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Effect of annealing treatments on the microstructure of $(Zr_{0.8}Sn_{0.2})TiO_4$ thin films sputtered on silicon

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Abstract

This paper describes physical properties of Zirconium Tin Titanium Oxide doped 1 wt.% ZnO thin films on n-type Si substrate were deposited by rf magnetron sputtering at a fix rf power of 300 W, a deposition pressure of 5 mTorr, a substrate temperature of 450 °C and a argon–oxygen (Ar/O_2) of 100/0. Particular attention will be paid to the effects of an annealing treatment in air ambient on the physical properties. The films were annealed at various temperatures from 500 °C to 700 °C and also changed annealing times from 2 h to 6 h. The powder target composition of $(Zr_{0.8}Sn_{0.2})TiO_4$ was synthesized in the experiment. The annealed films were characterized using X-ray diffraction (XRD). The surface morphologies of annealed film were examined by atomic force microscopy and scanning electron microscopy.

Keywords: Dielectric; rf magnetron sputtering; $Zr_{0.8}Sn_{0.2}TiO_4$ thin film

1. Introduction

Several structures of dielectric materials have been developed to suit the requirements of various applications in recent years. It is well known that the dielectric materials are being utilized for filter, for stabilization of the frequency of oscillation in microwave integrated circuits and for increasing the storage capacitance density in DRAMs. Zirconium tin titanium oxide is a very popular material used in microwave communication systems, because of its dielectric properties, which include high dielectric constant, high quality factor, and low temperature coefficient of resonant frequency in the microwave regime [1–6]. The base material of $(Zr,Sn)TiO_4$ is $ZrTiO_4$ that resembled α-PbO_2 and was reported in 1967 [7]. It has an order–disorder phase transition in which the disordering takes place at higher temperatures [8–10]. Addition of dopants such as Sn is correlated to changes in the order–disorder transformation that results in improved dielectric properties. Ceramics based on the solid solution $(Zr_{1-X}Sn_X)TiO_4$, with up to 20 at.% of Zr replaced by Sn, have been used as resonator materials since the 1970s, and it has been playing an important role in microwave communication system due to its excellent dielectric properties [3]. The XRD pattern of ZST with or without ZnO addition showed no difference [11]. It is owing to that Zn ions stayed at the boundary phase as sintering attributer and Q value promoter. The phenomena are very similar to the paper reported by Wakino et al. [3]. After the addition of 1 wt.% ZnO, it has a dielectric constant of 37, which is much higher than that of SiO_2. A high $Q \times f$ ($Q = 1/\tan\delta$ is the inversion of the dielectric loss, f is resonant frequency) value of 40 000 GHz can also be achieved. Furthermore, the temperature coefficient of resonant frequency can be adjusted to 0 ppm/°C [11].

For the next generation of ULSI dynamic random access memory (DRAM), it is widely believed that dielectric materials with high dielectric constant such as $SrTiO_3$, Ta_2O_5 and $(Ba,Sr)TiO_3$ will be needed for storage capacitors. The use of such thin films that are fabricated with high dielectric constant materials makes it possible to reduce the size of storage capacitors, and to simplify the memory cell structure for higher integration density. On the other hand, these prepared thin films are also capable in

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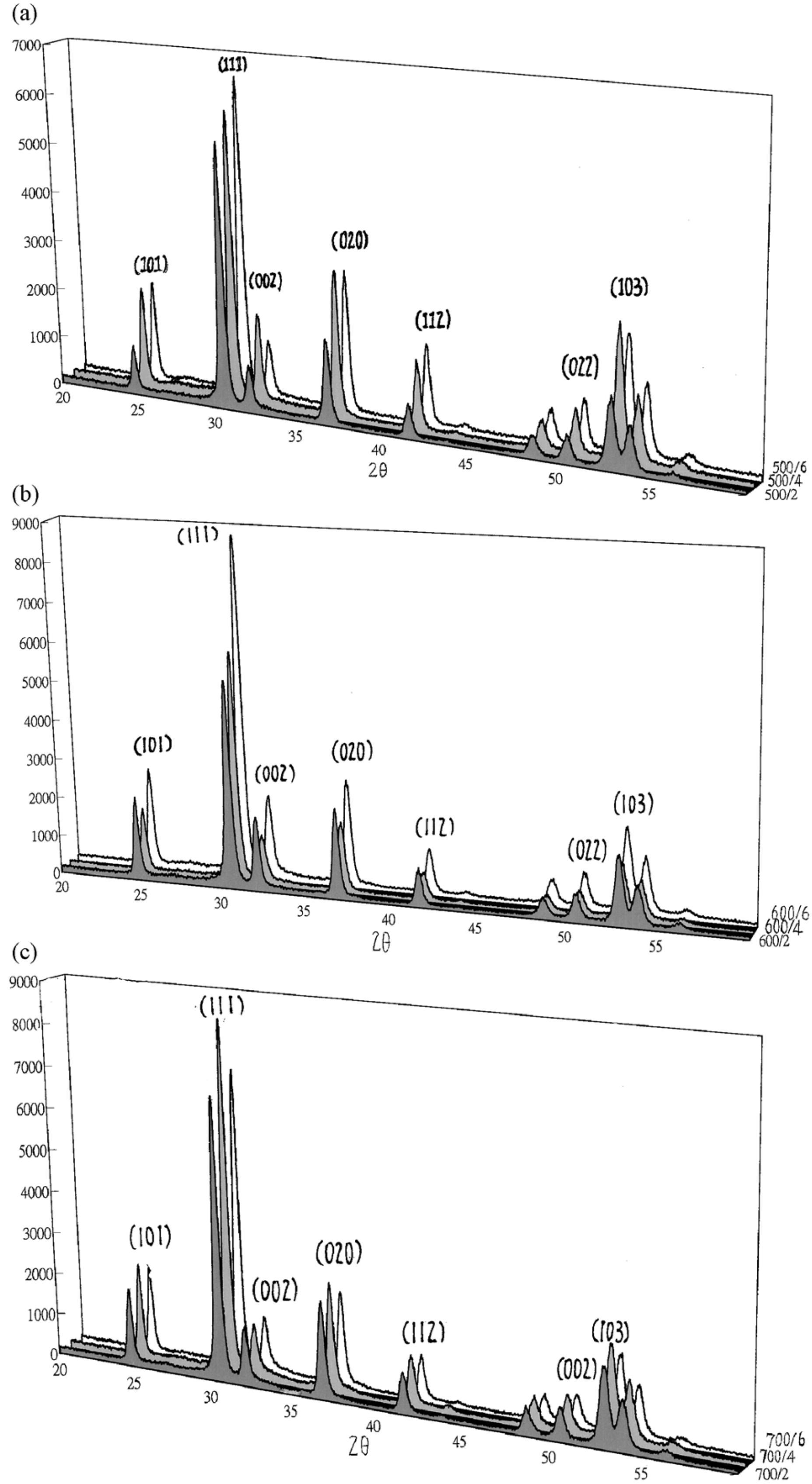

Fig. 1. X-ray diffraction patterns of the $Zr_{0.8}Sn_{0.2}TiO_4$ films at various annealing temperature and annealing time.