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Investigations on Structural and Optical parameters of ZnO Dye-sensitized solar Cell

M. Ismail Fathima and K.S. Joseph Wilson*

Department of Physics, Arul Anandar College (Autonomous),
Karumathur, Madurai – 625514, India

ABSTRACT

The importance of Diffusion length and Photo anode thickness and also role of MgO Antireflective coating (ARC) on ZnO with N719 dye sensitized solar cell (DSSC) has been theoretically explored. Electron transport and recombination depend upon the Diffusion length of the electron. The collection efficiency of DSSC examined by varying the Diffusion length and Photo anode thickness. Collective electron trapping and detrapping transaction depend on the photo anode thickness. It affect the electron injection. Diffusion length and photo anode thickness are interdependent parameters. It is concluded that the Definite Diffusion length and photo anode thickness are enhanced to upgrade the conversion efficiency of ZnO with N719 DSSC it is also found that MgO ARC in the N719 DSSC increase the light trapping and hence to increase the efficiency.

KEYWORDS: Dye sensitized solar cell, Diffusion length, Reflectivity, Conversion efficiency.

*Corresponding Author

K.S. Joseph Wilson

Department of Physics,

Arul Anandar College (Autonomous),

Karumathur, Madurai – 625514, India

Email: wilsonpra@yahoo.co.in

1. INTRODUCTION

In Recent years saw numerous studies initiated for efficiency improvement of the dye-sensitized solar cell (DSSC)[1]. Even if the top efficiency is still in the range comparable with those of amorphous silicon cells, a active merit of DSSC over solid-state solar cells has been indicated on account of its low-cost manufacturing feasibility. TiO_2 based DSSC has been reported to produce the highest solar to electric energy conversion efficiency up to 11% TiO_2 is used in DSSC application since it has high photo activity[2,12].Another photoactive oxide semiconductor, ZnO, is interesting to be employed as DSSC photo electrode. ZnO can be easily synthesized in various nanostructures[16]. It has higher band gap energy and bulk electron mobility than that of TiO_2 It allows better photo electro chemical properties of DSSC[14]. However, conversion efficiency of 5% is the best record for ZnO-based DSSC Most of studies have concentrated on several Internal parameters such as diffusion length, thickness of electrode, absorption coefficient of electrode materials and wavelength etc of DSSC[3]. Structural and optical parameters of ZnO nano particles enables to achieve high conversion efficiency with respect to incident solar energy of more than 11% . The goal of this study is to make better efficiency to reform the perfect diffusion length and photo anode thickness and also reduce the reflectivity loss by using Anti reflection coating in ZnO based DSSC[4,15].

2. THEORETICAL WORK

Photo anode is an important one is the mechanism of photon–electron conversion mechanism. Advancement of the photo anode design are essential for construct high-performance DSSCs. Commonly, key such as transparency, electron collection of electrodes, photo-electron generation rate, electron injection efficiency, diffusion and transfer ability, and charge carrier recombination rate etc. can be improved with perfect diffusion length with appropriates thickness of photo anode.

The diffusion length is determined by the efficiency of DSSC. In this work the short circuit current (J_{sc}) is calculated for various diffusion lengths of ZnO based N719 DSSC[2]. Various diffusion lengths are obtained from different absorption time of ZnO photo anode in the N719 dye[5]. The short circuit current is calculated using electron diffusion differential model formula (1)[6].

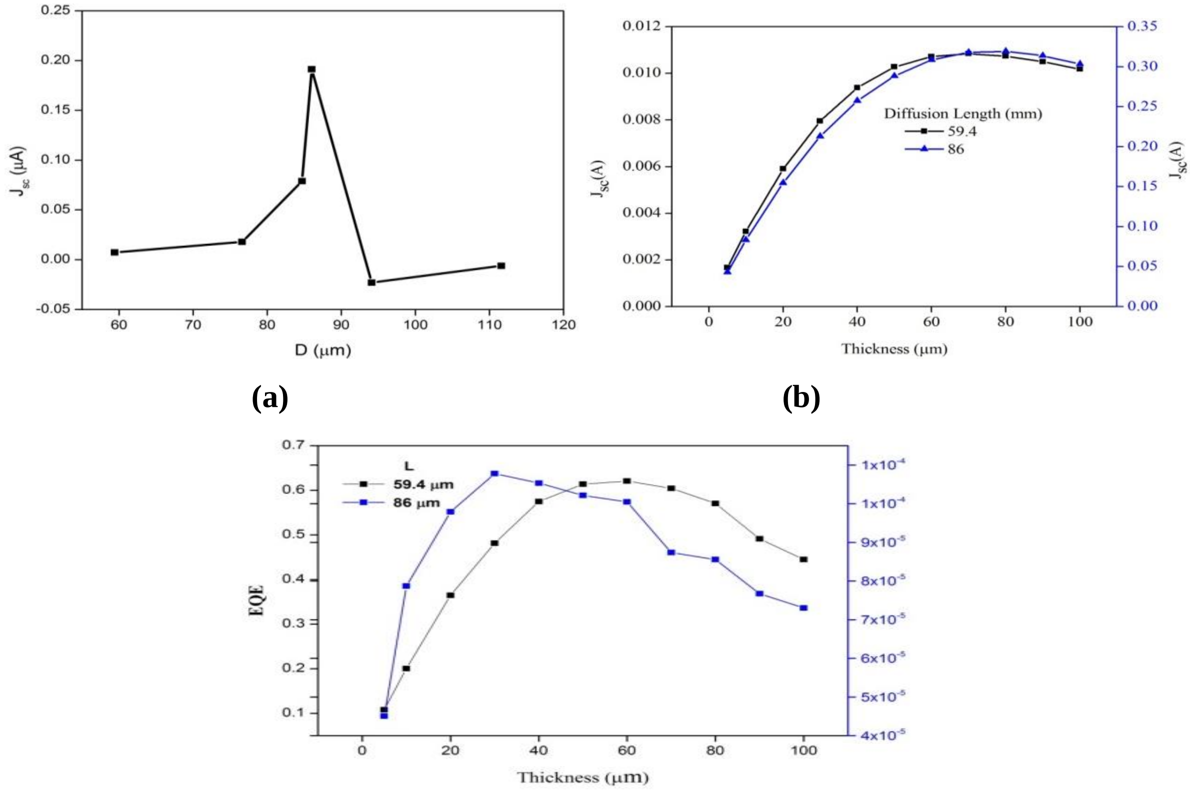
$$J_{sc} = \frac{q\varphi L\alpha}{1 - L^2\alpha^2}\left[-L\alpha + \tanh\left(\frac{d}{L}\right) + \frac{L\alpha \exp(-d\alpha)}{\cosh\left(\frac{d}{L}\right)}\right] \qquad (1)$$

q-1.602*10^{-19} coulombs,d -the electrode thickness

L-diffusion length of ZnO Photo electrode material is calculated by $L = \sqrt{D\tau}$, Φ- photon flux is calculated from $\Phi = \frac{p}{hf}$ where P=incident Power. The external quantum efficiency (EQE) is calculated from [7]

$$EQE = \frac{hc}{\lambda q} * \frac{J_{sc}}{P_{in}} \qquad (2)$$

where J_{sc} is the short circuit current ZnO based N719 DSSC



(a) **(b)**

(c)

Fig.1: (a) Diffusion length vs short circuit current 1(b) Thickness vs J_{sc} current 1(c) EQE vs thickness of ZnO dssc for two different diffusion lengths

The short circuit current is calculated for various diffusion length from 60μm to 100μm at 26.4 μm thickness. The variation of diffusion length with J_{sc} is shown in figure 1(a). Diffusion length and photo anode thickness is interdependent parameters[8,13]. The figure 1 (b) shows that J_{sc} value for the photo anode thickness varies from 5 to 100 μm at 59.4 μm and 86 μm diffusion length. The 86 diffusion length values obtain better short circuit current than 59.4 μm. It is found that the short-circuit current is 0.20 μA at 86 μm which is the highest value[8]. The figure 1 (c) shows that the theoretical calculated value of I external quantum effieicency (EQE) of two different diffusion length of ZnO based N719 DSSC. It explains high diffusion length is able to reduce the recombination rate hence increase the J_{sc} of DSSC[9]. It is found that the optimized photo anode thickness 40 to 60 μm for both diffusion lengths of ZnO based N719 DSSC.

3.EFFECT OF MGO ANTIREFLECTION COATING ON ZNO BASED N719 DSSC

The ARC is a crucial parameter to raise the light trapping in the solar cell. The dielectric materials used as a ARC[4]. In this work MgO dielectric coating used as a ARC on the upper surface of ZnO based N719 DSSC. The Reflectivity of ZnO based N719 DSSC with MgO ARC are calculated from the equation (3)[10].

$$R = \frac{(\eta_0 - \eta_m)^2 \cos^2 \delta_1 + \left[\left(\eta_0\eta_m / \eta_1\right) - \eta_1\right]^2 \sin^2 \delta_1}{(\eta_0 + \eta_m)^2 \cos^2 \delta_1 + \left[\left(\eta_0\eta_m / \eta_1\right) + \eta_1\right]^2 \sin^2 \delta_1} \qquad (3)$$

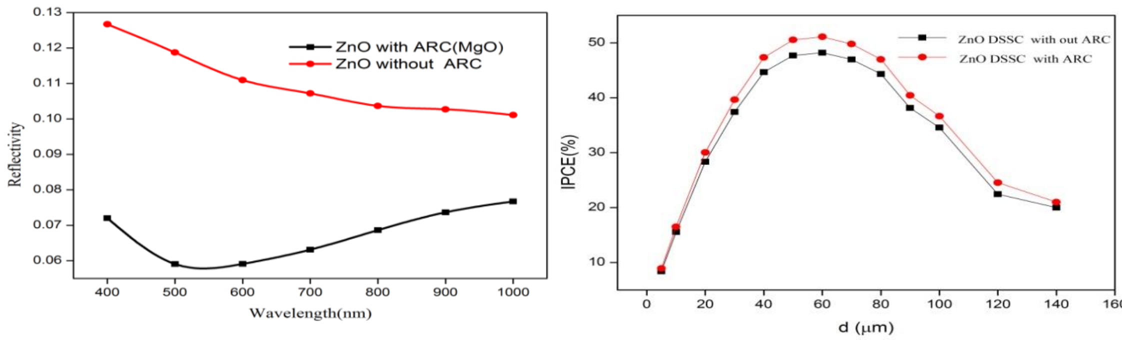
η_0, η_1, η_m is refractive index of air, ARC, substrate

The phase difference $\delta_1 = \frac{2\pi nd}{\lambda_0}\cos\theta$, where $\theta = 0$, d is the thickness of ARC λ_0 is the center wavelength

The Internal Photo Conversion Efficiency is calculated from[11].

$$IPCE = \frac{EQE}{1-R} \qquad (4)$$

Where R is reflectivity of Zno DSSC



(a) (b)

Fig.2: (A) Reflectivity Vs Wavelength 2(B) IPCE Vs Thickness Vs Of Zno Based N719 DSSC For Two Different Diffusion Lengths

The reflectivity variation of ZnO based N719 DSSC with and without MgO ARC are theoretically calculated from the equation (3) and plotted in figure 2(a) and (b).The reflectivity value varies from 0.13 to 0.06 at visible wavelength. it is found that the internal photo conversion efficiency (IPCE) varies from 45% to 50% using the MgO ARC on ZnO based N719 DSSC.

4. CONCLUSION

In this work the influence of internal parameters such as diffusion length and photo electrode thickness and the role of MgO ARC of ZnO based N719 DSSC are studied. It is found that the diffusion length and photo anode thickness are essential and interrelated parameters of DSSC. For efficient collection of electrons in a DSSC, the electron diffusion length needs to be at least 2-3 times larger than the thickness of the ZnO film. It concluded that diffusion length is 89.4 µm for the film having thickness in the range of 40-60 µm.At this range maximum photo generated charge carriers will be collected. As a result, the highest values of J_{SC} and efficiency are obtained for the thickness of ZnO layer of around 86µm of diffusion length with 40-60 µm of film thickness ZnO based N719 DSSC. It can be increased then by either improving the transport of charge carriers within device or by inhibiting electron hole recombination, and hence enhancing the charge life time as a result to it increase the short circuit current .The effect MgO Anti reflection Coating on DSSC is upgrade by the 5% (45% to 50%) IPCE of the DSSC at 550 nm wavelength. It is conclude that the MgO ARC is the effective single layer ARC reduce the reflection on ZnO based N719 DSSC.

6. ACKNOWLEDGEMENT

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7. CONFLICT OF INTEREST

Authors don't have any conflict of interest related to the manuscript.

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