Effect of Zinc doping on the optoelectronic properties of CdS thin films deposited by chemical bath deposition by utilizing an alternative Sulfur precursor

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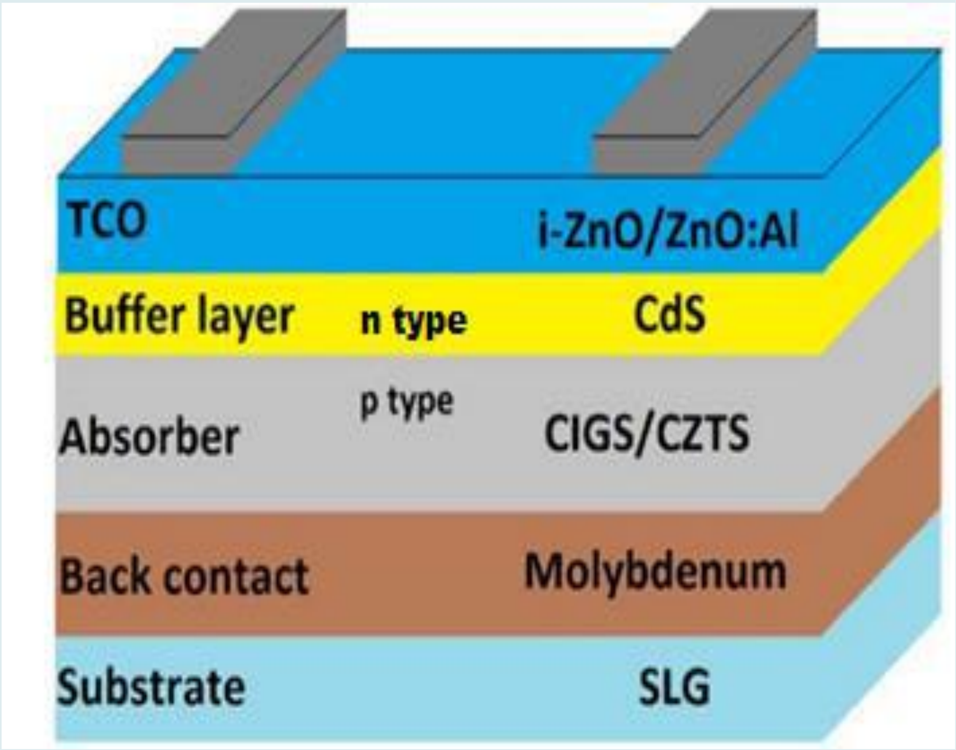
Introduction

Properties of Buffer Layer

- high energy band gap,
- uniform surface morphology
- pinhole-free film with a thickness in the range of 50 – 100 nm
- low conduction band offset
- n-type conductivity



Chemical Bath Deposition (CBD)

Advantages

- Relatively Inexpensive
- The major advantage of CBD is that it requires in its simplest form only solution containers and substrate mounting devices
- Chemical bath deposition yields stable, adherent, uniform and hard films with good reproducibility by a relatively simple process
- The growth of thin films strongly depends on growth conditions, such as duration of deposition, composition and temperature of the solution, and topographical and chemical nature of the substrate

Disadvantage

- One of the drawbacks of this method is the wastage of solution after every deposition

Growth Mechanism of CdS

The formation of CdS films is promoted by the reaction of a cadmium salt dissolved in a basic ammonium solution. According to the chemical reactions, complex ion $[Cd(NH_3)_4]^{2+}$ is deposited onto glass substrates as $Cd(OH)_2$ and further reacts with the Thiourea. $[Cd(NH_3)_4]^{2+}$ can be adsorpted on the substrate and reacted with S^{2-} to form CdS film, which can accelerate the process of reaction. When the Zn^{2+} was added into the solution for preparing of CdS thin film, the growth process of CdZnS thin film can be influenced by the concentration of Zn^{2+}

$$NH_4^+ + OH^- \rightarrow NH_3 + H_2O \quad (1)$$

$$Cd^{2+} + 4NH_3 \rightarrow [Cd(NH_3)_4]^{2+} \quad (2)$$

$$CS(NH_2)_2 + 2OH^- \rightarrow S^{2-} + CN_2H_2 + 2H2O \quad (3)$$

$$[Cd(NH_3)_4]^{2+} + S^{2-} \rightarrow CdS(s) + 4NH_3 \quad (4)$$

$$Zn^{2+} + 4NH_3 \rightarrow [Zn\,(NH_3)_4]^{2+} \quad (5)$$

$$[Zn\,(NH_3)_4]^{2+} + S^{2-} \rightarrow ZnS(s) + 4NH_3 \quad (6)$$

Experimental Procedure

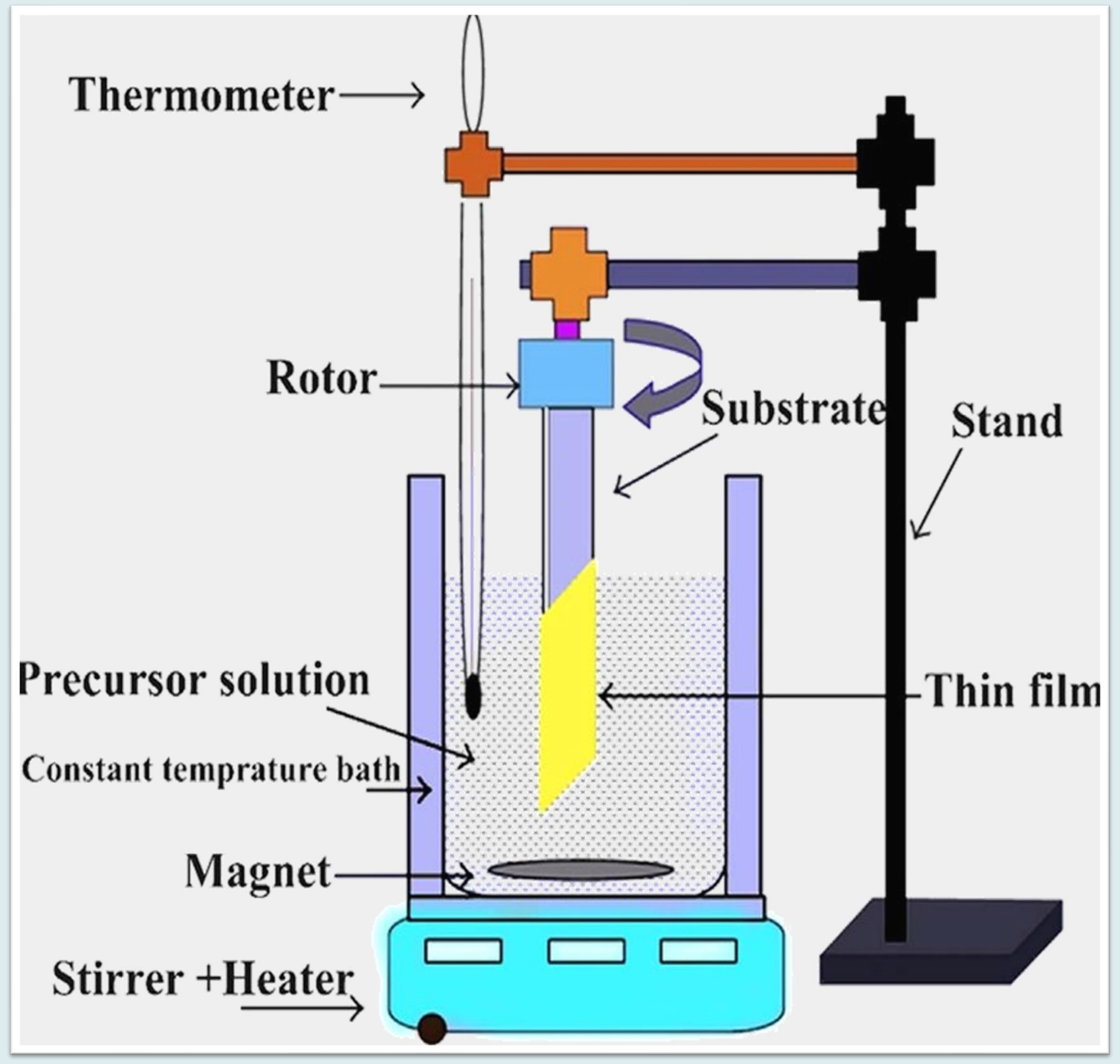


Figure: Schematic diagram of chemical bath deposition process

Optical Properties

- The averages optical transmittance of the films were found within the visible region spectrum (500-800 nm) and the value is over 80%
- It has been observed that optical transmittance has increased with the increase of Zn^{2+} concentration and thus results an increase in their optical bandgap value which is 2.45 eV for using N-Methyl Thiourea

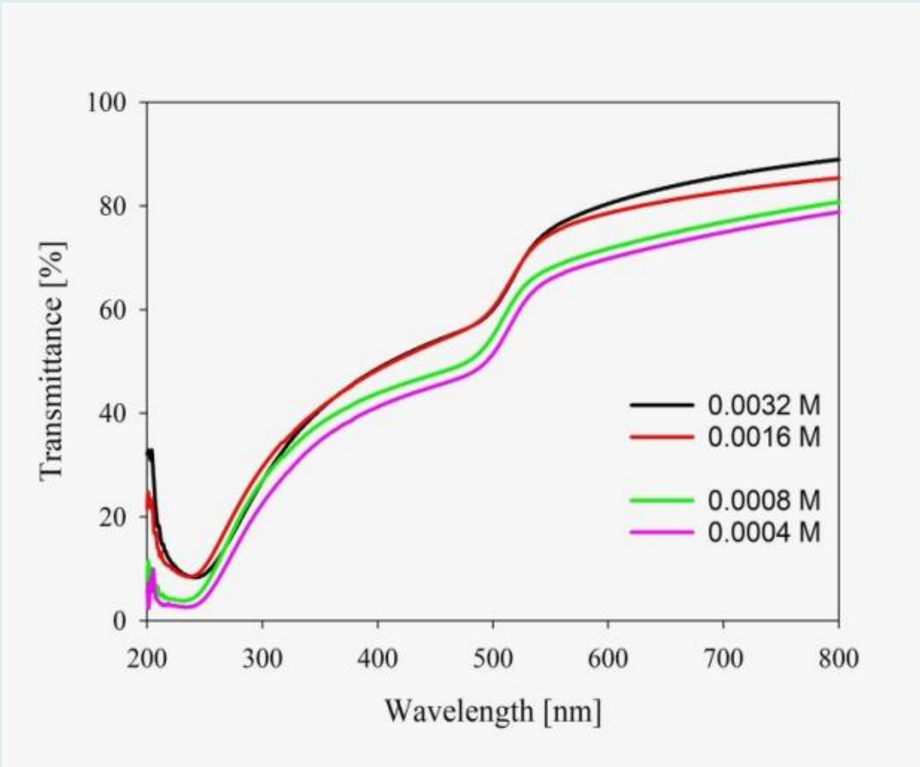


Figure: Transmittance spectrum using N-Methyl Thiourea

Structural Properties

- It is observed that the peaks are associated with the (111), (220) and (311) planes for cubic phase.
- It is revealed that peak tends to sharper and more intense with the increment of Zn^{2+} molarity along with using N-Methyl Thiourea

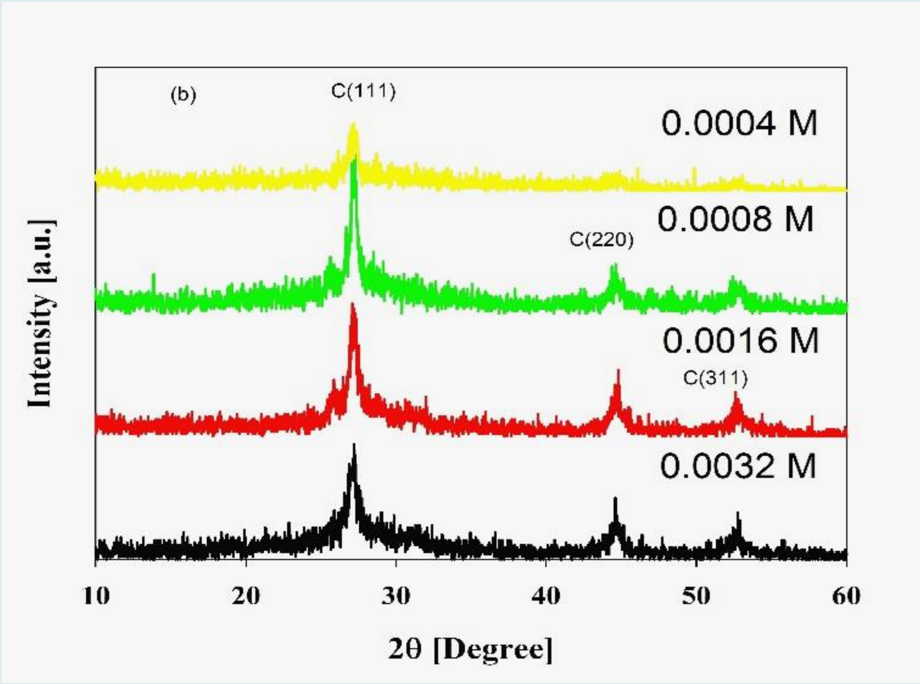


Figure: XRD pattern using N-Methyl Thiourea

Electrical Properties

- Carrier concentration increased for using N-Methyl Thiourea and it is in the range of 10^{14} cm^{-3} to 10^{15} cm^{-3}
- Due to the doping by zinc, the carrier concentration increased with the increased Zn^{2+} concentration

Conclusion

- CdS films with N-Methyl Thiourea showed better crystallinity than Thiourea
- It has been observed that with the increased Zn^{2+} concentration, films are more crystalline
- Moreover, transmittance of the film also increased with the doping of Zn^{2+} for both Thiourea and N-Methyl Thiourea
- The bandgap value increased using N- Methyl Thiourea
- However, future investigations are required to improve the film morphology and carrier concentration of CdS while using N-Methyl Thiourea as sulfur source

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