Electrical Properties of Fe_2O_3-ZnO Thick Film

H. Aliah[1], P Gumarang[2], R N Iman[3], A Sawitri[4], and D G Syarif[5]
{hasniahaliah@uinsgd.ac.id}

Department of Physics, Faculty of Science and Technology, UIN Sunan Gunung Djati Bandung, Bandung, Indonesia[1,2,3,4]
Center for Applied Nuclear Science and Technology (PSTNT)-BATAN Bandung, Bandung, Indonesia[5]

Abstract. The research about synthesis and fabrication of thick film Fe2O3-ZnO had been done to identify the electrical properties of thick film. The synthesis of thick film material was done by using precipitation method. Then, the fabrication was done by using screen printing method. The thick film was fired at 800°C for 2 hours. By electrical properties testing, it is informed that the increased temperature is accompanied by decreased resistance of the sample. The ethanol gas concentration also affects the resistance of the sample. Besides, the sensor gives a response of 100 ppm ethanol at the working temperature in the range of 180°C-320°C. Meanwhile, it also gives a response of 300 ppm ethanol at working temperature in the range of 180 °C-400°C. Based on the data, the response increases with the ethanol concentration addition. Thus, the sensitivity of thick film is inflicted by the increasing of ethanol concentration. Considering to the simple synthesis by using precipitation method and gas-sensing electrical properties, the thick film would be a promising candidate for applications in ethanol gas sensor.

Keywords: Gas sensor, Ethanol, Thick film, Resistance, Sensitivity.

1 Introduction

Today, alcohol type of ethanol is the most popular needs in everyday life. The ethanol gas sensor can be applied to detect ethanol in human breath, food, drinks, or ethanol in the air. In general, the material for the synthesis of ethanol gas sensor is oxide semiconductors such as SnO_2 [1], TiO_2 [2], and Fe_2O_3 [3–6]. One type of Oxide semiconductor, namely Fe_2O_3 can be derived from local mineral jarosite [7]. The used of Fe_2O_3 oxide obtained from jarosite as the application of ethanol gas sensors has been done by Aliah et al, 2018 with synthesizing Fe_2O_3 (based jarosite) plus Mn [8]. In addition, Aliah et al in 2019 succeeded in synthesizing the composite oxide matrix AB_2O_4 (ZnO and Fe_2O_3 composites derived from jarosite) and obtained the crystal structure of the spinel cubic / hexagonal composite with high crystallinity, so that it has great potential to be applied as a gas sensor [9].

In this research, ZnO and Fe_2O_3 composite oxide matrix composites (derived from jarosite) will be synthesized and the electrical properties and the response to ethanol gas are tested.

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2 Experiment

2.1 Synthesis of materials

Using the precipitation method, the thick film material of Fe_2O_3-ZnO was synthesized as the following steps. Firstly, 3.6504 g Zn acetate powder was dissolved into 200 ml aquades at 80 °C by using a magnetic stirrer with a rotation rate of 300 rpm. Then, 2.6498 g Fe_2O_3 powder was dissolved into 200 ml HCl 5 M using a magnetic stirrer with a rotation rate of 300 rpm at 80 °C. The solutions of Fe_2O_3 and Zn acetate were mixed until consistently uniform. Afterwards, they were precipitated with 200 ml NH_4OH 10 M. The precipitate was dried at 110 °C for 20 hours and then calcined at 800 °C for 2 hours. The result was grinded by a pestle. Finally, the material powder of Fe_2O_3-ZnO was obtained.

2.2 Fabrication and Characterizations of thick film

The powder of Fe_2O_3-ZnO was mixed with Organic Vehicle. The ratio of OV (Organic Vehicle) and powder was 30 : 70 respectively. The mixture was mixed consistently uniform until paste formed. Then, the silver electrode was coated on the alumina substrate and pured for 10 minutes at 600 °C. After that, the substrate was coated with Fe_2O_3-ZnO paste by using screen printing method (225 mesh screen size) to fabricate a thick film [18]. The thick film was fired for 2 hours at 800 °C. The thick film was characterized by using electrical tester in the air and ethanol gas atmosphere to obtain the sample electrical properties.

3 Result and Discussion

Electrical properties of thick film were determined by measuring electrical resistance at different temperature. **Figure 1** shows the resistance value of thick film as a function of temperature and ethanol gas concentration. Generally, it is known that the increased temperature is accompanied by decreased resistance of the sample. The ethanol gas concentration also affects the resistance of the sample. It is indicated by curve representation.

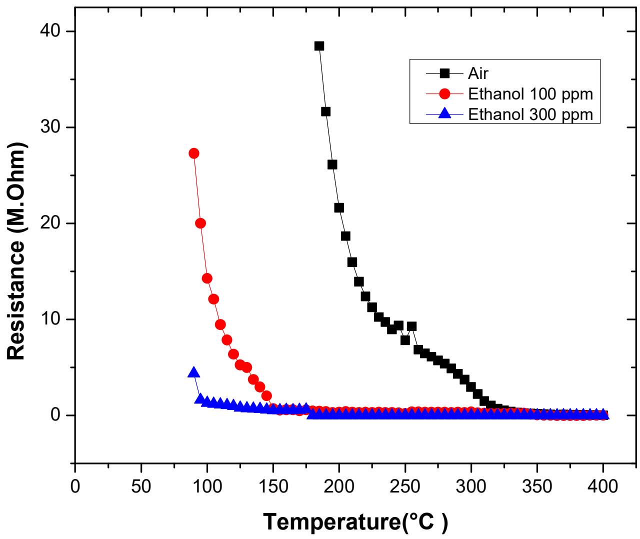

Figure 1. The changes of resistance to the temperature at Fe_2O_3-ZnO thick film.

The mechanism of reduction in resistance is explained as the following explanation. The surface of thick film absorbs oxygen gases. Then, the absorbed oxygen makes a bonding to free electron at the operating temperature and causes oxygen ion (O^- or O^2) formed. The absorption causes potential barrier which is called as initial potential barrier or initial electrical resistance. Ethanol gas molecules are reacting with oxygen gases which have been absorbed on the surface of thick film as ethanol gas absorption with certain concentration. The electron reduction is caused by this process. The reduction causes electron moved to the conduction band, so it makes potential barrier lower and electrical resistance decreased.

The gas sensor sensitivity/response value is mathematically determined by using Eq. 1 as follows [10].

$$S_g = [(R_0 - R_g)\times 100\%]/R_0 \tag{1}$$

Where S_g is response of N-type sensor material (%), R_0 is electrical resistance in air medium (MΩ) and R_g is electrical resistance in ethanol gas medium (MΩ). **Figure 2** shows the gas sensor sensitivity at different temperatures and ethanol concentrations. According to **Figure 2**, the sensor gives a response of 100 ppm ethanol at the working temperature in the range of 180 °C-320 °C. Meanwhile, it also gives a response of 300 ppm ethanol at the working temperature in the range of 180 °C-400 °C. The sensitivity of thick film is inflicted by the increasing of ethanol concentration. Thus, the thick film is well sensitive to detect the ethanol gas existence.

The initial contact temperature and the optimal temperature of our thick film in this research are lower than the results in previous researches which had been done by Chen [11] and Hung [12]. On the other hand, the initial contact temperature of Fe_2O_3-ZnO thick film in this research is higher than the results which had been done by Li [13]. The differences are caused due to the different materials used in the research.

It is known that the different methods cause different initial contact temperatures towards ethanol gas response. The initial contact temperature which has been obtained by Chen [11] is 220 °C, while our research informed at 180 °C. The another method which was done by Fan [14] showed the initial contact temperature at 150 °C and the optimum temperature at 250 °C. Song [15] also obtained the higher optimum temperature. Thus, different methods are affecting the sensitivity, initial contact temperature and optimum temperature of ethanol gas sensor.

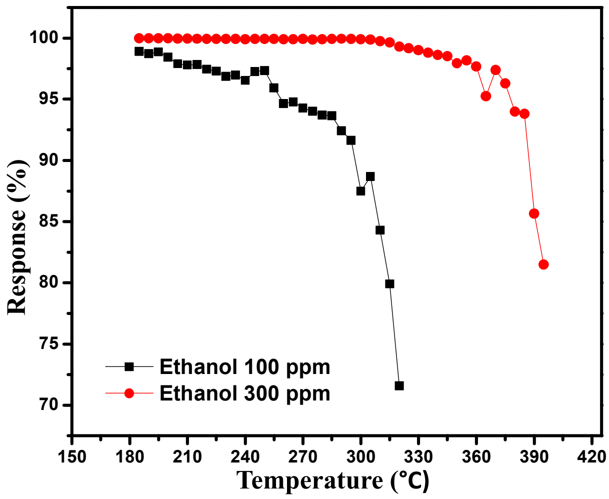

Figure 2. The sensitivity of Fe_2O_3-ZnO thick film.

4 Conclusions

In summary, the thick film material of Fe_2O_3-ZnO was synthesized by using precipitation method. Thick film was fabricated by using screen printing method and characterized by using electrical tester in the air and ethanol gas atmosphere. It is known that the increased temperature is accompanied by decreased resistance of the sample. Besides, the sensor gives a response of 100 ppm ethanol at the working temperature in the range of 180 °C-320 °C. Meanwhile, it also gives a response of 300 ppm ethanol at the working temperature in the range of 180 °C-400 °C. Based on the data, the response increases with the ethanol concentration addition. Thus, the sensitivity of thick film is inflicted by the increasing of ethanol concentration. Considering to the simple synthesis by using precipitation method and the gas-sensing electrical properties, the thick film would be a promising candidate for applications ethanol gas sensor.

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