J. Nano- Electron. Phys.
3 (2011) No1, P. 741-746

PACS numbers: 42.70.jk, 42.79. – e, 42.79.Ek, 82.35.Cd

$MoSe_2$ / POLYANILINE SOLAR CELLS

***H.S. Patel*[1], *J.R. Rathod*[2], *K.D. Patel*[1], *V.M. Pathak*[1], *R. Srivastava*[1]**

[1] Department of Physics,
S. P. University, Vallabh Vidhyanagar – 388 120, Gujarat, India
E-mail: yogvmpathak@yahoo.co.in

[2] D.J.M. Institute of technology and research,
Mogar – 388 340, Gujarat, India

Solar cells have been investigated since long for harnessing the solar energy. During this decade, a new direction has come up where in the polymers have been used in the fabrication of solar cells. Polyaniline is one of the polymers which has shown potential for its applications in heterostructure solar cells. This material is being used along with the semiconductors like InSe, TiO_2, Si *etc. to form the photosensitive interface. In this direction, we report our investigations on the use of Molybdenum diselenide (*$MoSe_2$*) as photosensitive semiconducting material in* $MoSe_2$ */ polyaniline solar cells. In this paper, the preparation of* $MoSe_2$ */ polyaniline solar cells has been reported. Also, the photovoltage → photocurrent characteristics of this structure have been discussed in detail in this paper. The variation of different parameters of* $MoSe_2$ */ polyaniline solar cells (like open circuit voltage, short circuit current, photoconversion efficiency and fill factor) with the intensity of incident illuminations has been reported in this paper. In present case, the photocurrent density was found to be around* $250\ \mu A/cm^2$ *with the photovoltage around* $8.5\ mV$ *(which is low) the photoconversion efficiency was found to be around* 0.7 % *along with the fill factor around* 0.33. *The efforts have been made to explain the low values of the photoconversion efficiency.*

Keywords: *POLYANILINE, MoSe*$_2$*, PHOTOVOLTAGE PHOTOCURRENTDENSITY CHARACTERISTICS, PHOTO CONVERSION EFFICIENCY, SOLAR CELLS.*

(Received 04 February 2011)

1. INTRODUCTION

During this decade, the use of polymers in solar cells has been focused as a new direction for the solar cell fabrication. Several organic/inorganic heterostructure solar cells have been investigated and reported by various workers [1-4]. Among all the polymers, the polyaniline and its derivatives have attracted much interest as intrinsically semiconducting / conducting polymers which may used in solar cells. This is because the polyaniline can be easily synthesized and doped as per the requirement. Also, it is architecturally flexible and tolerable with high stability against the environmental condition [5-7]. So far, group – VI transition metal dichalcogenides (TMDCs) have not been used as a photosensitive semiconducting material along with any polymer in solar cells. Therefore, the efforts have been made to study the photovoltaic characteristics of $MoSe_2$ / polyaniline solar cells. In present paper, we have reported our investigations on the fabrication and some characterization of these heterostructure solar cells. The results of all these investigations have been discussed in detail in this paper.

2. EXPERIMENTAL

$MoSe_2$ crystals used in present investigations have been grown by vapour transport technique using a two zone microprocessor controlled furnace [8]. The growth zone temperature and the source zone temperature were kept at 1050 °C and 1070 °C respectively. The heating rate and cooling rate used in the entire process were 50 °C/h. The total time period required for the complete growth process was 197 hours. These as grown $MoSe_2$ crystals were used as the base material (substrate) for the deposition of polyaniline films. A thick solution of diluted polyaniline was prepared in 0.1 N HNO_3 and it was slowly and gradually brought in contact to the irregularly shaped thin flake like $MoSe_2$ crystals fixed on the substrate holder of the spin-coating unit [9, 10]. Substrates were then rotated with the speed of 250 rpm for two hours at room temperature to deposit uniform films of polyaniline. The ohmic contacts were prepared using a highly conducting silver paste. The so prepared structure was used as heterostructure solar cell in present investigations. The $J_{Ph} \rightarrow V_{Ph}$ characteristics were studied under dark and illuminated conditions in range of 10 mW/cm ^{2} to 100 mW/cm ^{2} intensities of incident illuminations. The incandescent lamp was used as a source of polychromatic illuminations and solar meter was used for the measurement of intensities of polychromatic illuminations incident on the cells.

3. RESULS AND DISCUSSIONS

The $MoSe_2$ / polyaniline heterostructure was investigated to find out the photoconversion characteristics under dark and illuminated conditions. In Fig. 1, the $V_{ph} \rightarrow J_{ph}$ characteristics of this structure have been shown. Even in dark conditions (when the source of light was switched off), the voltage $\rightarrow$ current characteristics where investigated and shown in Fig. 1 (a). Fig. 1 (b) represents the photoconversion characteristic at different intensities of incident illuminations. From Fig. 1, it can be seen that in absence of any illumination, the level of voltage and current observed were very low as compared to the illuminated conditions. This is an indicative of the fact that the photogeneration of carriers in $MoSe_2$ and their subsequent transport across the $MoSe_2$ / polyaniline interface increases with increase in intensities (I_L) [11]. This clearly reveals the fact that $MoSe_2$ / polyaniline interface does exhibit the characteristics of solar cells. Here, the results of only one $MoSe_2$ / polyaniline structure (used as solar cell) have been discussed.

The short circuit current density (J_{sc}) and open circuit voltage (V_{oc}) are expected to increase with increase in the intensity of incident illumination. The variation of J_{sc} and V_{oc} with I_L has been shown in Fig. 2. In this figure J_{sc} has been seen to exhibit a linear dependence on I_L up to around 60 mW/cm^2 intensity, whereas V_{oc} shows slightly non-linear behavior but not the saturation characteristics up to 60 mW/cm^2.The entire process of photoconversion in our case involves three steps. (i) The incident quanta of polychromatic light are absorbed in $MoSe_2$. (ii) The carriers are generated in $MoSe_2$ and (iii) the photogenerated carriers are transported from $MoSe_2$ to polyaniline. The linear dependence of J_{sc} on I_L as mentioned above is due to the efficient photogeneration of carriers in $MoSe_2$ and their transport

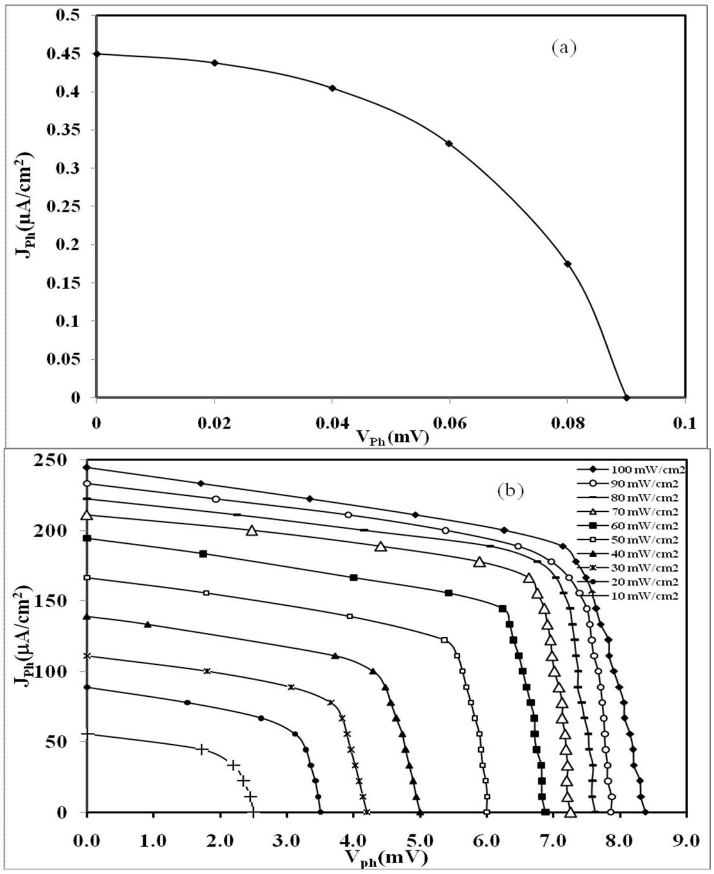

Fig. 1 *– The dark J_{ph}→V_{ph} characteristics of* MoSe$_2$ */ polyaniline solar cell (a) and J_{ph}→V_{ph} characteristics of* MoSe$_2$ */ Polyaniline solar cell at different intensities of illuminations (b)*

across the MoSe$_2$ / Polyaniline interface. Above 60 mW/cm^2 intensities, the deviation from this linearity is observed. The slope of the curve in this region seems to decrease. It may be attributed to the fact that the transport of photogenerated carries does not cope up with the generation of charge carriers. It means that the overall photoconversion characteristics above 60 mW/cm^2 intensities are dominated by the carrier transfer process across the MoSe$_2$ / polyaniline interface. Beside, below 60 mW/cm^2 intensities, the dominance of photogeneration of carriers leads to the linear variation of the graph shown in Fig. 2.

Using the data of photoconversion characteristics the photoconversion efficiency (η) and fill factor (FF) in present case were evaluated using the equation (1) and (2) [12],

$$\eta = \left(\frac{I_{mp}}{Area} \right) \tag{1}$$

and

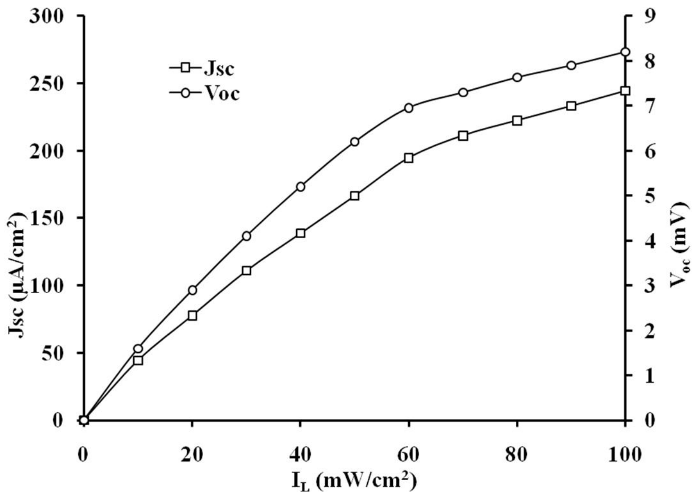

Fig. 2 – *$I_L \rightarrow J_{sc}$ and $I_L \rightarrow V_{oc}$ charactristics of* $MoSe_2$ */ polyaniline solar cell*

$$FF = \left(\frac{J_{mp} * V_{mp}}{J_{sc} * V_{oc}} \right) \quad (2)$$

where: V_{mp} is photovoltage correspond to the maximum power point, and J_{mp} is photocurrent density correspond to the maximum power point.

These two parameters have been calculated for all the intensities of incident polychromatic illumination and have been presented in Table 1.

From Table 1, it is quite evident that both the η and FF decrease with increase in I_L [13]. In fact, these two parameters are expected to increase with I_L at least up to 60 mW/cm^2 intensities because the J_{sc} and V_{oc} shows linear dependence on I_L in this range (as seen in Fig. 2). The decrease in η and FF with I_L may be related to the series resistance, the shunt resistance, the presence of trapping centers at the interface etc. The efforts have been made to investigate the effect of the presence of trapping centers at the $MoSe_2$ / polyaniline interface on the variation of photocurrent with intensity of incident illuminations (I_L).

Table 1 – *Variation of η and FF with I_L for* $MoSe_2$ */ polyaniline solar cell*

I_L (mW/cm^2)	η (%)	FF
10	0.7	0.33
20	0.65	0.32
30	0.6	0.30
40	0.56	0.29
50	0.52	0.27
60	0.58	0.26
70	0.45	0.25
80	0.41	0.24
90	0.36	0.23
100	0.32	0.20

The graph of $\ln(I_L) \to \ln(I_{sc})$ for $MoSe_2$ / polyaniline solar cell investigated in present case has been shown in Fig. 3. The slope of this graph was found to be 0.66. Under ideal conditions, this slope should be one indicating the transport of all the photogenerated carriers from semiconductor to polymer (in present case $MoSe_2$ to polyaniline). But the value of slope in present case indicates that some of the carriers are lost during the transport process from $MoSe_2$ to polyaniline. This is possible under the conditions were there is a presence of trapping centers at the interface. This possibility can exist in present case because the surface of $MoSe_2$ was not given any treatment before deposition of polyaniline film. The as grown surface of $MoSe_2$ crystal may have several defects or some other trapping centers developed during the growth process [14]. Unless some surface treatment is not being given, these defects on trapping centers remain present which may inhibit the transport of carriers across the interface [15]. These may be one of the major hindrances in the carrier transport mechanism in present case effective at the $MoSe_2$ / polyaniline interface which is limiting the overall photoconversion characteristics.

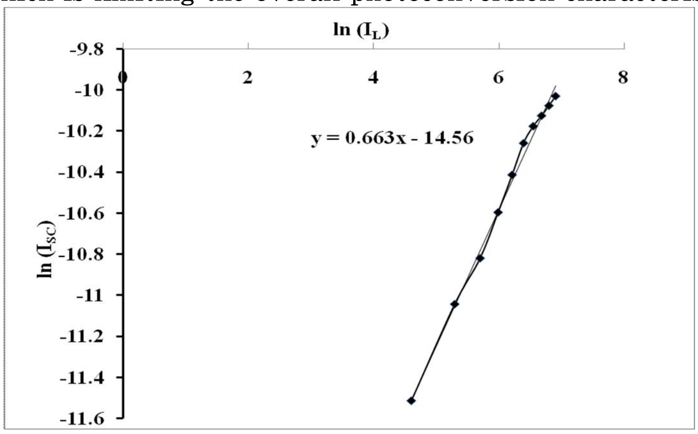

Fig. 3 *–* $\ln(I_L) \to \ln(I_{SC})$ *charactristics of* $MoSe_2$ */ polyaniline solar cell*

In present investigations polyaniline (emeraldine base) has been used as the conductive polymer for the hole conduction generated due to the photo absorption in $MoSe_2$. The structure of polyaniline has been shown in figure 4. It is know fact that the emeraldine base Polyaniline can be converted in to metallic state from insulating state if protons are added to the $-N=$ sites whereas the number of electrons in chain remain constant [16].

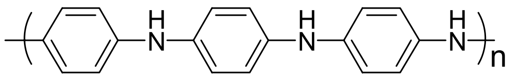

Fig. 4 *– Repeat unit structure of emeraldine base form of polyaniline*

In present investigations, the emeraldine base polyaniline has been prepared using 0.1 N HNO_3 as the solvent. This is always supposed to yield the conducting type polyaniline. The emeraldine base polyaniline works as a hole conductor in $MoSe_2$ / polyaniline heterostructure solar cell investigated in present case. This enhances the photoconversion characteristics of the solar cell structure under investigation. Here, the interface between $MoSe_2$ and polyaniline gives low values of photo voltages [17, 18].

4. CONCLUSIONS

From the investigations reported in this paper, it can be concluded that polyaniline can be successfully used in the fabrication of $MoSe_2$ / polyaniline heterojunction solar cells. The photoconversion efficiency was found to be low. This may be improved by giving some chemical and thermal treatments to $MoSe_2$ crystal prior to the deposition of polyaniline film. It can also be inferred that there are several parameters which limit the photoconversion characteristic of $MoSe_2$ / polyaniline solar cells. The low value of the slope of $\ln(I_L) \to \ln(I_{sc})$ reveals the fact that there is a presence of trapping centres at the $MoSe_2$ / polyaniline interface which dominants over the flow of photogenerated carriers from semiconductor to polymer. Also, it was observed that the photogeneration of carriers dominants the overall photoconversion behaviour of $MoSe_2$ / polyaniline interface up to the intensities of 60 mW/cm^2 of incident polychromatic illuminations. Above this intensity, the carrier transport mechanism across the interface is more effective.

REFERENCES

1. E.L. Williams, G.E. Jabbour, Q. Wang, S.E. Shaheen, D.S. Ginley, E.A. Schiff, *Appl. Phys. Lett.* **87,** 223504 (2005).
2. V. Gowrishankar, S.R. Scully, M. D. McGehee, Q. Wang, H.M. Branz, *Appl. Phys. Lett.* **89,** 252102 (2006).
3. A.R. Middya, E.A. Schiff, A.R. Middya, J. Lyou, N. Kopidakis, S. Rane, P. Rao, Q. Yuan, K. Zhu, *Electroabsorption and Transport Measurements and Modeling Research in Amorphous Silicon Solar Cells, Final Technical Report, 24 March 1998–15.*
4. August 2002 (National Technical Information Service, Document DE20031500360).
5. P.J. Alet, S. Palacin, P. Roca, I. Cabarrocas, B. Kalache, M. Firon, R. Bettignies, *Eur. J. Appl. Phys.* **36,** 231 (2006).
6. N.V. Blinova, J. Stejskal, M. Trchova, J. Prokes, M. Omastova, *Eur. Polym. J.* **43,** 2331 (2007).
7. A.G. MacDiarmid, *Rev. Mod. Phys.* **73,** 701 (2001).
8. B. Wessling, *Synth. Met.* **93,** 143 (1998).
9. S.Y. Hu, C.H. Liang, K.K. Tiong, Y.S. Huang, *J. Alloys Comp.* **442,** 249 (2007).
10. J. Paul, H. Lima, A.M. Andrade, *J. Mater. Sci Mater. El.*, **17 (8),** 593 (2006).
11. E. Kymakis, I. Alexandrou, G.A.J. Amaratunga, *J. Appl. Phys.* **93,** 1764 (2003).
12. G.G. Wallace, P.C. Dastoor, D.L. Officer, C.O. Too, *Chemical Innovation* **30(1),** 14 (2000).
13. M.A. Green, *Solar cells operating principles, technology and system applications* (*Prentice-Hall, Inc., Englandwoood Cliffs, N.J. 07632; 1982*).
14. C.F. Chung, Q. Xu, Y. Yang, *Appl. Phys. Lett.* **84,** 31813 (2004).
15. T. Ohmori, R.J. Castro, R.C. Cabrera, *Langmuir* **14**(21), 6287 (1998).
16. M. Yamaguchi, A. Khan, S.J. Taylor, et al., *J. Appl. Phys.* **86,** 217 (1999).
17. Z. Liu, J. Zhou, H. Xue, et al., *Synthetic Met.* **156,** 721 (2006).
18. P.Y. Stakhira, Y.I. Vertsimaha, O.I. Aksimentyeva, B.R. Cizh, V.V. Cherpak, *Physics and Chemistry of solid state* **6**, 96 (2005).
19. Y.C. Lee, J.L. Shen, K.W. Chen, et al., *J. Appl. Phys.* **99,** 063706 (2006).