MANIPAL RESEARCH COLLOQUIUM - 2023

A Comparative Study on Photodetection Capabilities of SILAR-deposited ZnO thin films

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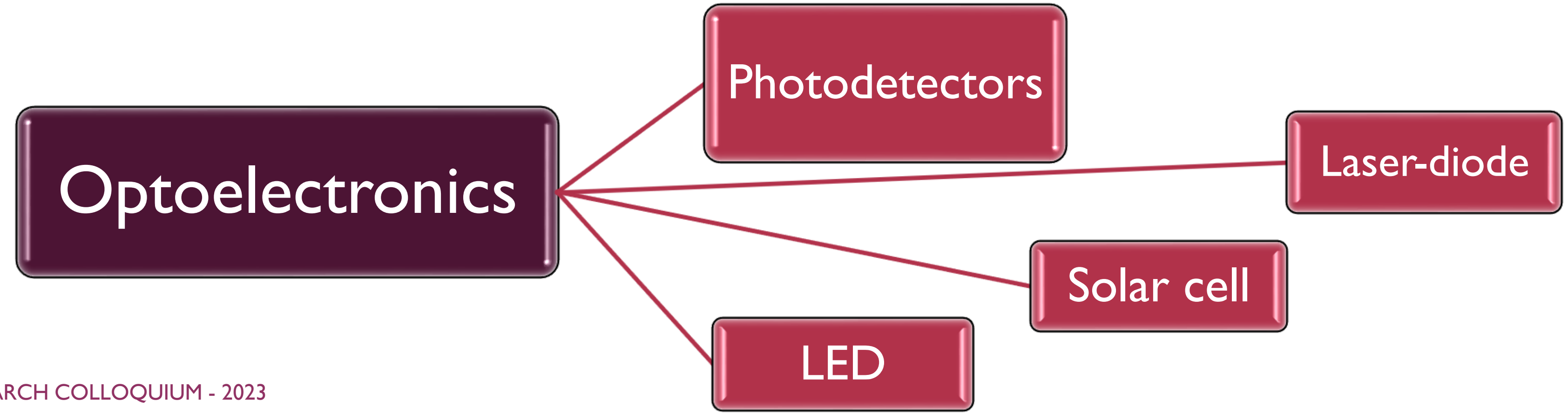
CONTENTS

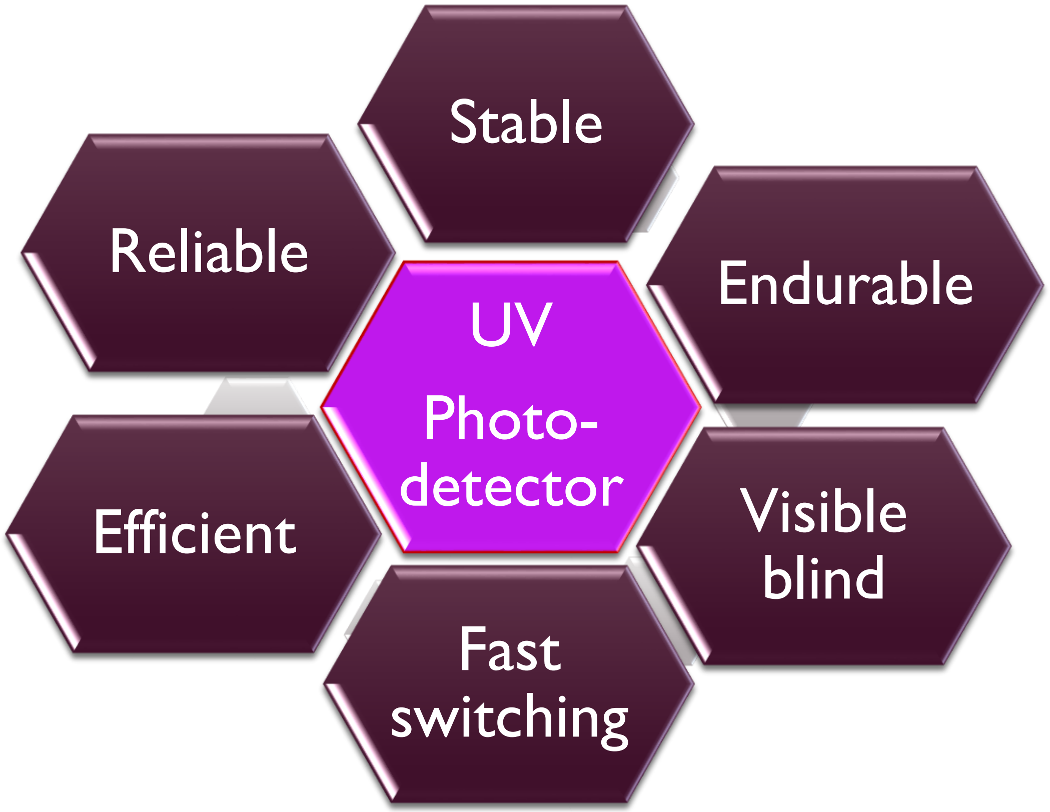
INTRODUCTION

Photon Detectors:

- Incident light generates electron-hole pairs
- Transportation to respective electrodes
- Extraction of these carriers as current.



Introduction



Why ZnO?

- Direct wide bandgap of nearly 3.37 eV with n-type semiconducting behaviour.
- Large exciton binding energy (60 meV) at room temperature.
- Abundance in nature leading to low cost of the material and low temperature deposition.
- Good thermal properties like high melting point, high thermal capacity and low coefficient of thermal expansion.
- Strong radiation hardness and chemical hardness and non-toxicity.

METHODOLOGY

SILAR:

- Cost effective
- Does not require high temperature, high vacuum
- Number of deposition parameters
- Undesirable precipitation is avoided
- Doping can be easily done

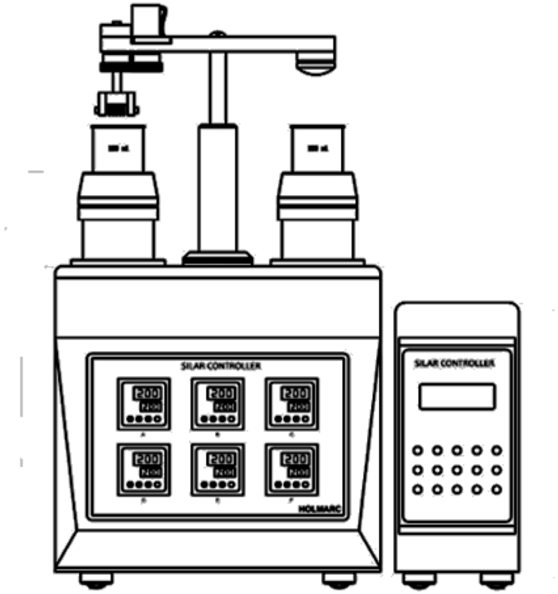


Figure 1: Schematic diagram of SILAR coating unit

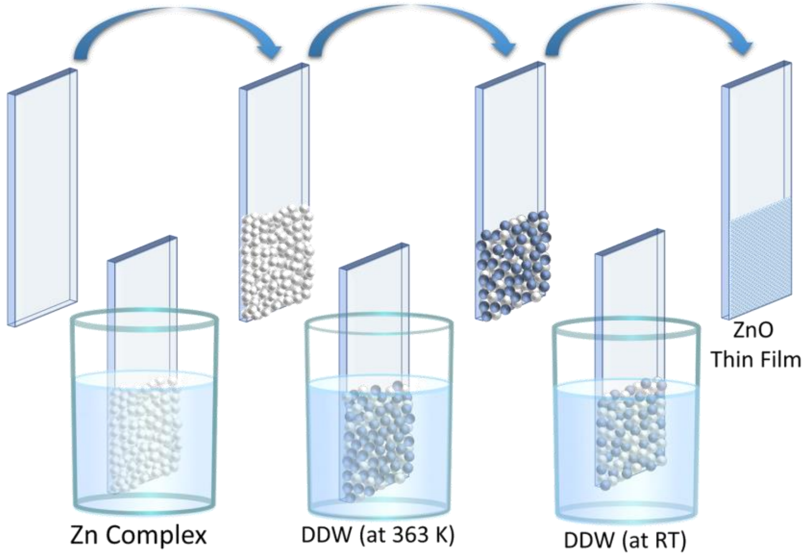


Figure 2: Schematic diagram of the mechanism of SILAR method

$ZnCl_2 + 4NH_4OH \longrightarrow [Zn(NH_3)_4]^{2+} + 4H_2O + 2Cl^-$ (in solution)

$[Zn(NH_3)_4]^{2+} + 4H_2O \longrightarrow Zn^{2+} + 4NH_4^+ + 4OH^-$ (in solution)

$Zn^{2+} + 2OH^- \longrightarrow Zn(OH)_2$ (in solution)

$Zn(OH)_2 \longrightarrow ZnO$ (at temperature = 323 K)

Precursor solutions:

- Aqueous solution of $ZnCl_2$ $Zn(SO_4)$, $Zn(CH_3COO)_2$
- Double distilled water at 353K
- Double distilled water at room temperature (for rinsing)

RESULTS AND DISCUSSION
STRUCTURAL ANALYSIS

- **X-Ray Diffraction**

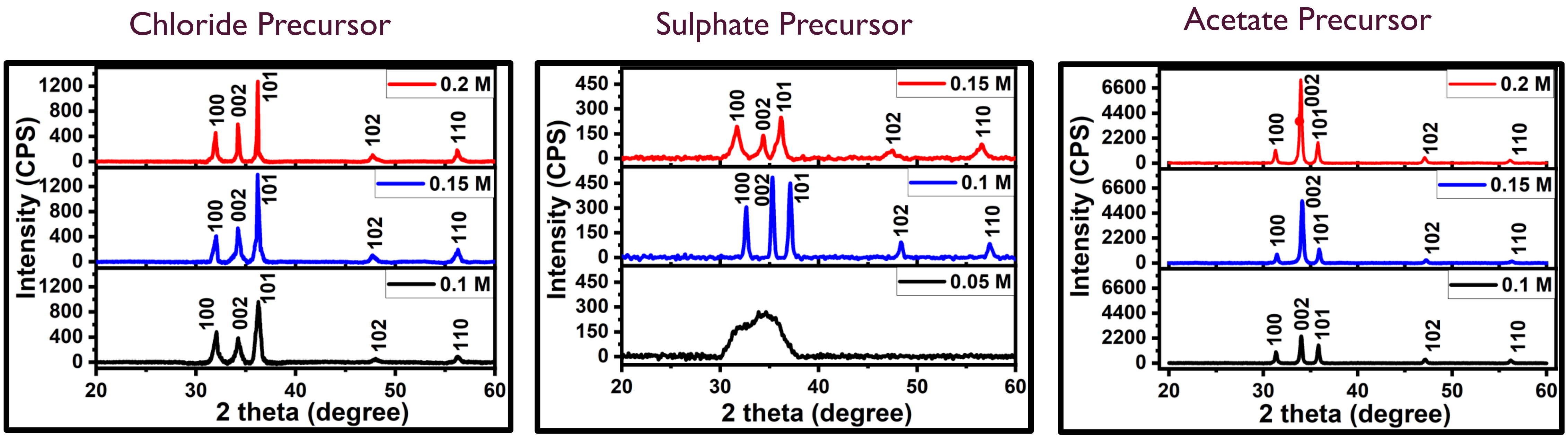


Figure 3: The XRD patterns of the ZnO thin films

Table 1: Structural Parameters of ZnO thin films

Precursor	Molarity (M)	Grain Size(D) (nm)	Micro strain (ϵ) x 10^{-3}	Dislocation density (δ) x 10^{15} (nm^{-2})
Zinc chloride	0.1	14	7.1	5.03
	0.15	22	4.7	2.14
	0.2	52	1.9	0.37
Zinc Sulphate	0.05	--	--	--
	0.1	26	4.4	1.5
	0.15	24	7.2	1.7
Zinc Acetate	0.1	26	4.15	1.47
	0.15	23	4.61	1.82

$D = \frac{K\lambda}{\beta cos\theta}$ - Crystallite size

$\delta = \frac{1}{D^2}$ - Dislocation density

$\epsilon = \frac{\beta}{4tan\theta}$ - Microstrain

MORPHOLOGY AND ELEMENTAL ANALYSIS

Chloride Precursor | Sulphate Precursor | Acetate Precursor

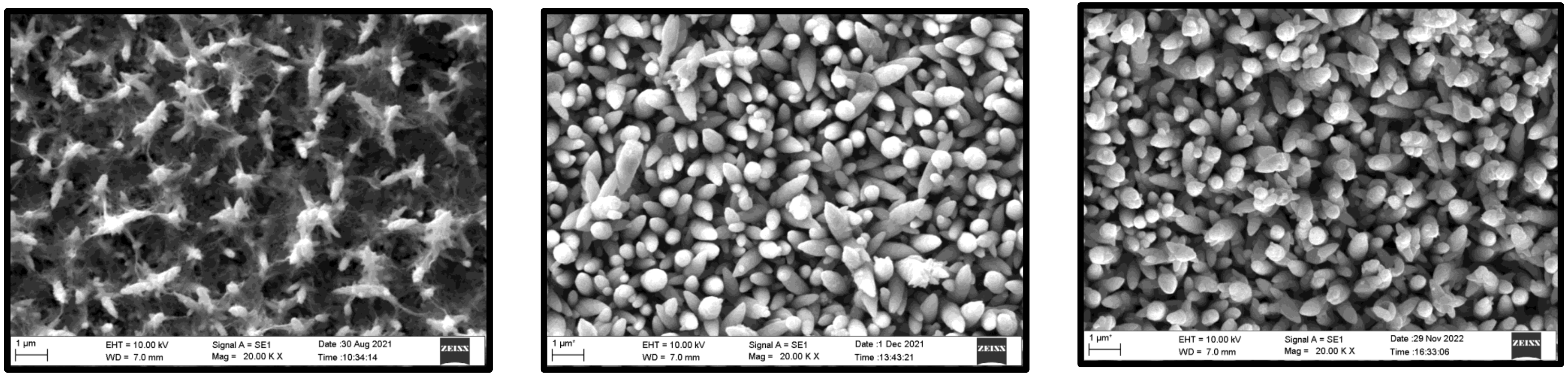


Figure 4: SEM images of ZnO thin films

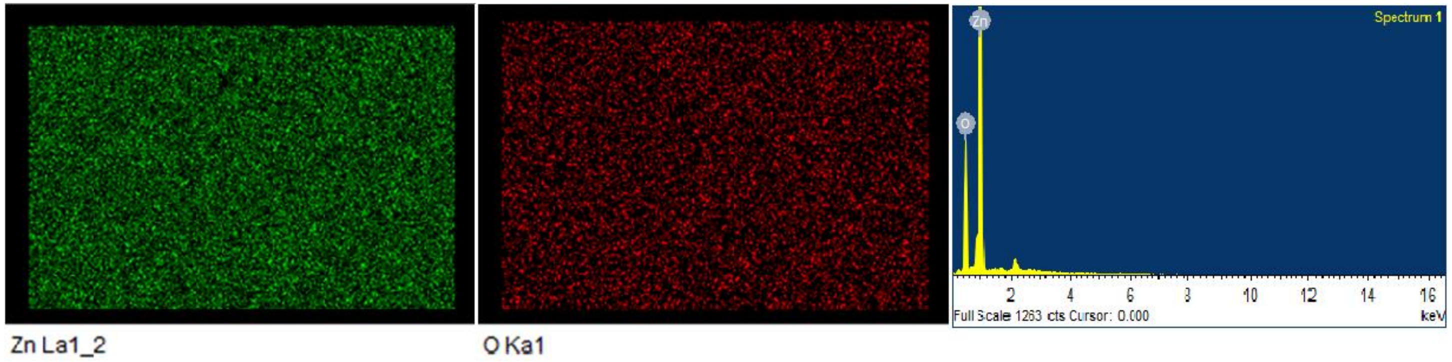


Figure 5: EDAX analysis of the ZnO thin films

OPTICAL ANALYSIS

UV-visible spectroscopy

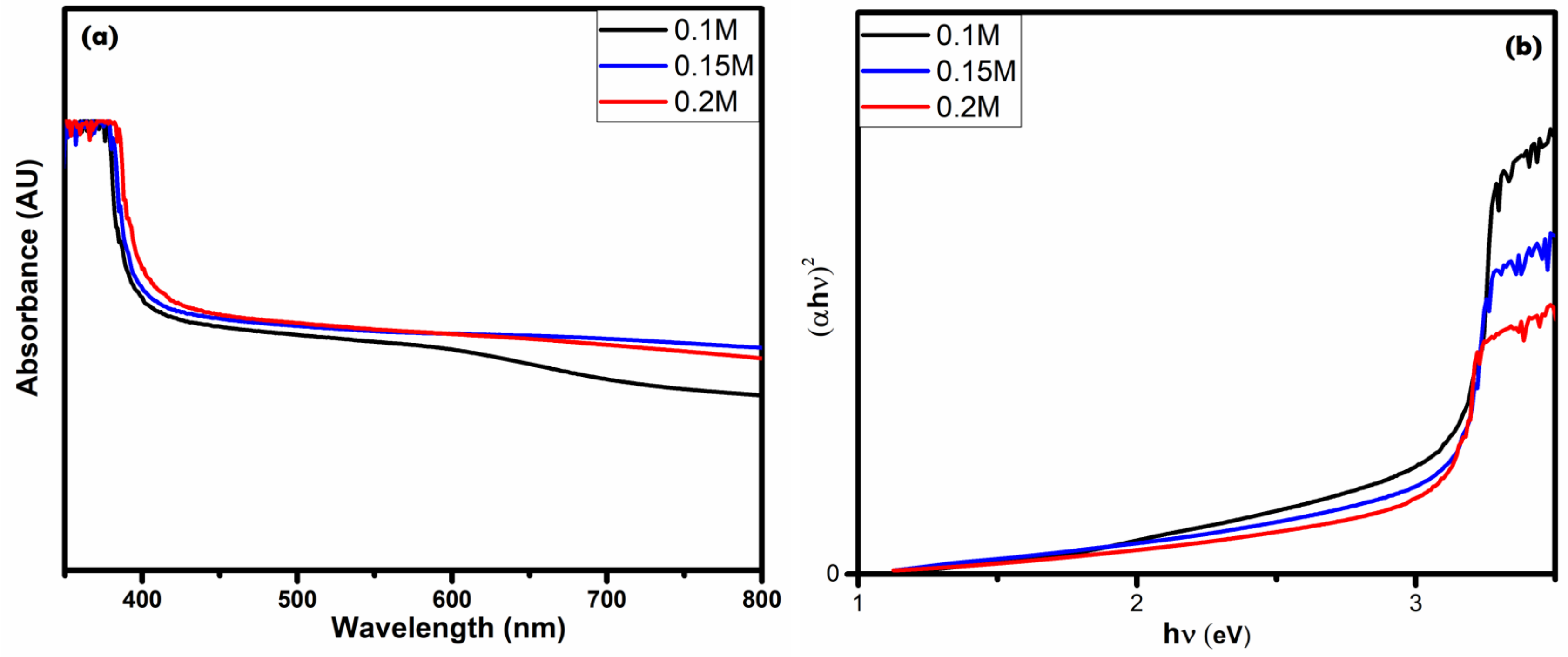
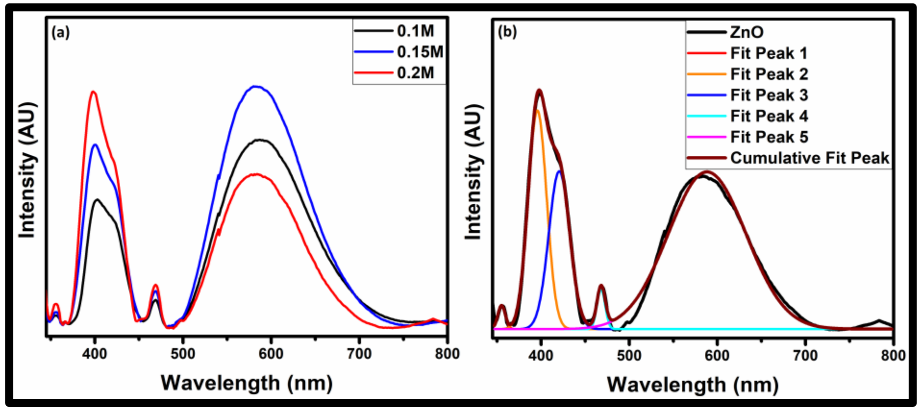


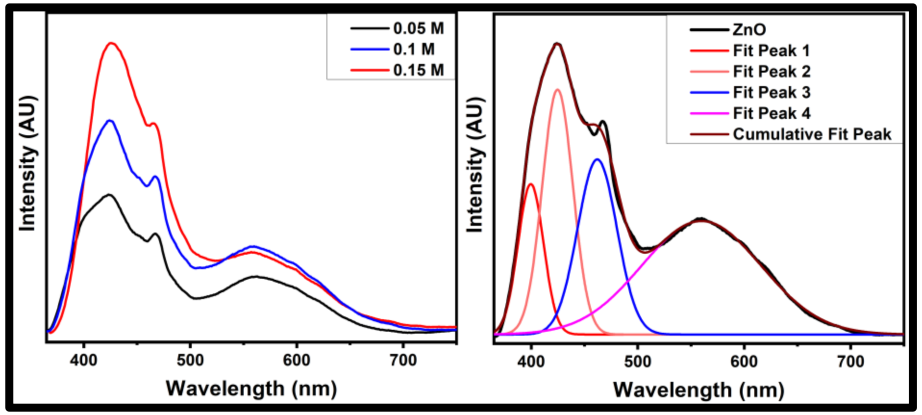
Figure 6 (a) UV-visible absorption spectra (b) Tauc's plot of the ZnO thin films

Photoluminescence spectroscopy

Chloride Precursor



Sulphate Precursor



Acetate Precursor

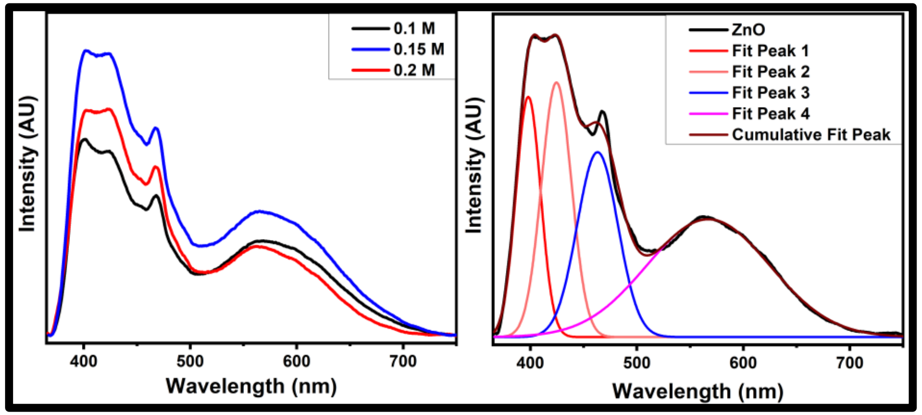


Figure 7: Photoluminescence plot of the ZnO thin films

I-V CHARACTERISTICS

Chloride Precursor

Sulphate Precursor

Acetate Precursor

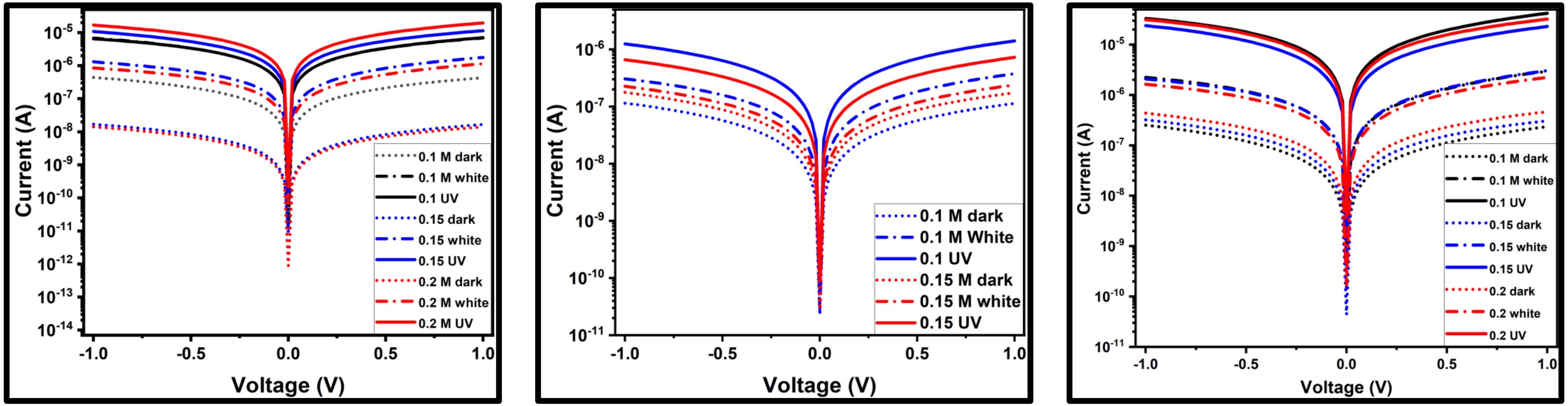


Figure 8: I-V characteristics of the ZnO thin films

CONCLUSIONS

- Properties of ZnO thin films, deposited using zinc chloride, zinc sulphate and zinc acetate precursors, were studied and compared.
- Films with zinc chloride and zinc acetate precursors exhibit good crystallinity.
- Morphology is sharp cone-like for all the samples with tightly packed cones for sulphate and acetate precursors.
- All the samples have bandgaps in the near UV region.
- Photoluminescence shows the intrinsic defects in ZnO.
- IV curves shows ohmic behaviour of ZnO/Ag. Current shows a significant rise on illumination with UV light. Chloride and acetate precursors showed better electrical properties compared to sulphate precursor.

REFERENCES

[4] A. Hastir, N. Kohli, and R. C. Singh, "Temperature dependent selective and sensitive terbium doped ZnO nanostructures," *Sensors Actuators, B Chem.*, vol. 231, pp. 110–119, 2016, doi: 10.1016/j.snb.2016.03.001.

[5] T. C. Paul and J. Podder, "Synthesis and characterization of Zn-incorporated TiO2 thin films: impact of crystallite size on X-ray line broadening and bandgap tuning," *Appl. Phys. A Mater. Sci. Process.*, vol. 125, no. 12, pp. 1–14, 2019, doi: 10.1007/s00339-019-3112-9.

[6] H. Wu *et al.*, "High-quality ZnO thin film grown on sapphire by hydrothermal method," *Mater. Lett.*, vol. C, no. 161, pp. 565–567, Dec. 2015, doi: 10.1016/J.MATLET.2015.09.048.

[7] N. Ekthammathat, S. Thongtem, T. Thongtem, and A. Phuruangrat, "Characterization and antibacterial activity of nanostructured ZnO thin films synthesized through a hydrothermal method," *Powder Technol.*, vol. 254, pp. 199–205, Mar. 2014, doi: 10.1016/J.POWTEC.2014.01.010.

[8] Ü. Özgür *et al.*, "A comprehensive review of ZnO materials and devices," *J. Appl. Phys.*, vol. 98, no. 4, pp. 1–103, 2005, doi: 10.1063/1.1992666.

[9] C. Tian *et al.*, "Performance enhancement of ZnO UV photodetectors by surface plasmons," *ACS Appl. Mater. Interfaces*, vol. 6, no. 3, pp. 2162–2166, 2014, doi: 10.1021/am405292p.

[10] N. H. Al-Hardan, M. J. Abdullah, H. Ahmad, A. A. Aziz, and L. Y. Low, "Investigation on UV photodetector behavior of RF-sputtered ZnO by impedance spectroscopy," *Solid. State. Electron.*, vol. 55, no. 1, pp. 59–63, 2011, doi: 10.1016/j.sse.2010.09.003.

[11] T. Zhang, Z. Xu, J. Chen, M. Li, Y. Lu, and Y. He, "Effects of oxygen pressure on PLD-grown Be and Cd co-substituted ZnO alloy films for ultraviolet photodetectors," *J. Alloys Compd.*, vol. 833, p. 155032, 2020, doi: 10.1016/j.jallcom.2020.155032.

[12] B. Q. Cao, T. Matsumoto, M. Matsumoto, M. Higashihata, D. Nakamura, and T. Okada, "ZnO nanowalls grown with PLD and their field emission and UV detector properties," *Opt. InfoBase Conf. Pap.*, pp. 10975–10980, 2009.

[13] Z. Zhan, L. Xu, J. An, H. Du, Z. Weng, and W. Lu, "Direct Catalyst-Free Chemical Vapor Deposition of ZnO Nanowire Array UV Photodetectors with Enhanced Photoresponse Speed," *Adv. Eng. Mater.*, vol. 19, no. 8, pp. 1–9, 2017, doi: 10.1002/adem.201700101.

[14] C. H. Chao and D. H. Wei, "Synthesis and characterization of high c-axis ZnO thin film by plasma enhanced chemical vapor deposition system and its UV photodetector application," *J. Vis. Exp.*, vol. 2015, no. 104, pp. 1–15, 2015, doi: 10.3791/53097.

[15] A. S. Ibraheam, J. M. Rzaij, M. A. Fakhri, and A. W. Abdulwahhab, "Structural, optical and electrical investigations of Al:ZnO nanostructures as UV photodetector synthesized by spray pyrolysis technique," *Mater. Res. Express*, vol. 6, no. 5, 2019, doi: 10.1088/2053-1591/ab06d4.

Thank you