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STRUCTURAL AND OPTICAL PROPERTIES OF TIN DOPED INDIUM OXIDE NANOPARTICLES

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Abstract: 5 at%Tin doped Indium Oxide nanoparticles were prepared by solid state reaction method. $(In_{0.95}Sn_{0.05})_20_3$ nanoparticles were sintered at 800^0C at reduced pressure. Structural and Optical properties were studied systematically. In present study, effect of tin dopant and oxygen vacancies were analyzed.

Key words: solid state reaction, dopant, sintered, nanoparticles, oxygen vacancies.

I.INTRODUCTION:

Since the discovery of room temperature ferromagnetism in Mn doped GaP and ZnO by Deitl et. al. [5], intense research has been carried out on different semiconductors. Indium oxide is the prominent material for spintronics materials. Indium oxide in thin film and nanostructure forms finds many optoelectronic applications such as solar cells, transparent conductors, flat panel displays, sensors, etc. Hence many preparation techniques were used for the preparation of pure and impurity doped indium oxide thin films and nanostructures. Moreover, it is known that a decrease in crystallite size leads to the change in the physical properties of materials such as optical transmittance, electrical conductivity, chemical, surface and band gap of the materials due to confinement effect.

Electron concentration will be increased by doping Sn in In_2O_3 matrix due to the electron donation by Sn^{4+} to the conduction band. Sn doped In_2O_3 nanocrystals show the intrinsic ferromagnetic property [2]. Anomalous Hall effect properties are also shown by Iron and Copper doped In2O3 and Indium-tin-Oxide films[3].

II.EXPERIMENTAL DETAILS:

Indium-tin-oxide $(In_{0.95}Sn_{0.05})_2O_3$ nanoparticles were synthesized by simple standard solid state reaction method. In a typical synthesis, commercially available In_2O_3 and SnO_2 (Sigma–Aldrich, 99.999% pure) powders were taken in desired ratios and mixed in Agate mortar and ground thoroughly for 12 hours using pestle. The ground fine stoichiometric samples were loaded into a small one end closed quartz tube of diameter 10 mm and length 10 cm, which was then enclosed by a bigger quartz tube of diameter of 2.5 cm and length of 75 cm with a provision to allow unwanted vapors to escape from the reaction chamber and it was evacuated to a pressure of $2x10^{-3}$ mbar using a rotary vane pump. The complete set up was placed in horizontal tubular microprocessor controlled furnace and heated for 8 hours at 800^0C. After that the samples were subjected to their structural and optical properties. The Structural properties of the nanoparticles were characterized by powder X-ray diffractometer (D8 Advance, BRUKER). The surface morphology of the nanoparticles were studied using TEM and EDAX (SUPRA 40 VP, CARL ZEISS) Optical properties of ITO nanoparticles were studied by diffuse reflectance spectroscopy (JASCO V-670). Fourier transform infrared (FT-IR) spectro- scopic analysis was carried out, using FTIR spectrophotometer (SHIMADZU), in order to find the bonding changes in ITO nanoparticles. Luminescent properties of the pure and impurity doped indium-tin-oxide nanoparticles were studied by luminescent spectrophotometer (Scinco Fluoro Master Plus fluorimeter) with excitation wavelength of 300 nm.

III.RESULTS AND DISCUSSIONS:

1.STRUCTURAL PROPERTIES:

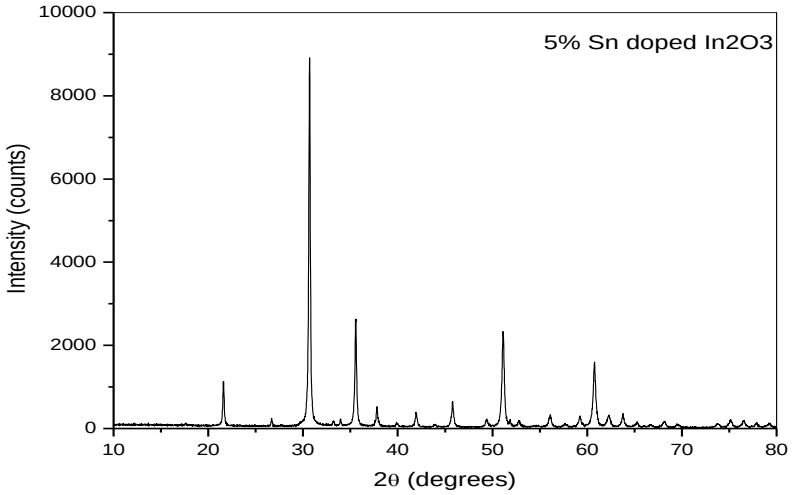

Fig.1 X-ray diffraction profile of 5at% Sn doped In_2O_3 nanoparticles

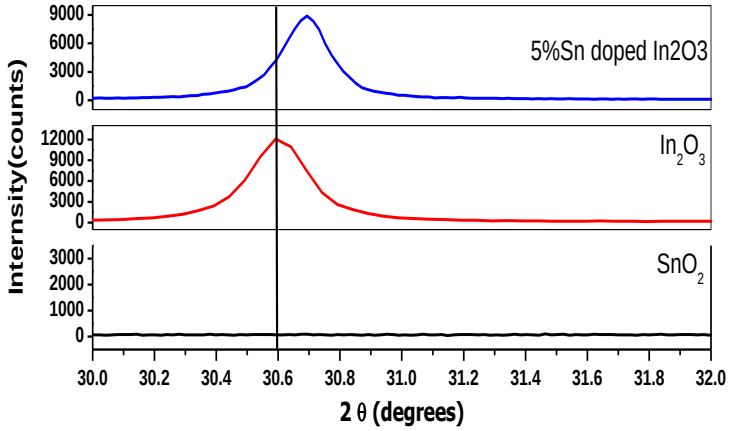

Fig. 2 (2 2 2) peaks of SnO2, In_2O_3 bulk materials and Sn doped In_2O_3 nanoparticles

Fig. 1 shows the X-ray diffraction profile of the 5 at% tin doped indium oxide nanoparticles in the diffraction range of 10^o-80^o. The diffraction peaks such as (2 1 1), (2 2 2), (4 0 0), (4 1 1), (3 3 2), (4 3 1), (5 2 1), (4 4 0), (4 3 3), (6 1 1), (5 4 1), (6 2 2), (6 3 1), (4 4 4), (5 4 3), (6 4 0), (7 2 1), were found in 5% Sn doped In_2O_3 nanoparticles among which (2 2 2) peak was predominant. All the indexed peaks exactly coincided with the cubic structure of In_2O_3 (JCPDS No. #06-0416) and no impurity phases were found in the Sn doped In_2O_3 nanoparticles. The intensity of the diffraction peaks decreased after doping Sn in In_2O_3 lattice. A small shift in diffraction angle observed towards higher angle as shown in fig. 2. A clear shift of the (2 2 2) peak towards higher angles was indicating a reduction in the lattice constant with Sn-doping.

We can see that the lattice constant decreased linearly from 10.112 Å (undoped with Sn) to 10.08 Å for 5 at% Sn doping indicating that Sn ions are incorporated into the In_2O_3 lattice by substituting the positions of In ions. The decrease in lattice constant is due to the stress produced, which is because of small difference in ionic radii of In^{3+} and Sn^{4+}.Similar results were also found in Fe and Sn co-doped In_2O_3 thin films by Pengfei et al in 2013. The crystallite size (D) was calculated by using the Debye-Scherrer formula,

$$D= k\lambda/\beta\cos\theta \quad \text{---------- (1)}$$

where, k is a constant, λ is the diffraction wavelength of CuK_α (λ= 1.5406 Å), β is the full width at half maximum (FWHM) and θ is the diffracted angle. The crystallite size was calculated using Scherer's relation and found that it was about 47 nm. Nanoparticles surface morphology studied by FESEM and TEM.

Fig.3 shows the field emission scanning electron microscope (FE-SEM) micrograph of the 5 at% Sn doped In_2O_3 nanoparticles. The micrograph shows well defined particles with varied geometries formed by floculations and aggregation. Few particles show surface geometry with aspects ratio >1.5. Average particle size was about 50 nm. The calculated particle size is in consistent with the average crystallite size found from XRD.

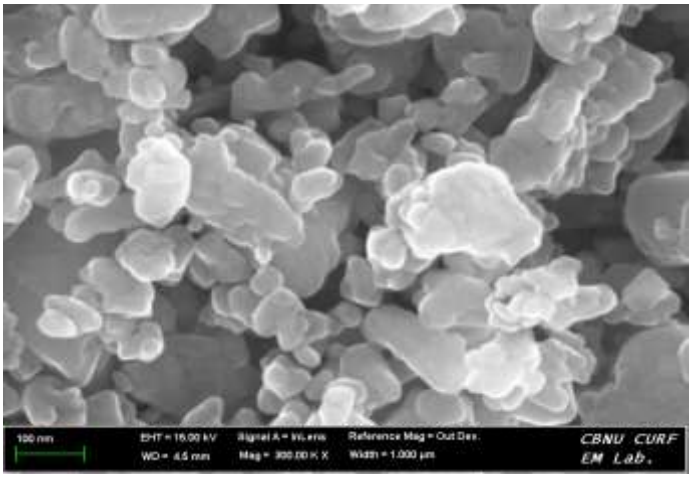

Fig. 3 FE-SEM image of 5at% tin doped indium oxide nanoparticles

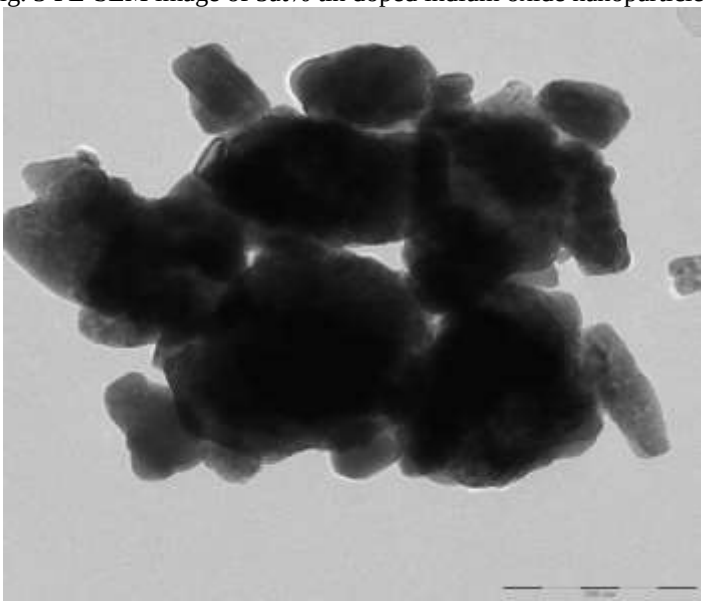

Fig 4 TEM image of 5at% Sn doped In_2O_3 nanoparticles

The 5 at% Sn doped In_2O_3 nanoparticles morphology and size have also been scanned by means of TEM. The 5 at% Sn doped In_2O_3 nanoparticles particle size found as 54 nm. The crystal planes found from SAED image were well coincided with crystal planes found from XRD.

Fig 5 SAED image of 5at% Sn doped In_2O_3 nanoparticles

2.ELEMENTAL ANALYSIS:

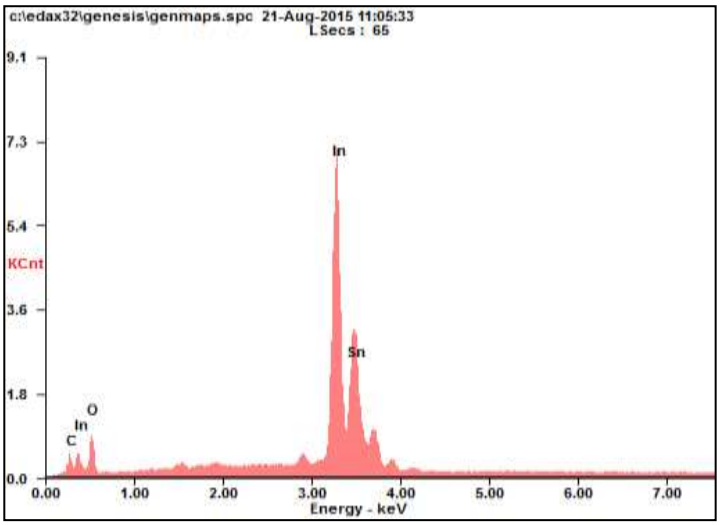

Fig 6 EDAX spectrum of 5 at% Sn doped In_2O_3 nanoparticles

EDAX spectrum shows all the constituent elements in 5 at% tin doped indium oxide nanoparticles and is close to targeted metal composition. However, oxygen content is less than the target value.

Table 1 Summary of atomic percentages

Element	Wt%	At%
CK	1.61	9.37
OK	8.19	35.82
InL	82.53	50.29
SnL	7.67	04.52
Matrix	Correction	ZAF

3. OPTICAL PROPERTIES:

Absorbance spectrum of Sn doped In_2O_3 nanoparticles show the less absorbance of visual light and high absorbance of UV and infrared light. Fig 6 shows the 5at% Sn doped In_2O_3 nanopaticles. Sn dopant and Oxygen vacancies were providing energy levels between conduction band and valence band, so that the energy gap is reduced from 3.5 to 3.2eV. Optical gap of Sn doped In2O3 nano crystals was increased because of Burstein-Mass effect[1].

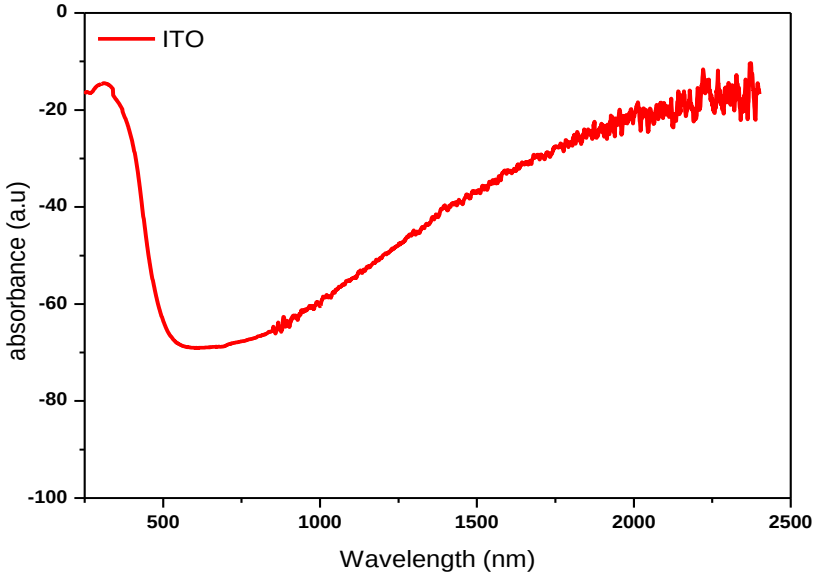

Fig 7 absorbance spectrum of 5 at% Sn doped In_2O_3 nanoparticle

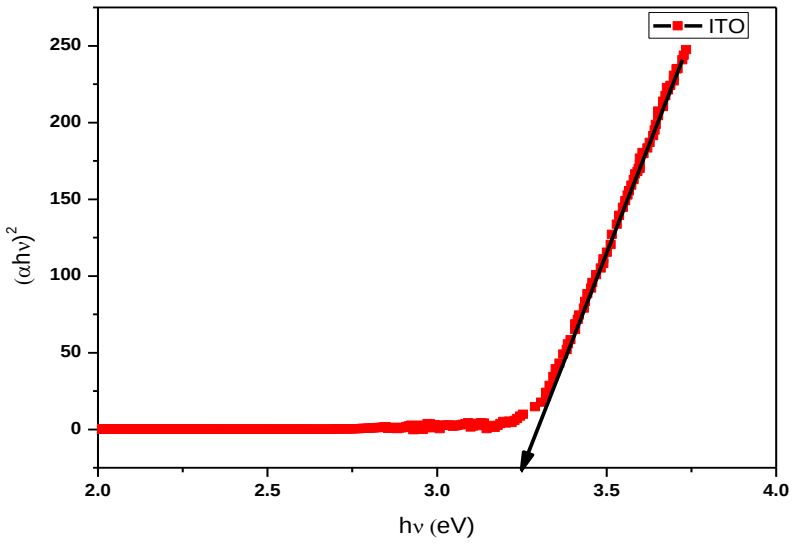

Fig 8 Plot of $(\alpha h\upsilon)^2$ versus hυ of the 5 at% Sn doped In_2O_3nanoparticles

IV. CONCLUSION:

5at% Sn doped In2O3 nanoparticles were prepared by solid state reaction method with particle size 47 nm. These nanoparticles show single crystalline nature and absorptive property at UV and Infrared regions. These nanoparticles had band gap of 3.2 eV.

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