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Deposition and Characteristics of Sputtered Coated CCTO Thin Layer on Silicon Wafer

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ABSTRACT. In the present study, the calcium copper titanate (CCTO) thin layer has been coated onto Si wafer at 300°C using a CCTO target by Radio Frequency (RF) magnetron sputtering in argon atmosphere. The surface morphology crystal structure was examined by X-ray diffraction (XRD), atomic force microscopy (AFM), scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDX), respectively. The CCTO layer revealed polycrystalline nature with characteristic peaks of (0 2 2), (2 2 4), and (0 2 4) at 34.19°, 54.75° and 61.29°. The average grain size and pore size of porous sputtered CCTO were determined as 20 nm and 15.70 nm, respectively.

Keywords: *CCTO thin layer, RF magnetron sputtering, Silicon wafer;*

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1. INTRODUCTION

$CaCu_3Ti_4O_{12}$ (CCTO) is perovskite-like compound, which possesses high dielectric constant ($\varepsilon_r \leq 10^5$) over a wide range of temperature from 100 to 600 K. This unprecedented characteristic makes it suitable for microelectronic applications. There are several methods for the deposition of CCTO thin including sol-gel process [1-2], pulsed laser deposition (PLD) [3-6], sputtering [7], and metal organic chemical vapor deposition (MOCVD) [8,9]. The RF magnetron sputtering has noticeable advantages over the other methods; it needs a very simple apparatus, high deposition rate, as well asdeposition on a large area. Most of the CCTO studies have focused on the preparation of bulk materials such as ceramics or single crystals using chemical methods and the identification of the possible mechanism regarding to its unique properties [10,11] However, thin layer have shown advantages over the bulk material for electronic applications [12-14]. The CCTO porous thin layer has been fabricated for different application such as humidity and gas sensor, dielectric constant applications [13,14]. It was reported that the properties of CCTO is dependent on the synthesis method as well as experimental conditions [15,16].

There are few studies available in the literature focusing on the fabrication of CCTO thin layer via RF magnetron sputtering process [12-14] to study the dielectric constant of gas sensors. However, the structural and physical properties of RF sputtered CCTO thin layer on Si wafer has not been discovered. The aim of this study is primary investigation of the crystallite structure and surface morphology of CCTO thin layer on Si wafer via RF magnetron sputtering.

2. MATERIALS AND METHODS

CCTO thin layerpreparation. The CCTO thin layer with the 400 nm thickness have been coated on Si wafer via RF magnetron sputtering technique with the target (CCTO, 99.9% purity) (76 mm in diameter and 5 mm in thickness). The Si wafer carefully washed by hydrocholoric acid (HCl), hydrogen peroxide (H_2O_2) and deionized water prior to coating process in order to eliminate surface impurities. The base pressure was set as 30×10^{-5} mbar in the coating chamber and CCTO target was pre-sputtered for ~300 s at 30 WRF power to eliminate pollution on the surface. The layer was coated at 1.23×10^{-2} mbar pressure, 10 sccm argon gas flow rate, and 150 W of RF power. The temperature of the substrate was retained at 300°C during coating process to enhance the layer crystallinity [17]. In order to analysis phase, surface topography and morphology of the CCTO thin layer, X-ray diffraction (XRD Bruker, D8 Advance system, Cu Kα irradiation, λ = 1.5405 Å), atomic force microscope (AFM) (Nano Navi, SPA 400) and scanning electron microscope linked with energy dispersive X-ray spectroscopy (SEM-EDX, Zeiss Supra™35VP) was used.

3. RESULTS AND DISCUSSION

Fig.1 shows the XRD pattern of the RF sputtered CCTO thin layer on the silicon wafer with 400 nm thickness. The characteristic peaks indicated body centered cubic perovskite structures (ICDD data card no. 98-006-9415) with space group of Im-3 [18]. Five peaks centered at 2θ = 34.19°, 54.75° and 61.29°were matched to diffraction planes of (0 2 2), (2 2 4) and (0 2 4), respectively. The characteristic peaks at 2θ=47.21°, 56.27°, 69.23°and 76.61°confirmed the crystalline structure of Si wafer (ICDD data card no. 98-002-2990). The peak at 69.14° of high intensity was ascribed to reflection lines of silicon wafer. Nevertheless, not all of the expected peaks for CCTO thin layer were observed in the XRD pattern. This may be attributed to the small quantity of deposited CCTO thin layer on the substrate.

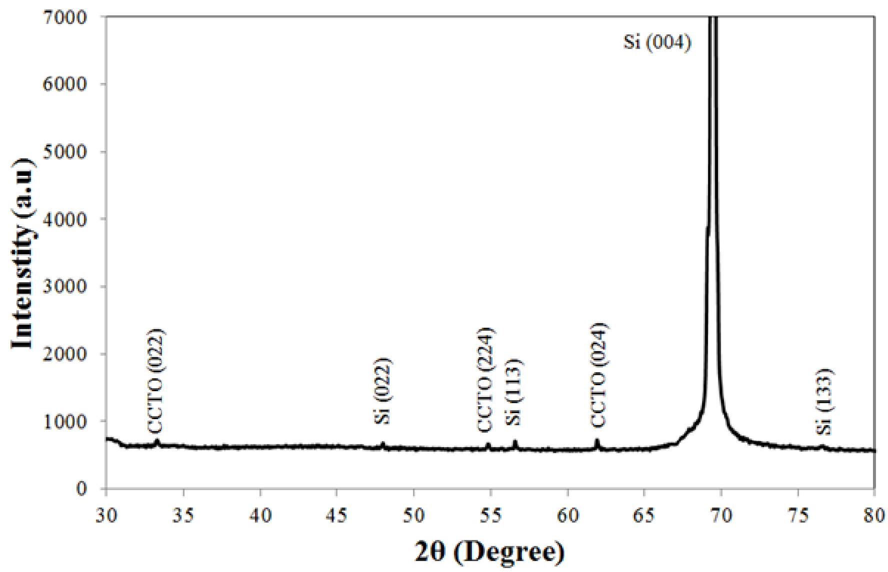

Fig. 1 XRD patterns of the sputtered CCTO thin layer on silicon wafer

The surface characteristic and size distribution of the CCTO thin layer was investigated by AFM analysis (tapping mode) at ambient condition. Fig. 2 depicts the 2D and 3D topography images of the porous CCTO thin layer with the 400 nm thickness. The roughness (Ra) and root mean square (RMS) of the roughness were calculated by using the scan area of 10 × 10 μm^2. Ra and RMS values obtained were 5.6 nm and 7.1 nm, respectively. The microstructure of CCTO layer consisted of small and large grains. The pore size was estimated around 15.7 nm by variations of surface profile as shown in Fig. 2(c).

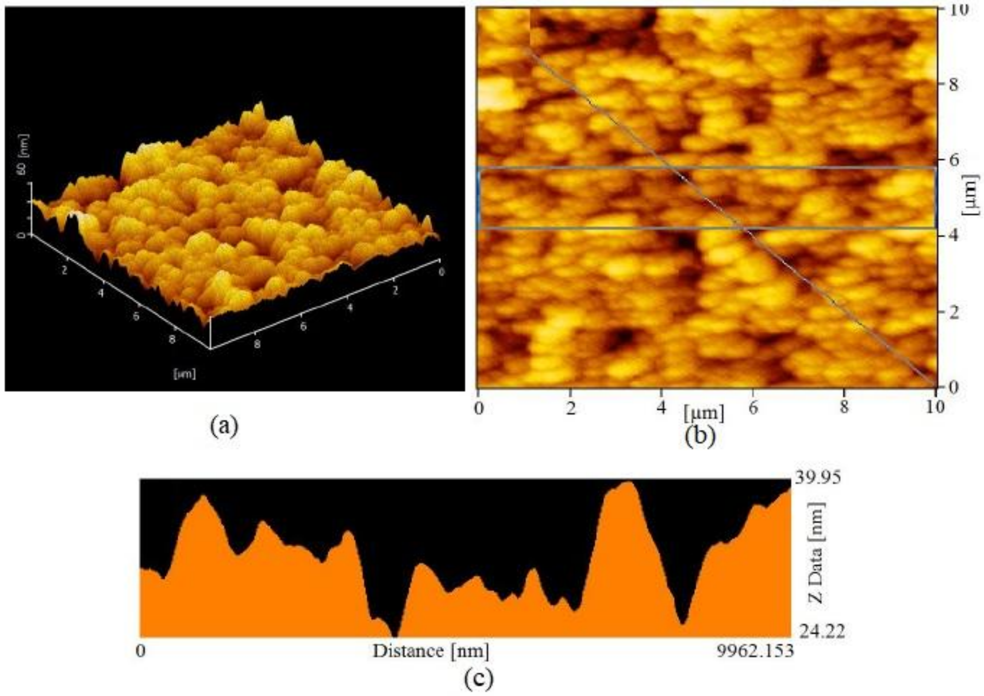

Fig. 2. Atomic force micrographs of CCTO thin layer (a) 3D image, (b) 2D image and (c) the corresponding average profile line

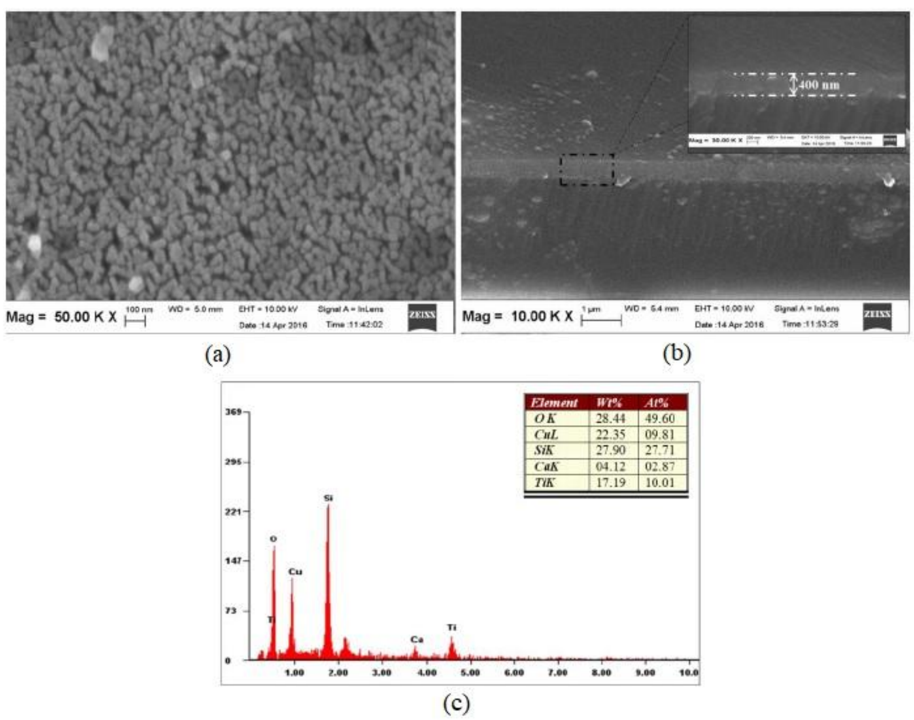

Fig. 3 SEM micrographs of CCTO thin layer (a) topside, (b) cross sectionand (c) EDX analysis

The surface morphology of the CCTO thin layeris shown in Fig. 3.The SEM images of CCTO thin layer exhibited a uniform surface morphology. The average distributed grain size on the layer surface was nearly 20 nm as shown in Fig. 3(a). It is obvious that CCTO thin layer have a porous intergranular structure. The cross-section of thickness related to CCTO thin layer is shown in Fig. 3(b). In addition, the chemical composition was quantitatively determined from EDX as in Fig. 3(c). The observed Si peak in the EDX table was belonged to the substrate.

4. SUMMARY

The CCTO thin layer with the 400 nm thickness was successfully coated on the surface of Si wafer via RF magnetron sputtering process at substrate temperature of 300 °C with 150 Wpower. The surface morphology and crystal structure were evaluated by X-ray diffraction (XRD), atomic force microscopy (AFM), scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDX). The results demonstrated the uniform intergranular porous microstructure of CCTO thin layer. The average grain size and pore size were also found to be 20 nm and 15.70 nm, respectively.

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