MID SEMESTER EVALUATION

RESEARCH AND DEVELOPMENT OF HETEROJUNCTION BASED PHOTODETECTOR

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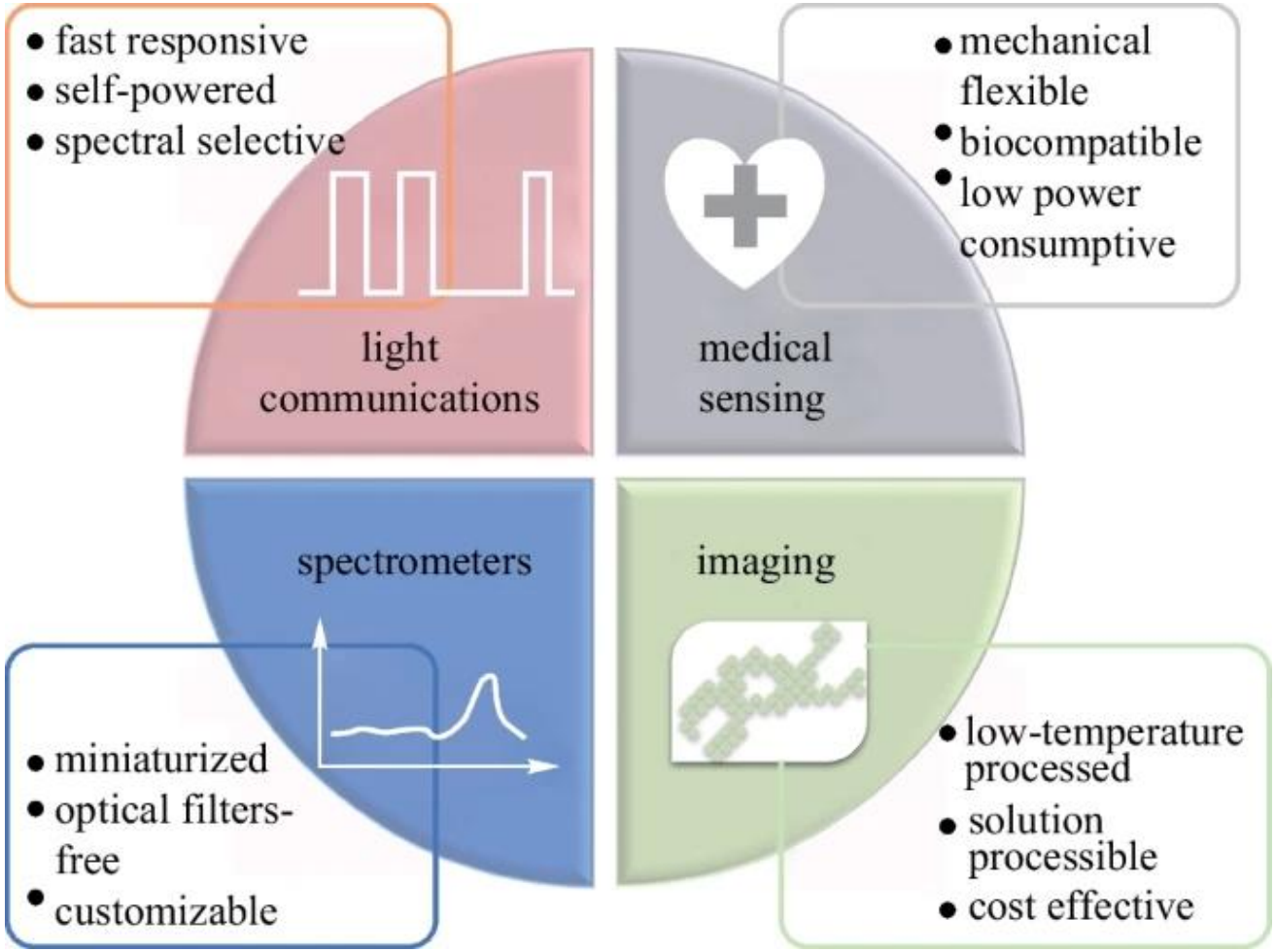
OUTLINE

- Motivation
- Introduction
- Objective
- Proposed work
  - ZnO Nanostructure growth
  - SEM and UV-Vis. result analysis
  - LSPR and Ag NPs deposition mechanism
  - Ag NPs deposition
  - SEM and UV-Vis. result analysis
  - COMSOL simulation for PVT
- Conclusion
- Plan of action
- Acknowledgements
- References

MOTIVATION

- Increase in demand of photodetectors



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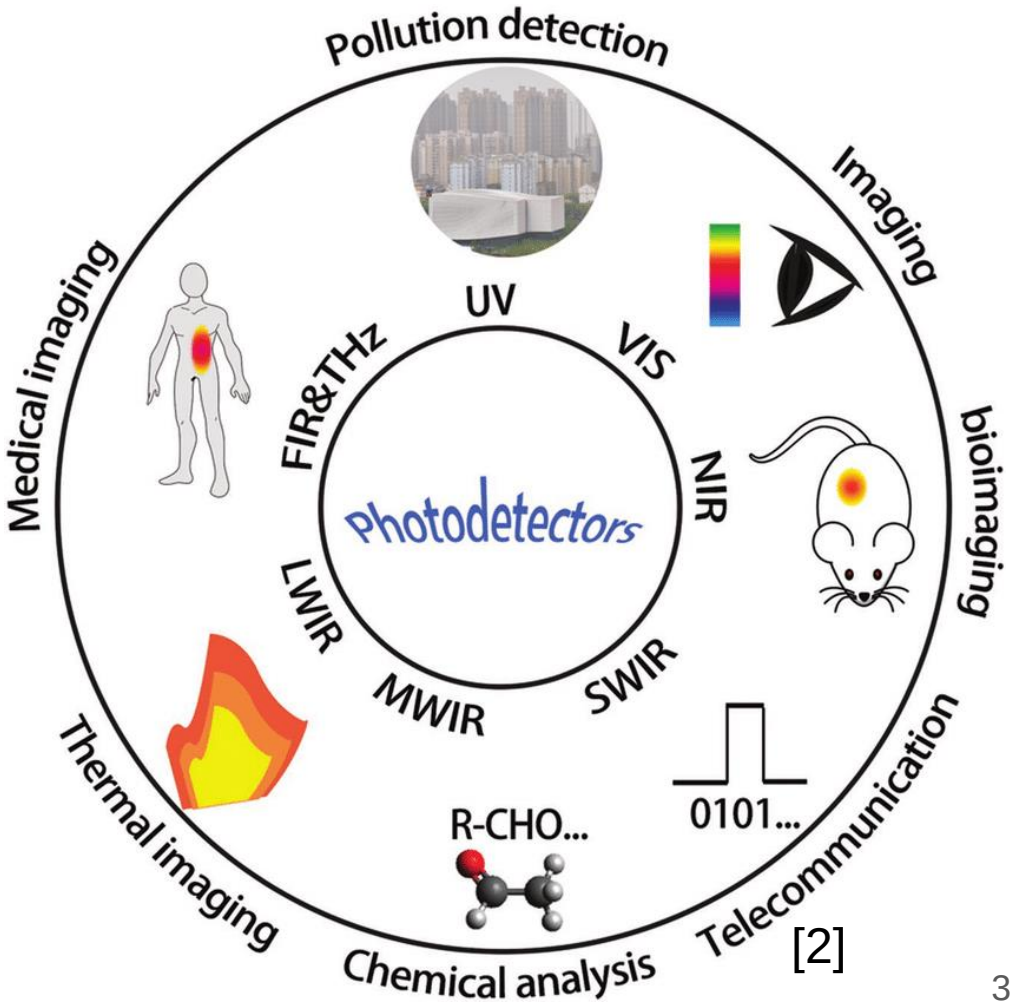
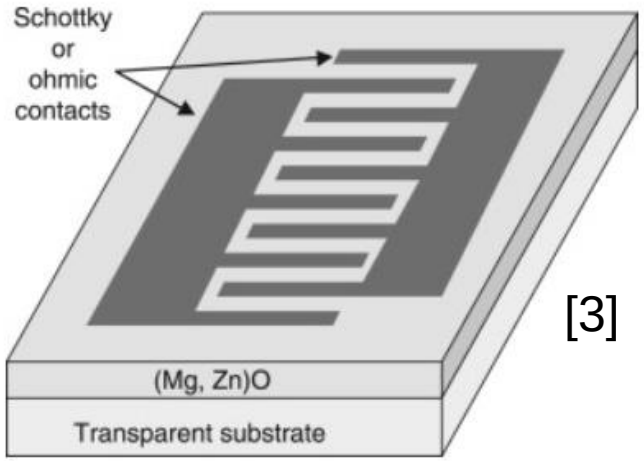


[2]

INTRODUCTION

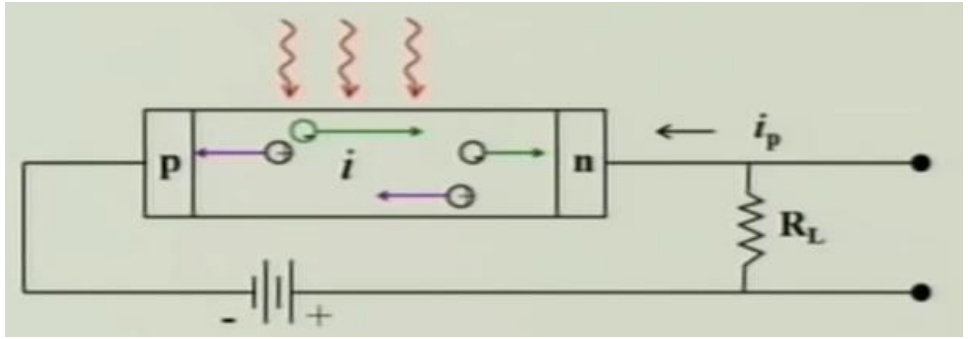
PHOTODETECTORS

- Photoconductor



[3]

- Photodiode



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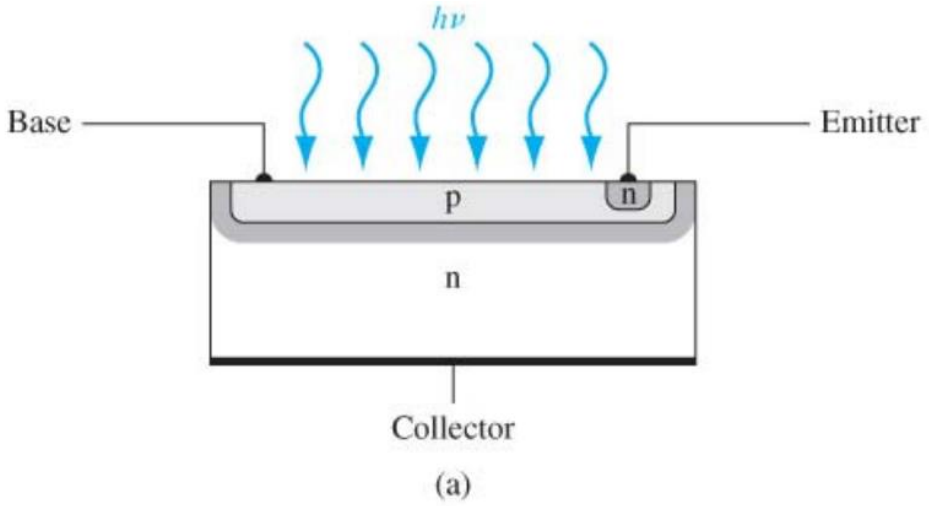
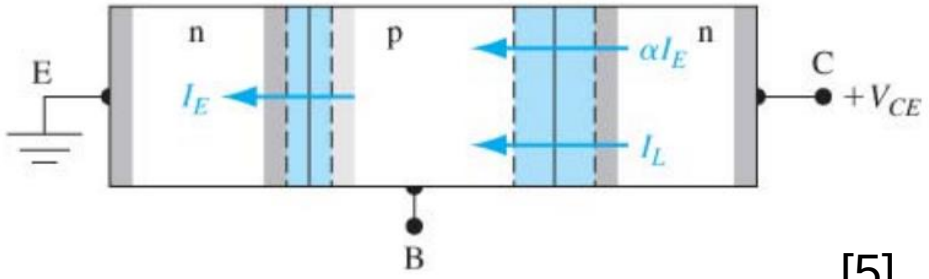
- Phototransistor

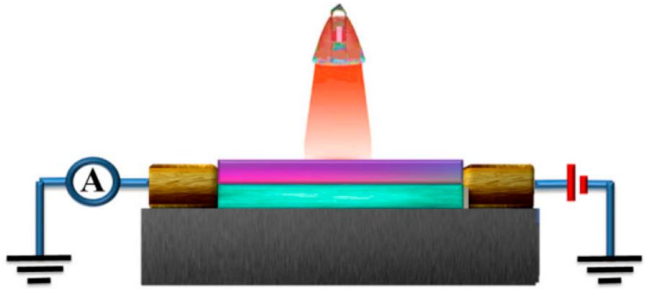




[5]

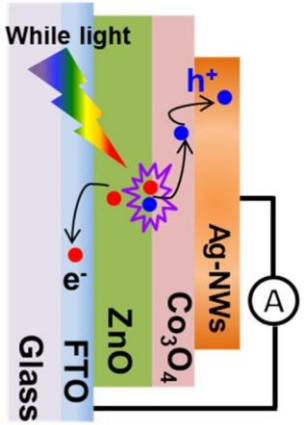
HETEROJUNCTION TYPES

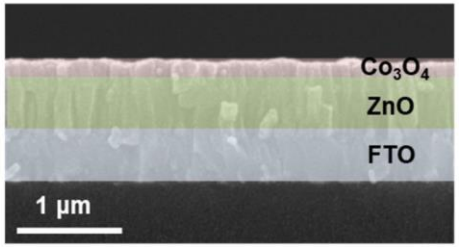
- Organic - Organic
  - Phthalocyanine/C_{60}
- Inorganic - Inorganic
  - ZnO/Co_3O_4
- Organic - Inorganic (Hybrid)
  - ZnO/P3HT



[8]

C_{60}





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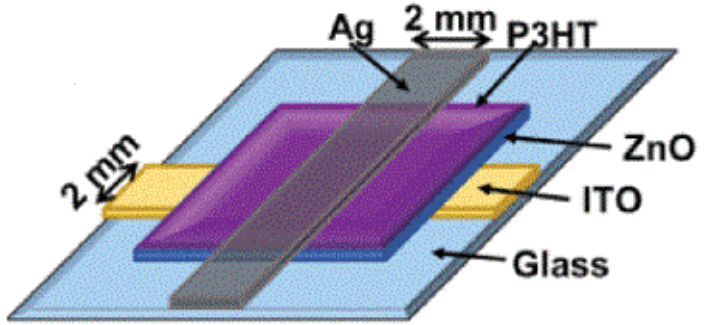


[10]

DEVICE PARAMETERS

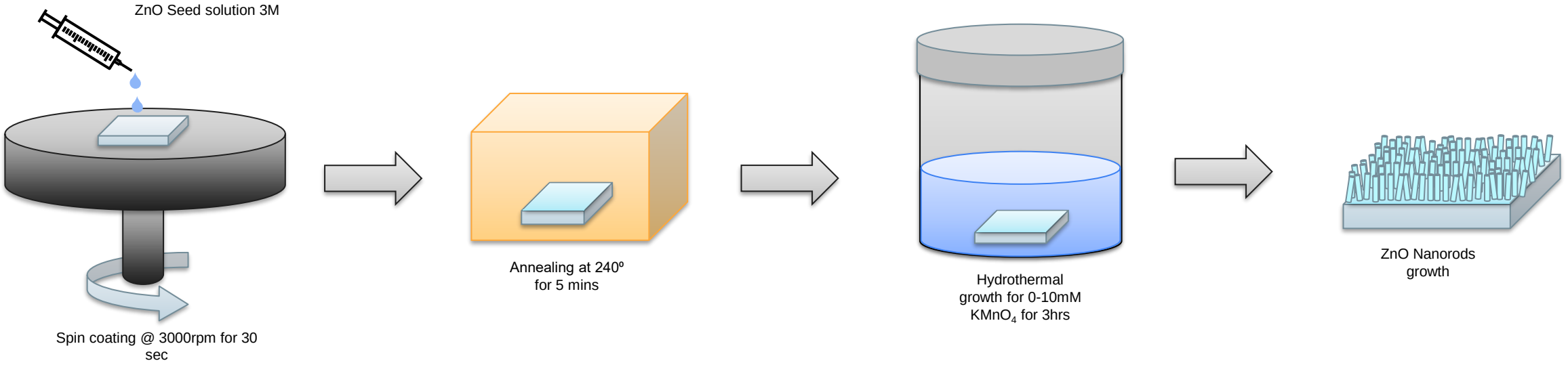
Metric	Definition	Unit
Rectification ratio	$\frac{I_{on}}{I_{off}}$	--
Responsivity (R)	$R = \frac{I_{ph}}{P_{in}} = EQE \times \frac{\lambda * q}{h * c}$	AW^{-1}
Photosensitivity (S)	$S = \frac{I_{ph} - I_d}{I_d}$	--
Specific Detectivity (D*)	$D^* = \frac{\sqrt{A}}{NEP} = R \times \frac{\sqrt{A \times BW}}{i_{in,N}}$	Jones

[8] [9]

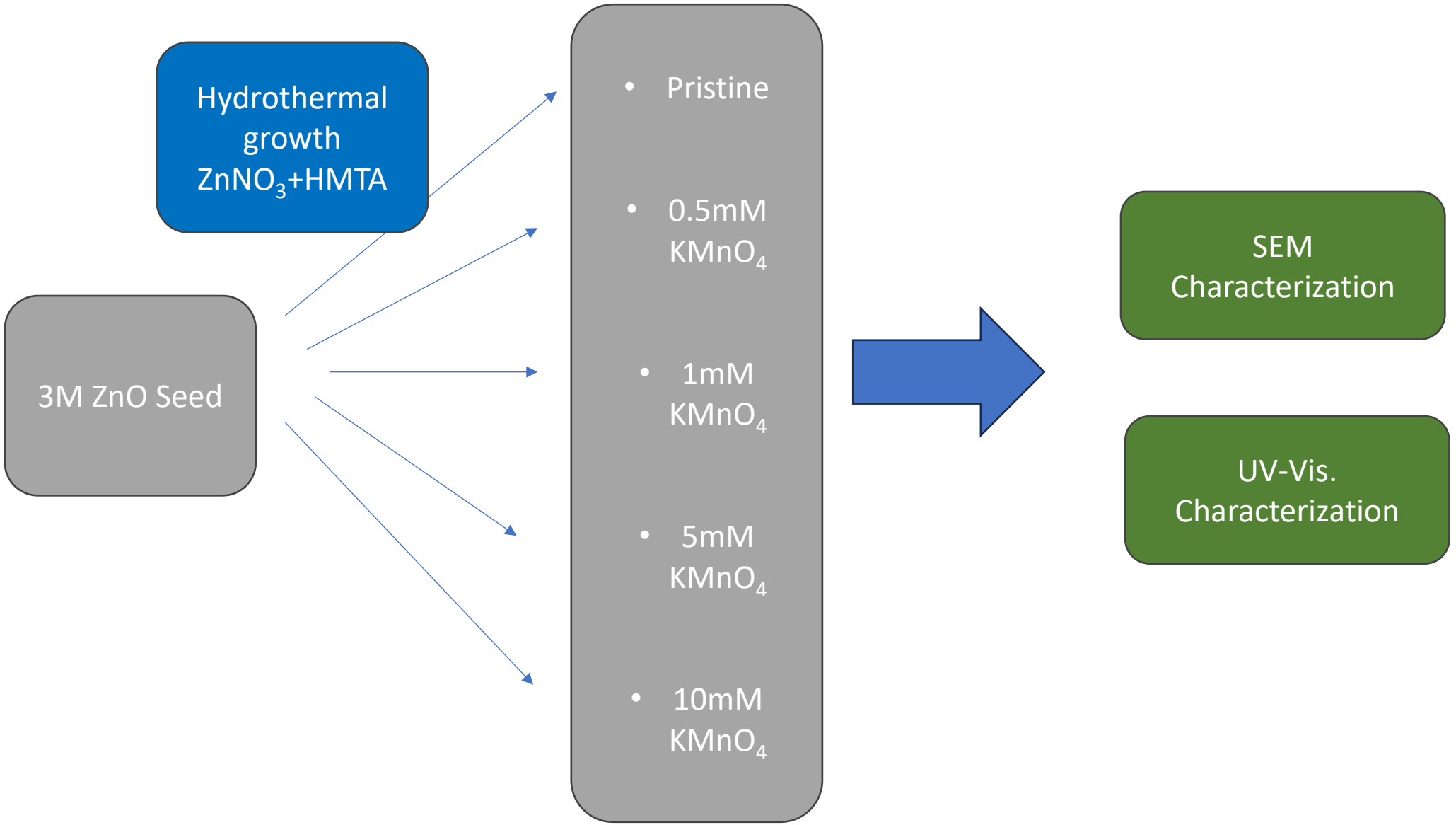
OBJECTIVES

- Fabrication of heterojunction photodetector using solution process.
  - Optimization of various parameters to obtain crystalline growth of ZnO nanorods.
  - Study effect of UV-irradiation time and $AgNO_3$:Ethanol conc. on Ag particle size deposited.
- To study physical vapor transport technique and perform simulation to get optimized parameters.
- Fabrication of heterojunction photodetector using physical vapor transport technique.

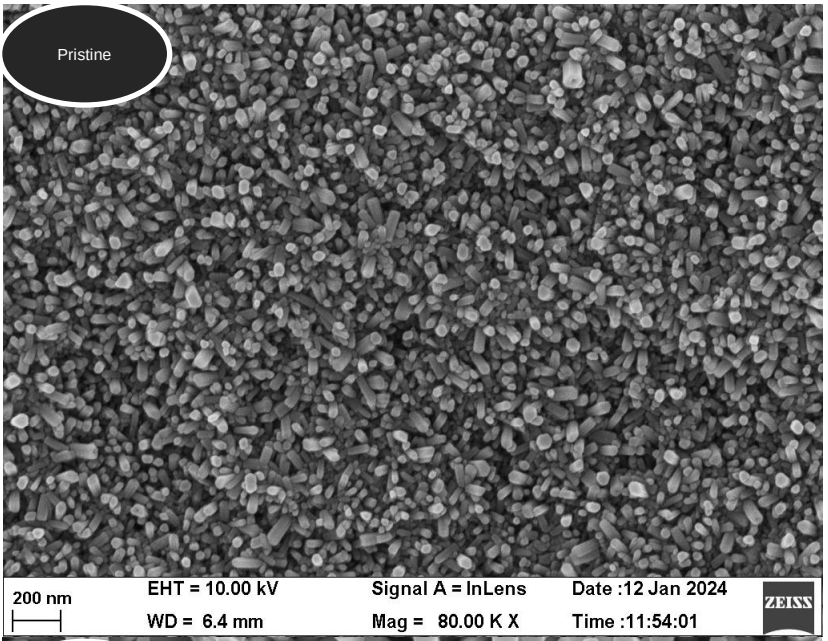
NANOSTRUCTURE GROWTH

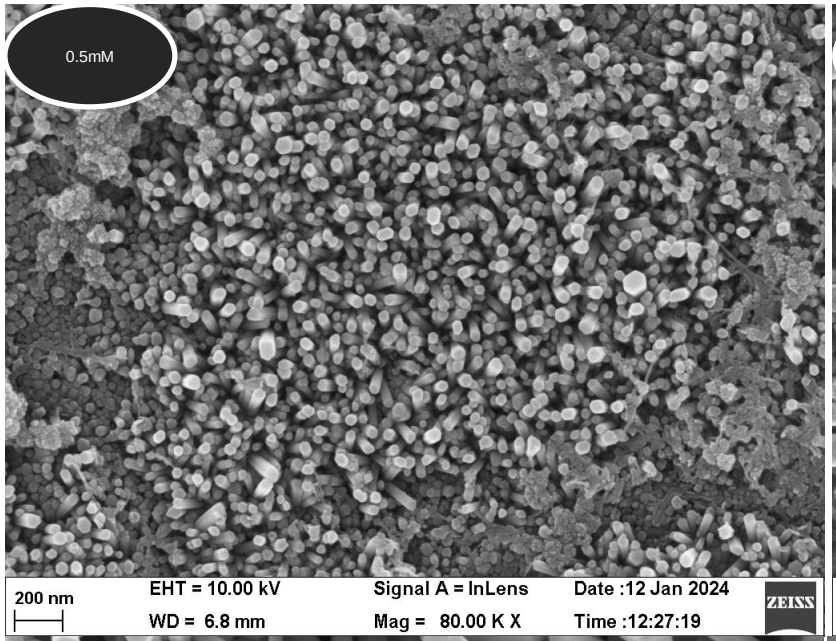


NANOSTRUCTURE GROWTH



SEM RESULTS


Pristine
200 nm
EHT = 10.00 kV
WD = 6.4 mm
Signal A = InLens
Mag = 80.00 K X
Date :12 Jan 2024
Time :11:54:01
ZEISS


0.5mM
200 nm
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WD = 6.8 mm
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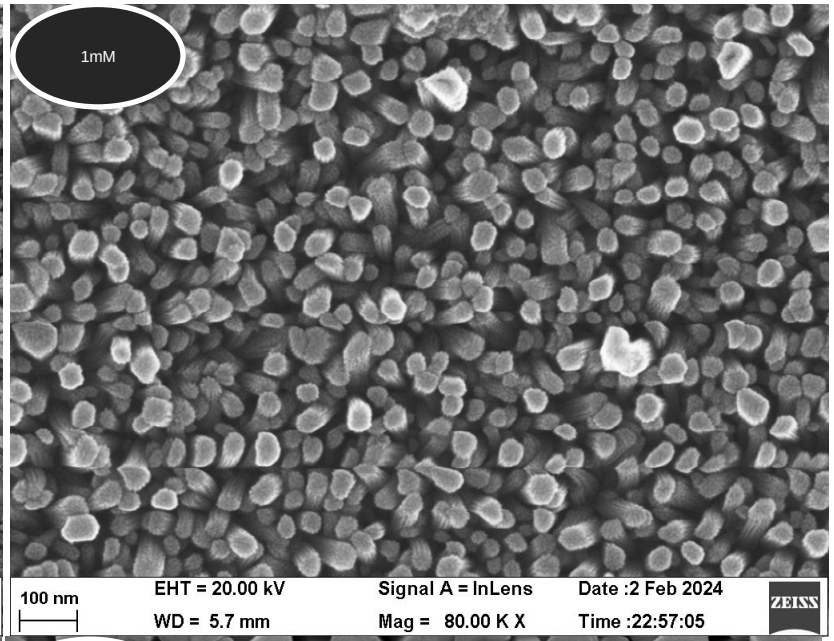
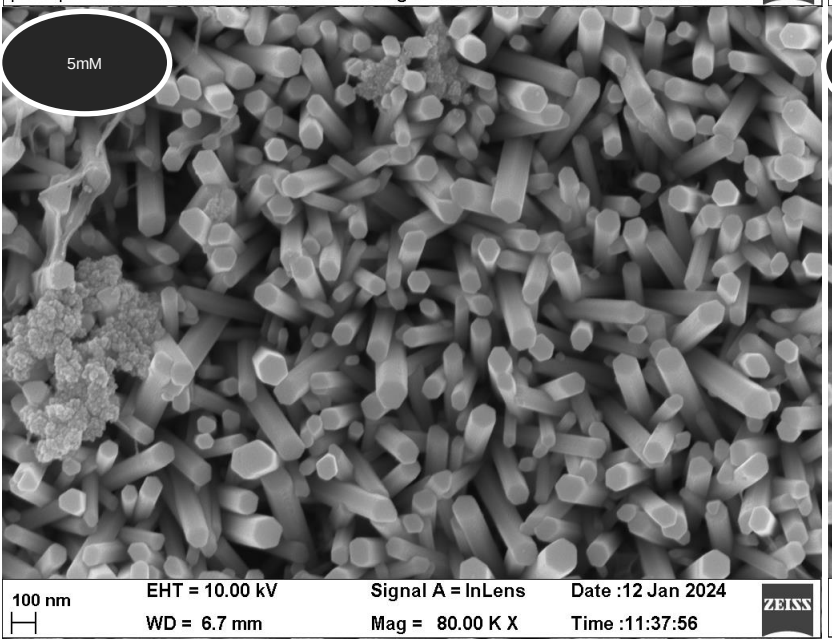
Mag = 80.00 K X
Date :12 Jan 2024
Time :12:27:19
ZEISS


1mM
100 nm
EHT = 20.00 kV
WD = 5.7 mm
Signal A = InLens
Mag = 80.00 K X
Date :2 Feb 2024
Time :22:57:05
ZEISS


5mM
100 nm
EHT = 10.00 kV
WD = 6.7 mm
Signal A = InLens
Mag = 80.00 K X
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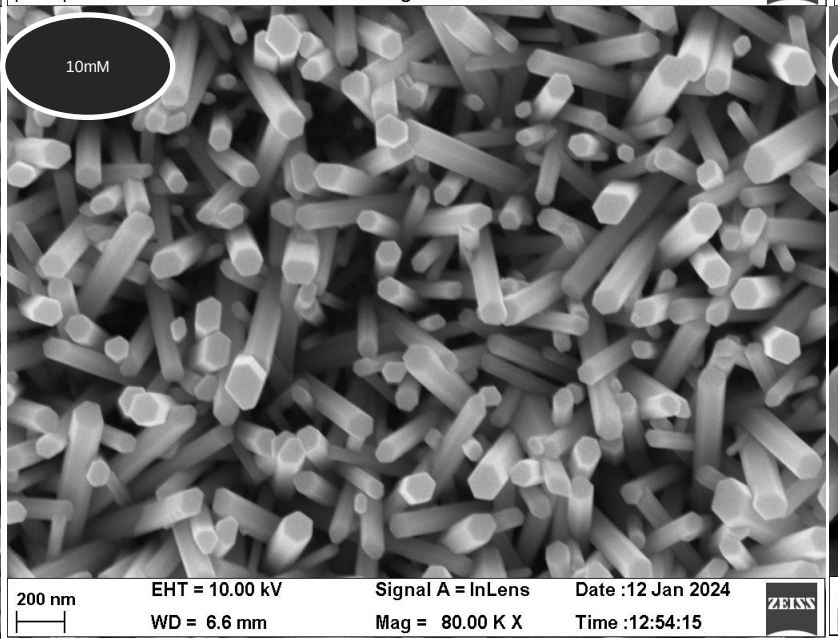
Time :11:37:56
ZEISS


10mM
200 nm
EHT = 10.00 kV
WD = 6.6 mm
Signal A = InLens
Mag = 80.00 K X
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Time :12:54:15
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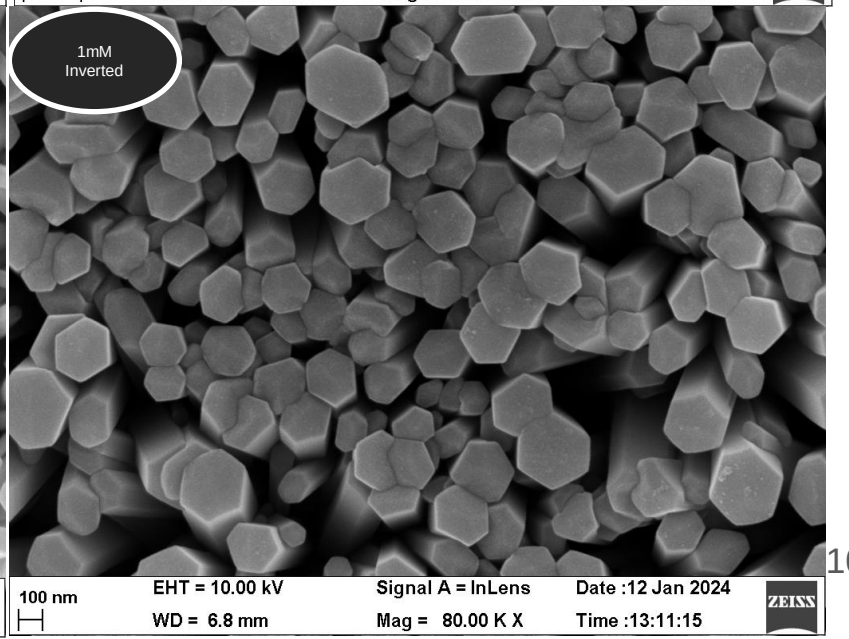
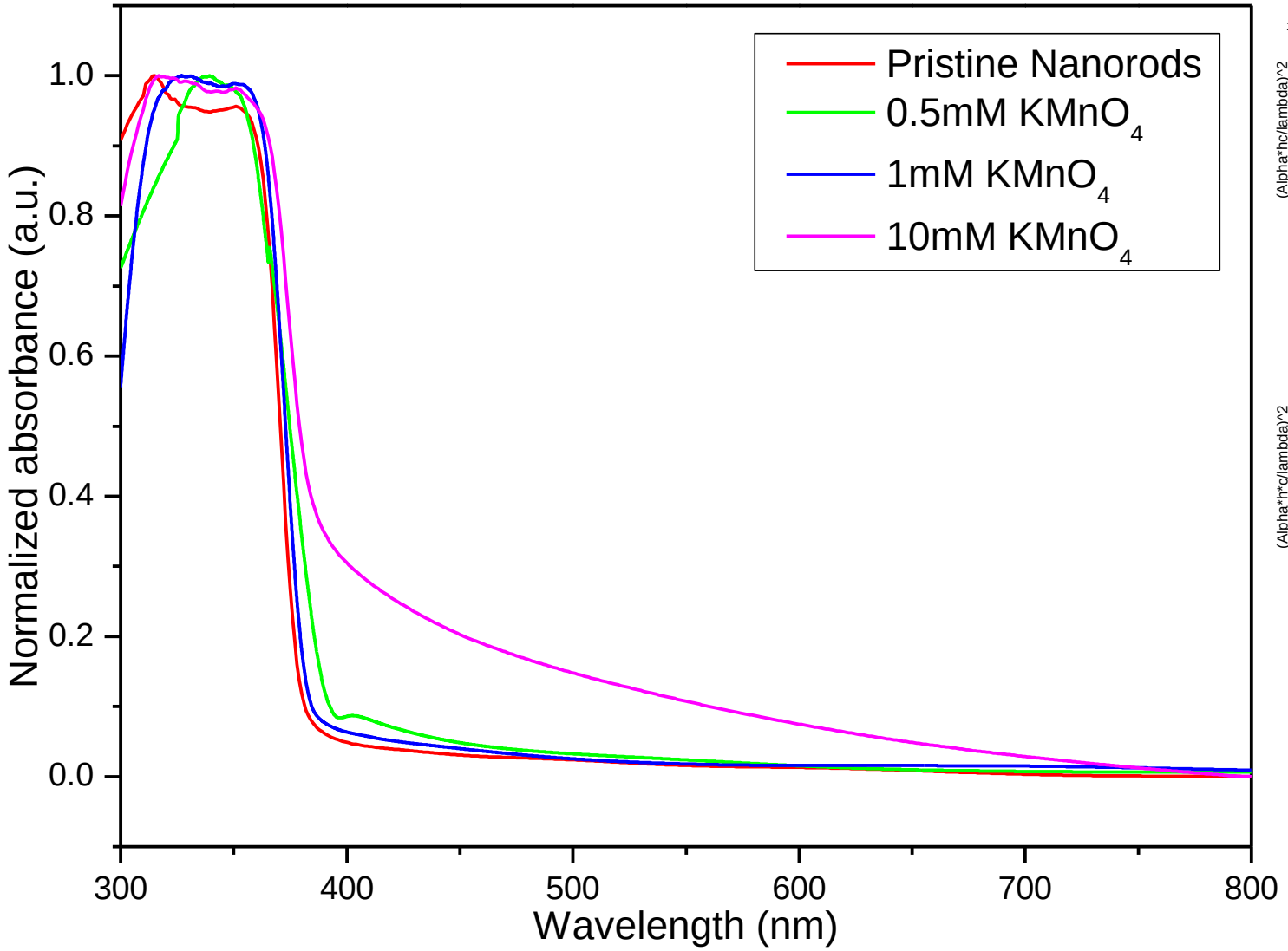
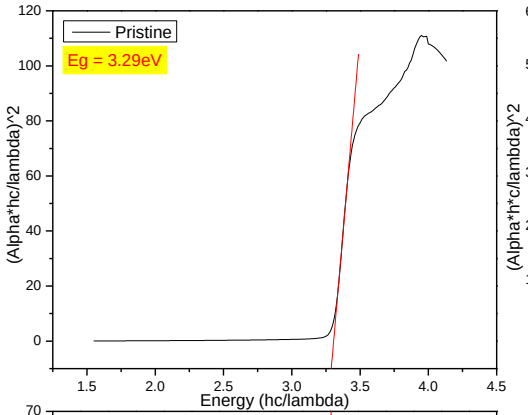
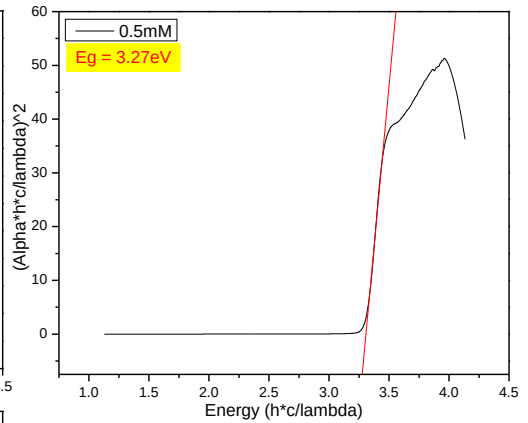
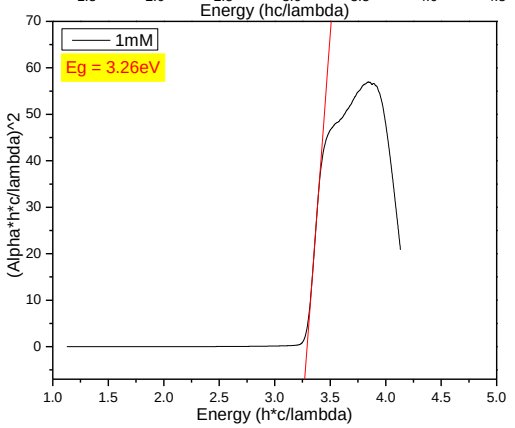

1mM
Inverted
100 nm
EHT = 10.00 kV
WD = 6.8 mm
Signal A = InLens
Mag = 80.00 K X
Date :12 Jan 2024
Time :13:11:15
ZEISS

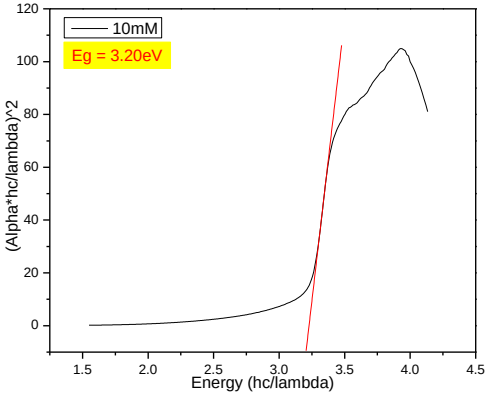
UV-VIS RESULTS





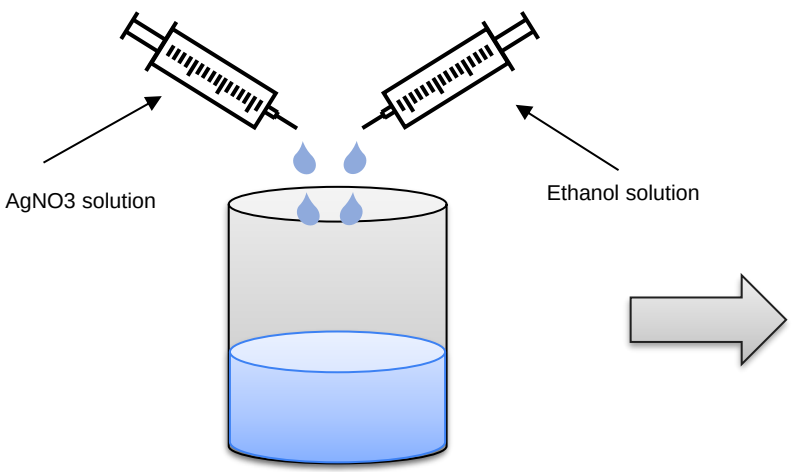




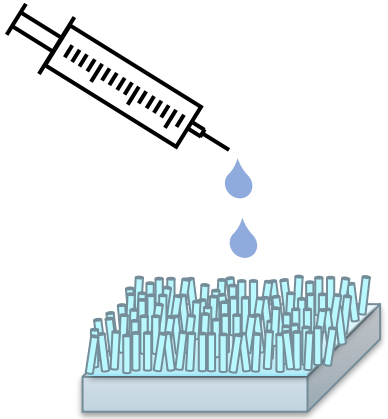


Sample Details	Bandgap (eV)
Pristine	**3.29**
0.5mM KMnO4	**3.27**
1mM KMnO4	**3.26**
10mM KMnO4	**3.2**

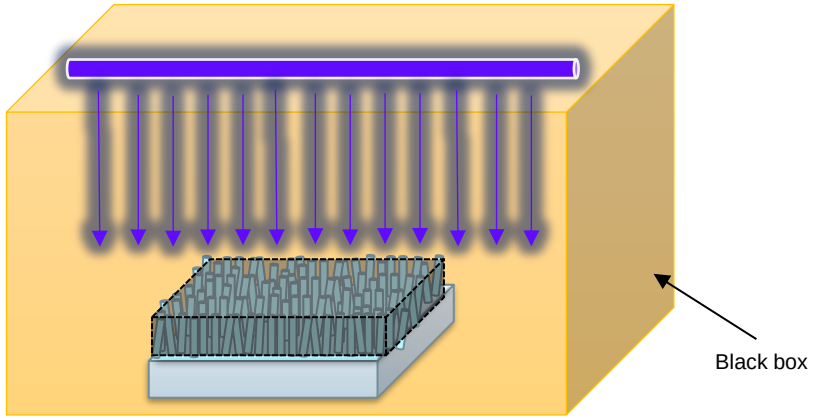
PCR (PHOTO CHEMICAL REDUCTION)



Preparation of AgNO3 : Ethanol solution of various concentrations



Drop casted the prepared solution on the nanostructure



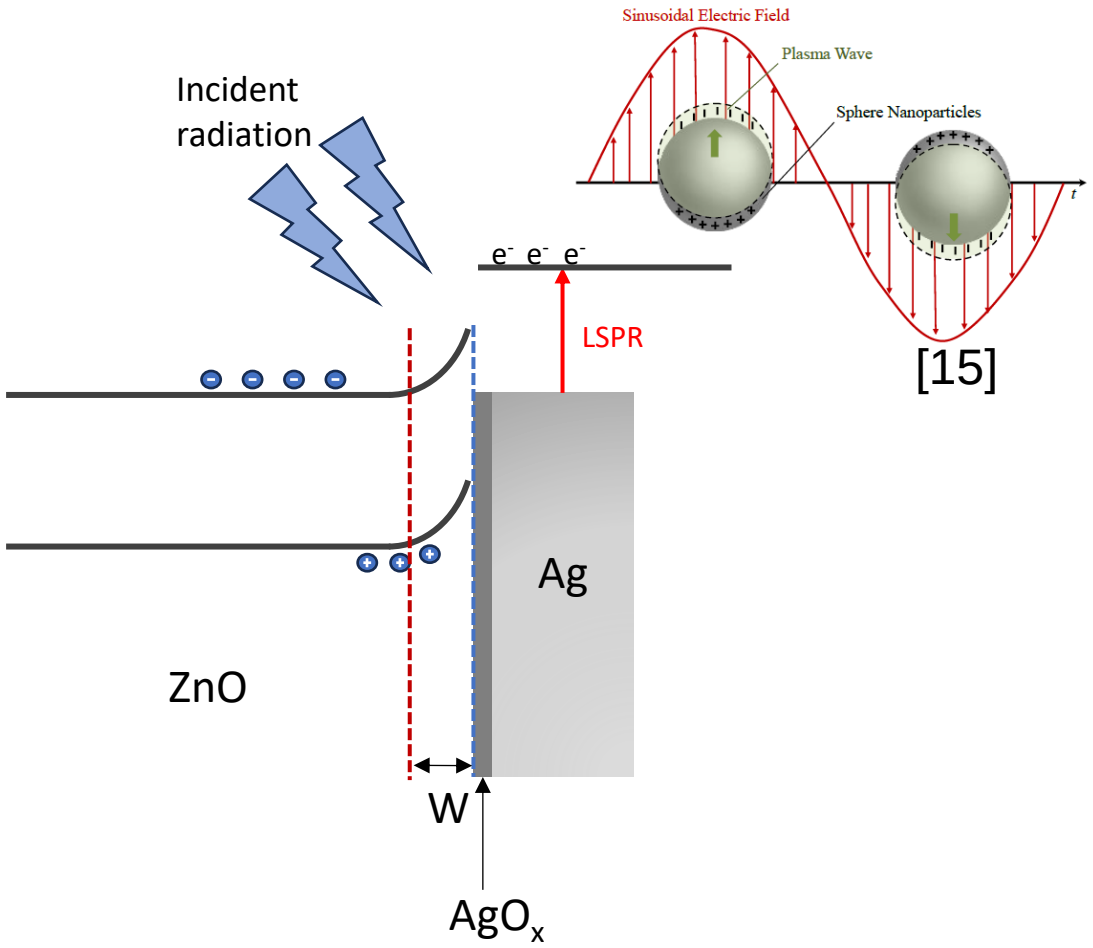
UV irradiation for 5 sec

Rinse in DI

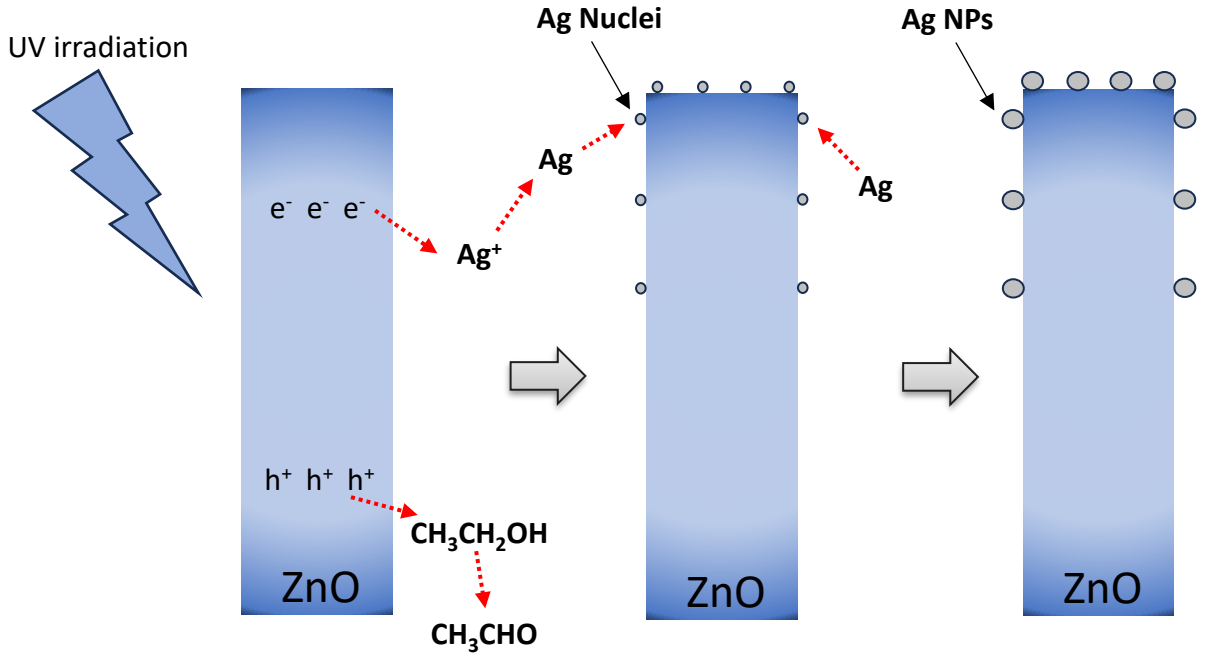
Ag NP deposited ZnO Nanorods

Localized Surface Plasmonic Resonance

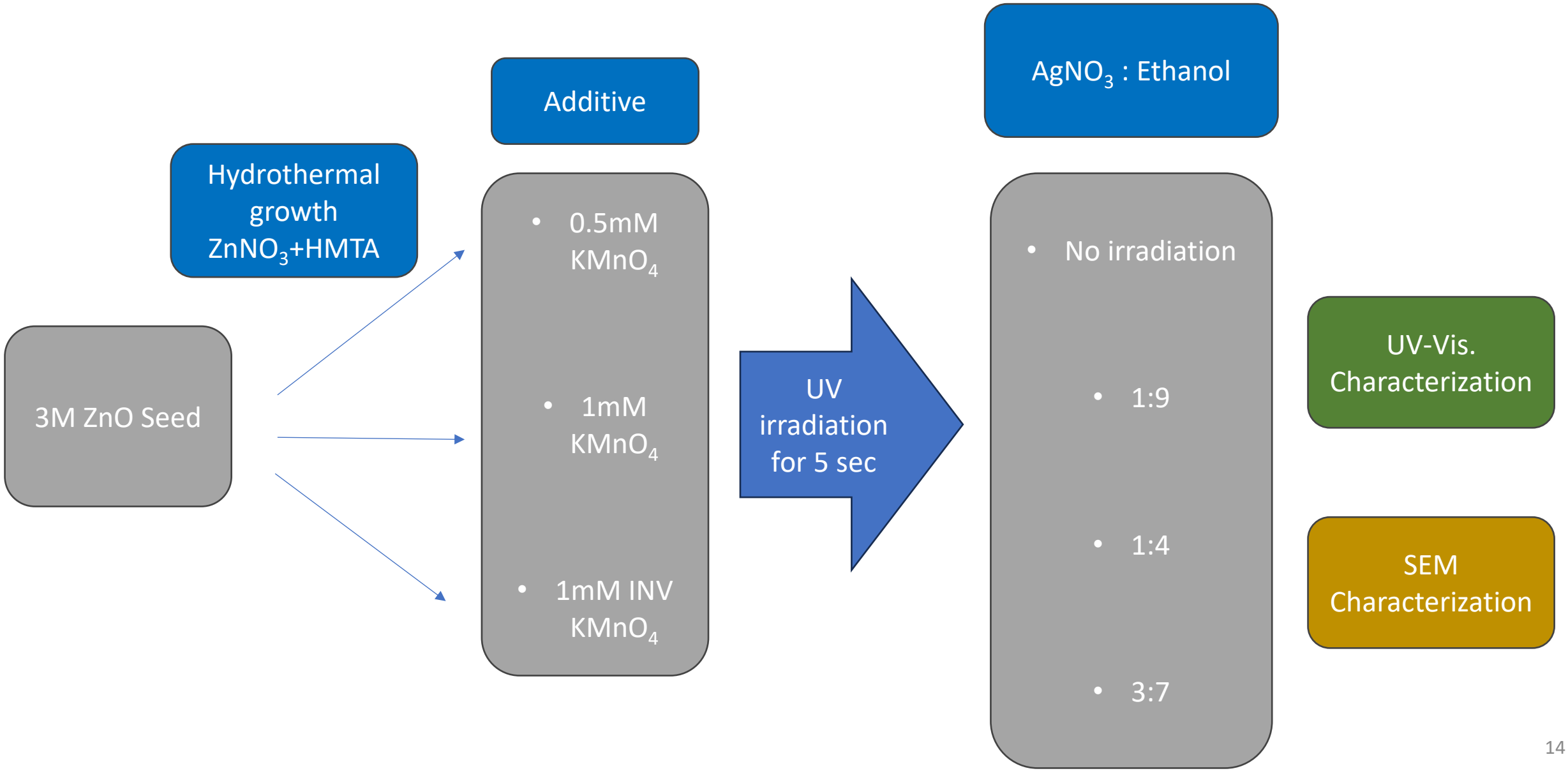
LSPR effect



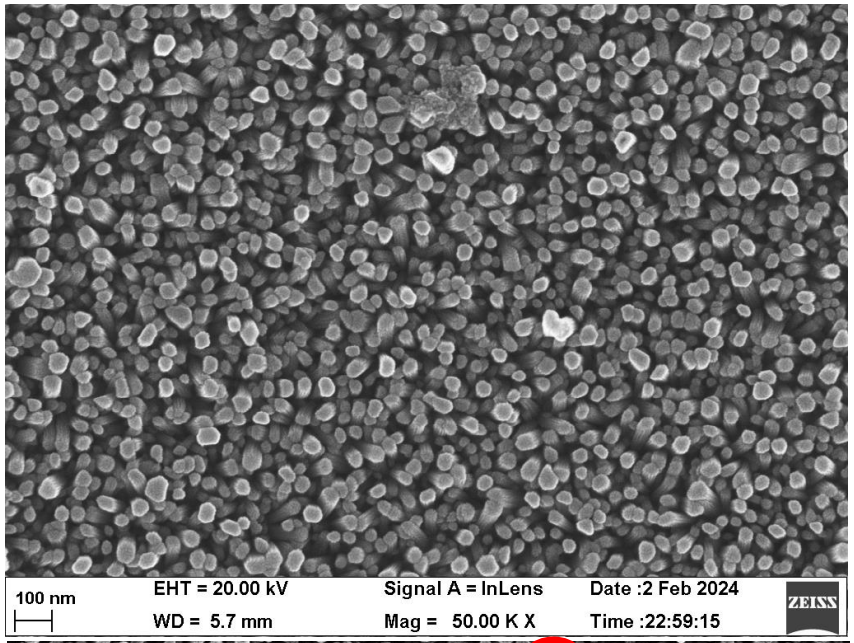
Ag NPs deposition mechanism



Ag NP DEPOSITION

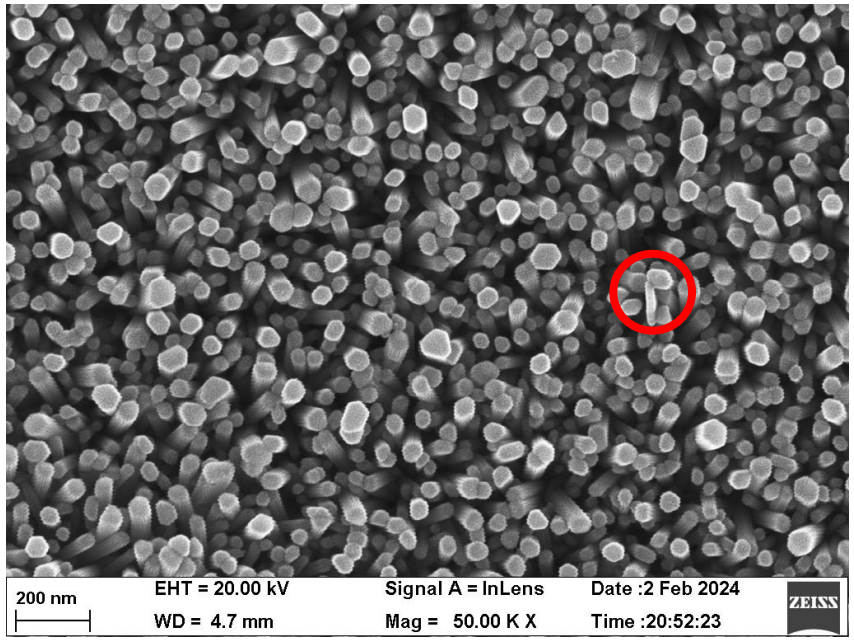


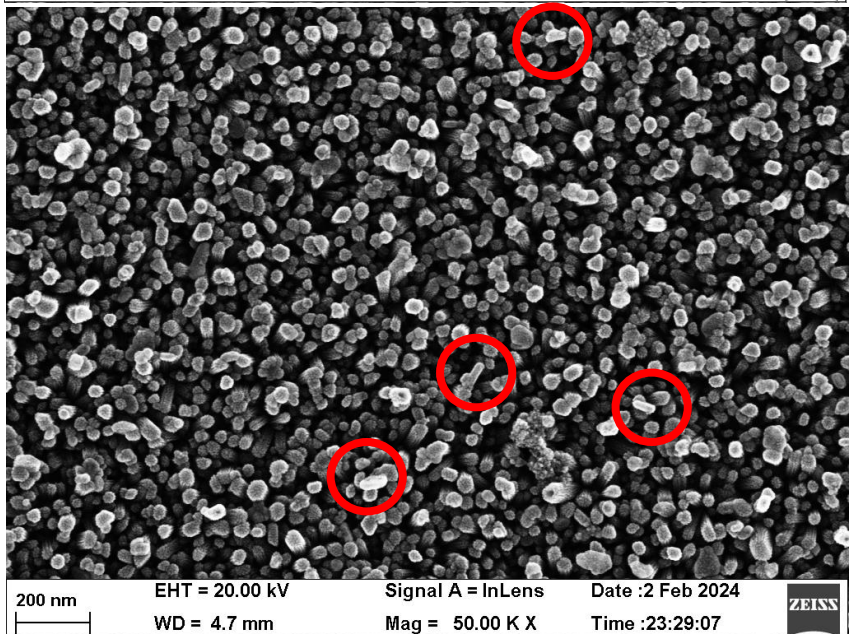
SEM RESULTS 0.5mM $KMnO_4$ with Ag NPs



No irradiation

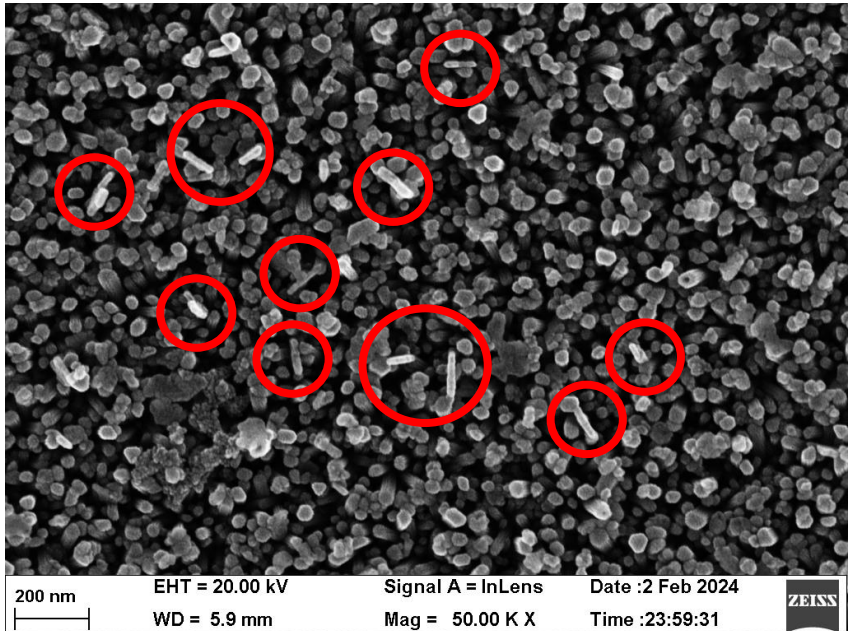
1:9 AgNO3 : Ethanol



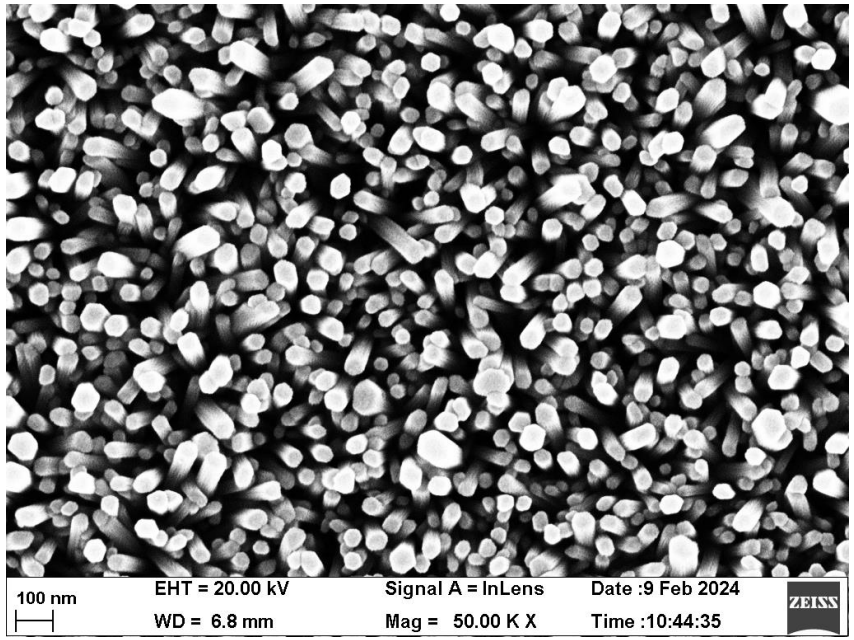


1:4 AgNO3 : Ethanol

3:7 AgNO3 : Ethanol

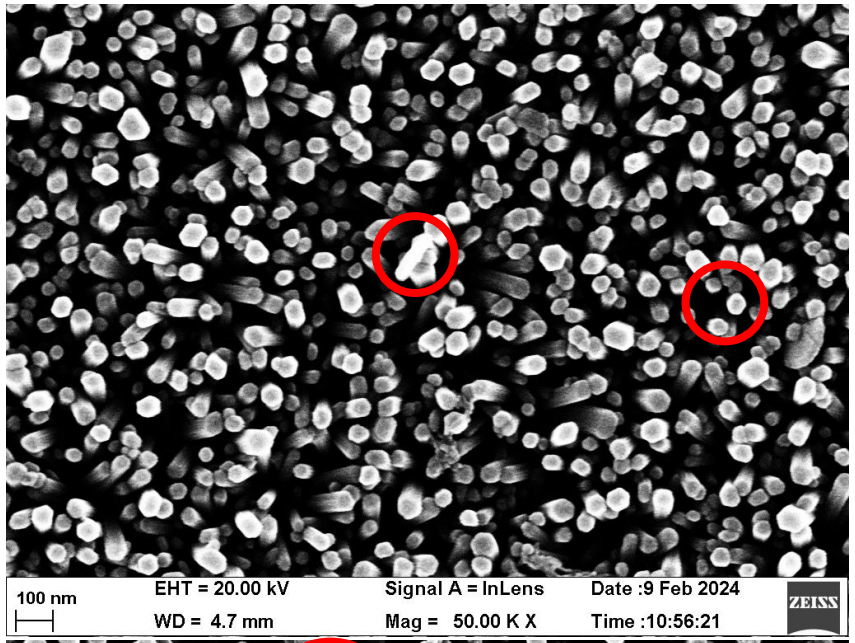


SEM RESULTS 1mM $KMnO_4$ with Ag NPs



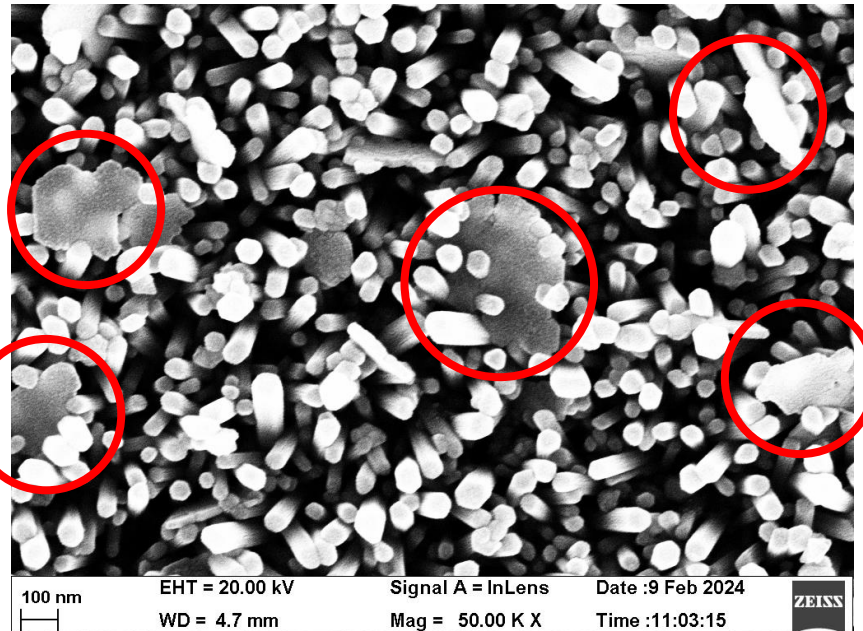
No irradiation

1:9 AgNO3 : Ethanol



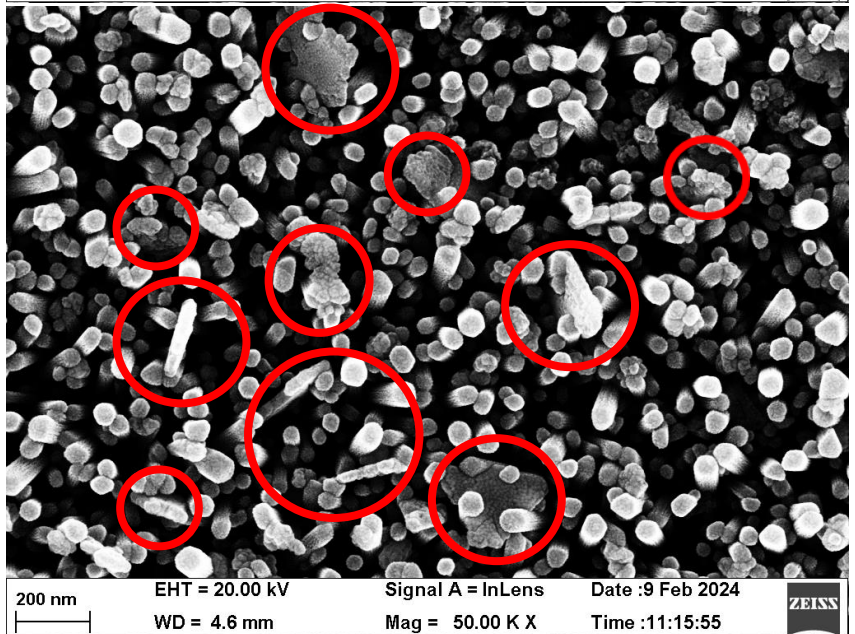
Increased diameter of ZnO nanorods

Increased growth rate of Ag NPs

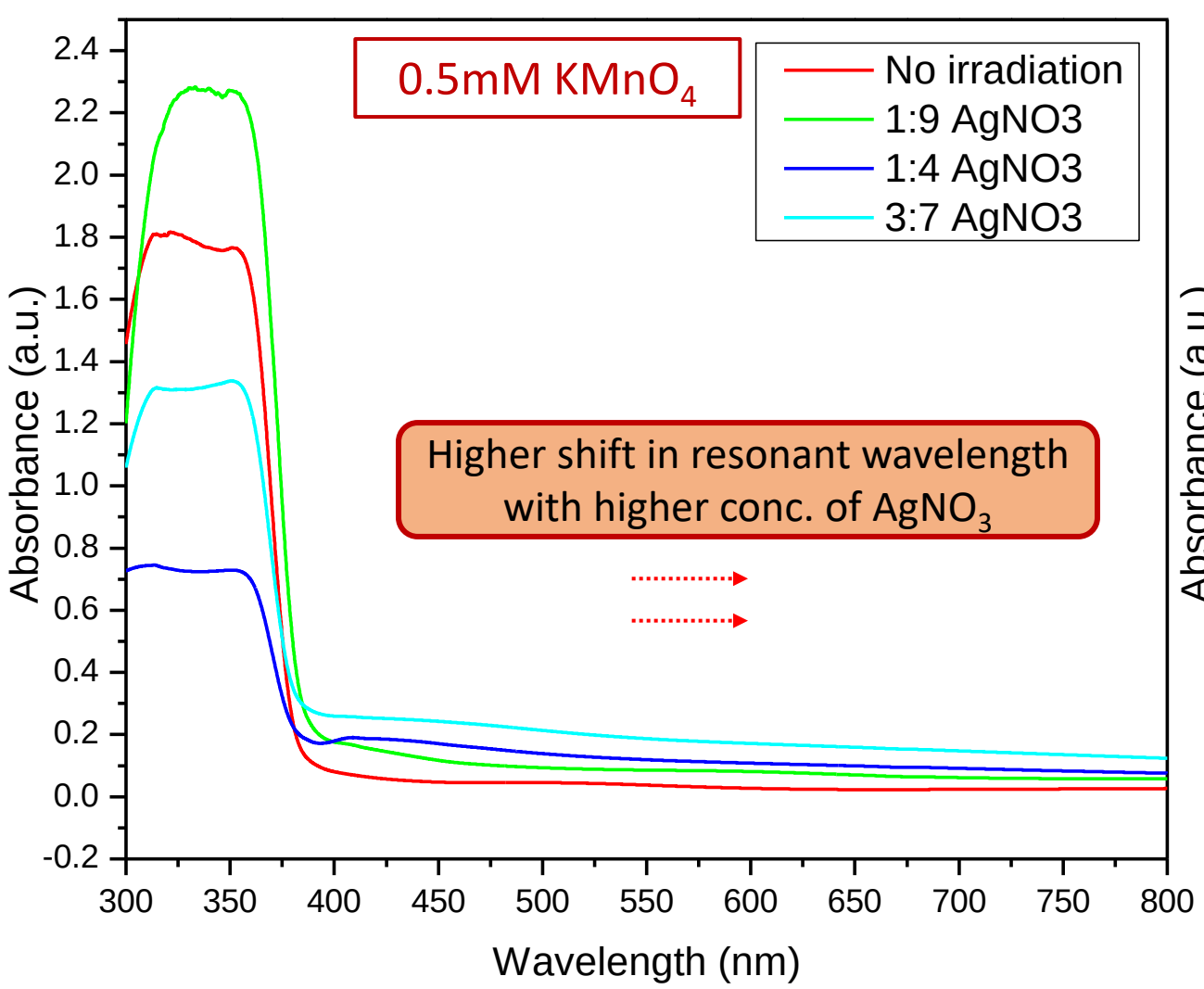


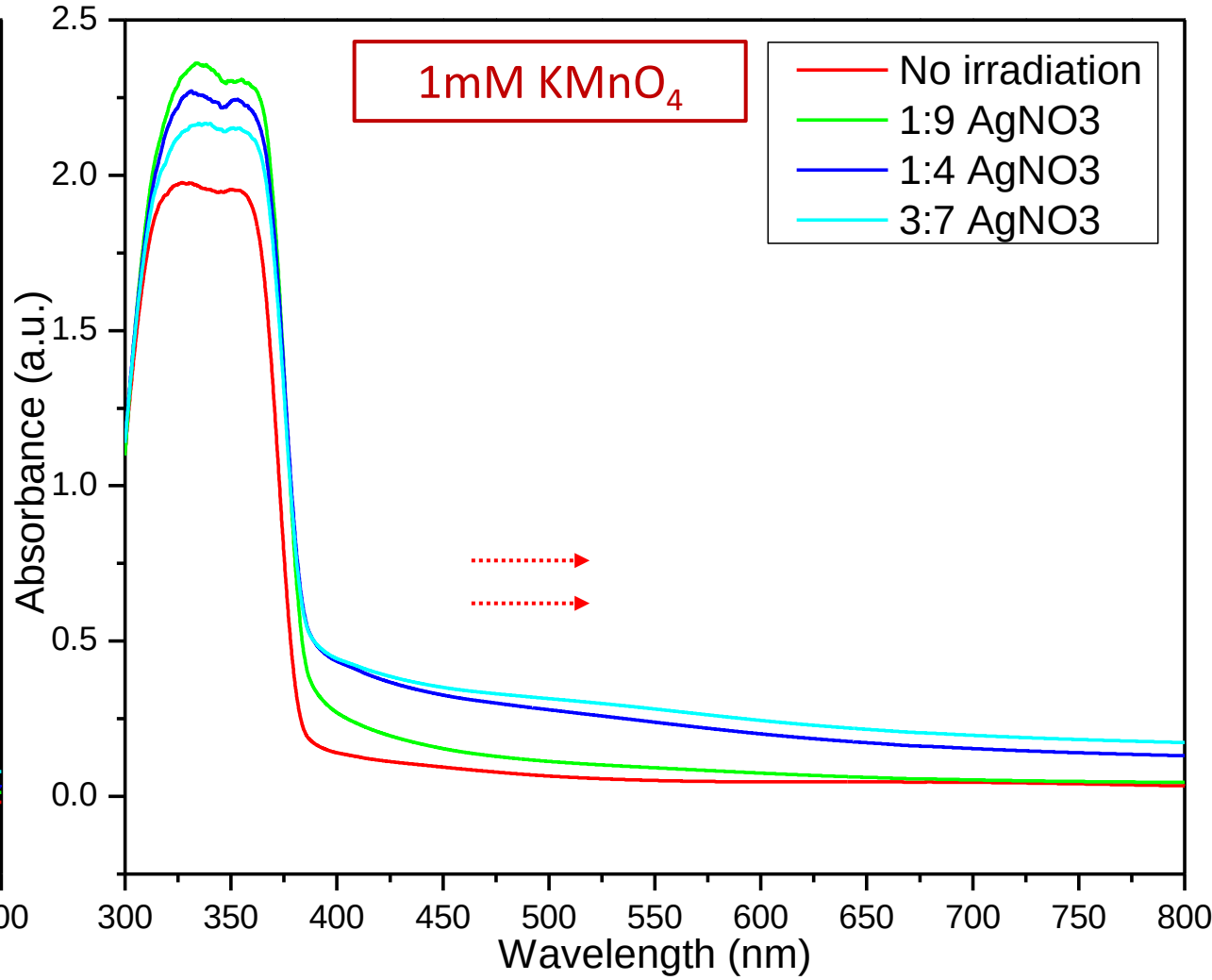
1:4 AgNO3 : Ethanol

3:7 AgNO3 : Ethanol

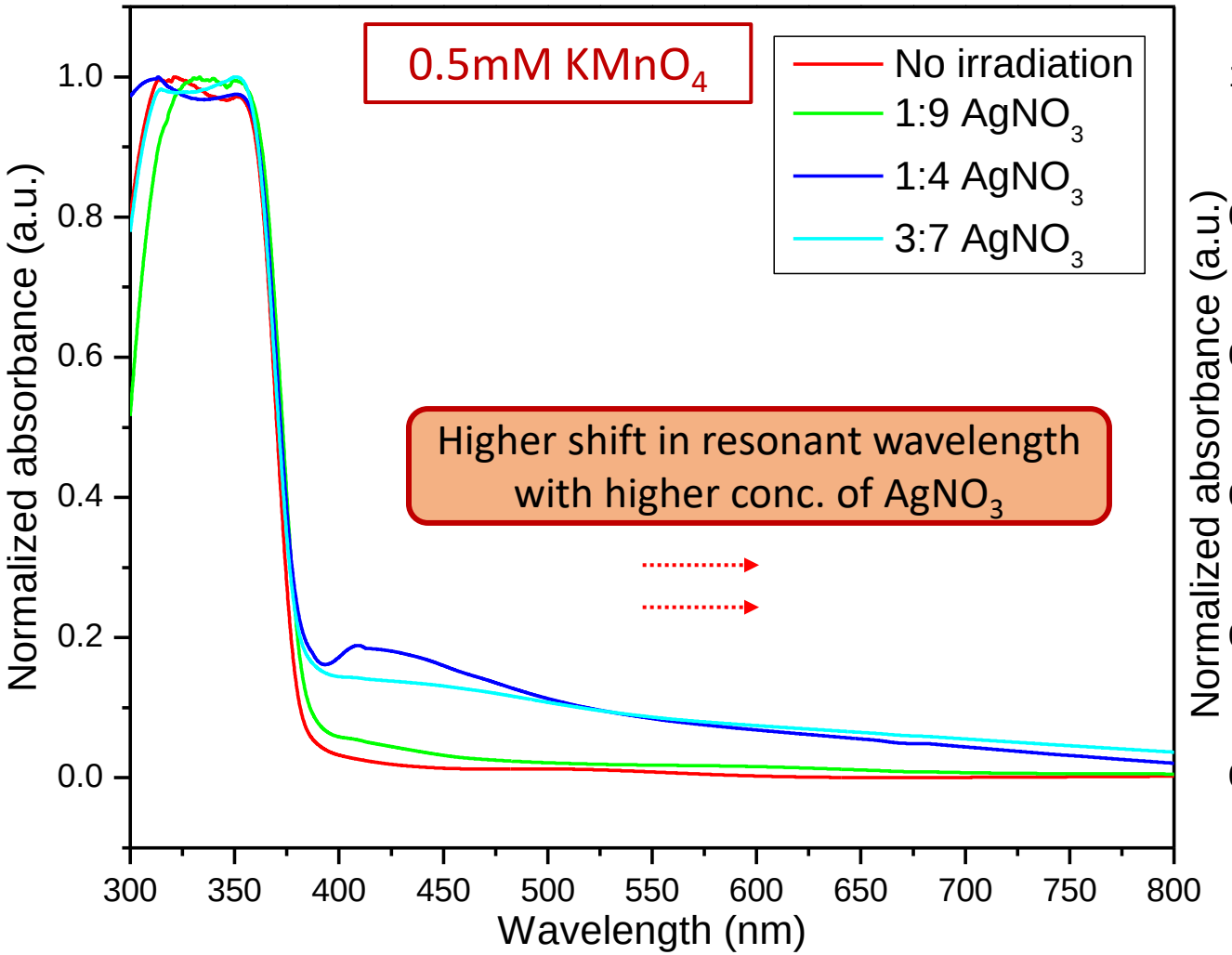


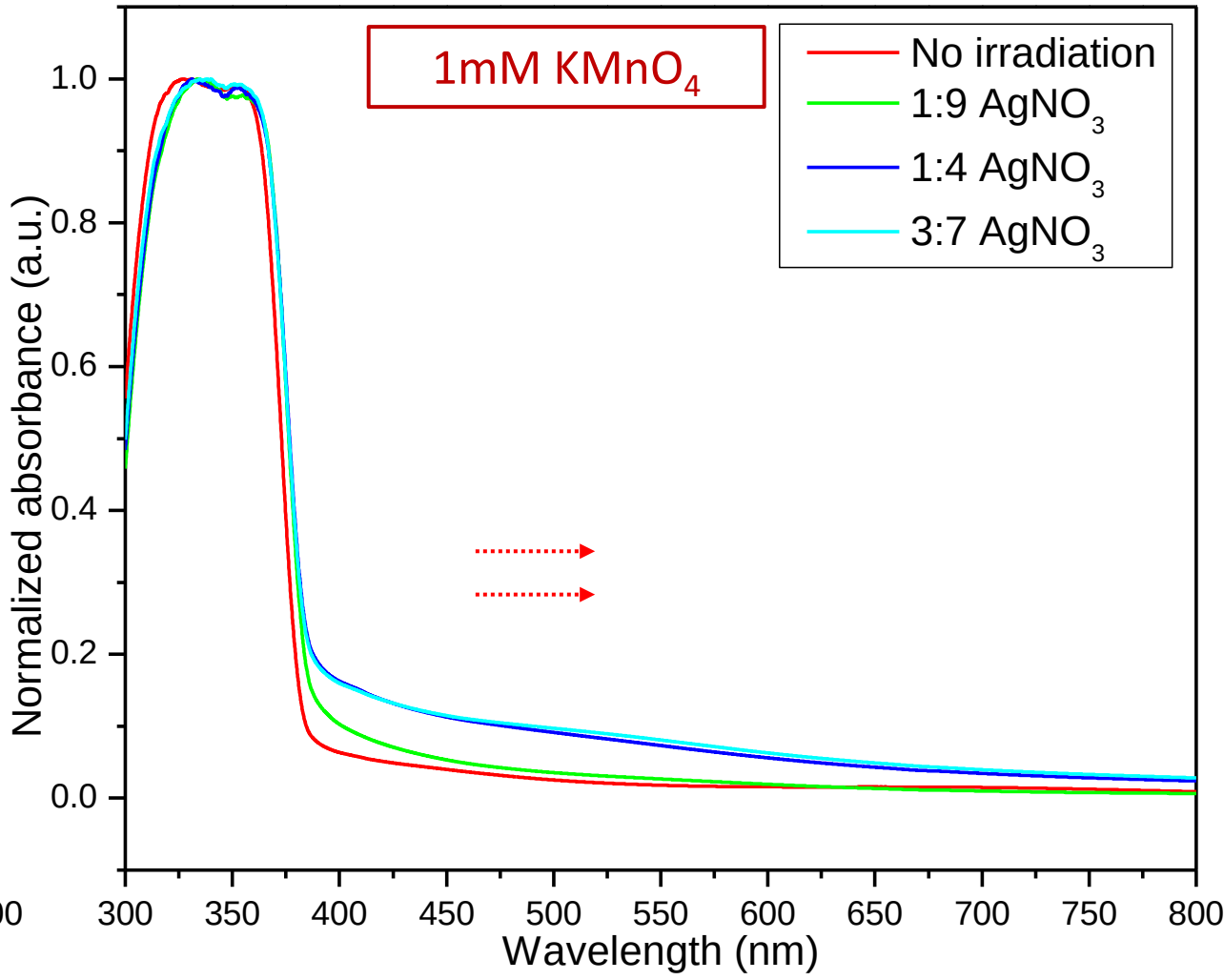
UV-VIS RESULTS





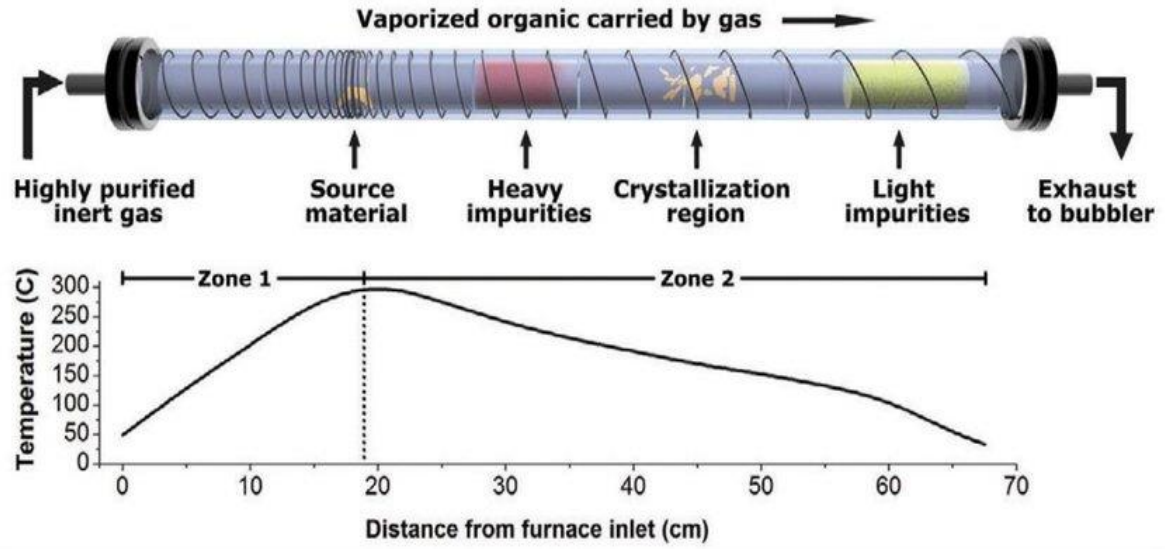
UV-VIS RESULTS





Physical Vapour Transport

PVT schematic



[12]

MULTIPHYSICS STUDY

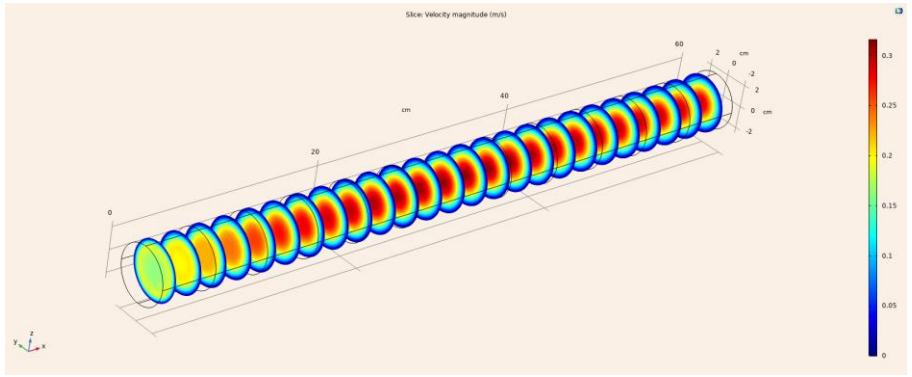
Laminar flow

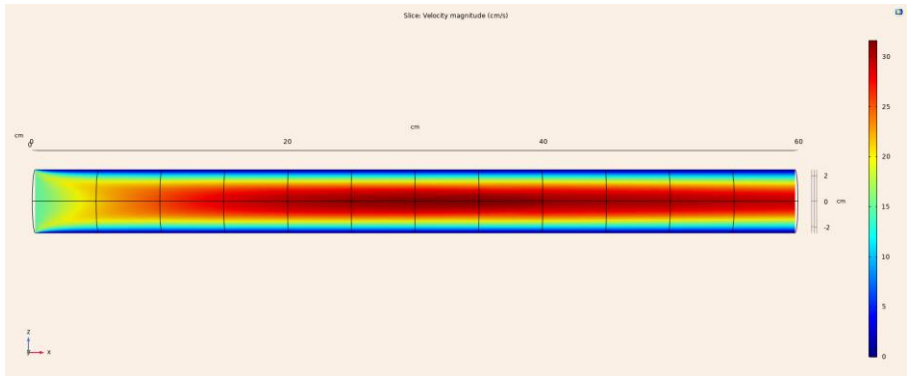
+

Heat transfer

COMSOL SIMULATION

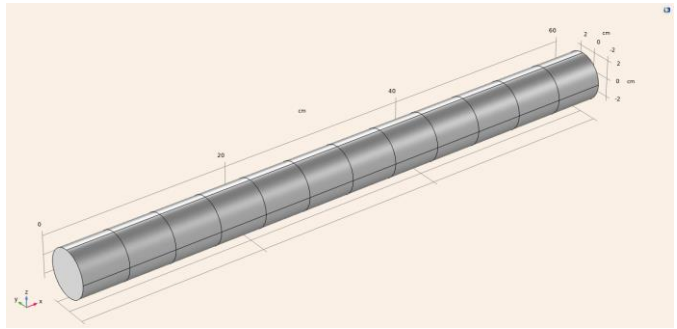
Velocity profile





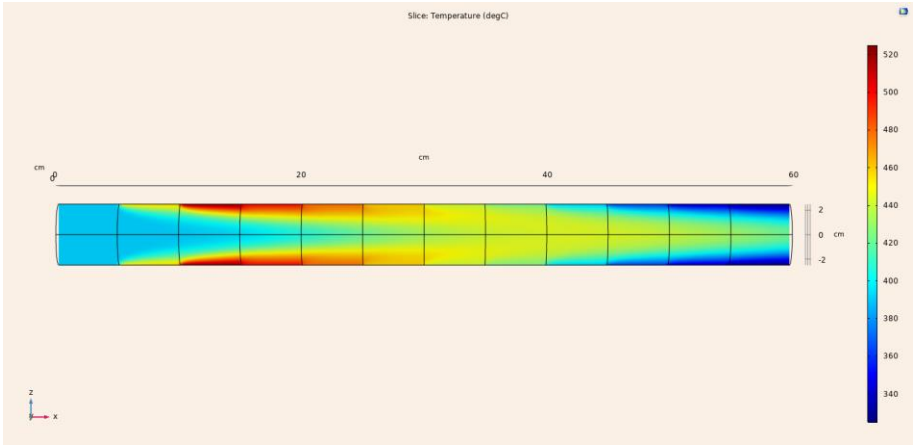
U_0 = 15 cm/s
P_0 = 0 Pa

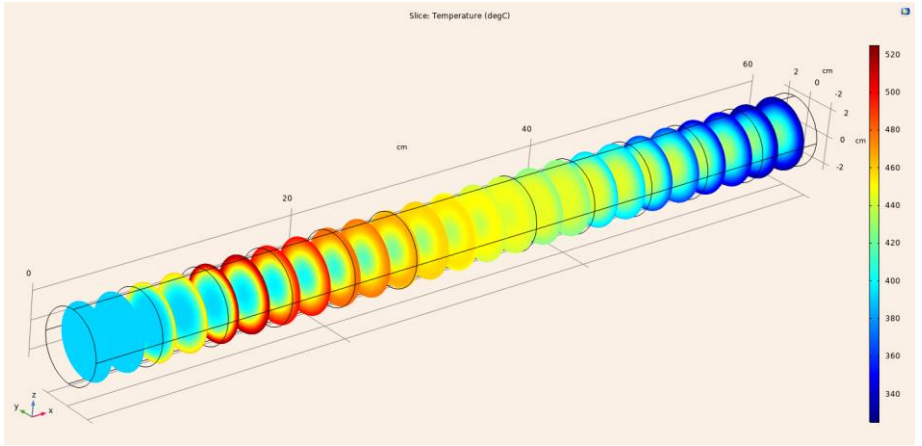
Defined boundary walls
U = 0 cm/s



Geometry

Temperature profile





$T_0 = t_n$ … n = 1 to 12

CONCLUSION

- Synthesized ZnO nanorods using various concentrations of $KMnO_4$ additive.
- With increase conc. of $KMnO_4$ increase in diameter of nanorods and lower shift in bandgap energy is observed.
- With increase in $AgNO_3$:Ethanol conc. the Ag NPs density and growth rate increases also on larger diameter nanorods growth rate and hence density is higher.
- For increasing conc. of $AgNO_3$:Ethanol the resonant wavelength is observed to have a higher shift.
- Temperature variation profile due to the gas flow in PVT tube is studied in COMSOL.

PLAN OF ACTION

Work	Sem1		Sem2		Sem3		Sem4	
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Experimental training and literature review about proposed topic								
Simulation								
Fabrication experiments								
Device fabrication and optimization								
Paper Writing								
Thesis Writing								

ACKNOWLEDGEMENTS

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- I would like to extend my gratitude to my PSPC members, Dr. Eswara Prasad Korimilli and Dr. Swaminathan Ramabadran.
- I am grateful to IIT Indore for providing the necessary resources for research.
- I would also like to thank my team and colleagues for technical discussions.
- I am thankful towards MHRD for providing for teaching assistantship.

REFERENCES

[1] Shan, T., Hou, X., Yin, X. et al. Organic photodiodes: device engineering and applications. Front. Optoelectron. 15, 49 (2022)

[2] Zhuge, Fuwei, et al. "Nanostructured materials and architectures for advanced infrared photodetection." Advanced Materials Technologies 2.8 (2017): 1700005.

[3] Phillips, J., et al. "Electronic and optoelectronic devices based on semiconducting zinc oxide." (2011): 101-127.

[4] M. R. Shenoy [NPTEL] “Semiconductor Optoelectronics, IIT Delhi” (Part IV-4)

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THANK YOU !