Journal of ELECTRONIC MATERIALS, Vol. 42, No. 8, 2013
DOI: 10.1007/s11664-013-2589-9

Effects of Growth Temperature and Annealing on Properties of $Zn_3Sn_2O_7$ Thin Films and Application in TFTs

YONG-YUE CHEN,[1] XI-KUN CAI,[1] ZHEN-YU YE,[1] XIONG WANG,[1] BING-PO ZHANG,[1] and HUI-ZHEN WU[1,2]

1.—Department of Physics, State Key Laboratory of Silicon Materials, Zhejiang University, Hangzhou 310027, People's Republic of China. 2.—e-mail: hzwu@zju.edu.cn

The effects of growth temperature and annealing on the physical properties of $Zn_3Sn_2O_7$ thin films were investigated in this work. The $Zn_3Sn_2O_7$ thin films were deposited on glass substrates by radio frequency (rf) magnetron sputtering. It is found that the films are amorphous regardless of the growth temperature. The film grown at room temperature shows the highest mobility of 8.1 $cm^2\ V^{-1}\ s^{-1}$ and the lowest carrier concentration of $2.0 \times 10^{15}\ cm^{-3}$. The highest carrier concentration of $1.6 \times 10^{19}\ cm^{-3}$ is obtained at the growth temperature of 250°C. Annealing treatment of the $Zn_3Sn_2O_7$ thin films resulted in increases of carrier concentration and mobility. The average transmittance of the as-deposited and annealed films reaches 80%. By using a $Zn_3Sn_2O_7$ thin film as the channel and a Ta_2O_5 thin film as the insulating layer, we fabricated transparent $Zn_3Sn_2O_7$ thin-film transistors with field-effect mobility of 21.2 $cm^2\ V^{-1}\ s^{-1}$, on/off current ratio of 10^5, threshold voltage of 0.8 V, and subthreshold swing of 0.8 V/decade.

Key words: XRD, electrical properties, optical properties, annealing, thin-film transistor (TFT)

INTRODUCTION

Thin-film transistors (TFTs) have been widely used in many fields, such as flat-panel displays, computers, and sensors. TFTs based on transparent conducting oxides (TCOs) such as ZnO,[1] SnO_2,[2] and multicomponent alloy oxides such as Zn-Mg-O,[3] Zn-Sn-O,[4] Zn-In-O,[5] and In-Ga-Zn-O[6] have attracted much attention in recent years because of their high electron mobility and high optical transparency in the visible region compared with amorphous silicon. Among these oxides, $Zn_3Sn_2O_7$ is a promising channel material for high-performance TFTs. The advantages of $Zn_3Sn_2O_7$ include its low sensitivity to visible light, physical robustness, and extremely high resistance to scratching, as well as the abundance of Zn and Sn on Earth.[7] $Zn_3Sn_2O_7$ thin films have been realized by many methods, such as spray pyrolysis, the sol–gel method, pulsed laser deposition, sputtering, and filtered vacuum arc deposition. In this work, $Zn_3Sn_2O_7$ thin films were deposited by rf magnetron sputtering using an alloy target. The effects of growth temperature and annealing on the structural, electrical, and optical properties of $Zn_3Sn_2O_7$ thin films were investigated. We also fabricated fully transparent $Zn_3Sn_2O_7$ TFT devices on glass substrates using a $Zn_3Sn_2O_7$ film as the channel and a Ta_2O_5 film as the insulating layer. The TFT devices exhibit good saturation characteristics and gate voltage control.

(Received November 14, 2012; accepted March 21, 2013; published online April 30, 2013)

EXPERIMENTAL PROCEDURES

$Zn_3Sn_2O_7$ Film

$Zn_3Sn_2O_7$ thin films were deposited on glass substrates by rf magnetron sputtering using an alloy target of 50 wt.%ZnO-50 wt.%SnO_2. High-purity (99.999%) argon was used as sputtering gas in the deposition process. The flow rate of Ar gas was 20 sccm, and the working pressure was 3.0 Pa. The target power was fixed at 300 W. The glass