DESIGN AND SIMULATION OF INDIUM GALLIUM NITRIDE MULTIJUNCTION TANDEM SOLAR CELLS

Nargis Akter

Lecturer, Department of CSE, International Islamic University Chittagong, Chittagong, Bangladesh

Abstract

As our global energy expenditure increases exponentially, it is apparent that renewable energy solution must be utilized. Solar PV technology is the best way to utilize the unlimited solar energy. The InGaN is a recently developed novel solar cell material for its promising tunable band gap of 0.7 eV to 3.4 eV for the realization of high efficiency tandem solar cells in space and terrestrial applications. In this work, various numerical simulations were performed using Analysis of Microelectronic and Photonic Structure (AMPS) simulator to explore the possibility of higher efficiency of InGaN based solar cells. At these aim three different types of InGaN based solar cells (single junction, double junction and triple junction) were designed and optimized. Numerical simulations were done with different band gap of InGaN material and found that maximum efficiency occurs around 1.2 eV to 1.5 eV, it has been optimized at 1.34 eV for (single junction solar cell) with maximum conversion efficiency of 25.02%. The single junction solar cell were simulated and optimized for optimum thickness of p-layer and n-layer. Doping concentration and back contact material of the designed cells were investigated and found that 1×10^{16} cm^{-3} of doping concentration for both p and n type material and Nical as back contact with Φ_{bL} of 1.3 eV are best fitted for higher conversion efficiency. From tunable band gap of $In_xGa_{1-x}N$ material, selection has been done at 1.61 eV, 1.44 eV and 1.21 eV for the top, middle and bottom cells respectively for the tandem triple junction and double junction (1.61 eV, 1.21 eV) solar cells. The best conversion efficiency of the single junction, double junction and triple junction solar cells are 25.019%, 35.45% and 42.34% respectively. Effect of tunnel junction for the tandem cells also investigated and found that required thickness for tunnel junction is around 25 nm with doping concentration, N_A and N_D of 1×10^{19} and 1×10^{16} respectively were found in this analysis. Finally, the temperature coefficient (TC) of the above proposed cells were simulated to investigate the thermal stability of the proposed cells. It has been found that the TC of InGaN cells is about -0.04%/°C, which indicate the higher stability of the proposed cells.

Keywords: *Solar electricity, Solar cells, InGaN, Tandem, Ultra thin film, AMPS, Conversion Efficiency, Thermal stability.*

----------***----------

1. INTRODUCTION

Indium Gallium Nitride (InGaN) thin film solar cell has recently been recognized as a leading photovoltaic candidate for the possibilities of high conversion efficiency. To attain the expected breakthrough of photovoltaic technology as a competitive energy source against fossil fuels, the cell higher conversion efficiency, low cost and stability are the main factors. The InGaN material has attractive tunable band gap of 0.7 eV to 3.42 eV and high optical absorption coefficient over 10^5/cm which indicates the better absorption of the Sun spectrum [1, 2]. It is a very potential material for ultra thin solar cells in space application. Its band gap can be tuned by varying the amount of Indium in the alloy. The possibility to perform band gap engineering with InGaN over a range that provides a good spectral match to sunlight makes InGaN suitable for solar photovoltaic cells. It is possible to grow multiple layers with different band gap of InGaN as the material is relatively insensitive to defects introduced by a lattice mismatch between the layers [3]. A two-layer multijunction cell with band gaps of 1.1 eV and 1.7 eV can attain a theoretical 50% maximum efficiency, by depositing multiple layers tuned to a wide range of band gaps an efficiency up to 70% is theoretically expected [3].

The layers of InGaN solar cell can be deposited using the cost effective techniques, such as Metal Organic Chemical Vapor Deposition (MOCVD), Metal Organic Vapor Phase Epitaxy (MOVPE), and Molecular Beam Epitaxy (MBE) [4]. In 2007 Jani et al. have reported GaN/InGaN solar cell [5]. Xiaobin Zhang et al. published 20.284% conversion efficiency of InGaN single junction solar cell in 2007 [6]. In 2008 same group published 24.95% conversion efficiency of single junction InGaN solar cell and the conversion efficiency of InGaN tandem solar cells for double junction and triple junction were 34.34% and 41.72% respectively [7]. Recently in 2011, S. Ben Machiche has achieved efficiency of 24.88% for single junction InGaN solar cell and efficiency of 34.34% and 37.15% for double junction and triple junction tandem solar cell respectively [8]. The III-V group materials are widely used for tandem solar cells for the space application, such as InGaP/GaAs double junction and InGaP/GaAs/Ge triple junction cells were developed in 2009. Triple junction structure of GaInP/GaAs/Ge shown efficiency of 41.6% [9]

but it should be noted that the 0.66 eV indirect band gap energy of Ge is not optimal as the material for the bottom sub cell in a triple junction cell. Recently, in 2012 a new structure of GaInP/GaAs/GaInNAs shows efficiency of 44%, which is the highest efficiency up to now [10]. But the problem of this structure is more complex quardinary alloy system of the cell and the toxicity as well as the cost of Arsenide (As) material is the biggest barrier of these material system. There are scopes to reduce the thickness to save materials and to increase the conversion efficiency by improving short circuit current density (*Jsc*), open circuit voltage (*Voc*) and fill factor (*FF*) with different proportion of x in $In_xGa_{1-x}N$ material system with different doping concentration. All the above ideas were modeled in this work and numerical analysis was done by using AMPS 1D simulator to achieve the best InGaN single junction solar cell for higher efficiency and stability. The proposed cell might be a basic component of tandem solar cells. The conversion efficiency has been found in this research work were 25.019%, *35.45% and* 42.34% respectively for the proposed InGaN single junction, double junction and triple junction tandem solar cell with the temperature coefficient (TC) of -0.04%/ºC.

2. DESIGN AND SIMULATION

One-dimensional AMPS numerical simulation of InGaN thin-film solar cells is used in this work. It is a powerful tool to build a reasonable physical model to test the viability and numerical simulations can help to predict any changes in cell performance resulting from the modified reasonable parameters [11]. Moreover, difficult experimental tasks can sometimes be by-passed with numerical modeling and simulations. The operation of semiconductor devices can be described by a set of basic equations. These equations are coupled with partial differential equations, for which it is often not possible to find general analytical solutions. These equations can be transformed into a set of nonlinear algebraic equations, which can be solved numerically with a computer.

Poisson's equation relates the electric field ***E*** to the charge density. In one dimension space, Poisson's equation is given by [11]:

$$\frac{dE}{dx} = \frac{\rho}{\varepsilon} \qquad (1)$$

Where, ε is the permittivity. Since the electric field ***E*** can be defined as $-d\Psi/dx$, where Ψ is the electrostatic potential and the charge density ρ can be expressed by the sum of free electron n, free hole p, ionized donor doping N_D^+, ionized acceptor doping N_A^-, trapped electron n_t and trapped hole p_t,

Poisson's equation can be written as [11]:

$$\frac{d}{dx}\left(-\varepsilon(x)\frac{d\Psi}{dx}\right) = q\left(p(x) - n(x) + N_D^+(x) - N_A^- + p_{t(x)} - n_{t(x)}\right) \qquad (2)$$

Due to complex and very costly fabrication methods of InGaN thin film solar cells, the need for numerical modeling method is higher for InGaN solar cells.

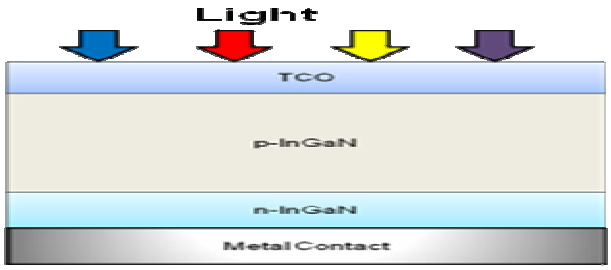
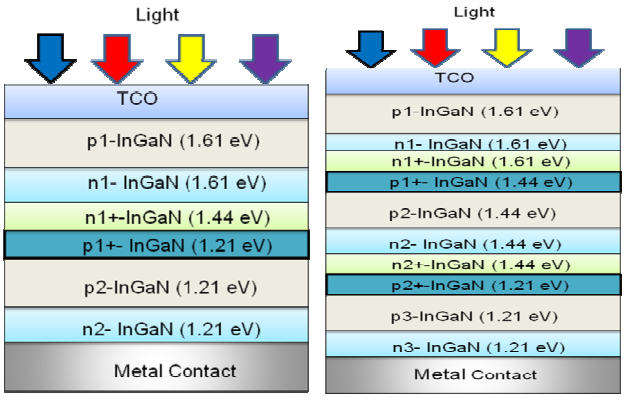


Fig -1: Single junction structure

Fig. 1 illustrates the proposed structure of InGaN based single junction structure and Fig. 2 illustrates the double junction and triple junction tandem solar cells structure. In the proposed $In_xGa_{1-x}N$ solar cell structure, a p-type layer which acts as absorber layer and an n-type layer are connected to form a single junction solar cell. A transparent and conducting oxide (TCO) about 200 nm is stagged which acts as the front contact of the cell, generally deposited on high quality glass substrate. Sun light strike at the p-type material over which a transparent conductor is connected as front contact and in the back surface a metal conductor is connected as back contact material as it should form an ohmic contact to the n-InGaN. TCO and back contact are used to achieve thin InGaN layer. The doping concentration ($5\times10^{17}cm^3$) used in the earlier study has been changed to ($1\times10^{16}cm^3$) more effective and today's practically achievable values for higher efficiency. Higher watt function metals such as Au/Ni/Pt need to be used for back contact as InGaN has high electron affinity. In this design back contact material Nical (Ni) has used with back contact barrier height of 1.3 eV. In this work, Analysis of Microelectronic and Photonic Structures (AMPS-1D) has been used to investigate the cell performance with $In_xGa_{1-x}N$.



(a) Double junction (b) Triple junction

Fig -2: Tandem Structure

For proper design of InGaN based solar cell, first one have to analyze the equation of material main parameters such as band gap, electron affinity, optical property, carrier mobility, density of states, permittivity, absorption coefficient, electric field distribution and stability at higher operating temperature etc. At room temperature, band gap (eV) of the $In_xGa_{1-x}N$ material is given by the relation [12]:

$$E_g(x) = 0.7x + 3.4(1-x) - 1.43x(1-x) \quad (3)$$

Where x is the proportion of In content in $In_xGa_{1-x}N$. The band gap of InN is 0.7 eV and the band gap of GaN is 3.4 eV. The 1.43 eV is the best fitted bowing parameter. From the equation (3), band gap of $In_xGa_{1-x}N$ were calculated and presented in the plotted in Fig. 3.

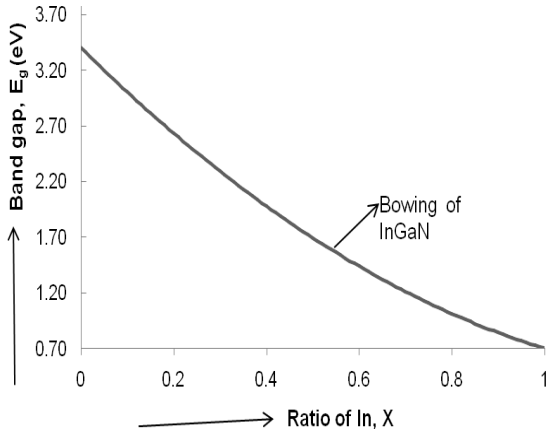


Fig -3: Band gap variation with the (x) proportion of In in $In_xGa_{1-x}N$ material.

From the Fig 3, it is clear that InGaN has promisisng tunable band gap of 0.7 eV to 3.4 eV.

The electron affinity of InGaN is expressed by the relation given below [13]:

$$\chi = 4.1 + 0.7(3.4 - E_g) \quad (4)$$

Where Eg is the band gap of the $In_xGa_{1-x}N$ material from equation (3).

The effective density of states in the conduction band: [13]

$$N_c = 0.9x + 1.8(1-x) \quad (5)$$

The absorption coefficient $\alpha(\lambda)$ is related to the particular wavelength and band gap of the $In_xGa_{1-x}N$ material [14].

$$\alpha(\lambda) = 2.2\times10^5 \sqrt{\frac{1.24}{\lambda} - E_g} \quad (6)$$

The effective density of states in the valence band [15]:

$$N_v = 5.3x + 1.8(1-x) \quad (7)$$

The relative permittivity, [13]:

$$\varepsilon_r = 14.6 + 10.4(1-x) \quad (8)$$

The above formulae are obtained from the linear fitting of the corresponding parameters of InN and GaN [16]. For designing of InGaN solar cell all parameters are calculated here and shown in the Fig. 4. From these values, several combinations of band gap have been tried and selection was made from best performance of the cells.

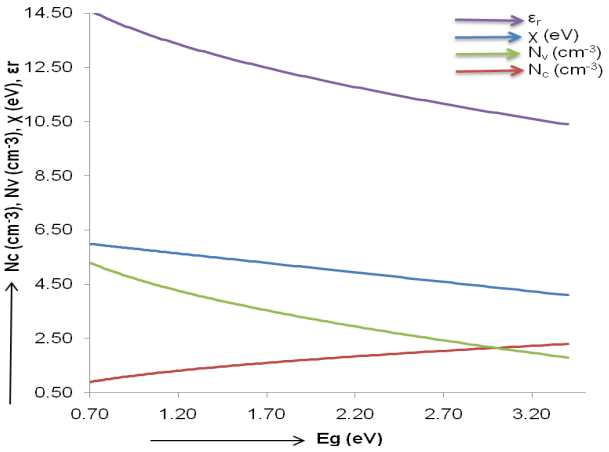


Fig -4: Device parameter and Band gap of $In_xGa_{1-x}N$

InGaN is a material with high electron affinity and when the band gap decreased electron affinity increased and relative permittivity of InGaN also increased. From Fig. 4 it is clear that the density of state at conduction band and valence band shows opposite behavior with the band gap. Effective density of state at conduction band decreased with decreased band gap while effective density of state at valence band increased.

Table 1 shows all the required parameters for the simulation of single junction, double junction and triple junction tandem solar cel

Table -1: Parameters for simulation

Type	x	E_g (eV)	ε_r	χ (eV)	Nc 10^{18} cm^{-3}	Nv 10^{19} cm^{-3}	N_A cm^{-3}	N_D cm^{-3}	μ_n	μ_n	D µm
p	0.64	1.34	13.09	5.54	1.40	4.04	10^{16}	0	955	169.8	0.5
n	0.64	1.34	13.09	5.54	1.40	4.04	0	10^{16}	955	169.8	0.1
p1	0.53	1.61	12.63	5.35	1.56	3.66	1×10^{16}	0	955	169.8	0.5
n1	0.53	1.61	12.63	5.35	1.56	3.66	0	1×10^{16}	955	169.8	0.1
n1+	0.6	1.44	12.92	5.47	1.46	3.90	0	3×10^{17}	433	169.8	0.03
p1+	0.7	1.21	13.34	5.63	1.32	4.25	1×10^{19}	0	73.53	3.15	0.02
p2	0.7	1.21	13.34	5.63	1.32	4.25	1×10^{16}	0	955	169.8	0.5
n2	0.7	1.21	13.34	5.63	1.32	4.25	0	1×10^{16}	955	169.8	0.1
p1	0.53	1.61	12.63	5.35	1.56	3.66	1×10^{16}	0	955	169.8	0.5
n1	0.53	1.61	12.63	5.35	1.56	3.66	0	1×10^{16}	955	169.8	0.1
n1+	0.53	1.61	12.63	5.35	1.56	3.66	0	3×10^{17}	433	86.5	0.03
p1+	0.6	1.44	12.92	5.47	1.46	3.90	1×10^{19}	0	73.53	3.15	0.02
p2	0.6	1.44	12.92	5.47	1.46	3.90	1×10^{16}	0	955	169.8	0.5
n2	0.6	1.44	12.92	5.47	1.46	3.90	0	1×10^{16}	955	169.8	0.1
n2+	0.6	1.44	12.92	5.47	1.46	3.90	0	3×10^{17}	433	86.5	0.03
p2+	0.7	1.21	13.34	5.63	1.32	4.25	1×10^{19}	0	73.53	3.15	0.02
p3	0.7	1.21	13.34	5.63	1.32	4.25	1×10^{16}	0	955	169.8	0.5
n3	0.7	1.21	13.34	5.63	1.32	4.25	0	1×10^{16}	955	169.8	0.1

3. RESULT AND DISCUSSIONS

One of the challenging issues of solar cells is related to the lesser material usage. The monocrystalline InGaN has high absorption coefficient over 10^5/cm, which means that all the potential photons of sunlight with energy greater than the band gap can be absorbed within few µm thin InGaN absorber layer. Moreover, $In_xGa_{1-x}N$ has direct band gap of 0.7 eV to 3.4 eV, to utilize whole solar spectrum. In my previous research it was published that absorber layer thickness of 0.5 µm is enough to create a best performance cell with 0.1 µm n layer at 1.34 eV [17]. In another work of triple junction tandem solar cell, bandgap selection has been made for the top cell, middle cell and bottom cell and they are 1.61 eV, 1.44 eV and 1.21 eV[18].

In this research it can be seen from the Fig. 5, electric field distribution of the cell that the field diminishes before 0.5 µm of p-InGaN thickness. The charge depletion extends approximately 0.5 microns into the p-InGaN layer. If the thickness of the p-InGaN layer is restricted to smaller values (<0.5 µm), then the InGaN layer is said to be 'fully depleted'.

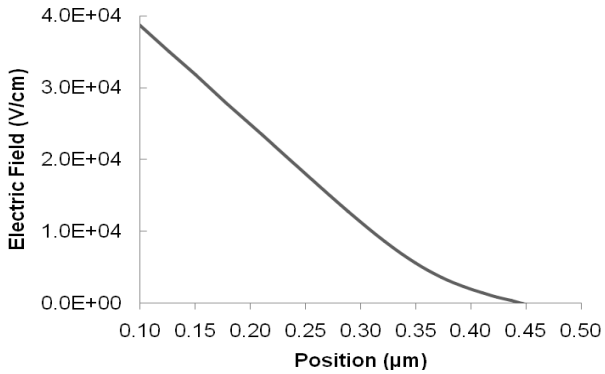


Fig-5: The electric field distribution in of InGaN absorber layer.

The carrier generation rate of 0.5 µm thick InGaN cells are calculated and found to be in the order of 5×10^{20} $cm^{-3}s^{-1}$ in the vicinity of InGaN junction as shown in Fig. 6. From the figure the carrier generation drastically decreases within just 0.5 µm of InGaN absorber layer thickness. So, 0.5 µm absorber layer has been selected for the different cell with o.1 µm n layer. single junction solar cell of InGaN. Previous result of single junction cell of this material are 24.95% and 24.88%. Absober layer thickness was selected at 0.5 µm for the top and bottom cells. This selectction has been made from rigorus simulation process by AMPS. The efficiency of the proposed double junction cell is 35.45%, which is higher than previously reported double junction cell of InGaN material. The reputed result are 34.43%. For the triple junction cell, selected bangaps are 1.61 eV, 1.44 eV and 1.21 eV for top, middle and bottom cell respectively.

Thickness of absorber layers are 0.5 µm . For triple junction cell efficiency is 42.34% that is also the highest for InGaN solar cell ever reported. The reputed results for triple junction solar cells are 41.72% and 37.15%.

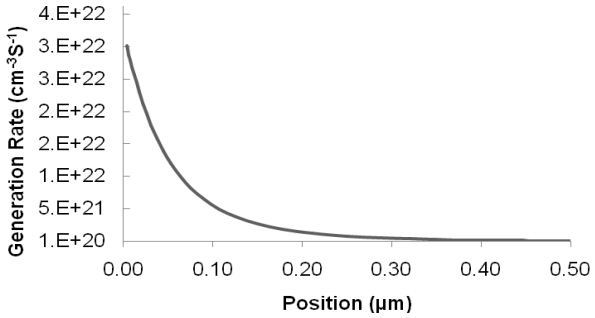


Fig-6: The calculated carrier generation rate in the InGaN solar cell

From this analysis, it can be concluded that 0.5 µm thickness of the absorber layer would be better for high efficient cell.

Band gap selection has been made from the numerical simulation for different ratio of Indium. From the result of this simulation, optimized band gap were selected 1.61 eV, 1.44 eV and 1.21 eV for the tandem top, middle and bottom cell respectively. For the double junction cell, band gap of 1.61 eV and 1.21 eV were selected for top and bottom cell respectively. And for the single junction solar cell, selected band gap is 1.34 eV, absorber layer thickness of the selected cell is 0.5 µm, which is 200 times lower than conventional solar cells. For the single junction solar cell the efficiency of designed cell is 25.019%, *Jsc*=30.883 mA/cm^2, FF=0.876 and *Voc*=0.925V. This efficiency is highest for a reputed

Effect of tunnel junction has been analyzed and thickness of the tunnel junction layer was optimized for the tandem cells\

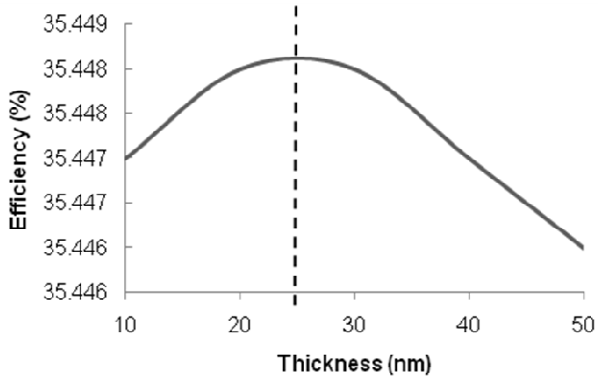


Fig-7: Effect of tunnel junction n layer thickness on tandem

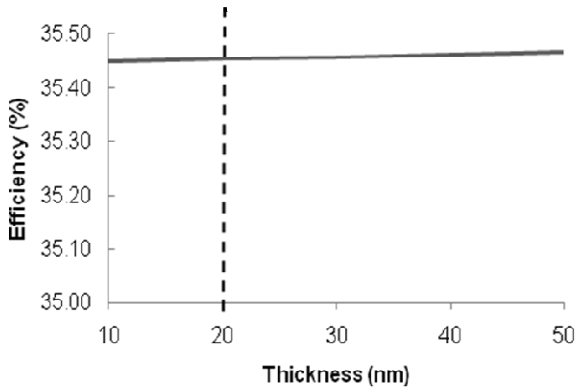


Fig-8: Effect of tunnel junction p layer thickness on tandem

From the proposed cells of single, double and triple junction, it is observed that the efficiency is increased in the tandem cells than single junction cell. In tandem cells, different cells with diffrent band gap are connected by tunnel junction to form a complete workable cell. The band gaps of the tandem cells are selected in such a way that it could absorb the maximum effective solar flux. The *Jsc* and *Voc* are very

important in tandem cell design. The *Jsc* follow the minimum value of the connected cells in series and *Voc* follow the higher value of the connected cell. In this work, three types of solar cells have been designed and found that the efficiency is 25.019%, 35.45% and 42.34% for single, double and triple junction respectively. The *Jsc* is 30.883 mA/cm^2, 33.984 mA/cm^2 and 36.15 mA/cm with *Voc* is 0.925V, 1.165V and 1.33V; FF is 0.876, 0.895 and 0.88 for the single junction, double junction and triple junction respectively which are shown in Table 2 for clear view.

Table 2: Comparison of Single, double and triple junction InGaN solar cells

Solar cell	*Jsc* (mA/cm^2)	*Voc* (V)	FF	Efficiency (%)
Single Junction	30.883	0.925	0.876	25.02%
Double Junction	33.984	1.165	0.895	35.45%
Triple Junction	36.15	1.33	0.88	42.34%

Three different cell efficiency curve from AMPS simulation are shown in Fig. 9.

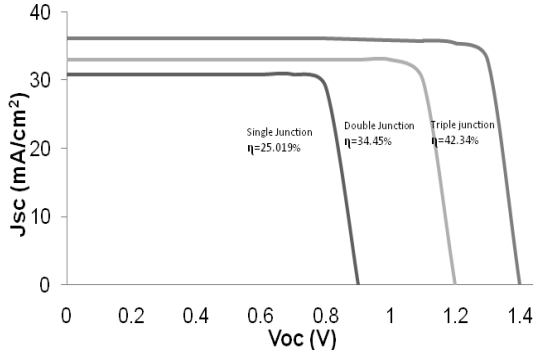


Fig-9: I-V curve of single, double and triple junction cells

An investigation has been done to understand the effect of higher operating temperature on the proposed cell efficiency with temperature ranged from 25 °C to 100 °C. The AMPS simulation results are shown in Fig. 10. It is evident from the Fig. 10 that the conversion efficiency linearly decreases with operating temperature at a temperature coefficient (TC) of -04%/°C, which also indicate the degree of stability of the cell at higher operating temperature or in stressed conditions.

For single junction, double junction and triple junction cell TC is -0.04%/°C. From the analysis of temperature dependency, cell stability is much better than other conventional solar cell. Therefore, the designed cell is more stable at higher operating temperature.

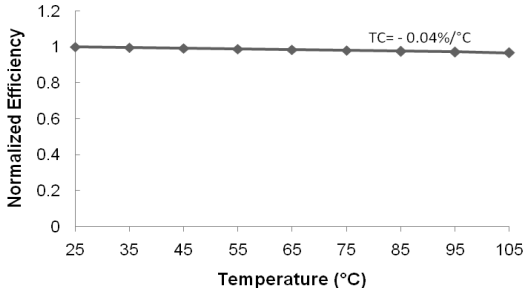


Fig-10: Effect of operating temperature on the tandem cell performance

CONCLUSIONS

Utilization of the enormous energy of the Sun by converting it into electricity is an emerging alternative way to fulfill the energy demand of the mankind. The PV solar cells are very potential which can be operate continuously without any maintenance, non-polluting and has the potentiality to fulfill the shared dream of humanity; clean and affordable energy from the sun, for all in everywhere. The number of materials that can be used for solar cell production is large. Recent studies suggest that thin films will dominate the worldwide terrestrial market in the near future, since they should be capable of reaching a lower price figure (in $/Watt). Among thin film InGaN is the favorable choice because it has important advantages as a material for solar cells, namely optimum tunable direct energy gap, higher absorption coefficient over 10^5/cm^3 and its ability to keep good electronic properties under different temperature. Because of the tunable band gap of 0.7 eV to 3.4 eV and the excellent semiconductor properties of InGaN, it is a promising material for single junction as well as tandem solar cells.

Numerical simulation of solar cell is an important way to predict the effect on cell performance and to test the viability of the proposed structure. A high efficiency InGaN single junction solar cell was designed and numerically optimized in this work with cell efficiency of 25.02%. The double junction and triple junction InGaN tandem solar cells were designed and numerically optimized in this work with the conversion efficiency of 35.45% and 42.34%. These simulated results are higher than the previously published results of InGaN solar cells. The thickness of the cells is reduced than other conventional solar cells and it will reduce the fabrication cost effectively. Effect of temperature of the proposed cells were investigated and found that temperature coefficient of the designed cells is -0.04%/°C, which indicate the thermal stability of the cell in stressed condition to some extent. Thermal stability of the proposed cells are in generally is higher than other conventional solar cell. This work has shown

an important way for the design and fabrication of single junction and tandem solar cells with InGaN material. Thus InGaN based tandem solar cells were designed and analyzed numerically. The designed cells of this work need to be fabricated for further investigation. Much more, research need to be done on this material for its design process and the fabrication techniques.

ACKNOWLEDGEMENTS

This work has been supported partially by the post graduate research grant of the Chittagong University of Engineering & Technology (CUET). I acknowledge to the above-mentioned university.

REFERENCES

[1]. Wu J, Walukiewicz W, Yu K M, Ager J W III, Haller E E, Lu H, Schaff W J, Saito Y and Nanishi Y 2002 Appl. Phys. lett. 80, 39-67, 2002.
[2]. Xiao H L, Wang X L, Wang J X, Zhang N H, Liu H X,Zeng Y P, Li J M and Wang Z G 2005 j. Crist. Groyh 276 401, 2005.
[3]. "Solar cell", *http://en.wikipedia.org/wiki/Solar_cell*, June 13, 2013.
[4]. "Characterization of InGaN based photovoltaic devices"www.sciencedirect.com/science/article/pii/S0040609 01200733X.July 5, 2013.
[5]. Jani, O., Ferguson, I., Honsberg, C.,Kurtz, S. Design and .characterization of GaN/InGaN solar cells. Appl. Phys. Lett. 91, pp.132-117, 2007.
[6]. "Simulation of In0.65Ga0.35N single junction solar cells" Journal of Physics D: Applied Physics, vol.40, pp.7335-7338, 2007.
[7]. Xiaoming; Shen Shuo; Lin Fubin; Li Yiming; Wei Shuiku; Zhong Haibin; Wan Jiangong Li "Simulation of the InGaN-based tandem solar cells" Photovoltaic Cell and Module Technologies II, edited by Bolko von Roedern, Alan E. Delahoy, Proc. of SPIE Vol. 7045, 2008.
[8]. "Potential of InxGa1-xN PhotovoltaicTandem"Revuedes Energies Renouvelables Vol.14, pp. 47-56,2011.
[9]. Takamoto T., Kodama T., Yamaguchi H., Agui T., Takahashi N., Washio H., Hisamatsu T., Kaneiwa M., Okamoto K., Imaizumi M., Kibe K., InGaP/GaAs solar cells. In Proceedings of the IEEE 4th World Conference on Photovoltaic Energy Conversion, Waikoloa, HI, USA, pp. 1769–1772, May 2006.
[10]. "Solar spectrum conversion for photovoltaics using nanoparticles"igitur-archive. library. uu.nl/milieu/2012-1102-00548/UUindex. html.
[11]. "AMPS Manual", The Electronic Materials and Processing Research Laboratory at the Pennsylvania State University, University Park, Pennsylvania, Pennsylvania State University, 2007.
[12]. Chris G., Van de Walle, M.D. McCluskey, C.P. Master, L.T. Romano, N.M. Johnson, "Large and composition-dependent band gap bowing in In*x*Ga1_*x*N alloys", Xerox Palo Alto Research Center, 3333 Coyote Hill Road, Palo Alto, California 94804, USA.
[13]. Levinshtein M.E., Rumyantsev S. L., Shur M.S.,"Properties of Advanced Semiconductor Materials", Wiley,Chichester,UK,1-90, 2001.
[14]. Li N., "Simulation and Analysis of GaN-based Photoelectronic Devices",Institute of Semiconduectors, Chinese Academy of Sciences, 2005.
[15]. Jiangong Li, Fubin Li, Shuo Lin, Shuiku Zhong, Yiming Wei, Xianghai Meng, Xiaoming Shen, "Theoritical Calculation of Conversion Efficiency of InGaN Solar Cells" *Chinese Journal of Semiconductors*, vol. 28, pp. 1392-1395, 2007.
[16]. Mnatsakanov T.T.,Livinshetein M.E., Pomortseva L.I., Yurkov S.N., Simin G.S., Asif Khan M.,"Carrier mobility model for GaN" *Solid-State Elrctron*, vol.47,pp. 111-115, 2003.
[17]. M. A. Matin, N. Akter, M. Quamruzzaman, N. Amin,"High Performance InGaN Solar Cell from Numerical Analysis" *International Journal of Engineering Research & Technoogy*, vol. 2, pp. 2739-2745, 2013.
[18]. N. Akter , M. A. Matin, N. Amin,"High Performance $In_xGa_{1-x}N$ Tandem Solar Cell Designed from Numerical Analysis" Procceedings of the IEEE Conference on Clean Energy and Technology, pp.469-472,

BIOGRAPHIES

Nargis Akter, M.Sc and B.Sc in EEE from Chittagong University of Engineering and Technology (CUET). Lecturer in theDepartment of CSE in the International Islamic University Chittagong, Bangladesh