Investigations on Tin Oxide Thin Films Prepared By the Method of Spray Pyrolysis

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Abstract: Tin Oxide (SnO₂) thin film is one of the transparent conducting oxide thin films. It finds its application in various fields such as solar cells, optoelectronic devices, gas sensors etc. Here Transparent Tin Oxide (SnO₂) thin films were deposited on glass substrates by Spray Pyrolysis Technique, a simple and relatively cost effective method by dissolving 0.1M of Stannic Chloride in ethanol at 400°C. The Structural characterization of these prepared films were done by using the X-ray diffraction technique and it is found that the prepared SnO₂ thin film is of n-type and exhibits a tetragonal structure having a particle size of about 0.43344x10⁻⁷m. The optical band gap of SnO₂ thin film is confirmed as 3.4842eV. The Thickness of thin film is estimated as 0.4205μm.

1. Introduction

A thin film is a layer of Material coating ranging from fractions of a nanometer to several micrometers in thickness. The controlled synthesis of material as thin film (a process referred to as deposition) is a fundamental step in many applications. A familiar example is the household mirror, which typically has a thin metal coating on the back of a sheet of glass to form a reflective interface. [1]. Thin film deposition process can be divided into two groups viz. Physical or chemical. The physical methods include Physical vapour deposition (PVD), Laser ablation, molecular beam epitaxy and sputtering. The Chemical methods include Gas-Phase deposition method and solution techniques. Spray pyrolysis is a processing research technique being considered to prepare thin and thick films, ceramic coatings and powders. [2, 3]. Thin film of different thickness, Surface morphologies, crystal sizes, electrical and optical properties can be deposited. [4].

The main purpose of depositing thin film coatings on an optical surface is to modify and provide environmental protection and/or improve optical performance. Unlike many other film deposition techniques, spray pyrolysis is a simple and relatively cost-effective processing method (especially when considering the cost of equipment). It is an extremely easy technique for preparing films of any composition.

SnO₂ thin films have been deposited using different techniques, such as spray pyrolysis, sol-gel process, chemical vapour deposition, sputtering, and pulsed laser deposition.

Spray pyrolysis is being used for several decades in the glass industry and in solar cell production [3]. In principle, spray pyrolysis is a simple technique where in ionic solution is prepared by starting materials in appropriate stoichiometric proportions of the constituent elements of the compound, and is sprayed over a heated substrate (around 300°C to 500°C). [8,9]

Spray pyrolysis involves a thermally stimulated chemical reaction between clusters of liquid vapour atom of different chemical species. This method lies somewhere between the thin film and thick film
techniques. Thin-film deposition using spray pyrolysis can be divided into three main steps: atomization of the precursor solution, transportation of the resultant aerosol, and decomposition of the precursor on the substrate [3].

The spray pyrolysis parameters influencing the structure and properties of the deposited films are temperature of the substrate, concentration of the precursor, spray duration and spray rate. In the present investigation, the spray pyrolysis technique is used to prepare thin films of SnO2. This technique is simple involving low-cost equipments and raw materials. Moreover, the deposition rate and the thickness of the films are controlled over a wide range by changing the spray parameter [10]. In this paper, the synthesis and characterization of tin oxide thin films is reported.

2. Experimental

SnO2 thin films were deposited by the method of Spray pyrolysis technique. Automated spray pyrolysis equipment is used for the synthesis of thin film in this work. The schematic diagram of this setup is shown in Figure 2.

2.1 Cleaning of Substrate

To prepare high quality thin film made of good type cleaning procedure of substrates glass is more essential. The step by step cleaning procedure is given below.

1. The glass substrates are initially washed in soap solution by scrubbing surfaces with the cotton swab dipped in liquid soap till they pass breathe figure test to remove oil, grease etc.
2. The glass plates are then rinsed thoroughly in deionized water to remove any traces of the soap solution left on the substrate.

3. Then the glass plates are soaked in chromic acid (90°C) for about two hours to dissolve the fine silica layer possibly formed on the surface and a new surface for the deposition of the film.
4. Finally, the substrates are rinsed thoroughly in deionized water and then cleaned with acetone.

Cleaning substrates were then placed on the substrate heater of the spray equipment to provide proper heating with uniformity to films. The glass plates were heated at a temperature of 400°C before the deposition of films.

The spray mixture is prepared by dissolving 0.1M of stannic chloride in ethanol. Total volume of the solution sprayed was 25ml. The stored solution was then applied in the rectangular shape on the glass slide. After that the furnace was turned off and the slide was allowed to cool slowly to room temperature.

3. Result and discussion

3.1. Structural Analysis

![Fig 3.1: XRD Spectra for the prepared SnO2 film](image)

Figure 3.1 shows the X-ray diffraction (XRD) pattern of Tin Oxide thin film deposited by Spray pyrolysis technique. The films were amorphous but when annealed at 400°C in air, distinct peaks of (110), (101), (200), (211), (220) and (301) orientation formed showing crystallization. which is in good agreement with the standard value, JCPDS.No 88-0287. All the peaks in the pattern is indexed to a tetragonal phase with lattice constants a = b =4.6986Å, c = 3.2212Å.

No additional peaks of any other phase have been detected, which indicates the purity of prepared sample. The sharp peaks also indicate that the
prepared SnO$_2$ thin film are high purity good crystalline particles. The particle size is calculated according to Debye- Scherrer formula,

$$D = \frac{(0.9\lambda)}{\beta \cos \theta}$$

Where, $\lambda$ is the length of CuK$\alpha$ Radiation, $\beta$ is the full width at half maximum, corresponding to the diffraction angle $2\theta$. It is found that the crystal size for the prepared SnO$_2$ thin film is found to be $0.43344 \times 10^{-7}$ m. Table 3.1 shows the Lattice parameters,

Table 3.1: Lattice parameter

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3.3 Optical Characterization

Photoluminescence spectra for the prepared SnO$_2$ thin films is recorded using Spectrofluorometer, under 450 high pressure Xenon lamp is used as an excitation source. The input excitation wave length is given by 330nm and related emission spectrum is shown in Fig.3.3.

$$E_g = \frac{hc}{\lambda e}$$

calculated using the formula.

Where, $E_g$ is the optical band gap, $h$ is the Planck’s constant, $c$ is the Speed of light, $\lambda$ is the Wavelength and $e$ is the Charge of electron.

Which is obtain as $3.4842$ eV. Also the prepared SnO$_2$ thin film emits blue fluorescence spectrum.

4. Conclusion

Tin Oxide (SnO$_2$) thin films have been successfully deposited on glass substrates using spray pyrolysis technique. This technique is simple and involves only low-cost equipment’s. The quality and properties of the films depend largely on the process parameters. The structural and optical properties of prepared SnO$_2$ thin films were studied by using XRD, FTIR, PL. The prepared SnO$_2$ thin film found to be in tetragonal structure with a particle size of $0.43344 \times 10^{-7}$ m. FTIR characterizations have confirmed the presence of Sn-O stretching mode corresponding to the vibration.
frequencies at 730.01cm\(^{-1}\) and 632.61cm\(^{-1}\). The optical band gap of SnO\(_2\) thin film is calculated as 3.4842 eV from the photoluminescence spectra.

5. References


