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

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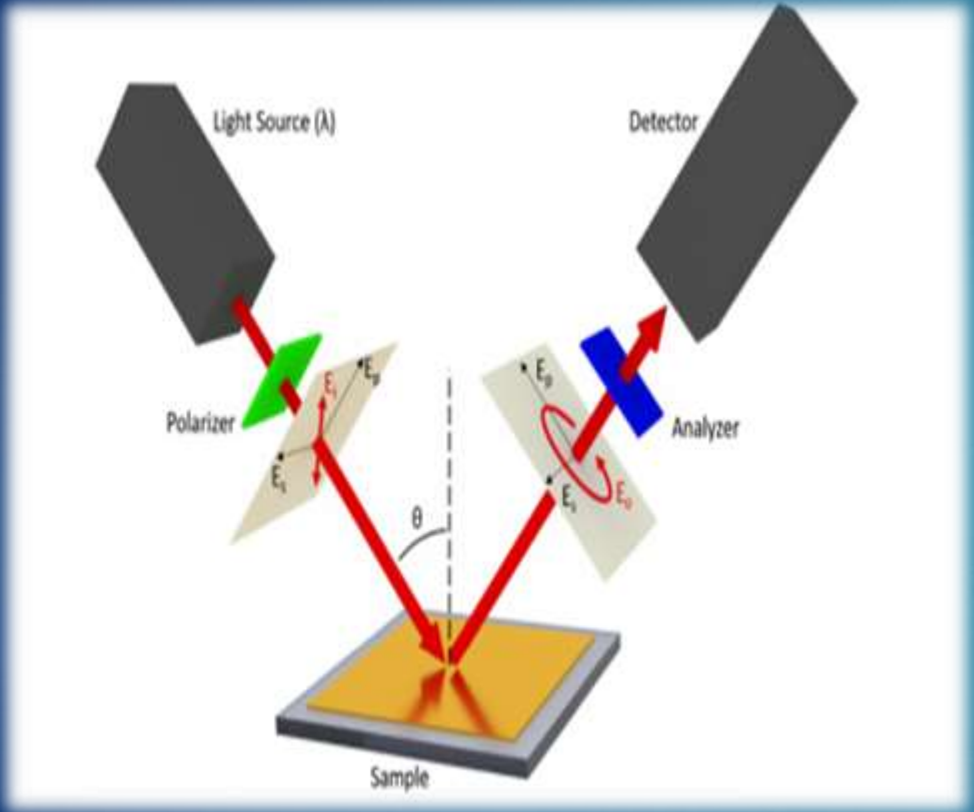
ELLIPSOMETRY



Ellipsometry method [3]

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

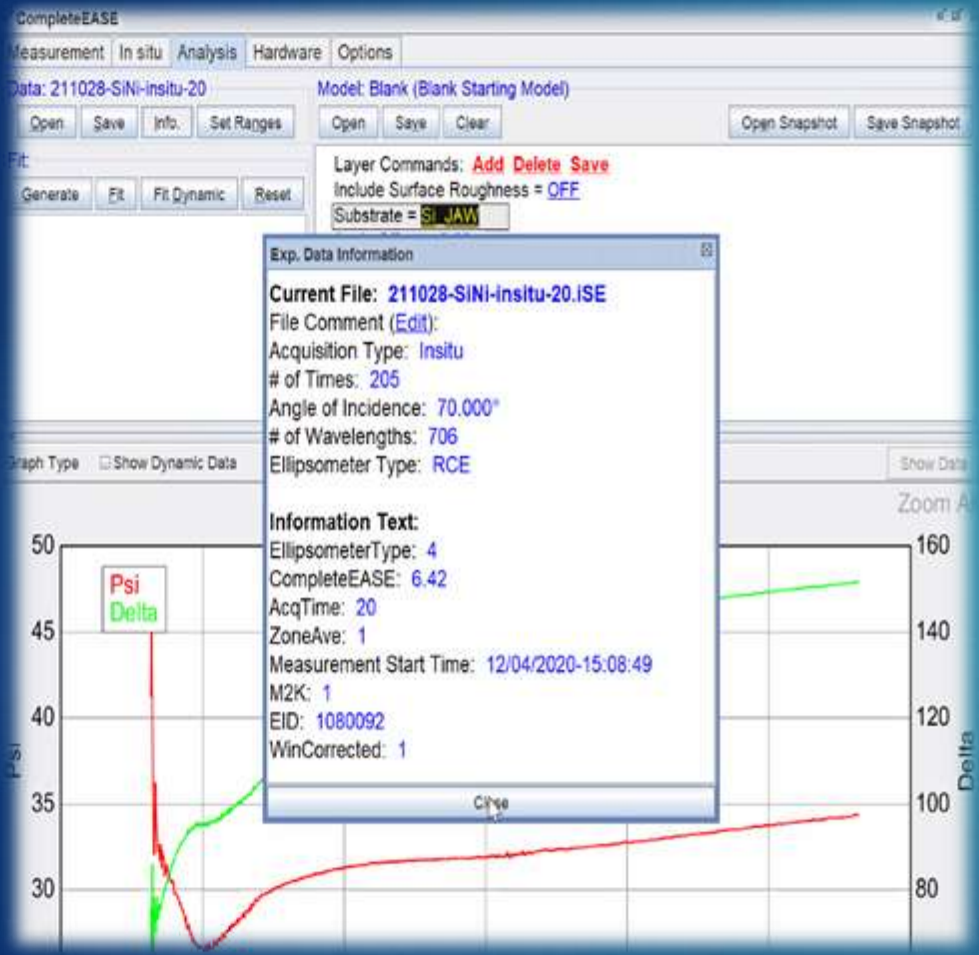
Here, a target is illuminated by light with well-defined polarization states to measure a number of field components of the reflected and/or transmitted light parameters.

Enabling principle of ellipsometry states that parallel (p) and perpendicular (s) polarized light reflect differently and ellipsometry determines the complex reflectivity ratio of p and s polarized light which is expressed in terms of ellipsometric Ψ and Δ angles. [8]

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

where, R_p and R_s denote the reflection coefficients of p- and s-polarized light, $\tan(\Psi)$ is the absolute value of the amplitude ratio and Δ is the phase difference of complex reflection coefficients.

OPTICAL MODELS



CompleteEASE User Interface

The evaluation software measures the uniformity of the samples with automated sample mapping and collects in-situ data with spectroscopic ellipsometry on the process chamber or with add-on temperature control stage or liquid cell.

It 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.

IN-SITU ELLIPSOMETRY

In Situ Spectroscopic Ellipsometry (SE) 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:

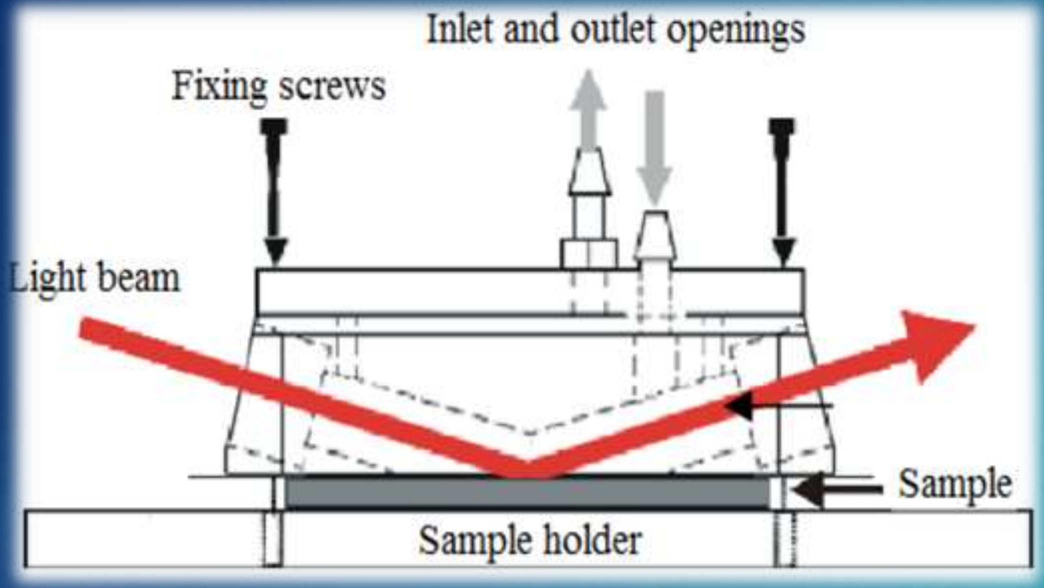
- Prior to Film Deposition for Accurate Substrate Characterization
- In Real-time for Thickness and Optical Constants Monitoring
- Before exposure to Air/Oxidation

In Situ SE uses light to probe the thin film in a non-invasive manner. The measurement can be directly taken from the surface of interest without any damage or special sample preparation. [2]

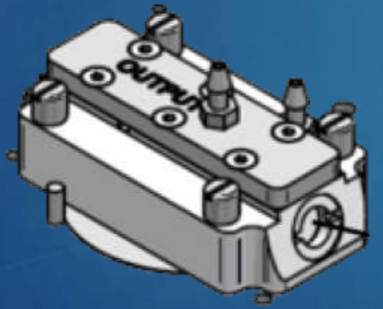
Ellipsometry determines the 'polarization' of light thus having various advantages over spectrophotometry: [2]

- Data not affected by coated windows,
- Collects accurate data even at low intensities,
- Polarization contains phase information, which is highly sensitive to very thin films.

CONVENTIONAL FLOW-CELL ELLIPSOMETRY



Beam path in a conventional flow cell

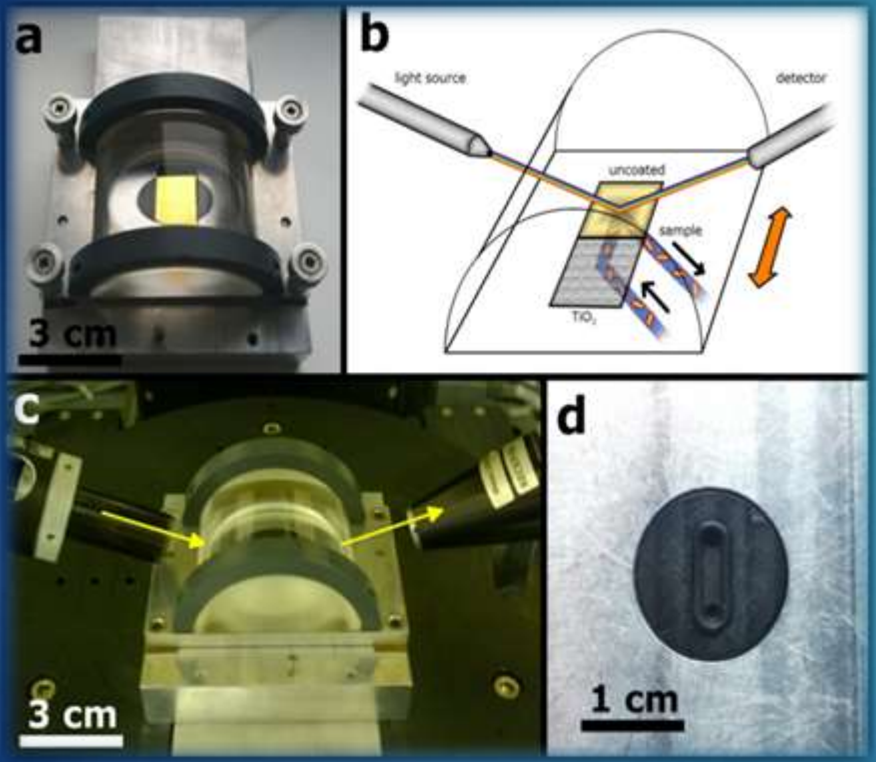


Flow-cells of 'through-liquid' configuration

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

INTERNAL REFLECTION ELLIPSOMETRY

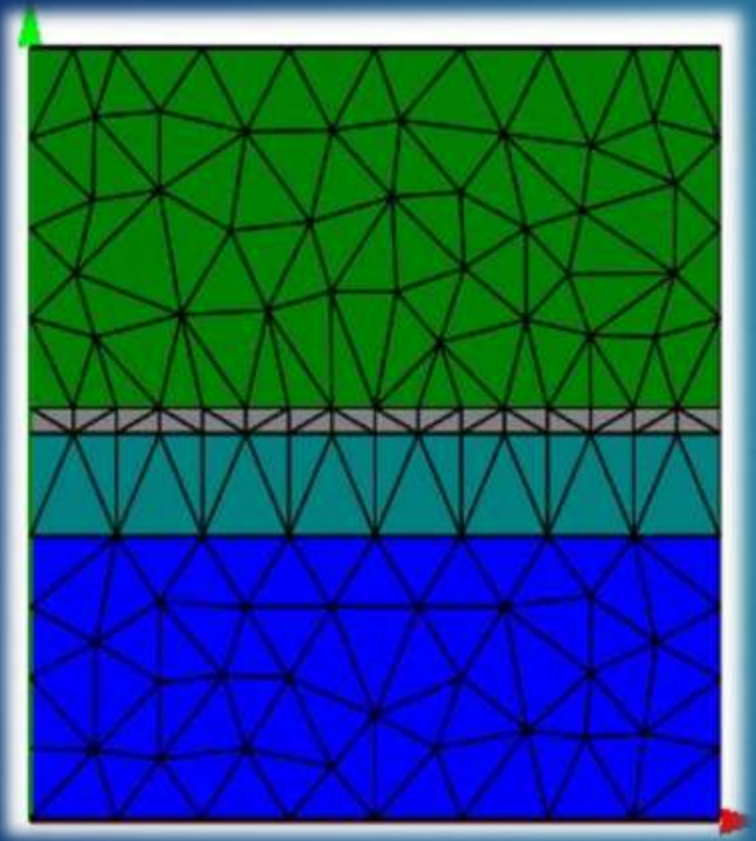


Kretschmann–Raether Flow cell[6]

Total Internal Reflection Ellipsometry (TIRE) is a combination of internal reflection and ellipsometry. When combined with surface plasmon resonance (SPR) effects, this technique becomes powerful for monitoring and analyzing adsorption and desorption on thin semitransparent metal films as well as for analyzing the semitransparent films themselves. [7]

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]

FINITE ELEMENT MODELING



JCM modelled K-R configuration

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::

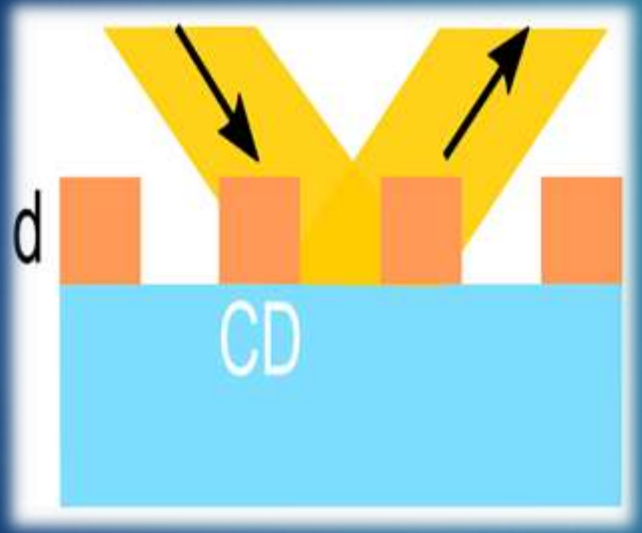
- JCMgeo
- JCMsolve
- JCMview
- JCMcontrol

For analysis and optimization of nano-optical and micro-optical systems, JCMsuite has applications in various domains. The design tasks can be embedded into scripting languages like MATLAB and Python. The major physical models treated by JCMsuite are as follows:

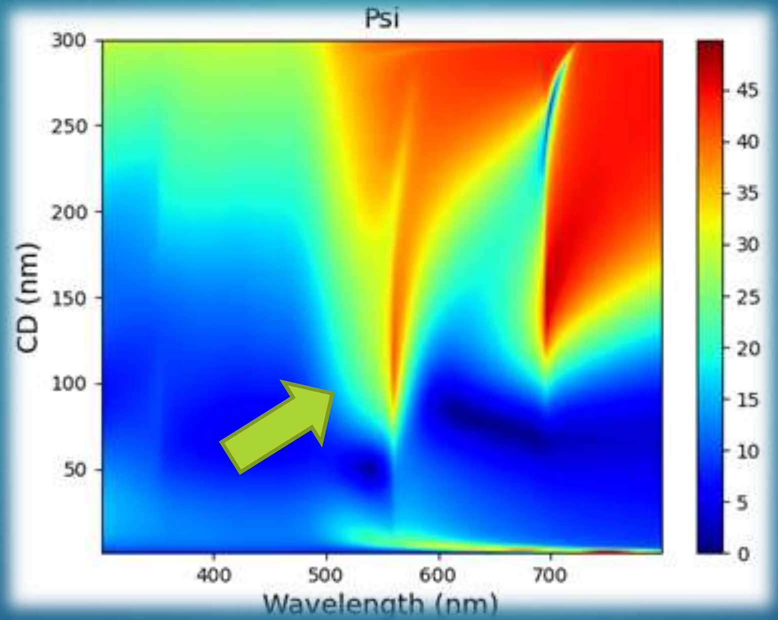
- Optical Scattering
- Optical Waveguide Design
- Optical Resonance
- Heat Conduction
- Linear Elasticity

CONVENTIONAL CONFIGURATION

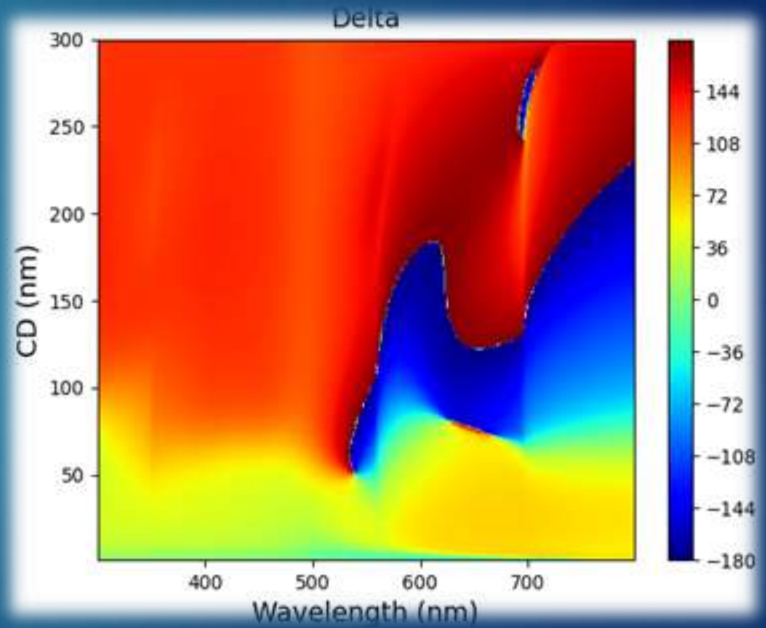
For our experiment, d = 40 nm Au on glass in reflection setup, i.e. air/Au-grating/glass, is modelled using JCMsuite. The parameters used are as follows:
Angle of Incidence (AOI) = 60º, Period = 300 nm, Unit cell = 300 nm x 300 nm, Critical Dimension (CD): Au line width.



Optical configuration



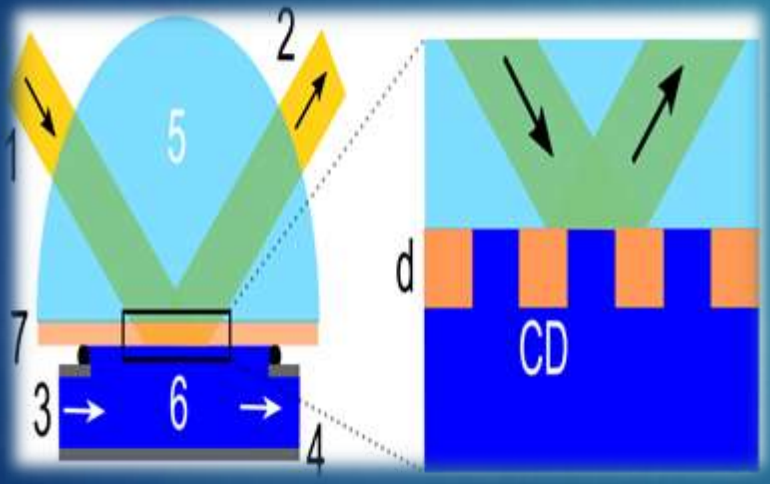
Psi results obtained



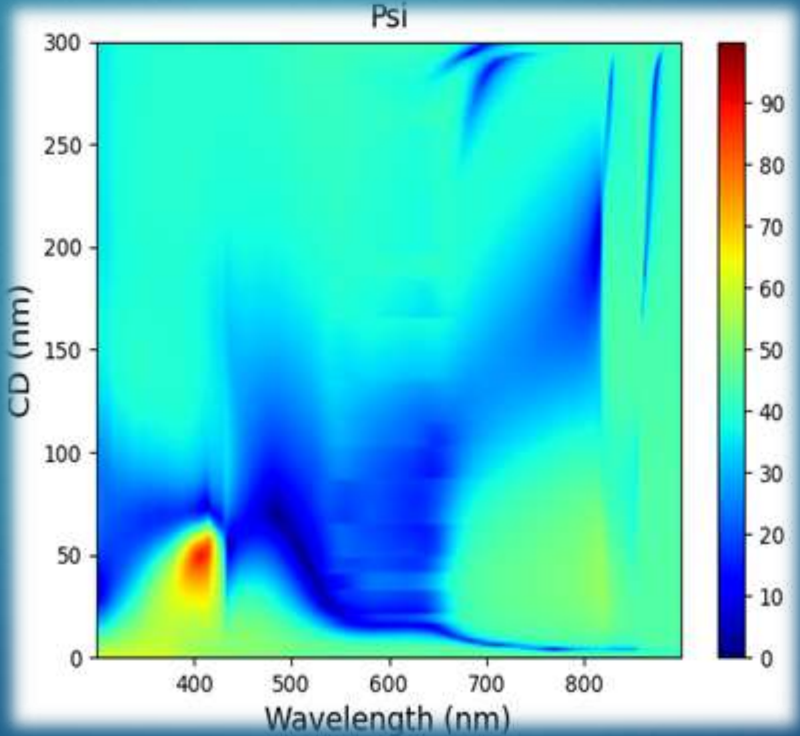
Delta results obtained

FINITE ELEMENT CALCULATIONS

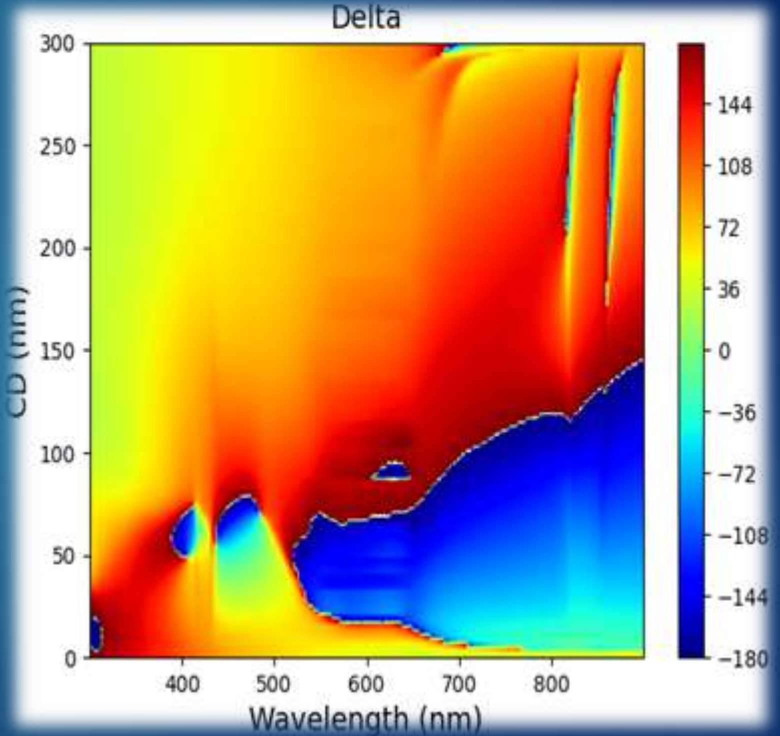
For our experiment, d = 40 nm Au on glass in Kretschmann-Raether setup, i.e. glass/Au-grating/water, is modelled using JCMsuite. The parameters used are as follows:
Angle of Incidence (AOI) = 75°, Period = 300 nm, Unit cell = 300 nm x 300 nm, Critical Dimension (CD): Au line width.



Optical configuration



Psi results obtained



Delta results obtained

FINITE ELEMENT CALCULATIONS

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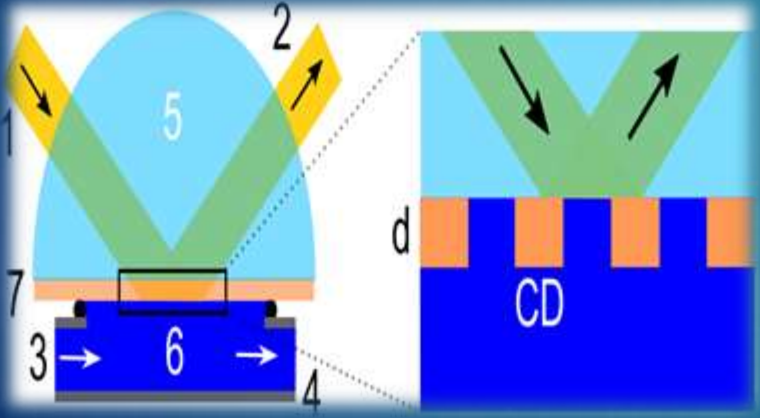
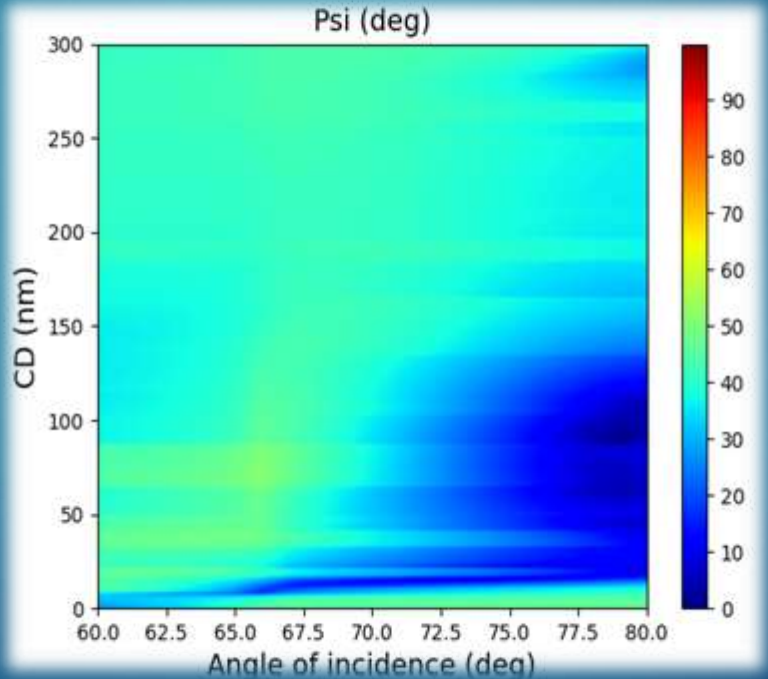
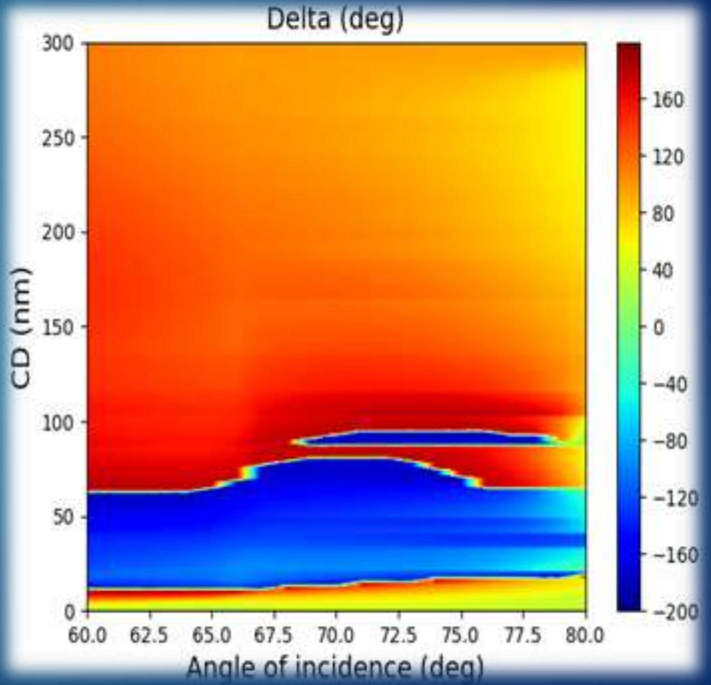


Optical configuration



Psi results obtained



Delta results obtained

WORK DONE

- Reading the related literature of ellipsometry and conducting further experiments and measurements on the ellipsometer.
- Using JCMsuite in combination with Python to determine the ideal grating sample and configuration to proceed with the main experiments in the near future simulations related to finite element modelling.
- Thickness analysis of prepared gold nanoparticles using CompleteEASE and Python. This has been followed by starting to write a research article on this work.
- Currently writing another review article on "In-situ ellipsometry at solid-liquid interfaces", which is due for submission in April 2023.
- Prepared and published a review article titled **"Real-Time Ellipsometry at High and Low Temperatures".**
- Presented and published on the topic **"Nanostructures for solid-liquid interface monitoring by Kretschmann-Raether ellipsometry"** at the SPIE Photonics West 2023-OPTO Conference, San Francisco, California.
- Contributed to the work titled "**Ellipsometry monitoring of sensor processes based on gold nanoparticle bonded proteins"** as a co-author which was presented and published at the SPIE Photonics West 2023-BIOS Conference, San Francisco, California.
- Contributed to the work titled "**Laser-induced magnetism in FeRh thin film"** as a co-author which has been submitted for publication.

COURSES COMPLETED:

- **Nanotechnology – chemical materials science (Éva Kiss)**
- **Numerical methods for the evaluation of optical measurements (Péter Petrik)**

FUTURE WORK

I am looking forward to build upon my preliminary work and studies conducted in this semester and I propose to accomplish the following work for the next semester:

- Completing the review article titled "In-situ ellipsometry at solid-liquid interfaces".
- Getting involved in investigations combining spectroscopic ellipsometry with cyclic voltammetry.
- Continuing the finite element simulations for gold nanoparticles with different grating size and thicknesses.
- Test measurements with the non-depolarizing Kretschmann-Raether flow cell.
- Further analysis of measurements on gold nanoparticles by spectroscopy and publishing it.

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THANK YOU