



A Detailed Investigation on Structural and Optical Properties of ZnO:Sn prepared by Co-precipitation Method

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ABSTRACT

ZnO:Sn nanopowders were synthesized by Co-precipitation method using zinc acetate dihydrate and tin chloride as a precursor. Co-precipitate of ZnO:Sn nanopowders with pure Zinc and different volume fractions of tin chloride (0.0250, 0.050, 0.1) were obtained by calcination process at 500 °C. The XRD studies have revealed that the grain size gradually decreased with increase in the content of Sn. The transformation of structural properties of the Sn dopant was confirmed by FESEM. EDAX results have confirmed the presence of ZnO and Sn in the powder. From the FT-IR spectra, the chemical bonding and the presence of particles of Sn were confirmed. From the UV-Vis. spectra, it has been found that the doped Sn increased the bandgap than pure Zinc. The blue region of ZnO:Sn nanopowders was confirmed by PL studies. These results collectively indicated that the structure of ZnO nanopowders are significantly affected by Sn dopant.

Keywords: ZnO; Tin; ZnO:Sn nanopowders; Co-precipitation method.

1. INTRODUCTION

Zinc oxide is a semiconducting material with a wide band gap (3.37 eV). It is widely used in transparent conducting films, gas sensors, surface acoustic wave devices, photocatalysts, environment weather sensors and optoelectronic devices. The unique properties of ZnO-based materials, such as low resistivity, non-toxicity, high transparency and high trapping characteristics, have been extensively investigated. Various morphologies and structures of ZnO can be produced using specialized synthesis methods, according to many scientists. To tailor the functional properties of ZnO nanoparticles, physical and chemical methods are commonly used (Shah *et al.* 2010; Ratner *et al.* 2003; Alagarasi *et al.* 2004). Furthermore, by controlling the structure of ZnO to be in low-dimensional features such as nanowire and nanorod, the properties of ZnO could be improved even further. Metal-doped ZnO nanostructures have been of great interest for improving ZnO properties (electrical, optical and magnetic) to meet the requirements of potential applications. ZnO had been reported to be effectively doped with Al, Ga, In, Sn and S in prior studies. Amount of the dopants could have a great influence on the structure and surface morphology of ZnO (Prasopporn *et al.* 2014). Along with other research works, the physical and chemical properties of ZnO were successfully synthesized by the incorporation with Sn. Sol-gel, Solid-state reaction, Hydrothermal and Co-precipitation methods have been used to successfully synthesize ZnO-based nanopowders (Raja *et al.* 2014).

Because of its simplicity, cheap cost and enormous capacity for producing single and multi-component metal oxide particles, the Co-precipitation method is one of the most successful ways for synthesizing various types of metal oxide materials. In this work, ZnO:Sn nanopowders were synthesized by using Co-precipitation process.

2. EXPERIMENT

2.1 Synthesis

For the synthesis of ZnO:Sn nanopowders by co-precipitation method, first the precursor of zinc acetate dehydrate (0.1 M) was dissolved in 100 ml of deionized water. Then tin dichloride of various mole concentrations (0.025, 0.050 and 0.1) was added in dissolved zinc acetate dehydrate. The added solution was homogeneously stirred for one hour. After one hour of stirring, the ammonia solution was added for increasing pH level to 14. Finally, the chemical co-precipitation was achieved, and the precipitated samples were washed with de-ionized water until pH became neutral (pH 7). Then they were dried at 80 °C for 24 h in an oven. Finally, the synthesized ZnO:Sn nanopowders were calcined for 4 h at 500 °C.

2.2 Characterization

Structural analysis of ZnO:Sn nanoparticles was done by using X-Ray Diffraction (XRD) technique. The Fourier Transform Infrared Spectroscopy (FT-IR) was

used to study the wavelength of materials. Surface analysis of materials was done by Scanning Electron Microscopy (SEM) and the optical behavior analysis by using UV-Visible spectroscopy. Then the levels of photon excitation were determined by Photoluminescence (PL) method.

3. RESULT AND DISCUSSION

The structural properties of synthesized nanopowders were detected by using Particle X-ray method. The obtained X-ray diffractogram of ZnO and ZnO:Sn nanopowders were shown in Fig. 1. The obtained peaks of nanopowders confirmed the presence of sharp and high-intensity peaks with high crystalline nature. These peaks were compared with JCPDS Card No. (36-

1451) and found to be in proximity with earlier literature. Diffraction peaks at 31.96° , 34.60° , 47.73° , 56.78° , 63.20° and 68.12° were corresponding to the planes of (100), (002), (200), (102), (110), (103) and (112). The structure of the prepared zinc oxide sample was confirmed as hexagonal wurtzite. The obtained grain sizes of the samples were 20.26, 19.8, 17.8 and 11.44 nm, decreasing gradually with respect to the Sn concentration. From this, it was observed that the planes in the pattern were slightly shifted with respect to the Sn's doping concentration during arbitrary orientation of the crystal. This plane shift with decreased crystallite size during Sn-doping formed was due to the variation of nucleation center densities (Wasi Khan *et al.* 2013). This also resulted in the formation of smaller crystallites.

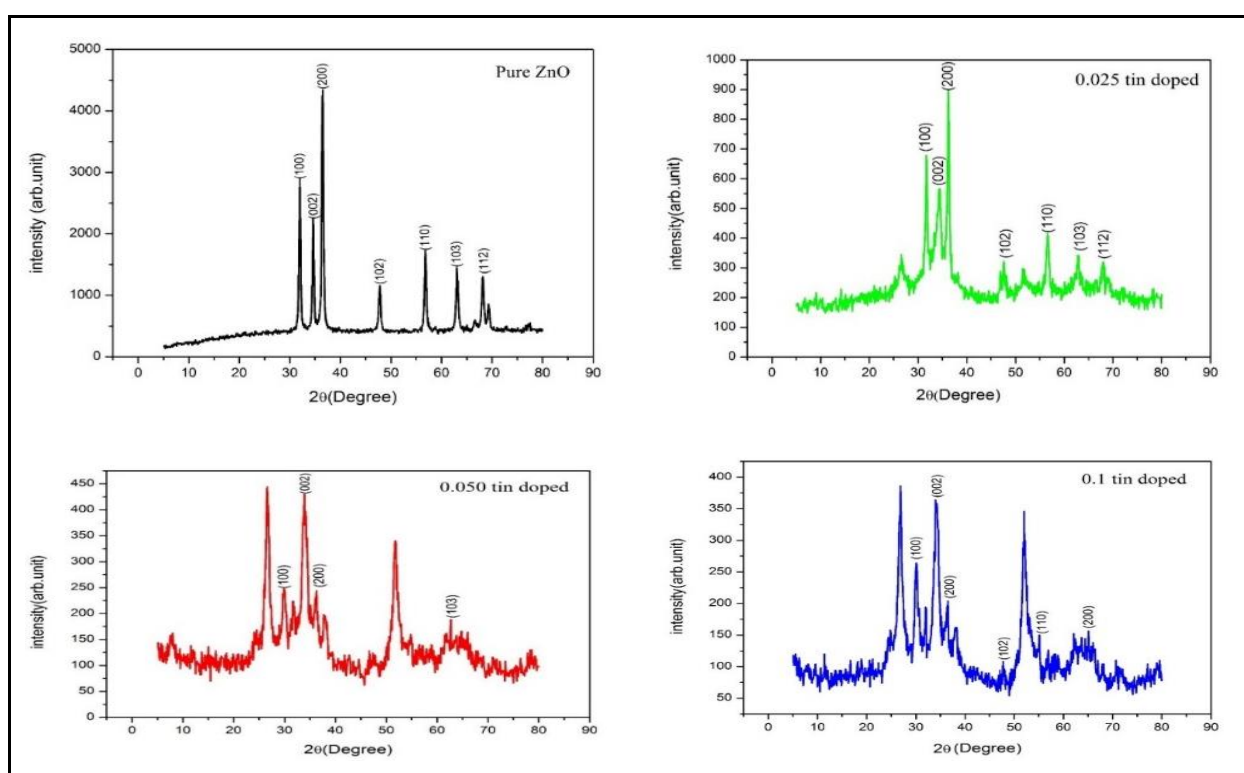


Fig. 1: XRD images of pure zinc and different volume fractions of tin chloride (0.0250, 0.050 and 0.1)

The SEM image (Fig. 2) confirmed the formation of ZnO:Sn nanoparticles. It was noted that the Sn particles were evenly agglomerated with ZnO particles. When the doping concentration of Sn was increased, the grain size agglomeration in nanoparticles also increased, resulting in the formation of tiny crystal particles. From this, it was confirmed that the morphological properties of nanoparticles were in good agreement with the structural properties.

Functional groups of all nanoparticles were analyzed by using FTIR spectra in the range of 400 to 4000 cm^{-1} . The FTIR spectra of pure ZnO and Sn-doped ZnO with various concentrations are shown in Fig. 3. The

obtained spectra revealed the presence of relevant functional groups in the prepared particles. The pure ZnO peak was observed in the 565 cm^{-1} region and O-H vibrational bending and vibration stretch peaks were observed in $1559, 3503\text{ cm}^{-1}$ region. At 0.250 concentration, ZnO and Sn peaks were observed in $561\text{ cm}^{-1}, 1130\text{ cm}^{-1}$ region. O-H vibrational bending and vibration stretch were assigned at $1523, 3617\text{ cm}^{-1}$ region. At 0.05 concentration, ZnO and Sn peaks were observed in $566\text{ cm}^{-1}, 1069\text{ cm}^{-1}$ region, O-H vibrational bending and vibration stretch were assigned at $1546, 3690\text{ cm}^{-1}$ region. The peaks were observed at $560\text{ cm}^{-1}, 1071\text{ cm}^{-1}, 1546\text{ cm}^{-1}, 3655\text{ cm}^{-1}$ region for 0.1 M

concentration. The hydroxyl O-H groups were water-adsorbed in all samples.

The UV-Vis. spectra of pure Zinc and Sn-doped ZnO nanopowder prepared with the various Sn-doping concentrations are shown in Fig. 4. The absorption peaks were observed at 334, 331, 340 and 340 nm. The doping of tin with Zinc oxide was confirmed by the small shift

in the absorption region. The bandgap of pure and Sn-doped ZnO nanoparticles at different concentrations was found to be in the range of 3.7 to 3.6 eV. With the increase in Sn concentration, the bandgap value of the sample decreased and was found to be better than pure ZnO. When Sn concentration increased, the blue shift was observed in the excitation absorption band.

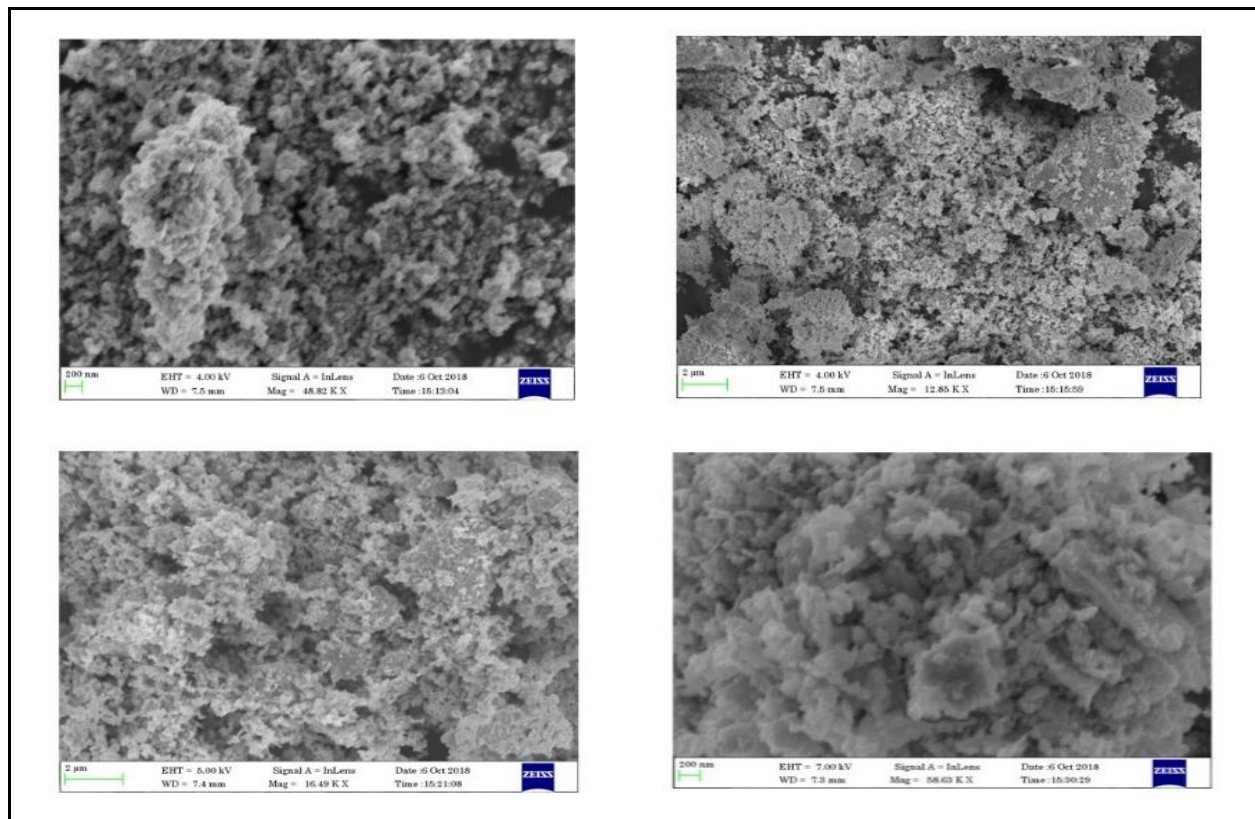
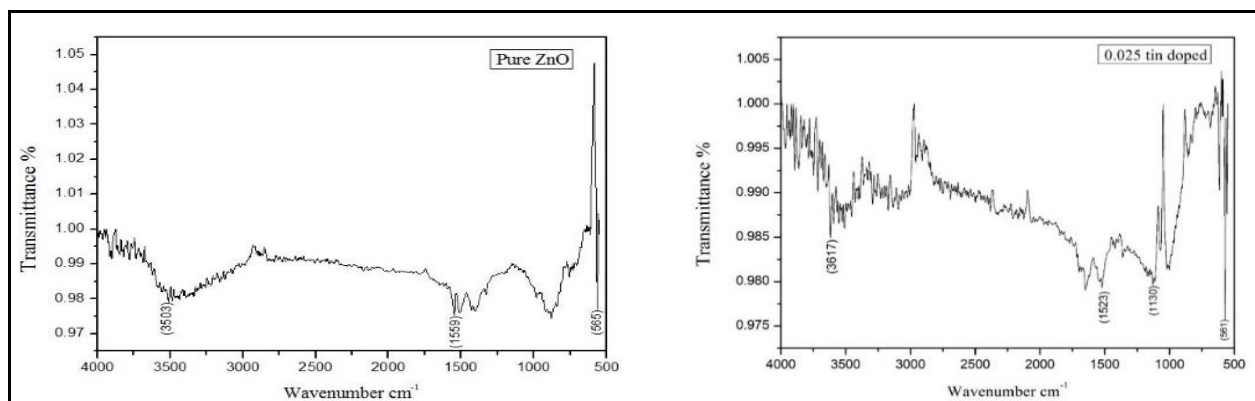


Fig. 2: SEM images of pure zinc and different volume fractions of tin chloride (0.0250, 0.050 and 0.1)



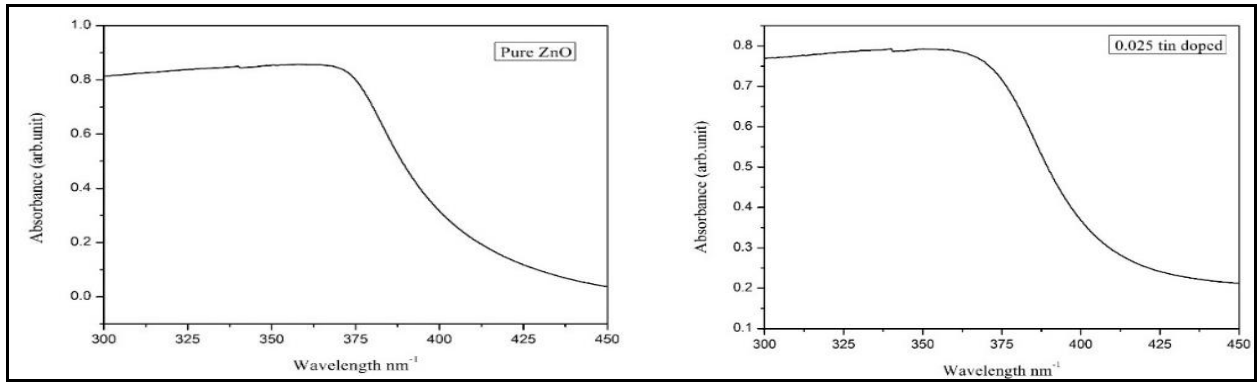


Fig. 3: FTIR images of pure zinc and different volume fractions of tin chloride (0.0250, 0.050 and 0.1)

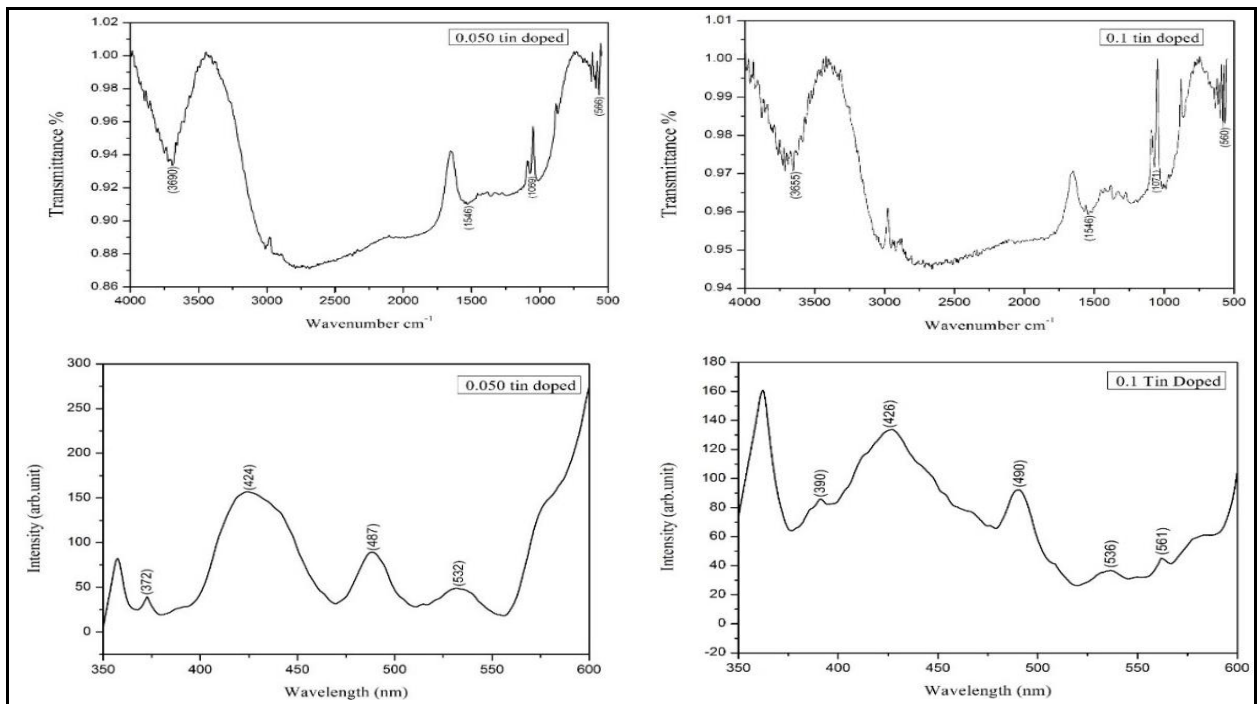


Fig. 4: UV images of pure zinc and different volume fractions of tin chloride (0.0250, 0.050 and 0.1)

The Photoluminescence patterns of ZnO and Sn-doped Zn were recorded at room temperature. The emission and excitation peaks were observed by the luminescent emission peaks; those observed in the range of 390, 366, 372 and 390 nm were present in the violet region, and were related to Near Band Edge (NBE) emission. The peaks in the range of 425, 398, 424 and 426 nm exhibited band excitation, in the violet region. The sharp and high-intensity peaks of 489 and 540 nm indicated the interstitials of Zinc and Oxygen ions. Other

high peaks of 489, 487 and 490 nm indicated the interstitials of ZnO and Sn ions. These were observed in the blue region.

The slightly increased and decreased intensity peaks were observed in the region of 450, 398, 424 and 426 nm. Those ranging peaks were shown the transition donor level due to conduction band to valence band. These results were in good agreement with the obtained UV-Vis. studies.

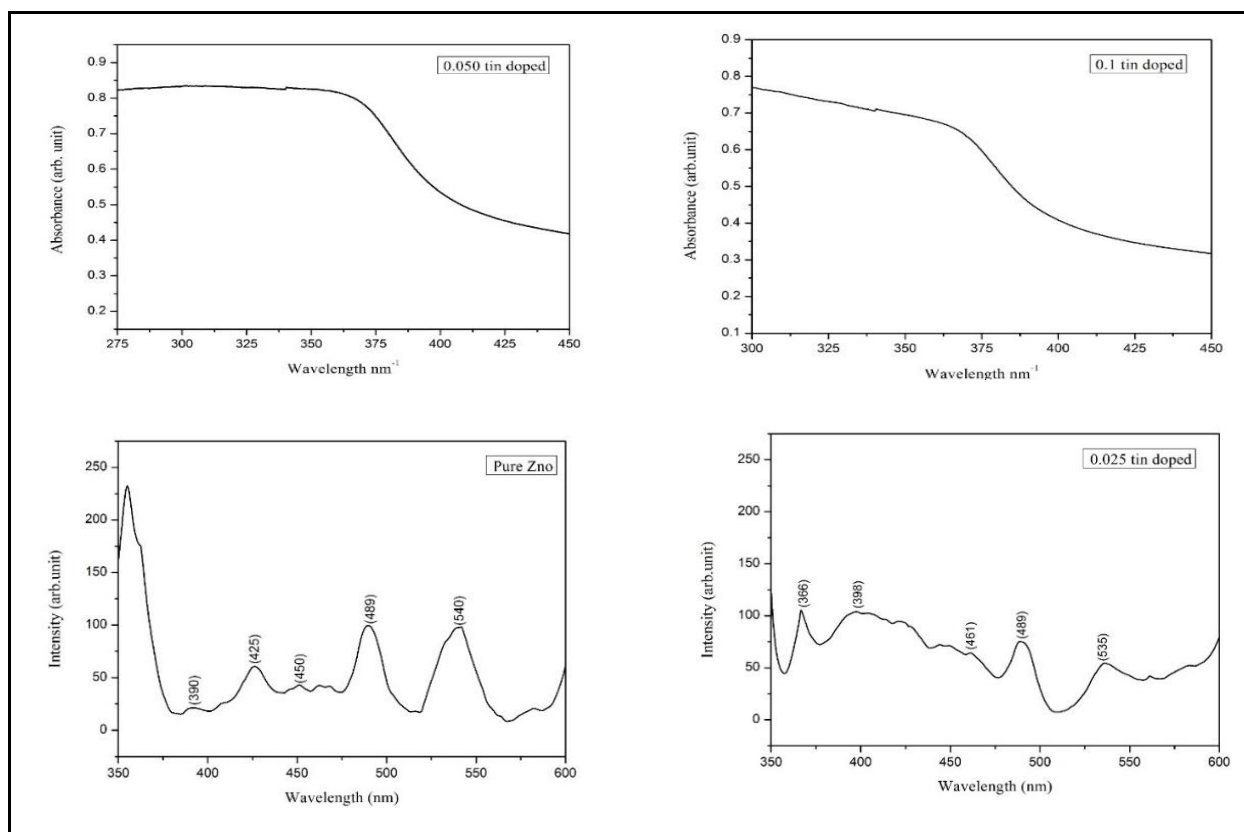


Fig. 5: PL images of pure zinc and different volume fractions of tin chloride (0.0250, 0.050 and 0.1)

4. CONCLUSION

In this work, pure ZnO and Sn-doped ZnO nanoparticles with various concentrations were synthesized by Co-precipitation method. The XRD patterns revealed that pure ZnO exhibited hexagonal structure. Due to Sn concentration, this phase was shifted into a cubic structure. The grain size decreased with respect to the concentration of Sn. The surface morphology (FE-SEM) confirmed the formation of doped nanopowders with slight variation in the morphology. FTIR spectra revealed the presence of relevant functional groups and chemical bonding in pure ZnO and ZnO:Sn nanoparticles. UV-Vis. results have shown that the optical band gap values decreased with respect to Sn concentration. PL spectra have shown the increase in emission wavelength with respect to the doping concentration. The results were in good agreement with UV-Vis. energy band gap values. It can be concluded that the optical band gap and luminescence of prepared nanopowders were highly dependent on dopant (Sn) concentration.

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CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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