Zinc Oxide Tetrapod Impregnated with Platinum for Ethanol Sensor

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ABSTRACT

Ethanol sensors were fabricated from tetrapod and tetrapod impregnated with platinum. The tetrapod was prepared from zinc powder by using thermal oxidation technique. Tetrapod were pressed into the cylindrical tube and sintering at temperature of 800oC for 12 hours. After that these tubes were dipped in chloroplatinic acid ($H_2PtCl_6*(H_2O)_6$) for 30 sec and sintered again at 400°C for 3 hours. Surface morphology was studied by FE-SEM. The sensors were tested toward ethanol vapor at concentration of 100 ppm and at the operating temperature of 200-280°C. It was found that there was no improvement of sensitivity for Pt impregnated sensor. However, the improvement of response and recovery for ethanol sensor based on zinc oxide tetrapod impregnated with platinum were observed.

Key words: Zinc oxide, Tetrapod, Ethanol sensor, Gas sensor

INTRODUCTION

Nowadays, gas sensors based on metal-oxides such as ZnO, TiO_2, SnO_2, and Fe_2O_3 are widely studied. Zinc Oxide (ZnO) is one of the promising metal oxide wide-band gap semiconductors for ethanol sensor. Recently, ZnO nanostructures have attracted much attention for gas sensors because of their increasing surface-to-volume ratio. ZnO nanostructures can be synthesized by several methods such as sputtering technique (Choopun et al., 2005(b)), vapor deposition (Chen et al., 2005), pulsed laser deposition (PLD) (Choopun et al., 2005(a)), metal organics chemical vapor deposition (MOCVD) (Xu et al., 2005) and oxidation method (Chen et al., 2004; Sekar et al., 2005; Zhang et al., 2005; Yawong et al., 2005), etc. The oxidation method is the most commonly used for preparation ZnO nanostructures due to low cost and ease of preparation compared to other methods.

In this work, ZnO tetrapods were synthesized by thermal oxidation technique. Ethanol sensors were fabricated from tetrapod and tetrapod impregnated with platinum and the ethanol sensing properties of sensors were reported.

MATERIALS AND METHODS

The tetrapod, prepared from zinc powder by thermal oxidation technique, was pressed into cylindrical tubes with approximately 2.5-3.5 mm long and then heated at 800°C for 12 hours. After heating process the tubes were dipped in chloroplatinic acid (H_2PtC_{l6}*$(H_2O)_6$) for 30 seconds and sintered again at 400°C for 3 hours. Field-Emission Scanning Electron Microscope (FE-SEM) was used for carried out the morphology of the samples. The Sensors were tested toward ethanol vapor at concentration of 100 ppm and at the operating temperature of 200-280°C.

RESULTS AND DISCUSSION

The morphologies of tetrapod and tetrapod impregnated with platinum, characterized by Field-Emission Scanning Electron Microscope (FE-SEM) with magnification of 3,000 and 5,000, were shown in Figures 1 and 2, respectively. The morphologies of tetrapod impregnated with platinum (Figure 2) consisted of sheet-like structure with smooth surface tetrapod which was different from tetrapod without impregnation (Figure 1).

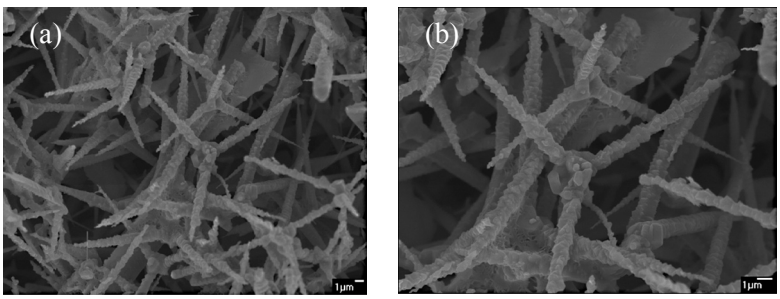

Figure 1. Morphologies of tetrapod by FE-SEM with magnification of (a) 3,000 and (b) 5,000.

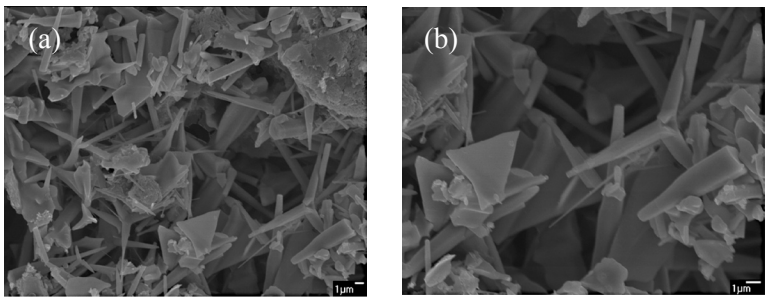

Figure 2. Morphologies of tetrapod impregnated with platinum by FE-SEM with magnification of (a) 3,000 and (b) 5,000.

Figure 3 showed Energy Dispersive Spectrometry (EDS) spectra of (a) tetrapod and (b) tetrapod impregnated with platinum. The spectra were obtained by focusing electron beam in a middle of nanostructures. The peaks at Zn and O signals were observed indicating Zn was oxidized with O and formed zinc oxide nanostructures. Note that Au signal can also be observed due to gold coating process.

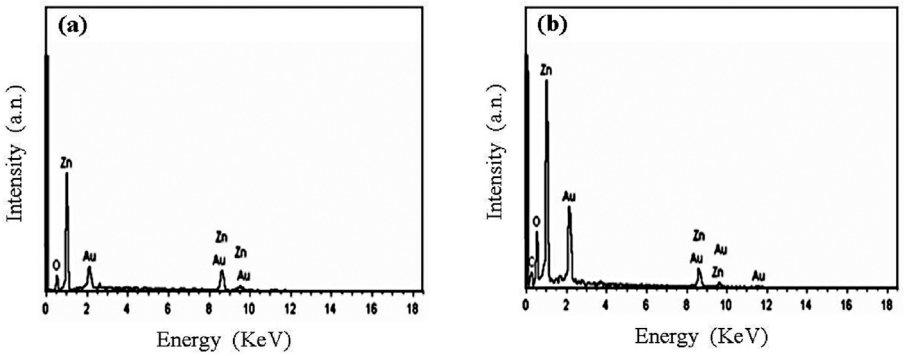

Figure 3. EDS spectra of (a) tetrapod and (b) tetrapod impregnated with platinum.

The response and recovery curves of ethanol sensors were detected from tetrapod and tetrapod impregnated with platinum under an ethanol vapor at concentration of 100 ppm at various operating temperatures of 200-280°C were shown in Figure 4. Because of the concentration of electron in conduction band of semiconductor depend on temperature, the electrical resistance of the ethanol sensors in air is higher than under the ethanol vapor and the electrical resistance decreased when the operating temperature increased. Explicitly, the characteristics of sensor depend on the operating temperatures. At operating temperature of 280°C, the resistance of tetrapod and tetrapod impregnated with platinum shows the lowest value.

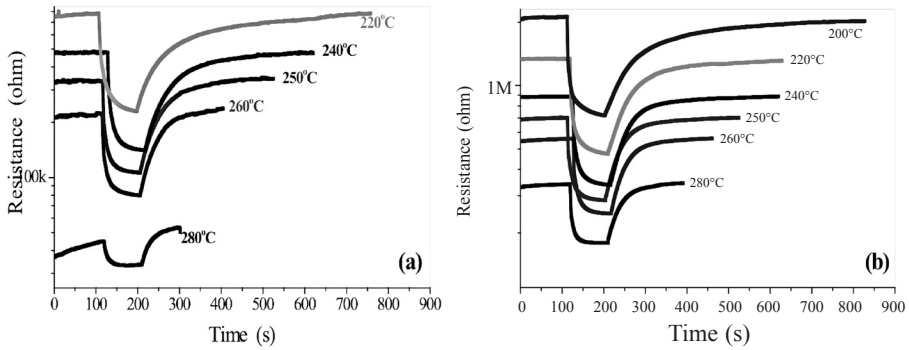

Figure 4. Response and recovery characteristics of sensors under an ethanol vapor at concentration of 100 ppm at various operating temperatures (a) tetrapod and (b) tetrapod impregnated with platinum.

The important parameters of ethanol sensor are sensitivity and response time which can be obtained from response and recovery curves. The sensitivity, S, of the sensor is defined as where is the electrical resistance of sensor in air and is the electrical resistance of sensor in ethanol-air mixed gas. The obtained sensitivity of tetrapod and tetrapod impregnated with platinum sensors under an ethanol vapor at concentration of 100 ppm and at the operating temperatures of 200-280°C as a function of operating temperatures was plotted in Figure 5. It showed that the sensitivity of tetrapod sensors, were higher than that of platinum impregnated tetrapod sensors, except at 280°C, and both decreased with increasing of operating temperature. However, there was no significant improvement of sensitivity for platinum impregnated tetrapod sensor. The highest sensitivity obtained at operating temperature of 200°C and 280°C for tetrapod impregnated with platinum and tetrapod sensors, respectively.

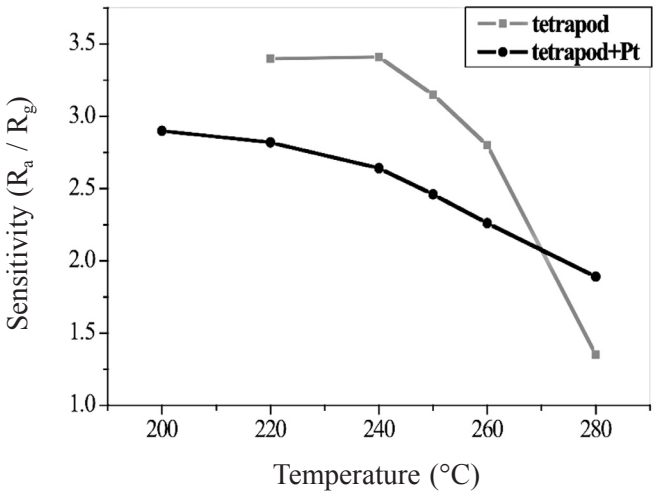

Figure 5. Plot of sensitivity as a function of ethanol concentration and operating temperature of tetrapod and tetrapod impregnated with platinum sensors.

The response time (τ^-_{90}) and also recovery time (τ^+_{90}) as a function of operating temperature of 200-280°C of sensors was plotted in Figure 6 (a) and (b), respectively. The plot showed that the recovery time decreased with increasing of operating temperatures. The response time and recovery time of platinum impregnated tetrapod sensors was shorter than those of tetrapod sensors indicating the improvement caused by platinum impregnation. This is due to platinum acts as catalyst in ethanol adsorption reaction and reduces the reaction time.

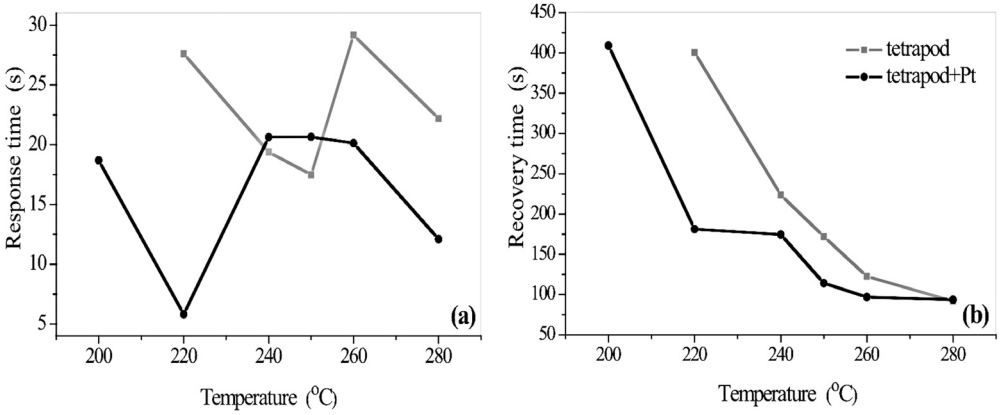

Figure 6. Plot of response time (τ^{-}_{90}) and recovery time (τ^{+}_{90}) of tetrapod and tetrapod Impregnated with platinum sensors under an ethanol vapor at concentration of 100 ppm and at various operating temperatures of 200-280°C.

CONCLUSION

Ethanol sensors based on ZnO tetrapod with and without platinum impregnated were fabricated and tested toward ethanol concentration of 100 ppm at the operating temperature of 200-280°C. It was found that the sensitivity and recovery time of sensors decreased with increasing of operating temperature. Also, the sensitivity of ZnO tetrapod impregnated with platinum sensor showed no improvement. However, the improvement of response and recovery time for ethanol sensors based on zinc oxide tetrapod impregnated with platinum was obtained.

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