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Sensing properties of nanostructured zinc oxide-based gas sensor fabricated using immersion method

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ABSTRACT – CH_4 gas sensor was fabricated using immersion method of the ZnO film. The effect of immersion time on the electrical, structural and sensing properties of the ZnO thin film were investigated. The highest conductivity of 7.80×10^{-3} Scm^{-1} was obtained for the ZnO thin film prepared at immersion time of 60 min. The sensitivity value also showed the highest value that is 18.2%.

1. INTRODUCTION

Zinc Oxide (ZnO) is an n-type semiconducting material which has large exciton binding energy of about 60 meV and has direct band gap energy of 3.37 eV at room temperature. It is non-toxic, readily available, transparent in visible range region and stable against thermal and chemical reaction [1-3].

ZnO thin films can be prepared using various techniques, such as chemical vapor deposition, electron-beam evaporation, spray pyrolysis, magnetron sputtering, ion-beam evaporation and sol-gel process. Among these methods, sol-gel does not required expensive and complicated equipment. It provides maximum control in homogeneity and easy to be coated on the desired shape and area [3]. Therefore, sol-gel immersion method has been chosen to prepare ZnO thin films.

Methane (CH_4) gas is a flammable, colorless and odorless gas. It is highly volatile when mixed with air which can cause explosion; therefore the monitoring of its leakage is very important.

In this paper, ZnO were prepared at different immersion time. Then the effect of immersion time on electrical and structural properties of the thin films was investigated. In order to study the sensing properties, the thin films were exposed to CH_4 gas using simple gas chamber setup.

2. METHODOLOGY

2.1 ZnO Thin Film Deposition Process

ZnO thin films were prepared using immersion method on glass substrates that were coated with Al-doped ZnO thin film which has been prepared earlier using spin-coating technique [4]. For immersion process, 0.1M zinc acetate dehydrate ($Zn(CH_3COO)_2 2H_2O$, 98% Sigma-Aldrich) was dissolved in a solution of 0.1M hexamethylenetetramine (HMT, $C_6H_{12}N_4$, 99% Aldrich) and deionized (DI) water. The molar ratio of HMT to zinc acetate was kept at 1.0. Then the solution were magnetically stirred and aged for 3 h at room temperature. The immersion process was done in water bath at 95°C for 20, 40, 60, 80 and 100 min.

2.2 Characterization

These thin films were analyzed using two point probe I-V measurement (Keithley 2400) and FESEM.

The resistivity of the thin film, ρ was calculated using equation (1):

$$\rho = \frac{V}{I} \cdot \frac{A}{l} \quad (1)$$

Where V is supplied voltage, I is measured current, A is area of electrode and l is the length between electrodes. The conductivity, σ was calculated as following equation (2):

$$\sigma = \frac{1}{\rho} \quad (2)$$

The gas sensitivity (S) is defined as the electric current generated in the gas sensor which were calculated using this equation (3):

$$S\ (\%) = ((I_{gas} - I_{air})/I_{air}) \times 100 \quad (3)$$

3. RESULTS AND DISSCUSION

Figure 1 show the I-V characteristics of ZnO thin films which were prepared using immersion method. As shown in Figure 1, the electrical conductivity of the films increasing with the increase of the immersion time. The film that immersed for 20 min that has lowest thickness film obtained higher value of resistivity might be due to high leakage current. So from this work, we found that by increasing the immersion time might increase the electrical conductivity of the film thus enhance its gas sensing properties. A similar observation also has been reported by H. Zhou et al. [5].

Table 1 shows the ZnO thin film properties at different immersion time. While, Figure 2 shows the response of ZnO thin film when exposed to CH_4 gas.

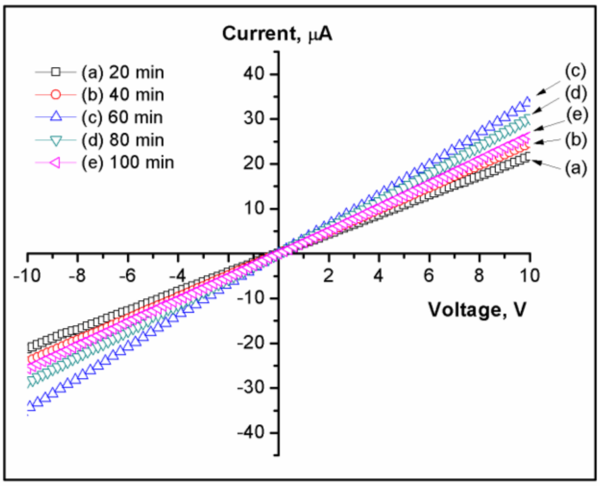

Figure 1 IV curve of ZnO thin film prepared at different immersion time.

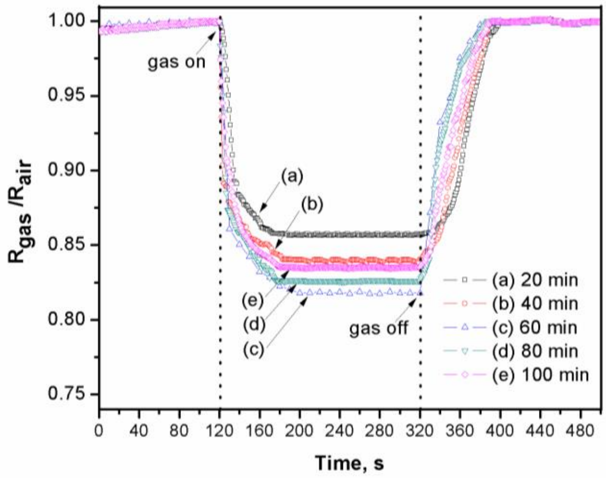

Figure 2 Response of ZnO thin film when exposed upon methane gas.

Table 1 ZnO thin film properties at different immersion time.

Immersion time (min)	Thickness (nm)	Conductivity (Scm^{-1})	Sensitivity (%)
20	350	3.58×10^{-3}	14.3
40	550	4.59×10^{-3}	16.0
60	9200	7.80×10^{-3}	18.2
80	1340	6.17×10^{-3}	17.4
100	1610	5.16×10^{-3}	16.5

4. CONCLUSION

The electrical and structural properties of ZnO thin films which were synthesized using immersion method at different time are investigated. The thin films were characterized using I-V measurement system and FESEM. The increase of immersion time has significantly improved the conductivity of the thin films. The results suggest that the optimum value of immersion time was 60 min which exhibited highest conductivity and sensitivity value of 7.80×10^{-3} Scm^{-1} and 18.2%, respectively.

5. ACKNOWLEDGMENT

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