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DEVELOPMENT OF HIGH-SENSITIVITY OPTICAL METHODS FOR THE MONITORING OF INTERFACES

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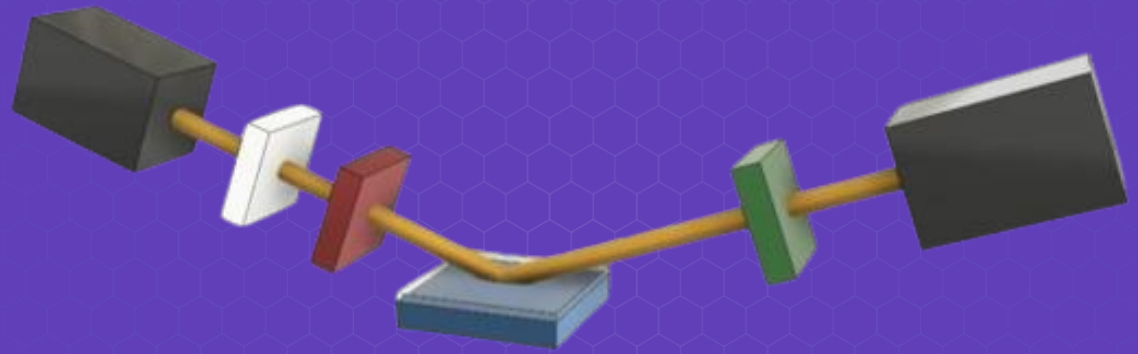

Ellipsometry Phenomenon

Ellipsometry measures the change of polarization of an incident beam caused by a sample for determining surface layers.

$$R_P/R_s = \tan(\Psi)\, e^{i\Delta} \qquad (1)$$

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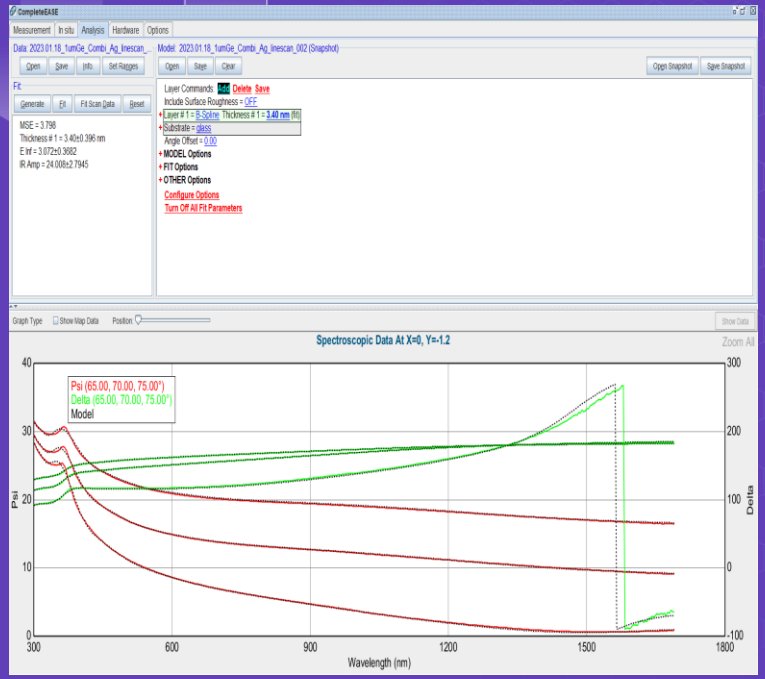
IN-SITU ELLIPSOMETRY & OPTICAL MODELS



CompleteEASE User Interface

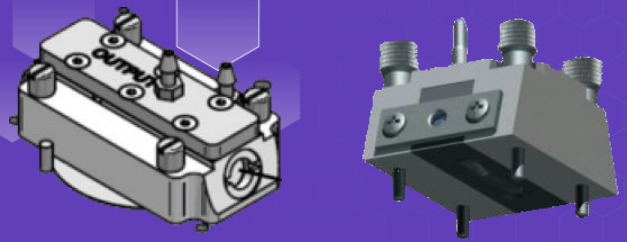
In Situ Spectroscopic Ellipsometry measures a sample "in position" as conditions are varied. It is also common to use in situ measurements to characterize optical constants during different process conditions.

With in situ capability, the sample can be characterized:

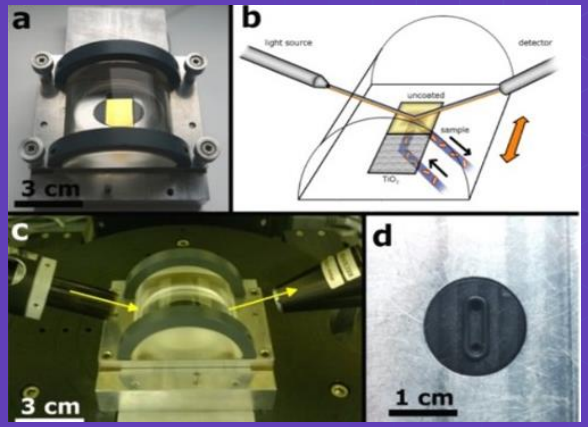
- ❑ Prior to Film Deposition for Accurate Substrate Characterization
- ❑ In Real-time for Thickness and Optical Constants Monitoring
- ❑ Before exposure to Air/Oxidation

The CompleteEASE software includes built-in models covering a wide range of typical samples that conveniently describe how to process the data to determine thin film properties. Real-time data acquisition is also possible to monitor and control the processes under investigation.

CONVENTIONAL FLOW CELL ELLIPSOMETRY



Flow-cells of 'through-liquid' configuration



Kretschmann–Raether Flow cell

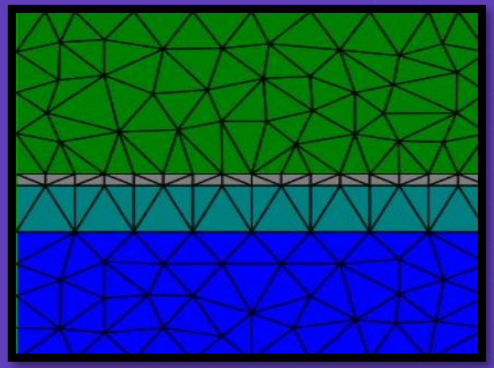
Features of the conventional setup:

- ❑Monitoring of the thickness of adsorbed layers
- ❑Kinetics of adsorption
- ❑Optical Constants (n,k)
- ❑Surface Quality before and after processing
- ❑Process Conditions that affect optical constants
- ❑Material Properties that have an effect on optical constants

Total Internal Reflection Ellipsometry (TIRE) is a combination of internal reflection and ellipsometry. In the Kretschmann–Raether prism geometry, the prism is mounted on a flow cell for measurements in liquids. The surface in contact with the liquid is a thin metal film evaporated on a glass slide, which is in optical contact with the prism by an index matching liquid. [6]

JCMWAVE

JCMsuite is a software package with a focus on fast and highly accurate electromagnetic simulations for finite element analysis.[1] It is based on the following modules:



JCM Modelled Kretschmann–Raether Configuration

JCMGeo
Finite Element mesh generator

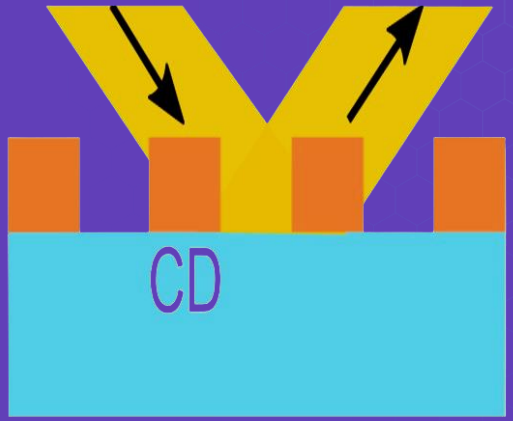
JCMSolve
Simulation engine

JCMView
Mesh & computed fields viewer

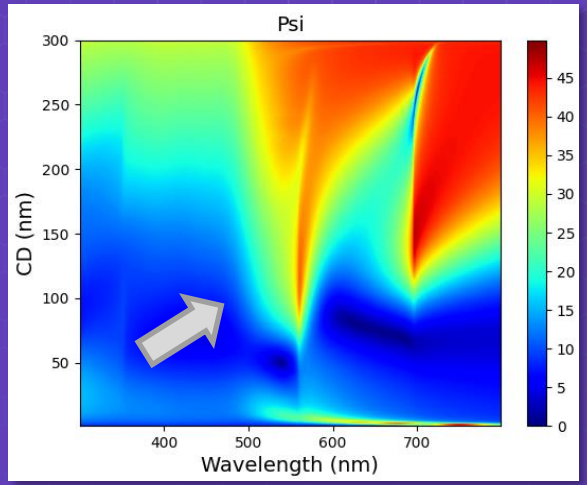
JCMControl
User Interface

CONVENTIONAL CONFIGURATION

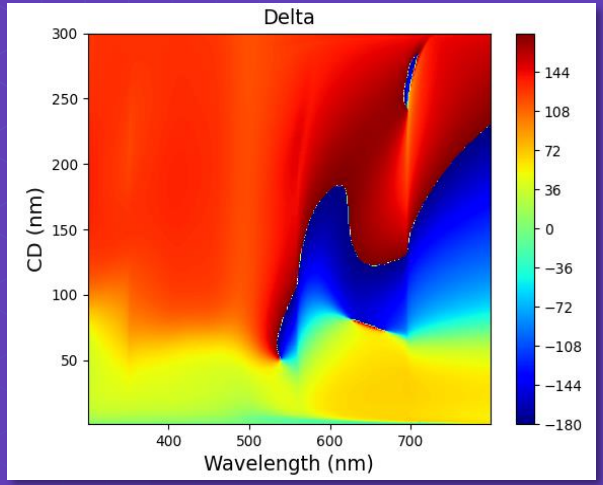
For our experiment, d = 40 nm Au on glass in reflection setup, i.e. air/Au-grating/glass, is modelled using JCMsuite. The parameters used are as follows:
Angle of Incidence (AOI) = 60°, Period = 300 nm, Unit cell = 300 nm x 300 nm, Critical Dimension (CD): Au line width.



Optical configuration



Psi results obtained



Delta results obtained

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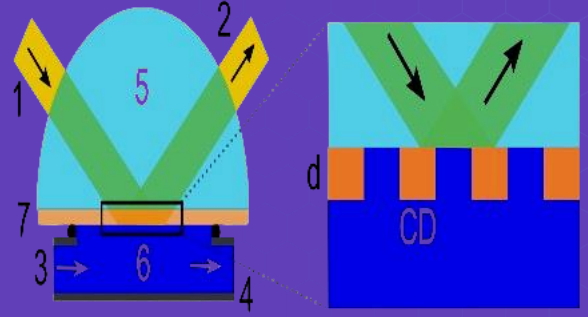
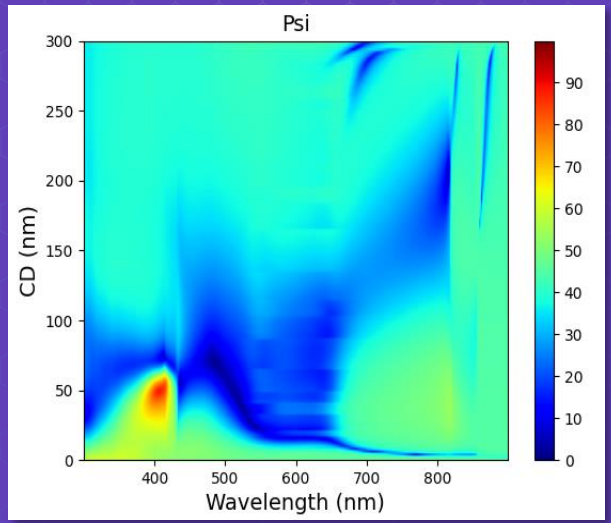
KRETSCHMANN–RAETHER CONFIGURATION

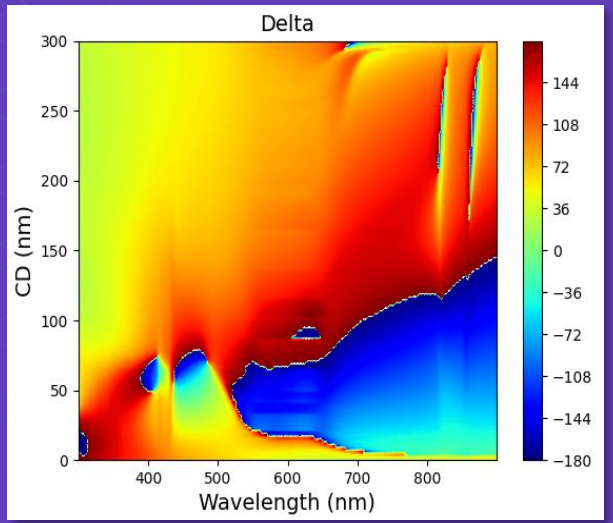
For our experiment, d = 40 nm Au on glass in Kretschmann-Raether setup, i.e. glass/Au-grating/water, is modelled using JCMsuite. The parameters used are as follows:
Angle of Incidence (AOI) = 75°, Period = 300 nm, Unit cell = 300 nm x 300 nm, Critical Dimension (CD): Au line width.



Optical configuration



Psi results obtained



Delta results obtained

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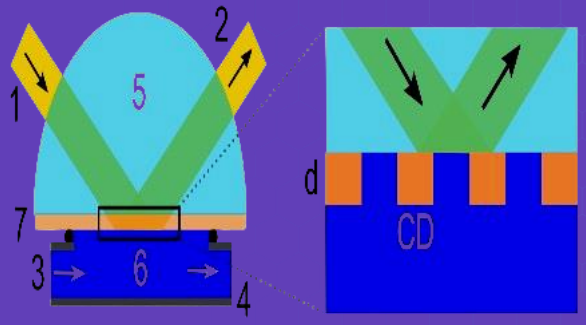
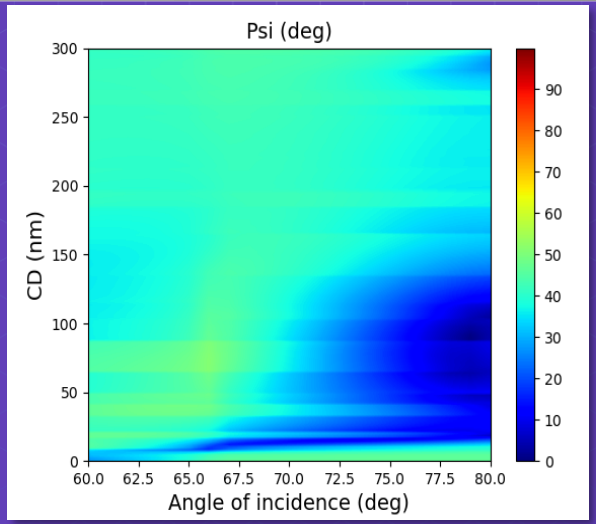
KRETSCHMANN–RAETHER CONFIGURATION

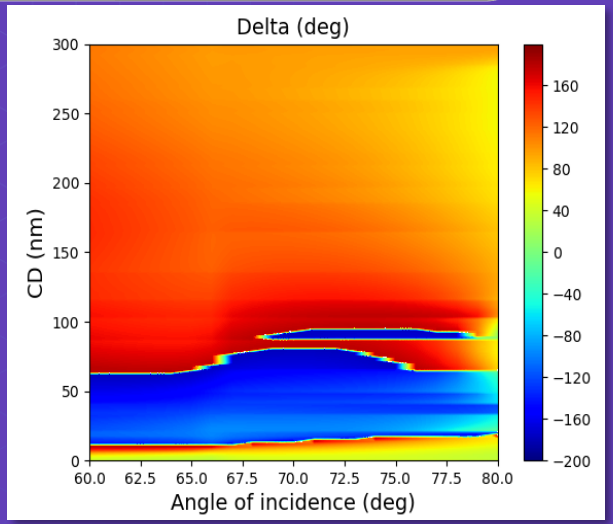
For our experiment, d = 40 nm Au on glass in Kretschmann-Raether setup, i.e. glass/Au-grating/water, is modelled using JCMsuite. The parameters used are as follows:
Angle of Incidence (AOI) = 75°, Period = 300 nm, Unit cell = 300 nm x 300 nm, Critical Dimension (CD): Au line width.



Optical configuration



Psi results obtained



Delta results obtained

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PUBLICATIONS

No	Publication	IF	Total credit	MTMT ID	Personal credit
1	Deshabrato Mukherjee and Peter Petrik. **"Real-Time Ellipsometry at High and Low Temperatures"**. ACS Omega 8, no. 4 (2023): 3684–97. https://doi.org/10.1021/acsomega.2c07438.	4.263	36	33570770	36
2	Deshabrato Mukherjee, Benjamin Kalas, Sven Burger, Gyorgy Safran, Miklos Serenyi, Miklos Fried, and Peter Petrik. **"Nanostructures for In-Situ Surface-Enhanced Kretschmann-Raether Ellipsometry"**. Photonic Instrumentation Engineering X, SPIE, 2023. https://doi.org/10.1117/12.2649080.	0.367	24	33699389	24
3	Zoltan Labadi, Csaba Bakos, Mate Szucs, Attila Bonyar, Deshabrato Mukherjee, Hajnalka Jankovics, Ferenc Vonderviszt, and Peter Petrik. **"Ellipsometry Monitoring of Sensor Processes Based on Gold Nanoparticle Bonded Proteins."** Colloidal Nanoparticles for Biomedical Applications XVIII, SPIE, 2023. https://doi.org/10.1117/12.2649990.	0.367	24	33724105	24
4	D.G Merkel, K. Sájerman., T. Váczi, S. Lenk, G. Hegedűs, S. Sajti, A. Németh, M.A. Gracheva, P. Petrik, D. Mukherjee, Z.E. Horváth, D.L. Nagy, A. Lengyel. **"Laser irradiation effects in FeRh thin film"**. Materials Research Express, 10 (7), Art. no. 076101, 2023. https://doi.org/10.1088/2053-1591/ace4a3	2.270	36	34536298	18
5	Chou Ta-Shun, Saud Bin Anooz, Rajmund Grüneberg, Jana Rehm, Arub Ahktar, Deshabrato Mukherjee, Peter Petrik, Andreas Popp. "**In - situ spectral reflectance investigation of heteroepitaxial grown β-Ga_2O_3thin films on c-plane Al_2O_3 via MOVPE process"** (2024) Applied Surface Science. https://doi.org/10.1016/j.apsusc.2024.159370	7.146	36	34503364	18
6	Saud Bin Anooz, Peter Petrik, Yankun Wang, Deshabrato Mukherjee, Martin Schmidbauer, and Jutta Schwarzkopf **"Dielectric function and interband critical points of compressively strained ferroelectric $K_{0.85}Na_{0.15}NbO_3$ thin film with monoclinic and orthorhombic symmetry"**. Optics Express, Vol. 32, Issue 9, pp. 15597-15609, (2024), https://doi.org/10.1364/OE.520426	3.605	36	34791151	18

CURRICULUM ACTIVITIES

No	Neptun Code	Subject	Professor	Semester
1	OATBESZGND	Research Report VI.	Dr. Recskiné Dr. Borsa Judit Ilona	6
2	OATKUTPGND	Research Project VI.	Dr. Recskiné Dr. Borsa Judit Ilona	6

- Reviewing the related literature of ellipsometry and finite modelling for my future publications and progress.
- I was also involved in investigations combining spectroscopic ellipsometry with cyclic voltammetry.
- I was able to conduct various measurements on new samples from Leibniz-Institut für Kristalzüchtung (IKZ), Berlin using the J.A. Woollam M-2000 DI ellipsometer in combination of TSEL-1000 heat cell stage ranging up to temperatures of 1000 °C. The samples were also measured with the J.A. Woollam Mark II IRS ellipsometer.
- Research article titled **"Optical and sensing properties of thermally generated gold nanoislands created by the annealing of layers with graded thickness"** was resubmitted post revisions for publication.
- Self-development of a novel non-depolarizing Kretschmann-Raether (KR) flow cell for ellipsometry and the preliminary set of sensing measurements of heavy metals were done which will be followed up with further studies and results for a publication. Certain experiments have already been completed for heavy metal sensing in an optical flow cell using monomers of genetically engineered flagellar filaments.
- The first grating structures that arrived from POLight project last semester was measured using M-2000DI SE and these set of experiments were mirrored to study the modeling capabilities for periodic plasmonic nanostructures on JCMSuite. Currently for the modelled grating structure, simulations are being carried out with modification of all the grating parameters such as Critical Dimension (CD), thickness of Au, Wavelength, Angle of Incidence(AOI) and Pitch.

CONFERENCES & FUTURE WORK

CONFERENCE: Presented my work titled **"Sensing properties of gold nanoparticles created by combinatorial magnetron sputtering & annealing"** at the 2024 E-MRS Spring Meeting, May 27-31, 2024, Strasbourg, France.

- Submission of review article titled **"In-situ ellipsometry at solid-liquid interfaces"** post the ISCMP 2024 conference.
- Final analysis of IKZ samples with SE and IRSE characterization along with heat treatment whose results will lead to an upcoming publication this year.
- Further experiments on the self-developed novel non-depolarizing KR flow cell for sensing measurements of heavy metals and results for another publication.
- Experiments related to heavy metal sensing in an optical flow cell using monomers of genetically engineered flagellar filaments.
- New grating samples from the POLight project has arrived recently which will be measured using M-2000DI SE and these will be again mirrored to study the modeling capabilities on JCMSuite. After the modulation of the grating parameter results obtained in this semester, it will be followed with simulations and experiments for interactions with bio-molecules for determining of sensing with and overlayer present. This will be a work which I propose to publish in a D1 journal before the submission of my thesis.
- Presentations at the ISCMP-2024 conference in Bulgaria followed by another presentation at EOSAM-2024 conference in Italy.
- Most of my research work over the last couple of years will be presented at the 10th International Conference on Spectroscopic Ellipsometry, ICSE-10 which will be held next year in USA.

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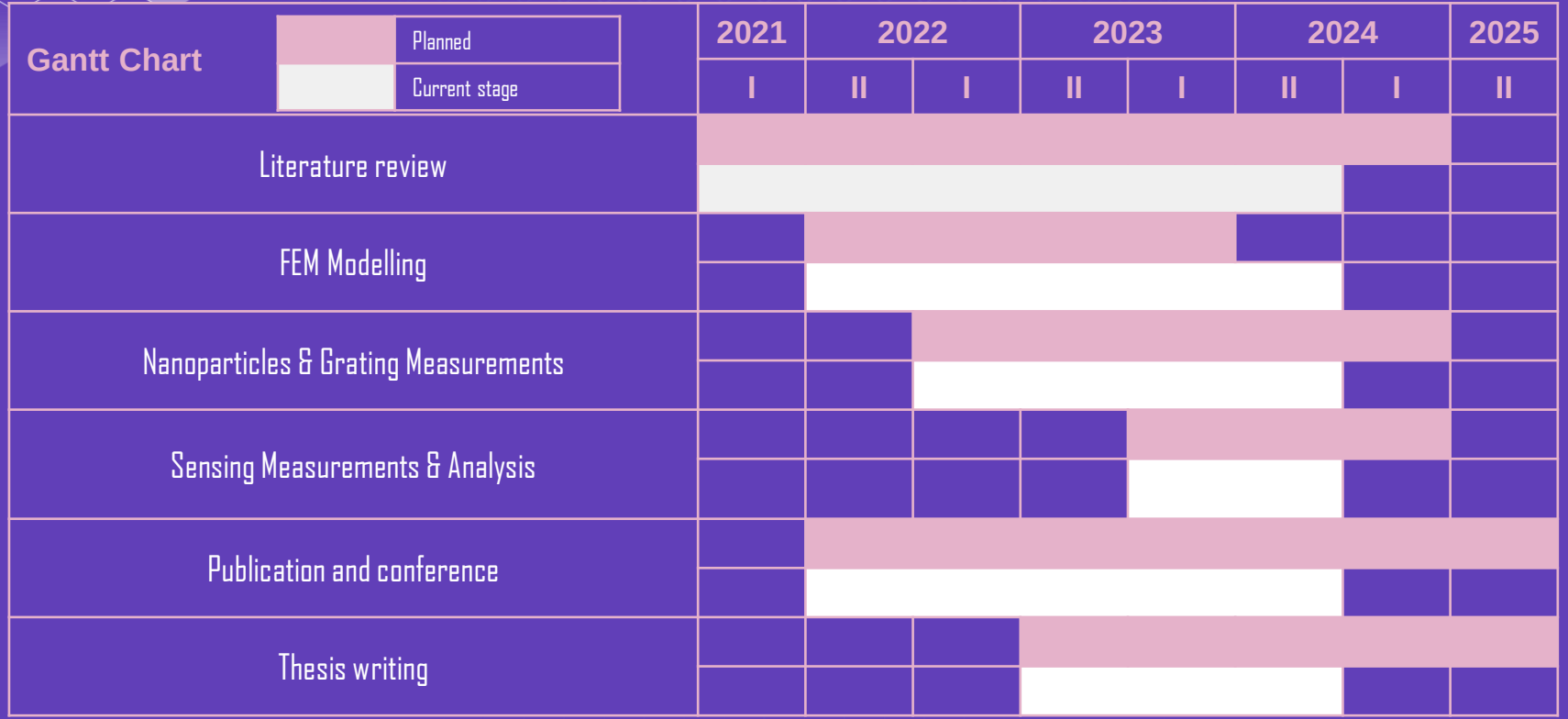
GANTT CHART



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THANKS