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Double Action p-n Junction Fabrication and Investigation for Solar cell and LED Application

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Abstract

Today, energy is fundamental agenda of the world. For electricity energy generation, price analysis factor is most crucial as cost of energy generation is increasing day by day throughout the world. This research describes some studies on low cost device with double action p-n junction. Thin films of ITO, n-type ZnS and Zn doped GaAs (1:2) are deposited on glass substrate by RF magnetron sputtering. Spectroscopic Ellipsometer is used for optical measurements of extracts. Under illumination (AM 1.5), device acts as solar cell with PCE of 2.4%. By applying reverse bias voltage radiative recombination also takes place in active region (E_g= 2.2ev) and device act as green color LED (with low band width) in wavelength range of 520-523nm. However, it is possible to improve emission capability and band width, by decreasing non-radiative recombination.

Keywords: Solar cell; thin film; sputtering; LED.

1. Introduction

The demand for energy with each passing day is growing by leaps and bounds because of change in technology and growth in population. This rising demand creates energy crisis. For economic stability these crisis are the biggest warning. If energy is conserved life is preserved. Solar energy has been gained considerable attention during the last decade from Wall Street and countries that are looking forward for energy independence. To put an end to our addiction on oil, energy from solar (PV) cells is significant solution [1]. Basically, Solar cells involves conversion of sunlight (directly) into electricity at the atomic level by utilizing the process called photovoltaic effect. The production of emf (electromotive force) within that part of the material which is non-homogeneous, when the light of the appropriate wavelength falls on it is called photovoltaic effect. Electromagnetic radiations can be converted into electricity (only) in specially prepared structures, where the photovoltaic effect is high enough.

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Despite the enormous success of solar (PV) cells cumulative PV deployment still accounts for less than one percent of global electric usage. More research is needed to achieve energy independence and to sustain further deployment [2]. Moreover, Lighting accounts for nearly one-fifth of total electric energy consumption. For buildings lighting system, energy consumption can reach up to thirty percent of total consumption. Because of greatest potential impact of LED lighting on energy savings, its use is increasing day by day as compared to conventional lighting. LED is a semiconductor device when we electrically (forward) biased it, it emits incoherent narrow spectrum light. Effect which takes place in LED is electroluminescence in which due to electric current minority carriers injection into that region of crystal takes place where they recombine (with majority carriers) & results in the emission of radiation due to recombination. The emitted light color depends on semiconductor material & its composition & can be visible, infrared, or ultraviolet [3]. In this research, instead of small stand-alone application, double action P-N junction device (that can emit and absorb light) is fabricated with the motivation of low cost, high efficiency, energy saving & environmental protection. Here, we demonstrate double action p-n junction device fabrication (acts as solar cells as well as LED) different from previous approaches leading to V_{oc}= 0.95 V, J_{sc} = (3.7 mA/cm^2) and PCE of 2.4 % under illumination and in reverse bias radiative recombination takes place in active region of p-n junction.

2. Experimental technique

Thin films of ITO (97.36 nm), ZnS (106.78 nm), Zn doped GaAs (1:2) (105.78 nm) were deposited on glass substrate by RF magnetron sputtering. Targets consist of 99.99 % pure ITO having four-inch diameter, 99.99% pure ZnS target having diameter 76 mm and 99.99% pure target of GaAs (having diameter 50.8 mm). For all samples, distance between target & sample holder was 16.5 cm. Sputtering was carried out at pressure of 1.70 ×10-3 pa. Ar was used as sputtered gas (residual pressure of gas 0.50 Pa) and RF power throughout the growth was maintained at 100 Watt. Sputtering time was 60 min for ITO and 30 min for ZnS and Zn doped GaAs (1:2). Figure 1 shows schematic configuration of cell structure.

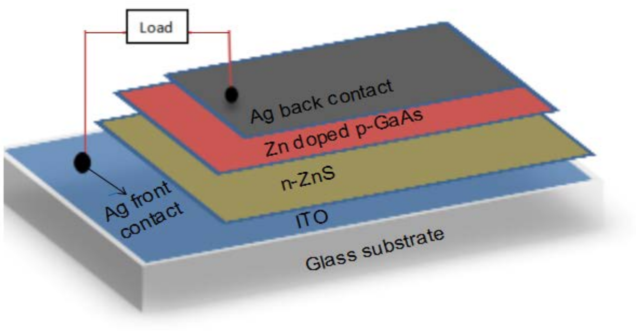


Figure 1: Structure of solar cell on glass substrate with double action p-n junction.

ITO due to its good combination of high transparency and high conductivity to light, high values of infrared reflectance and luminous transmittance, excellent substrate adherence and good electrical conductivity was used as a transparent electrode [4]. n-ZnS was used as buffer layer for maximum transmission (in the visible region) as it has wider band gap (3.7ev). Also, ZnS provide better lattice matching with GaAs. Zn doped Gallium arsenide (p-GaAs) (2:1) was used as absorber layer. Moreover, GaAs has high saturated electron velocity, high electron mobility, high absorption coefficient and direct band gap (1.2-1.7 eV). Due to wide band gap GaAs devices are not very sensitive to heat [5]. Finally, front and back contact of silver (Ag) was deposited on ITO and Zn doped GaAs (1:2), respectively.

Optical properties for thin films of ITO, n-ZnS, Zn doped GaAs(1:2) were measured by using JA Woolam Spectroscopic Ellipsometer. This is indirect method in which changes in optical parameters are monitored by some mathematical model. By using 4200-SCS's, I-V & C-V measurements on cell were performed in dark. Under illumination, (I-V) measurements by using Keithley 2400 were performed at room temperature with AM 1.5G light source. Under influence of solar radiation, (I-V) characteristics are controlled by changing (external) load. It changed from 'zero' to infinite load or short to open circuit conditions.

3. Results and Discussion

Figure 2 shows transmission spectra of ITO, ZnS, Zn doped GaAs(1:2) in wavelength range 250-850nm. Thin film of ITO shows transparency of 80% in visible region. The result confirms that in solar cell ITO is good to use as front side electrode. Thin film of ZnS shows transparency of 65% in visible region. So it can be used as buffer layer in cell. Also, it is good for increasing (I_{sc}).

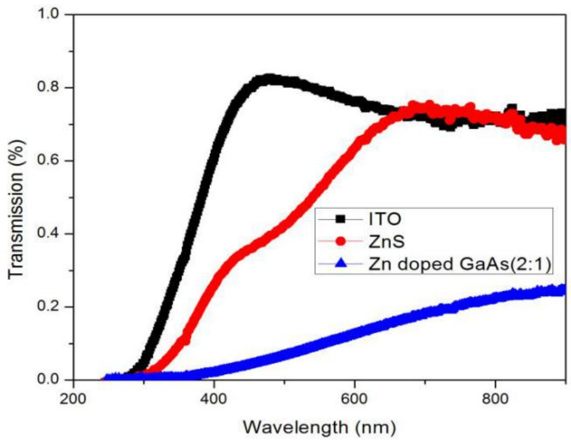
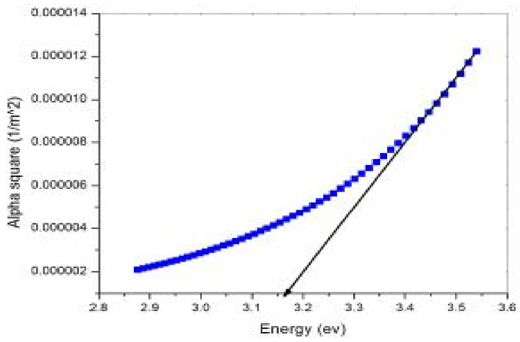


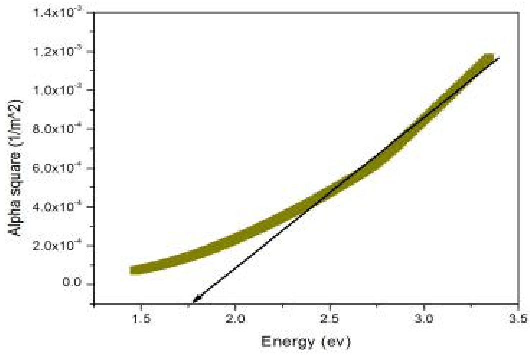
Figure 2: Optical transmission spectra of ITO, ZnS, Zn doped GaAs(1:2)

Band gap (E_g) of thin film of ITO, ZnS, Zn doped GaAs(1:2) is calculated by plotting α^2 versus energy of photon as shown in Figure 3(a) , (b) and (c). "α" is related to "E_g" of semiconductor by $\alpha(hv) = A(hv- E_g)^{n/2}$. Where "n" is constant, its value is 1 for materials having direct band gap compound semiconductor [7]. Value of E_g for thin films of ITO, ZnS and Zn doped GaAs (1:2) is found to be 3.1ev, 3.9ev & 1.7ev, respectively. Decrease in E_g of ITO is due to presence of defects at lattice site. Increase in E_g of ZnS is due to scattering by localize impurities in band gap.

(a)



(b)



(c)

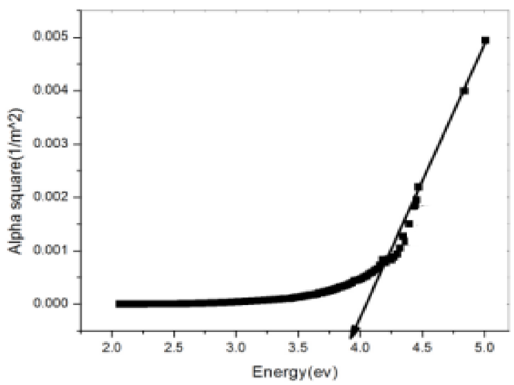


Figure 3: Optical Band gap of thin film of (a) ITO (b) Zn doped GaAs(1:2) (c) ZnS

J-V characteristics of fabricated cell in dark are shown in Figure 4. Measured cell area is 9.36cm^2. From dark J-V characteristic series resistance was found to be 7.65×E^{-11}Ωcm^2. From Figure 5 total saturation current (I_o= 31.15 mA/cm^2) of cell was determined by extra plotting straight line portion of ln(J)-V characteristic curve with current axis. From the slop of this characteristic curve ideality factor (n) was found to be 1.8.

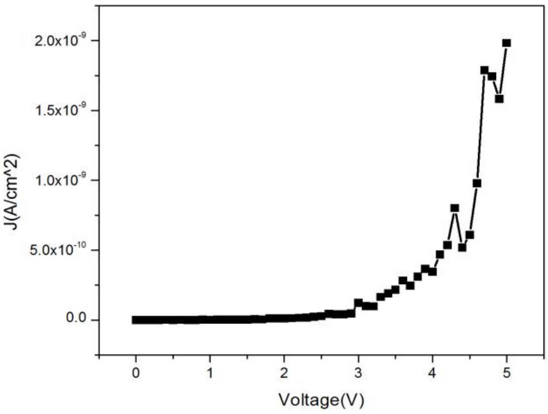


Figure 4: Dark I-V characteristics of cell

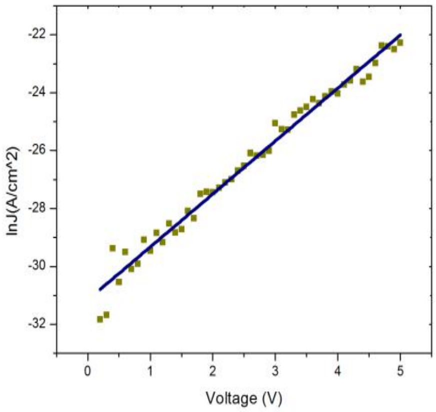


Figure 5: ln(J)-V curve in dark

Figure 6 shows capacitance-voltage measurements of cell in dark. Instead of plotting dC/dV, sometimes it is desirable to view data plotted as $1/C^2$ vs V. By slope of this curve doping density N(a) for the fabricated cell is found to be 6.4×10^9 cm^{-3}.

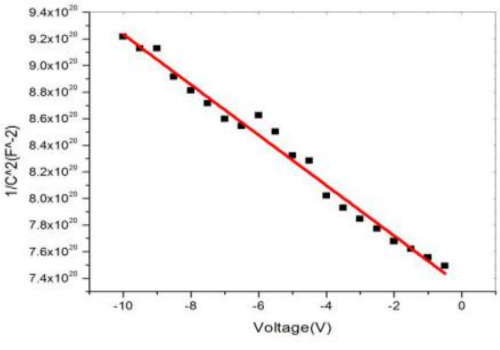


Figure 6: $1/C^2$ VS reverse V (voltage) at 100 KHz.

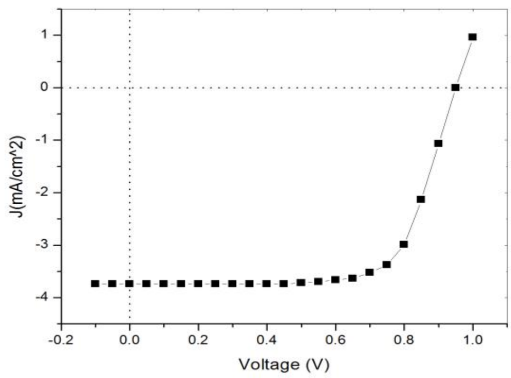


Figure 7: J-V charecteristic curve under illumination.

Table 1: Parameters of fabricated cell.

Incident light intensity	100 mW/cm^2
Short circuit current density (J_{sc})	3.7mA/cm^2
P_{max}	2.45mW/cm^2
Fill factor (FF)	70%
Efficiency (η)	2.4%
Voc	0.95V

J-V characteristic curve under illumination is shown in Figure 7. Parameters of fabricated cell are shown in Table. 1. Due to various recombination losses short circuit current density (Jo) is low and hence overall efficiency of fabricated cell is low.

To find the emission of light from device its luminescence was analyzed under reverse biasing by using JA Woolam Spectroscopic Ellipsometer**.** Figure 8 shows luminescence spectra of device in reverse bias. Sample was placed in sample holder. Spectroscopic lamp was turned off. Positive terminal of battery was connected with front contact (on n+ _ ITO) and negative terminal of battery was connected with back contact (Zn doped GaAs (2:1)). Peak intensity increases as we increase reverse bias voltage. When Reverse bias voltage was changed 0V to 0.5V,1V, 2V, 3V, 4V, 5V, 10V, 15V and 20V, highest intensity peak of energy 2.3 eV was obtained in wavelength range of 520-523 nm (Device acts as green color LED with small bandwidth). Therefore, for band to band recombination active region band gap should be 2.3eV. While, active region band gap was found to be 2.2eV from optical measurements. Difference of 0.1ev volt is due to presence of trap levels in the band gap. Therefore, some non radiative recombination can takes place. Further, band width can be increased by reducing non radiative recombination.

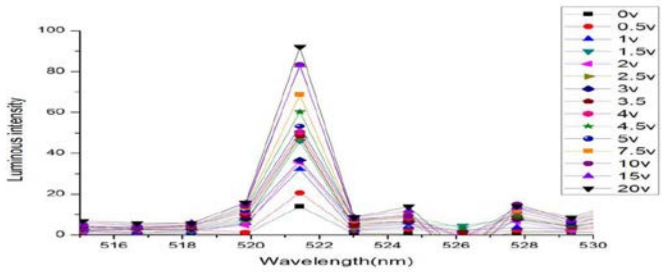


Figure 8: Luminescence Spectra of device in reverse bias.

4. Conclusion

Device with double action p-n junction was fabricated. Single Layers of ZnS, ITO, and Zn doped GaAs (1:2) were deposited by RF Magnetron sputtering and were characterized by spectroscopic ellipsometry and Keithley 4200 Semiconductor Characterization System. Under illumination, (AM 1.5) device acts as solar cell with PCE of 2.4%. Due to various recombination losses overall efficiency of solar cell is low. We have investigated that band to band recombination takes place in active region (E_g= 2.2eV) when reverse bias voltage was applied across the device. Hence, device acts as green color LED in wavelength range of 520-523 nm. Resulting band width was very small that can be increased by decreasing non radiative recombination which takes place in reverse bias.

5. Recommendations

- Individual layers need further study.
- interface may needs to be kept clean.

References

[1] Fahrenbruch, A., & Bube, R. (2012). Fundamentals of solar cells: photovoltaic solar energy conversion. Elsevier.

[2] Trykozko, R. (1997). Principles of photovoltaic conversion of solar energy. OPTOELECTRONICS REVIEW, 271-278.

[3] Singh, S. C. BASICS OF LIGHT EMITTING DIODES, CHARACTERIZATIONS AND APPLICATIONS.

[4] Wang, P., Li, X., Xu, Z., Wu, Z., Zhang, S., Xu, W., ... & Yu, Q. (2015). Tunable graphene/indium phosphide heterostructure solar cells. Nano Energy, 13, 509-517

[5] Tseng, C. Y., Lee, C. T., Pchelyakov, O. P., & Preobrazhenskii, V. V. (2015). Performance improvement mechanisms of pyramid-like via hole recessed GaAs-based solar cells grown on Si wafer. Solar Energy, 118, 1-6