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ساخت سلول خورشیدی حساس شده با رنگدانه با استفاده از نانوکامپوزیت TiOv/ZnO به منظور افزایش بازده

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چکیده - در این مقاله کامپوزیتی از نانوذرات TiOv/ZnO به عنوان مواد مورد استفاده در فوتوآند برای ساخت سلولهای خور شیدی حساس شده با رنگدانه سنتز و به وسیلهٔ آنالیزهای پراش پرتو ایکس (XRD) و طیف سنج مادون قرمز (FT-IR) ارزیابی شده و سپس نانوپودر سنتز شده با استفاده از محلول ساخته شده به خمیر تبدیل گردید. طبق بررسیهای پیشین، استفاده از فوتوآندهای ساخته شده از کامپوزیت این دو ماده نیمه ر سانا در مقایسه با استفاده از یکی از آنها، عملکرد فوتوولتائی بهتری را فراهم می کند. عملکرد سلول ساخته شده با استفاده از دستگاه شبیه ساز نور خور شید (۱۰۰ mW/cm) ارزیابی شده و بازده تبدیل نور به انرژی الکتریکی معادل ۱/۰۴٪ بد ستآمد. همچنین دیگر م شخ صههای فوتوولتائی شامل جریان مدار کوتاه، ولتاژ مدار باز و فاکتور پر شدن نیز به تریب ۱/۰۴۴۷ بدست آمدند.

كليد واژه - سلولهاي خورشيدي حساس شده با رنگدانه، فتوآند، فوتوولتائي، نانو كاميوزيت TiOv/ZnO

Fabrication of dye-sensitized solar cell using TiO₁/ZnO nanocomposite for efficiency enhancement

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1. Introduction

In the recent past, solar energy have attracted significant attention due to being sustainable and clean without carbon emotion. In 1991, O'Regan and Grätzel introduced first dye-sensitize solar cells (DSSCs) based on TiO₇ [1]. A typical DSSC consist of a semiconductor film coated on a fluorine-doped tin oxide (FTO) glass substrate to form photoanode, a platinum-coated FTO to form counter electrode, a liquid redox electrolyte and a solution contains dye molecules. Dye solution acts as a light absorber and injects electrons into the conduction band of a semiconductor. Injected electrons then diffuse through the semiconductor film, afterwards to the conductive glass substrate. The oxidized dye molecules regenerate by the redox system then these oxidized redox, regenerate by diffusing to the counter electrode where electrons receive from photoanode [7].

Semiconductor photoanode is the backbone of DSSCs and plays a vital role in the performance of DSSCs. TiO₇ is the most-used and well-known semiconductor material because of its advantages such as stability, non-toxicity, high surface area, low cost and high charge transfer capability $[7, \xi]$. Besides TiO₇, semiconductors such as ZnO, SnO₇, Fe_YO_Y, Nb_YO₂, ZrO_Y, Al_YO_Y and etc. have been studied. Among all semiconductor materials, ZnO showed better properties; however, its conversion efficiency is much lower than TiO_Y. In despite of TiO₇, ZnO possess higher electron mobility but on the other hand it has lower stability [°]. Subsequently, to use all benefits of these two materials, fabrication of TiO_Y/ZnO based DSSCs showed better performance compared with using one of them $[7-\Lambda]$.

In this study, to fabricate composite based DSSC, first TiO_x/ZnO composite paste was prepared as semiconductor film and then, the photovoltaic performance was evaluated.

Y. Experimental

Y,1. Materials and chemicals

Titanium oxide nanopowders (TiO_Y-anatase, $^{Y} \cdot - ^{\circ} \cdot ^{\circ}$ nm), zinc acetate dehydrate (Zn(CH_TCOO)_Y, Y H_YO, $^{Y} \cdot ^{\circ}$ DD), DDDDDDD DDDDD (D_YD_Y), DDDDDDD (DD) isopropoxide (Ti[OCH(CH_Y)_Y]_E), citric acid (C_YH_XO_Y). Acetonitrile (C_YH_YN), potassium iodide (KIO_Y) and iodine (I_Y) for preparing electrolyte solution. Ruthenium based dye (N^Y), platinum (Pt), FTO conductive glass (sheet resistance Y Y DD).

Y,Y. Preparation of TiO_Y/ZnO paste

Ethylene glycol was heated at $\ ^{\uparrow} \cdot \ ^{\circ} C$ then titanium (IV) isopropoxide was added and slowly stirred. Then, citric acid was added and the solution was stirred at a constant temperature of $\ ^{\uparrow} \cdot \ ^{\circ} C$ to get clear viscose solution. Zinc acetate dehydrate and TiO_{γ} nanoparticles powder at the optimum weight ratio (ZnO/TiO_{γ} = $\ ^{\gamma} (\ ^{\uparrow})$ [$\ ^{\uparrow}$, $\ ^{\uparrow}$] along with prepared solution were ground well to the mortar to obtain a viscous paste [$\ ^{\uparrow} \cdot$].

7,7. Preparation of electrolyte

For preparation of electrolyte solution, first, ' ml acetonitrile was added to ', o ml ethylene glycol under stirring. Subsequently, ', o g potassium iodide and ', o g iodine was added respectively. Prepared electrolyte was stirred until homogenous solution appeared ['1'].

Y.F. Fabrication of DSSC

For cleaning FTO glass substrate, it was sonicated with deionized water, hydrochloric acid, acetone and ethanol respectively and dried at ^V °C. To prepare the photoanode, TiO_V/ZnO paste was deposited onto a conductive glass substrate using doctor blade method. This electrode first pre-heated

at 'Y' °C, then calcined at £0.°C. For dye loading, the photoanode was immersed in '," mM dye solution (NY') in darkness for Y£ hrs. Counter electrode was obtained by depositing a thin layer of platinum on another conductive glass substrate. Finally, two electrodes were bonded together using surlyn sheet and then electrolyte solution was injected through a small hole on the counter electrode to fill the space between the two electrodes. The active area of fabricated cell is ',o cm*+,o cm. The photograph of the fabricated DSSC in laboratory scale is shown in Fig. '.

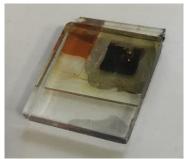


Fig. 1: The fabricated DSSC

T. Results and Discussion

The FT-IR spectroscopy was measured and given in Fig. 7, which obviously revealed the formation of ZnO in TiO₇ nanoparticles. The broad IR transmittance peak is in the "...-" cm⁻¹ range which indicated high amount of alcohol based component in prepared nanocomposite. In this curve, peaks at £11,9\lambda cm⁻¹ and \\\\,\\\\\ cm⁻¹ are for O-Ti-O bonding in anatase morphology and ZnO. Similarly, Fig. 7 shows the XRD pattern of TiO_Y/ZnO powder to examine the phase and crystallinity of the as-prepared nanocomposite. Sharp peaks indicate high crystallinity of TiO₇ and ZnO in the nanocomposite. The XRD peaks in the ۶۲,۸۵, ۶۸,۹۵, ۵۵۵ ۷۵,۲۵, ۵۵۵۵۵ ۵۵۵ attributed ۵۵ ۵۵۵ $(1 \cdot 1), (\cdot \cdot \xi), (7 \cdot \cdot), (1 \cdot \circ), (711), (7 \cdot \xi), (117), and (710)$ crystalline structures of anatase. As well, several slight diffraction peaks at $^{\gamma}\theta$ value of $^{\gamma\gamma,\gamma\circ}(^{\gamma,\gamma\circ})$, **™+**,**+**□ (···), **™5**,**™**□ (1·1), □□□ **V**·,·□ (**1·1**) □□□ □□□□

observed which was known as hexagonal ZnO nanoparticles.

These XRD results further confirmed the successful preparation of the nanocomposites consisting of both TiO₇ and ZnO phases. The sharpness, as well as line widths of the peaks, were certified that the ZnO has a nanocrystalline structure.

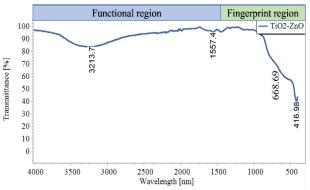


Fig. ^۲: FTIR spectra of the TiO₇/ZnO nanocomposite

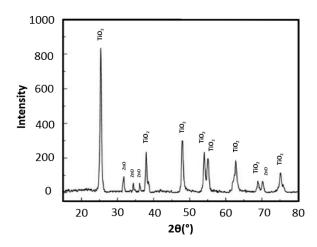


Fig. ": XRD pattern of the TiO_Y/ZnO nanocomposite

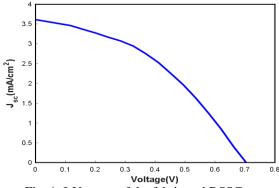


Fig. 5: I-V curve of the fabricated DSSC

F. Conclusion

DSSC based on TiO_Y-ZnO nanocomposite have been successfully fabricated using optimum amount of ZnO in prepared nanocomposite. The produced nanoparticles were used as a part of photoanode in the DSSC and the paste were prepared with simple method to use in the photoanode of the DSSC. Fabrication of electrolyte was also done at the laboratory. The fabricated nanocomposite was characterized using XRD, and FTIR techniques. The crystallography of the pastes, using X-ray experiment, illustrated the existence of both TiO₇ and ZnO in high crystalline structure. Presence of ZnO contents on TiO₇ surface enhance the rapid transport of free electrons. Consequently, the solar cell performance improved due to J_{sc} improvement. From the results of I-V curve characterization, with a short-circuit current of ξ , $\Lambda \xi$ mA/cm⁷, open-circuit voltage of ., V. to V and fill factor of ., T. tv represented photoelectric conversion efficiency of ١,٠٤٪. The gained results were attributed to the nanocrystalline TiO₇ and ZnO nanocomposite structure, which considerably enhanced the light absorption by multi-scattering effects, and dye adsorption due to smaller crystal size, more grain boundaries, and a bigger surface area.

References

[1] B. O'regan and M. Grätzel, "A low-cost, high-efficiency solar cell based on dyesensitized colloidal TiO Y films," *nature*, vol. Tot, no. Trit, pp. YTY-Yio, 1991.

- [Y] J. Gong, J. Liang, and K. Sumathy, "Review on dye-sensitized solar cells (DSSCs): Fundamental concepts and novel materials," *Renewable and Sustainable Energy Reviews*, vol. 17, no. Λ, pp. ολέλολι, Υ. 1 Υ/ 1 / 1 / 1 Υ. 1 Υ.
- [٣] S. S. Kanmani and K. Ramachandran, "Synthesis and characterization of TiO_T/ZnO core/shell nanomaterials for solar cell applications," *Renewable Energy*, vol. ٤٣, pp. ١٤٩-١٥٦, ٢٠١٢/٠٧/٠١/ ٢٠١٢.
- [٤] S. Umale, V. Sudhakar, S. M. Sontakke, K. Krishnamoorthy, and A. B. Pandit, "Improved efficiency of DSSC using combustion synthesized TiO_Y," *Materials Research Bulletin*, vol. 1.9, pp. ٢٢٢-٢٢٦, ٢.١٩/٠١/٠١/٢٠١٩.
- [o] Q. Zhang and C. J. N. Li, "TiO_Y coated ZnO nanorods by mist chemical vapor deposition for application as photoanodes for dye-sensitized solar cells," vol. 9, no. 9, p. 17٣9, Y 19.
- [7] W. Ahmad et al., "Synthesis of zinc oxide/titanium dioxide (ZnO/TiO_Y) nanocomposites by wet incipient wetness impregnation method and preparation of ZnO/TiOY paste using poly (vinylpyrrolidone) efficient dyefor sensitized solar cells," vol. YYY, pp. EVT-٤٨٠. ٢٠١٦.
- [V] M. Yang et al., "TiO_Y nanoparticle/nanofiber—ZnO photoanode for the enhancement of the efficiency of dye-sensitized solar cells," vol. V, no. ٦٦, pp. ٤١٧٣٨-٤١٧٤٤, ٢٠١٧.
- [A] A. M. Rheima, D. H. Hussain, and H. J. Abed, "Fabrication of a new photo-sensitized solar cell using TiO_Y\ZnO Nanocomposite synthesized via a modified sol-gel Technique," in *IOP Conference Series:* Materials Science and Engineering, Y·Y·, vol. 9YA, no. 0, p. ·OY·YT: IOP Publishing.
- [9] Y.-H. Nien *et al.*, "Investigation of Dye-Sensitized Solar Cell With Photoanode Modified by TiO₂-ZnO Nanofibers," vol. "", no. Y, pp. Y90-" · 1, Y · Y · .
- [1.] S. K. Park, T. K. Yun, J. Y. J. J. o. n. Bae, and nanotechnology, "Combined Embedding of N/F-Doping and CaCO_T Surface

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Shahid Chamran University of Ahvaz, Khuzestan, Iran, Feb. Y-T, Y·YY.

- Modification in the TiO $_{\Upsilon}$ Photoanode for Dye-Sensitized Solar Cells," vol. 17, no. Υ , pp. Y \circ V \circ -Y \circ V \circ , Y \circ V \circ .
- P. Gu *et al.*, "Influence of electrolyte proportion on the performance of dyesensitized solar cells," vol. V, no. 1., p. 1.0719, 7.1V.