VOLUME I
ISBN No.: 978-81-953602-0-8
Chemistry

Estd. 1957

NALLAMUTHU GOUNDER MAHALINGAM COLLEGE

An Autonomous Institution, Affiliated to Bharathiar University, An ISO 9001:2015 Certified Institution,

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One day International Conference

EMERGING TRENDS IN SCIENCE AND TECHNOLOGY (ETIST-2021)

27th October 2021

Jointly Organized by

Department of Biological Science, Physical Science and Computational Science

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ABOUT THE INSTITUTION

A nations's growth is in proportion to education and intelligence spread among the masses. Having this idealistic vision, two great philanthropists late. S.P. Nallamuthu Gounder and Late. Arutchelver Padmabhushan Dr.N.Mahalingam formed an organization called Pollachi Kalvi Kazhagam, which started NGM College in 1957, to impart holistic education with an objective to cater to the higher educational needs of those who wish to aspire for excellence in knowledge and values. The College has achieved greater academic distinctions with the introduction of autonomous system from the academic year 1987-88. The college has been Re-Accredited by NAAC and it is ISO 9001 : 2015 Certified Institution. The total student strength is around 6000. Having celebrated its Diamond Jubilee in 2017, the college has blossomed into a premier Post-Graduate and Research Institution, offering 26 UG, 12 PG, 13 M.Phil and 10 Ph.D Programmes, apart from Diploma and Certificate Courses. The college has been ranked within Top 100 (72nd Rank) in India by NIRF 2021.

ABOUT CONFERENCE

The International conference on “Emerging Trends in Science and Technology (ETIST-2021)” is being jointly organized by Departments of Biological Science, Physical Science and Computational Science - Nallamuthu Gounder Mahalingam College, Pollachi along with ISTE, CSI, IETE, IEE & RIYASA LABS on 27th OCT 2021. The Conference will provide common platform for faculties, research scholars, industrialists to exchange and discus the innovative ideas and will promote to work in interdisciplinary mode.

LIST OF ARTICLES

DSSC PERFORMANCE OF ZINC - TIN - VANADIUM OXIDE NANOCOMPOSITE USING BEETROOT (*BETA VULGARIS*) AS DYE SENSITIZER

M. Chitra [1] - K. Uthayarani [1*]- R. Vasanthapriya [1] and N. Neelakandeswari [2]

ABSTRACT: In this present work, zinc - tin - vanadium oxide (ZTVO) nanocomposite prepared using hydrothermal route was systematically characterized. Dye-sensitized solar cell (DSSC) was fabricated using this ZTVO nanocomposite as photoanode and betalain from beetroot (*Beta vulgaris*) as natural dye. This simple protocol was formulated at a low cost for the first time for DSSC fabrication and it has attained the efficiency of 3.41%. This better efficiency of ZTVO might be due to larger surface area, presence of pores in addition to smaller band gap (1.97 eV).

Keywords: nanocomposites, solar energy materials, zinc-tin-vanadium oxide, beetroot, natural dye, band gap

1. INTRODUCTION

The low-cost, high-efficiency and non-pollution aspects of Dye-sensitized solar cells (DSSCs) has considered as one of the most promising alternatives to silicon based photovoltaic cells in the last two decades [1]. DSSCs became more interesting since after the phenomenal work carried out by O'Regan and Gratzel in 1991. In the present scenario, natural dyes are employed as light harvesting elements to provide the charge carriers. These natural dyes provide a feasible alternative to expensive organic based DSSCs (rare metal complexes) owing to its low cost, non-toxicity, ease of extraction using simple chemical procedures, environmentall friendly, easily biodegradable, abundancy and large absorption coefficient. The pigmented dyes such as chlorophyll from fig leaves exhibited an efficiency of 0.64 %, anthicyanin ectracted from eggplant and that of pomegrante records an efficiency of 0.64 % and 2.00 % respectively, betalain from red turnip gives out 1.7 % efficiency etc. Among them in this present work,

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betalain pigment extracted from beetroot has been chosen for its abundant availablity and large absorption coefficient with an intention of achieving better efficiency.

The next critical component in such DSSCs is the photoanode with porous structured materials [2 - 4] over which dye molecules get adsorbed onto its surface. To achieve high performance, the photoanode needs to possess large surface area and good electron transport capability [3]. Also, nanocomposites made of metal oxides and multi-structured semiconductor metal oxides [5 - 8] provide efficient charge separation for effective path of electron transport and promotes larger surface area for dye adsorption. Thus, this made extensive research work to focuss on the metal oxide nanocomposite photoanodes using TiO_2, ZnO , SnO_2 etc., than individual metal oxide semiconductors (MOS) [9, 10]. DSSCs based SnO_2 photoanode materials [11] are also reported owing to its larger band gap and their ability to create fewer oxidative holes in the valence band under UV illumination. Vanadium oxide (V_2O_5) is a transition metal oxide which has important applications in various device fabrication and it shows metal–semiconductor transitions implying sudden change in electrical and optical properties [12]. All these individual MOS has been employed as DSSC materials by various researchers but as a single system, they possess low open circuit voltage (Voc). To overcome these difficulties and to enhance the probability of photoconversion, band gap narrowing needs to be achieved. Hence, in this present work, zinc - tin - vanadium oxide nanocomposite (ZTVO) has been prepared via hydrothermal route. DSSC studies has been carried by fabricating the cell using this nanocomposite aided by the betalain dye extracted from beetroot (*Beta vulgaris*) and the results are presented herein.

2. EXPERIMENTAL DETAILS

2.1 Synthesis of zinc - tin - vanadium oxide nanocomposite using hydrothermal route

The reagents used for this present work were of analytical grade purchased from Rankem and were used as such. The protocol for the synthesis of this composite has been reported earlier [13] and it has been proved to be a better ethanol sensor at room temperature.

2.2. Fabrication of Dye Sensitized Solar Cell (DSSC) using the composite and the natural dye

Initially, Fluorinated tin oxide (FTO) glass substrates were subjected to cleaning using standard procedure. The nanopowders obtained were mixed with triton X and is grounded well and coated on FTO substrates. The film was calcined at 500^o C for 15 min. 100 g of beetroot (purchased from local market) was taken, grinded well and it is treated with 50 ml of ethanol, kept in a hot plate at 100^0 C for 1h at room temperature. The concentrated dye solution extracted from beetroot was taken and the ZTVO film was soaked in the natural dye extract for 24 h. DSSC was assembled using dye sensitized ZTVO as the working electrode and graphite as the counter electrode. These two electrodes were assembled using a semi-closed DSSC method and the electrolyte (I_3^- solution) was filed and the photovoltaic measurements were studied.

3. CHARACTERISATION TECHNIQUES

The crystallinity of the sample was studied by X-ray powder diffraction (XRD) using PANALYTICAL X – Ray diffractometer (Cu- Kα radiation, λ= 1.54Å) in 2θ ranging from 20° - 80°. JOEL JEM 2100 Transmission microscope was used to record the Transmission electron microscopic (TEM) image as well as Selective area electron diffraction pattern (SAED). The optical property was studied using UV-visible diffuse reflectance spectrum (DRS) by JASCO - UV VIS spectrophotometer. The specific surface area was analysed based on the nitrogen adsorption isotherm. DSSC studies was carried out using LOT-LS0104 solar simulator (irradiance 100 mW/cm^2) and electrochemical workstation (Metrohm, Autolab 302NFRA2).

4. RESULTS AND DISCUSSION

4.1 Structural analysis

From the XRD pattern of ZTVO [13], phases such as SnO_2 [ICDD No:41-1445], Zn_2SnO_4 (ICDD No:24-1470), ZnV_2O_6 (ICDD No: 23-0757) and ZnV_3O_8 (ICDD No: 71-0731) were found to exist in sample in the proportion of 28%, 19%, 36% and 17% respectively. The formation of binary phases such as zinc stannate and zinc vamadate along with the individual SnO_2 is confirmed from the XRD pattern [13].

4.2 Morphological studies

High magnification HRTEM image of ZTVO is depicted in Fig. 1 (a) and the d-spacing for SnO_2 is found to be 0.332 nm and that of ZnV_2O_6 is found to be 0.312 nm and the values matches well with the corresponding standard values. From the SAED pattern shown in Fig. 1 (b), the polycrystalline nature is proved from the orientation of atoms in different planes and the presence of different phases has been indexed.

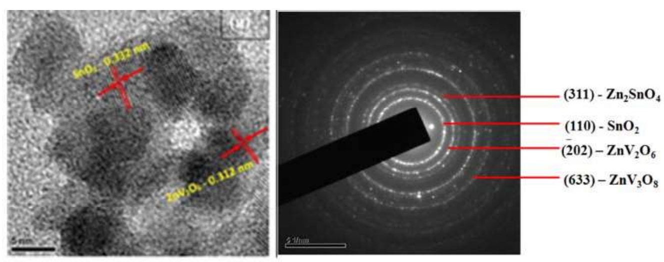

Fig. 1 (a) HRTEM image and (b) SAED pattern of ZTVO

4.4 Optical studies

From the diffuse reflectance spectrum of ZTVO shown in the inset of Fig. 2, a broad absorption edge is noticed around 600 nm. This might be due to the synergistic effect of the composite material and the band gap for ZTVO has been calculated to be 1.97 eV from the band gap determination plot in Fig. 2. Band gap (E_g) plays a crucial role in assisting the wavelength range for light absorption. So, smaller the band gap, larger will be the probability of photo conversion and hence ZTVO possessing the band gap of 1.97 eV could show better efficiency [15 - 17].

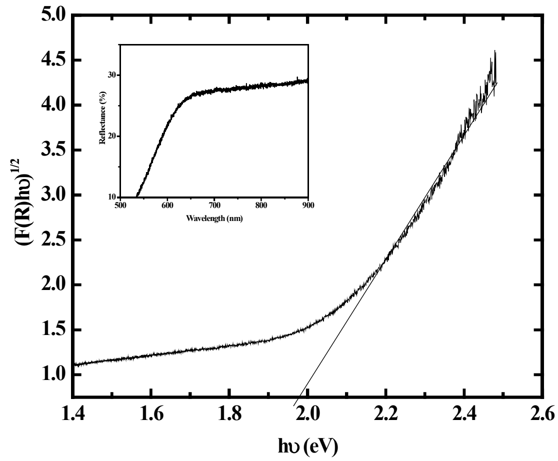

Fig. 2 Band gap determination plot of ZTVO
(inset : Diffuse reflectance spectrum)

4.5 Surface area analysis

The specific surface area of ZTVO calculated using BET analysis was found to be 167.3 m^2/g and pore size of 11 nm is obtained from the PSD plot (not shown). The synergistic effect [19 - 21] of the hierarchical nanostructured ZTVO offers large surface area which could favour better performance of the photoanode and henceforth DSSC performance.

4.6 DSSC measurements

Current - Voltage characteristics of DSSCs fabricated using ZTVO photoanodes is presented in Fig. 3 (a). The photovoltaic performance of the DSSCs is calculated using the formula reported elsewhere [22]. ZTVO serving the role of photoanode has been reported for the first time shows efficiency of 3.41% with a fill factor of 0.15. The schematic representation is depicted in inset of Fig. 3 (b).

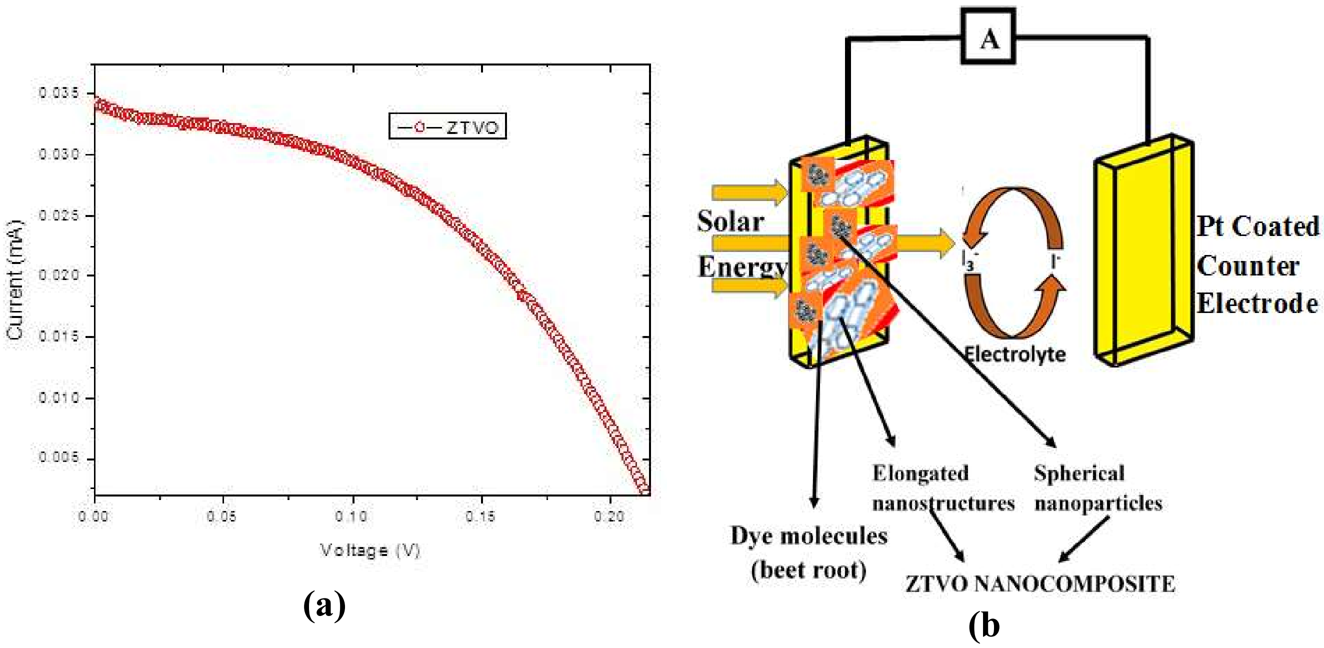

Fig. 3 (a) Current- Voltage characteristics and (b) Schematic Diagram of the fabricated DSSC using ZTVO and dye from Beetroot extract

A very strong parameter which favours the conversion efficiency is the smaller band gap [23] and in which the band gap of ZTVO (1.97 eV) proves to be the better photon converter. Since, porosity of the nanocomposite is also an important factor to be taken into account in which adsorption of dye molecules could be favoured so that better performance of DSSC could be achieved. The efficiency of DSSC using the beetroot as a natural dye with ZTVO as photoanode seems to be better than reported by M. Mazhar et al (0.30 %) and S. Sathyajothi et al (1.3 %)

5. CONCLUSION

ZTVO nanocomposite prepared via hydrothermal method was implemented as a photoanode and beetroot extract as the natural dye in fabricating a low cost DSSC for the first time. The elongated microstructures and spherical nanostructures possessing larger surface area of 167.3 m^2/g and smaller band gap of 1.97 eV are the strongest factors which gives a wide scope of ZTVO in fabricating DSSC to the commercial scale. These fabricated DSSC using beetroot extract as the dye reported for the first time exhibits considerable efficiency.

ACKNOWLEDGEMENT

Authors would like to thank DST, India for creating characterisation facilities under DST-FIST (SR/FST/COLLEGE-154/2013) scheme in Sri Ramakrishna Engineering College, Coimbatore Tamilnadu, India.

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Education is the manifestation of the perfection already in man

- Swami Vivekananda