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A Study on Surface Growth Direction and Particle Shape According to the Amount of Oxygen and Deposition Parameters

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Abstract

A zinc oxide thin film doped with aluminum was deposited by RF sputtering. The deposition temperature of the sputter chamber was kept constant at 350°C, the power supplied to the chamber was 75 W, the oxygen flow rate was changed to 10 sccm and 20 sccm, and the thin film deposition time was changed to 120 and 180 minutes. The structures of the deposited zinc oxide thin films were analyzed by van der Waals method using an X-ray diffractometer. As a result of X-ray diffraction, the amount of oxygen supplied to the zinc oxide thin film increased, and the surface growth of the (002), (400), (110), and (103) planes showed a change with increasing deposition time. Moreover, as the amount of oxygen supplied to the zinc oxide thin film increased, their shape was observed to be coarse, and the thin film' s particles shape was correlated with the oxygen chemical defect introduced.

Keywords: Zn0, Thin Films, Growth Surface, Defect

1. Introduction

Aluminum-doped semiconductor oxides have been extensively studied in recent years[1,2]. As thin films, they have been reported to have defects and electrical properties that depend on the thin film grain shape and growth direction[3,4]. Thin film growth methods include thermochemical vapor deposition[5,6], sputter deposition[7,8], and sol-gel method[9]. The sputtering method consists in ionizing a target by producing a plasma. This method is widely used because, for the same cost, it can deposit larger amounts of thin films than other deposition methods. The deposition temperature, the vacuum, and the voltage in the deposition chamber affect the plasma formation, and the initial conditions of the thin film may be changed. Zinc oxide (ZnO) has a wide energy gap, high transparency, it is easy to manufacture, and does not have toxic properties[10]. The amount of oxygen introduced and the zinc ion deficiency affect the stoichiometry of the entire ZnO thin film during manufacture[11]. The electrical and optical properties of ZnO affect the carrier density in the thin film. The stoichiometry may be imperfect on the surface and interface of the thin film, which may cause defects. The reason for the thin film carrier being generated depends on the amount of oxygen introduced into the chamber, the deposition time, the deposition temperature, and the vacuum state of the thin film[12,13]. In this study, the deposition temperature and power intensity were kept constant, the amount of oxygen introduced was increased from 10 to 20 sccm, and the deposition time was increased from 120 to 180 minutes. To investigate the structure of the grown thin film, the growth surface was observed using an x-ray diffractometer, and the shape of the thin film was visualized with an electron microscope. To investigate the stoichiometry of the thin film, the element composition ratio was investigated with EDX.

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2. Experimental Details

ZnO thin film doped with aluminum was produced by R-F sputtering. The target in the chamber was a Zn sample doped with Al (3%). MFC was used to control the amount of oxygen supplied to the thin film. To remove the organic substances present on the substrate

Table 1. Condition of Al-ZnO thin films

Sample	Power (W)	O Flow (sccm)	Deposition Temp (℃)	Deposition Time (min)
S1	75	10	350	120
S2	75	10	350	180
S3	75	20	350	120
S4	75	20	350	180

during deposition, the thin film was deposited after the preheating time. The deposition temperature was fixed at 350°C, and, during film growth, the vacuum pressure in the chamber was kept constant at 10^{-3} torr. The supplied voltage was adjusted so that the power intensity in the chamber was at constant 75 W. The amount of oxygen supplied to the thin film was varied to 10 sccm and 20 sccm, in order to examine different thin film shapes. The temperature of the silicon substrate was at constant 350°C, and the deposition time was changed to 120 and 180 minutes. The parameters of the thin films growth are shown in Table 1

3. Results and Discussion

Fig. 1 shows the X-ray diffraction pattern of the samples S1, S2, S3, and S4. As the thin film deposition time increased, the intensity of the (002), (400), (110), and (103) planes decreased in S1 and S2. In S3 and S4, the intensity of the (002) and (400) plane increased, while the (110) and (103) planes strength decreased. This shows that the (002) plane correlates with the amount of oxygen in the thin films.

Fig. 2 shows the thin film surfaces of S1, S2, S3, and S4. As the deposition time increased, the average particle size of S1 and S2 increased from 0.01 to 0.02 nm, and, in S3 and S4, the average particle size changed from 0.020 to 0.025 nm. This result shows that the (002) plane in the X-ray diffraction analysis is correlated to the growth intensity. The grain size of the thin film varies depending on the direction of the thin film surface growth. S1 and S2 are larger than S3 and S4, is that when the amount of oxygen introduced into the thin film is small, the stoichiometry of the thin film is well matched. The slower grain growth and the smaller particle size change as the deposition time is increased may be due to the stoichiometry of the thin film not being well matched.

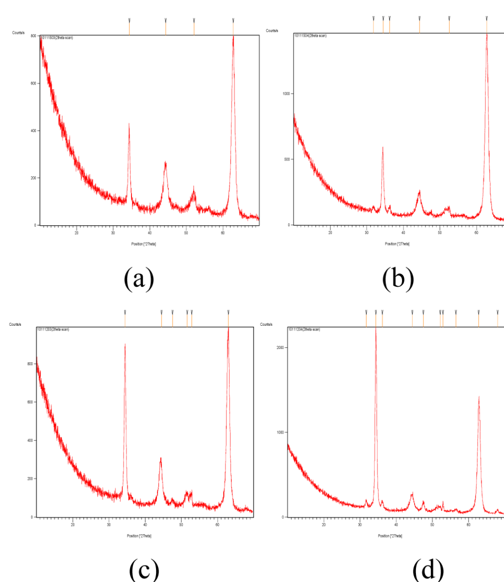

Fig. 1. X-ray diffraction patterns of Al doped ZnO thin films grown at 350°C. (a) S1, (b) S2, (c) S3, and (d) S4.

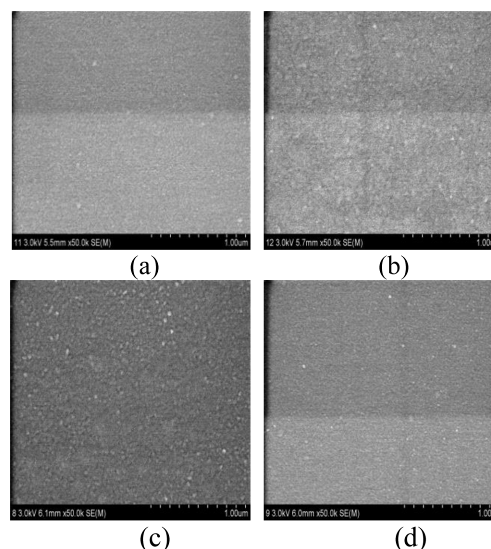

Fig. 2. SEM micrographs showing the surface morphology of Al doped ZnO thin films grown at 350°C. (a) S1, (b) S2, (c) S3, and (d) S4.

Fig. 3 is an elemental analysis of thin films S1, S2, S3, and S4. When the deposition time was increased, the component values of zinc ion decreased in all samples. Further, when the deposition time was increased,,

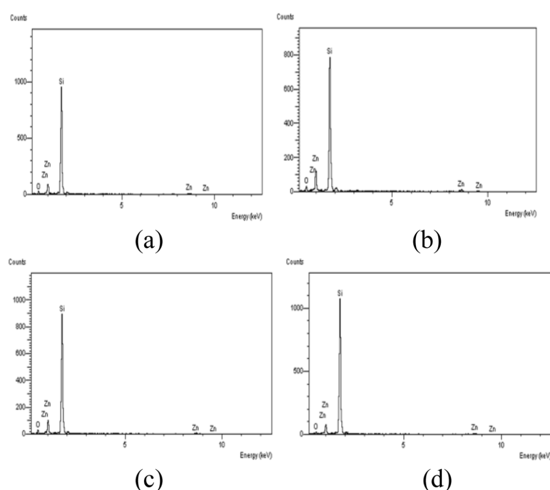

Fig. 3. EDX of Al doped ZnO thin films grown at 350°C. (a) S1, (b) S2, (c) S3, and (d) S4.

the value of Si components increased. No change in the amount of zinc atoms was observed as a result of a change in the oxygen content of the thin films, but the change in the amount of zinc atoms and silicon atoms due to the variation in the deposition time influenced the amount of oxygen introduced into the thin films.

4. Conclusions

It was observed that, rather than the amount of oxygen introduced, the change in the deposition time affected the surface growth of the thin films. In turn, the thin film grain sizes and the thin film elemental volume ratio affected the amount of change in the deposition time more than the amount of oxygen introduced. In conclusion, for thin films deposition, the change of the deposition time seems to be more important than the amount of oxygen added.

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