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Contributed Paper

Synthesis of ZnO Nanobelts by RF Sputtering

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ABSTRACT

ZnO nanobelts were synthesized by radio frequency (RF) sputtering on copper, silicon and alumina substrates. The sputtering time was 60 min, in argon atmospheric pressure of 40 mtorr. The ZnO nanobelts were characterized by Field Emission Scanning Electron Microscopy, Energy Dispersive Spectroscopy, and Transmission Electron Microscopy for morphology, composition and crystal structure, respectively. From these results, ZnO nanobelts on copper substrate exhibit single crystalline hexagonal structure with size ranging from 10-150 nm, and the length of several micrometers. The morphology of ZnO nanobelt is also influenced by the types of the substrate. These ZnO nanostructures could be further explored for the use as nano gas sensor.

Keywords: ZnO, nanobelts, RF sputtering

1. INTRODUCTION

In the past few years, the semiconducting nanostructures such as nanowires, nanorods, nanotubes, and nanobelts have caught much attention due to the great potential applications in industry, especially, applications for electronic and optoelectronic devices. The nanodevices fabricated from nanostructures are expected to have unique and fascinating performance due to quantum confinement effect.

Zinc Oxide (ZnO) is a wide band gap semiconductor which is an excellent candidate for use as semiconducting, photoconducting, piezoelectric and optical waveguide materials. It has a hexagonal close-packed structure (wurtzite type) with the bandgap of 3.37 eV and a large exciton binding energy of 60 meV. It also exhibits very excellent piezoelectric, chemical properties, and optical properties, for various applications such as ultraviolet-blue emission devices, piezoelectric devices, and vapor gas sensor devices [1].

ZnO nanostructure can be synthesized by various techniques such as chemical vapor deposition (CVD) [2], pulsed laser deposition (PLD) [3], metal-organic chemical vapor deposition (MOCVD) [4], electrochemical deposition [5], thermal evaporation [6] and sputtering [7,8]. For sputtering technique, it is the most commonly use for the preparation of polycrystalline ZnO thin films due to the advantages of lower deposition temperatures, less film damage, higher deposition rate, and compatibility with IC processing. However, there are a few reports on synthesis of ZnO nanostructure by sputtering. Recently, the growths of ZnO whiskers [7] and ZnO nanowires [8] by sputtering have been reported. W.T. Chiou and co-workers [8] have obtained ZnO nanowires on silicon substrates with copper metallization. They also suggested that copper plays an important role for the growth of ZnO nanowires.

In this paper, we report on the synthesis of ZnO nanostructure on copper, silicon, and alumina substrates using RF sputtering technique. Depending on the types of the substrate, various morphologies of ZnO nanostructure were obtained.

2. Materials and Methods

ZnO products were deposited on the substrate using a radio frequency magnetron sputtering. Initially, the sputtering chamber was evacuated to a pressure lower than $1x10^{-5}$ torr. Deposition of ZnO products was then carried out at a pressure of 40 mtorr on copper, silicon and alumina substrates. The deposition time was 60 min. The ZnO target had a purity of 99.9% and a diameter of 3 inches. During deposition of ZnO, the substrates were not heated. The specimens were analyzed using Field Emission Scanning Electron Microscopy (FE-SEM) for morphology, Energy Dispersive Spectroscopy (EDS) for composition, and Transmission Electron Microscopy (TEM) for crystal structure.

3. Results and Discussion

Normally, deposition of ZnO by sputtering technique would result in the formation of thin films which are transparent. However, ZnO products deposited on silicon, alumina, and copper substrates with the growth conditions mentioned above appear white indicating some different structures. ZnO products deposited on silicon and alumina substrates exhibit interesting microstructures as shown in FE-SEM image of Figure 1 (a) and (b), respectively. On silicon substrate, ZnO products exhibit irregular rod-like microstructures with the cross-sectional size ranging from 0.2 to 1 micrometer. Similar irregular rod-like microstructures with the smaller cross-sectional size ranging from 0.1 to 0.5 micrometer are also observed when deposited on alumina substrate. Moreover, ZnO micro-rod structures on alumina substrate also exhibit bush-like structures as shown in Figure 1 (c) which are different than

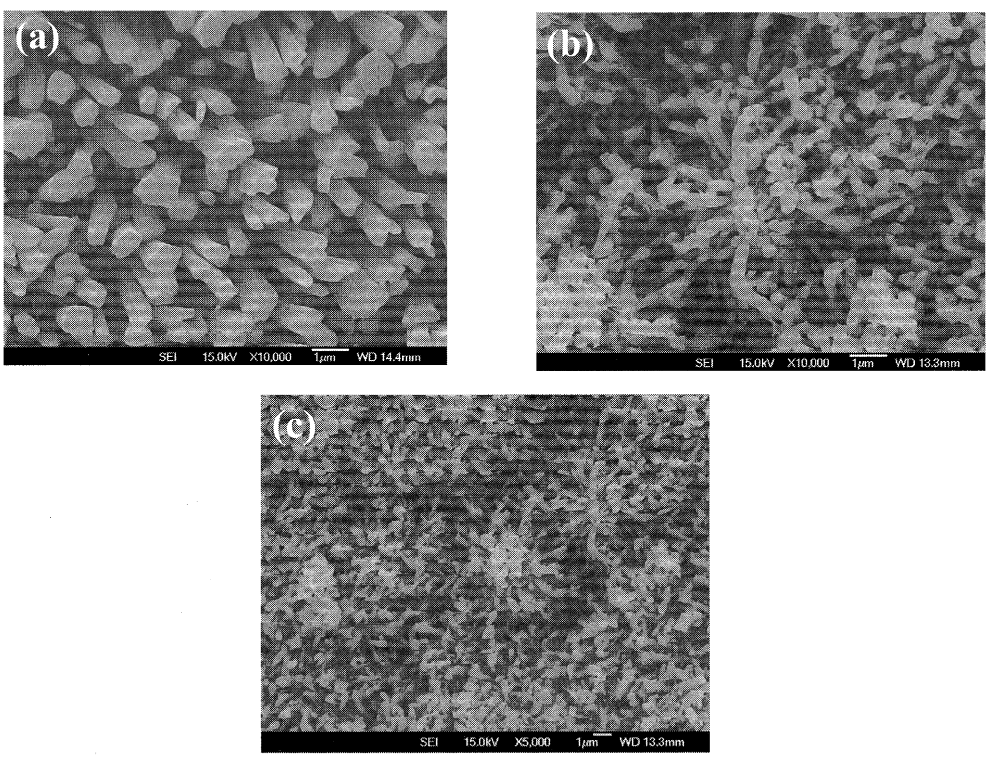

Figure 1. FE-SEM images of ZnO microstructures deposited on (a) silicon substrate (b) alumina substrate and (c) shows bush-like structures of ZnO on alumina substrate.

that of on silicon substrate. The reason for the formation of different structures is still unclear and it is ongoing research.

However, the morphology of the as–deposited ZnO products on copper substrate reveals quite different structures as shown in Figure 2 (a) and (b) at magnification of 25000x and 50000x, respectively. The belt-like structures with diameter ranging from several ten nanometers to 150 nanometers are observed. Clearly, the diameter of nanostructures is not uniform. The lengths of the nanostructures ranges from several tens to several hundreds nanometers and some of them even have lengths on the order of micrometers.

Figure 3 shows EDS spectrum of the as-deposited ZnO products on copper substrate. The peaks in the pattern agree to Zn, Cu and O elements. The Cu signal is expected to arise from the substrate.

Figure 4 shows TEM bright field image of ZnO products on copper substrate with the inset of selected area electron diffraction pattern (SADP). From TEM image, it is suggested that ZnO products on copper substrate have belt-like nanostructures with the thickness of about ten nanometers and several hundreds nanometers wide. Also, from SADP analysis, it is confirmed that the products on copper substrate are ZnO nanobelts with single crystalline hexagonal structure.

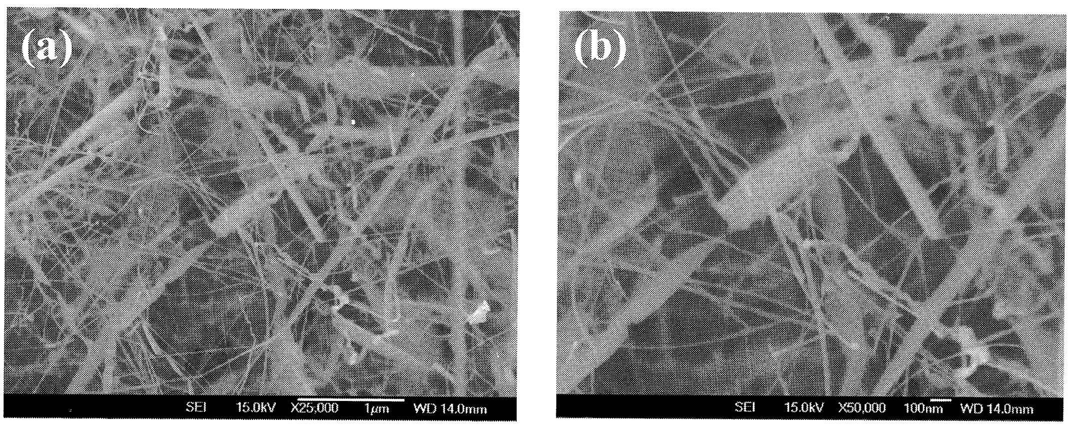

Figure 2. FE-SEM images of ZnO nanostructures on copper substrate at magnification of (a) 25000x and (b) 50000x.

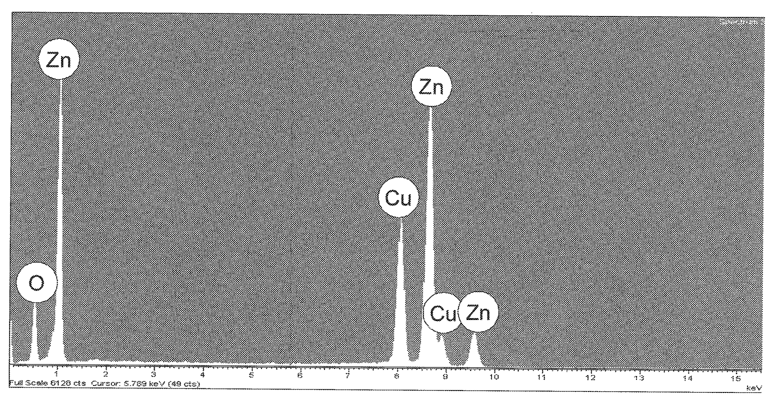

Figure 3. EDS spectrum of ZnO nanobelt.

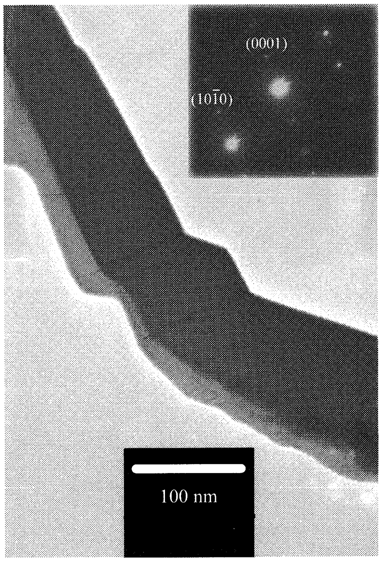

Figure 4. TEM bright field micrograph of ZnO nanobelt on copper substrate and inset the SADP of ZnO nanobelt.

4. Conclusion

We have successfully synthesized ZnO nanobelts on copper substrates by RF sputtering technique. The obtained ZnO nanobelts with cross-sectional size ranging from 10-150 nanometers are single crystalline hexagonal structure. These ZnO nanostructures could be further explored for the use as nano gas sensor.

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