FABRICATION AND STUDY OF SnO_2/INP HETEROJUNCTION SOLAR CELL BY SPRAY PYROLYSIS

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Abstract

SnO2/InP heterojunction solar cells have been prepared by spray pyrolysis low-cost technique with an open circuit voltage of 500 mV, a short circuit current density of 28 mA/cm^2, fill factor of 0.28, and conversion efficiency of 4%. Halogen lamp was used as a simulated AM 1 condition. Electrical properties of this heterojunction have been examined.

Key ward: Heterojunction Solar Cell, Spray Pyrolysis, conversion efficiency.

1. Introduction

The deposition and processing of wide-bandgap TCO/InP heterojunctions have become the topic of many recent investigations for next generation of very large area solar cells [1-5]. One of the promising techniques is the chemical spray pyrolysis (CSP). This technique is low-cost, simple, reliable, and practical.

In this technique, high efficient solar cells have been made [6-8].InP has a direct bandgap of 1.34 eV at 300 K is near the calculated optimum value for solar energy conversion [9]. SnO_2 is a wide-bandgap (about 3.4 eV) semiconductor with n-type conductivity. It has a high value of mobility for free carriers and Thin oxide films can be synthesized by numerous techniques such as chemical vapour deposition [15], spray pyrolysis [16], sputtering [17], and sol-gel deposition [13] SnO_2 semiconductor have been widely used for technical applications such as gas sensors, solar cells and transparent electrodes for optoelectronic devices. The SnO2/InP heterojunction has high efficiency solar energy conversion, it has efficiency is 13.8% [17], and other advantage it has low cost, radiation resistance [18].

In this paper, we report our experimental results on optoelectronics properties of SnO_2/InP solar cell made by CSP technique.

Experiment

The starting material used in the present investigation is single crystalline p-type zinc-doped InP wafers with orientation of (111) and resistivity of 12.5 Ω.cm. They were preliminary cleaned in a standard way. The heterojunctions were prepared by spraying 0.4M of an aqueous solution of $SnCl_4.5H_2O$ onto mirror-like InP substrate heated and maintained at 400 °C The thickness of polycrystalline SnO_2 film measured by gravimetric method was about 200 nm. Ag and Al electrodes were deposited on SnO_2 and InP respectively, by using thermal evaporation in a vacuum at 10^{-5} torr. By using blazer coating system. The structure of heterojunction solar cell is shown in Fig.(1).

The sensitive area of the cell was around 25 mm^2. The spectral responsivity at zero bias was investigated using monochromatic (MODEL746) in the range 450 to 1100 nm. The electrical characteristics of the heterojunctions were examined using C-V measurements using LCZ system hp/4192 ALF type at frequency of 0.5 MHz and reverse bias between (0-5) volts and I-V measurements under dark condition using Kethley 616 Digital Elecrometer. Seebeck method has been used to determine the conductivity type of SnO_2, The deposited films were subjected to X-ray diffraction (XRD, by CuKα line)

Results and Discussion

Fig.(2) shows the X-ray diffraction pattern of a typical SnO_2 film deposited on a glass substrate. The peaks at 2θ (27,36,53) correspond to diffraction from (110), (101), (211) planes of the SnO_2 tetragonal phase, respectively. Seebeck results shown in Fig.(3) that conductivity type of SnO_2 layer was n-type. C-V curve of the anisotype heterojunction was shown in Fig.(4).

Fig.(5) show C^{-2} versus Bias voltage for characteristics SnO_2/InP heterojunction This plot confirms that the junction was abrupt type and in good agreement with standard theory of diffusion model developed by Anderson. Since band bending be is primarily on the InP side.

The n-type conductivity of SnO_2 layer revealed from Seebeck measurements demonstrates an anisotype n-p heterojun-ction. I-V characteristics of SnO_2/InP anisotype heterojunction are illustrated in Fig.(6). Generally, I-V curve shows poor rectification (about 3 at I V) because of Soft breakdown is demonstrated from this figure.

Fig.(7) reveals the spectral respons-ivity plot of the solar cell. It is obvious that the peak response was at 600nm, this is because the SnO_2 layer acts as transparent heat mirror which transmit visible and reflect infrared radiation efficiently., In contrary to the conventional Si p-n junction solar cell that has peak response at 900 ± 50nm The shape of responsivity at the low wave-length region depends on the surface phenomena. Photons of these wavelengths are absorbed at the vicinity of the surface, where they generate charge carrier pairs, which may recombine, before they reach the p-n junction.

The recombination reduces carrier availability and consequently the responsivity [14]. On the other hand, it is evident from Figure 6 that responsivity curve has fall-off steeper for short wavelengths than long wavelengths region. For short wavelengths, this effect can be attributed to the parasitic light absorption in the SnO_2 (via band-to band transition) [5].

Fig.(8) demonstrates the light J-V curve plotted in the fourth quadrant to represent the power extracted from the devices. This figure describes the photovoltaic performance of the heterojunction, and from which, short circuit current density (Jsc) and open circuit voltage (Voc) can be found. The poor rectangularity of this figure is attributed to the high value of series resistance. Jsc and Voc of 28 mA/cm^2 and 500 mV respectively are registered from this figure.

Fig.(9) demonstrates the variation of the output power (the power extracted from the cell under simulated AM 1) versus voltage across the load resistance. The figure reveals that sprayed SnO_2/InP heterojunction is a suitable device to produce a high efficient solar cell with a conversion efficiency of 4%. The high value of conversion efficiency can be elucidated by the window effect taken place between these combinations. In contrast, the low value of fill factor (FF) of about 0.28 is probably due to oxide formation at the interface [7], which can be avoidable by using inert gas instead of air through the spray process.

Conclusions

Experimental study of pyrolytic spraying SnO_2/1nP heterojunction solar cell has shown that these cells exhibit reasonable efficiency per unit cost. C-V measurements showed that this heterojunction has an abrupt type with built-in potential of 1 V at InP side (i.e. the junction is one sided). I-V characteristics revealed that the junction has low rectification factor.

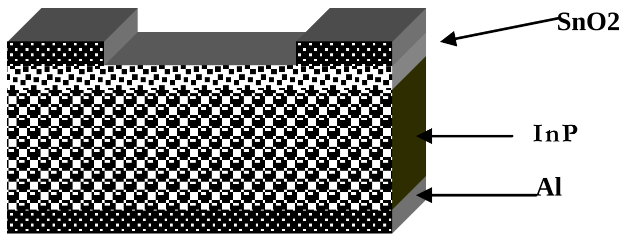

Fig.(1) : Cross-sectional view of heterojunction.

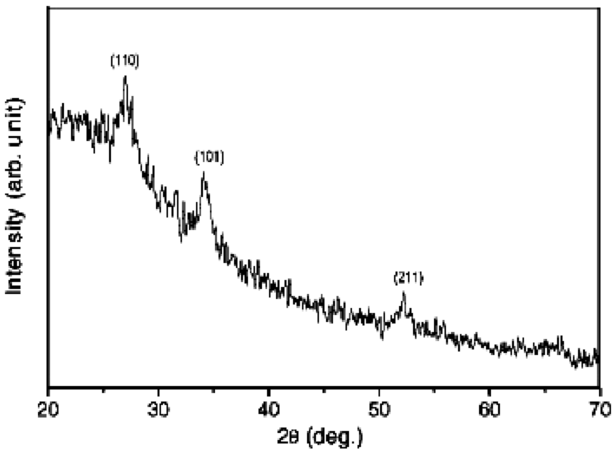

Fig.(2) : XRD patterns of the SnO_2 films on glass substrate.

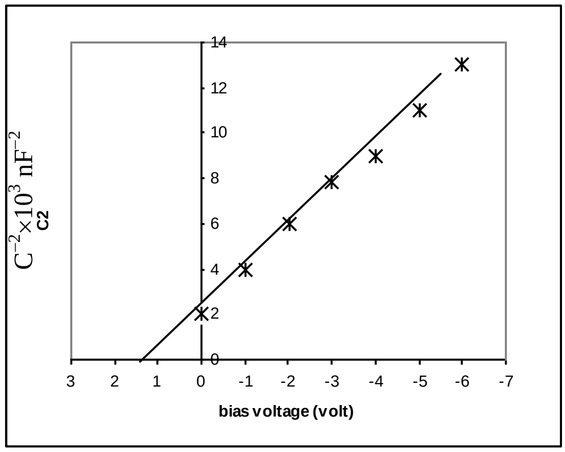

Fig.(5) : C^{-2} versus Bias voltage for characteristics SnO_2/InP heterojunction.

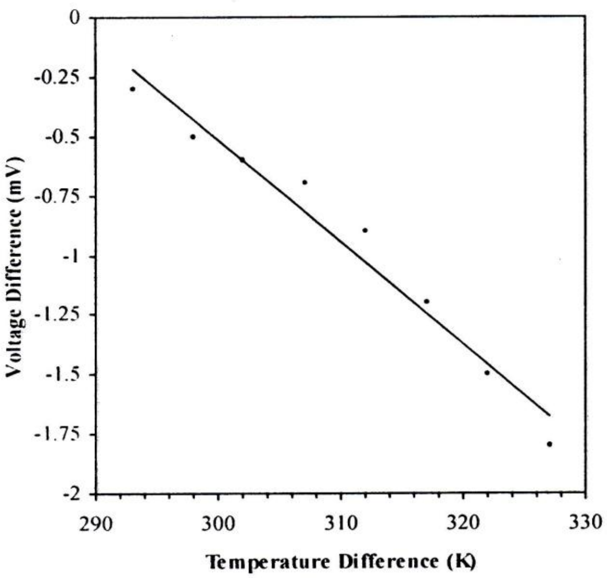

Fig.(3) : Thermovoltage as a function of temperature.

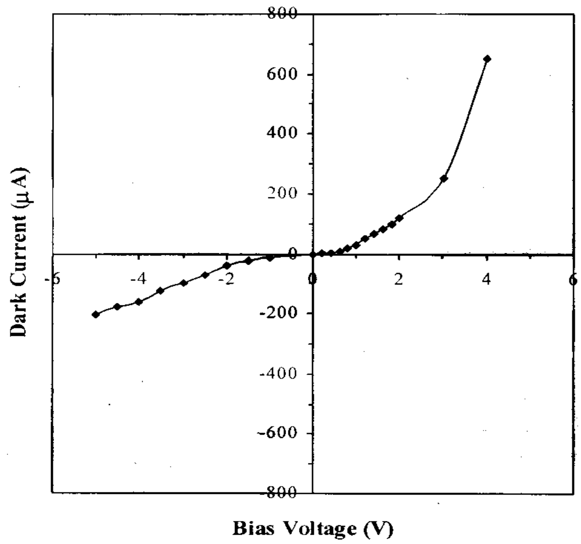

Fig.(6) : The I-V characteristic of SnO_2/InP cell under dark condition.

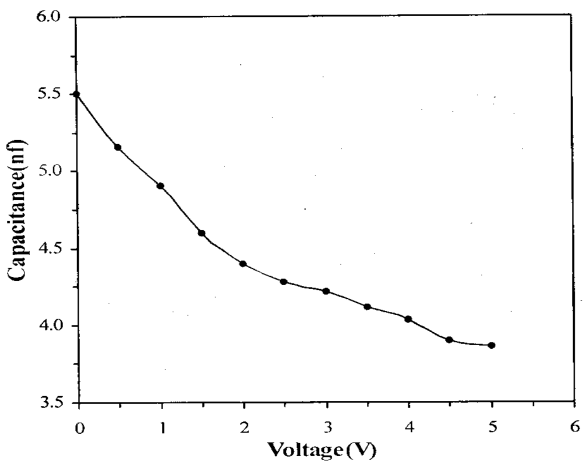

Fig.(4) : Capacitance vs reverse voltage curve.

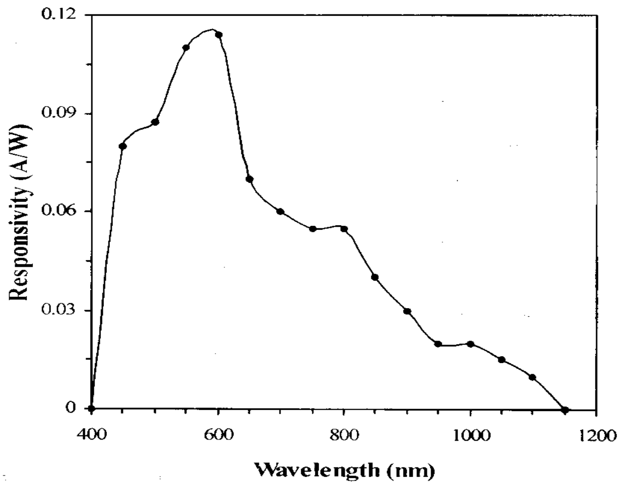

Fig.(7) : Spectral responsivity for SnO_2/InP.

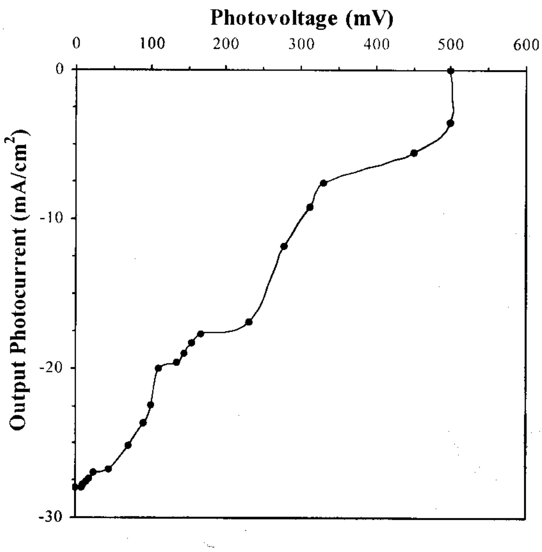

Fig.(8) : Illuminated J-V characteristics of the fabricated cell.

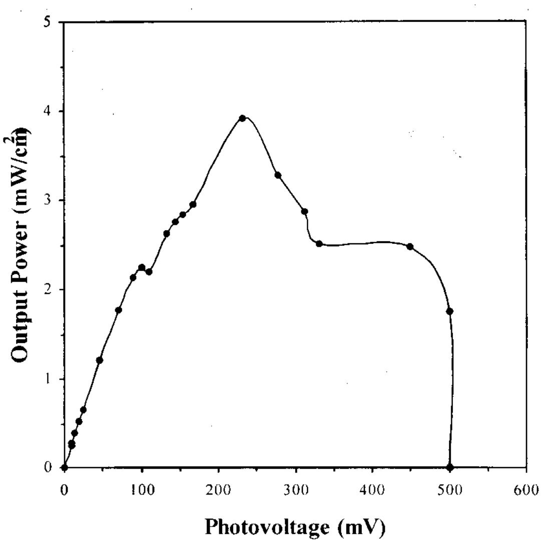

Fig.(9) : Photovoltaic performance of the cell.

References

[l] H. Kobayashi, T. Ishida, Y. Nakato, H. Tsubomura, J. Appl. Phys., 69, 1736 (1991).

[2] H. Kobayaslli, Y. Kogetsu, T. Ishida, Y. Nakato. J. Appl. Phys., 74, 4756 (1993).

[3] T. Ishida, H. Kouno. H. Kobayashi, Y. Nakato, J. Electrochem. Soc., 141, 1357 (1994).

[4] H. Kobayashi, S. Tachibana, K. Yamanaka, Y. Nakato, K. Yoneda, J. AppL Phys., 81,7630 (1997).

[5] D. Song. ,i. Zhao, A. Wang, P.\w'idenborg, W. Chin. A. G. Abcrly, 17 European PV Conference, Muulich, p. 1,(2001).

[6] T. Feng. K. Ghosh, C. Fishman, AppL Phys. Lett., 35, 266 (1979).

[7] F. J. Garcra, J. Momuci, Thin Solid Films, 97, 47 (1982).

[8] A. Phavdwaj, K. S. Kolonia, A. Raza, A. K. Sharma, B. K. Gupta, O. P. Agnihotvi. Solar Cells. 5, 305 (1982).

[9] L. Gouskov. H. I,.uquet, J. Fsta. C. Gril. Solar Cells. 5. 51 (1982).

[10] J. Shay, S. Wagner, M. Bettini, IEEE Trans. Electron Devices, 24, 483 (1992).

[11] K. Harsha, K. Bachmann, P. Schmidt, Applied Phys. Lett., 30. 645 (2003).

[12] R. Singh and J. Shewchwl, J. AppL Phys., 49, 45 (2004).

[13] A. Rasa, P. Agnihotry, B. Gupta, J. Phys. D: AppL Phys., 10, 1871 (1977).

[14] W. Budde, "Optical Radiation Measurements", Academic Press, New York.. p.240, (1992).

[15] M. Kojima, H. Kato, A. Imai, A. Yoshida, J. Appl. Phys. 64 ,1902. (1988).

[16] S. Kaneko, K. Nakajima, T. Kosugi, K. Murakami, in. K.M. Nair, A.S. Bhalla (Eds.), Dielectric Ceramic Materials, Ceram. Trans. Vol. 100, American Ceramic Society, Westerville, Ohio, 1999.

[17] B. Stjerma, E. Olsson, C.G. Granqvist, J. Appl. Phys. 76, 3797. (1994).

[18] I. Weinberg, D.J. Brinker, American society of mechanical engineers, 3, pp.121-126, (1988).

[19] T.J. Coutts, S. Naseem, appl.phy.lett. 46, pp164-166, (1985).

الخلاصة

تم تحضير الخلايا الشمسية ذات المفرق الهجين SnO_2/InP بطريقة الرش الكيميائي الحراري ذات الكلفة المنخفضة من دراسة الخصائص الكهروبصرية وجد ان فولتية الدائرة المفتوحة mV 500 وكثافة تيار دائرة القصر 28mA/cm2 وبعامل ملئ 0.28 وكفاءة تحويل 4% باستخدام مصباح هالوجين عند حالة AM1 وتم دراسة الخصائص الكهربائية للمفرق.