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Improving The Sensing Response of SnO_2 Hydrogen Gas Sensor Using Additive Ag as a Catalyst

Hamid SADEHGI* Vahdat NAZERIAN Alireza SALEHI

[1] Laboratory of Device Fabrication, Department of Electrical Engineering, K.N. Toosi University of Technology, Seyed Khandan, Tehran, IRAN

***Corresponding Author**
e-mail: sadeghi_itc@yahoo.com

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Abstract

In this research the effect of the thickness of Ag catalyst layer on the sensing response of tin oxide as a hydrogen gas sensor was investigated. First Ag layer of different thicknesses was sputtered on the client base glass and then sensitive tin oxide layer was sprayed on the Ag catalyst layer. So, the samples with Ag catalyst thicknesses of 10, 20 and 30 nm were fabricated. The sensing responses of the sensors with Ag catalyst and without catalyst layer were measured in response to various concentrations of hydrogen gas at different temperatures. It is observed that the response of the sensors with Ag catalyst increased significantly compared to the sensor without catalyst layer. An interesting result of the experiment shows that the sensing response of tin oxide sensor with 20 nm thickness of Ag catalyst was 52% at 250 ˚c while the response of the sensor without catalyst was 18% when exposed to 1500 ppm hydrogen gas, exhibiting the high performance of the sensor with appropriate thickness of Ag as catalyst.

Keywords: SnO_2 Gas Sensor; Sensing Response; Ag Catalyst.

INTRODUCTION

Sensors with conversion of physical and chemical quantities to electrical signals have provided the possibility of development of tools to allow more interaction with the environment and controlling of various processes. Powerful tools based on sensors have been made to simulate human capabilities. Among them can be referred to artificial visionary and artificial olfactory tools which the realization of the second case is possible by the development of gas sensors [1]. Tin oxide because of having special features such as high transparency and good electrical conductivity and other properties has many applications in various industries such as micro electronics, ceramics, glass and glazed work industry and etc [2-4].

In this paper sensitivity of tin oxide gas sensor with silver catalyst and without silver catalyst to hydrogen gas was investigated. The results obtained in this study show that with proper thicknesses of silver layer as catalyst in tin oxide gas sensor the sensitivity can be increased.

Experimental

For fabrication of tin oxide gas sensor with Ag catalyst, we used deposition of Ag layer using a sputtering system. First we clean the glass base with acid, alcohol and distilled water, respectively and then clean the chamber wall of sputtering machine with acetone before testing. Glass bases are put inside deposition chamber. The Ag of different thicknesses from 10 to 30 nm was deposited as catalyst of tin oxide gas sensor using Sputtering system. To grow thin layer of tin oxide we used spraying of solution directly on a hot base. A spray can be fed with a carrier gas such as air or nitrogen and also a hot base make the spraying technique [5]. Tin tetrachloride solution was sprinkled onto the base with a fixed rate and tin oxide layer grows on the base. Spray outlet diameter is 0.5 mm and the pressure of atmosphere is the desired pressure in system. We increase the temperature gradually. When the base temperature reaches to its stable state of 400 ˚c then the feeding tube of solution is entered into 0.2 molar solutions. After spraying and coating of thin layer we cut the fed sputtering. In tin oxide coating on the Ag substrate, the solution of 0.2 molar and the time of 5 minutes sprinkling are the best conditions for the preparation of tin oxide thin films using the coating method [6,7].

Measurement Method

For different measurements of the samples and also to compare and conclude the results obtained from the measurements, all samples are selected in the same size and were electrode by adhesive silver, then the samples are kept in 250 ˚c for 10 minutes to annealing and electrodes may have more strength. To measure the sensing response of the sensors, all samples were tested in the same condition.

To calculate the sensing response of the sensors towards gas we used the following equation [8]:

$$S = (\frac{\Delta R}{R_a}) \times 100 = \frac{(R_a - R_g)}{R_a} \times 100 \quad (1)$$

Where R_a is the sensor resistance in clean air and R_g is the sensor resistance after the gas exposure.

With Placing the sample into the chamber which its temperature is completely measurable and controllable and also installing the equipment to measure electrical resistance of the sample in each moment, we provided the conditions for gas sensing measurements. This experiment has been performed at temperatures between 50 ˚c to 250 ˚c for hydrogen gas. With exposure of a certain amount of the hydrogen into the chamber at various temperatures, the amount of sensing response of the sensor is measured.

RESULTS AND DISCUSSION

In Fig. 1 the sensing response of the samples without catalyst and with different thicknesses of silver as catalyst has been shown in exposure of various hydrogen gas concentrations at T=250°c.

It is observed that with increasing of hydrogen concentration the sensing response also increased so that the most response was 52% and obtained for the sample with Ag catalyst of 20 nm thickness in exposure of 1500 ppm hydrogen.

In Fig. 2 the sensing response of the samples with different thicknesses of 10, 20 and 30 nm Ag catalyst at various temperatures from 50°c to 350°c when exposed to 1000 ppm hydrogen has been shown.

It is seen that the sensing response increased with increasing of Ag catalyst thickness up to 20 nm and after that decreased with more increase of catalyst layer to 30 nm. The highest sensing response of 49 was measured for the sample with 20 nm catalyst at T=250°c.

Fig. 3 shows the sensing response of the sample without Ag catalyst versus different temperatures from 0 to 350°c when exposed to three different concentrations of 500, 1000 and 1500 ppm hydrogen.

It is shown that the response value of the sensor without catalyst increased from 0 to 18 with increasing of the temperature from zero up to 250°c and then decreased to a lower value of 3 with more increase of the temperature to 350°c when subjected to 1500 ppm hydrogen.

To investigate the effect of silver catalyst on response of the sensors, the sensing response of the sample with Ag catalyst of 20 nm versus different temperatures from 0 to 350°c has been shown in Fig. 4 when exposed to three different concentrations of 500, 1000 and 1500 ppm hydrogen.

It is exhibited that the response value of the sensor with catalyst layer of 20 nm increased from 10 to 52 with increasing of the temperature from zero up to 250°c and then decreased to

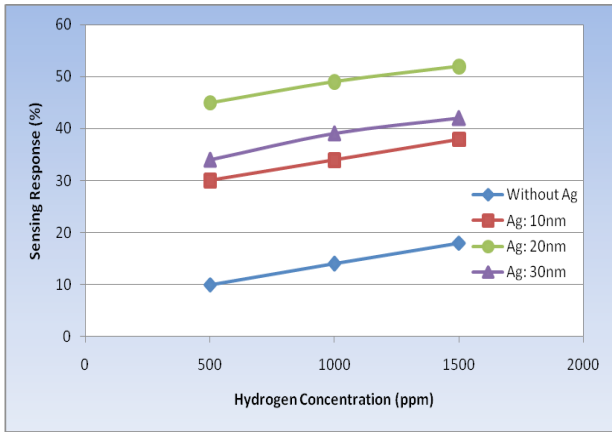

Fig.1. Sensing response of the samples without catalyst and with different thicknesses of Ag catalyst versus different hydrogen gas concentrations at T=250°c.

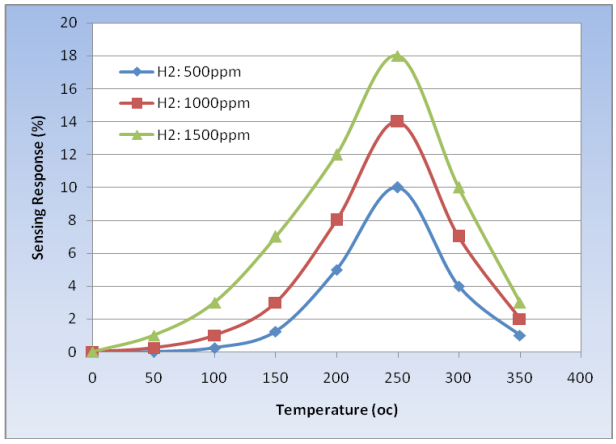

Fig.3. Sensing response of the sample without Ag catalyst versus different temperatures in exposure of various hydrogen concentrations.

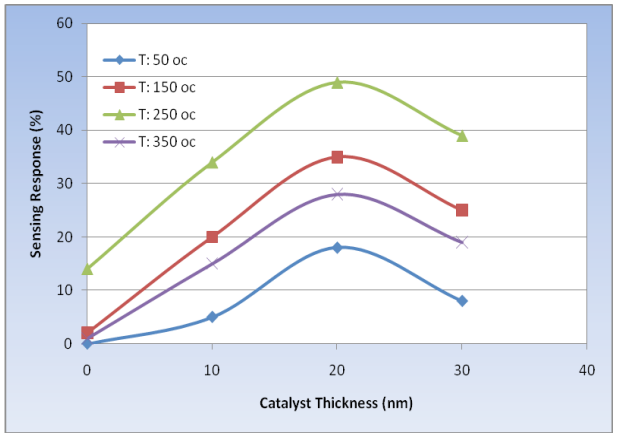

Fig.2. Sensing response of the samples versus different thicknesses of Ag catalyst at various temperatures in exposure of 1000 ppm hydrogen.

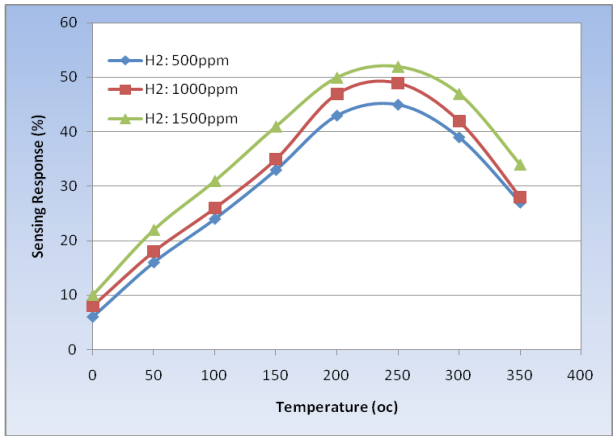

Fig. 4. Sensing response of the sample with catalyst thickness of 20 nm versus different temperatures in exposure of various hydrogen concentrations.

a lower value of 34 with more increase of the temperature to 350°c when subjected to 1500 ppm hydrogen. The SEM photos taken from the sample surfaces showed that samples with a thickness of 20 nm entitled more uniform and more porous structure rather than the samples without catalyst and other catalyst thicknesses. It is exhibiting the high performance of the sensor with appropriate thickness of Ag layer as catalyst used to improve the sensing response of the sensor in exposure of hydrogen gas.

CONCLUSION

In this study, tested samples have been made based on a silver catalyst layer with thickness of 10, 20 and 30 nm. The sensing response of these samples and sample made without the catalyst layer in the presence of hydrogen gas were measured. The results showed that in low thickness with increasing thickness of silver layer the rate of sensor sensitivity will rise, thereafter with further increase thickness of silver layer sensitivity reduced. So using a good thick layer of silver catalyst leads to increase the sensitivity of tin oxide hydrogen gas sensor.

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