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Influence of the InGaZnO channel layer thickness on the performance of thin film transistors

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A B S T R A C T

We report on the electrical properties of bottom-gate InGaZnO (IGZO) thin film transistors (TFTs) with different channel layer thicknesses. The IGZO channel layer with thickness varied from 25 to 120 nm were deposited by radio frequency sputtering. Al_2O_3 films were deposited on highly-doped n-Si substrate by atomic layer deposition (ALD) as gate insulator in this work. The influence of the IGZO channel layer thickness on the performance of TFTs is studied. The performance of devices is found to be thickness dependent. The best performance of devices is obtained from a 58 nm thick IGZO TFT, which shows a field-effect mobility in the saturation region of 6.2 cm^2/Vs, a threshold voltage of 2.1 V, an I_{on}/I_{off} ratio of approximately 6.4×10^7, and a subthreshold swing of 0.6 V/dec.

1. Introduction

TFTs have received considerable attentions and increasing interests because of their potential application in displays [1,2]. For the past 10 years TFTs made with amorphous and poly silicon have been extensively applied in flat panel display industry [3]. But these TFTs (especially the amorphous silicon ones) actually have some problems: such as light sensitivity and light degradation, low effect mobility and small drain current (typically about 10 μA), which limit their application to other types of flat panel displays such as the organic light emitting diode display (OLED) [4]. One approach to resolve these problems is to use the oxide semiconductor as a channel layer for TFTs. IGZO is one of

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potential candidates used as the active layer due to their high mobility, enhanced stability even though it has amorphous-phase [5]. Due to the high interest of application of IGZO TFTs in future electronics, it is very important to get an insight in the key factors that affect the electrical properties of these transistors [6]. Some groups [7–9] reported that the channel layer thickness is one of vital factors affecting the performance of the TFTs.

As an important part of a TFT, the gate insulator plays an important role in the TFT performance. A number of gate insulators have been investigated for TFTs, such as HfO_2 [10], SiO_2 [11], Si_3N_4 [12], Y_2O_3 [13] and Al_2O_3 [14,15]. Due to its low interfacial trap density with oxide semiconductors. ALD has become an interesting technique for producing high quality inorganic thin films. ALD is a gas-phase thin film deposition process based on successive self-limited gas-solid surface reactions. The precursor gasses are pulsed into the reactor chamber alternately, separated by inert gas pulses to clean the reactor chamber from excess precursors and by-products. Al_2O_3 from trimethyl aluminum (TMA; $Al(CH_3)_3$) and water as precursors is one of the most studied ALD systems [16]. Most of the literature deal with Al_2O_3 films prepared by using H_2O and O_3 as a source of oxygen, H_2O is convenient and cheap, so we select H_2O. Al_2O_3 is thermally and chemically stable, has high electrical resistivity and it adheres well to many surfaces [17], which makes it attractive for such applications as TFTs. In the present work, the ALD technique has been applied to the growth of Al_2O_3 films as gate insulator.

Up to now, to our limited knowledge, there are few reports on the IGZO channel layer thickness on the performance of TFTs with ALD growth Al_2O_3 film as gate insulator. In this work, TFTs with different thicknesses of IGZO channel layer were fabricated and the resultant effect on the device is discussed.

2. Experiments

The IGZO TFTs with Al_2O_3 gate insulators were fabricated on the highly-doped n-Si substrate. Usually, the substrate in TFT structure is glass substrate. However, glass substrate need to prepare ITO (or metal) as bottom-electrode, so we employ Si wafers as substrate in order to reduce the influence of other experimental process. The TFTs structure used in this study was shown in Fig. 1.

The Al_2O_3 gate insulator (220 ± 2 nm) was deposited at 300 °C using alternating exposures of $Al(CH_3)_3$ and H_2O vapor at a deposition rate of 0.66 Å per cycle by atomic layer deposition. IGZO films with a thickness ranging from 25 to 120 nm were deposited by rf-magnetron sputtering at room temperature using a IGZO target (99.99%, In_2O_3, Ga_2O_3, ZnO = 1:1:1 mol%) at input power of 50 W, gas mixing ratio of Ar:O_2 (30:1), The pressure of the chamber before sputtering was 5×10^{-4} Pa and total pressure of 0.8 Pa. After deposition of IGZO layer, about 200 nm Al was deposited by thermal evaporation to form the source and drain electrodes through a shadow-mask with the channel width (W) of 1000 μm and channel length (L) of 50 μm. Thermal annealing was carried out at 300 °C for 35 min in atmosphere. The thickness of the film was measured by the alpha step (Dektak 3st). The electrical characteristics of IGZO TFTs were measured using Agilent E3647A Dual output DC power supply and Keithley 6485 Picoammeter and related software. The capacitance characteristics were measured using Agilent E4980A LRC meter. An atom force microscope (AFM, nanonaviSPA-400 SPM) was used to investigate the surface properties of films. The microstructure and thickness of the films were examined by a scanning electron microscope (SEM) model Hitachi-S4800.

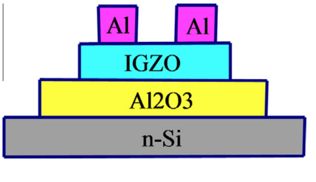

Fig. 1. Schematic structure of the IGZO TFTs.