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Nanostructured zinc oxide gas sensors by successive ionic layer adsorption and reaction method and rapid photothermal processing

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Abstract

Undoped and Sn, Ni-doped nanostructured ZnO thin films were deposited on glass substrates using a successive ionic layer adsorption and reaction (SILAR) method at room temperature. The SILAR deposited zinc oxide films have been rapid photothermal processing (RPP) at various temperatures to study the effect of annealing on the sensing properties. Structural, electrical and sensing properties were investigated by means of X-ray diffraction (XRD), Energy Dispersive X-ray spectroscopy, scanning electron microscopy, electrical resistivity, and sensitivity measurements. Microstructures of the deposited films were studied for different concentrations of dopants and zinc-complex solution and temperatures. The results of influence of growth processes, doping, and RPP on phase structure, surface morphology, particles size and resistivity values are presented and discussed. The average grain size determined from XRD patterns was 240, 220 and 265 Å for ZnO, Sn–ZnO and Ni–ZnO films, respectively. Moreover, electrical characterization of the sensors prepared from SILAR deposited nanostructured zinc oxide thin film has been carried out. The variation in resisitivity of the ZnO film sensors was obtained with doping and post-deposition rapid photothermal processing in vacuum and N_2 ambient. Electrical resistivity measurements showed semiconducting nature with room temperature resistivity 1.5×10^5, 6.1×10^2, 70 Ω cm for as-deposited ZnO, 4 at.% Ni–ZnO and 4 at.% Sn–ZnO, respectively. These values decreased to 1×10^4, 2×10^2, 30 Ω cm for RPP annealed films. The types of doping and temperatures of RPP were found to have an important role in determining the sensitivity and resolution of the NO_2, NH_3 ZnO-based sensors. While the nanostructured ZnO sensor showed higher ammonia sensitivity than that of NO_2, an enhanced NO_2 sensitivity was noticed with the ZnO films doped with 4 at.% Sn and higher NH_3 sensitivity was obtained by 4 at.% Ni doping of zinc oxide thin films.

Keywords: ZnO; SILAR; RPP; Sensor; Nanostructure

1. Introduction

The semiconductor zinc oxide is recognized as one of the most important semiconductor materials which exhibits numerous characteristics that may enable its efficient utilization for various technological applications such as antireflection coatings, transparent electrodes in solar cells [1,2], piezoelectric devices [3], varistors [4], surface acoustic wave devices [5], electro- and photoluminescent devices [6], gas sensors [7,8], and others. Recently zinc oxide has attracted worldwide research interest because it is considered a promising material for thin film gas sensors in electronic noses [9,10]. Although ZnO is one of the earliest discovered semiconducting oxide gas sensing materials and there are many reports concerning the sensitivity properties of ZnO, most of these works has been done on powder samples usually pressed in pellets and sintered at high temperatures (900–1300 °C) [11,12].In recent years, there appeared many publication on ZnO nanorod or thin film gas sensors using various synthesis techniques including molecular beam epitaxy [13–17], chemical vapor deposition [18,19], sputtering [20,21], thermal evaporation [22,23], and reactive vapor deposition [24].

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