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Characterization and NO_2 gas sensing properties of spray pyrolyzed SnO_2 thin films

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ABSTRACT

The nanocrystalline tin oxide (SnO_2) thin films were synthesized with varing precursor concentrations of the solution by spray pyrolysis technique for NO_2 gas detection. The structural, morphological, optical and electrical properties of nanocrystalline SnO_2 films were studied with XRD, SEM, UV–visible and two probe resistivity measurement setup. The XRD analysis shows SnO_2 thin film has tetragonal rutile structure. From XRD analysis the crystallite size and dislocation density were determined by considering the full width at half maximum (FWHM) from the diffracted peaks. The crystallite size and dislocation density were varies between 4.796 nm to 11.563 nm and 7.484×10^{15} lines/m^2 to 43.592×10^{15} lines/m^2 respectively, while optical band gap energy found in the range of 3.40 eV to 4.06 eV. The gas sensing properties were studied using indigenously built gas sensing unit. The gas response of NO_2 gas at 150 °C optimized operating temperature for 40 ppm is found to be 556, with recovery and response time is 48 s to 224 s and 100 s to 46 s respectively.

1. Introduction

Twenty first century leading with number of crises before the people, one of them is monitoring and detection of toxic and hazardous gases such as CO, CO_2, CH_4, NO_2, etc in industrial as well as domestic fields. Among them the dangerous gas likes nitrogen dioxide (NO_2) which is produced during the combustion in factories, thermal power plants, and chemical plants and in motor vehicles [1]. The formation of O_3 (Ozone) which is a major component of smog is yield by NO_2. The lower level ozone gives rise to the decrease in lung capacity [2] and increase in respiratory problems [3]. Also, NO_2 transforms chemically to nitric acid that can corrode metals and fade fabrics. NO_2 is a harmful gas with threshold limit value (TLV) of 3 ppm. The threshold limit value (TLV) is the maximum concentration of the chemical that is allowable for repeated exposure without producing adverse health effects [4]. To detect such a toxic gases, gas sensing devices play very important and significant role at lower concentration level. There are variety of metal oxide semiconductors (MOS) such as Zinc Oxide (ZnO), Tungsten Oxide (WO_3), Titanium oxide (TiO_2) and Tin dioxide (SnO_2). Among them a well-known n-type SnO_2 (also called cassiterite phase) (Eg = 3.65 eV) is mainly used for detection of wide spectrum of oxidizing and reducing gases in an operating temperature range of 200–500 °C [5,6]. SnO_2 has high reactivity towards reducing gases at relatively low operating temperature, easy adsorption of oxygen upon its surface due to its natural non-stoichiometry, stable rutile phase and many more desirable attributes such as cheapness and simplicity [7]. The conductance of film decreases in the presence of oxidizing gases where as increases in the presence of reducing gases [8]. SnO_2 films can be synthesized by various techniques, but thin film technology seems to be the most suitable for preparation of gas sensors. Different physical as well as chemical deposition routes such as sputtering [9], thermal evaporation [10], sol-gel and spray pyrolysis [11,12] were used to prepare SnO_2. Spray pyrolysis has proved to be simple, reproducible; inexpensive as well as suitable for large area application. The spray pyrolysis technique is one of the important and versatile film deposition techniques which fulfill the basic criteria of film deposition route. Also this technique offers several advantages to control the morphology and growth of material. The compact structure and large surface area may be achieved by this technique which enhances the good sensing performance. Spray pyrolysis does not require high quality targets/or substrates, it is more advantageous than any vapour deposition methods when considered in the point of view of industrial applications [13].

In this study, SnO_2 thin films were deposited using simple and cost effective spray pyrolysis technique and its sensor response towards the various concentration of NO_2 gas was investigated. Meanwhile, the structural, morphological, optical and electrical properties of SnO_2

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