Zinc Oxide Nanowires Impregnated with Platinum and Gold Nanoparticle for Ethanol Sensor

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ABSTRACT

Zinc oxide nanowires impregnated with platinum and gold nanoparticle were used for ethanol sensor. Zinc oxide nanowires were prepared by thermal oxidation reaction. Firstly, zinc oxide powder was pressed into cylindrical tube and then sintered at 600°C for 12 hr at normal atmosphere. After that these tubes were dipped in chloroplatinic acid ($H_2PtCl_6*(H_2O)_6$) or in gold nanoparticle solution for 1 hr and sintered again at 400°C for 6 hr. The samples were tested toward ethanol vapor at concentration of 100 ppm and at working temperature of 180-300°C. The enhancement of sensitivity and recovery time were observed for ethanol sensor based on zinc oxide nanowire impregnated with platinum, but no enhancement was observed for zinc oxide nanowire impregnated with gold nanoparticle.

Key words: Zinc oxide, Nanowire, Ethanol sensor, Platinum and gold nanoparticle

INTRODUCTION

Zinc oxide is wide band gap metal oxide semiconductor with energy gap of 3.37 eV at room temperature (Zhang et al., 2005). Zinc oxide is widely used for various applications such as pyroelectric devices, transistors, piezoelectric devices, mechanical devices and surface acoustic wave devices. For gas sensor applications, zinc oxide is an interesting material which is sensitive to toxic and combustible gases and also can be prepared in various forms such as whisker, tetrapod, nanowire, nanobelt (Ting et al., 2007). ZnO nanostructures have caught attention due to their increasing surface-to-volume ratio which could be resulted in enhancement of sensing properties (Ramgir et al., 2006). In this paper, ethanol sensors based on zinc oxide nanowires impregnated with platinum and gold nanoparticle were fabricated and their ethanol sensing properties were investigated.

MATERIALS AND METHODS

Zinc powder was grounded and pressed into cylindrical tube, then, the tubes were sintered at 600°C for 12 hr at normal atmosphere to produced zinc oxide nanowires. After sintering process, the samples were dipped in gold nanoparticle solution or chloroplatinic acid (H_2PtCl_6*$(H_2O)_6$) for 1 hr and sintered again at 400°C for 6 hr. After that, the samples were tested toward ethanol vapor at concentration of 100 ppm and at temperature of 180-300°C. The surface morphology was characterized by using Field Emission Scanning Electron Microscope (FE-SEM).

RESULTS AND DISCUSSION

The FE-SEM images of zinc cylindrical tube before sintering and after sintering process at 600°C for 12 hr at normal atmosphere were shown in Figure 1 (a) and (b), respectively. The wire-like nanostructures with diameter of about 100 nm and length of about 10 μm were observed after sintering process. Figure 2 showed the surface morphologies of zinc oxide cylindrical tube, (a) impregnated with gold nanoparticle solution and (b) chloroplatinic acid after sintering at 400°C for 6 hr. It can be seen that ZnO nanowires impregnated with gold nanoparticle and platinum exhibited slightly larger size than that of without impregnation.

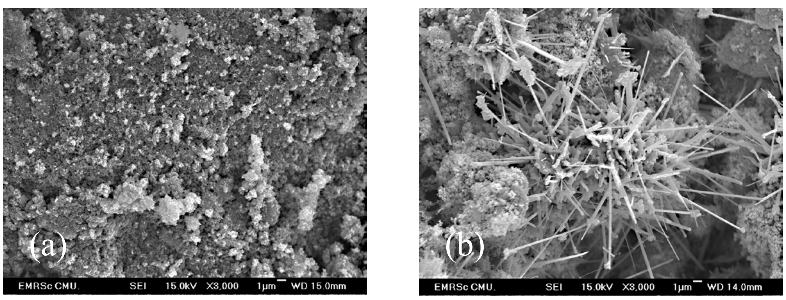

Figure 1. FE-SEM images of (a) zinc tube before sintering and (b) zinc oxide tube after sintering.

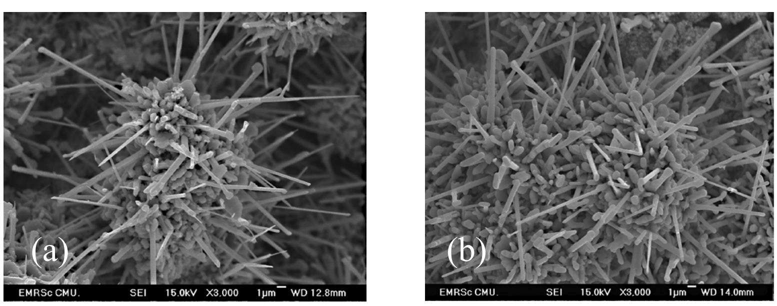

Figure 2. FE-SEM images of (a) zinc oxide nanowires impregnated with gold nano-particle and (b) zinc oxide nanowires impregnated with platinum.

The response and recovery characteristics of (a) zinc oxide sensors (b) zinc oxide nanowires impregnated with gold nanoparticle sensors and (c) zinc oxide nanowires impregnated with platinum sensors under an ethanol vapor at concentration of 100 ppm at various operating temperatures were shown in Figure 3. Clearly, the characteristics depended on the operating temperatures. It is worth to note that the resistance in air decreases as increasing operating temperature which is a common semiconductor property of zinc oxide.

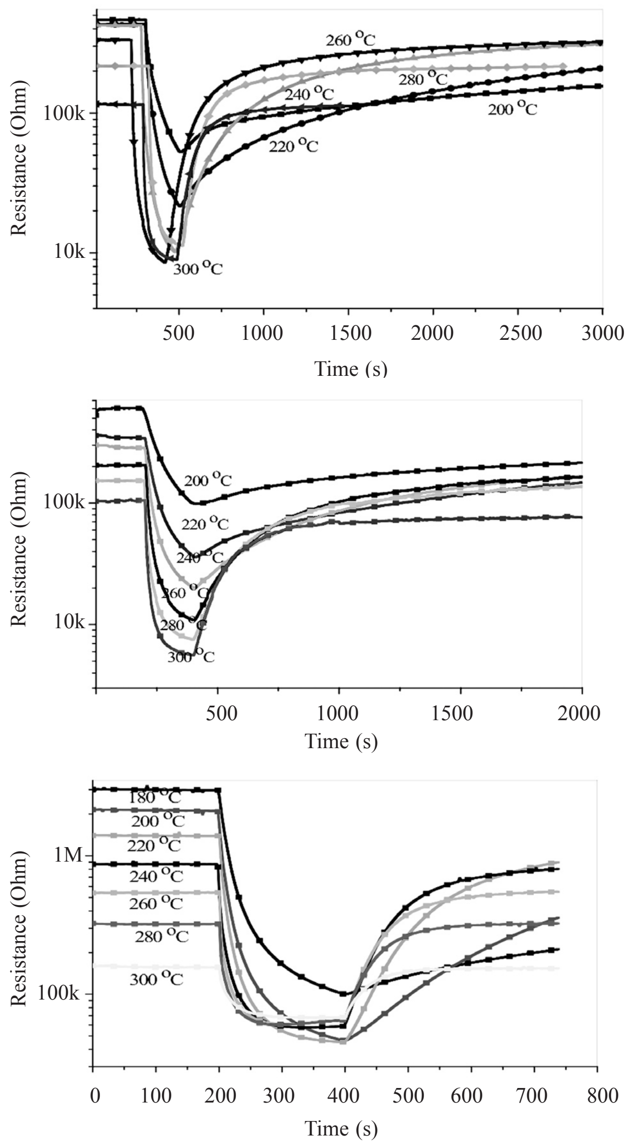

Figure 3. Response and recovery characteristics of (a) zinc oxide sensors (b) zinc oxide nanowires impregnated with gold nanoparticle sensors and (c) zinc oxide nanowires impregnated with platinum sensors under an ethanol vapor at concentration of 100 ppm at various operating temperatures.

The sensitivity obtained from response and recovery curves as a function of operating temperatures was plotted in Figure 4. The highest sensitivity was observed for sensors based on zinc oxide nanowire impregnated with platinum at 200°C and had close value to that of zinc oxide nanowire at optimum operating temperature. For sensors based on zinc oxide nanowire impregnated with gold nanoparticles, the sensors exhibit the lowest sensitivity at optimum temperature. This indicated the enhancement of sensitivity when impregnated zinc oxide nanowire with platinum.

Moreover, the recovery time as a function of operating temperatures was plotted in Figure 5. Clearly, the recovery time of sensors based on zinc oxide nanowire impregnated with platinum exhibited significant shorter recovery time than the rest at entire operating temperature. This suggested that impregnated platinum to zinc oxide nanowire sensors could enhance the recovery time. The enhancement of sensitivity and recovery time for sensors impregnated with platinum is due to platinum acts as catalyst in ethanol adsorption and desorption reaction and thus, increases sensitivity and reduces recovery time.

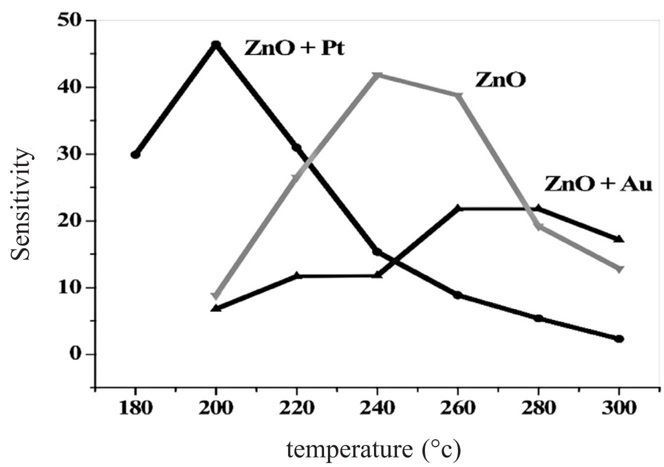

Figure 4. Sensitivity as a function of operating temperatures for zinc oxide nanowires, zinc oxide nanowires impregnated with gold nanoparticle and zinc oxide nanowires impregnated with platinum.

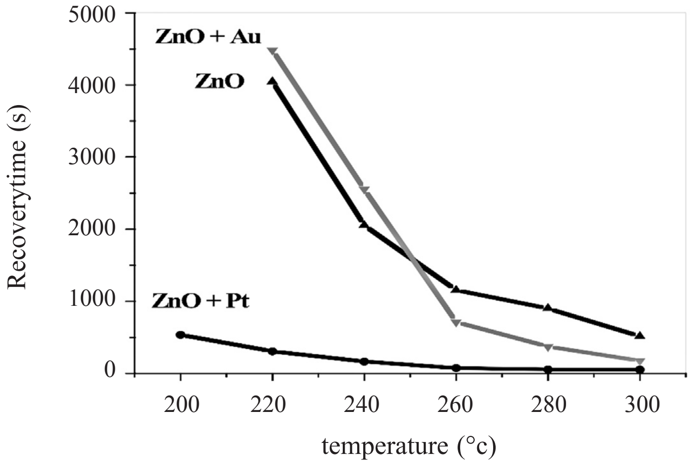

Figure 5. Recovery time as a function of operating temperature for zinc oxide nanowires, zinc oxide nanowires impregnated with gold nanoparticle and zinc oxide nanowires impregnated with platinum.

CONCLUSION

In conclusion, ethanol sensors based on zinc oxide nanowires, zinc oxide nanowires impregnated with gold nanoparticle, and zinc oxide nanowires impregnated with platinum were fabricated. The slightly enhancement of sensitivity and the significance enhancement of recovery time were observed for ethanol sensor based on zinc oxide nanowires impregnated with platinum, tested under ethanol concentration of 100 ppm. However, no enhancement was observed for sensors based on zinc oxide nanowire impregnated with gold nanoparticle. Thus, platinum impregnation is one of the techniques that could be used for enhancement the ethanol sensing properties of zinc oxide nanowire sensors.

ACKNOWLEDGEMENTS

This work is supported by the Commission of Higher Education (CHE) and Thailand Research Fund (TRF) and by the Nanoscience and Nanotechnology Center, Faculty of Science, Chiang Mai University. Weerayut Wongka would like to acknowledge the Graduate School, Chiang Mai University for financial support.

REFERENCES

Jelena M. J., V. K. Nedeljko, M. V. Ljiljana, and G. N. Stelios. 2007. Spillover of primary oxides as a dynamic catalytic effect of interactive hypo-d-oxide supports. Electrochimica Acta 53: 349–361.

Ramgir N. S., Y. K. Hwang, S. H. Jhung, H. K. Kim, J. S. Hwang, I. S. Mulla, and J. S. Chang. 2006. Co sensor derived from mesostructured Au-doped SnO_2 thin film. Appl. Surf. Sci. 252: 4298-4305.

Ting, J. H., I. Cherng Chen, Y. Wen Chen, and Ch. Liang Hsu. 2007. ZnO nanowire-based CO sensors prepared on patterned ZnO: Ga/SiO_2/Si templates. Sens. Actuators B. 125:498–503.

Wang X., J. Zhang, Z. Zhu, and J. Zhu. 2006. Effect of Pd^{2+} doping on ZnO nanotetrapods ammonia sensor. Colloid. Surf. A. 276: 59-64.

Zhang B. P., N. T. Binh, Y. Segawa, K. Wakatsuki, and N. Usami. 2003. Optical properties of ZnO rods formed by metalorganic chemical vapor deposition. Appl. Phys. Lett. 83: 1635-1637.

Zhang J., Y. Yang, B. Xu, F. Jians, and J. Li. 2005. Shape-controlled synthesis of ZnO nano and micro-structures. J. Cryst. Growth 280: 509-515.

Zhu B. L., C. S. Xie, A. H. Wang, D. W. Zeng, W. L. Song, and X. Z. Zhao. 2005. The gas sensing properties of thick film based on tetrapod-shaped ZnO nanopowders. Mater. Lett. 59:1004-1007.