Nanoscale Characterisation of Metal Films Adhesion for Plasmonic Applications

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Creators: Thøger Eskildsen, Shima Kadkhodazadeh, FIRST NAME LAST NAME, Mario Heinig

Affiliation: Danmarks Tekniske Universitet / Technical University of Denmark

Template: Danmarks Tekniske Universitet / Technical University of Denmark

ORCID iD: 0000-0003-2744-7972

Project abstract:

Deposition of thin metal films on dielectric or semiconductor substrates is central to many technological applications, including plasmonics and microelectronic devices. In this respect, good adhesion between the deposited metal and the underlying substrate is a must, in order to ensure device integrity and optimal performance. For plasmonic applications, noble metals such as gold and silver are the most popular choices, due to their superior plasmonic properties in the visible light wavelength range. However, deposition of ultrathin and ultrasmooth layers of these metals on surfaces, required in applications such as plasmonic waveguides and hyperbolic metamaterials, is a challenge. Gold, while more chemically stable than silver, exhibits poor adhesion to underlying substrates, requiring the deposition of a second material in between (adhesion layer), in order to obtain uniform coverage. This, however, adversely affects the plasmonic properties of the structure.

This project is dedicated to advancing the fabrication of thin film metallic layers for plasmonic applications through employing electron microscopy methods to understand the important three-fold relationship between fabrication, micro/nanostructure and plasmonic property in these structures. While certain recipes and processing steps are widely used in thin metal film deposition, a better knowledge of how/why these steps affect the micro/nanostructure, chemistry and in turn, optical properties of the resulting structures is still needed.

The focus aspects of the project are:

· Using various deposition techniques for obtaining thin metallic films on dielectric substrates with various adhesion layers. The main interest is deposition of metals (gold in particular) and other plasmonic materials aiming at (but not limiting to) plasmonic waveguides and hyperbolic metamaterials. This part will be carried out in the state of the art cleanroom facilities at Danchip

· Employing electron diffraction methods to study changes in crystal structure, orientation and grain size. This will include in-situ investigations of the film microstructure as a function of e.g. annealing temperature or time.

· Understanding the adhesion mechanism using Electron energy-loss spectroscopy (EELS) to probe chemical composition, as well as changes in oxidation state, coordination, bond lengths, etc, down to the atomic scale.

· Optical characterisation of the thin film structures in TEM using EELS mapping of the surface plasmons. This will include in-situ studies of the evolution of the surface plasmons as a function of e.g. annealing temperature or time.

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Data Collection

The Data will be colleceted by Mario Frederik Heinig, mainly at DTU Nanolab, but also at NTNU during the external stay (2019/2020) (An external stay is mandatory during a PhD at DTU)

Fabrication: Thin film fabrication requires cleanroom access for physical vapour deposition (PVD) as the sputter-system Lesker CMS 18 for DC/AC sputtering another type is electron beam evaporation, here either E-Beam Evaporator (Temescal) or Physimeca metal evaporator will be used. Pre-treatment steps by chemical solutions (Piranha) or plasma cleaning will be recorded in the process flow as well as characterization methods used within the cleanroom facility.

sample fabrication steps are documented in the process flow under "cleanroom_work_marhein"
Labmanager comment section will be used to note sample fabrication parameters
deposition documentation of the process flow (word file) + sample list (excel sheet)

Characterization: Electron microscopy data in the form of images, maps and spectra (3D data) as well as other characterization methods such as AFM, contact angle measurements, XPS, ATR-FTIR will be aquired.

The Equipment will be Electron microscopes of the types (FEI Tecnai T20G2, FEI Titan Analytical 80-300ST TEM, FEI NOVA 600 NanoSEM, FEI Helios nanolab 600 and SEM Zeiss Supra 40VP) and the types encountered during the external stay. The software used with the equipment to aquire data will be ASTEC, Digital Micrograph and TIA and the data will be ordered according to the the standards of these programs.

Characterization data of AFM, contact angle measurements, XPS and ATR-FTIR will be saved in their dedicated program types with the sample name (including the progress steps and parameters) in a clear folder structure (method dedicated folders and subfolders with aquiring dates).

There are no legal/ethical or issues to be considered. There are no restrictions to the data yet.

Data Storage

data is saved on M-drive under "Thin film adhesion_Mario project"
as well as on a shared folder on the O-drive "Thin film adhesion_Mario project"

Raw data:
The raw and processed data will be stored permanently digitally in O:\Cen-all\Shima\Thin film adhesion_Mario project (direct link: O:\Cen-all\Shima\Thin film adhesion_Mario project)

The data will typically be generated as either measurements or preperation procedure documentation gatherd during a single day and therefore a folder structure of the type
type-date-measurement type-sample-composition
Type: P for preperation, M for measurement
Date: YYMMDD
measurement type: Examples such as EELS, STEM, TEM, SEM or a combination of these
Example: If on the 1/12/2018 a sample, consisting of Au on APTMS, was prepared with immersion deposition of the organosilane and a sputtering deposition (Lesker) of 10nm Au on APTMS and SEM images were aquired the folder containing these images would be named **SEM** with a subfolder **2018-12-01** with images called **L_APS_Au_01**

Processed Data and results:
In the previously mentioned folders a subfolder named PROCESSED will be placed here. Processed data and results (typically final figures and images and so on) will be placed here.

Documentation

Documentation files will be placed in dedicated method sorted folders with subfolders of raw data folders and processed folders. These will contain further subfolders named by the date of the data aquisition. The purpose of these is to be able to trace results directly to the methods used.

method -dates - sample/material - significant parameters (listed sample in excel sheet) images, maps, spectra, tables, word documents, movies

Data Sharing

The drive where the data is stored is shared among the relevant researchers

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Long-term Preservation

The DTU infastructure keeps the files indefinently. Regarding formats the programs used are often backward compatible and older formats of the data are ofthen cracked formats so for example python packages such as hyperspy allows users to read the data.

data will be stored 5 years after the project