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Thermal-frequency dependence study of the sub-band localized states effect in Sb-doped SnO_2 based Sol-gel thin films

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Abstract

Films of transparent conducting antimony-doped tin oxide have been deposited by sol-gel based Dip-coating technique. The morphological analysis revealed that the deposited films are homogenous, smooth and the roughness depends on the Sb-doping. The Raman scattering showed that the vibrational modes are sensitive to oxygen deficiency, structural disorder and were red-shifted compared to the rutile SnO_2 single crystal. The FTIR study depicted the presence of Sn-O (610 cm^{-1}) and Sn-O-Sn (740 cm^{-1}) bonds in the films. Optical measurements revealed high transparency (~ 85 %) over the visible region. The optical band gap varies from 3.87 to 3.79 eV with increasing the width of tail states and corresponds to direct allowed transition in the bulk. The ac-conductivity (σ_{ac}) exhibits a semiconductor temperature-dependence behavior and varies from extrinsic to intrinsic conduction. The thermal energy promotes the polarization involving electrons localized at randomly oriented oxygen vacancies of the inhomogeneous dielectric structure grain/grain boundary and induces high dielectric constant. σ_{ac} was found to follow the power law: $\sigma_{ac} = A.\ f^{0.49}$ at high frequencies and the experimental results showed that the correlated barrier hopping mechanism is appropriate for the charge transfer between localized states.

Keywords: Tin oxide, sol-gel, oxygen vacancies, ac-conductivity, dielectric constant.

1. Introduction

High quality thin films are indispensable for the optoelectronic devices. In this respect, SnO_2 is a material of choice owing to its wider optical transparency than many other metal oxide semiconductors with ~ 80% in the visible range and higher electron mobility (~ 12.5 $cm^2\ V^{-1}\ s^{-1}$) [1] due to lower effective mass ~ 0.17 m_e for electrons and ~ 0.45 m_e for holes, which results in faster electrons collection [2].

When perfectly stoichiometric, SnO_2 is highly resistive, and the electrical conduction is obviously correlated with non-stoichiometry and oxygen deficiency i.e. Sn^{2+} self-doped SnO_x ($1< x <2$) is *n*-type semiconductor with free carriers density of ~ 10^{18} cm^{-3} [3]. The progress with these materials has been hindered, due its low-energy conduction band among metal