Effect of B-doping on the crystal structural and optical properties of zinc oxide thin films for photonic devices[1)]

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Abstract

Effect of B-doping B_2H_6 on the crystal structural and optical properties of zinc oxide (ZnO) thin films has been studied. The crystal orientation of these films were evaluated by X-ray diffraction. It was found that the (110) reflection peak was dominant for all the film and became less pronounced as the B_2H_6 flow rate was increased. The grain size of thin film decreased as B_2H_6 flow rate was increased. The transmittance in the ultra-violet wavelengths region shifted to higher energy as the B_2H_6 flow rate was increased. It was also found that the refractive index ZnO thin films increased as the B_2H_6 flow rate was further increased. These doping effects should be minimised in order to grow low resistivity ZnO film with excellent optical properties for application to photonic devices.

Keywords: doping, crystal structural, optical properties, transmittance, refractive index.

Sari

Efek doping boron (B) terhadap struktur kristal dan sifat optik lapisan tipis ZnO untuk divais optoelektronik

Telah dilakukan studi tentang pengaruh doping B_2H_6 terhadap struktur kristal dan sifat optik lapisan tipis ZnO. Orientasi kristal lapisan tipisnya dievaluasi dengan difraksi sinar-x. Diperoleh bahwa puncak refleksi (110) mendominasi seluruh film dan berkurang sejalan dengan penambahan laju aliran B_2H_6. Ukuran butir kristal dari film juga berkurang sejalan dengan penambahan laju aliran B_2H_6. Transmitansi pada daerah panjang gelombang ultra violet bergeser ke arah energi yang lebih tinggi sejalan dengan penambahan laju aliran B_2H_6. Ditemukan pula bahwa indeks bias lapisan tipis ZnO bertambah sejalan dengan penambahan laju aliran B_2H_6. Efek-efek doping tersebut harus diminimalkan agar dapat diperoleh lapisan ZnO beresistivitas rendah dengan sifat optik yang baik untuk aplikasi pada divais fotonik.

Kata kunci: doping, struktur kristal, sifat optik, transmitasi, indeks bias.

1 Introduction

Zinc oxide (ZnO) as a semiconducting, photoconducting, piezoelectric, and optical waveguide materials show a wide range of scientific and technological applications. The properties of ZnO include the optical transparency in the visible region, high refractive index, the anisotropy in crystal structure, the nonstoichiometric defect structure, the wide-band gap, large piezoelectric constants, and strong acoustooptical electrooptical and nonlinier optical coefficients[1)].

Undoped ZnO thin films usually show a low resistivity. However, the donor-like states are thermally unstable[2)]. To obtain films with a stable and low resistivity, doping process is necessary. The addition of dopant may influence the structural and optical properties of the films. This paper reports the result of a study on the effect of boron (B)-doping on the crystal structure and the optical properties of ZnO thin films.

2 Experimental

Metalorganic chemical vapor deposition (MOCVD) method was used to grow the film. Figure 1 shows a schematic diagram of the ZnO deposition system. Diethylzinc (DEZ) and H_2O as reactant gases. The B_2H_6 gas was used as n-type dopant gas. The DEZ and H_2O were contained in bubblers and were kept in temperature-controlled bath. The reactant gases were bubbled with Ar as carrier gas. The flow rates of DEZ/H_2O transported to the growth chamber were kept at 20 sccm. ZnO films were grown on a Corning 7059 glass substrate. Total pressure during the growth was kept at 1 Torr.

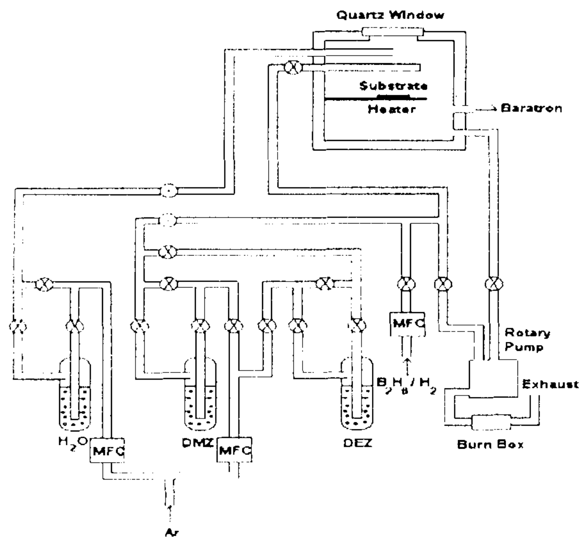

Figure 1 Schematic Diagram of the ZnO Deposition System.

The crystal orientation of the films were evaluated by X-ray diffraction and the optical properties were measured by the double-beam monochromator in atmospheric ambient.

3 Results and discussion

Figure 2 shows X-ray diffraction pattern of the undoped ZnO thin films. It can be seen that the (110) reflection peak was dominant for all the film, suggesting that the c-axis of the crystal was parallel with substrate surface. The effect of boron-doping process on crystal orientation was examined. Only (110) and (100) reflection peaks appear in all of those films. Figure 3 shows X-ray diffraction intensity ratio of the ZnO thin films ((110)/(100)) as a function of B_2H_6 flow rate. The (110) reflection peak became less pronounced as B_2H_6 flow rate was increased. This result indicates that the c-axis orientations are still parallel to the substrate surface with a different crystal orientation [3].

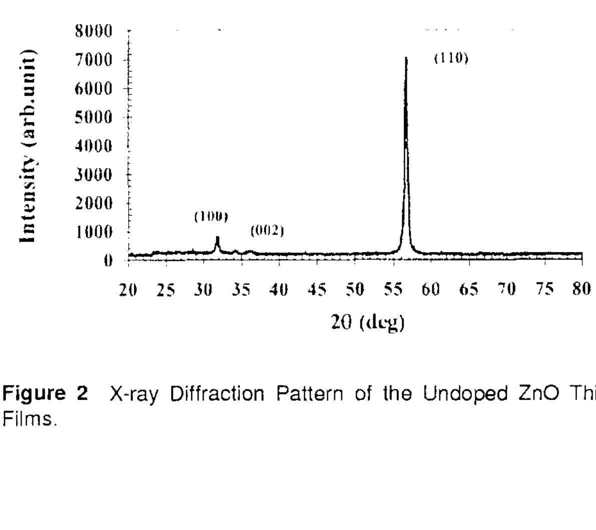

Figure 2 X-ray Diffraction Pattern of the Undoped ZnO Thin Films.

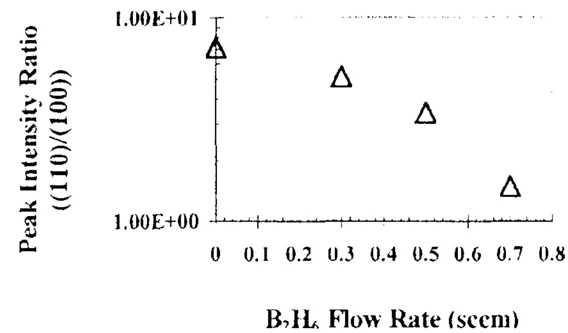

Figure 3 X-ray Diffraction Intensity Ratio of the ZnO Thin Films as a Function of B_2H_6 Flow Rate.

The grain size of films was also calculated from X-ray diffraction pattern data by using Scherrer's formula. As shown in fig. 4, the grain size changes with the B_2H_6 flow rate. It is found that the grain size of thin films decreases as B_2H_6 flow rate was increased. This result indicates that the grain size of crystal are affected by addition of boron atom into ZnO lattice, as a result of a change in the crystal orientation of the film.

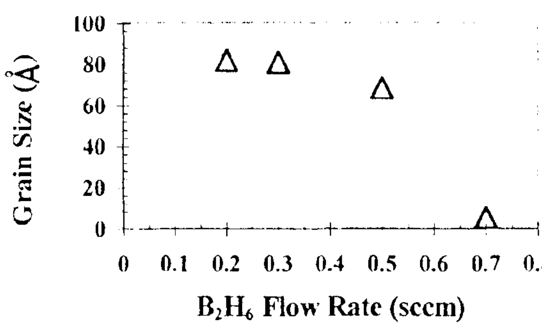

Figure 4 The Grain Size of ZnO Thin Films as a Function B_2H_6 Flow Rate.

For application to the photonics devices, ZnO thin films should have a high transparency. Therefore, the optical properties of the doped ZnO thin films were observed from the transmittance data measured at wavelengths region of ultraviolet, visible to near infra-red and the result is shown in Fig.5. It was found that the transmittance of ZnO thin films is transparent and has a high transmittance of around 90% at visible wavelength range. It can also be seen that the transmittance of the film in ultra-violet wavelengths region shifts to higher energy as B_2H_6 flow rate is increased. This phenomenon is known as Burstein-Moss shift[4].

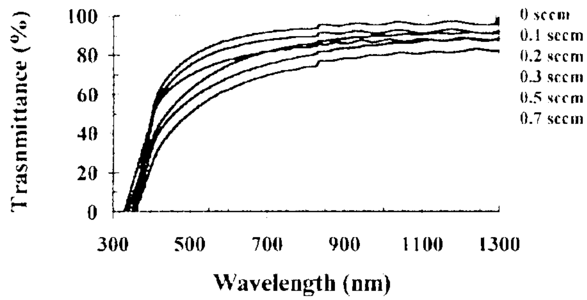

Figure 5 Transmittance of ZnO Thin Films Deposited at Various B_2H_6 Flow Rate.

The refractive index of the films is also evaluated from transmittance data. The refractive index is one of the important parameters which determines the reflectance of the film when they are used as window layer in photonic devices. The result of the estimated refractive index is shown in Fig 6. It is clear that the refractive index increases as B_2H_6 flow rate is increased.

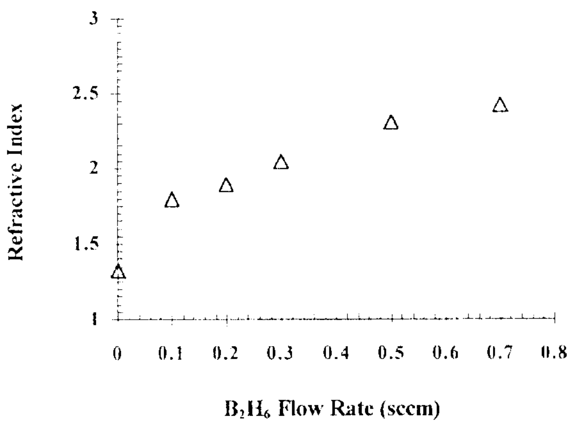

Figure 6 Refractive Index of ZnO Thin Films as a Function B_2H_6 Flow Rate.

4 Conclusions

Effect of B-doping on the crystal structural and optical properties of zinc oxide (ZnO) thin films has been studied. It was found that the (110) reflection peaks was dominant for all the films and became less pronounced as the B_2H_6 flow rate was increased. This result indicated that the c-axis orientations were parallel to the substrate surface. It was also found that the grain size of the film became smaller as the B2H6 flow rate was increased. The obtained film showed a high transparency at visible wavelength region, suggesting that they are suitable for being used as a transparent material in photonics devices.

5 Acknowledgement

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6 References

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