Zinc Oxide Nanowires by Oxidation of Zinc Powder for Ethanol Gas Sensor Application

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ABSTRACT

Zinc oxide nanowires were prepared by oxidation of zinc powder. The oxidation of zinc was performed by heating a tube of zinc powder at various duration times and temperatures. Field Emission Scanning Electron Microscopy (FE-SEM), Energy Dispersive Spectrometry (EDS) and Transmission Electron Microscopy (TEM) were used to characterize the tube. It was found that the diameter of zinc oxide nanowires ranged from 60–620 nm and depended on the heating time and temperature. Also, from TEM results, it was found that the obtained zinc oxide nanowires exhibited single-crystalline property. These zinc oxide nanowires could be used for ethanol gas sensor application.

Key words: Zinc oxide, Nanowires, Oxidation

INTRODUCTION

For gas sensor applications, ZnO is one of the promising metal oxide wide-band gap semiconductors. ZnO ceramic and thin film gas sensors were widely investigated in the past. However, ZnO nanostructure gas sensors are expected to possess high performance due to a huge surface-to-volume ratio of nanostructures. Therefore, it is essential to synthesize high-quality ZnO nanostructures.

ZnO nanostructures can be synthesized by various growth techniques, such as pulsed laser deposition, sputtering and oxidation. The oxidation technique is a simple, low-cost and most commonly used for the preparation of ZnO nanostructures.

Zhang and co-workers (Zhang et al., 2005) reported the growth of ZnO nano- and micro-structures by oxidation of zinc foils at 700°C for 15 min, with heating rates of 27.5, 68, 97 and 340°C/min. They found that the different morphologies of ZnO nanostructures such as nanowires, nanoneedles and nanotetrapods had been obtained through controlled heating rates.

Also, Sekar and co-workers (Sekar et al., 2005) obtained ZnO nanowires on Si (100) substrate by oxidation of zinc powders at 600°C for 90 min in oxygen and nitrogen ambient. They observed ZnO nanowires with diameters of 30–60 nm and lengths of 2–4 μm.

Meng and co-workers (Meng et al., 2005) reported the growth of ZnO nanowires on Si (111) substrate by oxidation of zinc powders at 430 and 520°C for 30 min in argon and nitrogen ambient. They observed needle-like ZnO nanowires with the length of 2.8–3.2 μm, a top diameter of 30 nm and root diameter of 100 nm at 430°C. They also observed rod-like

ZnO nanowires with a homogeneous diameter from top to root between 40-120 nm and length of 1 μm at 520°C.

Gao and co-workers (Gao et al., 2005) obtained 3D interconnected ZnO nanowires networks on Si (110) and alumina substrates by oxidation of ZnO powders at 1,400°C for 30–120 min under a constant pressure of about 300 mbar in argon carrier gas. They observed ZnO nanorods and nanowires with a diameter of 20–100 nm and the growth direction along the c-axis.

In this work, we report on the preparation of ZnO nanowires by oxidation of a tube of zinc powders in air at atmospheric pressure. The diameter of ZnO nanowires as a function of heating temperature and duration time were investigated.

MATERIALS AND METHODS

Zinc metal powder (99.9%) was pressed to form a tube with a diameter of about 3 mm. Then, the tubes were sintered in a horizontal furnace in alumina crucible in air at atmospheric pressure at temperature of 600, 700, and 800°C for 24 hr with the heating rate of 10°C/min from room temperature. The ZnO nanowires were characterized by Field-Emission Scanning Electron Microscope (FE-SEM) for morphology, Energy Dispersive Spectrometry (EDS) for chemical composition and Transmission Electron Microscope (TEM) for crystal structure.

RESULTS AND DISCUSSION

After sintering, the tube color changed from grey to white which is a typical color for ZnO nanostructures. The morphology of the sintered ZnO tube products, sintered at 600°C for 6 hr is shown in Figure 1 (a) and (b). The ZnO nanowires grown on surface of zinc tube were observed to have diameters between 60–180 nm. Moreover, the leaf-like ZnO nanostructures mixed with ZnO nanowires were also observed with a root diameter of 200 nm and top diameter of 15 nm.

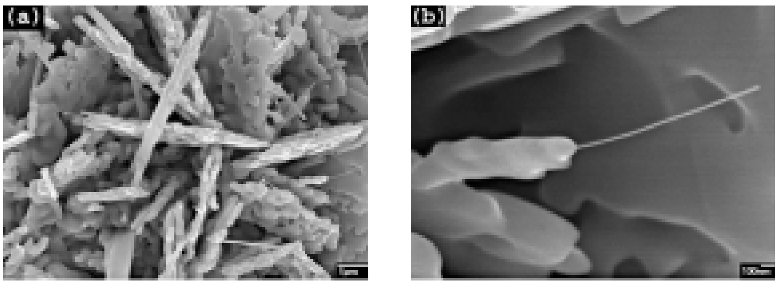

Figure 1. FE-SEM images of ZnO nanostructures grown at 600°C for 6 hr with magnifications of (a) 10,000 and (b) 50,000.

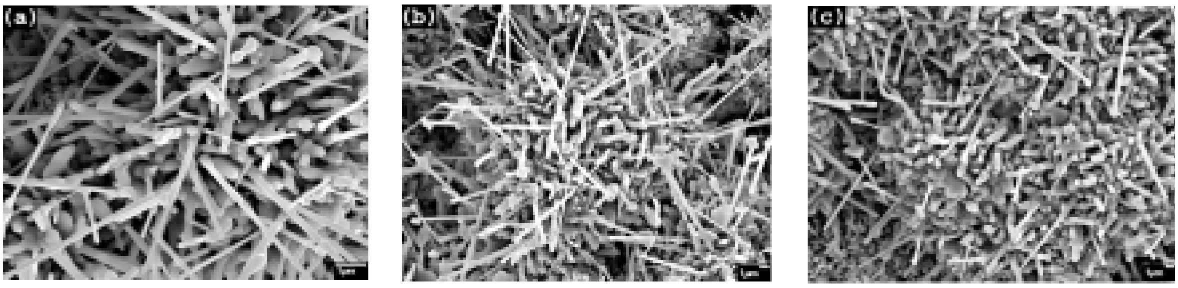

Figure 2. FE-SEM images of ZnO nanostructures grown at (a) 600°C, (b) 700°C and (c) 800°C for 24 hr.

FE-SEM images of ZnO nanowires on the tube surface sintered at different sintering temperatures for 24 hr are shown in Figure 2. At all sintering temperatures between 600–800°C, the ZnO nanowires had been observed but no leaf-like ZnO nanostructures occurred at sintering temperature of 700–800°C. Also, it was observed that the number of ZnO nanowires was higher at higher sintering temperatures. The diameters of ZnO nanowires at different sintering temperatures and times are listed in Table 1. The diameter of ZnO nanowires slightly depends on both sintering time and temperature but strongly depends on sintering temperature. The diameter of ZnO nanowires was slightly larger when sintered at longer time. The higher sintering temperature, the larger the diameter of ZnO nanowires and the diameter was up to 300–620 nm at sintering temperature of 800°C.

Table 1. The diameter of ZnO nanowires at different oxidation conditions.

Conditions	Diameters of nanowires (nm)
600°C, 6hr	60–180
600°C, 24hr	70–200
700°C, 24hr	140–290
800°C, 24hr	300–620

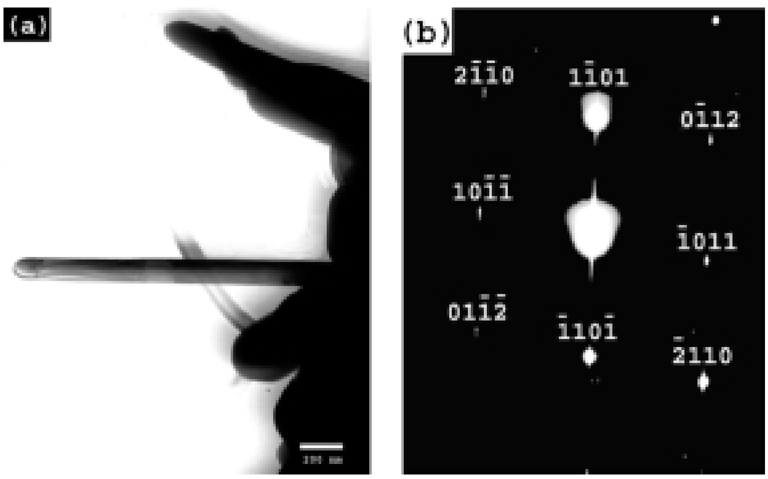

Figure 3. (a) TEM bright field image and (b) the associated SADP of ZnO nanowire.

Figure 3 (a) shows TEM bright field image of ZnO nanowire, sintered at 600°C on surface of sintered tube with the associated SADP in Figure 3 (b). The wire-like structure is clearly observed from TEM image. The SADP shows a spot pattern, indicating a single-crystalline property of the nanowire corresponding to the hexagonal structure of ZnO with the lattice constants, a = b = 3.2 Å, and c = 5.2 Å, and the spots can be indexed as shown in Figure 3 (b).

CONCLUSION

Zinc oxide nanowires have been successfully prepared by oxidation of zinc powder. The oxidation of zinc was performed by heating a tube of zinc powder at various duration times and temperatures. It was found that the diameter of zinc oxide nanowires ranged from 60–620 nm and slightly depended on the sintering time but strongly depended on sintering temperature. From TEM results, it was found that the obtained zinc oxide nanowires exhibited single-crystalline property. These zinc oxide nanowires could be used for ethanol gas sensor application.

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