Oxygen Partial Pressure Dependent Properties of Nanocrystalline Nickel Oxide Films

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Abstract Nickel oxide thin films have been successfully deposited by dc reactive magnetron sputtering technique on glass substrates at different oxygen partial pressures. X-ray diffraction analysis revealed that the preferred orientation changed from (200) to (220) with increasing oxygen partial pressure. Fine grains with RMS roughness of 9.4 nm were observed at an oxygen partial pressure of 6×10^{-4} mbar.

Keywords Oxide coating · Sputtering · Oxygen partial pressure · Surface morphology

1 Introduction

Nickel oxide is a semi-transparent, wide band gap, and p-type transparent conducting oxide. In the fabrication process of electronic and optoelectronic oxide semiconductor devices, it is necessary to combine a p-type and an n-type semiconductor to form p-n junction. However, most of the oxide semiconductor materials show n-type properties because cation interstitials formed much more easily than anion interstitials. As a candidate of p-type oxide semiconductor, nickel oxide thin films with NaCl-type structure have a variety of applications due to excellent chemical stability,

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as well as optical, electrical, and magnetic properties [1]. Several techniques like spray pyrolysis [2], sputtering [3], vacuum evaporation [4], electron beam evaporation [5], chemical deposition [6], sol–gel [7], pulsed laser deposition [8] and plasma-enhanced chemical vapor deposition [9] have been employed for the deposition of NiO thin films. Among these methods, reactive sputtering is considered to be the most widely useful technique having high deposition rates, uniformity over large areas of the substrates and easy control over the composition of the deposited films. In the present study, NiO thin films were deposited using dc reactive magnetron sputtering technique and studied the effect of oxygen partial pressure on the structural and morphological properties.

2 Experimental Details

Nickel oxide thin films were deposited on Corning 7,059 glass substrates by dc reactive magnetron sputtering at various oxygen partial pressures. The sputtering conditions maintained during the growth of NiO films were as follows: Sputtering target is pure Nickel (99.98 %), target to substrate distance was maintained as 70 mm, ultimate pressure in the chamber was 5×10^{-6} mbar. Nickel oxide films were deposited in the oxygen partial pressure range of 4×10^{-4}–8×10^{-4} mbar at a sputtering power of 150 W, substrate temperature of 523 K and sputtering pressure of 4×10^{-2} mbar.

3 Results and Discussion

All the deposited films were polycrystalline in nature with cubic structure. At the oxygen partial pressure of 4×10^{-4} mbar, the films showed (220) orientation along with (200), on further increasing the oxygen partial pressure to 6×10^{-4} mbar the intensity of the (220) peak was increased and becomes sharper, and (200) peak was disappeared. Beyond this oxygen partial pressure, the intensity of the (220) peak was decreased (Fig. 1). The grain size of the films was calculated from the (220) orientation by using Scherrer formula [10]. The grain size of the films increased from 28 to 29 nm with increase of oxygen partial pressure from 4×10^{-4} to 6×10^{-4} mbar, thereafter it was decreased to 22 nm at higher oxygen partial pressure. The decreasing of the grain size was attributed to the segregation of oxygen into the grain boundaries, which causes limited grain boundary mobility, and therefore a decrease in grain size [11]. Figure 2 shows the AFM images of NiO films at different oxygen partial pressures (Fig. 2). The surface roughness of the films was reduced from 11.2 to 9.4 nm with increasing of the oxygen partial pressure from 4×10^{-4} to 6×10^{-4} mbar. Beyond this oxygen partial pressure the films getting rough with RMS roughness of 10 nm. From the histograms (Fig. 3), the grain size of the films was 29, 41 and 25 nm for oxygen

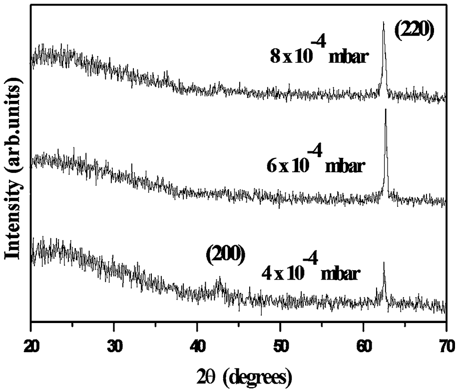

Fig. 1 X-ray diffraction profiles of NiO films at various oxygen partial pressures

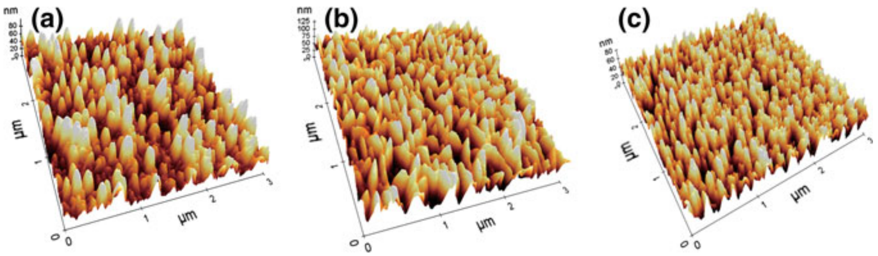

Fig. 2 AFM images of NiO films at different oxygen partial pressures **a** 4 × 10^{-4} mbar **b** 6 × 10^{-4} mbar **c** 8 × 10^{-4} mbar

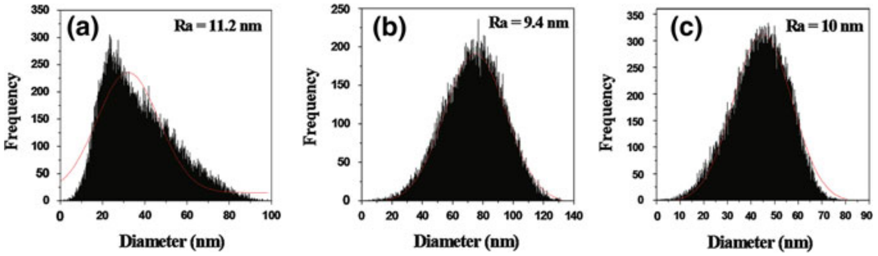

Fig. 3 Histograms of NiO films at different oxygen partial pressures **a** 4 × 10^{-4} mbar **b** 6 × 10^{-4} mbar **c** 8 × 10^{-4} mbar

partial pressure of 4 × 10^{-4}, 6 × 10^{-4} and 8 × 10^{-4} mbar, respectively. The variation in the grain size values were in accordance to the XRD results, but the grain sizes determined by AFM histograms were greater than that measured by XRD. This is caused by the different grain size criteria, underlying the different methods. From the AFM and XRD results, the films growth towards the (220) orientation exhibited smooth surface with bigger grains.

4 Conclusion

The deposited films as a function of oxygen partial pressure exhibited (220) as preferred orientation. Fine and uniform grains with RMS Roughness of 9.4 nm were observed at oxygen partial pressure of 6×10^{-4} mbar.

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