Characterization of Zinc Oxide Thin Films for Gas Sensing Applications through Sputter Deposition and Thermal Annealing

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Abstract

ZnO is a strategic material for various sensing application. We have deposited the thin film of zinc oxide (ZnO) on silicon dioxide (SiO_2) substrates from room temperature using Radio frequency (RF) magnetron sputtering method. We present our results on characterization of these thin films of ZnO deposited by RF sputtering and post annealing methods. The characterization techniques involved, X-Ray Diffraction (XRD) and energy dispersive X-ray (EDX). ZnO thin films by sputter have been annealed at different temperatures from 200^0C to 400^0C for gas sensing applications.

*Keywords:*RF magnetron sputtering, ZnO Thin Film, Annealing, Energy dispersive X-ray and X-Ray Diffraction.

Introduction

Zinc oxide is attracting significant attention in this regard as it is a wide direct band-gap oxide semiconductor that has been identified as having significant potential application in electronic, optoelectronic and information technology device platforms due to its electrical and optical properties [1, 2]. Several thin film deposition techniques have been demonstrated to produce pure ZnO films, including sputtering [3], molecular beam epitaxy [4], and metal-organic chemical vapour deposition [5]. ZnO a wide band gap (3.4 eV) II-VI compound semiconductor, has a stable wurtzite structure with lattice spacing a = 0.325 nm and c = 0.521 nm. It has attracted intensive research effort for its unique properties and versatile applications in transparent Electronics, ultraviolet (UV) light emitters, piezoelectric devices, and chemical sensors. ZnO is a transparent oxide semiconductor (Eg~3.3 eV at 300 K). RF magnetron sputtering enables large area deposition of ZnO films with microcrystalline phase without intentional substrate heating. Post deposition oxygen in the ZnO films is unstable and easily desorbed from the films by thermal annealing [6].

Experimental detail

A p type silicon substrate of 3 inch diameter with <100> orientation was used in this experiment. The resistivity of the wafer was 1-10 ohms-cm and the thickness of wafer was about 400 µm. A standard RCA cleaning process is used to removing the contamination from the wafers. We have taken the SiO_2 substrate and grow the oxide layer (oxide thickness – 100nm and grown at a temperature of 1100 °C). After that ZnO thin film was deposit by RF sputtering.

The target used for fabrications of zinc oxide films was cylindrical metallic zinc with 99.95% purity of 6 inch diameter and 5–6 mm thickness. Magnetron sputtering was carried out in oxygen (60%) and argon (40%) mixed gas atmosphere by supplying RF power at a frequency of 13.56 MHz high-purity mixed oxygen-argon gas mixer was introduced during deposition raising the pressure in the chamber to 1.1 x 10^{-5} Torr. Oxygen concentration in the sputtering gas was 60% and the sputtering power was 500 W. The target to substrate distance was 15 cm and was kept fixed for each deposition runs. ZnO films were characterized for structure, morphology and orientation by X-Ray Diffraction. Film thickness was measured by surface profilometer. The resulting thickness of all the films is about 1975Å. Annealing the ZnO thin films were done in air by using Oxidation Furnace between 200 ^{0}C to 400 ^{0}C for a period of 30 min. XRD patterns of the films were recorded with the help of Spectrometer (M/s Bruker X-ray Diffractometer) using CuKα radiation.

Results and Discussion

Film thickness was measured by Surface profilometer. The resulting thickness of all the films is about 1975Å. To determine the crystal orientation XRD

Spectrometer m/s Bruker was used. The (002) peak of ZnO is found to overlap. Measurements of EDX revealed that post-deposition annealing has affected the oxygen concentration in the film very slightly. Fig.-3 shows the XRD pattern of thin ZnO film annealed at different temperatures in the range 250 °C to 400 °C. It is evident that in the figure there are some similarities of specific crystalline orientations where as in the case of annealed samples below 250 °C does not show the clear orientation values. With the increase of temperature the specific orientations dominate indicating the influence of oxygen and its presence in the sputter deposited films. Film annealed at 350 °C has additional phases and probably it is a better temperature suitable for gas sensing applications.

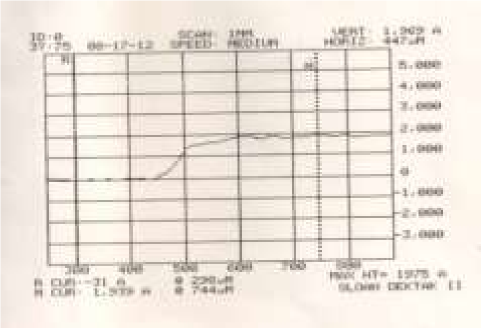

Fig. (1)

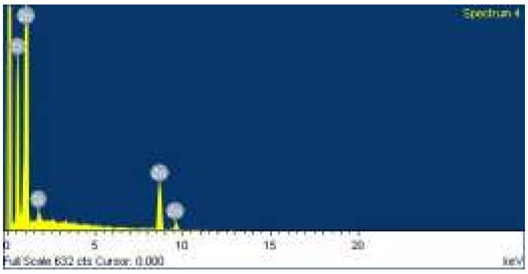

Fig. (2) EDX image of ZnO thin film sample.

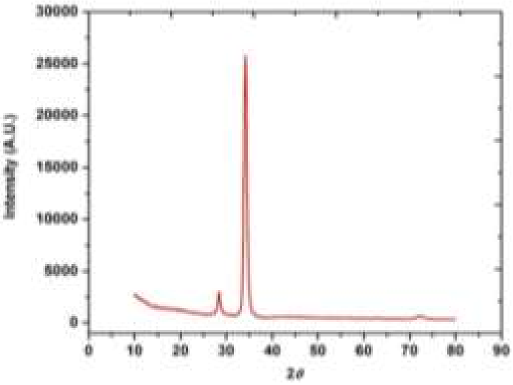

Fig. 3(a) XRD Image of Annealed at 300 °C.

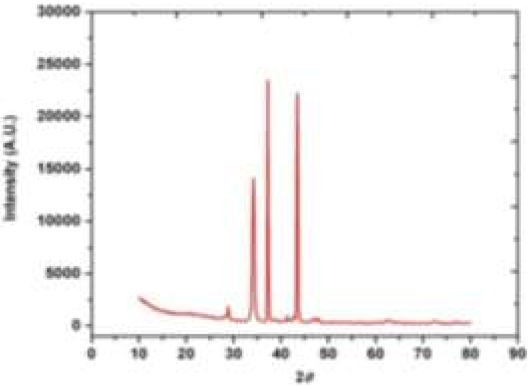

Fig. 3 (b) XRD Image of Annealed at 350 °C

Fig.1. Thickness measurement of ZnO using surface profiler. Fig.2. EDX image of ZnO thin film sample. Fig. 3 (a)-(b) XRD patterns of the as-grown the ZnO thin films at different annealed temperature.

Conclusions

The influence of post-annealing (250°C to 400°C in air) on the properties of ZnO sputtered thin films was analysed. This indicates that the ZnO films on all the data are preferably c-axis oriented.

Acknowledgement

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References

[1] S.J. Pearton, C.R. Abernathy, M.E. Overberg, G.T. Thaler, F. Ren, J. Kim, “Wide band gap ferromagnetic semiconductors and oxide”, J. Appl. Phys. 93 (2003) 1.

[2] Y. Natsume, H. Sakata, “Zinc Oxide films prepared by sol-gel spin-coating”, Thin Solid Films 372 (2000) 30.

[3] P. Nunes, D. Costa, E. Fortunato, “Performances presented by zinc oxide thin films deposited by r.f. magnetron sputtering”, Vacuum 64 (2002) 293.

[4] D.C. Look, D.C. Reynolds, C.W. Litton, R.L. Jones, D.B. Eason, G. Gantwell, “Characterization of homoepitaxial *p*-type ZnO grown by molecular beam epitaxy”, Appl. Phys. Lett. 81 (2002) 1830.

[5] K. Tominaga, T. Takao, A. Fukushima, T. Moriga, “Amorphous ZnO–In2O3 transparent conductive films by simultaneous sputtering method of ZnO and In2O3 targets”, Vacuum 66 (2002) 505.

[6] T. Hiramatsu, M. Furuta, H. Furuta, T. Matsuda, T. Hirao, “Influence of Thermal Annealing on Microstructures of Zinc Oxide Films Deposited by RF Magnetron Sputtering”, Jpn. J. Appl. Phys. 46 (2007) 3319-3323.