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The effects of Ni doping on the Structural, Microstructural, and Optical properties of tin oxide films using PSP method

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Abstract – In this study, we used a pneumatic spray pyrolysis technique at 450°C to deposit $Sn_{1-x}Ni_xO_2$ thin films ($0.0 \leq x \leq 0.10$) on glass substrates. The influence of doping content on the films structural and optical was investigated. Structural characterization by X-ray diffraction indicated that the rutile phase of SnO2 is present in all thin films, and crystallite sizes are estimated to be in the range of 27–47 nm. The optical bandgap energy increases from 3.83 to 4.01 eV as the dopant content increases according to the Burstein-Moss effect. Resistivity is affected by doping and the thickness of thin films.

Keywords – Thin Films; X–Ray Diffraction;Optical Properties

I. INTRODUCTION

As a result of their unique structural (suitable textured morphology), electrical (relatively low resistivity, on the order of 10^{-15} Ω sq^{-1}), and optical (high optical transmittance) characteristics, transparent semiconductor oxide (TCO) thin films have been the subject of intense research for several years [1,2]. These materials are very important from a technological point of view, and their applications are extremely diverse; they are found in sectors such as electronics [3], silicon solar cells [4], optoelectronics [1] and photovoltaic conversion [5]. Tin oxide is one of these chemicals (SnO2).

In this work, thin films of pure and Ni doped SnO2 films are deposited by ultrasonic spray pyrolysis (USP) technique onto glass substrates at 450 °C for 30 min. The effects of the doping on structure and optical properties are discussed.

II. MATERIALS AND METHOD

A. *Film preparation*

In this The thin films of pure and nickel-doped tin oxide at 2 at.%, 5 at.%, and 10 at.% of Ni were prepared by pneumatic spray pyrolysis on a glass substrate, using tin chloride dehydrate content [SnCl2-2H2O] (purity: 99.99%) as a precursor, and nickel chloride [Ni] (purity: 90.00%) as a doping source. The sputtering solution was prepared from a mixture of tin chloride [SnCl4, 2H2O] (Fulka 99.9%) (0.6 g) dissolved in 10 ml of distilled water (resistivity = 18.2 MX cm) and 10 ml of methanol (CH3OH) (Merck 99.5%) with a source of nickel (NiCl2–6H2O) (Fulka 99.9%) for different doping concentrations (2, 5 and 10 at.%). This solution was agitated for 1 h using a heated magnetic stirrer at room temperature. The thin films are deposited onto microscope coverglass substrates (30 × 12 × 1.2 mm3) uheated at 450°C.

B. *Characterization techniques*

The structure of the films is characterized by X-ray diffraction (Rigaku Ultima IV equipped with Cu–Kα radiation, 0.15418 nm). The optical properties are determined by measuring the transmittance of the films using a SpectroScan 80D spectrophotometer UV–vis in the 190–1100 nm spectral range.

III. RESULTS AND DISCUSSION

A. *Structure and microstructure analysis*

The XRD spectra of SnO2, Sn1–xNixO2 [0.00 \x B0.10] thin films, obtained by the pneumatic pyrolysis technique, is shown in figure 2. This shows that all the films crystallize into a rutile-like tetragonal structure of SnO2 according to JCPDS card no: 77-0452, by the presence of peaks with directions (110), (101), (200), (211), (310) and (301) [6]. Moreover, the XRD spectra confirm the absence of anyother diffraction peak related to metal clusters and/or oxide impurity phases such as NiO, NiO2, which confirm the insertion of Ni into the SnO2 lattice

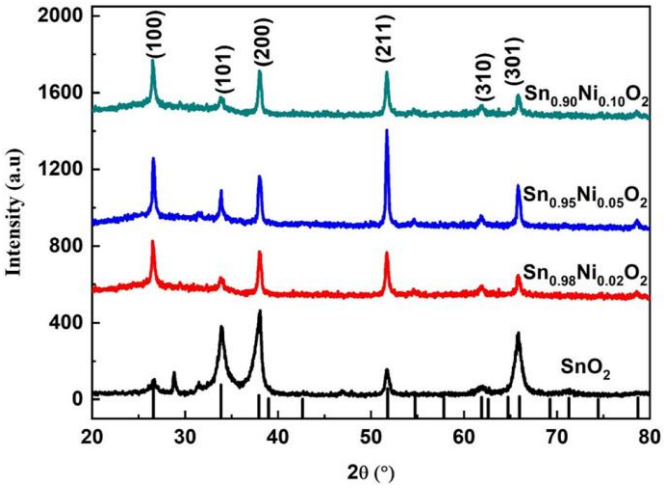

Fig. 1 XRD patterns of Ni-doped SnO2 sprayed thin films.

B. *Structure and microstructure analysis*

Figure 2. We performed microstructural studies of pure and nickel-doped SnO_2 thin films to highlight some effects due to the change in doping content. Scanning electron microscopy (SEM) micrographs of the surface of Sn1–xNixO2 layers (x = 0.02, 0.05 and 0.10) are shown in figure 3a–d, respectively. The SEM observations showed that the Ni–SnO2 layers have tightly packed regular grains with an almost smooth grain surface, fine and small grain size distribution, with no pin-holes and fissures.

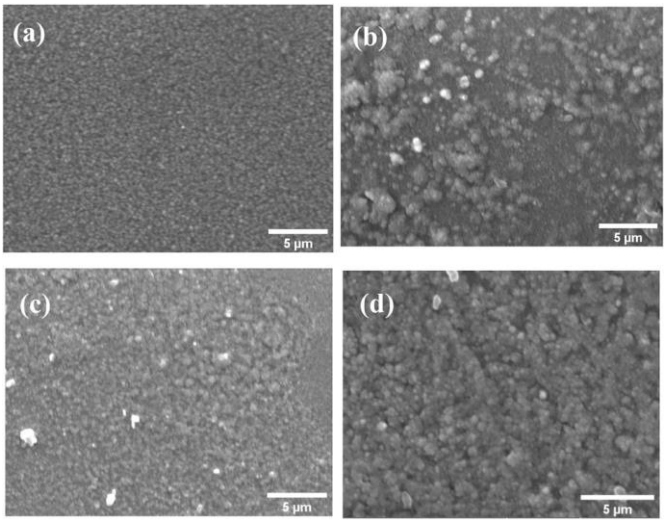

Fig. 2 SEM images of nickel-doped SnO2 sprayed thin layers: (a) 0 at.%, (b) 2 at.%, (c) 5 at.% and (d) 10 at.%. films.

C. *Optical analysis*

shows Figure 3 shows the variation of the transmittance as a function of the wavelength in the range [190–1100 nm] for the undoped and Ni-doped SnO2 samples prepared at different contents (2, 5 and 10 at.%). It can seem that all the layers show good optical transparency in the visible range, with a transmission value that varies between 76 and 82% in the visible range after doping. This result shows that Ni doping improves the optical properties that have an important role in photovoltaic devices [7,8]. It is also noted that the 10 at.% Ni-doped layer has the highest transparency in the visible range. In addition, the transmission edge shifts to lower wavelengths (blue shift) with the doping, resulting in an increase in the bandgap energy from 3.83 to 4.01 eV

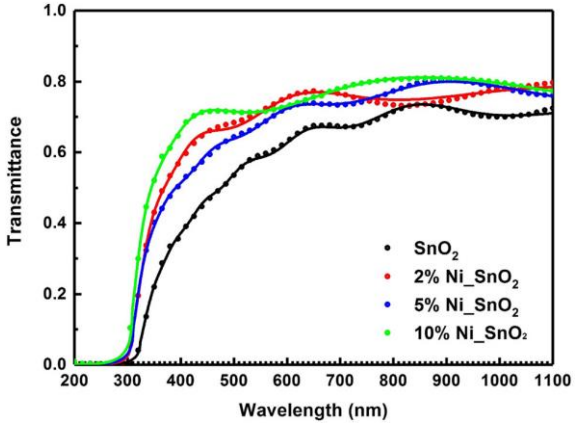

Fig. 3 Transmission spectra of SnO2, Sn0.95Ni0.05O2 [x = 0.02, 0.05 and 0.10]. Measured (full circles) and calculated (solid lines) transmittance spectra of films

IV. CONCLUSION

This study consisted of the elaboration and characterization of SnO_2, $Sn_{1-x}Ni_xO_2$ [x = 2, 5 and 10 at.%] thin films deposited by the pneumatic spray pyrolysis technique in order to study the influence of nickel doping on the different structural, microstructural and optical properties of the films obtained. The results of the XRD characterization show that all the films are polycrystalline with a tetragonal structure of the rutile type. The increase in the concentration of the Ni dopant clearly causes an increase in the intensity of the peaks. All the Ni-doped SnO2 films showed a preferential growth trend along the (200) direction. The average crystallite size varied between 27 and 47 nm. SEM revealed a smooth surface. The UV–visible spectrophotometer analysis represents an important feature in evaluating the quality of the deposited films. The average transmittance was found to be around 76–82% with the presence of an interference fringe. In the visible range, which indicates that our films are homogeneous and smooth, in other words, the values of optical bandgap energy obtained from our films are in the range of 3.83–4.01 eV.

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