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Dye-sensitized solar cell characteristics of nanocomposite zinc ferrite working electrode: Effect of composite precursors and titania as a blocking layer on photovoltaic performance

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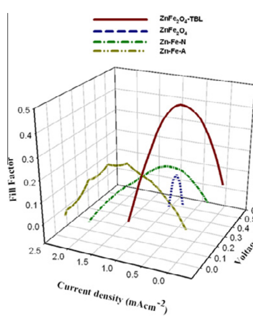
HIGHLIGHTS

- Nanocomposites of zinc ferrite have been prepared by different precursors.
- Nanocomposites of zinc ferrite working electrode have been fabricated.
- Dye-sensitized solar cell characteristics of composites have been examined.
- Zinc ferrite was used as working electrodes in dye sensitized solar cells.

GRAPHICAL ABSTRACT



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ABSTRACT

This research investigates the performance of a zinc ferrite (ZF) as working electrodes in a dye-sensitized solar cell (DSSC). This ZF working electrode was prepared by sol–gel and thermal decomposition of four different precursors including: zinc acetate dihydrate ($Zn(CH_3COO)_2 \cdot 2H_2O$), ferric nitrate nonahydrate ($Fe(NO_3)_3 \cdot 9H_2O$), iron(III) acetate; $Fe(C_2H_3O_2)_3$, and zinc nitrate hexahydrate, $Zn(NO_3)_2 \cdot 6H_2O$. The effects of annealing temperature and precursors on the structural, morphological, and optical properties were investigated. The field emission scanning electron microscope images (FESEM) and scanning electron microscopy (SEM) show that ZFe films are polycrystalline in nature and homogeneous with densely packed grains. Nanoporous zinc ferrite coatings were prepared by doctor blade technique on the fluorine-doped tin oxide (FTO) and used as working electrodes in DSSC. In all DSSCs, platinized FTO and $[Co(bpy)_3]^{2+/3+}$ in 3-methoxy proponitrile were used as counter electrode and redox mediator system respectively. Comparing the fill factors of four different zinc ferrite nanocomposites, the highest fill factor was for $ZnFe_2O_4$–TBL sample. Cell fabricated with ZnFeA working electrode shows relatively higher J_{sc}.

Introduction

DSSCs have proposed as a low-cost, easy and an alternative to conventional solar cell technology [1]. DSSCs consist of a porous nanocrystalline film of wide band gap semiconducting oxide working electrode immobilized onto a conducting material, adsorbed dye, an electrolyte and a counter electrode. In these DSSCs, the sensitizer as the light harvesting component is of vital importance to photovoltaic performance. Several inorganic, organic and hybrid compounds have been investigated as sensitizers [2–16]. DSSCs are attractive because their production cost in large scale fabrication would be expected to be a fraction of that of the silicon solar cell [17]. DSSCs are consider to have the advantages of high efficiency and cost effectiveness compared with the silicon solar cells. Increasing the conversion efficiencies have been limited due to recombination between electrons and either the oxidized dye molecules or electron-accepting species in the electrolyte during the

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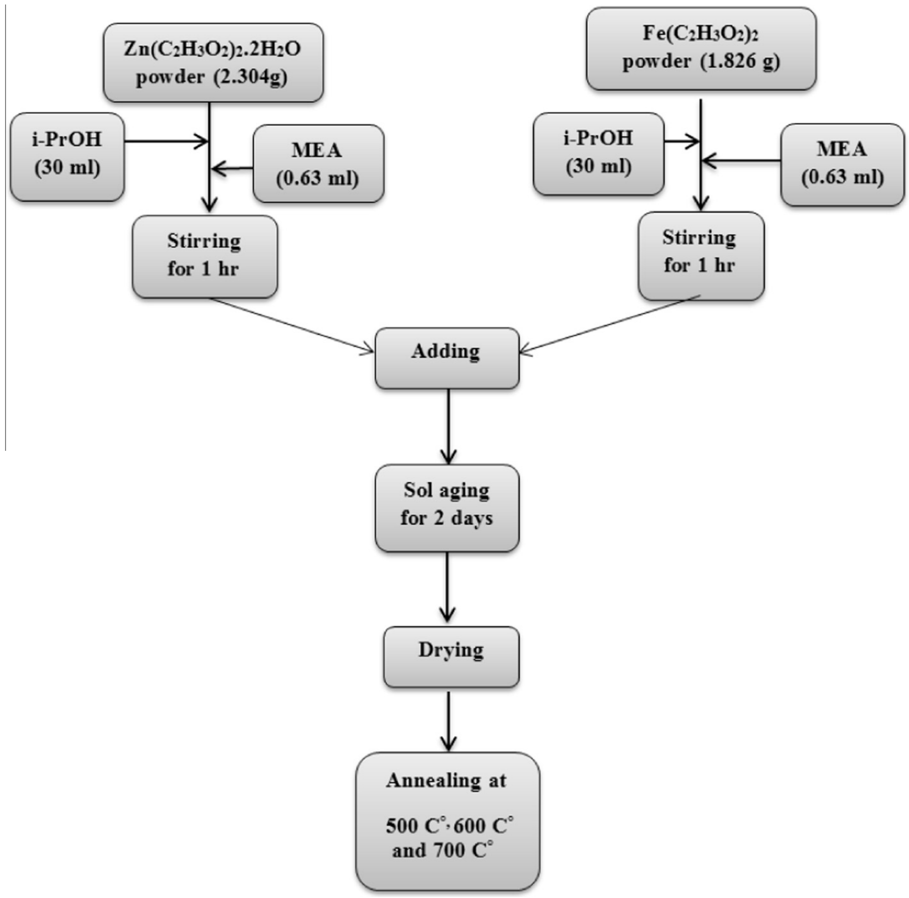

Fig. 1. Flow chart for preparation of zinc ferrite nanoparticle prepared by sol–gel method using $Fe(C_2H_3O_2)_3/Zn(C_2H_3O_2)_2 \cdot 2H_2O$ precursor of used for working electrode in DSSC.

charge transport process [18–21]. Zinc oxide is a well-known alternative to titanium dioxide which allows to be produced in a wide variety of nanostructures [22–29]. However, the low electron injection efficiency of zinc oxide resulted in a low conversion efficiency of DSSC based on a pure zinc oxide. To overcome this problem, DSSC fabricated by composite materials have concerned new interest due to the advantages of composite materials with high electron transport rate [30,31]. Recently, Zhang et al. have studied the application of nanostructured ZnO in DSSC [21]. Structural, optical, photoluminescence and refractive index dispersion properties of nanostructure ZnO have been studied [32,33]. Zinc ferrite ($ZnFe_2O_4$) was synthesized via a sol–gel method [21]. Previously the synthesis of zinc oxide composites, the photo-activity of $ZnTiO_3$ and $ZnZrO_3$ were reported by our research group [34–42]. We are interested to study the photocatalytic activity of $ZnFe_2O_4$ nanocomposite.

In this research we have prepared $ZnFe_2O_4$ nanocomposites by a simple sol–gel method. Structural, morphological, and optical properties of nanocomposites were characterized by diffuse reflectance spectroscopy (DRS), field emission scanning electron microscopy (FE–SEM) and X-ray diffraction (XRD). The effects of the zinc ferrite precursors on the power conversion efficiency of a DSSC were also examined.

Materials and methods

Materials

Zinc acetate dihydrate ($Zn(CH_3COO)_2 \cdot 2H_2O$), ferric nitrate nonahydrate ($Fe(NO_3)_3 \cdot 9H_2O$), iron(III) acetate; $Fe(C_2H_3O_2)_3$, zinc nitrate hexahydrate, $Zn(NO_3)_2 \cdot 6H_2O$, isopropanol (IP) and monoethanolamine (MEA) analytical grade were used as zinc and iron precursors, respectively.

Preparation of zinc ferrite ($ZnFe_2O_4$) nanocomposite using acetate precursors (ZnFeA)

Zinc acetate dihydrate ($Zn(CH_3COO)_2 \cdot 2H_2O$), 2.3 g as zinc precursor was dissolved in the mixture of isopropyl alcohol (IP), 30 mL and monoethanolamine (MEA), 0.63 mL with vigorous stirring to obtain a uniform sol. This sol was added to a mixture of iron(III) acetate; $Fe(C_2H_3O_2)_3$, in 30 mL isopropyl alcohol, and 0.63 mL monoethanolamine. This sol was aged for 2 days at ambient temperature in a closed vessel. The composite sol dried at 110 °C. The solid product was thermally treated in air at 700 °C for 2 h. The nanocomposite was labeled as ZnFeA in which Zn–Fe denotes the zinc ferrite and A denotes zinc and iron acetate precursors (Fig. 1).

Preparation of zinc ferrite ($ZnFe_2O_4$) nanocomposite using zinc acetate and iron nitrate precursors (ZnFeN)

Zinc acetate dihydrate ($Zn(CH_3COO)_2 \cdot 2H_2O$), 0.22 g as zinc precursor was dissolved in the mixture of isopropyl alcohol, 15 mL and monoethanolamine, 0.86 mL with vigorous stirring to obtain a uniform sol. Ferric nitrate nonahydrate ($Fe(NO_3)_3 \cdot 9H_2O$), 0.40 g as iron precursor was added to the above sol with vigorous stirring. This sol was aged for 1 day at room temperature. The composite sol dried at 120 °C and thermally treated in air at 700 °C for 2 h. The