Structural and Electrical Characterization of Sn doped ZnS Thin Films Synthesized by Chemical Bath Deposition (CBD)

Presented by

Farzana Akter Sohaly
Department of Electrical & Electronic Engineering
University of Dhaka

Outlines

- Introduction of thin films
- Various deposition techniques of thin films
- Applications
- Fabrication process of Sn doped ZnS thin films
- Results & Discussion

Define Thin film!

- A **thin film** is a layer of materials ranging from fractions of a nanometer(monolayer) to several micrometer in thickness.
- Thin film technology is a ‘self organizing’ structural evolution.

Fig.1: Thin film using material Cu,Sn,Zn,S developed by IBM

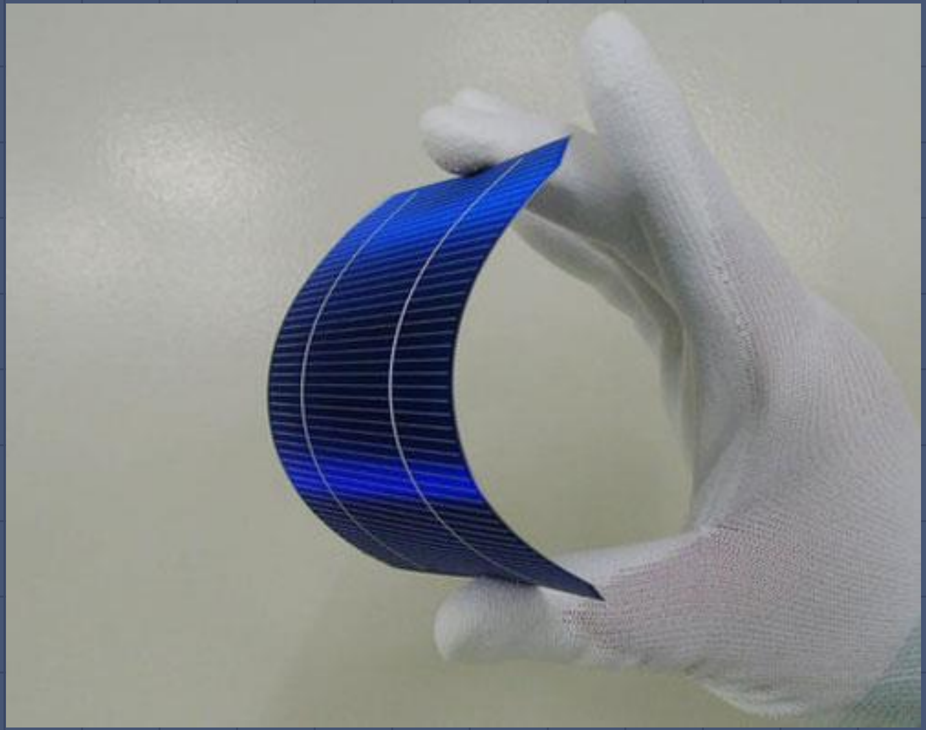


Fig.2: Smallest solar cells thinner than human hair

Source: [1]https://inhabitat.com/ibm-releases-cheaper-40-more-efficient-thin-film-solar-cell/
[2]https://www.pinterest.com/pin/274438789522796l0/

Thin film Market Demand

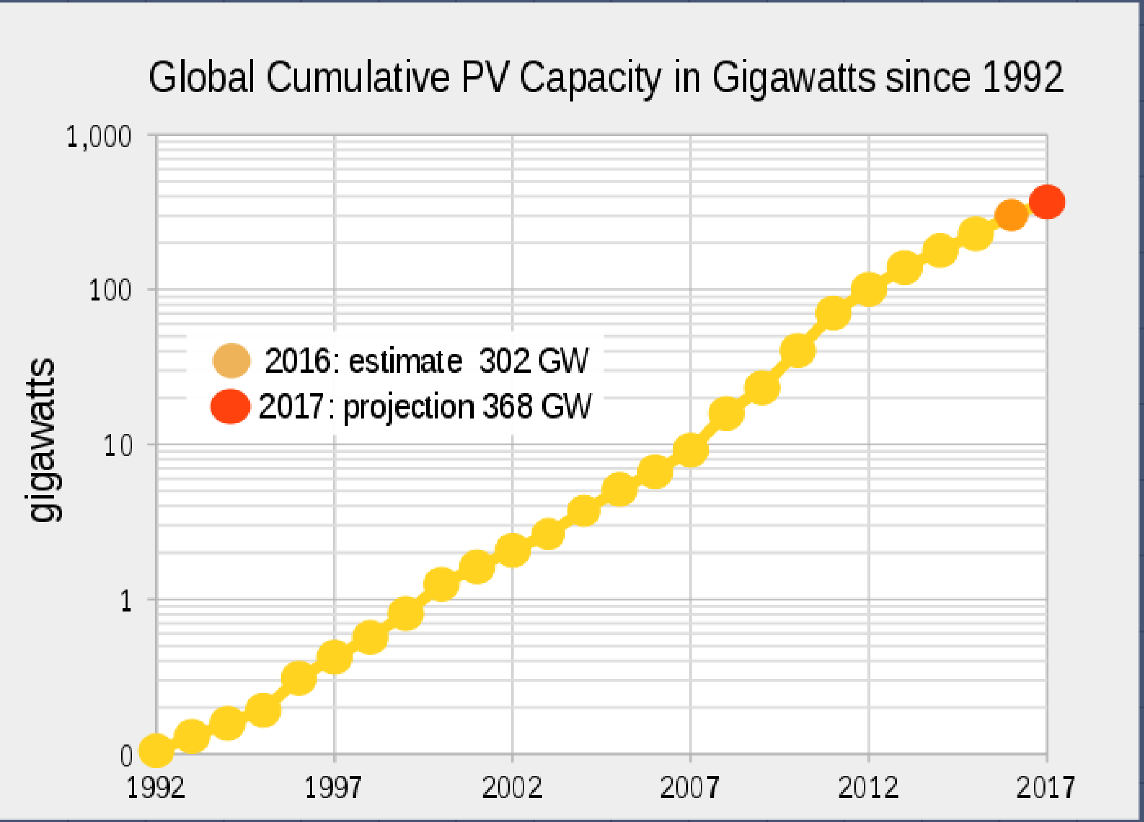


Fig.3: The prospects of solar energy industry globally

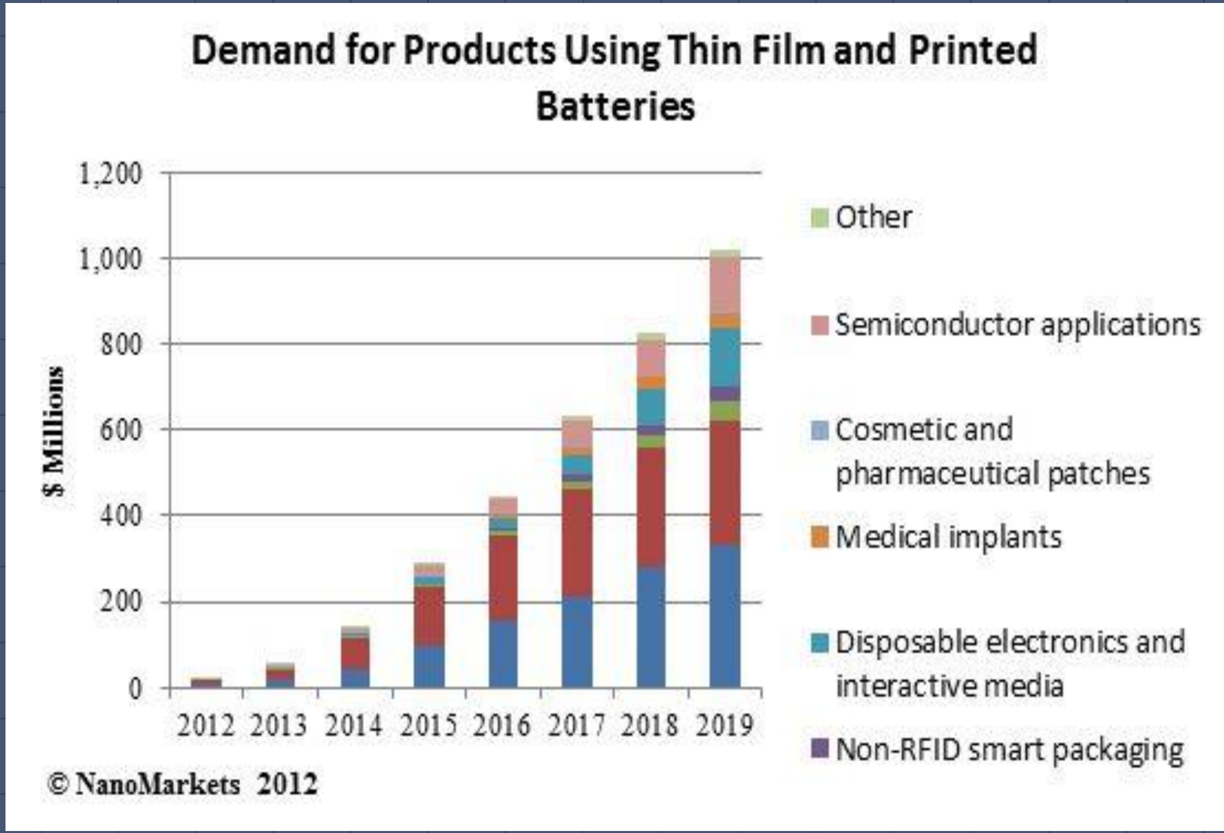


Fig.4: Demand for using thin film and printed batteries

Source:[3] NanoMarkets, "Thin-Film and Printed Battery Markets – 2012"

[4]https://medium.com/@solar.dao/hopes-and-fears-the-prospects-of-solar-energy-industry-cd637dfcff88

Applications

- ZnS thin film can be used as

    1. Antireflection coating for solar cell
    2. Optoelectronic devices
    3. photosynthetic coating
    4. photoluminescence devices

    and many more

- **Our main goal is to apply Sn doped ZnS thin film as a buffer layer in solar cell**

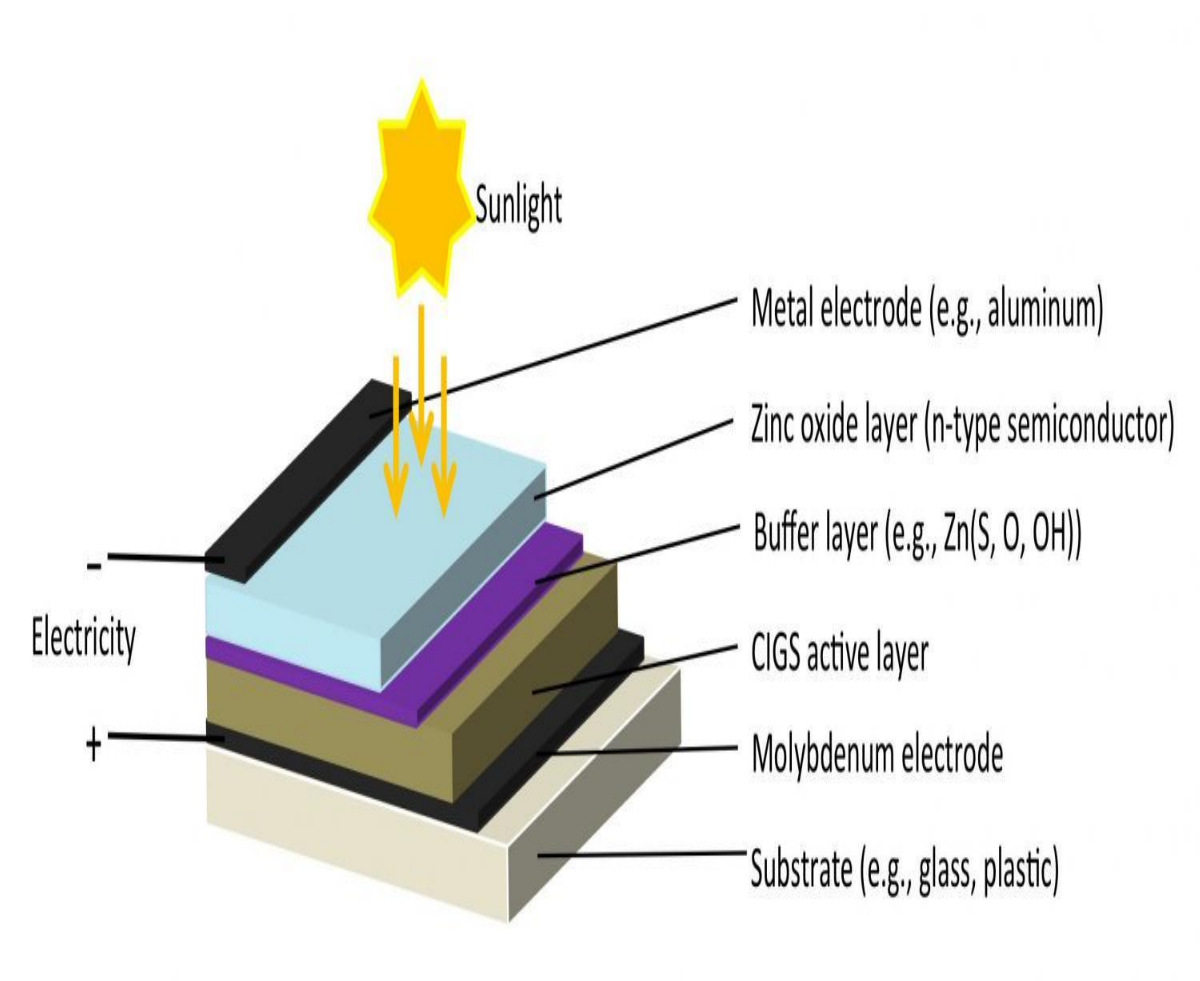
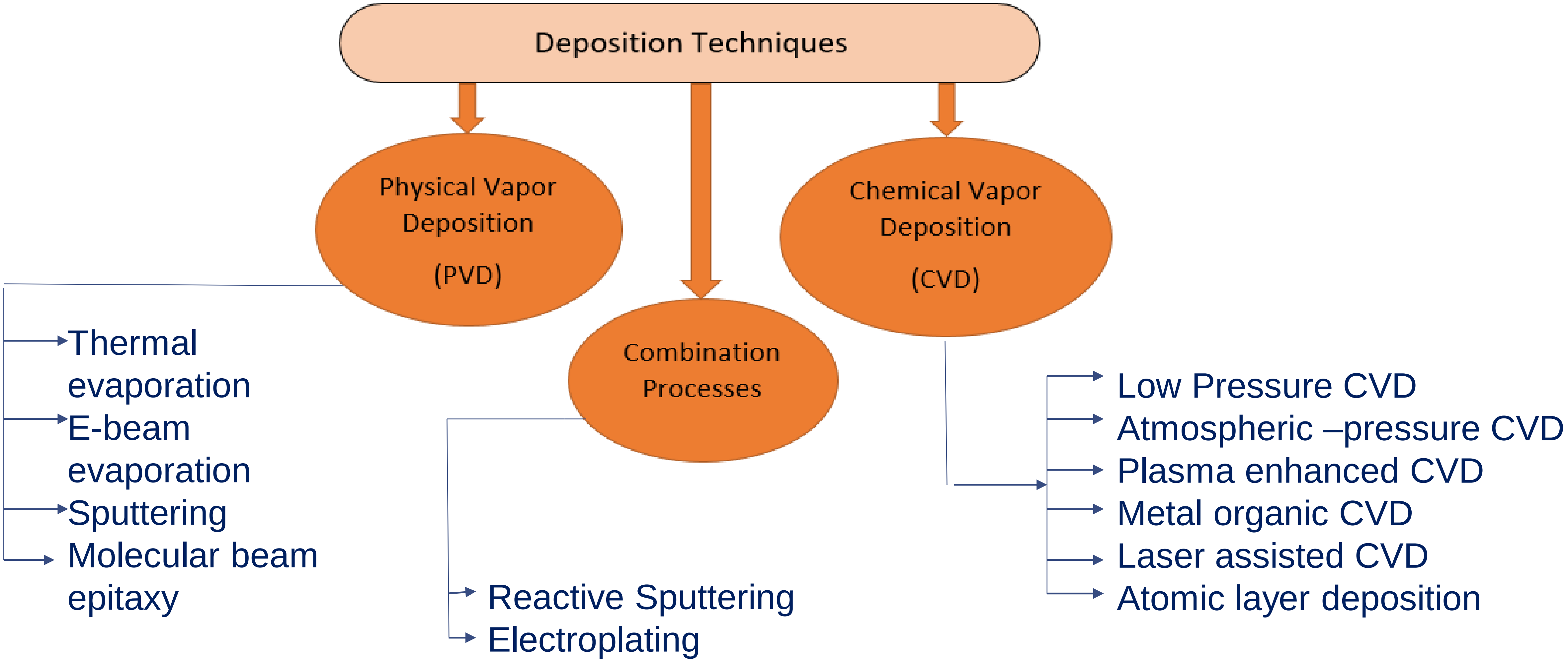


Fig.5: The configuration of a typical CIGS solar cell

Thin film deposition technique



Why Chemical Bath Deposition??

- **Chemical bath deposition** (CBD) is a method to deposit thin films and nanomaterials by chemical reaction. It is also known as **Chemical Solution Deposition** (CSD).

- Substrates are immersed in a chemical bath containing precursor solution.

- It requires low cost and low temperature (highest 90 ^{o}C) .

Advantages

✓ Solution containers and substrate mounting device

✓ Stable, adherent, uniform and hard films

✓ Suitable method for highly efficient film

✓ No need of vacuum environment

Disadvantages

✓ Waste of solution

✓ Substrate cleaning

Chemical Bath Deposition Process

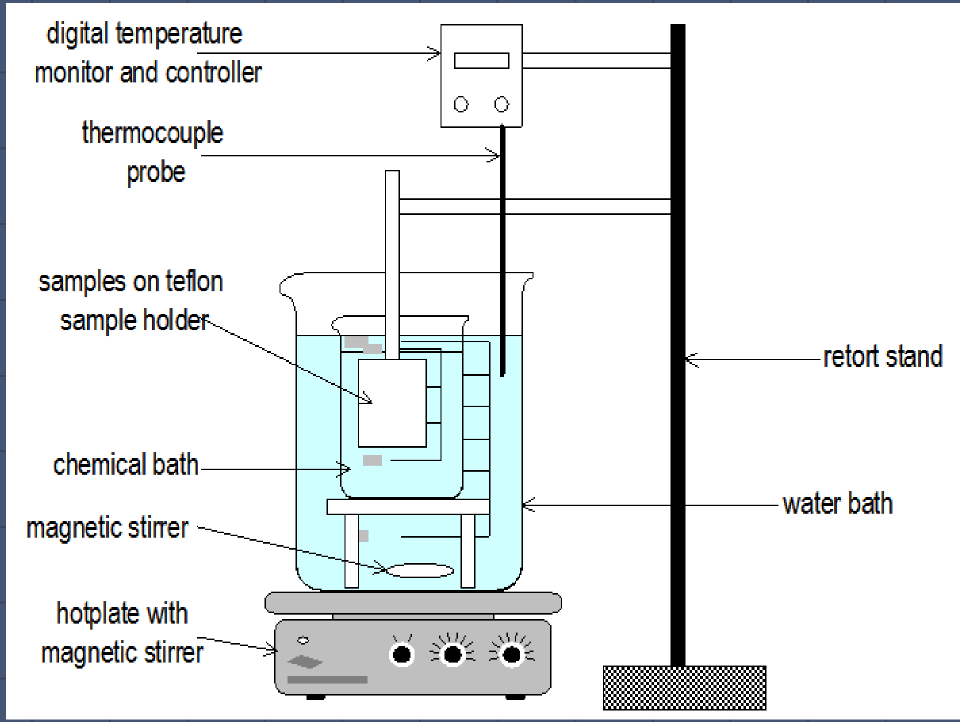


Fig.6: Chemical Bath Deposition Set-up

Fig.7: A Sample of Sn doped ZnS thin film

❖ Deposition processes is done to controllably transfer atoms from a source to a substrate

Source: [6]https://www.researchgate.net/figure/2-Chemical-Bath-deposition-set-up175_fig23_264928627

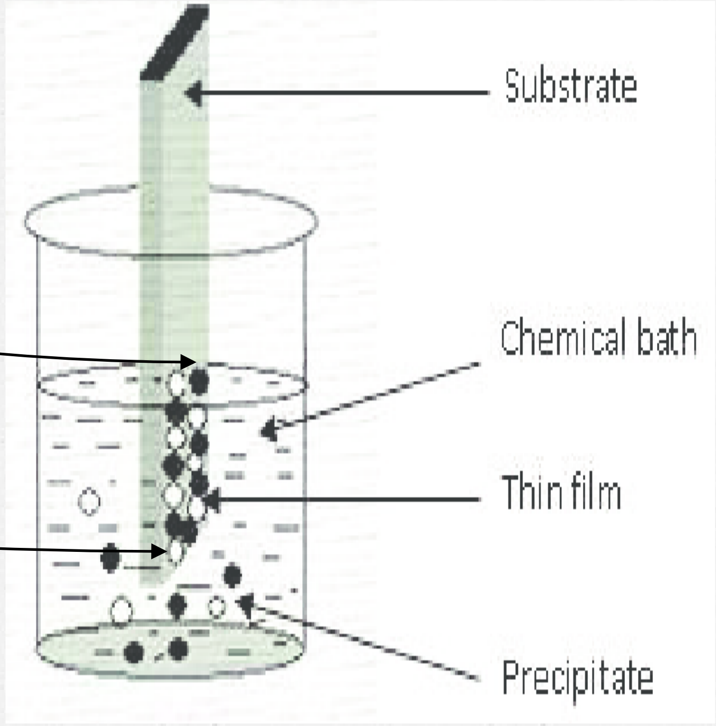
Chemical Reaction

$ZnCl_2 \, . \, 2H_2O = Zn^{2+} + 2H_2O + 2Cl^-$

$Zn^{2+} + 4NH_3 = Zn(NH_3)_4{}^{2+}$

$SC(NH_2)_2 + 2OH^- = S^{2-} + CH_2N_2 + 2H_2O$

$Zn(NH_3)_4{}^{2+} + SC(NH_2)_2 + 2OH^- = Zn + 4NH_3 + CH_2N_2 + 2H_2O$



Source: [8]https://www.researchgate.net/figure/Schematic-of-Chemical-Bath-Deposition_fig1_303843308

Fig.8: Deposition of cation and anion on substrate

X-ray Powder Diffraction Pattern

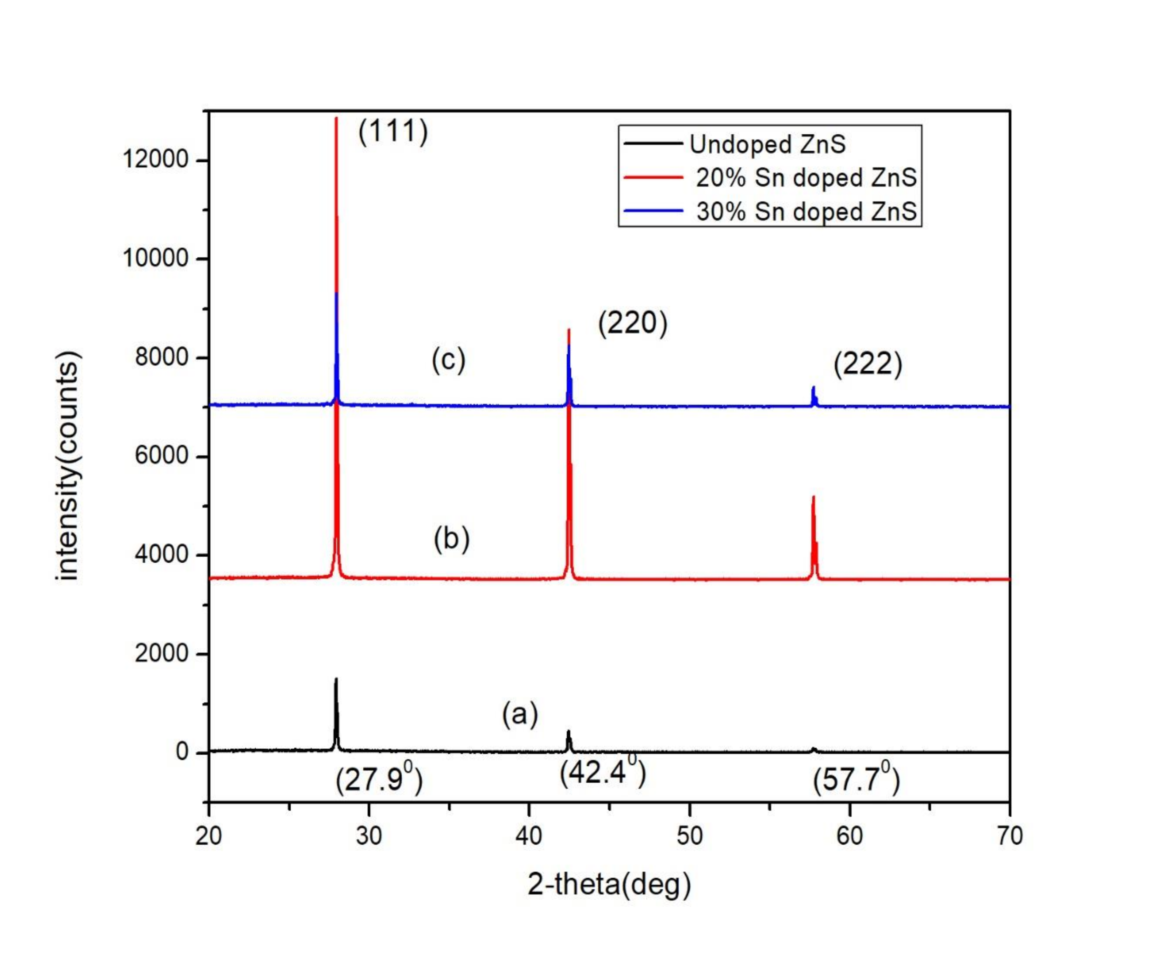


Fig.9: X-ray diffraction pattern for a)Undoped ZnS,

b)20% Sn doped ZnS, C) 30% Sn doped ZnS

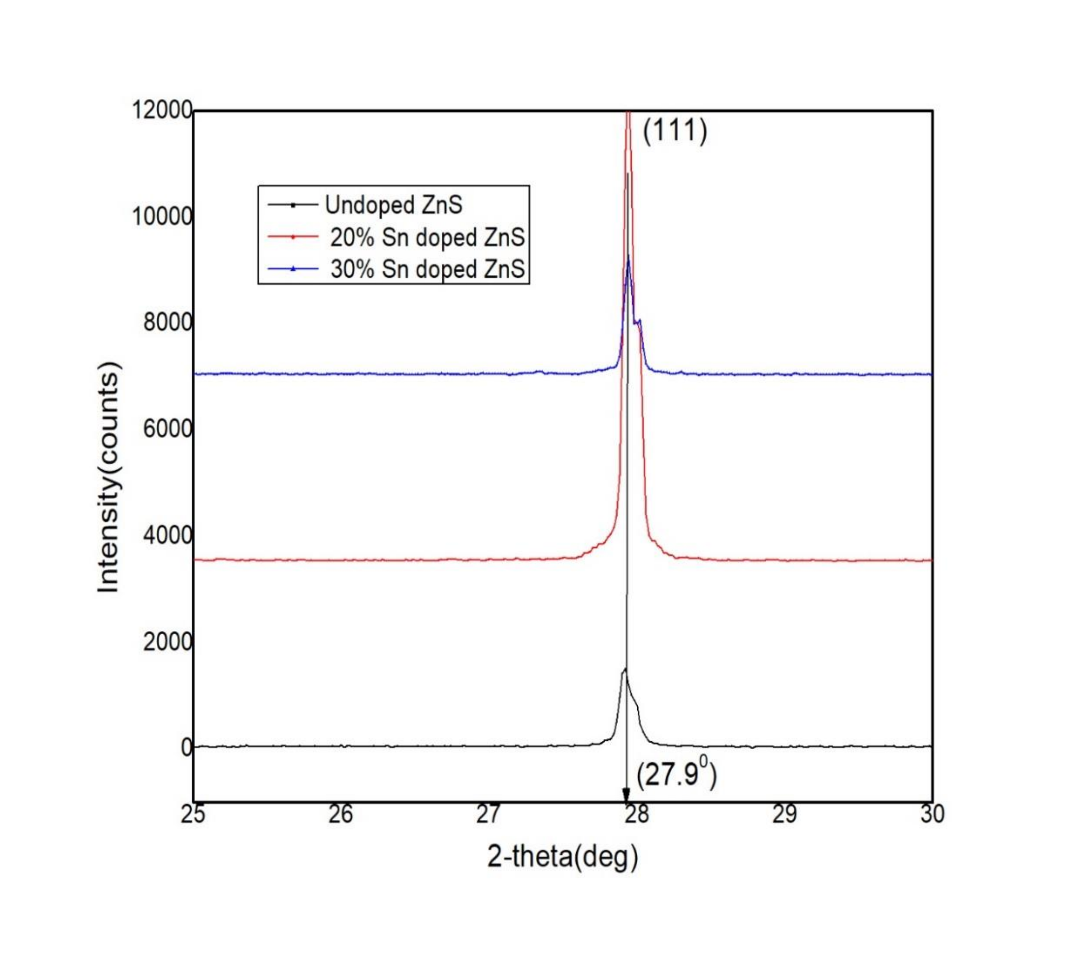


Fig.10: Left shift of 2-theta angle for (111) plane

XRD Analysis

- The crystal structure is cubic (zinc blend).
- The crystallite size is calculated from Debye-Scherrer's formula for (111) plane-

Crystallite Size , D= 0.9λ/β Cosθ ,

Dislocation density, $\delta = 1/D^2$

Microtrain, ε= βCosθ/4

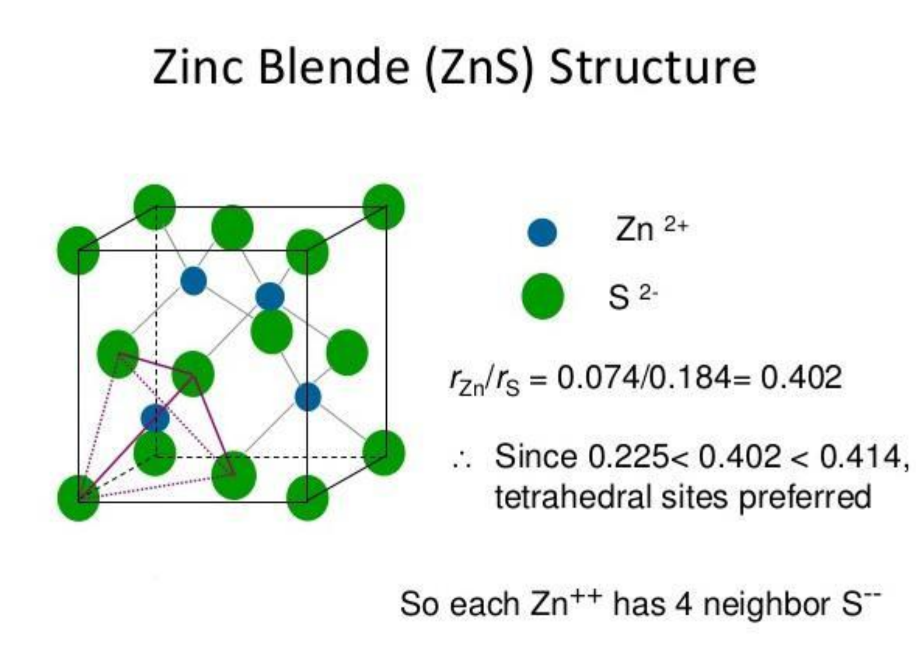


Fig.11: Crystal structure of Zinc Blende

For plane(111) at 2θ = 27.9 °			
Thin film	Crystallite size, nm	Dislocation density, m^{-2}	Microstrain
Undoped ZnS	112.14	7.95×10^{13}	3.09×10^{-4}
20% Sn doped ZnS	136.44	5.37×10^{13}	2.54×10^{-4}
30% Sn doped ZnS	146.24	4.67×10^{13}	2.37×10^{-4}

Source:
[11]http://www.smartway2study.com/2016/03/zinc-blend-zns-structure.html

UV-Visible Spectrophotometer Spectra

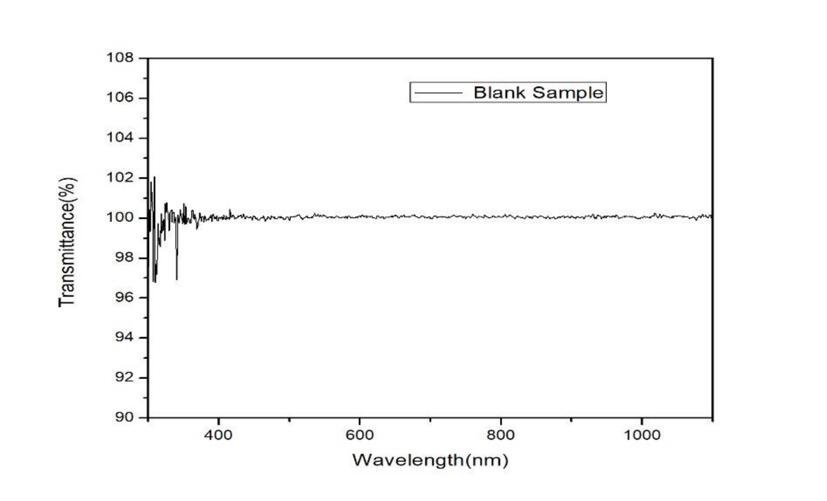


Fig.12: Transmission spectra for a blank sample

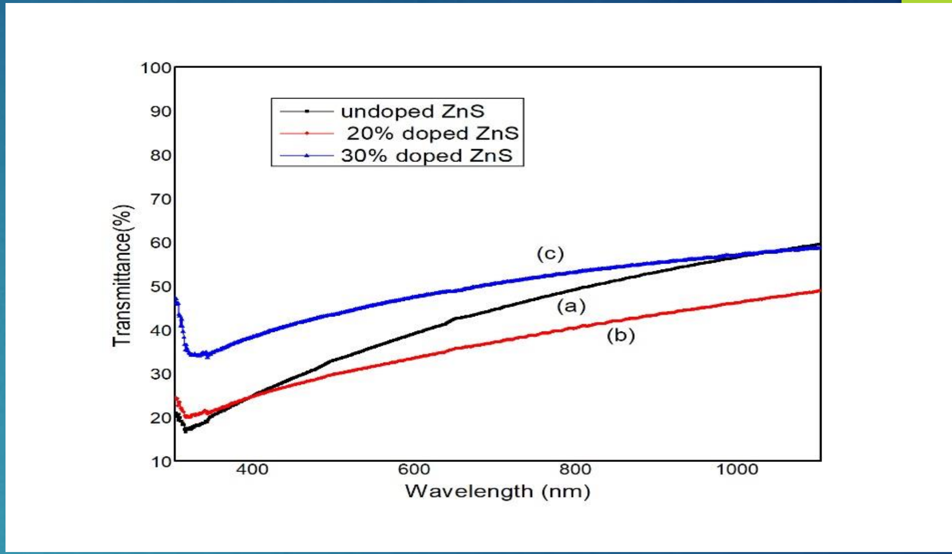


Fig.13: A graph of transmittance (%) against wavelength(nm)

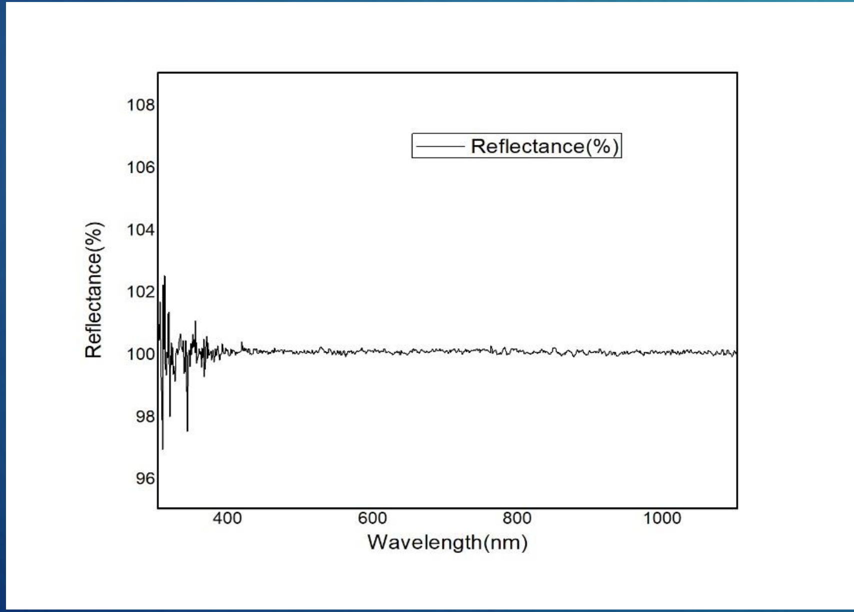


Fig .14: Reflectance spectra for a blank sample

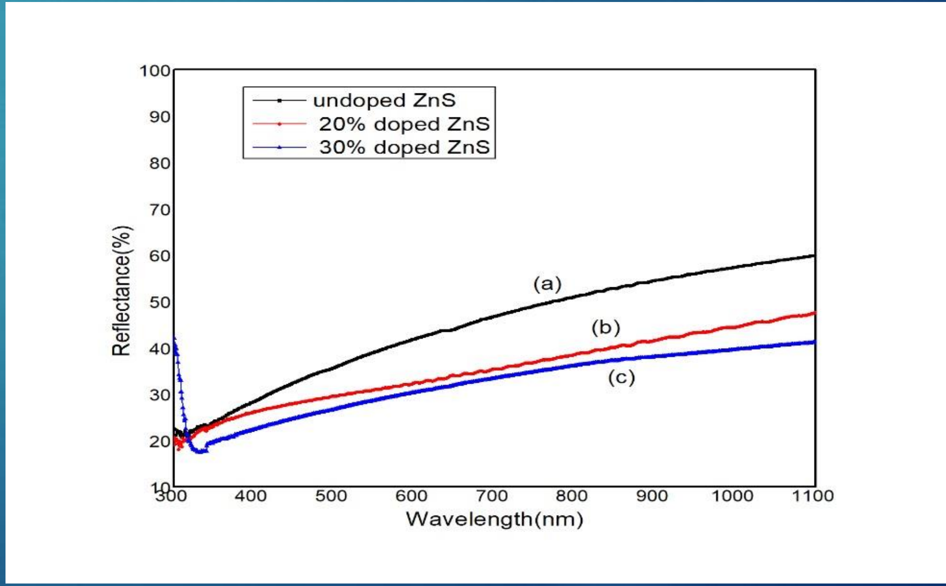


Fig.15: A graph of Reflectance(%) against wavelength(nm)

Absorbance

Absorbance is calculated by the relation

$$T+R+A=1$$

$$\text{or, } A= 1-(T+R)$$

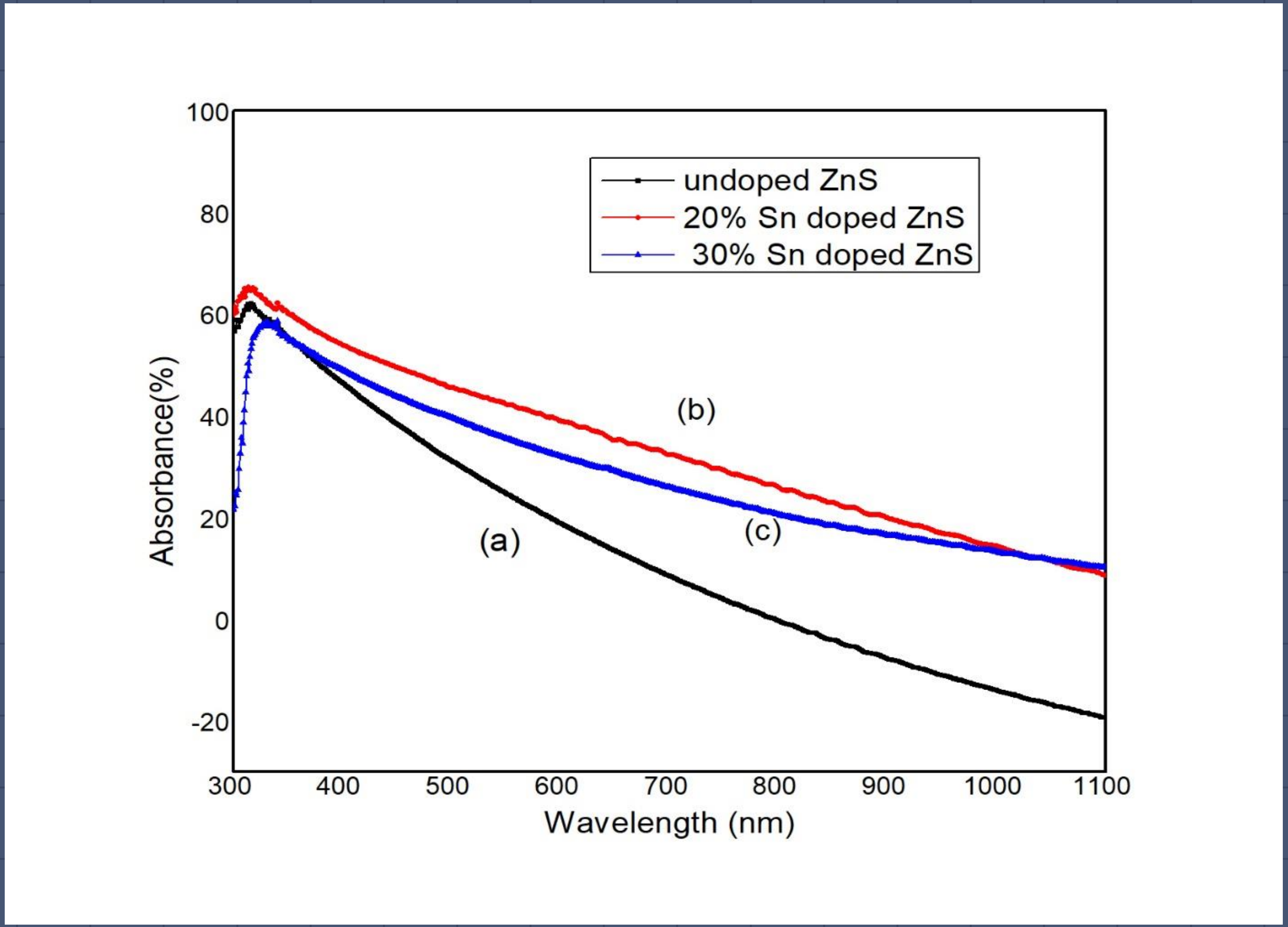


Fig.16: A graph of absorbance (%) against wavelength (nm) a) Undoped ZnS b) 20% Sn: ZnS c) 30% Sn: ZnS

Direct Band Gap

The value of E_g can get by usually the Tauc relation,

$\alpha h\nu = A\ (h\nu - E_g)^n$

Where n= 1/2

Film	E_g = hv(eV)
Undoped ZnS	3.9 eV
20% Sn doped ZnS	4.2 eV
30% Sn doped ZnS	3.7 eV

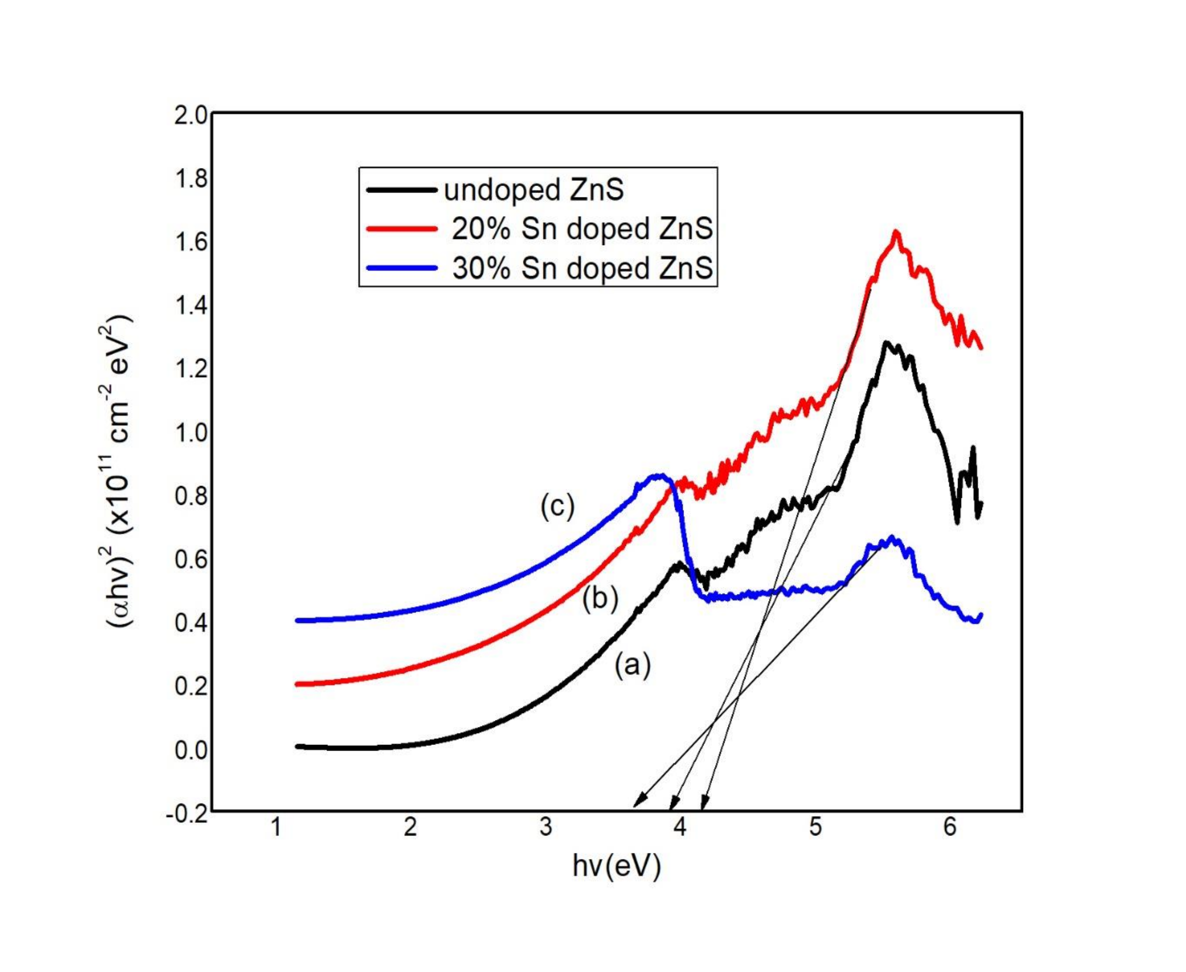


Fig.17: Graphical determination of band gap a) undoped ZnS,b) 20% doped ZnS, c) 30% doped ZnS

Refractive index pattern

Refractive indexes across wavelength are calculated by

$$\eta = (1 + \sqrt{R}) / (1 - \sqrt{R})$$

Where,

R= Reflectance

Extinction Coefficient, K= αλ/4π

here, α= Absorption coefficient

λ= Corresponding wavelength

Absorption Coefficient, α= 2.303*A/t

Here, A= Absorbance

t= Film thickness

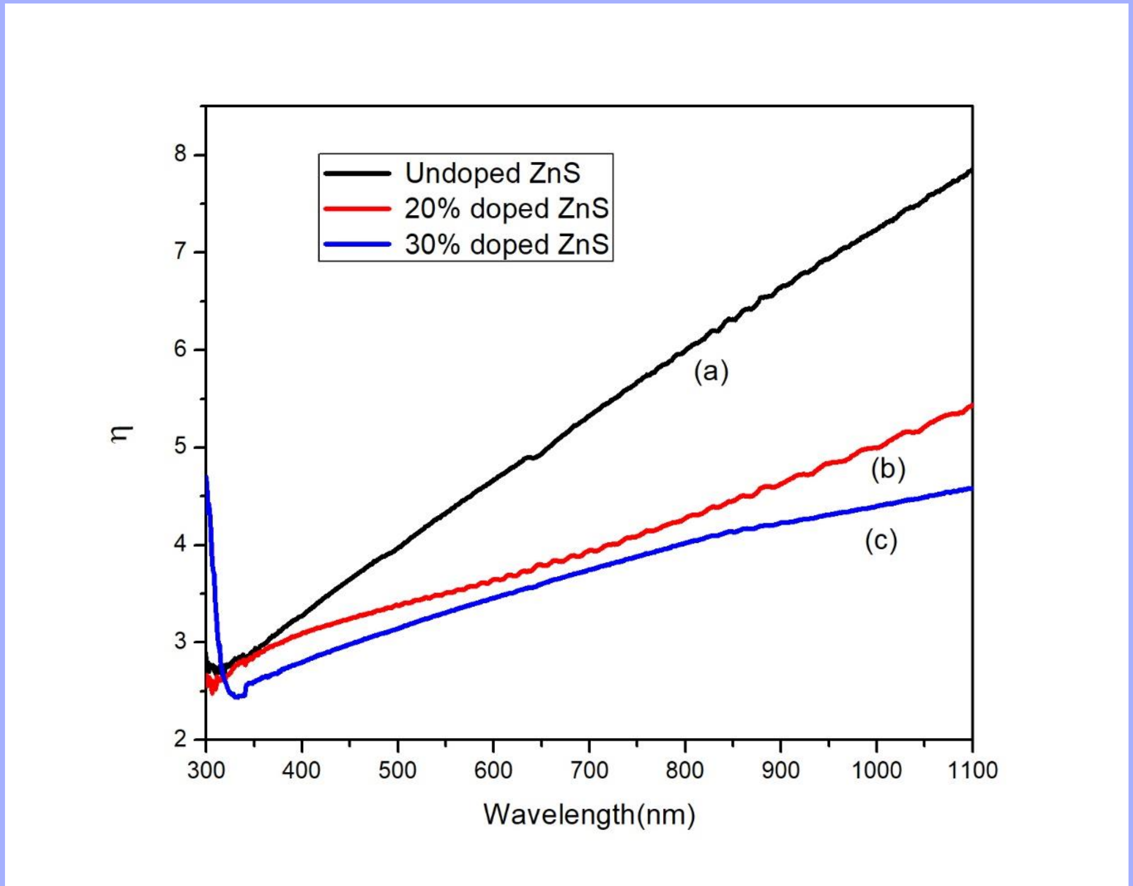


Fig.18: A graph of refractive indexes along wavelength (nm)

4 - Point Probe Measurement

Resistivity ,ρ is calculated by the formula

$\rho = a2\pi s\ (V/I)$

or $\rho = 4.53t\ (V/I)$

Where , t = Wafer thickness

s = Distance between two successive probe

Thin film	Temperature	Resistivity, ρ(Ω.m)
❑ 30% Sn doped ZnS	20 ^{o}C	1.44
	25 ^{o}C	0.724
❑ 20% Sn doped ZnS	20 ^{o}C	8.285
	25 ^{o}C	0.3

Acknowledgement

- Department of Electrical & Electronic Engineering, University of Dhaka
- Experimental Physics Division, Atomic Energy Centre, Dhaka
- Centre for Advanced Research in Sciences(CARS), University of Dhaka
- Materials Science Division, Atomic Energy Centre, Dhaka


THANK YOU
FOR YOUR
TIME