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

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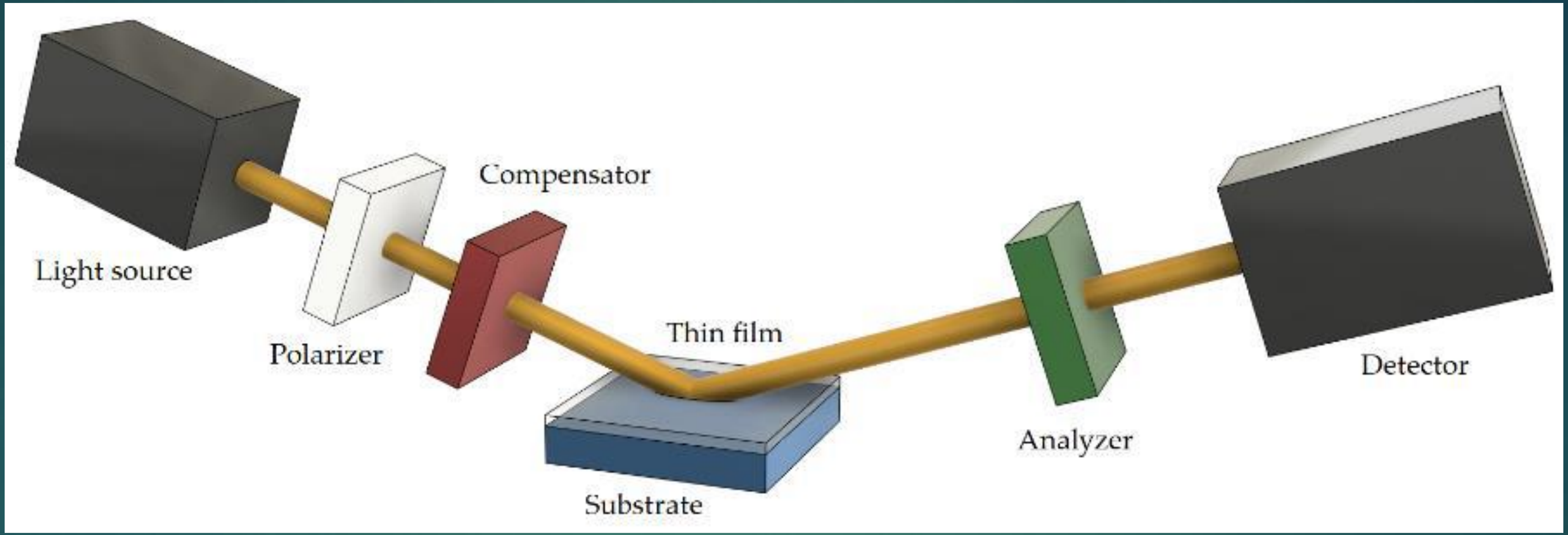
ELLIPSOMETRY

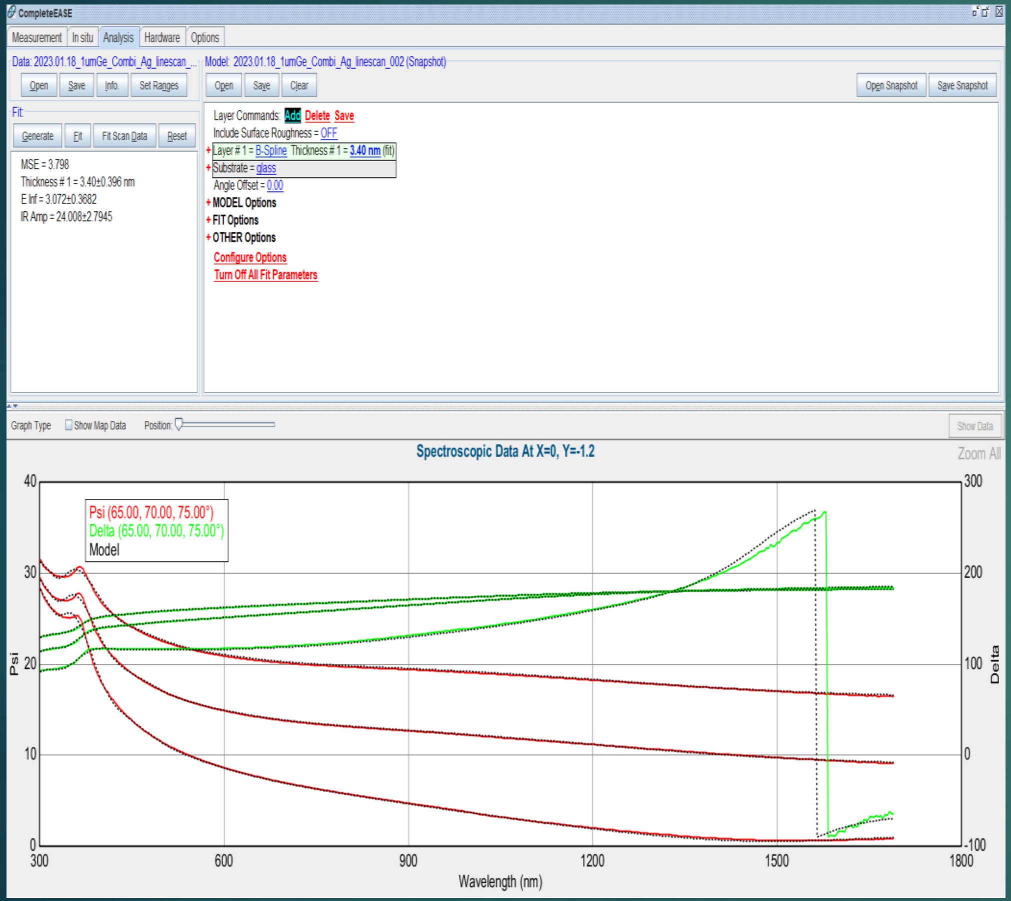


Ellipsometry phenomenon

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

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

IN-SITU ELLIPSOMETRY & OPTICAL MODELS



CompleteEASE User Interface

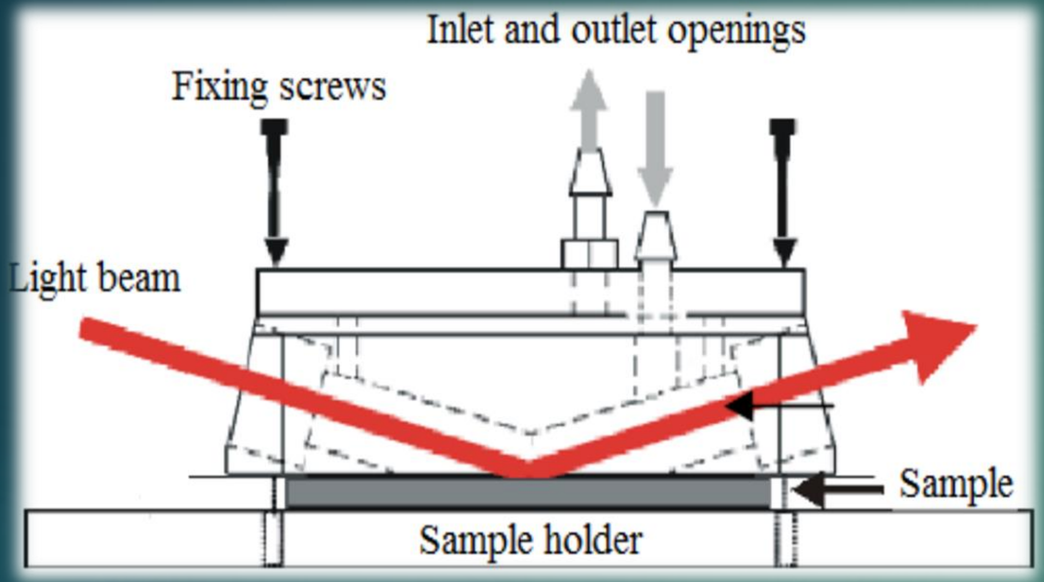
In Situ Spectroscopic Ellipsometry measures a sample "in position" as conditions are varied. It is also common to use in situ measurements to characterize optical constants during different process conditions.

With in situ capability, the sample can be characterized:

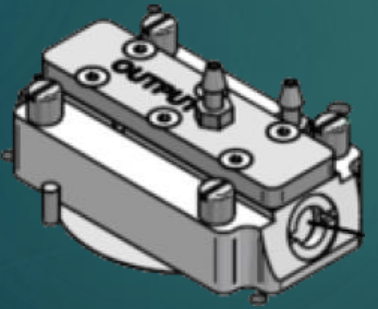
- ❑ Prior to Film Deposition for Accurate Substrate Characterization
- ❑ In Real-time for Thickness and Optical Constants Monitoring
- ❑ Before exposure to Air/Oxidation

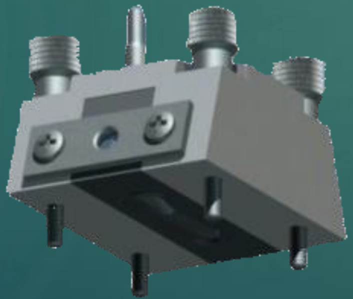
The CompleteEASE software includes built-in models covering a wide range of typical samples that conveniently describe how to process the data to determine thin film properties. Real-time data acquisition is also possible to monitor and control the processes under investigation.

CONVENTIONAL FLOW CELL ELLIPSOMETRY



Beam path in a conventional flow cell



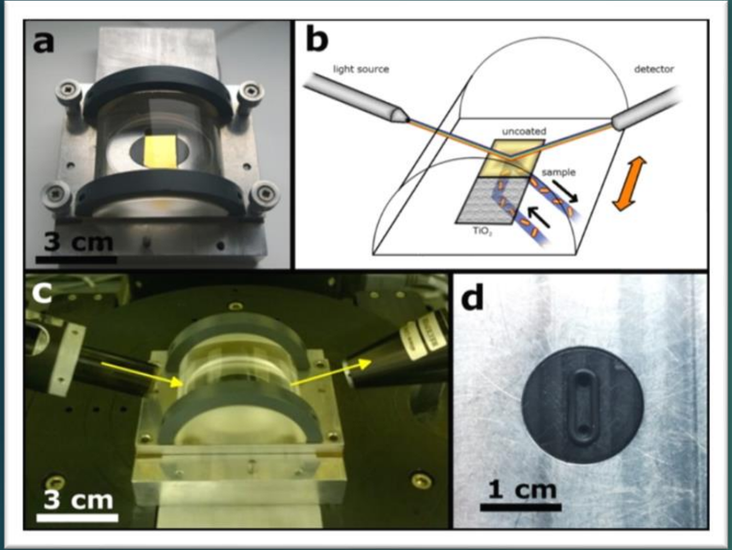


Flow-cells of 'through-liquid' configuration

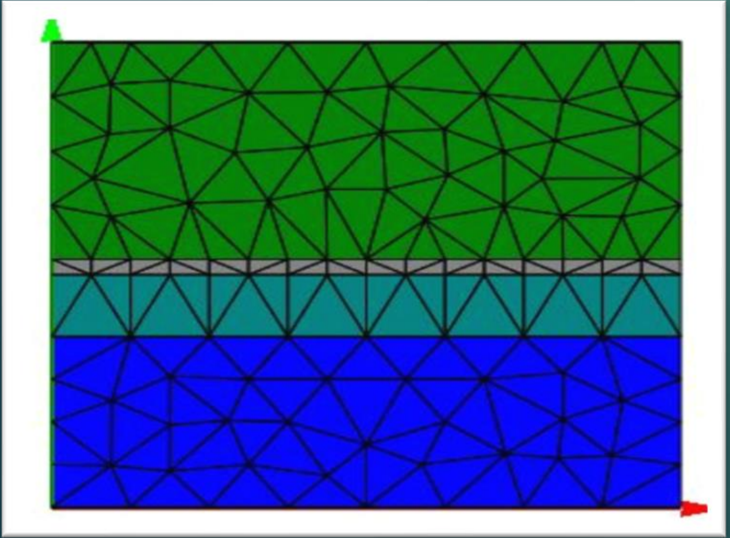
Features of the conventional setup:

- 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 & FEM



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]



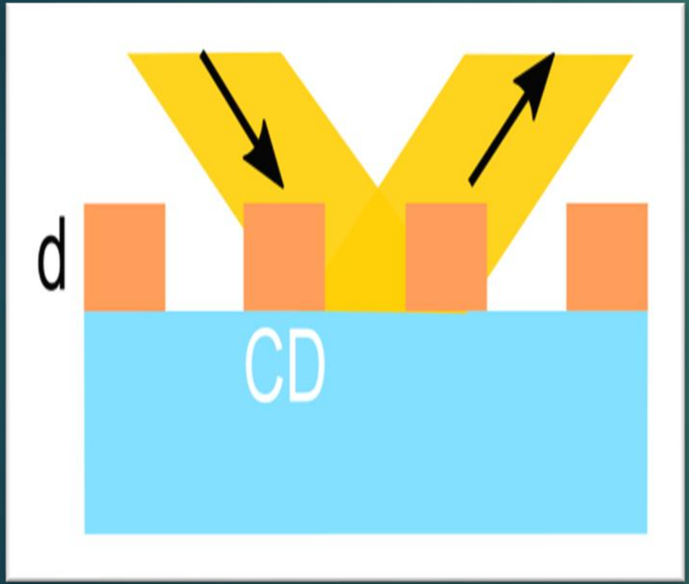
Kretschmann–Raether Flow cell & JCM Modelled K-R Configuration

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::

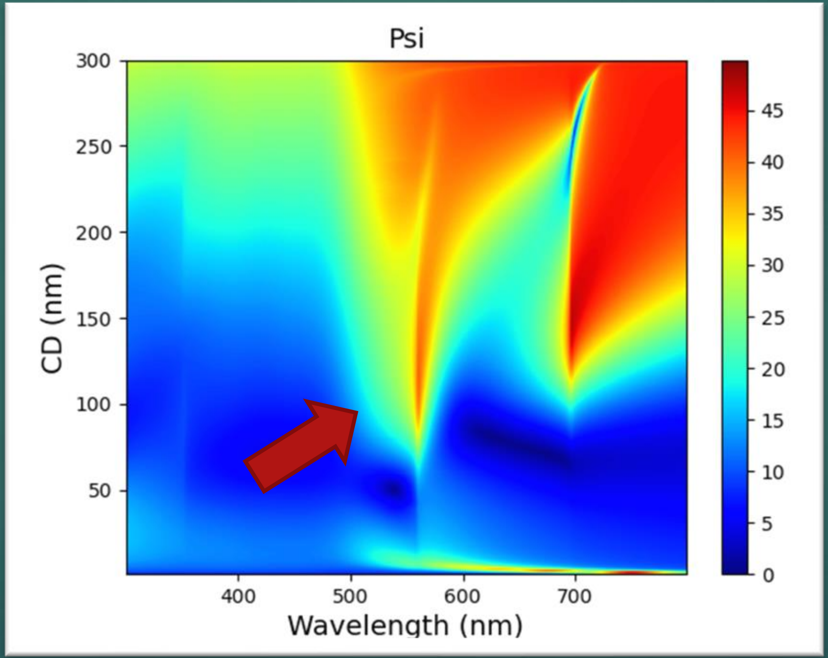
- JCMgeo
- JCMsolve
- JCMview
- JCMcontrol

CONVENTIONAL CONFIGURATION

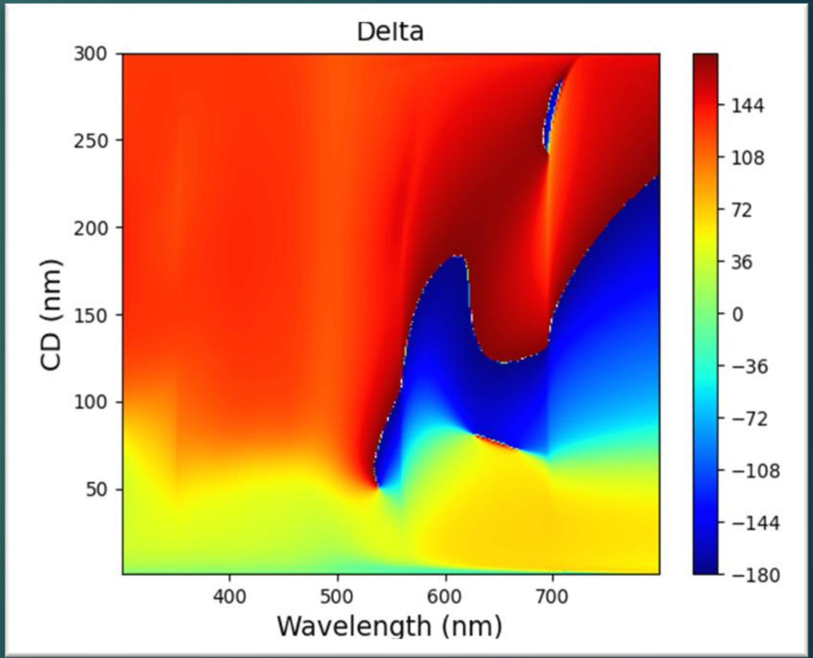
For our experiment, d = 40 nm Au on glass in reflection setup, i.e. air/Au-grating/glass, is modelled using JCMsuite.
The parameters used are as follows:
Angle of Incidence (AOI) = 60º, Period = 300 nm, Unit cell = 300 nm x 300 nm, Critical Dimension (CD): Au line width.



Optical configuration



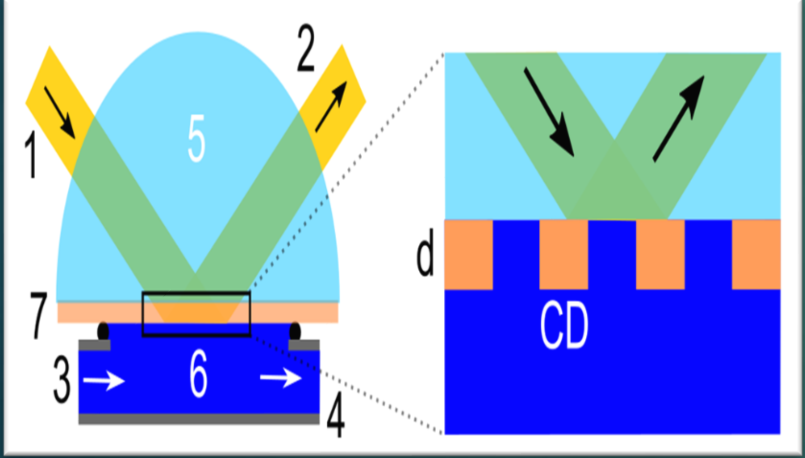
Psi results obtained



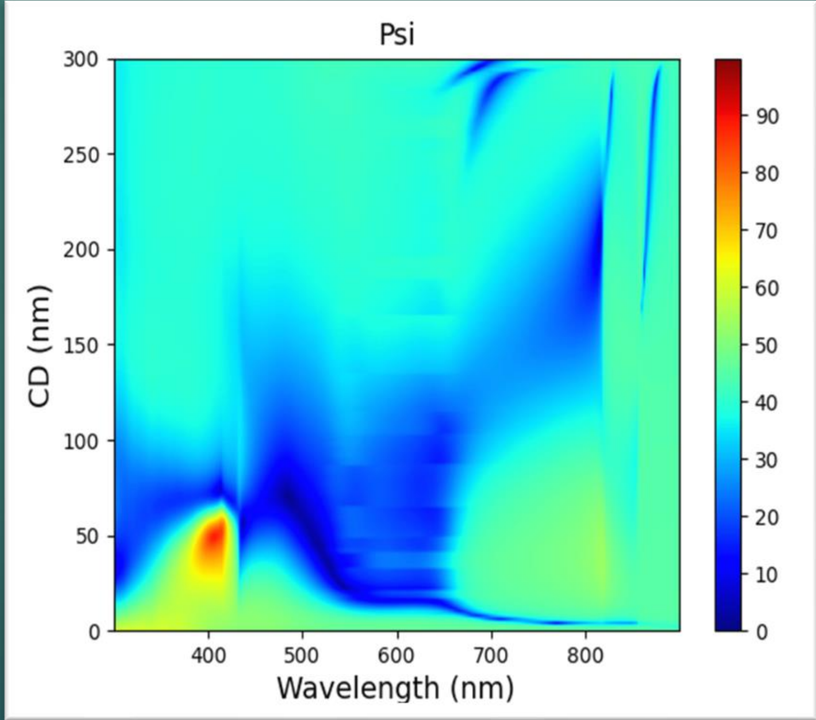
Delta results obtained

KRETSCHMANN-RAETHER CONFIGURATION

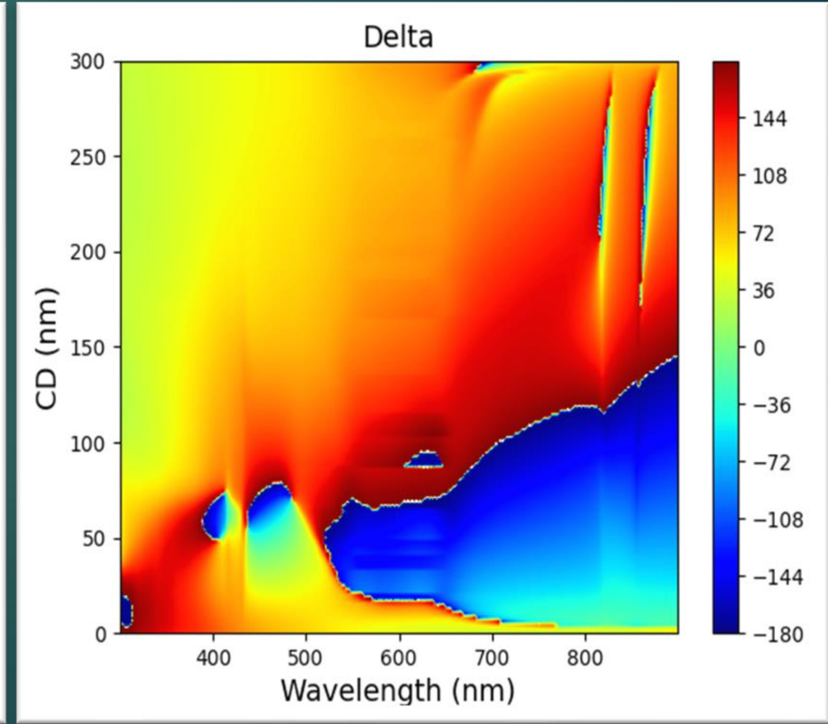
For our experiment, d = 40 nm Au on glass in Kretschmann-Raether setup, i.e. glass/Au-grating/water, is modelled using JCMsuite. The parameters used are as follows:
Angle of Incidence (AOI) = 75º, Period = 300 nm, Unit cell = 300 nm x 300 nm, Critical Dimension (CD): Au line width.



Optical configuration



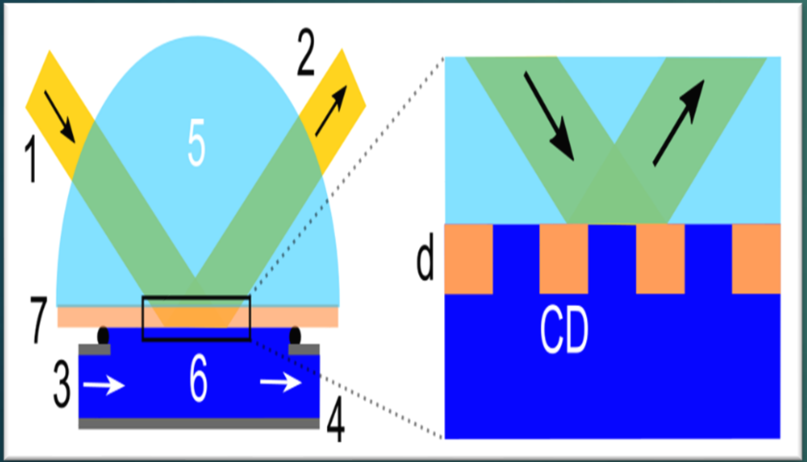
Psi results obtained



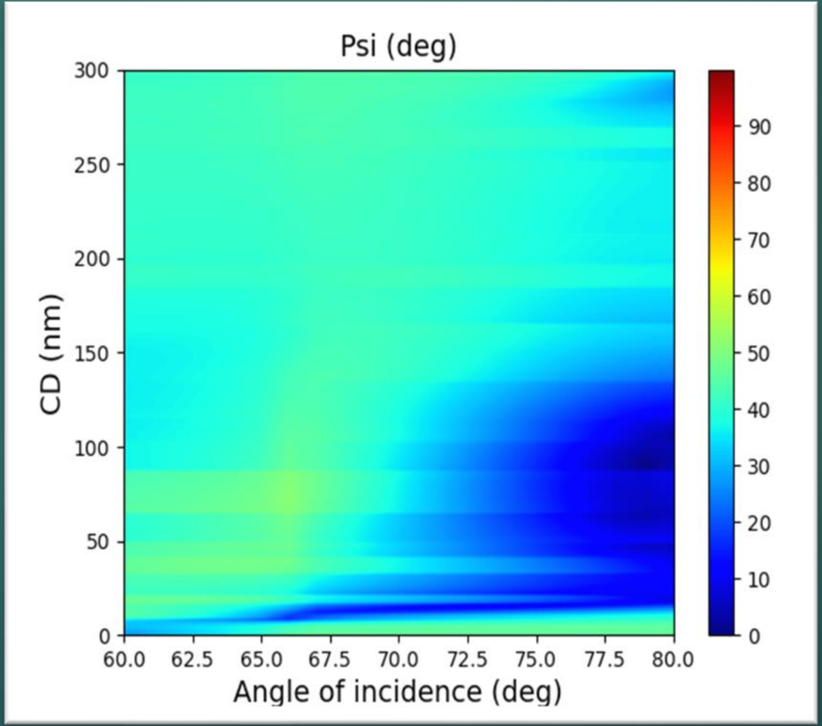
Delta results obtained

KRETSCHMANN-RAETHER CONFIGURATION

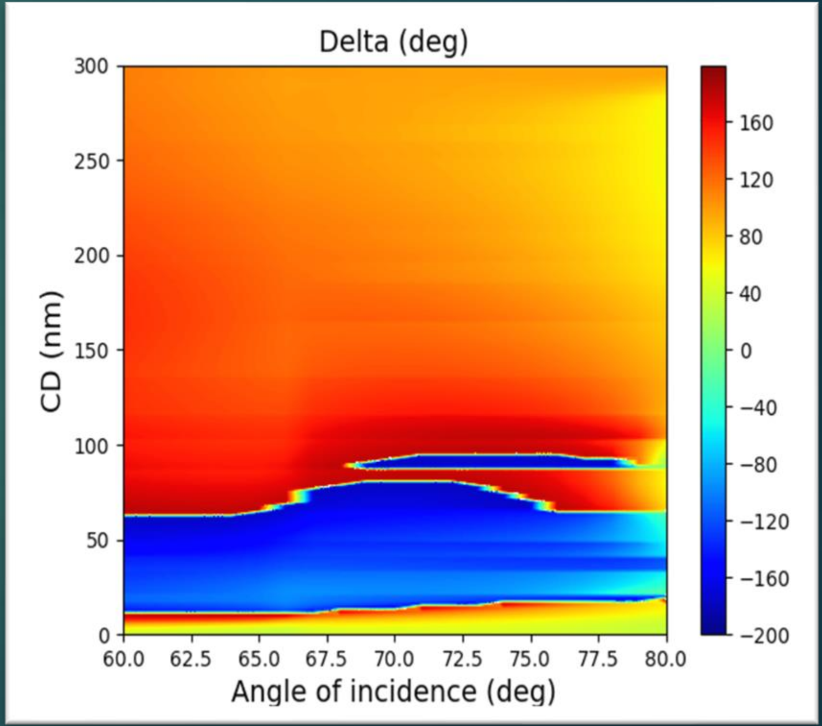
For our experiment, d = 40 nm Au on glass in Kretschmann-Raether setup, i.e. glass/Au-grating/water, is modelled using JCMsuite. The parameters used are as follows:
Angle of Incidence (AOI) = 75°, Period = 300 nm, Unit cell = 300 nm x 300 nm, Critical Dimension (CD): Au line width.



Optical configuration



Psi results obtained



Delta results obtained

CURRICULUM ACTIVITIES

No	Neptun Code	Subject	Professor	Semester
1	DATBESZ5ND	Research Report V.	Dr. Recskiné Dr. Borsa Judit Ilona	5
2	DATKUTP5ND	Research Project V.	Dr. Recskiné Dr. Borsa Judit Ilona	5

No	Publication	IF	Total credit	%	Personal credit
1	Mukherjee, Deshabrato, and Peter Petrik. "**Real-Time Ellipsometry at High and Low Temperatures**" ACS Omega 8, no. 4 (January 31, 2023): 3684–97. https://doi.org/10.1021/acsomega.2c07438.	4.263	36		36
2	Mukherjee, Deshabrato, Benjamin Kalas, Sven Burger, G. Safran, M. Serenyi, Miklos Fried, and Peter Petrik. "**Nanostructures for In-Situ Surface-Enhanced Kretschmann-Raether Ellipsometry**" In Photonic Instrumentation Engineering X, edited by Yakov Soskind and Lynda E. Busse, 37. San Francisco, United States: SPIE, 2023. https://doi.org/10.1117/12.2649080.	0.367	24		24
3	Labadi, Zoltan, 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**. In Colloidal Nanoparticles for Biomedical Applications XVIII, edited by Marek Osiński and Antonios G. Kanaras, 24. San Francisco, United States: SPIE, 2023. https://doi.org/10.1117/12.2649990.	0.367	24		24
4	Merkel D.G., Sájerman K., Váczi T., Lenk S., Hegedűs G., Sajti S., Németh A., Gracheva M.A., Petrik P., Mukherjee D., Horváth Z.E., Nagy D.L., Lengyel A. "**Laser irradiation effects in FeRh thin film**" (2023) Materials Research Express, 10 (7), Art. no. 076101. https://doi.org/10.1088/2053-1591/ace4a3	2.270	36		18
5	Chou Ta-Shun, Bin Anooz Saud , Grüneberg Raimund, Rehm Jana, Ahktar Arub, Mukherjee Deshabrato, Petrik Peter , Popp Andreas. **"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		18

CURRICULUM ACTIVITIES

CONFERENCES ATTENDED

- **50. Műszaki Kémiai Napok**, April 26-28, 2022, Veszprém, Hungary
- **Face2Phase Conference**, November 7-9, 2022, Delft, Netherlands
- **SPIE Photonics West Conference**, January 28-February 2, 2023, San Francisco, United States of America.
- **36th European Conference on Surface Science (ECOSS-36)**. August 28 – September 1, 2023, Lodz, Poland.
- **12th Workshop on Spectroscopic Ellipsometry (WSE)**. September 18-22, 2023. Prague, Czech Republic.
- **ROMPHYSCHEM 17th edition**. September 25-27, 2023, Bucharest, Romania.

OTHER WORKS

- Reviewing the related literature of ellipsometry and finite element modelling.
- Attended the online seminar "**3rd Edition of Surface Science Discussions**" on January 9-10, 2024.
- Conducting various measurements on varied samples from Leibniz-Institut für Kristalzüchtung (IKZ), Berlin using the TSEL 1000 heat cell stage on the J.A. Woollam M-2000 DI ellipsometer ranging up to temperatures of 1000 °C. These will lead to an upcoming publication this year.
- Involved in investigations combining spectroscopic ellipsometry with cyclic voltammetry.
- A research article titled **"Optical and sensing properties of thermally generated gold nanoislands created by the annealing of layers with graded thickness"** was recently submitted for publication.
- Progressing with a review article on **"In-situ ellipsometry at solid-liquid interfaces"** which will be submitted soon.

FUTURE WORK

- Sensing measurement of heavy metals in a self-developed novel non-depolarizing Kretschmann-Raether flow cell for ellipsometry. The cell has been constructed and the preliminary set of sensing measurements were done and will be followed up with further studies and results for a publication.
- Analysis of amorphous carbon samples for sensing applications. All the measurement data are available.
- Measurement on gold grating nanostructures in a Kretschmann-Raether flow cell for ellipsometry. Study of the modeling capabilities for periodic plasmonic nanostructures. The preparation of the grating structures had been due for a long time that was recently supplied by a partner of an international project. The measurements and analysis will be done in this upcoming semester.
- Heavy metal sensing in an optical flow cell using monomers of genetically engineered flagellar filaments. Pre-experiments have already been completed. All the required materials are available for the investigations.
- Review of in situ ellipsometry at solid-liquid interfaces.

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- Matthias Wurm, Tobias Grunewald, Sven Teichert, Bernd Bodermann, Johanna Reck, & Uwe Richter, "Some aspects on the uncertainty calculation in Mueller ellipsometry"; **Optics Express** Vol. 28, Issue 6 pp. 8108-8131, (2020)
- Postava, K., Maziewski, A., Yamaguchi, T., Ossikovski, R., Visnovsky, S., & Pistora, J. "Null ellipsometer with phase modulation"; Optics Express, 12(24), 6040, (2004).
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- Arwin, H., Poksinski, M., & Johansen, K. "Total internal reflection ellipsometry: principles and applications"; Applied Optics, 43(15), 3028, (2004).
- Hiroyuki Fujiwara, "Spectroscopic Ellipsometry Principles and Application" Japanese Edition, Copyright 2003, ISBN 4 621 07253 6, Published by Maruzen Co. Ltd, Tokyo, Japan

Thank You