JOURNAL OF MATERIALS SCIENCE **39** (2004) 3235– 3236

Room temperature growth of high quality ZnO thin film on sapphire substrates

NAM HO KIM, HYOUN WOO KIM*
School of Materials Science and Engineering, Inha University, Yonghyun-dong, Nam-ku, Incheon 402-751, Korea
E-mail: hwkim@inha.ac.kr

Zinc oxide (ZnO) is a versatile material for many applications due to its structural, electrical, and optical properties [1]. The ZnO films have been grown by various deposition methods, such as sputtering [2, 3], sol-gel process [4], spray pyrolysis [5, 6], chemical vapor deposition (CVD) [7, 8], and molecular beam epitaxy (MBE) [9–11]. Among them, the best technique is the sputtering method due to its simplicity and the possibility of obtaining good orientation and uniform films even at low deposition temperature. We have grown ZnO film on sapphire substrate at room temperature using the RF magnetron sputtering system. Since the most essential process is the collision of metal atoms and reactive gas molecules on the substrate, we have varied the RF power for changing the collision energy and obtaining the high quality film. Although many researchers have studied on ZnO films, there are rare reports on growing the highly crystalline ZnO thin films at room temperature.

The ZnO film was deposited on sapphire (001) substrates. Before loading into the reactor, the substrate was cleaned in acetone for 10 min then rinsed by deionized water for one minute. In this experiment, we have used a ZnO (99.99% purity) target with a diameter and a thickness of 75 and 6 mm, respectively. A schematic diagram of the RF sputtering system used in our experiments is previously reported [12]. RF sputtering was carried out in an Ar (99.99% purity) gas atmosphere by supplying RF power of 80–250 W at a frequency of 13.56 MHz. The flow rate of the Ar gas was set to 30 sccm. The distance between target and substrate was about 80 mm. The ZnO film was grown at room temperature at a pressure of 5.0×10^{-2} Torr. Before deposition, the pressure of the RF sputtering system was about 6×10^{-6} Torr. The structural characteristics of the films were analyzed by X-ray diffraction (XRD) using Cu K_{a1} radiation ($\lambda = 0.154056$ nm) and by scanning electron microscopy (SEM) (Hitachi S-4200).

Fig. 1 shows XRD patterns of ZnO thin films deposited on sapphire substrates at 25 °C with an RF power ranging from 80–250 W. Especially, the θ-2θ scan data of ZnO films with the RF powers of 150–200 W exhibit a strong 2θ peaks at 34.438°, corresponding to the (002) peaks of ZnO. The XRD data of the films grown with the RF powers of 150–200 W indicate that the strong (002) peak is observed and the other peaks are not observed, revealing the high degree of c-axis orientation. Also, the XRD patterns of the ZnO film indicates that full-width at half-maximum (FWHM) of the (002) diffraction peak is about 0.26° at an RF power of 150 W.

Fig. 2 shows the cross-sectional and plain-view (inset) SEM image of ZnO thin films grown at 25 °C with an RF power ranging from 80–250 W. In order to exclude the thickness effect, we have fixed the thickness of ZnO layers to be about 500–600 nm. When the RF power is 250 W, the ZnO film structure consists of many grains with random orientation. When the RF power decreases from 250 to 150 W, the grain structure looks more columnar. We surmise that the randomly oriented grain structures changes to the columnar grain structures with decreasing the RF power from 250 to 150 W. The SEM images agree with XRD data. At much lower powers of 80–100 W, the films have been exfoliated from the substrates during growth. We surmise that excessive RF power induces the faster reaction rate and possibly the severe surface damage, resulting in the poor crystalline quality. However, too small RF power may contribute to the over-growing of *c*-axis oriented grains and thus the larger lattice mismatch between the film and substrate may cause the strain relaxation, resulting in the film decohesion. Since we cannot understand the detailed mechanism at this

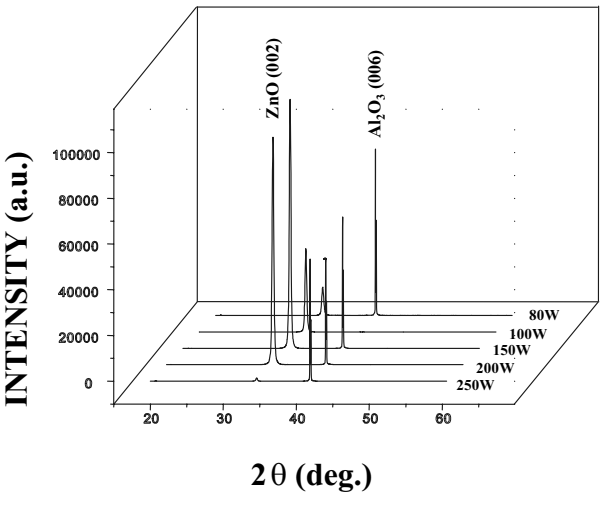

Figure 1 XRD patterns of ZnO thin films on sapphire substrates with growth temperature of 25 °C and RF powers of 80–250 W.

*Author to whom all correspondence should be addressed.

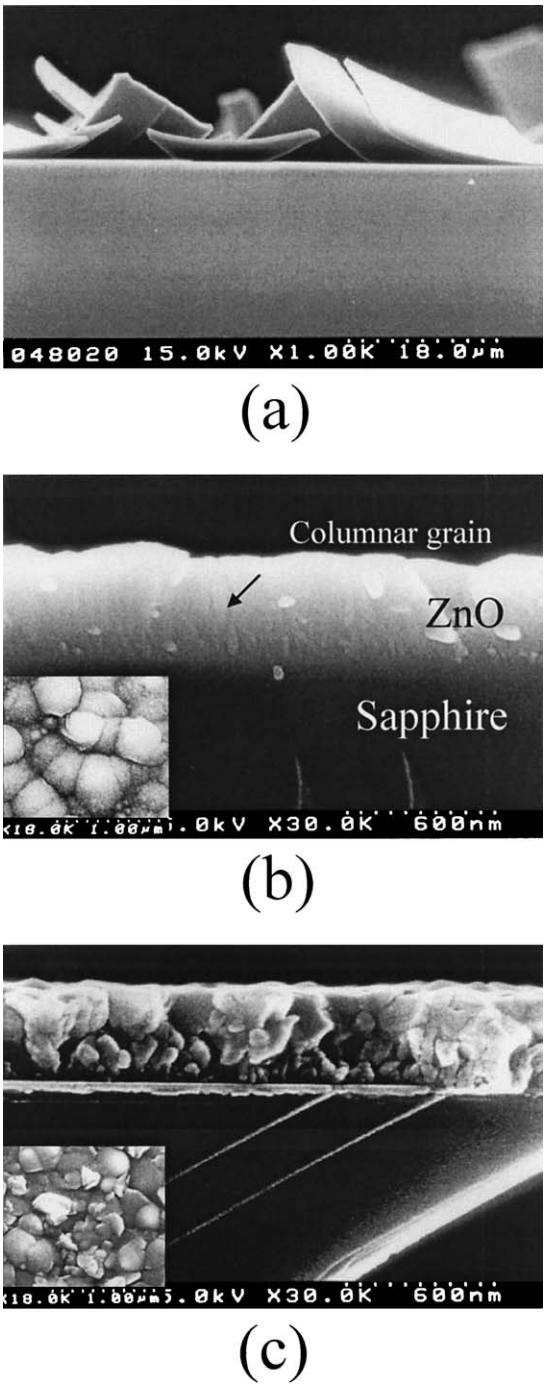

Figure 2 SEM images of ZnO film grown at 25 °C with the RF power of (a) 80 W, (b) 150 W, and (c) 250 W.

moment, further study is underway to understand this observation.

In conclusion, we demonstrate the growth of ZnO thin film on sapphire substrate at 25 °C, using the RF magnetron sputtering system. XRD and SEM coincidentally reveal that the growth of *c*-axis-oriented and highly crystalline ZnO thin film is achievable even at room temperature by using the RF sputtering method. This result will be useful for increasing the potential application of ZnO film on electronic and optoelectronic devices.

Acknowledgment

This work was supported by Inha University Research Grant (INHA-22098).

References

1. C. R. GORLA, N. W. EMANETOGLU, S. LIANG, W. E. MAYO, Y. LU, M. WRABACK and H. SHEN, *J. Appl. Phys.* **85** (1999) 2595.
2. R. ONDO-NDONG, F. PASCAL-DELANNOY, A. BOYER, A. GIANI and A. FOUCARAN , *Mater. Sci. Eng.* B **97** (2003) 68.
3. B. X. LIN, Z. X. FU and Y. B. JIA, *Appl. Phys. Lett.* **79** (2001) 943.
4. J.-H. LEE, K.-H. KO and B.-O. PARK, *J. Cryst. Growth* **247** (2003) 119.
5. R. AYOUCHI, F. MARTIN, D. LEINEN and J. R. RAMOS-BARRADO, *ibid.* **247** (2003) 497.
6. B. J. LOKHANDE, P. S. PATIL and M. D. UPLANE, *Mater. Lett.* **57** (2002) 573.
7. B. S. LI, Y. C. LIU, D. Z. SHEN, J. Y. ZHANG, Y. M. LU and X. Q. FAN, *J. Cryst. Growth* **249** (2003) 179.
8. G. DU, J. WANG, X. WANG, X. JIANG, S. YANG, Y. MA, W. YAN, D. GAO, X. LIU, H. CAO, J. XU and R. P. H. CHANG, *ibid.* **243** (2003) 439.
9. K. IWATA, P. FONS, S. NIKI, A. YAMADA, K. MATSUBARA, K. NAKAHARA, T. TANABE and H. TAKASU, *ibid.* **214/215** (2000) 50.
10. Y. F. CHEN, N. T. TUAN, Y. SEGAWA, H. J. KO, S. K. HONG and T. YAO, *Appl. Phys. Lett.* **78** (2001) 1469.
11. D. M. BAGNALL, Y. F. CHEN, Z. ZHU, T. YAO, S. KOMAYA, M. Y. SHEN and T. GOTO, *ibid.* **70** (1997) 2230.
12. H. W. KIM, K. S. KIM and C. LEE, *J. Mater. Sci. Lett.* **22** (2003) 1117.

Received 2 October
and accepted 11 November 2003