Original Research Paper

Volume - 13 | Issue - 01 | January - 2023 | PRINT ISSN No. 2249 - 555X | DOI : 10.36106/ijar

Physics

EXPERIMENTAL SURVEY TOWARDS PHOTOELECTRIC (PEC) PROPERTIES OF YTTRIUM CHALCOGENIDE THIN FILMS

U. K. Mohite

Department of Physics, M.B.S.K. Kanya Mahavidyalaya, Kadegaon,Dist.- Sangli-415304(M.S.).

ABSTRACT The study of yttrium Chalcogenide as storage electrode was carried out by designing a special three electrode storage cell system. It consists of three electrodes, namely, storage electrode, photoelectrode and counter electrode. Electrodeposited yttrium chalcogenide film and CdSe film on to a stainless steel substrate has been used as a storage electrode and photoelectrode respectively. The graphite rod was used as a counterelectrode. These three electrodes were immersed in two rectangular transparent plastic boxes containing suitable electrolytes. Boxes were bridged together by agar-agar gel. The cell was illuminated by a high intensity lamp. The electrical characteristics in the mode of charging and discharging were studied.

KEYWORDS : Storage cell, storage electrode, photoelectrode, counterelectrode and agar-agar gel.

INTRODUCTION

The social prosperity and economic development depend on the sustainable energy conversion and storage, for a sustainable society, energy is unquestionably one of the grand challenges [1, 2].. There is urgent need of clean, affordable and reliable energy that can substitute fossil fuels and limits the carbon emission issue. Therefore, the interest of researchers focused towards the development of technology to make availability of clean and renewable energy, especially the intermittent energy, energy conversion and storage [3, 4]. Now a day, there is vast demand for electrochemical energy conversion and storage devices, especially portable devices, consumer electronics, and electric vehicles [5–7]. Derek P Gregory has been reported use of rare earth hydrides for storing hydrogen in both stationary and mobile applications [8]. Therefore, it should require rapid development of new materials with high performance in energy conversion and storage devices. In our opinion, scientists underestimated this field and started working with material having low cast and easy availability. The best materials, for examples, so far reported with relatively with high efficiency and stability for long time are CdSe, WSe_2, CuIn Se_2[9-12].

Photo electrochemical cell can be converted into rechargeable electrochemical storage cell, when storage electrode, capable of undergoing a reversible chemical change is used in it [13]. A reversible chemical reaction occurs at the storage electrode of the type,

$AX + ne^- \leftrightarrow A + X^{n-}$

Where A is storage electrode, X is solute present in the electrolyte. Construction of such a cell requires stable low resistance separator which minimizes direct chemical reaction of the electro active redox species, and the selected redox couples suitable to semiconductor photoelectrode. The PEC cells employing third electrode as a storage electrode have been reported in the literature [14-19].

Experimental Techniques

Preparation of yttrium Chalcogenide Films:

The films have been electrodeposited from no-aqueous formaldehyde bath onto a stainless steel substrate at room temperature. The yttrium-sulphide and yttrium-selenide films are electrodeposited from the baths,0.05M Y $(NO_3)_3$ - 0.05M CH_3CSNH_2 - 0.05M CH_3COONa, and 0.05M Y $(NO_3)_3$ - 0.05M SeO_2 - 0.05M CH_3COON respectively. The yttrium-telluride film has been electrodeposited by the method of layer-by-layer deposition. Initially yttrium was deposited onto a stainless-steel substrate from the bath of 0.05M Y $(NO_3)_3$ - 0.05M CH_3COONa solution and thereafter tellurium was electrodeposited from the bath of saturated TeO_2 - 0.05 M CH3COONa solutions.

Preparation Of Photo Anode (CdSe Films):

The CdSe films are electrodeposited from the aqueous bath onto a stainless steel substrates of size 1×1.5 cm^2 at room temperature. The bath composition was 0.1M $CdCl_2$ – 0.05M SeO_2. The PEC properties of the film was tested with electrolyte 0.1M (Na_2S-S-NaOH) as an electrolyte and graphite as a counter electrode. In order to increase the photo effect, the films are Annealed at 200°C.

Preparation Of Electrolyte:

The stable electrolyte for the photoanode (CdSe) is polysulphide [20]. It was prepared by taking A.R. Grade Sodium hydroxide and sulphur from. B.D.H., India, and A. R. Grade sodium sulphide, from the Fluka. Appropriate amount of NaOH and Na_2S were dissolved in double distilled water at room temperature. In this solution, sulphur powder was added and mixture warmed up to 55°C with constant stirring. The mixture was maintained at this temperature till all sulphur powder dissolves. The solution was cooled to room temperature, filtered and preserved in the glass stopper air tight bottle. The colour of the solution was yellowish pink. The yttrium sulphide films are stable in the ferri-ferrocyanide electrolyte. This electrolyte was prepared by taking appropriate amount of potassium ferricyanide and potassium ferrocyanide of analytical grade, dissolved in double distilled water and preserved in the glass stopper air tight bottle.

Design Of The Three Electrodes Storage Cell:

The design of three electrode battery was reported by many researchers in various journals [21-25]. Here, cell consists of three electrodes, namely, CdSe as a photo electrode, graphite as counter electrode and yttrium selenide as storage electrode. Two rectangular transparent plastic boxes were fixed with M-seal by conducting bridge of 3 cm in length formed with Agar-Agar gel. The size of each rectangular box is 4.0×1.5×7.5cm^3. One compartment of cell consists of CdSe as a photoanode (5cm^2 area) and graphite rod (6.2cm^2 area) as the counterelectrode. The volumes of the electrolytes were 35 cc in each compartment of the cell. The electrolyte 0.1 M (Na_2S-NaOH) was used in first compartment. The other compartment consists of 0.1 M $[K_3Fe(CN)_6]$ – $K_4Fe(CN)_6$ electrolyte with yttrium sulphide storage electrode which is kept in dark.

The cell was illuminated by using 500 Watt tungsten filament lamp. The light intensity was 200 . The electrical characteristics in the mode of charging were studied with the circuit diagram shown in fig.1 and fig.2 respectively. In fig. 1)- CdSe photoanode, 2)- Counter electrode, 3) Y-S_e storage electrode, 4) Agar-Agar gel, 5) 0.1 M (Na_2S - S – NaOH) and 6) $K_3Fe(CN)_6$] – $K_4Fe(CN)_6$. The current and voltages were recorded using the digital current and volt meters respectively.

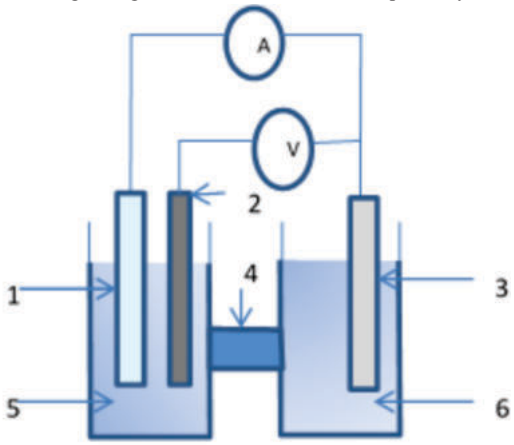

Fig.1: Schematic diagram of the redox storage cell during charging

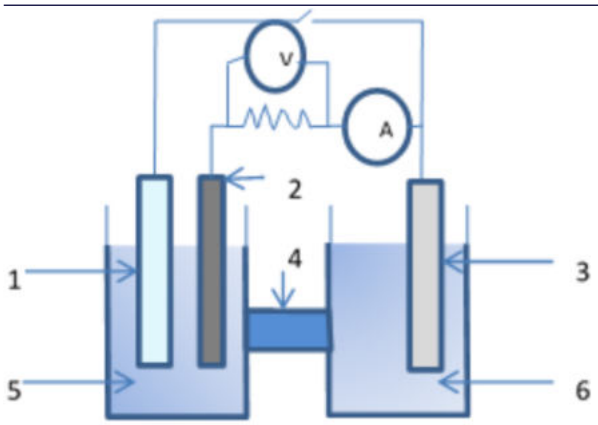

Fig.2: Schematic diagram of the redox storage cell during discharging

DISCUSSION:

The Configuration of the Cell and Charge Transfer Mechanism:

The configuration of the cell was as follows:

n - CdSe/ 0.1M (Na_2S - S – NaOH) / C / 0.1M - [$K_3Fe(CN)_6$] – $K_4Fe(CN)_6$] /Y- S_e.

During charging the photoreaction occurring at the two electrodes can be described as follows:

$n - CdSe + h\upsilon \rightarrow e^- + h^+$ $(h\upsilon > E_g)$

Due to localized electric field at junction,

$e^- + h^+ \rightarrow e^-_{bulk} + h^+_{surf}$

(i.e. near the interface of the semiconductor electrolyte)

$2h^+ + S^{2-} \rightarrow S$ (at the CdSe)
i.e. oxidation of electrolyte would occur, which is present near interface.

$e^-_{bulk} \rightarrow e^-$ Storage electrode

(Transfer to through back of semiconductor to the storage electrode)

$2e^- + Y\text{-}S_e \rightarrow Y + S^{2-}$

Where, Y-S_e is the storage electrode.

During discharging,

$S + 2e^- \rightarrow S^{2-}$ (in the first compartment) And

$Y + S^{2-} \rightarrow Y\text{-}S + 2e^-$ (in the storage compartment)

$Y + S^{2-} \rightarrow Y\text{-}S_e + 2e^-$ (in the storage compartment)

$Y + S^{2-} \rightarrow Y\text{-}Te + 2e^-$ (in the storage compartment)

Charging and Discharging Studies of the CdSe/ 0.1M (Na_2S - S – NaOH) / C / 0.1M - [$K_3Fe(CN)_6$] – $K_4Fe(CN)_6$] / (Y-S or Y-Se or Y-Te

During the period of charging photocurrent raised from 150 to 225 $\mu A/cm^2$ and 15 to 225 $\mu A/cm^2$ for Y-S and Y-Se within the period of 120, 80 and minutes respective, For Y-Te it is increased from 110 to 180 $\mu A/cm^2$ within the period of 130 minutes.

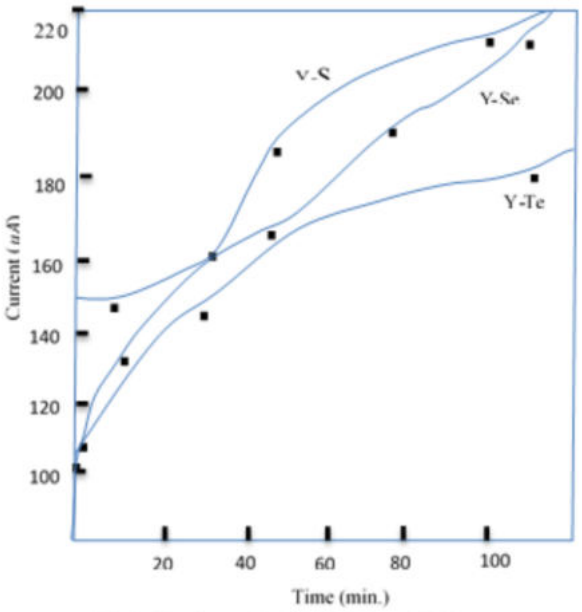

Fig.3: Charging cycle of Y-S, Y-Se and Y-Te electrodes

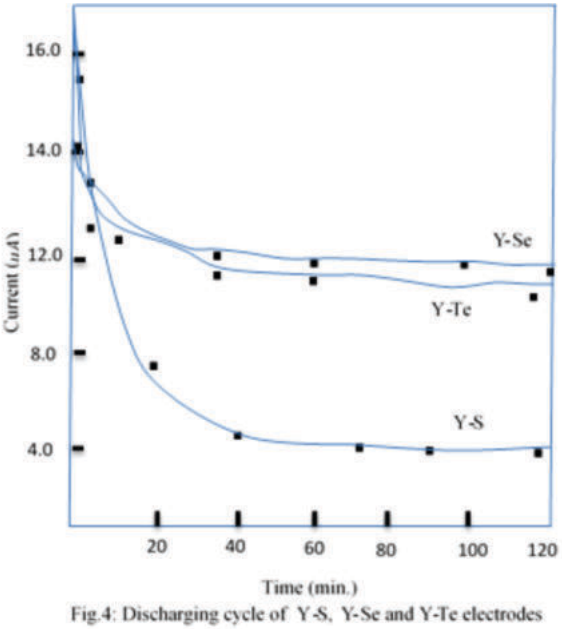

Fig.4: Discharging cycle of Y-S, Y-Se and Y-Te electrodes

CONCLUSION

From above studies of charging and discharging characteristics, it is concluded that yttrium chalcogenide films may be used as a storage electrode.

REFERENCES

[1] AS Arico, P Bruce, B Scrosati, JM Tarascon, W Van Schalkwijk, Nanostructured materials for advanced energy conversion and storage devices, Nat. Mater. 4(2005) 366.
[2] S Chu, A Majumdar, Opportunities and challenges for a sustainable energy future, Nature ,448(2012)294.
[3] C Liu, F Li, LP Ma, HM Cheng, Advanced Materials for Energy Storage, Adv. Mater. 22(2010)28.
[4] A Manthiram, Y Fu, SH Chung,C Zu, YS Su, Rechargeable Lithium–Sulfur Batteries Chem. Rev.114(2014)11751.
[5] W Lv, Z Li, Y Deng, QH Yang, F Kang, Graphene-based materials for electrochemical energy storage devices: Opportunities and challenges,Energy Storage Mater. 2(2016)107.
[6] Yu-Guo Guo, Jin-Song Hu, and Li-Jun Wan, Nanostructured Materials for Electrochemical Energy Conversion and Storage Devices, Adv. Mater. 20(2008)2878.
[7] Ye Luhan, Wen Kechun, Zuoxiang Zhang, Fei Yang, Yachun Liang,Weiqiang Lv and et. al., Highly Efficient Materials Assembly Via Electrophoretic Deposition for Electrochemical Energy Conversion and Storage Devices, Advanced Energy Materials.2016: Review.
[8] P Gregory Derek, Prospects for the use of hydrogen as an energy carrier; Proceedings of

the 13th Rare earth conference held at Wheling, West Virginia. 1(1977)16.
[9] J. Manassen, G. Hodes and D, Cahen, Semiconductor liquid junction solar cells,Electrochemical soc.77(1977)34.
[10] Xiaohui Zhang, BinYao, Li Yongfeng, Zhanhui Ding, Haifeng Zhao, Ligong Zhang and et. al. Influence of WSe_2 buffer layer at back electrode on performance of Cu,ZnSn(S,Se), solar cells, Solar Energy.199(2020)199128.
[11] MT Gutirrez and J Ortega, Photoelectrochemical Study of Electrodeposited Polycrystalline CdSe in Ferro-Ferricyanide System, J. Electrochem. Soc.136(1989)2316.
[12] Ueno Y,Kaigawa H,Ohashi T,Sugiura and Minoura H, Chemical bath precipitation of CdSe particles for use in a photoelectrochemical cell, Solar Energy Mat.15(1987)430.
[13] Sharon Maheshwar, P Veluchamy , C Natarajan, Kumar Dhananjay, Solar rechargeable battery—principle and materials, Electrochimica Acta.36(1991)1107.
[14] Joost Manassen, Gary Hodes and David Cahen,Photoelectrochemical Energy Conversion and Storage: The Polycrystalline CdSe Cell with Different Storage Modes, Journal of Electrochemical Soc.124(1977)532.
[15] Cao Liuyue, Maria Skyllas-Kazacos, and Da-Wei Wang, Solar Redox Flow Batteries: Mechanism, Design, and Measurement, Advance Sustainable Systems; Review.1(2018)33.
[16] KM Gadave, CH Bhosale and CD Lokhande, Electrochemical storage cell formed with HgS films,Bull. of electrochem.,(1993)262.
[17] CD Lokhande,MD Uplane and SH Pawar, Studies on photoelectrochemical storage celis formed with CdS:Cu electrode,Solid State Communication.43(1982)623.
[18] SS Dhumure and CD Lokhande , Studies on photoelectrochemical storage cells formed with chemically deposited CdSe and Ag2S electrodes, Sol. Energy Matter. and Sol.Cells.29(1993)183.
[19] SH Pawar, MP Patil and VN Shinde, Photoelectrochemical redox storage cell using electrodeposited CdSe as semiconductor-septum Bull.of Electrochem.,9(1993)252.
[20] SS Dhumure and CD Lokhande, Studies on photoelectrochemical storage cells formed with chemically deposited CdSe and Ag2S electrodes, Solar Energy Materials and Solar Cells.29(1993)183.
[21] J Costard, M Ender, Weiss and E Ivers-Tiffee, Three-Electrode Setups for Lithium-Ion Batteries. Journal of the Electrochemical Society.164(2017)80.
[22] JY Song, HH Lee, YY Wang and CC Wan, Two and Three-Electrode Impedance Spectroscopy of LithiumIon Batteries, Journal of Power Sources.111(2002) 255.
[23] D Robert. Minter, J Daniel. Robles, Conner Fear, Yevgen Barsukov and P Partha. Mukherjee, Three-electrode Coin Cell Preparation and Electrodeposition Analytics for Lithium-ion Batteries,Journal of visualized Experiments. 135(2018)57735.
[24] JB Goodenough and KS Park, The Li-Ion Rechargeable Battery: A Perspective, Journal of American Chemical Society. 135(2013)1167.
[25] Johannes Landesfeind, Daniel Pritzl, and A Hubert. Gasteiger, An Analysis Protocol for Three-Electrode Li-Ion Battery Impedance Spectra,164(2017)1773.