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Fabrication of Dye Sensitized Solar Cells by the Plasmonic Effect of Silver Nanoparticles and Basella Alba Dye

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Abstract

Dye-sensitized Solar cells are the most promising devices among third-generation solar cells because of low cost, easy production, environmental friendliness, and relatively high conversion efficiency. In this present work, the power conversion efficiency of dye-sensitized solar cell has been increased by incorporating silver nanoparticles into TiO_2 photo anodes. TiO_2 nanoparticles were prepared by sol-gel method. Silver nanoparticles were prepared by chemical reduction method. As prepared TiO_2 nanoparticles were annealed at 300˚c for 2h.TiO_2 have been characterized by X-ray diffraction analysis. From XRD the average particle size was calculated as 49nm and it exhibits a tetragonal shape, and characterized by scanning electron microscopy confirms the spherical shape in nature. The silver nanoparticles were characterized by Scanning Electron Microscopy and UV-visible spectroscopy. From the characterisation results it was found that the silver nanoparticles are spherical in shape and shows the maximum absorption peak at 437nm. Organic dye from Basella Alba fruit extract was used and it was subjected to different temperatures and were coated on the cells. The prepared Solar cells were characterized by current-voltage (I/V) characteristics and efficiencies of Solar cells were calculated.

Keywords: Dye Sensitized Solar Cells; Silver Nanoparticles; Basella Alba

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1. Introduction

Dye Sensitized Solar Cells (DSSC) is an efficient type of thin film photovoltaic cell. Dye Sensitized Solar Cells are one of the impartment alternative technologies for solar energy protection. There are various types of solar cells that convert sun light energy in to electrical energy. Solar energy provides less harmful to our environment than other methods of energy production. Modern Dye Sensitized Solar Cells, or Gratzel cells, are based on a concept invented in 1988 by Brain O'Regan and Michael Graztal. Dye sensitized solar cells(DSCs) based on nano crystalline semiconducting oxides and dye sensitizers were introduced by Micheal Gratzel in 1991[1-3].DSSC comprises of nono-crystalline porous semiconductor electrode with absorbed dye, an electrolyte, and counter electrode. The DSSC produce electricity through electron transfer. The photon excitation of dye will cause an injection of an electron into the conduction band of the TiO_2 layer and these electrons will circulate the external loop through the load. Meanwhile dye molecule which lose electron will be restored by electron donation from redox electrolyte (iodide/triiodide) [4]. The dye plays a major role in absorption and conversion of incident light ray to electricity. There are two types of dyes organic dyes such as natural dyes from leaves, fruits and flowers and inorganic dyes such as ruthenium (Ru) which provide greater efficiency. However, ruthenium based dyes are quite expensive. There is an alternative method for using inorganic dyes are natural dyes. Doping of silver nanoparticle is an effective way to achieve a significant increase on the efficiency of the solar cells. Loading of silver enhances optical absorption of the dye by localized surface Plasmons which has contributed to increase photocurrent and an improved efficiency [5-8]. In this present study, the DSSCs have been fabricated by using chemical reduction method for synthesis of Ag nanoparticles mixed with TiO_2 photo anode and plasmonic effect of Ag NPs on DSSC has been studied.

2. Experimental procedure

2.1 Materials

Silver nitrate($AgNO_3$), Tri sodium citrate($Na_3C_6H_5O_7$), Titanium tetra isoproxide [$Ti(OCH(CH_3)_2)]_4$, sigma-Aldrich,97%], iso-propanol [$(CH_3)_2CHOH$, sigma-Aldrich,99.7%] Nitric acid [HNO_3],glacial acetic acid,Triton-100 were used as received without any further purifications. Fluorine doped tin oxide (FTO) conducting slides of size 2.5mm*2.5mm (7-10Ω) were used, and Basella Alba (Malabar spinach) fresh fruits were collected from the garden and used to prepare the dye.

2.2 Synthesis of TiO_2 nanoparticles

The Titanium dioxide was prepared by sol-gel method. Initially 10ml of iso-propanol was added to 12ml of distilled water. Then 20ml solution of Titanium Tetra Iso Propoxide (TTIP) was added to the iso-proponal solution drop by drop under constant stirring at 80˚C. After 1h, concentrated HNO_3 (0.8ml) mixed with deionised water was added to the TTIP solution and stirred continuously at 60˚C for 3h and high viscous sol gel was obtained. The prepared gel was dried in hot air oven and it is annealed at 300 ˚C for 2h. [9]

2.3 Synthesis of silver nanoparticles

Silver nanoparticle was prepared by chemical reduction method. The solution of silver nitrate was prepared by dissolving 0.0169g of silver nitrate in 100ml of distilled water and it is heated. 1% of Tri sodium citrate solution was prepared by dissolving 1g Tri sodium citrate into 100ml distilled water. 20ml of silver nitrate solution was kept in the hot plate at 90˚c for 5mins and 2.5ml of tri sodium citrate was added drop by drop to it. Once the reduction process begins colour change was observed and the colourless solution is changed to pale yellow in colour. Then it is stirred for 15mins using magnetic stirrer [10-11]

2.4 Preparation of dye

The Basella Alba is an edible perennial vine in the family basellaceae. Basella alba known as Malabar spinach or cyclone spinach is shown in Fig.1. Basella Alba rubra contains maximum betacyanin flovonoid the range of absorption in the visible light spectrum of betatains pigment. Chemical structure of betacyanin is shown in Fig.2. It also contains certain phenolic phytochemicals and it has an antioxidant properties. Basella Alba fruit (Malabar spinach) was mashed with mortar and pestle 20ml of ethanol was added to the extract and filtered, and it was subjected to various temperatures 60˚C, 70˚C, 80˚C [12]

Scientific Classfication:

Kingdom: plantae
Clade: Angiosperms
Clade: eudicots
Order: caryphyllales
Family: Basellaceae
Genus: Basella
Species: B.alba

Fig.1.Basella Alba (Malabar spinach)

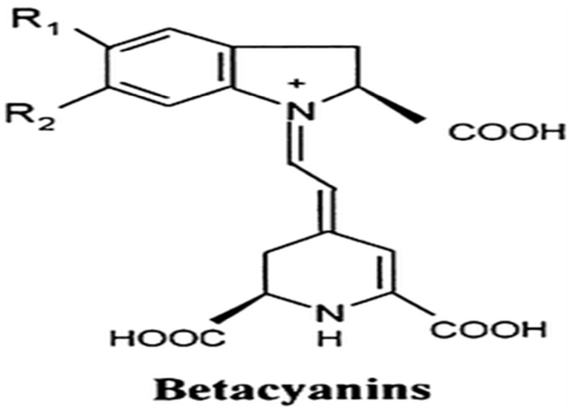


Fig.2.Chemical structure of betacyanin molecules

2.5 Synthesis of electrolyte

The electrolyte solution was prepared by mixing 0.08789 ml of 4-tert-butyl pyridine was added to 0.13385g of Lithium iodide and 0.0253809g of iodine mixed in 2ml of acetonitrile and stirred for 15mins. The prepared mixture was used as an electrolyte.

2.6Assembly of DSSC

Fluorine doped Tin Oxide films of 25mm*25mm (7-10Ω) were used for the preparation of the cells and it was washed with ethanol, cleaned and dried. The four edges of the glass plates were covered with scotch tape. The photo anode was prepared by adding 0.5gm of the as prepared TiO_2 powder added to 2ml of ethanol, two drops of Triton X-100, 12 drops glacial acetic acid and was added until the mixture become creamy paste. 0.25ml of Ag nano colloidal solution was added to the as prepared paste [13-15]. The mixture was coated uniformly on the conducting side of fluorine doped tin oxide (FTO) glass plate by sliding a glass rod and it was dried for several hours. The coated area was about1cm. After drying completely, the tape was removed carefully. The coated cells were sintered at 450˚c for 30mins in a furnace and allowed to cool down to room temperature. To sensitize the photo anode, the TiO_2 layers without and with silver Nanoparticles were immersed into the dye solution for 12hours and kept in darkness at room temperature. The counter electrode was prepared by depositing platinum on ITO glass plate. The Dye Sensitized Solar Cells were assembled by sandwiching the prepared photo anode with a platinum coated counter electrode, as prepared electrolyte injected between the two electrodes. All measurements were performed earlier after the preparation of the devices to avoid any changes in the dye and photoelectric properties caused by ageing. Fig.3. shows the fabricated Dye Sensitized Solar Cell.

Fig.3.Prepared solar cells

3. Results and Discussion

3.1 X-Ray Diffraction Studies

The structural analysis of TiO_2 particles was carried out using XRD Rigaku Miniflux 600 instrument. Fig.4. shows the XRD patterns of TiO_2 powder which was annealed at 300˚c for 2h. XRD patterns exhibited diffraction peaks at 25.32˚, 30.54˚, 37.97˚, 47.88˚and 54.28˚with the corresponding (101),(004),(200),(211) and (105) planes respectively. All observed peaks are in good agreement with the JCPDS no: 89-4921[16]. It is in the Anatase phase. The cell parameter are a=b=3.777≠c=9.501 and the lattice is body center cubic and it exhibits tetragonal shape. Average particle size was estimated using Debye -Scherrer equation.

$$D=k\ \lambda/\beta\ \cos\theta \text{ ------------- (1)}$$

Where k=0.9; λ is Cu Kα radiation wavelength; λ=1.540 Aº. The Average particle size calculated was to be around 49 nm.

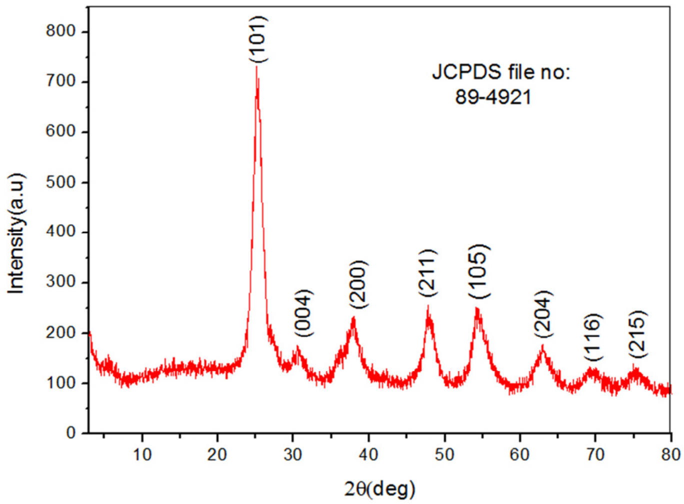
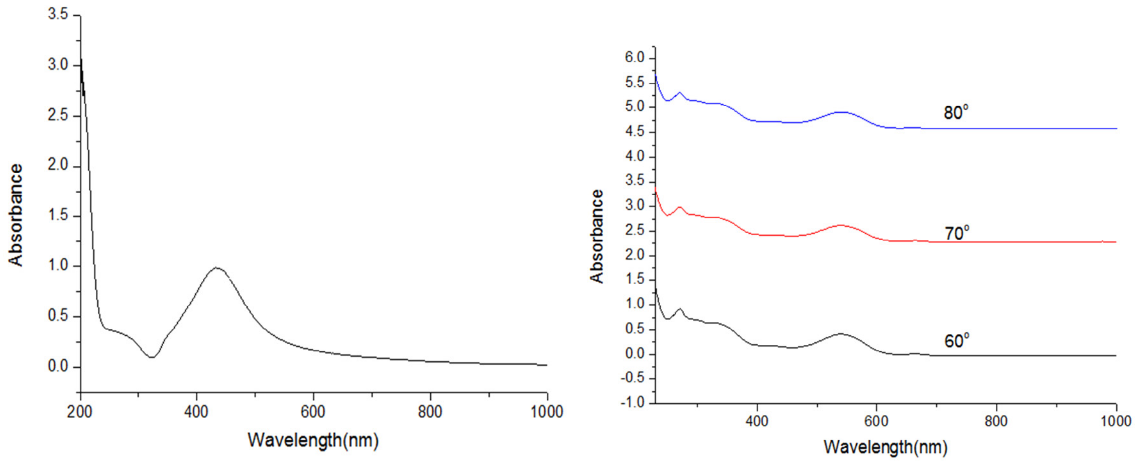


Fig.4. XRD pattern of TiO_2 powder (300˚c)

3.2 UV-Visible spectroscopy Studies

UV-Visible absorption spectroscopy has been used to study the optical properties of silver and Basella Alba using UV-Vis lambda 750. The absorption spectra of silver nanoparticle is shown in Fig.5(a), which shows the absorption peaks at 437nm . It confirms the presence of silver nanoparticle [17].

Fig.5(b) shows the absorption spectrum of Basella Alba fruit extract for three temperatures at 60˚C, 70˚C, 80˚C. The maximum peaks were obtained at 541nm and the band gaps for consequent three temperatures are 3.05ev, 3.31ev, 3.50ev respectively.

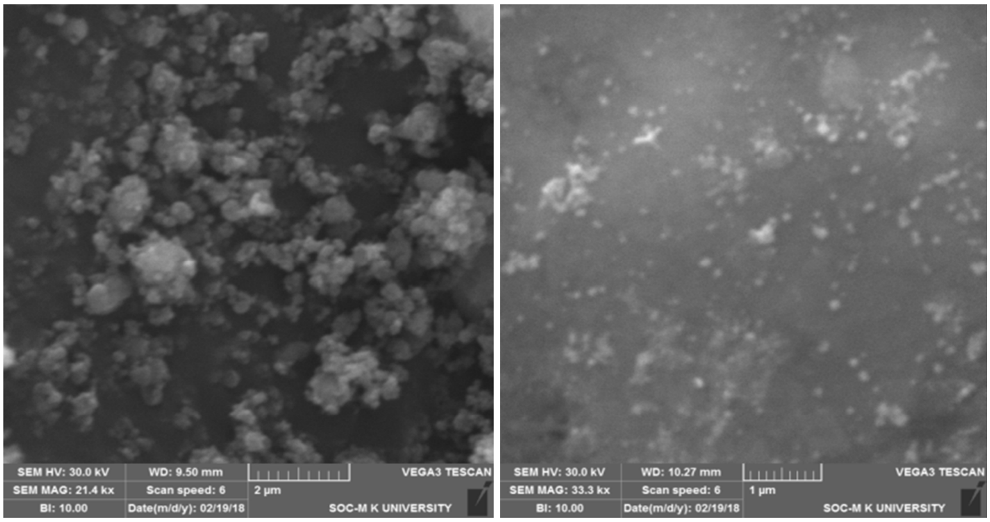


(a) (b)

Fig.5. UV-vis spectroscopy of (a) silver nanoparticle, (b) Basella Alba for (60˚C, 70˚C, 80˚C)

3.3 Scanning Electron Microscopy Studies

Scanning Electron Microscopy (SEM) technique is used to study the surface morphology of the prepared nanoparticles. Fig.6(a) Shows the SEM image of synthesised TiO_2 nanoparticle and it exhibits spherical in shape[18-20]. Fig.6(b). Shows the SEM image of silver nanoparticle and it was observed that they are spherical in shape and distributed uniformly.



(a) (b)

Fig.6 Scanning Electron Microscopy of (a) TiO_2, (b) Ag Nanoparticle

3.3 EDAX Studies

Energy dispersive X-Ray analysis (EDAX) of TiO_2 nanoparticle was performed. Fig.7. shows the EDAX spectra of TiO_2 and indicates the presence of Ti and O with weight percentage of 96.50 and 3.50 respectively [21]. No impurity peak is observed in the EDAX spectra.

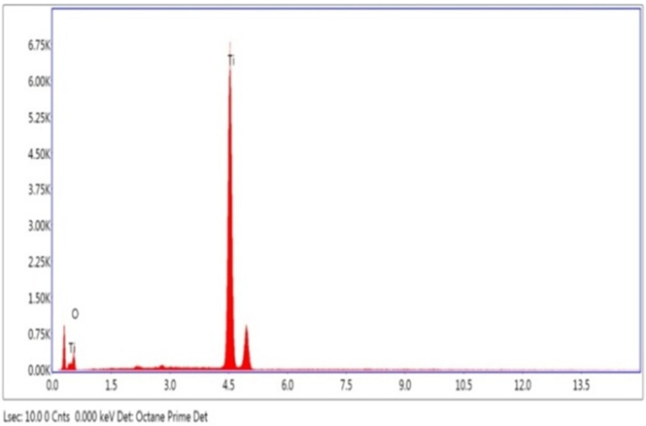
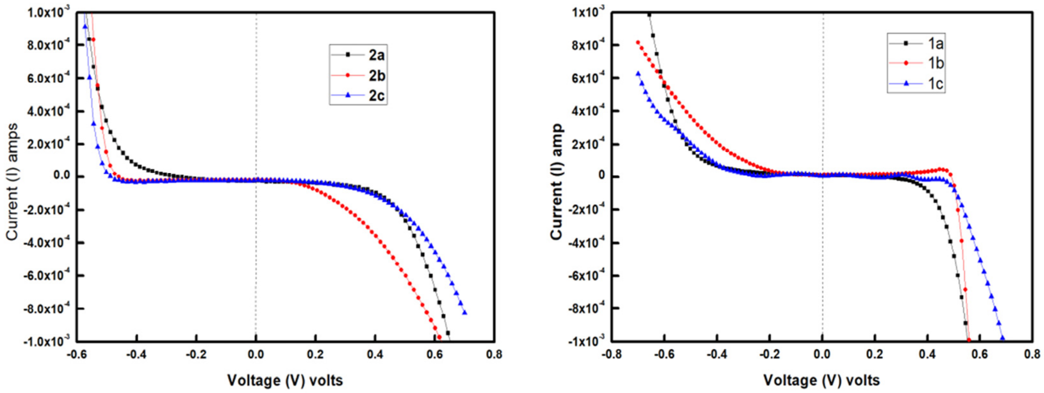


Fig. 7 EDAX spectra of TiO_2

3.4 I-V characterization Studies

The current-voltage characteristics of DSSCs were carried out using a solar stimulator with light intensity of 100mW/cm^2 at 1.5 AM was employed to illuminate the solar cells. I-V curves for the DSSCs fabricated using TiO_2 with silver nanoparticle for three temperatures i.e. (60˚C, 70˚C, 80˚c) for both without and with silver doped cells are shown in Fig.8. The photovoltaic parameters as calculated from I-V curve are summarized in Table.1. DSSC fabricated silver doped cell at 80˚c temperature exhibit larger short current density of 45.8µA and with higher efficiency of 0.81%.



(1) (2)

Fig.8. I-V characteristics of as prepared DSSCs (1) Non-silver doped (2) silver doped

Table1. Photovoltaic parameters of the as prepared DSSC's

Sample	Voc (v)	Isc(μA)	η%
2a Non-Ag doped at 60˚C	0.18	5.8	0.08
2b Non-Ag doped at 60˚C	0.33	11.7	0.09
2c Non-Ag doped at 60˚C	0.35	23.5	0.28
1a Ag doped at 60˚C	0.34	28.8	0.36
1b Ag doped at 70˚C	0.47	34.7	0.66
1c Ag doped at 80˚C	0.48	45.8	0.81

Conclusion

Titanium dioxide nanoparticles were prepared by sol-gel method and silver nanoparticles were prepared by chemical reduction method. The as prepared TiO_2 powder was characterized by XRD, SEM, and EDAX and as prepared silver nanoparticle was characterized by UV-Vis.spectroscopy and SEM. From XRD analysis, the average particle size of TiO_2 was calculated as 49nm. SEM image of TiO_2 displayed the uniform morphology in the form of spherical shape. EDAX confirmed the samples were in pure form. UV-Vis spectroscopy of silver nanoparticle showed the maximum absorption peak at 437nm confirmed that it suitable for DSSCs. The band gaps of Basella Alba dye for three temperatures (60˚c, 70˚c, 80˚c) are 3.05eV, 3.31eV, 3.50eV and the band gap increased with the increase of temperature. I-V characteristics curves were plotted and photo electrochemical properties were investigated for the prepared solar cells. The highest conversion efficiency obtained for silver doped solar cells was at 80˚c. The open circuit voltage (Voc) was 0.48v and short circuit current (Isc) was 45.8μA and the corresponding efficiency was 0.81%.

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