Chemical Engineering Journal 213 (2012) 70–77

Contents lists available at SciVerse ScienceDirect

Chemical Engineering Journal

journal homepage: www.elsevier.com/locate/cej

Functional properties of amine-passivated ZnO nanostructures and dye-sensitized solar cell characteristics

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HIGHLIGHTS

- Shape controlled and monodispersed synthesis of ZnO nanosheets.
- HMTA act as an efficient surface passivating agent to limit the particle size.
- Functional properties of ZnO nanostructures have been enhanced by amine molecules.
- ZnO based DSSC exhibits the efficiency of 3.21% using N719 sensitizer.

ARTICLE INFO

Article history:
Received 4 June 2012
Received in revised form 24 September 2012
Accepted 2 October 2012
Available online 12 October 2012

Keywords:
ZnO nanostructures
Wet chemical synthesis
Surface passivation
Optical properties
Dye-sensitized solar cells

ABSTRACT

Monodispersed ZnO nanosheets have been synthesized by a facile wet chemical approach using hexamethylenetetramine (HMTA) as an organic ligand. The synthesized samples were characterized by X-ray diffraction, field emission scanning and transmission electron microscopy, UV–visible absorption, photoluminescence spectrophotometry and X-ray photoelectron spectroscopy surface analysis. The role of HMTA concentration on the formation and functional properties of ZnO nanostructure were investigated. Particle agglomeration was restricted and the nanosheet size was limited to 20 nm by passivation of the amine molecule. The 0.05 M HMTA-capped ZnO nanosheets yield a high near band edge luminescence intensity. Dye sensitized solar cells were fabricated using synthesized ZnO nanostructures and a maximum efficiency of 3.21% was achieved.

1. Introduction

ZnO nanostructures have been investigated extensively owing to their excellent optical and electrical properties [1–3]. ZnO is an important II-VI semiconductor since it has a direct band gap of 3.37 eV and high exciton binding energy of 60 meV. ZnO nanostructure applications have been realized in several fields such as solar cells, transparent electrodes, light emitting diodes, and sensors [4–9]. Recently, several reports have shown that nanostructured ZnO is a potential material for the preparation of a photoanode in the development of dye-sensitized solar cells (DSSCs) [10–15]. Several methods exist for the preparation of ZnO nanostructures such as vapor phase transport [16], thermal evaporation [17], electrodeposition [18], hydrothermal growth [19], microwave irradiation [20] and the wet chemical route [21]. Among the methods, the wet chemical route is simple and inexpensive and can be extended to large-scale production. In addition to that, monodispersed synthesis of nanostructures is very important for potential applications [22–25]. To investigate the functional properties and fabricate high efficiency DSSC devices, highly monodispersed nanostructures are required. Since the high reaction rate in solution route results in irregular morphology and Ostwald ripening leads to the formation of crystals of various sizes, the reaction system has to be controlled using additives such as organic ligands and surfactants. Several reports exist on the synthesis of ZnO nanostructures by the chemical route using organic ligands such as thiols and amines [26–29]. However, thiol molecules possess a sulfur group which yields a ZnO–ZnS core–shell structure. Amine molecules are the best choice in surface passivating ligands owing to their chemisorption nature which exists by virtue of their lone pair electrons on the nitrogen atoms. A variety of amine molecules have been realized as potential ligands for the surface passivation of semiconducting nanoparticles such as triethylamine, hexylamine, butylamine and ethylenediamine [30,31]. In our previous report, ethylenediaminetetraacetic acid was used as a

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http://dx.doi.org/10.1016/j.cej.2012.10.001