© 2017 IJSRSET | Volume 3 | Issue 8 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

Deposition of Copper Doped Zinc Oxide Nanoparticles for Cadmium Sulfide Sensitized Solar Cell

Sunita K. Kokate[a] , Kakasaheb C. Mohite[b]

[a]School of Energy Studies, Savitribai Phule Pune University, Pune, Maharashtra, India

[b]C T Bora College, Shirur, , Pune, Maharashtra, India

ABSTRACT

The fabrication of Cu doped ZnO photoelectrodes and its performance for CdS quantum dot sensitized solar cell; are reported here. Zinc oxide (ZnO) nanoparticles were formed chemically using Zn $(NO_3)_2$ as precursor. Copper doped ZnO films were deposited on both ITO and glass substrates. The crystalline nature of films was confirmed by X-ray diffraction (XRD) and morphological study; was carried out from scanning electron microscopy (SEM). Energy Dispersive Spectroscopy (EDS) spectrum confirms the incorporation of copper in crystal lattice. After doping of copper in ZnO, CdS quantum dots were deposited on to the Cu: ZnO films. Finally, The CdS QDSSC device was made using CdS/Cu:ZnO as photoanode, polysulphide as electrolyte and carbon black as counter electrode. The enhancement in efficiency has been observed for CdS sensitized Cu: ZnO solar cell with respect to ZnO.

Keywords: Cu doped ZnO, Chemical method, CdS Solar Cell, *J-V* characteristics.

I. INTRODUCTION

High manufacturing and installation cost of traditional semiconductor heterojunction photovoltaic devices i.e. crystalline silicon solar cells, initiated the search of different material and their forms; which are economical and give high performance solar cells [1]. Quantum dot sensitized solar cells (QDSSCs) have involved considerable attention recently and are undergoing through innovative developments as the next generation of solar cells [2].

ZnO film plays important role in technological application such as solar cells, spintronic devices, thin film gas sensors, photo-detectors, surface acoustic wave devices, varistors, nano-lasers and light emitting diodes [3-10]. Because of its potential applications, ZnO thin films have been studied most widely. Researchers have reported their work on different materials such as Mg, Cu, Al, Mn, Fe, Ni and co-doped ZnO thin films [11-19]. Different deposition techniques, have been reported for doped and undoped ZnO [20-28]. SILAR method is mostly used as it exhibits properties such as thickness can be uniform, perfect control of compositions, and large surface area coating [29-30].

Here we report wet chemical synthesis of copper doped zinc oxide. Further SILAR technique is used to deposit CdS QDs was deposited on Cu doped zinc oxide (Cu:ZnO) films by SILAR technique. XRD, SEM, TEM, FTIR and UV-Visible spectroscopy (UV-Vis) are used to characterize the Cu: ZnO and CdS/Cu:ZnO films. The solar cell characteristics of Cu doped zinc oxide film with and without CdS sensitization; are investigated.

II. Experimental Details

2.1 Preparation of Cu:ZnO Nanoparticulate Powder and Films

The copper doped ZnO nanoparticles were synthesized by wet chemical method. 0.1 M solution of zinc nitrate and copper nitrate keeping the molar ratio of Cu and Zn at 5:95, were used. 1M solution of sodium hydroxide is added until precipitation takes place.

Porous Cu:ZnO films were deposited on cleaned ITO (Indium Tin oxide) using doctor blade technique using Cu:ZnO paste. The paste was prepared using Cu:ZnO synthesized powder of nanoparticles and successively added by ethyl cellulose, terpineol and acetyl acetone were used to obtain proper consistency of paste. The films were sintered 1 h at 450 °C.

2.2 Sensitization of Films with CdS

CdS was deposited using SILAR technique [31]. Above films were used to SILAR using 0.05 M cationic precursor solution of cadmium nitrate in ethanol and 0.05 M anionic precursor solution; sodium sulfide in methanol and rinsed in methanol. Five such cycles were repeated to sensitize the film with CdS.

Finally, the films were characterized by XRD, EDS, UV-Vis and SEM. The structural characterization of Cu:ZnO, CdS/ Cu:ZnO films were studied out by using Philips X-ray diffractometer (Bruker axs, D-8 Advance, λ=1.54056Ǻ for Cu-Kα radiation). Morphological study of all synthesized films were studied by using a scanning electron microscope (JEOL-JSM 6360-A, operating at 5 kV), optical absorbance was studied with UV-Vis spectrometer (JASCO V-670), FTIR (JASCO, FT/IR- 6100). The solar cell was devised with polysulphide as electrolyte and carbon as cathode and its performance, was studied on Keithley 2420 source-meter.

III. RESULTS AND DISCUSSION

3.1 X-Ray Diffraction

X-ray diffraction is used determine to identify the structure and crystallite size. Figure 1 shows XRD of Cu:ZnO and CdS sensitized CdS/Cu:ZnO. The XRD data is according to JCPDS card no.79-0207, (100), (002), (102), (110), (103), (200), (112) and (201) planes with wurtzite hexagonal structure [32]. The peaks corresponding to (011), (020), (012), (211), (220) of CdS [JCPDS card no.43-0985] are seen overlapping (100), (101), (110), (103), (200) peaks of Cu:ZnO.

3.2 Morphological study

Scanning electron micrograph indicating that the study of surface morphology chemically deposited Cu:ZnO nanoparticulate films and sensitization of Cadmium sulphide on copper doped zinc oxide (CdS/Cu:ZnO) films by using SILAR technique is shown in fig. 2. SEM shows regular shaped spherical nanoparticles. The average grain size of film of Cu:ZnO nanoparticles is 124 nm and it is increased to about 171 nm for CdS sensitized Cu:ZnO films.The distribution of nanoparticles is seen dense and even on the whole mass of crystallite.

3.3 Energy Dispersive Spectroscopy

Figure 3 shows the EDS spectrum of Cu:ZnO and (CdS/Cu:ZnO). Figure 3(a) shows the typical EDS spectrum for Cu:ZnO nanoparticulate films. The ratio of average atomic Zn:O were in the ratio of 19:81. Good stoichiometry of the Cu:ZnO films is with 5% Cu ions. Figure 3(b) shows the EDS spectra of CdS sensitized Cu doped ZnO nanoparticles. The spectra indicates that the presence of Cd and S in the sample.

3.4 Fourier Transform Infrared Spectroscopy (FTIR)

FTIR technique gives information about chemical bonding in a sample. The characteristic peaks shown by FTIR spectra of Cu doped ZnO and CdS sensitized Cu doped ZnO nanoparticles are as shown in fig. 4. The peaks observed at 3460 cm^{-1} and 1360 cm^{-1} refers to normal O–H stretching vibration of H_2O in Cu–Zn–O lattice [33] which occurs due to moisture in the sample and the atmosphere. The peaks observed at 760 and 896 cm^{-1} correspond to Zn-O stretching and deformation vibration, respectively. Peaks between 2830 cm^{-1} and 3000 cm^{-1} may be due to vibration of C-H stretching in alkane groups. The peak at 505 cm^{-1} may be due to oxygen deficiency and/ or oxygen vacancies in ZnO [34]. The peak around 1730 cm^{-1} is indication of presence of C-O stretching vibrations [35].

3.5 UV-Visible absorption studies

Figure 5 shows the UV-visible spectra of CdS QD sensitized Cu:ZnO nanoparticles film. The visible light absorption increases with CdS deposition [36]. Here in our case the absorption spectrum of Cu doped ZnO with CdS deposition is same as that of bare ZnO film, which occurs because small amount of CdS is deposited on Cu:ZnO films [37, 38].

3.6 J–V characteristics

The CdS/Cu:ZnO/ITO films are tested for their solar cell performance. Figure 6 illustrates the J-Vcharacteristics for CdS deposited on Cu:ZnO substrate. Cell were fabricated using the CdS/Cu:ZnO/ITO clamped with platinum counter and polysulphide was used as electrolyte. Cells were tested under illumination of LED lamp of intensity 15mW cm^{-2}. Jsc was found to be 0.34 mA cm^{-2} with Voc = 177 mV, efficiency η = 0.073% and FF = 0.19. Jeong MS et al reported CdS sensitization generates sufficient electron which helps to increase Jsc [40]. Electrons cannot be injected into ZnO as effectively as it can be injected in smaller sized CdS [41].

The related result show better performance with the earlier works on the dye [42] or quantum dots-sensitized [43-45] solar cells.

IV. Conclusions

These results clearly demonstrate that the Cu:ZnO and CdS/Cu:ZnO films have been successfully deposited by chemical and SILAR technique respectively and its structural, morphological and optical properties are studied. As deposited CdS/Cu:ZnO thin films are found to be n-type and photoactive. CdS/Cu:ZnO QD photoanode gives a good photovoltaic performance. The results on fabricated solar cell indicate that the synthesized films could be useful for solar cells.

V. Acknowledgements

Authors are thankful to Advance Physics Laboratory, Savitribai Phule Pune University (SPPU), Pune, Maharashtra for availing laboratory facilities.

VI. REFERENCES

[1]. M. Graetzel, R. Janssen, D.B. Mitzi, and E.H. Sargent, Nature, Volume 304, page 488, 2012.
[2]. P.V. Kamat, J Phy. Chem. Lett, Volume 4, Page 908, 2013.
[3]. O. Kluth, G. Schope, J. Hupkes, C. Agashe, J. Muller, and Rech B, Thin Solid Films, Volume 442, Page 80, 2003.
[4]. S.T. Shishiyanu, T.S. Shishiyanu, and O.I. Lupan, Sensors Actuators B Chem., Volume 107, Page 379, 2005.
[5]. E. Suvaci and I.O. Ozer, J Eur Ceram Soc, Volume 25, Page 1663, 2005.
[6]. T. Meron and G. Markovich, J Phys. Chem. B, Volume109, Page 20232, 2005
[7]. S. Liang, H. Sheng, Y. Liu, Z. Huo, Y. Lu, and H. Shen, J Cryst Growth, Volume 225, Page 110, 2001.
[8]. N.W. Emanetoglu, C. Gorla, Y. Liu, S. Liang, and Y. Lu, Mater Sci Semicond Process, Volume 2, Page 247, 1999.
[9]. N. Saito, H. Haneda, T. Sekiguchi, N. Ohashi, I. Sakaguchi, and K. Koumoto, Adv. Mater., Volume 14, Page 418, 2002.
[10]. M.H. Huang, S. Mao, H. Feick, H. Yan, Y. Wu, H. Kind, E. Weber, R. Russo, and P. Yang, Science, Volume 292, Page 1897, 2001.
[11]. U.N. Maiti, P.K. Ghosh, S. Nandy, and K.K. Chattopadhyay, Physica B, Volume 387, Page103, 2007.
[12]. K.J. Chen, F.Y. Hung, S.J. Chang, and Z.S. Hu, Appl. Surf Sci., Volume 255, Page 6308, 2009.
[13]. J.G. Lu, K. Huang, J.B. Zhu, X.M. Chen, X.P. Song, and Z.Q. Sun, Physica B, Volume 405, Page 3167, 2010.
[14]. C.Y. Tsay, H. C. Cheng, Y.T. Tung, W.H. Tuan, and C.K. Lin, Thin Solid Films, Volume 517, Page 1032, 2008.
[15]. S. Fujihara, C. Sasaki, and T. Kimura, J Eur. Ceram Soc., Volume 21, Page 2109, 2001.
[16]. D.Y. Wang, J. Zhou, and G.Z. Liu, J Alloys Compd., Volume 487, Page 545, 2009.
[17]. M.S. Wang, K.E. Lee, S.H. Hahn, E.J. Kim, S. Kim, J.S. Chung, E.W. Shin, and C. Park, Mater. Lett., Volume 61, Page 1118, 2007.
[18]. X.C. Liu, Z.Z. Chen, B.Y. Chen, E.W. Shi, and D.Q. Liao, J Cryst. Growth, Volume 312, Page 287, 2010.
[19]. H. Xu and X.Y. Li, J Cryst. Growth, Volume 312, Page 851, 2010.
[20]. M.R. Waugh, G. Hyett, and I.P. Parkin, Chem. Vapor Deposition, Volume 14,Page 366, 2008.
[21]. Y. Miao, Z.Z. Ye, W.Z. Xu, F.G. Chen, X.C. Zhou, B.G. Zhao, L.P. Zhu, and J.G. Lu, Appl. Surf. Sci., Volume 252, Page 7953, 2009.
[22]. B. Houng, C.S. Hsi, B.Y. Hou, and S.L. Fu, J Alloys Compd., Volume 456, Page 64, 2008.
[23]. D. Wang, J.W. Zhang, Y.P. Peng, Z. Bi, X.M. Bian, X.A. Zhang, and X. Hou, J Alloys Compd., Volume 478, Page 325, 2009.
[24]. B. Xiao, Z.Z. Ye, Y.Z. Zhang, Y.J. Zeng, L.P. Zhu, and B.H. Zhao, Appl. Surf Sci., Volume 253, Page 895, 2009.
[25]. P. Singh, A. Kaushal, and D. Kaur, J Alloys Compd., Volume 471, Page 11, 2009.
[26]. S.W. Xue, X.T. Zu, W.L. Zhou, H.X. Deng, X. Xiang, L. Zhang, and H. Deng, J Alloys Compd., Volume 448, Page 21, 2008.

[27]. Z. Xiao, M. Okada, G. Han, M. Ichimiya, K. Michibayashi, T. Itoh, Y. Neo, T. Aoki, and H. Mimura, J Appl. Phys., Volume 104, Page 073512, 2008.
[28]. A. Sugunan, H.C. Warad, M. Boman, and J. Dutta, J Sol-Gel Sci. Techn., Volume 39, Page 49, 2006.
[29]. R. Zamiri, B.K. Singh, D. Dutta, A. Reblo, and J.M.F. Ferreira, Ceram. Int., Volume 40, Page 4471, 2014.
[30]. H.M. Pathan and C.D. Lokhande, Bull Mat Sci, Volume 27, Page 85, 2004.
[31]. H.J. Lee, M. Wang, P. Chen, D.R. Gamelin, S.M. Zakeeruddin, M. Gratzel, and M.K. Nazeeruddin, Nano Lett, Volume 9, Page 4221, 2009.
[32]. L. Chow, O. Lupan, G. Chai, H. Khallaf, L.K. Ono, B.R. Cuenya, I.M. Tiginyanu, V.V. Ursaki, and V. Sontea, A Schulte Sensors and Actuators A, Volume 189, Page 399, 2013.
[33]. J. Diouri, J.P. Lascaray, and M.E. Amrani, Phys Rev B, Volume 31, Page 7995, 1985.
[34]. G. Xiong, U. Pal, J.G. Serrano, K.B. Ucer, and R.T. Williams, Phys. Stat Sol, Volume 3, Page 3577, 2006.
[35]. Y. Abboud, T. Saffaj, A. Chagraoui, A.E. Bouari, K. Brouzi, O. Tanane , and B. Ihssane, Appl. Nanosci., Volume 4, Page 571, 2014.
[36]. C. Li, T. Ahmed, M. Ma, T. Edvinsson, and J. Zhu, Appl. Catalysis B Environ, Volume 138, Page 75, 2013.
[37]. C.C. Vidyasagar, Y.A. Naik, T.G. Venkatesh, and R. Viswanatha, Powder Tech, Volume 214, Page 337, 2011.
[38]. N. Soltani, E. Gharibshahi, and E. Saion, Chalcogenide Lett., Volume 9, Page 321, 2012.
[39]. T.J. Coutts, Sol Energy Mater, Volume 50, Page 99, 1978.
[40]. M.S. Jeong, M.K. Son, S. Kim, S. Park, K. Prabakar, and H. Kim, Thin Solid Films, Volume 570, Page 310, 2014.
[41]. K. Poornima, K.P. Krishnan, B. Lalith, and M Raja, Superlattices and Microstructures, Volume 83, Page 147, 2015.
[42]. M. Paulose, K. Shankar, O.K. Varghese, G.K. Mor, B. Hardin, and C.A. Grimes, Backside Nanotechnology, Volume 17, Page 1446, 2006.
[43]. S.C. Lin, Y.L. Lee, C.H. Chang, Y.J. Shen, and Y.M. Yang, Appl. Phys. Lett., Volume 90, Page 14351, 2007.
[44]. T. Toyoda, K. Oshikane, D. Li, Y. Luo, Q. Meng, and Q. Shen, J Appl. Phys., Volume 108, Page 114304, 2010.
[45]. G. Zhu, L. Pan, T. Xu, and Z. Sun, ACS Appl. Mater Interfaces, Volume 3, Page 1472, 2011.