, the GaN has a higher value than InN for the efficiency in the thickness of (0.2 μm) where its efficiency was (29.15%) for GaN versus (19.69%) for InN.

Table 1. Calculate the fill factor(FF) and efficiency (η) of GaN/Si.

Thickness(μm) Top layer(GaN)	V_m(V)	I_m(A) x10^{-8}	V_{oc}	I_{sc}(A) x10^{-8}	FF %	Efficiency (η) %
0.2	0.51	4.54	0.57	4.57	88.89	29.15
0.4	0.5	4.53	0.56	4.57	88.5	27.09
0.6	0.53	3.64	0.58	3.8	87.53	22.38
0.8	0.51	2.63	0.53	2.82	89.74	15.66
1	0.48	2.34	0.54	2.38	87.39	13.23

Table 2. Calculate the fill factor(FF) and efficiency (η) of InN/Si.

Thickness(μm) Top layer(InN)	V_m(V)	I_m(A) x10^{-8}	V_{oc}(V)	I_{sc}(A) x10^{-8}	FF %	Efficiency (η) %
0.2	0.46	2.8	0.54	3.09	77.19	19.69
0.4	0.44	2.32	0.52	2.71	72.24	15.60
0.6	0.44	2.32	0.52	2.71	72.24	8.71
0.8	0.38	1.5	0.46	2.05	60.44	8.71
1	0.38	1.65	0.46	2.24	60.85	9.58

This study will help to know the optimum thickness for these two materials, and in the end, these results will encourage the fabrication towards the solar cells structures within this thickness.

4. Conclusions

In this study, the designs of (InN/Si) and (GaN/Si) solar cells were carried out by using the numerical simulation method. Our results described how the thickness affects on the efficiency. It was found in Figs. (4, 5) that the best efficiency values got in thickness (0.2 μm). The wafer thickness which we used was 50 µm is not sufficient to produce high efficiency solar cells. Thus, we need to increase the wafer thickness to be ≥100 µm because the silicon has a big diffusion length (L) and this allows to use a bigger thickness.

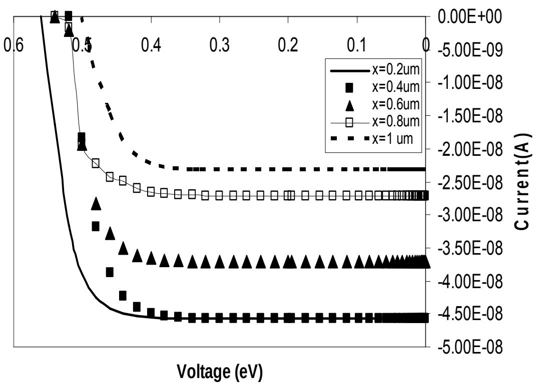

Fig. 4. The I-V characteristics of (GaN/Si) as a function of the thickness variation (x).

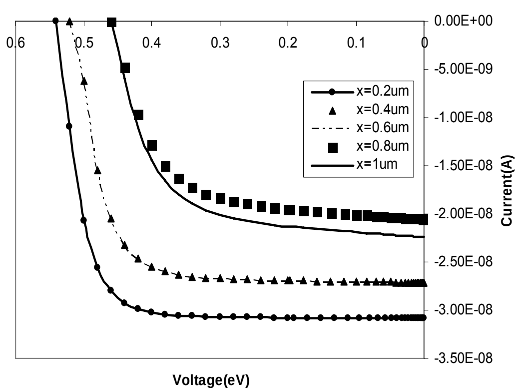

Fig. 5. The I-V characteristics of (InN/Si) as a function of the thickness variation (x).

Hence, V_{oc} is the key parameter to assess whether reducing the thickness was beneficial or not. So a slight improvement in V_{oc} was expected when reducing the thickness for the low lifetime.

The increase in the solar cell performance is ascribed to the increase in the open circuit voltage (V_{oc}) of the solar cell without significant loss in the short circuit current (J_{sc}). Therefore, a significant cost reduction has been realized when the wafer thickness is reduced while yield and cell performance are maintained. This reduction in thickness often results in a decrease in the cell performance compared to the solar cell with the conventional thickness.

References

[1] K. R. McIntosh, M. J. Cudzinovic, D. D. Smith, W. P. Mulligan, R. M. Swanson, Proceeding of the 3rd World Solar Energy Conference, Osaka, Japan, 2003.
[2] Keith R. McIntosh, Nicholas C. Shaw, Jeffrey E. Cotter, Proceedings of the 19th European Photovoltaic Solar Energy Conference, Paris, France, 2004.
[3] S. Strite, H. Morkoc, J. Vac. Sci. Technology B**10**, 1237 (1992).
[4] F. Ali, A. Gupta, eds., HEMTs and HBTs; Devices, Fabrication and Circuits, Artech House, Norwood MA, 1991.
[5] S. M. Sze, ed., High-speed semiconductor devices, John Wiley & Sons, New York, 1990, Chapter 5.
[6] S. J. Pearton, J. C. Zolper, R. J. Shul, F. Ren, Appl. Phys. Rev. **86**(1), 57 (1999).
[7] J. O. Schumacher, W. Wettling: "Device physics of silicon solar cells", in Photoconversion of Solar Energy, **3**, edited by M. Archer, Imperial College Press, London, 2000, ISBN 1-860-94161-3.

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