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Electrical Characteristics of Thin-Film Transistors Fabricated Utilizing a UV/Ozone-Treated TiO_2 Channel Layer

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Thin-film transistors (TFTs) utilizing TiO_2 channel layers were fabricated by using a solution process. Atomic force microscopy images showed that the surface morphology of the TiO_2 films became uniform due to the ultraviolet (UV)/ozone treatment. X-ray photoelectron spectroscopy showed that the UV/ozone treatment reduced the amount of oxygen deficiency in the TiO_2 films, resulting in a decrease of the electron concentration on the surface. The performance of the TFT devices was significantly improved due to a decrease of the off-current level resulting from the enhanced uniformity and the decrease of the trap level resulting from the UV/ozone treatment.

Key words: Thin-film transistor, TiO_2 channel layer, structural properties, electrical characteristics

INTRODUCTION

Thin-film transistors (TFTs) based on oxide semiconductors have attracted a great deal of interest because of their promising applications in flat-panel displays due to their excellent device characteristics of high mobility and high transparency.[1,2] Oxide semiconductors, such as In-Zn-O, Ga-In-Zn-O, or Hf-In-Zn-O, have been extensively investigated for alternative applications in amorphous-Si TFTs for high-resolution display panels with large areas. The characteristics of TFT devices depend significantly on the utilization of In to achieve high mobility. Because the average amount of In that exists in the Earth's crust is 0.1 ppm, In availability is limited. Titanium oxide (TiO_2) semiconductors are available for mass production at low cost due to Ti being the ninth most abundant element in the Earth's crust. TiO_2 wide-bandgap thin films with superior transparency properties have stimulated interest in their potential applications in transparent electronics, such as transparent magnets[3] or conductors,[4] and TiO_2 thin films have been applied in optoelectronic devices utilizing the physical characteristics of photocatalysis,[5] dye-sensitized photovoltaic effects,[6] and large photoinduced hydrophilicity.[7]

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TFTs utilizing TiO_2 channel layers have been extensively fabricated by using various synthesis methods, such as magnetron sputtering,[8] chemical vapor deposition,[9] and colloidal nanoparticle dispersion.[10] However, studies of TFTs based on TiO_2 layers acting as channel layers and formed by using a sol–gel method have not been performed yet, except for a spray pyrolysis method.[11] The sol–gel deposition method has emerged as an excellent candidate due to its promising application in the fabrication of next-generation TFTs and its advantage of relative simplicity, potential for mass production, and low cost. Some investigations concerning increases in the surface oxygen concentration and work function in the metal oxide layers due to ultraviolet (UV)/ozone treatment have been conducted. Utilization of UV light provides an effective way to remove undesired impurities from the surface.[12] TFTs based on TiO_2 channel layers have been particularly attractive because of the excellent advantage of low operating voltages. Even though some studies on the fabrication and device characteristics of TFTs based on TiO_2 channel layers have been performed,[8–11,13,14] investigations concerning the electrical characteristics of TFTs fabricated utilizing TiO_2 channel layers by using a sol–gel method have not been reported yet.

This paper reports data on the enhancement of electrical characteristics in TiO_2-based thin-film transistors due to UV/ozone treatment. Atomic force