Growth of ZnO thin film on SiO_2 substrates by the RF magnetron sputtering method

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In recent years, ZnO thin films have been extensively studied for surface acoustic wave (SAW) devices, optical wave-guides, and transparent conducting coatings [1]. Since ZnO has a wide band gap of 3.37 eV, low power threshold for optical pumping at room temperature, and UV emission resulting from a large exciton binding energy of 60 meV, it can be used in light emitting diodes (LED), photodetectors, electroluminescence devices and the next generation of UV lasers. ZnO films have been grown by various deposition methods, such as sputtering [2], sol-gel process [3], spray pyrolysis [4, 5], pulsed laser deposition [6, 7], ion beam deposition [8], plasma enhanced chemical vapor deposition (PECVD) [9], atomic layer deposition (ALD) [10], filtered cathodic vacuum arc technique [11], evaporation [12], metal-organic chemical vapor deposition (MOCVD) [13], and molecular beam epitaxy (MBE) [14]. Among them, one of the most commonly used techniques is a sputtering method due to its simplicity and the possibility of obtaining good orientation and uniform films even on amorphous substrate or at low growth temperature. Since amorphous substrates such as SiO_2 and glass substrate have obvious technological advantages and potential applications [15], we have grown ZnO film on SiO_2 substrate using a RF magnetron sputtering system. Although many researchers have grown ZnO films on sapphire, Si or glass substrates, there are few reports on growing ZnO thin films on SiO_2 using a RF sputtering technique.

The ZnO film was deposited on SiO_2 substrates. The SiO_2 layer had been thermally grown with a thickness of 60 nm. Before loading into the reactor, the substrate was cleaned in acetone for 10 min then rinsed in deionized water for one minute. In this experiment, we used a ZnO (99.99% purity) target with a diameter and a thickness of 75 mm and 60 mm, respectively. Fig. 1 shows a schematic diagram of the RF sputtering system used in our experiments. RF sputtering was carried out in an Ar (99.99% purity) gas atmosphere by supplying RF power of 300 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 200 °C temperature at a pressure of 5.0×10^{-2} Torr and deposition was carried out for 30 min. 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 CuKa1 radiation ($\lambda = 0.154056$ nm) and by scanning electron microscopy (SEM) (Hitachi S-4200).

Fig. 2 shows XRD patterns of ZnO thin films on SiO_2 substrates at 200 °C and 300 W. The θ-2θ scan data of ZnO films exhibits a strong 2θ peak at 34.438 °, corresponding to the (002) peaks of ZnO.

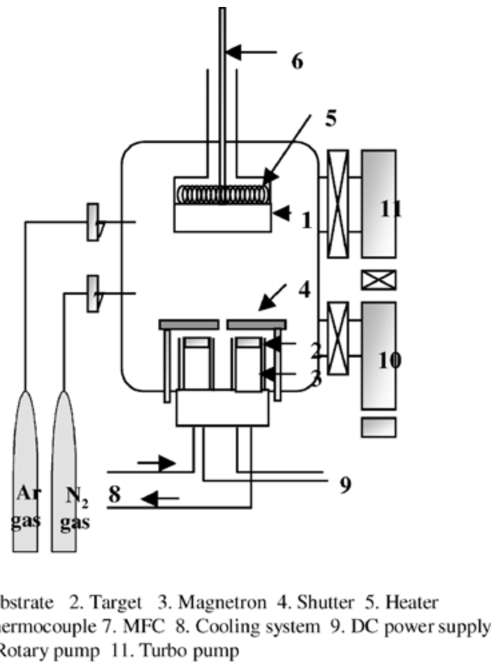

Figure 1 Schematic diagram of RF magnetron sputtering system.

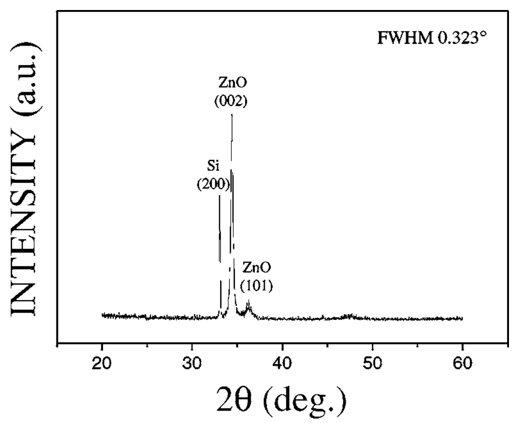

Figure 2 XRD patterns of ZnO thin films on SiO_2 substrate with growth temperature of 200 °C and 300 W.

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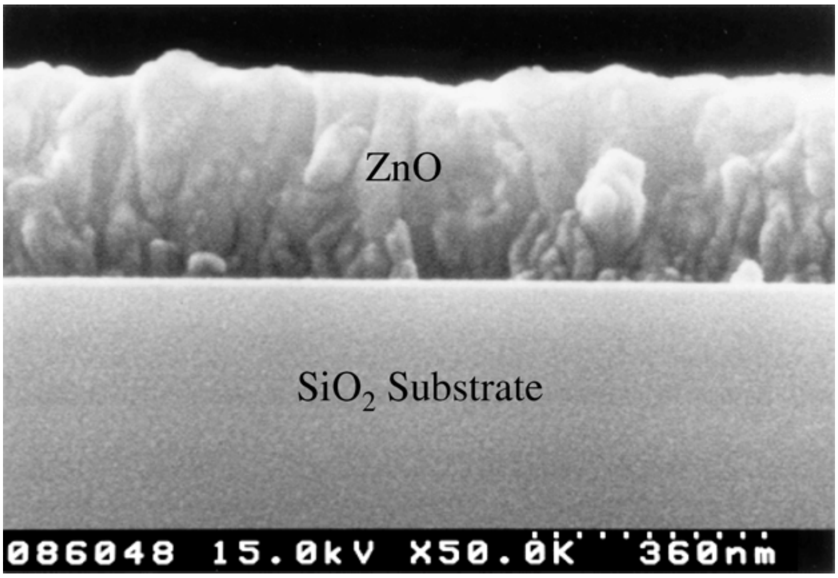

Figure 3 Cross-sectional SEM image of ZnO film grown on SiO_2 substrate.

The observation of the strong (002) peak indicates that the film is grown with a c-axis orientation. The film has other peaks such as (101), (100), etc., corresponding to the granular structure of the film. Furthermore, investigation of the XRD patterns of the ZnO film grown on SiO_2 substrate indicates that full-width at half-maximum (FWHM) of the (002) diffraction peak is about 0.323° at a growth temperature of $200\,^\circ C$.

Fig. 3 shows the SEM image of ZnO thin films grown on SiO_2 substrate at $200\,^\circ C$ and 300 W. The thickness of ZnO layers was measured and found to be 300 nm. The ZnO film structure consists of some columnar-structured grains, representing c-axis oriented grains. This agrees with XRD data. Since we do not understand the detailed growth mechanism at this time further study is underway to understand this observation.

In conclusion, we have demonstrated the growth of ZnO thin film on SiO_2 substrate at $200\,^\circ C$ and 300 W, using the RF magnetron sputtering system. XRD data reveals that the ZnO film is highly c-axis-oriented and the line width of the ZnO (002) peak is significantly small, corresponding to FWHM of 0.323°. We revealed by XRD and SEM that the growth of a c-axis-oriented ZnO thin film on SiO_2 substrate is achievable by using the RF sputtering method. This result will be useful for increasing the potential application of ZnO film in electronic and optoelectronic devices.

Acknowledgments

This work was supported by grant No. R05-2001-000-00843-0 from the Basic Research Program of the Korea Science & Engineering Foundation.

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Received 10 March and accepted 9 April 2003