

OPTICAL PROPERTIES OF Co-SUBSTITUTED SnO_2 NANOGRANULAR THIN FILMS

Gopinadhan K.[@], Dinesh K. Pandya, Subhash C. Kashyap and Sujeet Chaudhary,

Thin Film Laboratory, Department of Physics, Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110 016

([@]Email: gopinadhan_k@yahoo.com)

Introduction

Co-doped SnO_2 thin films are very interesting in the current field of **spintronics**(**Spin based Electronics**) because

- It combines optical transparency, semiconductivity and ferromagnetism.
- Its strong structure-property relationship.
- It allows tuning of the magnetic memory by applying Voltage, it has Spin-FET characteristics.

Film Preparation Details

Technique Used: Spray Pyrolysis.

Precursors Used: $\text{SnCl}_4 \cdot 5\text{H}_2\text{O}$ for Sn, $(\text{CH}_3\text{COO})_2\text{Co} \cdot 4\text{H}_2\text{O}$ for Co.

Deposition Temp.: 450°C.

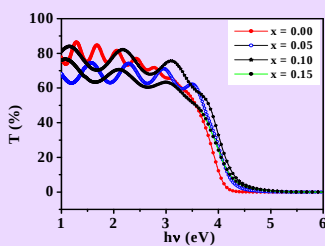
Post-deposition Treatment: Annealing at 500°C for 30min in air.

Volume Flow Rate: 10ml/min.

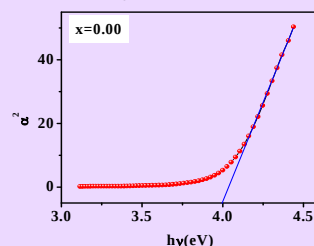
Carrier Gas Used: Nitrogen.

Substrate Used: Quartz.

Optical Properties of $\text{Sn}_{1-x}\text{Co}_x\text{O}_{2-\delta}$ thin films

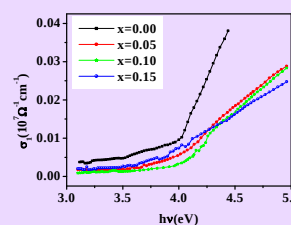


- Transmittance edge is blue-shifted on Co-doping.
- For, $x=0.10$, maximum blue-shift=200 meV at 20%T.



- Tauc's Plot-Estimation of Direct Band Gap (E_g).
- Absorption Coefficient (α)= $2\pi ck/\lambda$, Where k : Extinction coefficient calculated from Tömlén eqn.³, d : thickness of the film.
- For direct band gap $\alpha \propto (h\nu - E_g)^{1/2}$.

Optical Conductivity



Real Part of Optical Conductivity $\propto \text{Re}(4\pi n k/\lambda)$, Where n -real part of ref. index.

The absence of in-gap absorption indicates

- Band calculations are not capturing the electronic structure of Co under assumed charge state.
- On-site Coulomb energy on adding another electron to the Co ion is large.

What is the cause of Blue-shift?

Possible reasons

- Change in lattice constant
- Quantum size effect
- Change in electronic structure
- Burstein-Moss shift

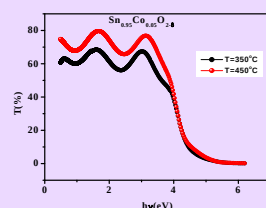
Is it due to Lattice Constant variation?

x	Lattice constant 'a' (Å)	Lattice constant 'c' (Å)	Crystallite size (nm)
JCPDS	4.737	3.186	-
0.00	4.7369	3.1838	26.7
0.05	4.7382	3.1873	13.6
0.10	4.7365	3.186	12.3
0.15 (SnO_2)	4.7333	3.1854	9.1
Co_3O_4			16.2

No,

Negligible change in lattice constant 'a', and 'c'.

Is it due to Quantum Size Effect?



No,

- Absorption edge has not been shifted on varying the dep. temperature.
- The grain size has been changed from 20nm to 10nm.

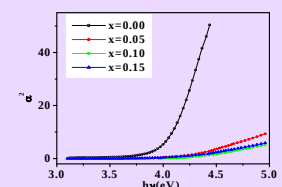
Is it due to change in electronic structure?

If SnO_2 ($E_g=4.0\text{eV}$) and Co_3O_4 ($E_g=1.5\text{eV}$) forms an alloy, there should have been a red-shift.

Rigid alloy concept is therefore ruled out.

The observed absence of below band gap absorption indicates that the absorption takes place at a higher energy than the fundamental absorption.

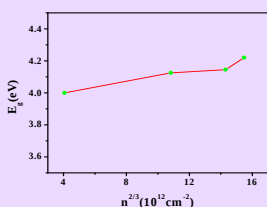
How does $\alpha^2(h\nu)$ varies with Co-doping. Can it give some insight?



The change in the slope of α^2 with Co-doping indicates

- O and Sn band edges are not effected.
- Reduction of the interband oscillation strength upon Sn dilution by Co

Is it Burstein-Moss Shift?



Yes,

The linear relation-ship confirms that the blue-shift has its origin in the B-M effect

Where the extra-electrons are coming from?

In SnO_2 , Sn:O=1:2, in Co_3O_4 Co:O=1:1.33.

For every Sn substitution by Co necessitates the removal of oxygen.

Each Oxygen vacancy donates 2 electrons to the conduction band.

Conclusions

- The direct band gap (E_g) has been blue-shifted on Co-doping.
- The maximum shift is observed for $x=0.10$, i.e. 220meV.
- The most probable reason for blue-shift lies in the Burstein-Moss Effect

References:

- 1.K. Gopinadhan, D. K. Pandya, S. C. Kashyap, and S. Chaudhary, *J. Appl. Phys.* 2006(Accepted).
- 2.K. L. Chopra, S. Major, and D. K. Pandya, *Thin Solid Films* 102, 1 (1983).
- 3.S. G. Tomlin, *J.Phys. D.: Appl. Phys.* 1, 1667 (1968).
- 4.J. R. Simpson, H. D. Drew, S. R. Shinde, R. J. Choudhary, S. B. Ogale, and T. Venkatesan, *Phys. Rev. B.* 69, 193205 (2004)