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Synthesis of zinc oxide nanorods and nanoparticles by chemical route and their comparative study as ethanol sensors

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ABSTRACT

A comparative study of sensing response of zinc oxide nanoparticles and nanorods to ethanol vapours has been reported in this paper. Zinc oxide powder has been synthesized as nanoparticles and nanorods by following a chemical route. The reaction temperature is found to be playing a critical role in the selective synthesis of morphologically distinct nanostructures. Synthesized zinc oxide powder was characterized by using TEM and XRD techniques. Zinc oxide samples were deposited as thick films to act as gas sensors and their comparative response to ethanol vapours was investigated at different temperatures and concentrations. In this work the effect of sintering temperature on the particle size and sensor sensitivity was also studied. The studies revealed that particle size increases with the sintering temperature while sensitivity decreases. The investigations also revealed that sensing response of ZnO nanoparticles is exceptionally higher than that of ZnO nanorods.

1. Introduction

For the past few decades, solid state sensors based on semiconductor metal oxides have attracted attention of many researchers [1–3]. The scientific fraternity is exclusively exploiting a novel material ZnO for various sophisticated applications such as transparent electrodes in the solar cells, varistors, piezoelectric devices, gas sensors, etc. [4]. The preference of zinc oxide has gained impetus during last few years because of the possibility of its relatively simple synthesis into nanoscale structures. Nanostructures like rods and particles have become the most promising research material because of their wide range of applications. Different techniques namely sol–gel [5], spray pyrolysis [6], hydrothermal method [7,8], electrospinning [9], thermal evaporation [10,11], etc. [12–17] are prevalent for the synthesis of zinc oxide nanoparticles and nanorods. In the present work, nanorods and nanoparticles have been prepared by chemical route and different morphologies were obtained by varying reaction temperature.

During preparation and processing of material, heat treatment such as sintering plays a vital role in modification of its morphological properties as reported in literature [18]. Sintering is the consolidation of a powder by means of prolonged use of elevated temperatures, which are, however, below the melting point of any major phase of the material. It facilitates the movement of atoms or molecules through the mechanism of mass transport that may be lattice diffusion, surface diffusion or evaporation–condensation and results in the grain growth which has detrimental effect on the properties of the material. The investigations of thermally treated nanorods and nanoparticles are discussed in the present study. The thin or thick film of active gas sensing material is deposited using a number of sophisticated techniques such as chemical vapours deposition (CVD) [19], sputtering [20,21], molecular beam epitaxy (MBE), screen printing [22,23], etc. [24]. However, with thick films, gas sensors based upon semiconductor oxides have certain advantages over other types of gas sensors such as low cost, simple construction, small size and good sensing properties [22]. In the present study we have used thin slurry of oxide powder to deposit a thick film. Finally the sensing response of nanorods with nanoparticles of zinc oxide to ethanol at different temperatures has also been compared.

2. Experimental details

2.1. Preparation of zinc oxide nanorods

Zinc oxide powder was prepared by following a simple chemical route, starting with a 0.2 M solution of $ZnCl_2$ prepared in distilled water, adding ammonium hydroxide dropwise at room

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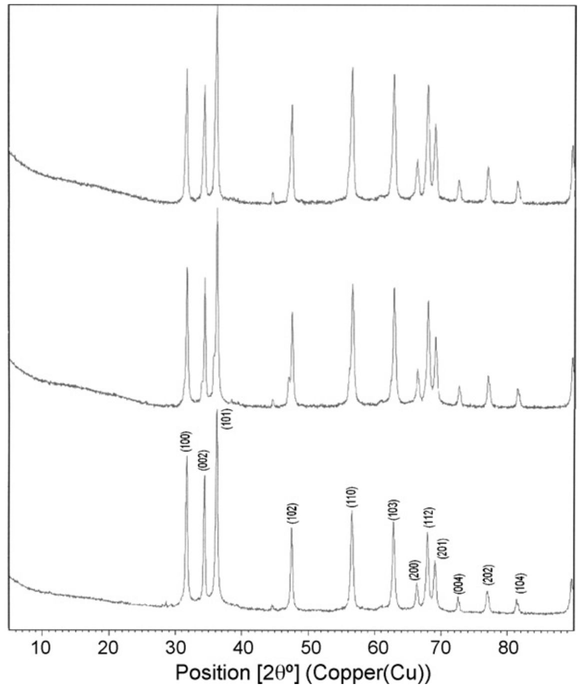

Fig. 1. XRD plot of ZnO powder samples prepared at room temperature and sintered at 400 °C (bottom), 600 °C (middle) and 800 °C (top), respectively.

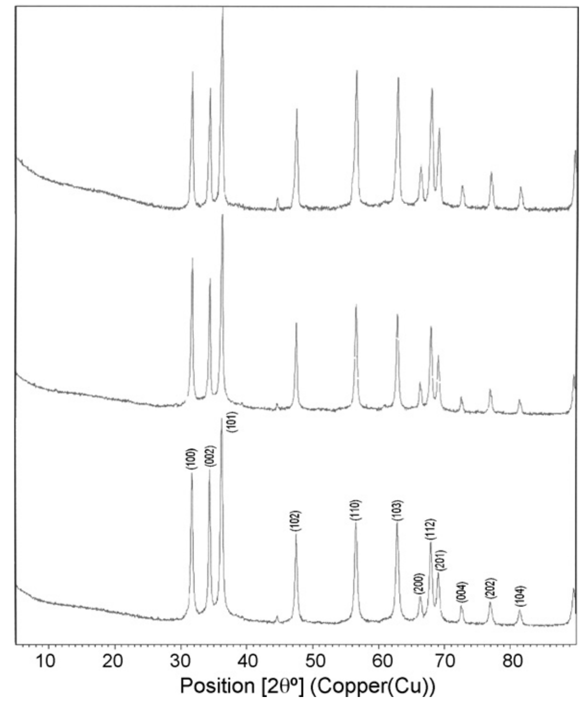

Fig. 2. XRD plot of ZnO powder samples prepared at 50 °C and sintered at 400 °C (bottom), 600 °C (middle) and 800 °C (top), respectively.

temperature with continuous stirring to yield precipitates of zinc hydroxide. The precipitates thus obtained were separated from rest of the liquid by filtering and were dried into powder at 120 °C temperature.

The powder thus obtained was crushed and divided into three parts. To observe the effect of sintering on the structure and sensitivity to ethanol vapours, each part of powder was sintered in air at the temperatures of 400 °C, 600 °C and 800 °C, respectively for 3 h.

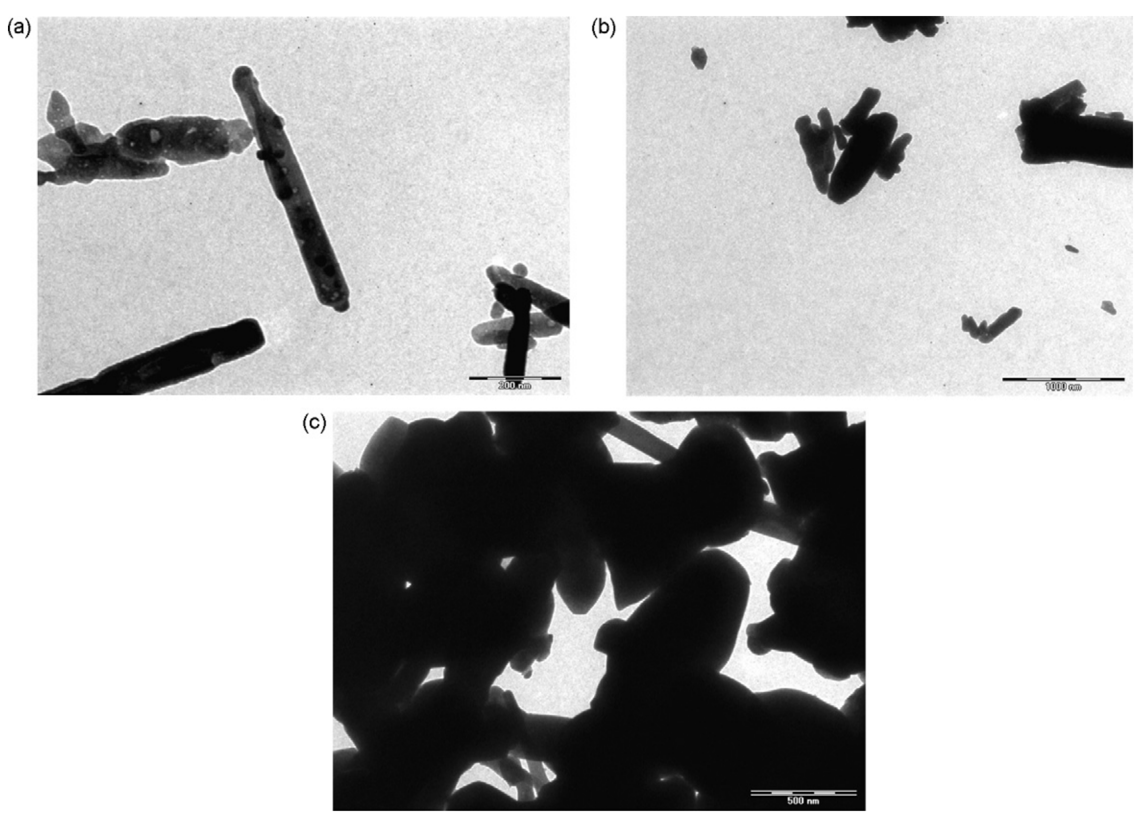

Fig. 3. TEM images of nanorods of zinc oxide sintered at 400 °C (a), 600 °C (b) and 800 °C (c), respectively.