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Sensing properties of CdS-doped tin.oxide thick film gas sensor

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ABSTRACT

The tin oxide (SnO_2) thick film gas sensor is fabricated by employing screen-printing technology. The pure SnO_2 thick film is doped with 1 or 2 wt% of cadmium sulphide (CdS) by its weight and, thereby, the effect of dopant is presented. X-ray diffraction (XRD) analyses are administrated, which suggest that CdS dopant inhibits the crystallite growth leading to nanometric reduction in grain size. The fabricated gas sensor is responsively studied on exposure to liquid petroleum gas (LPG), methanol, and acetone. It is observed that CdS (2 wt%) doped structure exhibited highest response and is more selective to methanol (70 for 5000 ppm) over LPG and acetone at the operating temperature 200 °C. The CdS-doping improved response- and recovery-time from 90 s and 200 s, for undoped-film, to 40 s and 110 s for methanol (5000 ppm at 200 °C).

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1. Introduction

Unlike traditional chemical detection of noxious gases, there is inexorable shift towards designing and fabricating electronic sensors (structures). Amongst various kind of sensors, the chemical gas sensors, recently, received surge of interests on account of their better sensitivity and selectivity for inflammable, combustible and pollutant gases/odors [1]. Semiconducting SnO_2 films are extensively used for sensing and discrimination of several reducing gases [2]. The noble metals such as Pt, Pd, and Ni are utilized as dopants in SnO_2 thick/thin film to enhance its sensitivity, selectivity and to improve response and recovery times [3]. It is investigated that adsorbed oxygen gas molecules on the surface modify the conductivity of SnO_2 thick film layer. Moreover, these oxygen species reacts with exposing (reducing) gases resulting in enhancement of conductance. Other oxides such as ZnO, TiO_2, Fe_2O_3, WO_3, ZrO_3, and V_2O_5 are also applied to detect gases/odors [4–11].

For a film, structural stability, porosity and large surface-volume ratio are salient factors in determining its suitability in gas-sensor technology. It is established fact that reduction in grain size of a material increases sensitivity [12,13]. Yamazoe et al. [14] studied additives' effects in semiconductor gas sensors. Dopant like CaO, MgO are seen to inhibit grain growth and, thereby, increasing gas-sensitivity. Other additives such as ZnO, CuO, and MnO affect conductivity of SnO_2 considerably leading into reduction of resistivity. Castro et al. [15] reported the effect of nickel oxide doping in SnO_2, which resulted maximum sensitivity for ethyl alcohol. Jain et al. [16] studied the effect of Ni and Al doping on a screen-printed SnO_2 thick film and showed that Ni/Al doping results the broadening in the XRD peaks, thus lowers the grain size and improved the gas sensitivity for LPG. Tianshu et al. [17] investigated Cd-doped SnO_2-based sensor for the detection of ethanol and hydrogen. He reported that CdO doping suppresses SnO_2 crystallite growth effectively. ZnO, Fe_2O_3 are used by Arshak and Gaidan [18] and the structure is reported to be appropriate detector for methanol, ethanol and propanol.

In the present study, we investigated the role and effect of CdS on SnO_2 thick film. The undoped and doped structure is analyzed and its suitability for detection of LPG, methanol and acetone is studied. In Section 2, the preparation of SnO_2 paste and fabrication of undoped and doped thick film sensors are described. The measurement results, its discussions and mechanism responsible for sensing the incoming gases are presented in Section 3 and Section 4 concludes the findings.

2. Experimental

2.1. Preparation of tin oxide paste

Doped and undoped paste of SnO_2 is prepared in the laboratory. The tin oxide (SnO_2) powder and glass binder (10 wt% of SnO_2) are weighed using electronic balance. Taking SnO_2 powder along with glass binder in the ball mill (Zirconia Ball Mill, Retsch), a mixture is obtained after 3–4 h of processing. Fine grains are, then, mixed with organic binder (diethyl glycol monobutyl) and organic solvent (α-terpinol) in ball mill for 1–2 h, which results an undoped SnO_2

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