# MICROSTRUCTURE AND STRUCTURAL PROPERTIES OF (Cu, Al, In) DOPED $SnO_2$ THIN FILMS DEPOSITED BY SPIN COATING METHOD

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## Abstract

The effect of Cu,Al and In doping on the microstructural and structural properties of the $SnO_2$ thin films were studied. The undoped, Cu, Al and In (5 mol%) doped$SnO^2$ thin films were deposited on glass substrates by sol-gel and spin coating technique. The microstructure properties of the samples were investigated by X-ray diffraction (XRD) method. It was determined that the samples formed at polycrystalline structure in tetragonal phase and structure was not changed by doping materials. The surface morphology of the samples were investigated by scanning electron microscopy (SEM). The lattice parameters, unit cell volume, crystallite size and grain size were determined.

**Keywords:** Tetragonal type thin films, Sol-gel process, XRD, SEM

## Introduction

Tin dioxide ($SnO_2$) has been intensively investigated because of its rich physical properties and large applications in commercial devices. The $SnO_2$ with a wide-band-gap(Eg=3.6-4.0eV) is one of the excellent semiconductors which can be applied to solid state gas sensors, sensing arrays, solar cells, photovoltaic cells, organic light emitting diodes, touch sensitive screens and thin film transistors.[Bagheri Mohaghegi M M ef al (2008), Bagheri Mohagheghi MM et al 2008,Khan AF et al (2010),Khan Af et al 2010,Moharrami F et al (2012 ]. The $SnO_2$ thin films can be fabricated by a number of techniques such as chemical vapour deposition (CVD), metalorganic deposition, rf sputtering, sol-gel dip coating, spin coating and spray pyrolysis. [Maekava T et al (2001) , Yin LT et al (2000), Yin LT et al (2000), Ouerfelli J et al (2008).] It was clearly established spin coating that structural, electronic transport and optical properties of $SnO_2$ films are very sensitive to preparation method, deposition conditions, dopant atoms and amount of dopant atoms.

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## Experimental

The glass substrates were ultrasonically cleaned by keeping in ethanol and in the distilled water, for ten minutes, respectively. Then the glass substrates were dried. Then the glass substrates were dried. The films were deposited on the glass substrates by spin coating technique. In order to prepare the coating solution, firstly, Cu,Al and In (5 mol%) doped $SnO_2$ powder mixed by conventional stoichiometric composition. The mixture powder is ground by agate mortor to obtain the homogeneous and uniform grain size of powder. This powder is heat treated at 500° C for 1 hr. The crystalline powder, were mixed with 2-methoxgethanol solution by using sol-gel method. And then these pastes were coated on glass substrates and annealed at 400°C for 1 hr, respectively.

## Results and Discussion

The XRD patterns of undoped and Cu, Al, In doped $SnO_2$ films are shown in Fig.1(a~d). The films deposited showed four peaks namely (110), (101),(200) and (211). Since all the peaks are sharp it is evident that the films deposited are polycrystalline in nature and the positions of X-ray diffraction peaks fit well with the tetragonal structure of $SnO_2$ (JCPDS Card tin oxide, 72-1147), As seen from fig 1 (a~d), the preferred orientation is (101) plane for undoped $SnO_2$ film. The addition of Cu, Al and In atoms do not affect the preferred orientation along (101) plane and crystal structure. The dopants form extra peaks in the XRD pattern of doped $SnO_2$ films because dopant atoms do not incorporated homogeneously into the tin oxide matrix.

The lattice constants a and c for the tetragonal phase structure are determined by the relation

$$\frac{1}{d^2} = \left(\frac{h^2}{a^2} + \frac{k^2}{a^2}\right) + \left(\frac{l^2}{c^2}\right)$$

where d and (hkl) are the interplanar distance and Miller indices, respectively. The calculated lattice constants a, c and c/a vlues are given in Table (1).

**Table 1: Lattice parameters and crystallite size values of $SnO_2$ films prepared for various dopant atoms**.

| Doping Atom | a ($\dot{A}$) | b ($\dot{A}$) | c/a | D (nm) | V $(nm)^3$ |
|---|---|---|---|---|---|
| Undoped | 4.7630 | 3.1903 | 0.67 | 31.6339 | 0.0725 |
| Cu | 4.7467 | 3.1911 | 0.67 | 31.6887 | 0.0719 |
| AI | 4.7629 | 3.1913 | 0.67 | 31.0877 | 0.0721 |
| In | 4.7548 | 3.1893 | 0.67 | 28.7258 | 0.0721 |

Fig(2). (a) to (d) SEM micrograph of undoped, Cu, Al and In (5mol%) doped thin film. from the SEM images, it can be seen that the particles are in fairly dense, and crack-free. The estimated grain size are listed in Table(2).

**Table 2: The values of $SnO_2$ films prepared for various dopant atoms.**

| Doping Atom | Grain Size (m) |
|---|---|
| Undoped | $0.6818 \times 10^{-6}$ |
| Cu | $0.5740 \times 10^{-6}$ |
| Al | $0.5545 \times 10^{-6}$ |
| In | $0.6060 \times 10^{-6}$ |

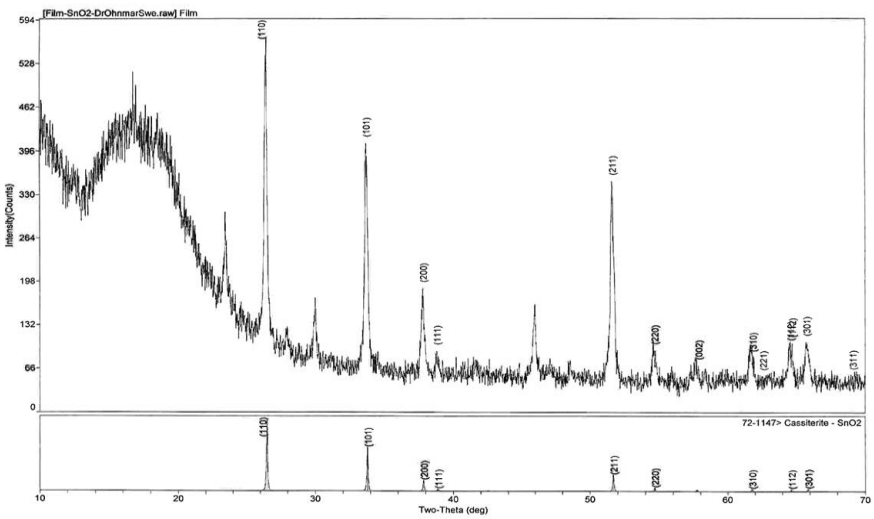


**Figure 1:(**a). The diffraction peak of undoped$SnO_2$ film

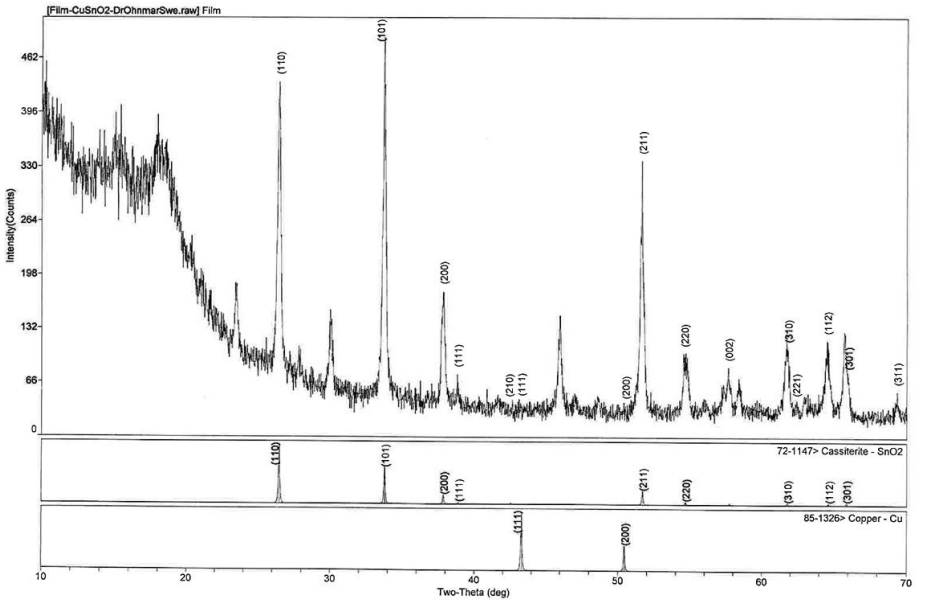


**Figure 1:(**b). The diffraction peak of Cu doped $SnO_2$ film

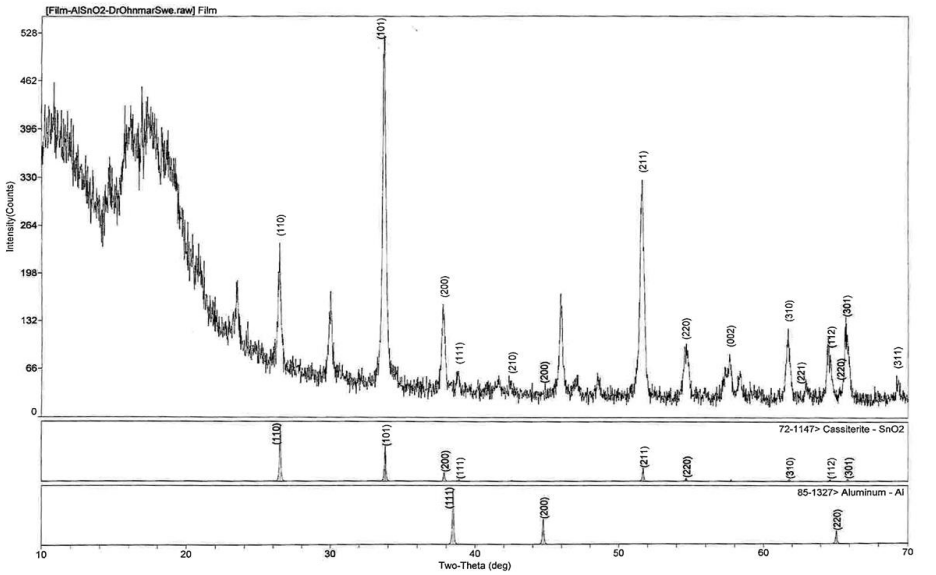


**Figure 1: (**c). The diffraction peak of Al doped $SnO_2$ film

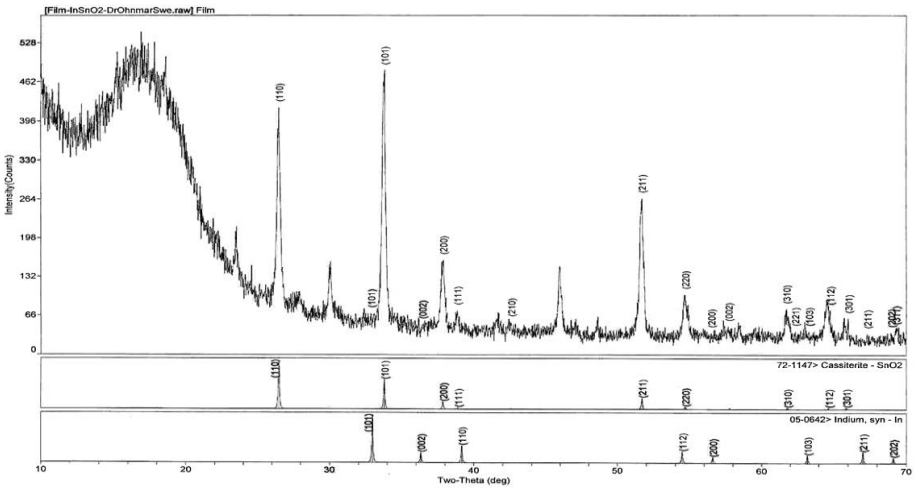


**Figure 1: (**d). The diffraction peak of In doped $SnO_2$ film

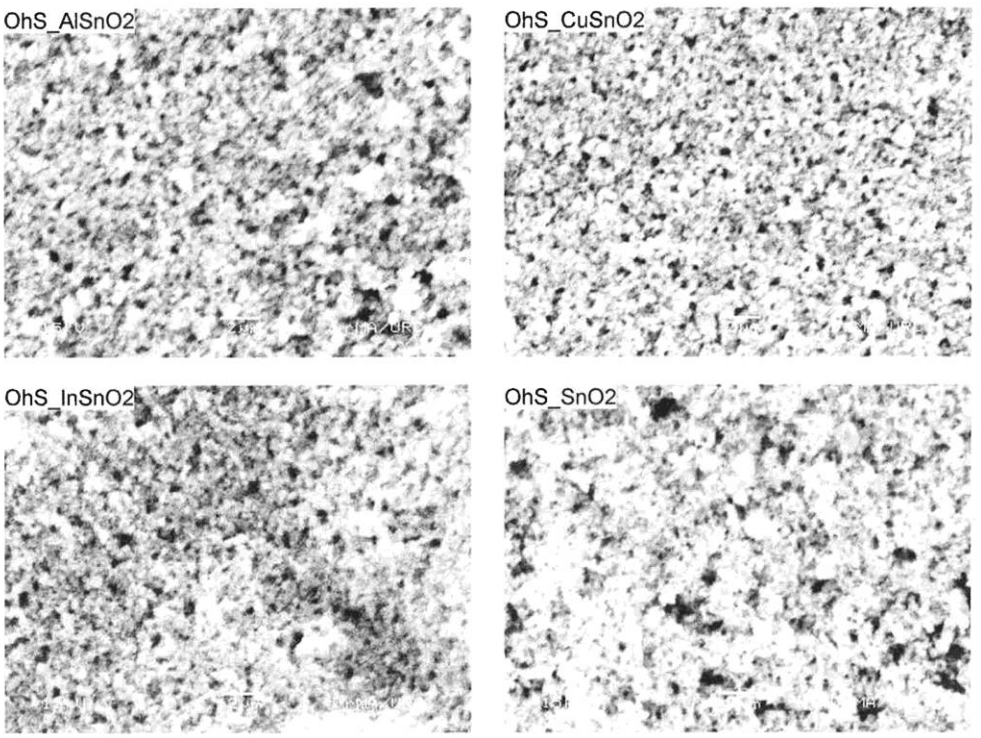


**Figure2:** The Scanning electron micrograph of undoped, Cu, Al, In doped $SnO_2$ film

## Conclusion

In this study it was concluded that the kind of dopant atoms dit not change the structure of undoped and Cu, Al and In doped $SnO_2$ films grown by spin coating technique. The orientation of the films was along the (101) plane. The films were polycrystalline in nature and had tetragonal structure. The ratio of lattice parameters (c/a) was found as 0.67. The crystallite size of the films calculated from XRD depending on the kind of dopant atoms.

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