Effect of substrate telnperat111"e on the bonded states of indium tin oxide thin films deposited by plasma enhanced chemical vapor deposition

Abstract

Indium tin oxide (ITO) thin films were deposited on Si(100) substrates using plasma enhanced chemical vapor deposition technique. The metal-organic sources used in this study were Tris (2,2,6,6-tetramethyl-3.5-heptanedionato) indium(III) and tin(III) acetate of 99.9% purity, which are readily available. The deposition of ITO films was carried out for 1 h at different reaction temperatures (200, 250, 300 and 350 °C), with oxygen as reaction gas (20 sccm) and argon as carrier gas (200 sccm). The deposited films were analyzed using X-ray diffraction (XRD). Scanning electron microscope (SEM) and X-ray photoelectron spectroscopy (XPS). The minimum sheet resistance, measured using a four-probe method, was 2500 Ὼcm^{-2} at a deposition temperature of 300 C. XRD analysis shows a structural change and a highly textured film with (100) preferred orientation with increasing deposition temperature Growth rate, estimated from SEM images of the deposited film was ~10^{10} cm^{-2} h^{-1}. It was observed from XPS results that oxygen atoms were bonded to In and Sn atoms indicating formation of ITO compound (bonded states of In_2O_3). It is also seen that all the examined ITO film contains amorphous and crystalline phases.

1. Introduction

Indium-tin-oxide (ITO) thin films have been studied extensively in the optoelectronic industry because they combine unique transparent and conducting properties. ITO is a highly degenerate it-type semiconductor, which has low electrical resistivity (2-4X 10^{-4} Ὼcm) due to high carrier concentration and location of Fermi level (Ec) above the conduction level (EC). The degeneracy is caused by both oxygen vacancies and substitutional tin dopants created during film growth. The carrier concentration of highly conducting ITO films is in the range of $l0^{20}$-$l0^{21}$ cm^3. Furthermore, ITO is a wide band gap semiconductor (Eg: 3.5-4.3 eV), which shows high transmission in the visible and near-IR regions of the electromagnetic spectrum. Due to these unique properties, ITO has been used in a wide range of applications. For example, ITO films are used as: transparent electrodes in flat panel displays and solar cells; surface heaters for automobile windows: camera lenses: storage-type cathode ray tubes; biological devices as well as transparent heat reflecting window material for building, lamps etc. They are also used as optoelectronic devices, electroluminescent devices,photovoltaic cells and electrochroinic devices [1-13]. However, the attainments of these properties are strongly dependent on the oxygen pressure, substrate temperature, starting material (precursor) and the preparation conditions. which affect. in particular, the oxidation, tin incorporation and/ or tin activation into Sn^{4+} state [9-24]. Each one of these free carrier sources has a specific influence on the structural and the electrical characteristics of the oxide film. For example, an oxygen vacancy can donate free electrons for conduction, but highly oxygen deficient films show reduced optical transmittance and poor ‘Sn’ doping efficiency, whereas doping by Sn^{4+} ion can provide one tree electron for conduction without significant reduction of visible transmittance and may create