



# Sn doping effects on the structural, microstructural, Seebeck coefficient, and photocatalytic properties of ZnO thin films

Sabrina Roguai<sup>a,b,\*</sup>, Abdelkader Djelloul<sup>a,b</sup>

<sup>a</sup> LASPI<sup>2</sup>A Laboratoire des Structures, Propriétés et Interactions Inter Atomiques, Université Abbes Laghrour, Khenchela 40000, Algeria

<sup>b</sup> Science of Matter, Abbes Laghrour University, Khenchela, Algeria

## ARTICLE INFO

Communicated by Prof. F. Peeters

### Keywords:

Sn-doped ZnO films  
Pneumatic spray  
Photocatalyst  
Methylene blue

## ABSTRACT

Successful ZnO, Sn<sub>x</sub>Zn<sub>1-x</sub>O [x = 0.01 and 0.03] films were synthesized by pyrolysis on glass substrates at  $T_s = 450\text{ }^\circ\text{C}$  for 1 h. Sn doping effect on structural, microstructural, Seebeck coefficient and optical characterizations were performed. It found that all films crystallize in the hexagonal würtzite structure. The success of the 1 at.% Sn doping is confirmed by the SEM images which show that the microstructure of the 1 at.% Sn doped ZnO is rather similar to that of the undoped ZnO film and shows spherical grains, by further increasing the Sn content (3 at.%), the films show a small spherical grains. Through FTIR analysis, distinct characteristic absorption peak at  $449\text{ cm}^{-1}$  for the Zn–O stretching mode with some changes in intensities. ZnO, ZnO:Sn films transmit decrease from 87 to 66% with doping content, while the bandgap energy not affected with doping. The Seebeck coefficient decreases from  $|188|$  to  $|110|\mu\text{V/K}$ , while the carrier concentration increases from  $3.37 \times 10^{18}$  and  $1.00 \times 10^{19}\text{ cm}^{-3}$  with doping content. The photocatalytic activity of Zn<sub>1-x</sub>Sn<sub>x</sub>O investigated by testing the degradation of methylene blue (MB).

## 1. Introduction

ZnO thin films are of great interest due to its special characteristics, such as non-toxicity, abundance in nature, high chemical and thermal stability and direct band gap (3.3 eV) [1]. These benefits are of immense importance in different domains such as gas sensors [2], piezoelectrical devices [3], surface acoustic wave devices [4] and solar cells [5,6].

Nevertheless, the surface conductance of this material is affected by chemisorptions and oxygen adsorptions. The electronic and optical characteristics of this material have been investigated by several scientists for specific uses [7]. The electrical and optical characteristics of various ZnO-doped metal ions have been analyzed [7,8].

Many types of dopants have been used (Al, In, As, S, Sn, Mn, etc. [9, 10]) for many important applications in ZnO thin films, these dopant elements offer a manner to regulate the electrical, optical, and magnetic properties, which make doped ZnO films promising candidates as high conductivity and transparency conductors in visible light range.

The Zinc oxide doped with Sn can increase the optical, electrical and structural properties of ZnO thin films [11,12]. As Sn<sup>4+</sup> replaces Zn<sup>2+</sup> in the ZnO crystal structure, two more free electrons are capable of participating in electrical conduction. Due to their nearly identical

radius, Zn can be easily substituted by Sn without causing significant lattice distortion.

TZO Thin films elaborated by the spray pyrolysis technique indicate that the optical properties of this system are not affected by the doping. While for the structural properties, the crystallite size increased with doping and reached a maximum value (42 nm) at 3 at.% doping [8]. Another study utilizing the same doping technique reported that the crystallite size attained a value of 95 nm at 2 at.% and 3 at.% doping, resulting in greater porosity values [13]. Recent works, thin films of Zn<sub>1-x</sub>Sn<sub>x</sub>O (x ≤ 10 at.%) indicates that the doping influence on the optical properties that it observing a decrease in the values of the bandgap energy from 3.26eV to 2.96eV. To the structural and microstructural, it shows a decrease in crystallite size values (50-26 nm, XRD) and the grain size (280-60 nm, SEM and AFM) [14].

Thanks to these properties, TZO thin films have several applications such as sensing applications [15], optoelectronic applications [16], dyesensi-tizedsolarcells (DSSC) [17,18]. Transparent electrode materials [19] or anti-reflecting coatings (ARC) in semiconductor solar cells [20], photocatalytic activity [21].

Various deposition methods can be used to synthesize ZnO:Sn thin films, such as sol-gel [22], electron deposition [23], spray pyrolysis

\* Corresponding author. LASPI<sup>2</sup>A Laboratoire des Structures, Propriétés et Interactions Inter Atomiques, Université Abbes Laghrour, Khenchela 40000, Algeria.  
E-mail address: [rog.sabrina@yahoo.fr](mailto:rog.sabrina@yahoo.fr) (S. Roguai).