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A Review On The Absorber Materials In Dye Sensitized Solar Cell

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***Abstract*—This paper reports on the fabrication of dye sensitized solar cell using various types of photo electrodes. They have been widely used because of their unique properties including high absorbance coefficient, chemical stability and electrochemical activity at nanoscale. In this work, the growth conditions will be optimized in order to determine the best power conversion efficiency.**

Keywords—thin films; dye sensitized solar cell; band gap; semiconductor

I. INTRODUCTION

Recently, a number of works which describe the power conversion efficiency of fabricated dye sensitized solar cells (DSSC) have been done by many researchers and successfully published their results in many papers. The investigation of this type of solar cell is important due to many advantages such as inexpensive [1, 2], efficient solar energy conversion [3], flexibility [4] and easy production [5]. Generally, the dye sensitized solar cell consists of a photoelectrode and a catalytic electrode [6] with an electrolyte between them [7]. In order to study the photoelectrochemical properties of nanoparticles, various parameters including conversion efficiency, open circuit voltage, close circuit current density, fill factor, interface charge resistance and an incident photon will be investigated. Researchers understand that these photoelectrochemical properties are strongly depend on the morphological properties of nanoparticles, spectroscopic characteristics of dyes and the electrical behavior of electrolytes.

Nowadays, scientists have to look for renewable energy sources because of the consumption of fossil fuels are increasing day by day [8]. In this work, dye sensitized solar cell will be fabricated by using different photo electrodes. Then, the performance of solar cell will be evaluated based on photoelectrochemical parameters.

II. LITERATURE SURVEY

Rani and Ernest [9] designed the dye sensitized solar cell using different photo electrodes, namely zinc oxide (ZnO) and gallium doped zinc oxide thin films. The experiment results show that gallium doped zinc oxide films have the larger surface area. Therefore, it reaches the efficiency of 4.3% than the zinc oxide electrode of 2.5%. In other words, the conversion efficiency in latter case is low due to the order less structure of film which was supported by the scanning electron micrographs. On the other hand, they also prepared gallium doped zinc oxide films of different concentrations of gallium. They conclude that the efficiency of the solar cell increases for every increment in the concentration of gallium from 0.0001 M (3.9%), 0.0002 M(4.1%) to 0.0003 M (4.3%).

The influence of zinc oxide coated titanium dioxide (TiO_2) working electrode in dye sensitized solar cell was studied by Chou et al [10]. They presented some results such as the band gap and atomic percentage of zinc dispersed in the zinc oxide coated TiO_2 films were increased at longer soaking time and with a higher concentration of zinc acetate dihydrate. It is due to more zinc oxide was deposited on the TiO_2 films, then might facilitate the creation of the energy barrier in the working electrode of a dye sensitized solar cell. As a result, conversion efficiency of the zinc coated TiO_2 electrode (6.7%) exceeds that of the conventional solar cell with a TiO_2 electrode (5.9%).

Anca et al [11] investigated the influence of surfactant in morphology and optical properties of zinc oxide nanostructures. They found that more uniform distribution of particles dimensions and a higher crystallinity for triton-100 as a surfactant. Also, the mean diameter of nanoparticles about 19 nm and 30 nm could be detected for the films prepared using triton X-100 and PEG 200, respectively. Lastly, they conclude that the higher values of efficiencies (1.01-1.19%) in the case of zinc oxide in the presence of triton X-100 than that of films obtained in the presence of PEG 200 (0.24%).

Wu et al [12] developed dye sensitized solar cell based on nickel oxide (NiO) electrodes. They point out that the conversion efficiency of solar cell based on improved hydrothermal method was twice as high as that of primary hydrothermal method. On the other hand, they reported that the reaction solution concentration has great effect on the properties of the NiO films. For example, the morphology of NiO changes from flocks consisting of nanosheets to flower like microspheres as shown in scanning electron microscopy analysis. Also, conversion efficiency is increased from 0.015% to 0.036% as the solution concentration was increased from 15 to 50 mM in primary NiO photocathodes.

ZnO and Al-doped ZnO thin films were deposited on transparent conducting oxide glass using glass rod spreading method by Suri et al [13]. They choose ZnO in their experiment due to many reasons such as its stability against photo corrosion and photochemical properties similar to TiO_2. They found that the lower conversion efficiency of the Al doped ZnO (0.6 %) compared to ZnO (1.43 %) because of lower injection efficiency and less porosity in this type of solar cell.

Supphadate & Sasimonton [14] demonstrated an improvement of conversion efficiency of DSSC by addition of stannic oxide (SnO_2) into ZnO photoanode. They proposed that the power conversion efficiency reaching a maximum value of 1.75 % where additive SnO_2 weight ratio of 7 %, indicating that the conversion efficiency changed with SnO_2 weight ratio. They explain that the conversion efficiency is reached by reduction of transfer resistance to induce pathway direction for electron transfer in photoanode.

The cupric oxide (CuO) nanoparticles were conducted by Jitendra et al [15]. The obtained nanoparticles show monoclinic structure and exhibit spherical morphology as indicated in X-ray diffraction (XRD) and scanning electron microscopy (SEM) investigations. Additionally, these compounds show good surface for the electrocatalytic activity towards the reduction of I_3^- (triiodide) to I^-iodide ions in redox electrolyte as reported in cyclovoltammetry analysis. Lastly, they claim the conversion efficiency of 3.4 % was achieved in their fabricated solar cell by using CuO nanoparticles.

Electrophoretic deposition technique was used for the fabrication of TiO_2 films on the conductive substrate by Masood et al [16]. They analyzed that an increase of deposition cycle lead to linear increases of film thickness and cell efficiency. For example, the power conversion efficiency was increased from 0.074% to 6.56% as the film thickness was increased from 1.5 µm to 24 µm. On the other hand, the mean sizes of nanoparticles were increased as the annealing temperature was increased from 150 °C (21 nm) to 500 °C (26.5 nm) according to the scanning electron microscopy results. Lastly, they suggest that the optimized annealed temperature should be 500 °C because of successfully yielded the highest conversion efficiency of 6.6 %.

Zinc oxide nanoparticles were electrodeposited on TiO_2 photoanode by Mozaffari et al [17] in order to suppress the electron recombination process. In order to achieve this objective, various deposition times and concentrations of zinc should be examined in their experiments. They observe that a large amount of ZnO was covered on TiO_2 nanoparticles at high concentration of zinc (1 x 10^{-3} M) and longer deposition time (300 s). Lastly, they suggest that the best conditions to produce higher conversion efficiency of 4.56 % were at deposition time of 15 seconds and concentration of zinc was 1 X10^{-6} M by comparing the results of all accomplished experiments.

Chou et al [18] studied the applicability of n-type TiO_2 and p-type NiO on the fluorine doped tin oxide substrate in dye sensitized solar cell. They also analyzed the influence of the mass ratio of TiO_2 to Ni and the number of coatings of TiO_2 particles on the conversion efficiency. The power conversion efficiency increases from 3.1 % to 3.6 % as the mass ratio of TiO_2 to Ni changes from 10:0.1 to 10:0.2, indicating that conversion efficiency increases with increasing the mass of Ni in TiO_2/NiO particles.

TABLE I. CHEMICAL BATH DEPOSITED THIN FILMS

NiS [20]
CdS [21]
Cu-Sn-S [22]
Cd-Zn-S [23]
Cu_2S [24]
Cu-Cd-S [25]
FeS_2 [26]
SnS [27, 28]
ZnS [29]
MnS [30]
Cd-S-Se [31]
ZnSe [32]
NiSe [33, 34]
PbSe [35]
Cd-Zn-Te [36]
SnSe [37]
FeS [38]
CuS [39]
Zn-Ni-S [40]
Ni-Pb-S [41]
In_2S_3[42]
MnS_2 [43]
Ag-Sn-S [44]
FeS [45]
CdSe[46]
PbS [47]

As pointed out by many researchers, there are many disadvantages could be observed in dye sensitized solar cell including higher recombination of charge carriers between the nanoparticle grain boundaries of photoanode, dye agglomeration over photoanode and the liquid electrolyte degradation due to environmental factors [19]. Therefore, another type of solar cell called thin film solar cell could be used to convert sunlight into electrical energy. Recently, thin films solar cell is produced by depositing thin layers on the substrate using chemical deposition technique. Many researchers have reported that the chemical bath deposited films (Table 1) and electrodeposited thin films (Table 2) always been cheaper but less efficient than conventional crystalline silicon technology.

TABLE II. ELECTRO DEPOSITED THIN FILMS

CdSe [48]
ZnS [49]
$CuInSe_2$ [50]
Cu_4SnS_4 [51]
Cu_2ZnSnS_4 [52]
$Cu_xSn_yS_z$ [53]
ZnTe [54]

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CONCLUSION

Literature review shows that there are many scientists actively engaged in the research of dye sensitized solar cell. Dye sensitized solar cells could be fabricated based on the TiO_2, CuO, NiO and ZnO acting as an electrode. This type of solar cell has potential to be renewable energy sources due to can convert the solar energy into electrical energy. This review paper clearly shows that the conversion efficiency depends on the photo electrodes.

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