Influence of O\textsubscript{2} admixture and sputtering pressure on the properties of ITO thin films deposited on PET substrate using RF reactive magnetron sputtering

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Abstract

A systematic study of the growth of indium tin oxide (ITO) thin films on polyethylene terephthalate substrate was carried out using RF reactive magnetron sputtering. The effect of oxygen admixture to sputtering gas, sputtering pressure (4.5×10\textsuperscript{-1} to 6.8×10\textsuperscript{-1} Pa), RF power (30–50 W) and growth time (15–50 min) on the electrical and optical properties of ITO thin films was investigated. An indium tin alloy (90:10) of 99.999% purity was used as target. Deposition was carried out at room temperature. Cracks in the films were not observed. It is found that the increase in admixture of O\textsubscript{2} to Ar sputtering gas decreases the growth rate. A minimum value of resistivity (7×10\textsuperscript{-2} Ω cm), decreases in the mobility, reduction in particle size, an average transmittance of ~80% in UV–Vis range with carrier concentration of ~5.9×10\textsuperscript{19} atoms/cm\textsuperscript{3} and mobility of ~37 cm\textsuperscript{2}/V s was found with increasing O\textsubscript{2} admixture. The increase in sputtering pressure has less effect on growth rate, changes the distribution of particles with increase in their sizes, little variation in Sn/In ratio and a minimum resistivity of 1.9×10\textsuperscript{-3} Ω cm. The increasing pressure results in improved transmittance to above 80%. Increase in RF power results in a minimum resistivity of 1.9×10\textsuperscript{-2} Ω cm (at 50 W) and decreases the carrier mobility to 3.5 cm\textsuperscript{2}/V s. A linear increase in the film thickness with increase in optical transmittance to ~85 is found with increasing growth time. It can be concluded that the film grown at 18% of O\textsubscript{2} admixture, 5.6×10\textsuperscript{-1} Pa sputtering pressure and RF power of 50 W, can meet the requirement of a good transparent and conducting ITO film on polymer substrate.

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1. Introduction

Indium tin oxide (ITO) thin films have been studied extensively in the optoelectronic industry because they combine unique transparent and conducting properties. Indium oxide (In\textsubscript{2}O\textsubscript{3}) by doping with Sn results in an n-type semiconductor and is usually called as ITO. ITO is a highly degenerate semiconductor i.e. it has so many dopants that the electron concentration in the conduction band (CB), or hole concentration in the valence band (VB), is comparable with the density of states in the band. The degeneracy is caused by both oxygen vacancies and substitutional tin dopants created during the film growth. It has low electrical resistivity (2–4×10\textsuperscript{-4} Ω cm) due to high carrier concentration and the location of the Fermi level (E\textsubscript{F}) above the conduction level (E\textsubscript{C}). The carrier concentration of highly conducting ITO films is in the range of 10\textsuperscript{20}–10\textsuperscript{21} atoms/cm\textsuperscript{3}. Furthermore, ITO is a wide band gap semiconductor (E\textsubscript{g}: 3.5–4.3 eV, the gap between the CB and VB where no wavelike electron orbital exists), which shows high transmission in the visible and near-IR regions of the electromagnetic spectrum. Due to these