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Bias voltage dependence properties of Nb-doped indium tin oxide thin films by RF magnetron sputtering at room temperature

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ABSTRACT

Niobium doped indium tin oxide (ITO:Nb) thin films were fabricated on glass substrates by RF magnetron sputtering from one piece of ceramic target material at room temperature. The bias voltage dependence of properties of the ITO:Nb films were investigated by adjusting the bias voltage. Structural, electrical and optical properties of the films were investigated using X-ray diffraction (XRD), atomic force microscopy (AFM), UV–visible spectroscopy, and electrical measurements. XRD patterns showed a change in the preferential orientations of polycrystalline crystalline structure from (222) to (400) crystal plane with the increase of negative bias voltage. AFM analysis revealed that the smooth film was obtained at a negative bias voltage of -120 V. The root mean square (RMS) roughness and the average roughness are 1.37 nm and 1.77 nm, respectively. The films with the lowest resistivity as low as $1.45\times10^{-4}\,\Omega$ cm and transmittance over 88% have been obtained at a negative bias voltage of -120 V. Band gap energy of the films, depends on substrate temperature, varied from 3.56 eV to 3.62 eV.

1. Introduction

Transparent and conductive oxides (TCOs) thin films have been widely used as transparent electrode for flat panel displays and photovoltaic technologies [1,2]. More recently, TCOs has been used for flat panel displays including liquid crystal displays, organic light emitting diodes and plasma displays. Among the various TCOs thin films, tin doped indium oxide (ITO) is widely used in flat displays, solar cells and architectural glasses and other fields [3]. ITO film is a heavily doped, high-degenerate n-type semiconductor with a good electrical conductivity and transmittance in the visible region; it also has resistance to chemical corrosion and good processing performance [4]. ITO

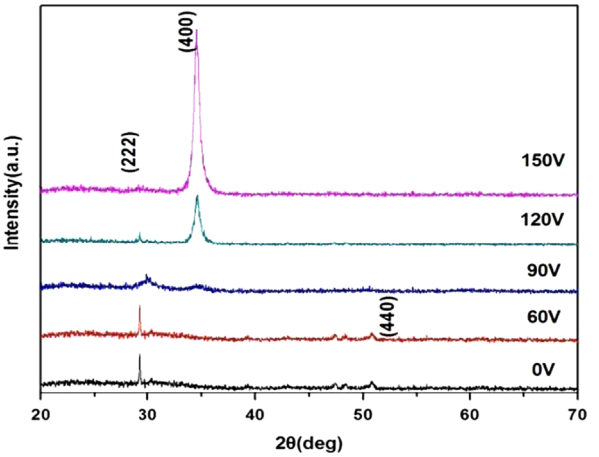

Fig. 1. XRD spectra for ITO:Nb films at different negative bias voltages.

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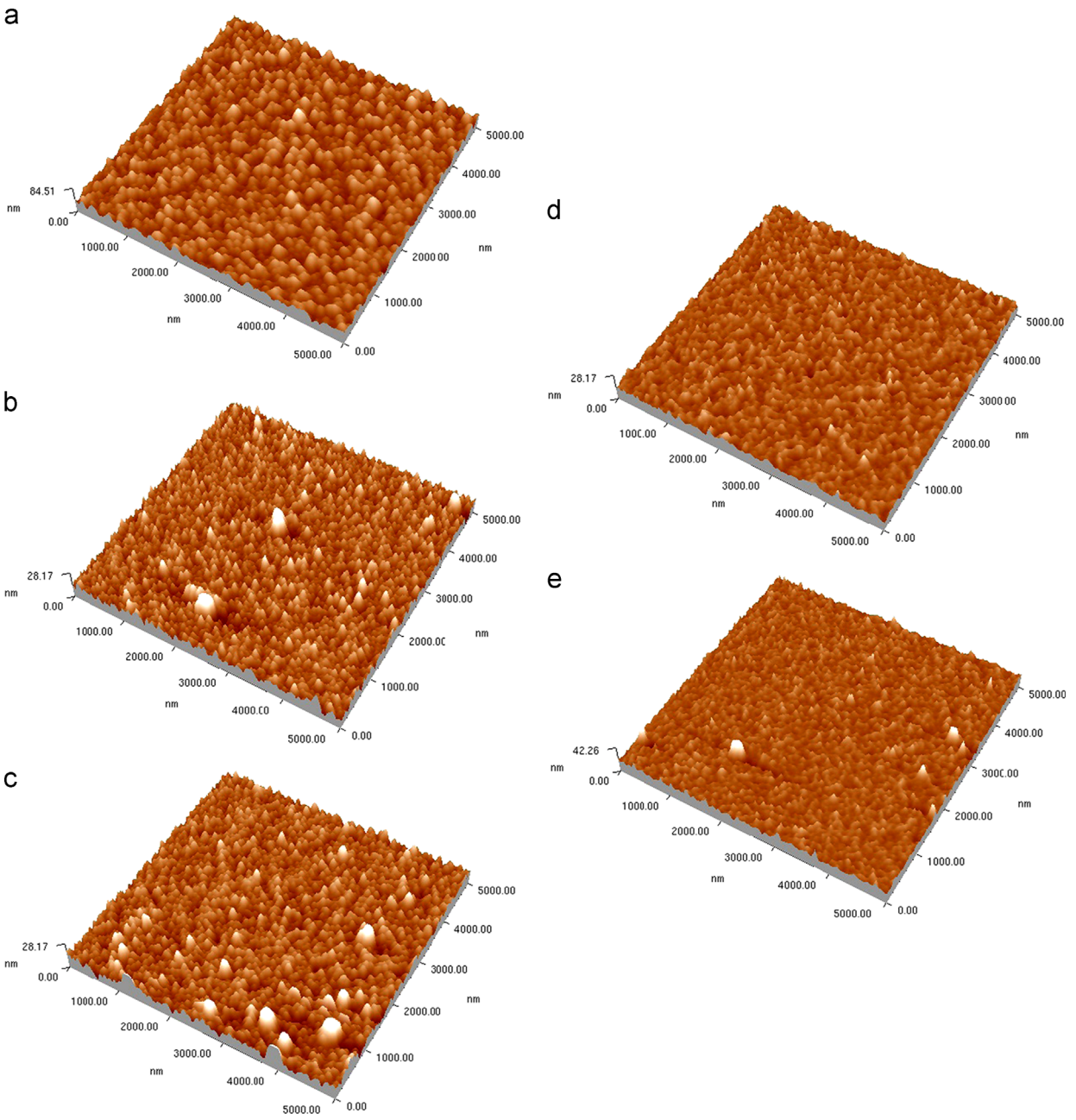

Fig. 2. AFM surface morphology and roughness of ITO:Nb films at (a) 0 V; (b) −60 V; (c) −90 V; (d) −120 V; (e) −150 V.

films can be prepared by variety of techniques such as magnetron sputtering [5], ion assisted deposition [6], pulsed laser deposition (PLD) [7], dip coating [8], ion beam sputtering [9], sol–gel [10], reactive thermal evaporation [11], etc. Magnetron sputtering offers not only the possibility to prepare ITO films at low processing temperature and on large areas [12] but can also obtain excellent optical and electrical properties. So it is widely used in thin film technology.

With the continuous developing of thin films technology, dual ITO thin film is unable to meet higher performance requirements. Many studies aimed at improving the photoelectrical properties of traditional binary ITO (In_2O_3:SnO_2) films by doping other elements. Besides tin, other elements such as Nb [13], Zr [14], Ti [15], Mo [16], W [17], Ce [18], and Ag [19] have also been employed as dopants.

To the best of our knowledge, there is so far no report on the bias voltage dependence of properties for the obtained ITO:Nb films. In this paper, we demonstrate that control over the cationic composition in ITO-based oxides films by RF magnetron sputtering. A bias voltage dependence of the structural, electrical and optical properties for the Nb-doped ITO (ITO:Nb) films were investigated.