

Thermal annealing effect on properties of Zn thin films deposited on Si (111) substrates by dc sputtering

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Zn films were deposited on silicon (111) by dc sputtering deposition technology from high purity Zn targets with a purity of 99.99 %. Then, annealing of Zn films was performed in air for 1 hour at 800 °C. The effects of annealing on the structural and optical properties of ZnO thin films on Si(111) substrates were investigated using atomic force microscopy (AFM), X-ray diffraction (XRD), and photoluminescence (PL) measurements. XRD patterns and AFM showed that the annealed ZnO films grown on Si(111) substrates have c-axis preferential orientation, the crystallinity of the ZnO films grown on Si (111) substrates was improved, and the grain size increased by thermal annealing. PL spectra is clearly visible at 382 nm for ZnO film grown on Si(111) substrates.

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1. Introduction

Zinc oxide (ZnO) is a wide band gap metal oxide semiconductor with a direct energy gap (3.37eV) and a larger exciton binding energy (60 meV), which assures more efficient exciton emissions at higher temperatures. The ZnO thin films have attracted significant attention as a wide gap semiconductor due to their wide range of electrical and optical properties. They have wide potential application in optoelectronics, electronics and information technology devices including sensors, displays, and solar cells.

Many different deposition methods, such as molecular beam epitaxy (MBE), metal organic chemical vapor deposition (MOCVD), sputtering chemical vapor deposition (CVD), pulsed laser deposition (PLD), spray pyrolysis and also the sol-gel technique, have been used for the growth of ZnO films on various substrates [1-9]. In many studies, ZnO nanostructures are grown on sapphire substrates, due to the same hexagonal type lattice structure. Compared with sapphire, silicon substrates are cheaper and available in large size.

Undoped ZnO usually contains various intrinsic defects such as Zn vacancies, interstitial Zn, O vacancies, interstitial O [10], and antisite O (O_{Zn}) [11]. These intrinsic defects form either acceptor level or donor level in the band gap that would greatly affect the optical properties of ZnO [10].

In this paper, we report the effect of annealing on properties of Zn thin films grown on silicon substrates by dc sputtering deposition technology from high purity Zn targets with a purity of 99.99 %.

2. Experiment

Zn films were deposited by dc sputtering deposition technology from high purity Zn targets with a purity of 99.99 %. Subsequent, annealing of Zn films was performed in air for 1 h at 800 °C. The thickness of ZnO film was determined by a surface step profile analyzer. Structural characterization using atomic force microscopy (AFM) and X-ray diffraction (XRD) (PANalytical X'pert PRO MRD) were carried out. The optical properties of ZnO layers were examined by PL spectroscopy at room temperature using a He-Cd laser (325 nm) as an excitation source.

3. Results and discussion

Fig. 1 shows the XRD patterns of the Zn films annealed in air grown on (111) Si substrates. It is clear that all the films show a preferential (0 0 2) orientation, indicative of a strong c-axis orientation perpendicular to the substrate surface. The intensity of the (0 0 2) annealed ZnO peak is stronger and sharper, and the full-width at half-maximum (FWHM) of the (0 0 2) ZnO peak for the annealed ZnO film is smaller. Since the (0 0 2) crystallographic plane has the lowest surface free energy, other planes require more energy to be developed. The average grain size in the annealed ZnO film estimated by Scherrer's equation is about 82 nm.

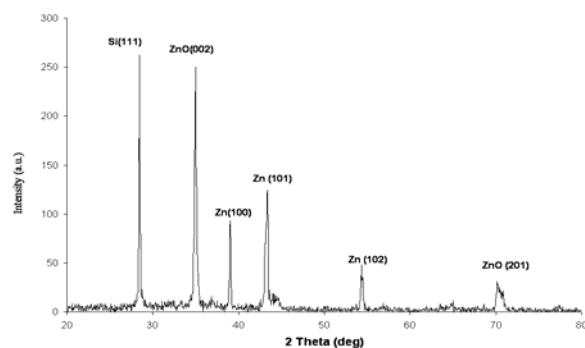


Fig. 1. X-ray diffraction (XRD) patterns of the Zn films grown on (111) Si substrates: (a) annealed sample.

Fig. 2. shows the AFM images of the annealed ZnO films. The grain sizes of the annealed sample are obviously larger than those of the as-grown Zn thin films sample, where estimates of the average grain sizes are as following: 15 nm for the annealed sample and 8 nm for the as-grown Zn thin film sample, which is consistent with the XRD results. At high annealing temperature, the atoms have sufficient activation energy to occupy the correct sites in the crystal lattice structure.

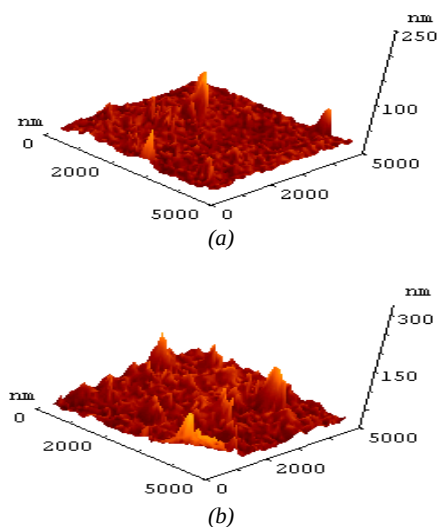


Fig. 2. AFM images of ZnO films: (a) as-grown Zn thin film; (b) annealed ZnO sample.

The PL spectra obtained from the surfaces of the ZnO thin film is depicted in Fig. 3. PL spectra is clearly visible at 382 nm for ZnO film grown on Si(111) substrates. The PL analysis indicates that the growth of ZnO thin film with the presence of the defect-related band. Yellow band emission is observed. Defects such as dislocation, residual dopants, or complex defects always cause inhomogeneous strain fields that broaden spectroscopic lines for electronic transitions. A few reports have also focused on ZnO thin films annealed in a nitrogen (N_2) ambient [12, 13]. Kong et al., [12] suggested that the Zn_i played a major role in the red emission of undoped ZnO films annealed in a N_2

ambient whereas the zinc vacancies (V_{Zn}) played a key role in the green emission of those annealed in an O_2 ambient.

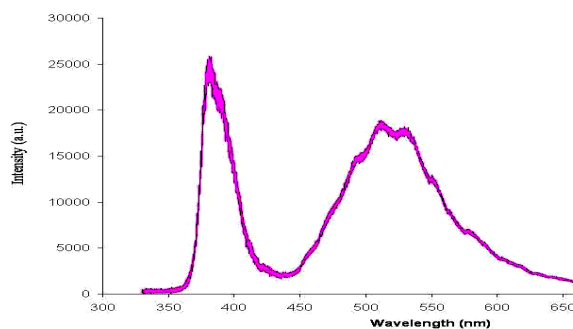


Fig. 3. PL spectra of the annealed ZnO film sample.

4. Conclusions

In conclusion, we have studied the thermal annealing effects on the structural and optical properties of Zn films grown on the (111) silicon substrates. The results show that the film quality, morphology and intensity of UV NBE peak are improved by annealing at 800 °C in air for 1 h. Room-temperature PL spectrum of the ZnO thin films shows a UV emission peak at ~382 nm and a green emission peak at ~513 nm, which can be ascribed to the near band-edge emission and the deep-level emission.

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