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Effects of O_2/Ar flow ratio on the alcohol sensitivity of tin oxide film

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Abstract

The aim of this study is to find the effects of oxygen flow rate during manufacturing on the sensitivity of SnO_2 (tin oxide) thin films to ethanol (C_2H_5OH). In this study, an RF sputtering process was employed to fabricate the SnO_2 thin films. The SnO_2 was deposited on gold electrode silicon microchips. A target composed of SnO_2 doped with 1 at.% Li was used with a working pressure of 3 mTorr. The RF power was fixed at 150 W. The reaction gas was a mixture of argon and oxygen. The total flow rate was constant at 50 sccm with the O_2/Ar ratio varying from 0.2 to 0.8. An annealing heat treatment was employed at 400 °C for 1 h to stabilize the properties of the films. The sensitivity of the film to ethanol was tested by placing the micro-reactor device on a hot plate, heated to 300 °C, and measuring the variation of electrical resistivity of the film with and without the presence of ethanol. The results show that an O_2/Ar flow ratio of 0.2 produces films with the highest ethanol sensitivity. Before heat treating, the ethanol sensitivity was 126. After heat treating at 400 °C for 1 h, the sensitivity decreased to 104.

Keywords: Gas sensor; Ethanol; Tin oxide; Sensitivity

1. Introduction

In 1953, Brattain and Bardeen discovered that gas adsorption by a semiconductor produced a conductance change. Since then, a great deal of research has been conducted to realize commercial semiconducting devices for gas detection [1]. Since 1962, SnO_2-based

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gas sensors have become the predominant solid-state devices for gas alarms used in domestic, commercial and industrial premises [2]. SnO_2 gas sensors have been used extensively due to their sensitivity to reducing gases of low concentration and their ability to operate at lower temperatures [3–9].

The advantages of semiconductor gas sensors based on SnO_2 are high sensitivity, simple design, low power consumption and low cost. Studies of various techniques for improving sensitivity have shown that the oxygen content of a SnO_2 thin film has a major effect on its electrical properties [10,11]. As the sensing mechanism usually relies on the sudden change in the electrical resistance of the sensor when the particular gas to be detected is present, it is believed that the oxygen content in SnO_2 films can play an important role in the sensitivity of the device. A number of studies have been conducted on SnO_2 films as ethanol sensors [6,12–16]. However, the effects of the oxygen flow rate used during sputtering are not fully understood [18].

In this study, the effect of the oxygen content of SnO_2 films on ethanol sensitivity was investigated. An RF sputtering process was employed to fabricate the films and the O_2/Ar flow ratio was controlled during the deposition process to adjust the oxygen content of the SnO_2 film.

2. Experimental method

SnO_2 thin films were deposited on gold electrode micro-heating devices by sputtering. SnO_2 film gas sensors were fabricated as shown in Fig. 1. SiO_2 was produced by thermal oxidation to serve as the isolation layer. The gold electrodes were formed through thermal evaporation. The active area of the sensor was about 25 mm^2. The target was composed of SnO_2 doped with 1 at.% Li. The working pressure was 3 mTorr and the RF power was 150 W. The reaction gas was a mixture of argon and oxygen gases. The total flow rate was fixed at 50 sccm and the O_2/Ar flow ratio was varied from 0.2 to 0.8. An annealing heat treatment was employed at 400 °C for 1 h to stabilize the properties of the films. grazing incident X-ray diffraction (GID) and a field emission scanning electron microscope (FE-SEM) were used to examine the crystal structure and surface morphology of the film. The X-ray incident angle was 1°, the scan speed was 1°/min, and the value of 2θ ranged from 20 to 60°. The sensitivity of the sensor was measured by using the apparatus schematically shown in Fig. 2. The sensors were placed on top of the hot plate in a chamber containing ambient atmosphere. The hot plate was heated to 300 °C. Ethanol gas with a concentration of 2000 ppm was introduced into the test chamber to investigate the sensing characteristics of the sensor. The probes, connected to a HP-34401A multi meter, were used to measure the variation of the electrical resistance of the sensor. In order to measure the response and recovery times, the electrical resistance of the sensor was continuously monitored while the sensor was first exposed to air and then a small container holding pure ethanol was introduced into the test chamber. After about 70 s, the alcohol container was removed. The test was repeated several times. The data acquisition rate for the resistance measurement was one datum per second. The sensitivity of the film to ethanol was then determined by the change in resistance.

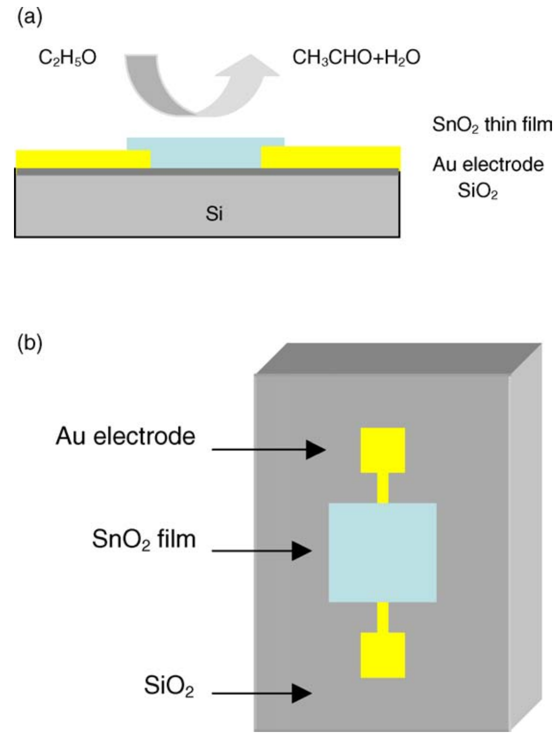

Fig. 1. Structure of the SnO_2 thin-film gas sensor: (a) cross section and (b) top view of the device.