The nanocrystallinity enhancement and optical characteristics of pre-hydrothermally treated ZnO nanoparticles

A.H. Yuwono*, G.Ramahdita and N. Sofyan
Department of Metallurgy and Materials, Faculty of Engineering, Universitas Indonesia, West-Java 16424, Indonesia
*Corresponding author: ahyuwono@metal.ui.ac.id

Keywords: ZnO nanoparticles, pre-hydrothermal treatment, enhanced nanocrystallinity, optical absorbance, band gap energy.

Abstract. In the current research, ZnO nanoparticles have been synthesized via sol-gel technique assisted by a pre-hydrothermal treatment at 150°C with various holding time of 0, 24, 48 and 72 hours. This route was specifically aimed at investigating the effect of this treatment on the nanocrystallite size, crystallinity and band gap energy of the resulting nanoparticles. The results of investigation showed that an increasing of pre-hydrothermal treatment duration from 0 to 72 hours has increased the crystallite size of ZnO nanoparticles from 3.47 to 13.85 nm, and decreased the band gap energy from 3.10 to 3.08 eV.

Introduction

Zinc oxide (ZnO) is both scientifically and technologically important material. It is a semiconductor possessing wide band gap energy ($E_g$) of 3.07 eV and large exciton binding energy of 60 meV at room temperature [1]. Due to lack of point symmetry in its wurtzite structure, ZnO is piezoelectric. With these characteristics, ZnO is very promising for applications in the areas of sensors [2], optoelectronic devices [3], and piezoelectric devices [4]. In addition, ZnO nanostructures is nowadays considered as a potential candidate to replace titanium dioxide (TiO$_2$) in dye sensitized solar cell (DSSC) [5]. With its characteristic as direct band gap semiconductor, ZnO is expected to be more responsive in the photon absorption mechanism than TiO$_2$, which is an indirect band gap material. Moreover, reducing the size of ZnO down to nanometer scale as nanoparticles has been thought as one of strategies to enhance the performance of DSSC, considering a higher surface to volume ratio in comparison to its bulk form, which in turn provides a more pronounced interaction with the dye molecules.

Among other processing techniques for preparing ZnO nanoparticles, wet-chemistry sol-gel technique is well-known as simple and cheap method. Through low-temperature synthesis approach, this technique can achieve better control of growth or particle size and creates new morphologies or structures that may not be stable if synthesized at higher temperature. However, normally the resulting sol-gel derived inorganic phase is rather amorphous, which limits its potentials for certain applications. In the current work, therefore, a pre-hydrothermal treatment at relatively low temperature has been applied on the zinc-acetate precursor solution, aimed at assisting the nanocrystallinity enhancement of ZnO nanoparticles upon subsequent drying and annealing treatments.

Experimental

The synthesis procedure for ZnO nanoparticles in this study was adopted from the route developed by Spanhel and Anderson [6]. Typically, 0.1 M of zinc precursor was prepared by dissolving 0.55 grams of zinc acetate dehydrate (Zn(CH$_3$COO)$_2$.2H$_2$O) in 50 ml ethanol at atmospheric pressure and room temperature. At the same time, 0.1 M alkaline solution was synthesized by dissolving 0.20 grams of sodium hydroxide (NaOH) in 50 ml ethanol. Both precursors were thoroughly stirred for 2