

Zinc Oxide Nanostructure by Oxidization of Zinc Thin Films

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ABSTRACT

The zinc oxide nanostructures were synthesized by oxidizing zinc thin films. The zinc thin films were grown on silicon and alumina substrates by dc sputtering at various times from 30, 60 and 90 minutes. The zinc thin films were then heated at various temperatures from 600, 800 and 900°C for 6 hr. The obtained zinc oxide nanostructures were investigated by Field Emission Scanning Electron Microscopy (FE-SEM). The zinc oxide nanostructures are found to have a potential application for nanodevices such as nano gas sensor.

Key words: Zinc oxide, Nanostructures, Oxidation, dc sputtering

INTRODUCTION

ZnO is an n-type wide band gap semiconductor with the band gap of 3.37 eV and has various potential applications such as optoelectronic devices, chemical sensors and gas sensors. Also, bio-safe characteristics of ZnO make them very attractive for biomedical applications. Moreover, ZnO in the form of nanostructures would enhance the gas-sensing properties of gas sensors due to a huge surface area. Thus, it is a great interest to study the synthesis of ZnO nanostructures.

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)), metalorganic chemical vapor deposition (MOCVD) (Xu et al., 2005) and oxidation (Chen et al., 2004; Sekar et al., 2005; Zhang et al., 2005). The oxidation method is a simple, low-cost and most commonly used for the synthesis of ZnO nanostructures. Chen and co-workers (Chen et al., 2004) reported that ultra-fine ZnO nanowires could be easily synthesized at 800°C in air via oxidation of ZnO nanowires which was produced by heating ZnO+C mixture at 1,100°C under a flow of nitrogen gas. Zhang and co-workers (Zhang et al., 2005) have successfully synthesized ZnO nanostructures by oxidizing zinc foils at 700°C in air without the presence of catalyst and carrier gas. The different morphologies of ZnO nano- and micro-structures such as porous membrane, nanowires (or nanorods), nanobelts, nanoneedles and nanotetrapods have been achieved through tuning the heating rates in a tube furnace. Sekar and co-workers (Sekar et al., 2005) reported that ZnO nanowires were grown on Si (100) substrates by oxidation of metallic Zn powder at 600°C. Sea-urchin-like nanostructures, consisting of straight nanowires of ZnO with blunt-faceted ends, have been observed.

Most of the oxidation works were on the oxidation of zinc powder or zinc metallic foil or sheet. However, the work on the oxidation of zinc thin films has been rarely reported. In this work, we report on the preparation of ZnO nanostructures by oxidation of zinc thin films. The zinc thin films were prepared by dc sputtering technique.

MATERIALS AND METHODS

The thin films of zinc were prepared by dc sputtering, at argon pressure of 30 mtorr, power of 200 watts and time duration of 30, 60 and 90 minutes on silicon and alumina substrates. The oxidation of the zinc thin films was performed by heating the thin films at various temperatures from 600, 800 and 900°C for 6 hours to obtain ZnO nanostructures. The ZnO nanostructures were characterized by Field-Emission Scanning Electron Microscopy (FE-SEM) for morphology.

RESULTS AND DISCUSSION

A typical color of zinc thin film is grey. After heating, a color of thin film turns white which is a typical color for ZnO nanostructures. The general morphology of the heated ZnO nanostructures is shown in Figures 1, 2 and 3. Figure 1 shows FE-SEM image of ZnO nanostructures deposited on alumina substrates at various sputtering times and then, heated at 600°C for 6 hr. Our preliminary results are based on the heating time of 6 hr. The columnar-like structures had been observed. It is note worthy that wire-like structures have been typically observed in the case of oxidation of zinc powder.

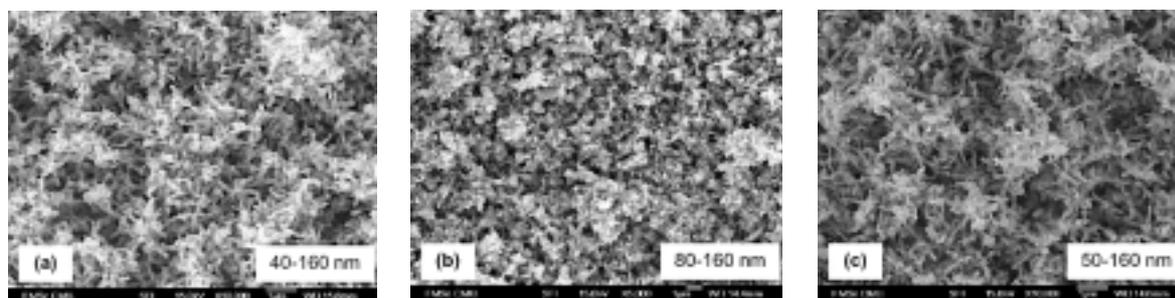


Figure 1. FE-SEM images of ZnO nanostructures deposited on alumina substrates at (a) sputtering time of 30 minutes, (b) sputtering time of 60 minutes, and (c) sputtering time of 90 minutes and then, heated at 600°C for 6 hr.

It can be observed that the size of ZnO nanostructures almost does not depend on the sputtering times. The film thickness estimated from crosssection of SEM is 206, 413 and 620 nm for sputtering times of 30, 60 and 90 minutes respectively. This indicates that the thickness of zinc thin films has almost no effect on the size of ZnO nanostructures. Moreover, the similar results have been observed for ZnO nanostructures deposited on silicon substrate at various sputtering times and then, heated at 600°C for 6 hr (not shown).

Figure 2 shows FE-SEM image of ZnO nanostructures deposited on silicon substrates at sputtering time of 90 minutes and heated at various temperatures for 6 hr. Clearly, the size of ZnO nanostructures depends on the heating temperature, i.e., the higher the heating temperature the larger, the size of ZnO nanostructures. The higher temperature means higher given energy and results in more oxidation. The same results have been observed in the case of deposition on alumina substrates as shown in Figure 3. However, the size of ZnO nanostructures in the case of deposition on alumina substrates is larger than in the case of deposition on silicon substrates. The reason for the larger size is still under investigation.

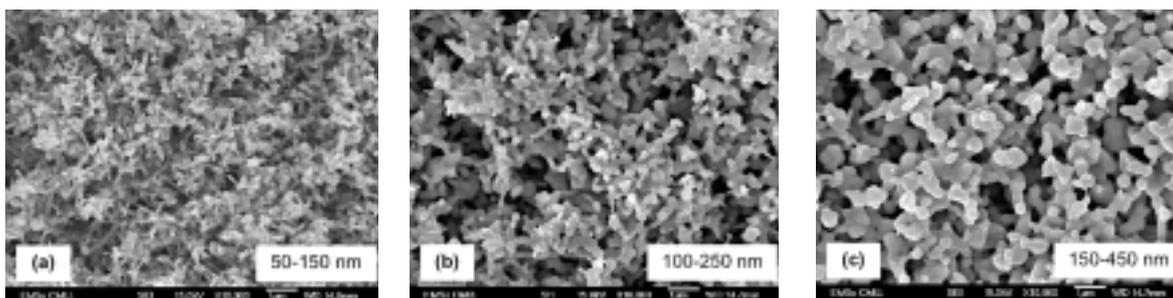


Figure 2. FE-SEM images of ZnO nanostructures deposited on silicon substrates at sputtering time of 90 minutes and heated at various temperatures (a) 600°C, (b) 800°C, and (c) 900°C for 6 hr.

In the case of ZnO nanostructures grown on p-type silicon substrate, the structure would become p-i-n diode structure (p-Si/i-SiO₂/n-ZnO) because there is a naturally-formed SiO₂ layer on silicon substrate. This p-i-n structure could be used for nanodevices such as nano gas sensor.

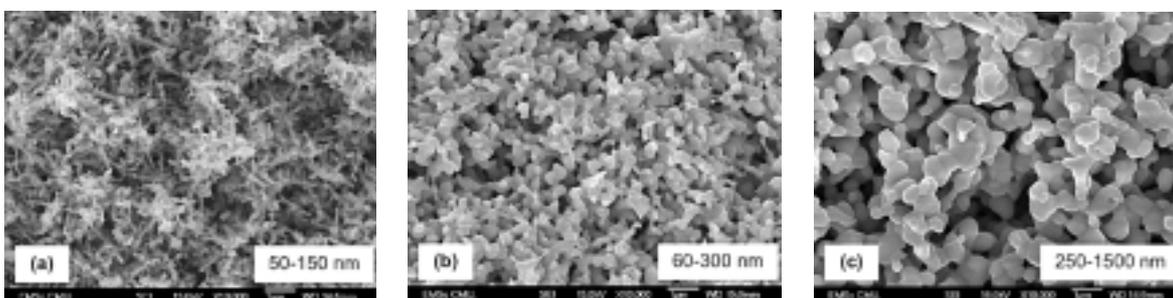


Figure 3. FE-SEM images of ZnO nanostructures deposited on alumina substrates at sputtering time of 90 minutes and heated at various temperatures (a) 600°C, (b) 800°C, and (c) 900°C for 6 hr.

CONCLUSION

The zinc oxide nanostructures were successfully synthesized by oxidizing zinc thin films. The zinc thin films were grown on silicon and alumina substrates by dc sputtering at various times from 30, 60 and 90 minutes. The zinc thin films were then heated at various temperatures from 600, 800 and 900°C for 6 hr. The size of ZnO nanostructures almost does not depend on sputtering time but strongly depends on heating temperatures. The zinc oxide nanostructures have a potential application for nanodevices such as nano gas sensor.

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