A Study on Dye Sensitized Solar Cells Characteristics of Nb:ZnO Nanoparticles Film Electrode

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***Abstract*-We have investigated the effect of Nb:ZnO nanoparticle (Nb:ZNP) properties on the dye-sensitized solar cells (DSSCs) performance. ZnO Nanoparticles were used by sol gel method and was mixed Nb in 10 vol%. The Nb:ZNP film electrode was coated on FTO glass by spin coating method. The X-ray diffraction (XRD) and scanning electron microscope (SEM) of Nb:ZNP films electrode were confirmed successful for structural and morphological properties. The electrical properties of Nb:ZNP film electrode was found that the energy conversion efficiency of 8.98%, J_{SC} of 14.6 mA/cm^2, V_{OC} of 0.546 V and FF of 36.54% at solar simulator at 200 W/m^2. The short circuit current (I_{SC}) was 136.45 µA. The NZO can achieve photovoltaic conversion efficiency which was more than about 9.1% for ZNP films. The use of Nb:ZNP film working electrode is sufficient to be built and tested cathode electrode for DSSCs application.**

I. INTRODUCTION

Dye-sensitized solar cells (DSSCs) are admired to be economically due to its low cost materials and its simplicity. DSSCs were first discovered and considered immensely after B. O'Regan et al. [1] reported the efficiency of DSSCs in 1991. DSSCs have been one of the most widely research topics. Since DSSCs device's color can be alter by using a different type of dyes and substrates, and furthermore attractively for building integrated photovoltaics (BIPV). DSCs are a new technology of solar cells, and it is simple process of plants. DSCs are mainly composed of a working electrode, electrolyte solution, and a counter electrode [2, 3]. The working electrode use titanium dioxide (TiO_2) or zinc oxide (ZnO) film electrode and dye-sensitized use as N719, N353, K19, C101 and other [4-8].

ZnO is known to be one kind of the important photocatalysts due to there are advantages, such as low price, nontoxicity, and high photocatalytic activity [9]. A ZnO nanoparticle (ZNP) based solar cell is attractive material for DSSCs application due to its characteristic and the process that can be grown from low temperature and low cost solution [10, 11]. However, because of the low efficiencies in such a way those one-dimensional (1D) nanostructures have been less surface area to absorb dyes. Therefore, the ZNP films showed a semiconducting behavior with low efficiency [12]. These problems can be improved working electrode layer by adding niobium (Nb) in order to increase electric power conversion efficiency of DSSCs. So, we are interesting on working electrode using ZnO nanoparticle mixed niobium. Nb was identified that a n-type transition metal oxide semiconductor, has wide band gap between 3.2-4 eV which is higher conduction band edge than that TiO_2 material. So, Nb can be increased open circuit voltage (V_{OC}) and photo-conversion efficiency (η) [13].

In this paper, we present Nb-doped ZnO nano-particles (Nb:ZNP) thin film electrode for DSSC application. The ZnO nanoparticle and Nb (V) ehthoxide were mixed in rate 90:10 vol% and coated on FTO glass. The used NZO films electrode for DSSC can improve electric power conversion efficiency and open circuit voltage stability.

II. EXPERIMENTAL SETUP

A. Working Electrode and Counter Electrode

This work, we fabricated a DSSC with Nb doped ZnO nanopaticles (ZNO) film working electrode. The ZnO nanoparticles was prepared by sol gel method [13-16], zinc acetate dehydrate [$Zn(CH_3COO)_2{\cdot}2H_2O$], triethanolamine (TEA), distilled water, and ammonium hydroxide (NH_4OH).

The prepared TEA was dissolved in water in ratio 30:20 ml by stirring at 500 rpm for 1 h, and added ethanol 2 ml, stirred for 3 h. The zinc oxide was prepared by 0.5 M of $Zn(CH_3COO)_2{\cdot}2H_2O$ dissolved in water at 50 ml, and stirring at 500 rpm for 1 h. The TEA and ZnO solutions were mixed while drop wise NH_4OH of 10 ml with continuous, heating and stirring at 150 ˚C for 1 h. After that, the solutions were added 10 mL of distilled water during stirring for 1 h (or in the formation of a white solution). The fabricated solution was washed by DI water or EtOH and was filtered fi 5-10 times. The obtained ZNP powder was evaporated by vacuum at 100 °C, 12 h and was calcined at 450 °C for 2 h, as shown in fig 1.

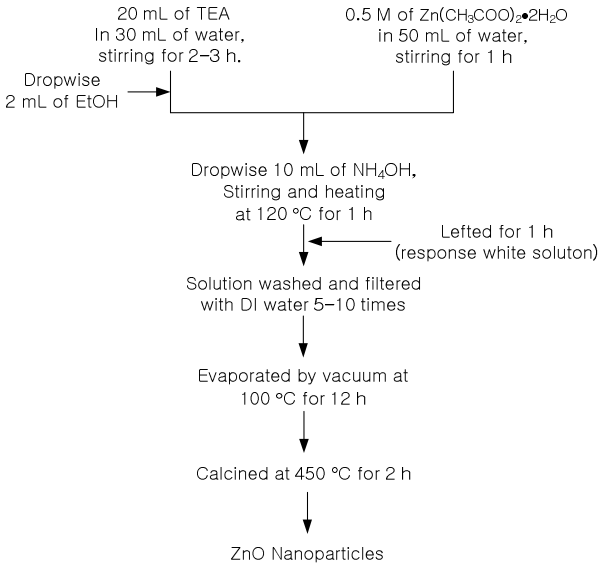


Fig. 1. Process of ZnO nanoparticles.

The fabricated ZNP power at 0.25 g was added EtOH at 100 ml and stirring for 2 h, drop wired with niobium (V) ehthoxide in 20 ml, added ethyl cellulose at 1.6 g and stirring and heating 40°C for 20 min, and added α-terpinol of 20 ml. The NZO solution was evaporated by vacuum at 40°C for 20 min. The use FTO glass at 2×3 cm^2 was cleaned by ultrasonic cleaner. The obtained Nb:ZNP paste was coated on FTO glass by spin coater at 1000 rpm 15 s, 1×1 cm^2 of size. And, the dye-sensitized N719 [di-tetrabutylammonium cis-bis (isothiocyanato) bis(2,2′ -bipyridyl-4,4′ -dicarbo xylato) ruthenium(II)] was immersed in 0.3 mM with 20 mL of ethanol for 24 h, and then washed with ethanol, can describes in detail a previous report [17-20]. The counter electrode was prepared by platinum (Pt) paste, coated by spin coater.

The prepared working electrode and counter electrode of DSCs were fabricated by overlap as sandwich between working electrode and counter electrode. The distance of both electrodes was ~30 µm. The both electrodes were sealed by spacer polymer film (Surlyn film, thickness 25 µm) and hot melted seal at 120 °C for 10 min. The prepared liquid electrolyte was injected between a working electrode and a counter electrode with hypodermic syringe and sealed be epoxy. The structure of DSSCs with Nb doped ZNP is shown in fig. 2.

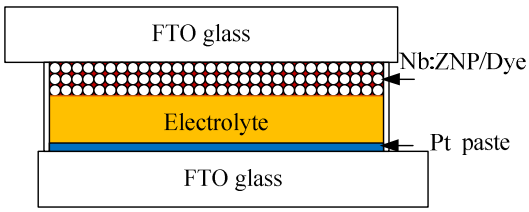
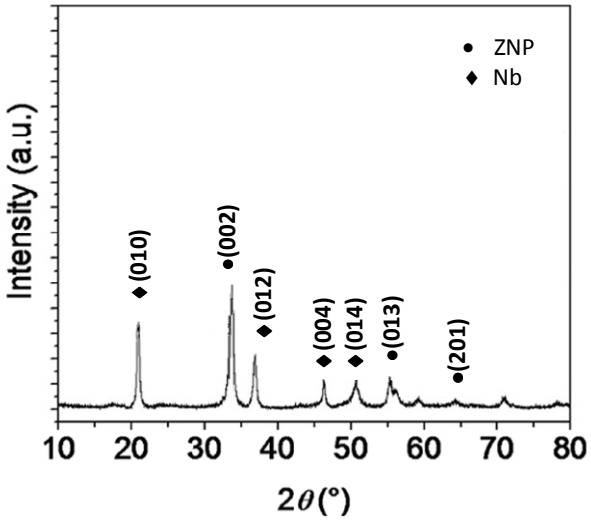


Fig. 2. Structure of DSC with Nb doped ZNP.

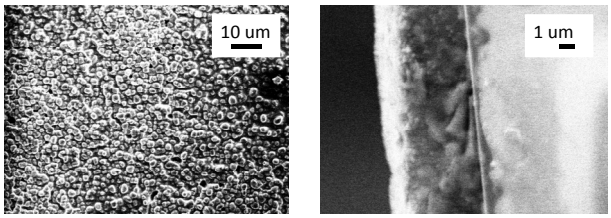
The crystallization properties of the Nb:ZNP film was investigated by X-ray diffraction (XRD), the morphological properties was measured scanning electron microscope (SEM). The conversion efficiency of fabricated DSCs with Nb:ZNP film electrode was investigated using I-V solar simulator with white light at 250 mW/cm^2 from a 300 W of solar simulator.

III. EXPERIMENTAL RESULTS

The crystalline of Nb:ZNP film was analyzed by XRD pattern is show fig. 3(a). The strong peak intensity of Nb:ZNP film was at 34.21° (2θ) corresponding to the ZNP (002) plan and 21.35° is observed corresponding to the Nb (010) plan, respectively. At (002) plane was found that the strong peak intensity of ZNP stronger than the Np material due to the volume of Nb less doped ZNP. Figure 3(b) shows top view (Left) and cross-sectional view (Right) SEM image of Nb:ZNP film coated on FTO. The top view SEM image had the very rough and rounded on the surface of produced film, and the cross view showed a thickness of the film, which was a condition at ~10 µm.



(a)



(b)

Fig. 3. (a) XRD pattern (b) SEM image of Nb:ZNP film.

The electrical properties of DSSCs with Nb:ZNP was compared by ZNP working electrode. Figure 5 shows I-V curves photovoltaic performances of DSSCs with Nb:ZNP and ZNP film elecrtode which was tested under a solar simulation AM 1.5 light illumination at 200

mW/cm^2. The open circuit voltage (V_{OC}), current density (J_{SC}), fill factor (FF) and efficiency (η) can summarize in table 2. The conversion efficiency of DSCs with Nb:ZNP and ZNP film electrode can calculated in equation (1),

$$\eta = \frac{V_{OC} I_{SC} FF}{P_{in}} \quad (1)$$

TABLE 2. SOLAR CELL PARAMETER CHARACTERISTIC OF DSCS USING NB:ZNP AND ZNP.

Sample	V_{OC} (V)	J_{SC} (mA/cm^2)	FF (%)	Efficiency (%)
Nb:ZNP	0.546	14.6	36.54	8.98
ZNP	0.421	11.1	19.11	8.16

The DSCs using Nb:ZNP was highest energy conversion efficiency of 8.98%, J_{SC} of 14.6 mA/cm^2, V_{OC} of 0.546 V and FF of 36.54% which more than that the ZNP was efficiency of 8.16%, J_{SC} of 11.1 mA/cm^2, V_{OC} of 0.421 V and FF of 19.11%. The both working electrodes show that the J_{SC} increased significant with change a working electrode. The short circuit current (I_{SC}) of Nb:ZNP film electrode was 136.45 μA. However, The conversion efficiency of Nb:ZNP film electrode was more than that the ZNP film electrode from purchase company due to the charge transfer resistance of ZNP film electrode was higher than that the Nb:ZNP film electrode, and the large difference between of the both working electrodes.

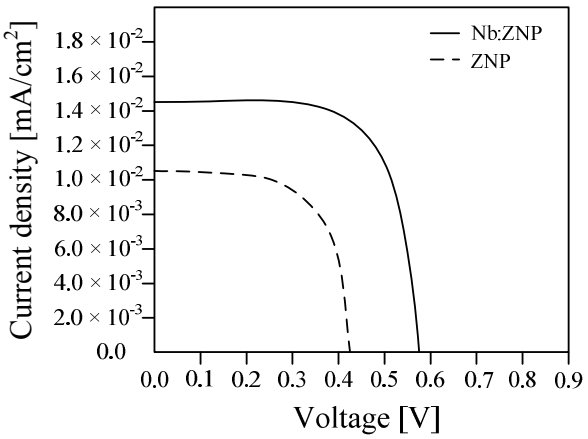


Fig. 5. I-V curve of the DSCs with MnO_2:CCE and CCE.

IV. CONCLUSIONS

In the study, an investigation using XRD and SEM of Nb:ZNP film was found that strong peak 34.21° and 21.34° (2θ) correspond to ZnO (002) and Nb (010) plan, respectively. The surface had the very rough and rounded on the surface of produced film, and showed a thickness of the film, which was a condition at ~10 μm. The electrical properties of Nb:ZNP film electrode was showed highest energy conversion efficiency of 8.98%, J_{SC} of 14.6 mA/cm^2, V_{OC} of 0.546 V and FF of 36.54% which efficiency was more than that ZNP film electrode about 9%. The used of Nb:ZNP films electrode for DSSC is significant to increase electric power conversion efficiency.

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