Property of gallium doped Zinc Oxide thin film deposited with various substrate temperatures using D.C. magnetron sputtering

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Abstract

In this paper, we study the effect of substrate temperature on property of Ga doped ZnO (GZO) thin film for transparent conductive oxide (TCO).GZO thin films have been deposited on corning glass 1737 by D.C. magnetron sputtering. We investigated the structural and electrical properties of GZO films using the X-Ray Diffractometer(XRD), Field Emission Scanning Electron Microscopy(FESEM) and 4-points probe .

1. Objectives and Background

A prerequisite material for flat panel display is transparent conductive oxide material. Nowadays, tin doped indium oxide (ITO) is commercial material for TCO. But ITO has some problem. Indium is not only expensive but also toxic material. Furthermore indium oxide is unstable in H_2 plasma. Therefore, there are many researches for alternative TCO materials. One of the alternative TCO materials is some elements such as B, Al, Ga, In and Ti doped zinc oxide because zinc is very abundant and non toxic material [1-5]. Also, doped ZnO thin film has low resisitvity and high transmittance in the range of visible light wavelength. There are many methods for thin film deposition on substrate like evaporation [6], spray pyrolysis [7], sol-gel method [8], chemical vapor deposition (CVD) [9], pulsed laser deposition (PLD) [10], molecular beam epitaxy (MBE) [11] and magnetron sputtering [12]. Among the mentioned method, D.C. magnetron sputtering method has some merits to deposit the thin film. For example, an easy deposition of large area, high deposition rate, low deposition temperature, good adhesion between film and substrate, good surface uniformity and simple equipment [13]

In this experiment, we research the influence of substrate temperature on structural and electrical properties of Ga doped ZnO thin film deposited by D.C. magnetron sputtering.

2. Experiments

Gallium doped zinc oxide thin films were deposited on corning glass 1737 using D.C magnetron sputtering. The target was fabricated by sintering the zinc oxide and gallium oxide (94.5:5.5 wt %). To prepare the substrate, we cleaned the corning glass with acetone and methanol, and rinsed it with D.I. water for ten minute in ultrasonic bath. The deposition chamber was evacuated at 2×10^{-6} torr pressure and Ar gas flowed into the chamber until 5×10^{-3} torr pressure. The deposition experiment was carried out with various substrate temperatures. The thickness of all of the specimens was fixed at 100 nm. We measured it using surface profiler (Alpha- Step 500, TENCOR, USA).

To investigate the structural property of the deposited film, X-Ray Diffractometer (XRD) and Field Emission Scanning Electron Microscopy (FESEM, s-48000, Hitachi,) were used. The resistivity of the deposited films was measured by 4-point probe(CMT-SR 1000N, Changmin tech).

3. Results

3.1 Structure and surface morphology

ZnO:Ga thin films were deposited with various substrate temperature. The structural property of deposited thin films are investigated by XRD and XRD pattern is shown in figure 1. In all of specimens, (002) and (004) preferred orientation peaks are observed at $2\Theta = 34.4 \pm 0.3$ °, 72.3 ± 0.3 °. The intensity of peak increases with increasing substrate temperature from 100 to 250 ℃, but the intensity of peak decreases when the substrate temperature is over the 250 ℃. The grain size and FWHM (full width half maximum) are shown in figure 2. The grain size is calculated by Sherrer's formula [14]. The formula is showed below.

$$D = \frac{0.9 \times \lambda_{CuK\alpha}}{\cos\theta\, \Delta(2\theta)}$$

From this formula, there is reversible relation between grain size and FWHM. Grain size of the deposited film has a similar tendency about the XRD intensity peak of GZO films. The surface morphology of deposited film with substrate temperature is investigated by FESEM and shown in figure 3. As mentioned above, the tendency of between grain size and substrate temperature is coincided with FESEM image.

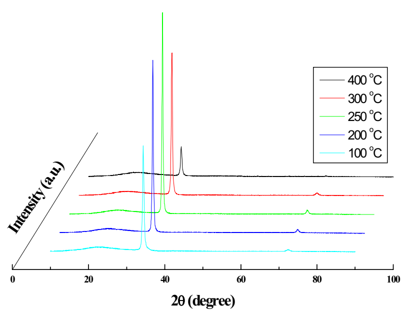


Figure 1. XRD pattern of GZO thin films deposited with various substrate temperatures

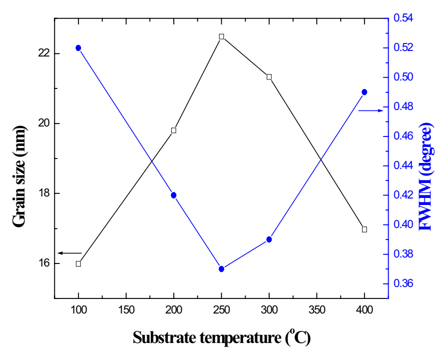
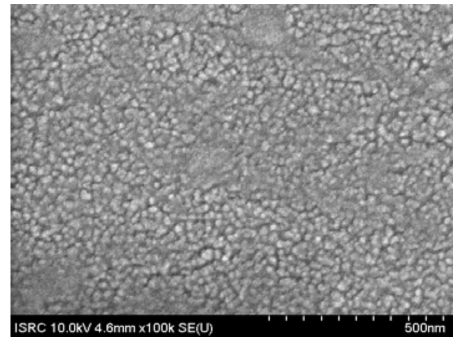
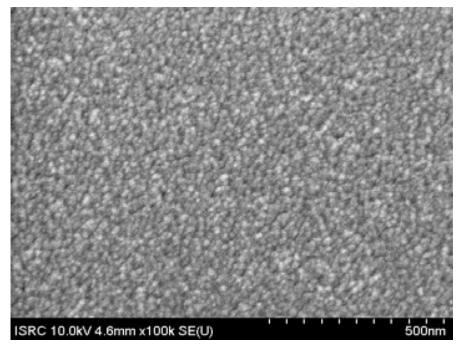


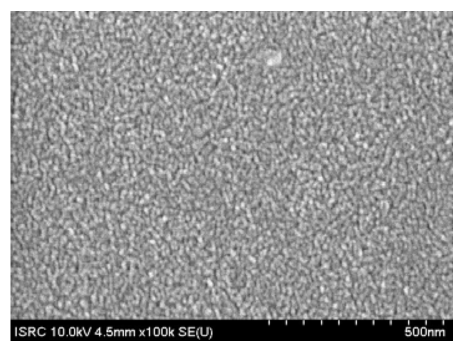
Figure 2. Full width at half maximum (FWHM) of XRD (002) peaks and the grain sizes for GZO films deposited with various substrate temperature



(a) 100 ℃



(b) 250 ℃



(c) 400 ℃

Figure 3. SEM image of surface for GZO deposited with various substrate temperature

3.2 Electrical property

The resistivity of GZO thin film was measured by 4 – point probe and shown in figure 4. As the substrate temperature was elevated to 250 ℃, the resistivity was decreased. But the resistivities of GZO films deposited at over the 250 ℃ are increased. This phenomenon may be concluded that incident particle on substrate can get the enough energy to move for stable site at below 250 ℃ [15]. Thus, more increasing the substrate temperature, the crystallinity of GZO thin film is more improving. Therefore, carrier mobility is increasing. However, at over the 250 ℃, zinc atom can get excess thermal energy to re-evaporate[16]. From this cause, carrier concentration and mobility decrease. In this experiment, we got the lowest resistivity of 5.3 $\times 10^{-4}$ Ω· ㎝.

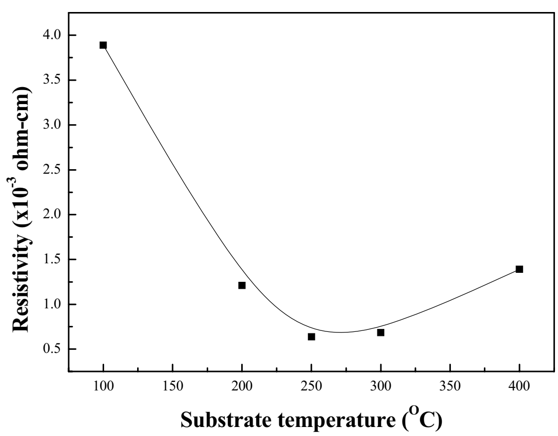


Figure 4. Electrical resistivity of GZO thin films deposited with various substrate temperature

3.3 Optical property

We measured the optical transmittance of GZO thin films deposited at substrate temperature of 100 to 400 ℃ using UV-Vis. Spectrometer. The transmittance of GZO films was shown in figure 5 and table 1. It was seen that all films exhibit average transmittance of above 80 % in the visible region except that GZO thin film was deposited at 100 ℃. As the substrate temperature was elevated to 250 ℃, the transmittance was increased. But the transmittance of GZO films deposited at over the 300 ℃ was decreased.

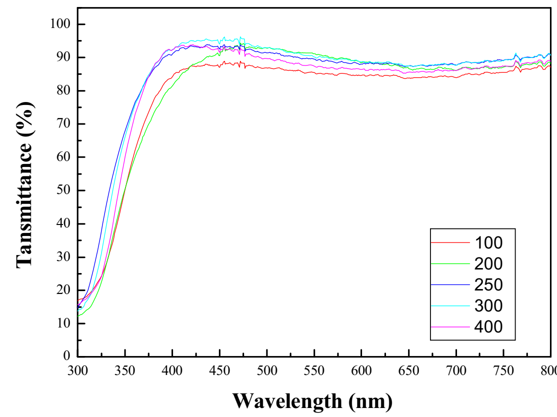


Figure 5. The transmittance of GZO thin films deposited with various substrate temperature

	100℃	200℃	250℃	300℃	400℃
T(%) / 550nm	85	91	90	90	87
T(%) / Vis range	78	81	84	84	82

Table 1. The transmittance value of GZO thin films deposited with various substrate temperature

4. Conclusion

In this experiment, GZO thin films were deposited with various substrate temperatures on corning glass 1737 using D.C. magnetron sputtering. The structural and electrical properties of GZO were investigated by some methods. Our first intention is to check the probability of GZO thin film for TCO. For this reason, we have researched the method of improvement for electrical property of ZnO film. Selection of dopant element and change of the deposition temperature are cases in that point. Thus, we obtained the lowest resisitivity of 5.3 $\times 10^{-4}$ Ω· ㎝ in the experiment. This value is enough lower to apply for TCO.

5. Acknowledgements

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6. References

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