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Research Article

The Influences of Thickness on the Optical and Electrical Properties of Dual-Ion-Beam Sputtering-Deposited Molybdenum-Doped Zinc Oxide Layer

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The thickness of transparent conductive oxide (TCO) layer significantly affects not only the optical and electrical properties, but also its mechanical durability. To evaluate these influences on the molybdenum-doped zinc oxide layer deposited on a flexible polyethersulfone (PES) substrate by using a dual-ion-beam sputtering system, films with various thicknesses were prepared at a same condition and their optical and electrical performances have been compared. The results show that all the deposited films present a crystalline wurtzite structure, but the preferred orientation changes from (002) to (100) with increasing the film thickness. Thicker layer contains a relative higher carrier concentration, but the consequently accumulated higher internal stress might crack the film and retard the carrier mobility. The competition of these two opposite trends for carrier concentration and carrier mobility results in that the electrical resistivity of molybdenum-doped zinc oxide first decreases with the thickness but suddenly rises when a critical thickness is reached.

1. Introduction

Transparent conductive oxides (TCOs), such as indium tin oxide (ITO), have been extensively applied for electrodes in flat displayer, panel, sensor, organic light emitting diode, solar cell, and so forth [1–4]. To moderate the impact of indium shortage, various zinc oxides, which have advantages on low cost, environmentally friendly, easy to etch, and non-reactive with hydrogen plasma [5], have been developed as new alternatives. Doping elements of group II and IV is a known method to increase the carrier concentration for improving the conductivity of zinc oxide. Among these doped zinc oxides, the molybdenum-doped zinc oxide (hereafter abbreviated as MZO), in which every substitution of Mo^{6+} for Zn^{2+} site in the wurtzite cell can induce 4 extra carriers, promotes it to be the most potential n-type transparent semiconductor over all alternatives.

To fulfill the demands of flexible and portable electronic, polymeric materials are the currently most chosen substrates of TCOs for such applications. However, the low thermal tolerance of commonlyused polymers restricts the options for the process temperature of other integrated materials. Dual-ion-beam sputtering deposition (DIBSD) [6] is one of the low-temperature deposition techniques. DIBSD is to use an argon ion beam generated from the ion source to sputter atoms of the target surface. The high kinetic energy transferred from the incident ions to the sputtered particles provides them the required activation energy for the nucleation and synthesis reactions during the film growth. Furthermore, one additional assistant ion beam irradiates the deposit surface simultaneously, which provides an additional energy for adatoms migration to arrange a dense crystalline structure. Both kinds of ion beam enable the deposition of crystalline MZO films onto the polyethersulfone (PES) substrates at low processing temperature.

It is well known that the electrical conductivity usually increases and the optical transparency usually decreases with the thickness of TCO layer [7]. To trade off between