C−2−3 High Rate Deposition of ZnO Film Using Improved DC Reactive Magnetron Sputtering Technique

Tomonobu Hata, Toshiharu Minamikawa, Etsuji Noda and Toshio Hada

Faculty of Technology, Kanazawa University,

Kodatsuno 2, Kanazawa, Japan.

Introduction A zinc oxide (ZnO) thin film has been used in transducers for exciting a surface acoustic wave (SAW) on nonpiezoelectric substrates. Several techniques have been developed in recent years to deposit highly oriented films on nonpiezoelectric substrates. However, the deposition rate of the film is not so high from 0.2 to 1.5 μm/h. In order to increase the deposition rate we applied a planar reactive magnetron sputtering technique[1,2]. A novel point of our system is the use of a solenoid coil around a bell jar to increase the parallel component of the leakage magnetic lines. This greatly increased a beam current and deposition rate. We used a metal target and applied a dc reactive magnetron sputtering technique in 100% oxygen gas. Highly oriented ZnO film (c-axis orientation) were fabricated on the glass substrates with very high deposition rate (~10 μm/h).

Description of New Equipment Figure 1 shows a schematic diagram of the new reactive magnetron sputtering system. A disk of zinc metal (purity 99.99%) was used as a target. On the back of the target a coaxial type magnet (center is N) was fixed to produce a leakage flux on the target surface. Another solenoid coil was placed around a cylindrical bell jar to push away the leakage flux to the target surface. These two magnetic fluxes played an important role on this system. The shape of the magnetic lines visualized by a magnetic tape develpoer are shown in Fig. 2. Fig. 2(a) is for conventional magnetron sputtering and Fig. 2(b) is for our improved one. The application of these two magnetic fluxes greatly increase the beam current. An increase in the beam current corresponds to an increase in the deposition rate of the ZnO film. Fig. 3 shows the relation between the beam current and deposition rate. As this figure shows, deposition rate reaches more than ~10 μm/h. This value has not been attained by any other sputtering system. As 500 mA is the

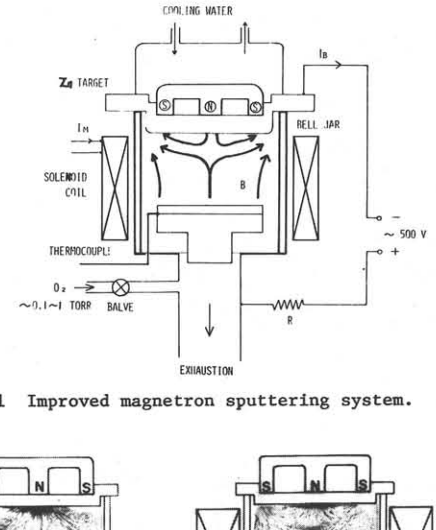

Fig.1 Improved magnetron sputtering system.

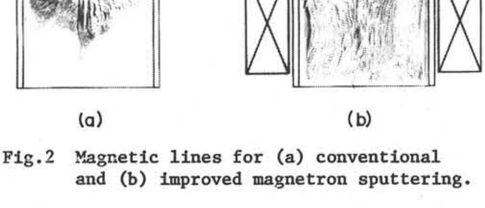

Fig.2 Magnetic lines for (a) conventional and (b) improved magnetron sputtering.

limit of our power supply, a higher deposition rate will be obtained at a larger beam current. The substrate was neither heated nor cooled during sputtering. The temperature shown in Fig.3 is the final one.

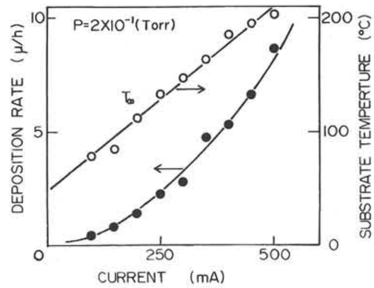

Fig. 3 Beam current dependence of deposition rate and substrate temperature.

<u>Film Evaluation</u> Sputtered ZnO film were first examined by X-ray diffraction using Cu-Kα ray. Fig. 4 is an X-ray diffraction pattern of the film sputtered on the glass slide. A diffracted peak is from (002) plane and it shows that a c-axis highly aligned film is obtained. Fig.4(b) shows the locking curve from (002) plane. A half width of around 5° or smaller is obtained for any film which is sputtered at 0.1~0.4 Torr.

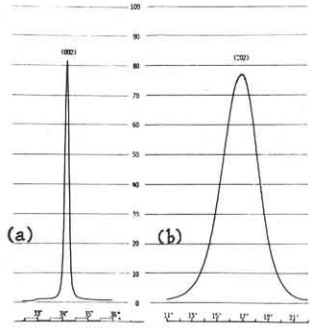

Fig. 4 X-ray diffraction spectra. (a) (002) peak, (b) locking curve.

Fig.5 shows a typical reflection electron diffraction pattern (HEED) for the sputtered film.

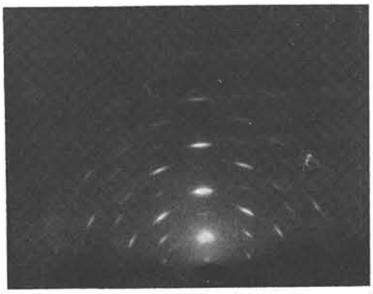

Fig. 5 Reflection electron diffraction pattern highly oriented c-axis normal ZnO film.

Fig. 6 shows the relation between the deposition rate and oxygen gas pressure for relatively new target. The deposition rate for well-used target is higher more than two times than that for a new target. The maximum value for deposition rate is obtained around 0.2~ 0.4 Torr. Qualities of the film estimated by the X-ray diffraction pattern and the colour of the films are also shown in the figure.

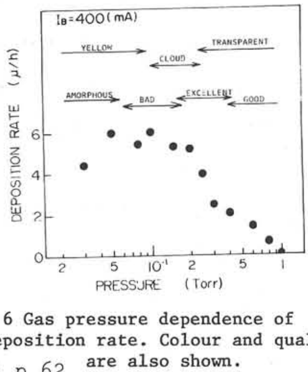

Fig. 6 Gas pressure dependence of deposition rate. Colour and qualities are also shown.

<u>Conclusion</u> A new type of dc reactive magnetron sputtering technique was shown. Characteristics are described below.

(1) Deposition rate increases with increasing beam current and it attains ~10 μm/h for 500 mA beam current. It will be increased an order for larger beam current.

(2) Excellent ZnO films were obtained at 0.2~ 0.4 Torr oxygen gas pressure. They can reproduce very easily.

(3) This technique can be applied to any sputtering system to obtain a high rate deposition.

<u>References</u> 1) T.V.Vorous, Solid State Tech.,(Dec. 1976) p.62
2)R.W.Wilson and L.E.Terry, J. Vac. Sci. Tech. <u>13</u>, 1,(1976)p.157