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Nanostructured zinc oxide films synthesized by successive chemical solution deposition for gas sensor applications

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ABSTRACT

Nanostructured ZnO thin films have been deposited using a successive chemical solution deposition method. The structural, morphological, electrical and sensing properties of the films were studied for different concentrations of Al-dopant and were analyzed as a function of rapid photothermal processing temperatures. The films were investigated by X-ray diffraction, scanning electron microscopy, energy dispersive X-ray spectroscopy, X-ray photoelectron and micro-Raman spectroscopy. Electrical and gas sensitivity measurements were conducted as well. The average grain size is 240 and 224 Å for undoped ZnO and Al-doped ZnO films, respectively. We demonstrate that rapid photothermal processing is an efficient method for improving the quality of nanostructured ZnO films. Nanostructured ZnO films doped with Al showed a higher sensitivity to carbon dioxide than undoped ZnO films. The correlations between material compositions, microstructures of the films and the properties of the gas sensors are discussed.

1. Introduction

Zinc oxide is a II–VI group semiconductor material with a direct bandgap of 3.37 eV (at 300 K), a large exciton binding energy (60 meV), and a Wurtzite structure similar to GaN [1]. ZnO has been investigated intensively due to its unique characteristics that may enable its efficient utilization in many commercial applications such as integrated optics, antireflection coatings, liquid crystal displays [1–5], piezoelectric [6,7], surface acoustic wave devices [1,8], electro- and photoluminescent devices [1], chemical and biological sensors [9,10]. More recently, zinc oxide has attracted considerable interest as a nanostructured material for thin film gas sensors in electronic noses [11,12], and as a nanostructured electrode material [13]. A major advantage of ZnO is that its properties can be readily modified and controlled by appropriate doping either by cationic (Al, In, Ga) or anionic (F) substitution [14], and by post-growth annealing. Investigations on nanostructured semiconducting oxide films for nanotechnology applications [15,16] demonstrated the potential to increase the gas response of ZnO films, since their performance is directly related to the exposed surface area, electrical and sensitivity characteristics.

Several techniques for synthesis from aqueous solution at low temperatures have been developed [17–27], and in particular the successive chemical solution deposition (SCSD) method [25]. It has proven to be a useful technique for growing nanostructured ZnO thin films [21,22,26]. The SCSD is a simple and flexible method which offers an easy way to dope film through a well-controlled heterogeneous reaction. It does not require high quality substrates with planar surfaces, and it can be operated at room temperature without the need for vacuum. Growth parameters are relatively easy to control, and stoichiometric deposition with different grain structures can be realized [25–27,9]. However, the SCSD synthesis of Al-doped ZnO (AZO) films and effect of post-grown rapid photothermal processing (RPP) of nanostructured doped ZnO has not been extensively studied.

In this paper we present results on SCSD synthesis as well as the effects of Al dopants and rapid photo thermal processing temperature on structure, morphology, Raman spectra and X-ray photoelectron spectroscopy (XPS) characteristics of nanostructured ZnO thin films. The combined results demonstrate the potential to improve the carbon dioxide gas sensor response of SCSD grown ZnO thin films.

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