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Synthesis of Spherical Nano ZnO Particles by Modified Precipitation Method for Dye-Sensitized Solar Cell Applications

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Abstract: The present work reports the synthesis of spherical agglomerated nano ZnO by a modified precipitation method using zinc nitrate and NaOH in aqueous solution for dye-sensitized solar cell applications. The precipitated compound was calcined and characterized by XRD and scanning electron microscopy (SEM). The XRD studies showed that the ZnO nanoparticles exhibit good crystallinity. The SEM results showed that the nano particles size varies from 90 – 130 nm and they are agglomerated. The UV – visible absorption studies of the synthesized sample showed absorption at 361 nm. The synthesized ZnO nanoparticle based solar cell was fabricated and its power conversion efficiency was found to be 0.90 %.

Keywords: ZnO nanoparticle, dye sensitized solar cell, precipitation, scanning electron microscopy (SEM)

I. Introduction

ZnO being a direct wide bandgap (3.3 eV) semiconductor play an important role in interdisciplinary material science, especially in the fabrication of electronic devices. The nano structured ZnO has attracted considerable attention for its potential applications in many technologies including solar cells, electroluminescent devices, electro chromic windows and chemical sensors. [1 – 6]. ZnO with high surface area, good electrical, electrochemical and structural properties are required for the high performance of these devices. The ZnO nano particles are synthesized by sol–gel, precipitation and hydrothermal methods [7 – 8]. The present work reports synthesis of spherical agglomerated nano ZnO particles by a modified precipitation method using zinc nitrate and NaOH in aqueous solution and its use in dye-sensitized solar cells.

II. Materials and methods

A. Materials

Zinc nitrate (Sigma-Aldrich 99 % pure) was used as the precursor and NaOH (Sigma-Aldrich 99 % pure) was used as a precipitating agent to synthesize ZnO nanoparticles. Double distilled water was used to wash out the precipitates.

B. Modified Precipitation Method

ZnO nanoparticles were synthesized by modified precipitation method using zinc nitrate and NaOH as precursors. In the present work, the aqueous solution (0.2 M) of zinc nitrate ($Zn(NO_3)_2.6H_2O$) and the solution (0.4 M) of NaOH were prepared with double distilled water, respectively. The NaOH solution was slowly added into zinc nitrate solution using burette at room temperature under vigorous stirring, which resulted in the formation of a white suspension. The white product was centrifuged at 6000 rpm for 25 min and washed three times with double distilled water and washed with supreme alcohol at last. The precipitate was then dispersed in 12 ml of methanol and 3 ml

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of chloroform. The dispersed solution was transparent and stable for up to 3 weeks.

C. Zinc Oxide Dye-sensitized Cell

Schematic of the assembled cell is shown in fig 1. The developed ZnO electrode was made to soak in a 1:1 volume mixture of acetonitrile and tert-butanol with ruthenium dye for 2 h at 70° C. The surplus unanchored dye was then rinsed off using absolute ethanol and then air-dried. Platinum sputtered indium tin oxide (ITO) glass was used as the counter electrode. 0.1 M of lithium iodide, 0.03 M of iodine, 0.5 M of 4-tert-butylpyridine and 0.6 M of 1-propyl-2, 3-dimethyl imidazolium iodide dissolved in acetonitrile was used as redox electrolyte solution. The electrolyte solution was injected into the cell and sealed with glass using epoxy.

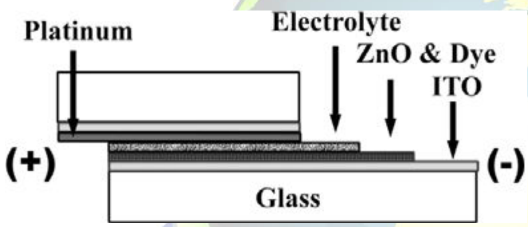

Fig. 1. Schematic diagram of an assembled ZnO dye-sensitized cell

D. Characterization

X-ray diffraction (XRD) patterns were recorded using a Bruker D8 Advance diffractometer equipped with Ni filter and operated at 40 kV, 30 mA (Cu Kα_1 radiation). Scanning electron microscopic images were recorded with SEM, JSM-35CF. Photocurrent characteristics of the photovoltaic cell were measured under irradiation of a 100 mW cm^{-2} xenon lamp. The UV visible spectrum of the sample was obtained using a Shimatzo's UV visible spectrophotometer-1800.

III. Results and Discuission

A. XRD and SEM Analysis

A typical XRD pattern of the synthesized nano ZnO is shown in figure 2. This pattern confirms the formation of ZnO in wurtzite structure. The narroe and sharp peaks confirms good crystallinity of the ZnO powder.The formation of wurtzite structure is attributed to the processing conditions of the modified precipitation method.The morphology of the synthesized nano ZnO is shown in figure 3. The image clearly depicts the formation of loose aggregates with spherical particles size ranging from 92–131 nm. The occurrence of loose aggregates with fine spherical particles is the inherent nature of this synthesis method, which could be seen in other nano particles as well.

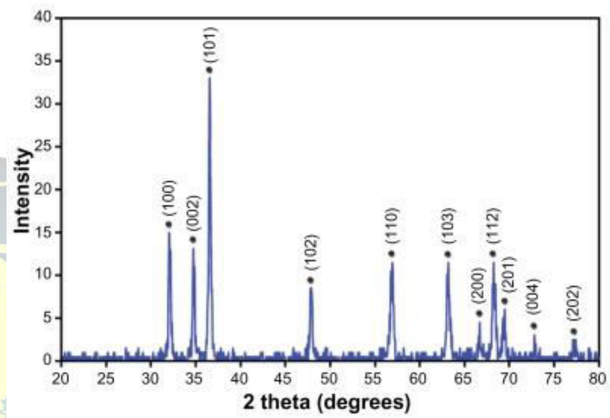

Fig. 2. A typical XRD pattern of the synthesized nano ZnO

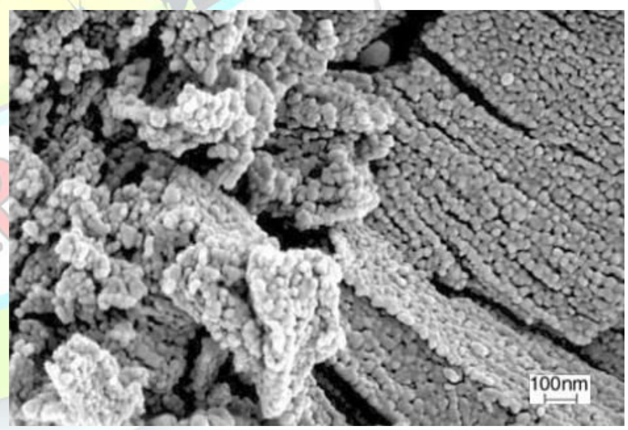

Fig. 3. SEM image of synthesized nano ZnO

B. UV – Visible Analysis

The UV visible spectrum of the synthesized ZnO nanoparticle is shown in figure 4. It is found that the sample absorbs the radiations in the UV range up to 361nm and almost all the visible spectrum radiations are transmitted by the ZnO nanoparticles. From the absorption characteristics the band gap of the ZnO nanoparticles was calculated to be 3.3eV. The obtained spectra of the nano particles exhibit a

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red shift. This is attributed to the narrowing of the energy bandgap as particle size is increased relatively.

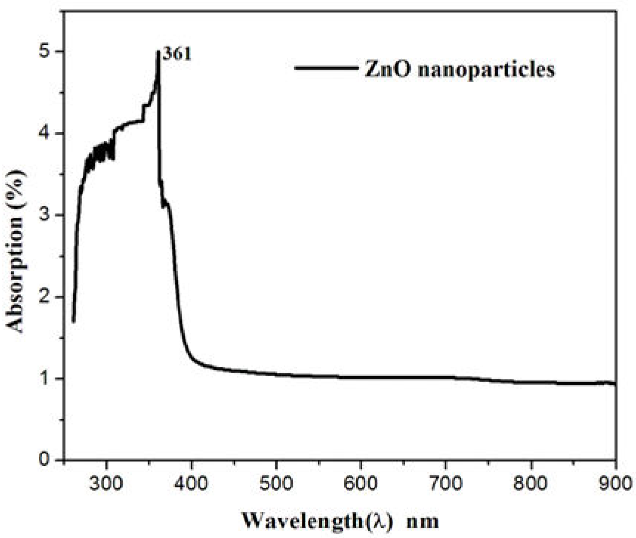

Fig. 4. UV visible spectrum of the synthesized ZnO nanoparticle

C. ZnO Based Solar Cell

The effect of the spherical ZnO nanoparticle on the photovoltaic performance of a dye-sensitized solar device is investigated. Under the irradiation of a 100 mW cm^{-2} xenon lamp, the obtained I –V characteristics of the nanoparticle based dye-sensitized solar cells are shown in figure 5. The average short circuit current density (I_{sc}) and the open circuit voltage (V_{oc}) of ZnO nanoparticle-based solar cells are 2.28 mA cm^{-2} and 0.7 V, respectively. The nanoparticle -based solar cell exhibits average cell efficiency (η) of 0.90% [9]. The result clearly shows an effective increase in the conversion efficiency of the cell which is attributed to the increased surface area of the nanoparticle. This is evident from the dye absorption characteristics of the spherical nano ZnO particles shown in the figure 6. The plot shows higher absorption of the dye due to the spherical morphology of the particle. At the present stage, efficiency of the solar cell (η) is not optimized with respect to the parameters like thickness of the film, loading of dye (sensitizing time, sintering temperature and time), architecture of the cell, etc. Our future work will include the optimization of the stated parameters towards the enhancement of the efficiency of the solar cell (η).

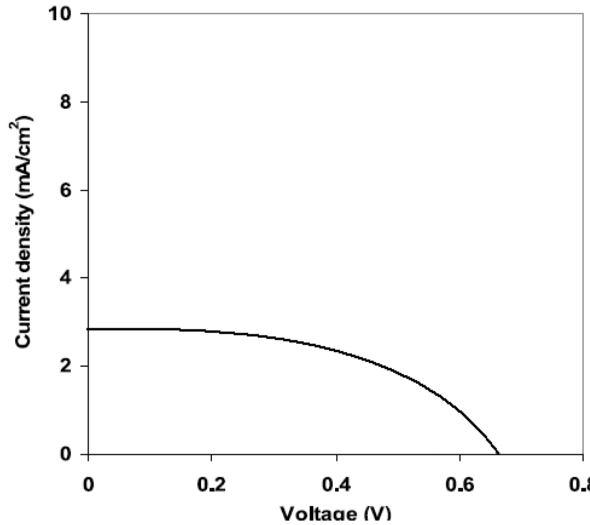

Fig. 5. I –V characteristics of the nanoparticle based dye-sensitized solar cell

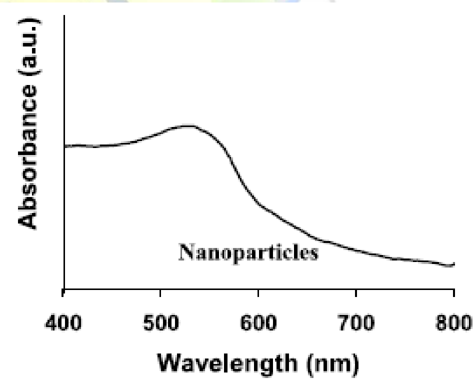

Fig. 6. Dye absorption characteristics of the spherical nano ZnO particles

IV. Conclusion

The modified precipitation method could be successfully used to synthesis loose aggregates with fine spherical particles size ranging from 92–131 nm. The The formation of wurtzite structure and loose aggregates with fine spherical particles are attributed to the inherent nature this synthesis method. The nano ZnO particles synthesized by this method showed red shift in their absorption characteristics with a peak at 361 nm. The high surface area and high dye absorption characteristics of the nano ZnO particles made the ZnO nanoparticle based solar cell with power conversion efficiency of 0.90 %.

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