Topic 1: **Fundamentals of ellipsometry**

Ellipsometry is a versatile non-destructive and non-contact optical technique for thin-film characterization. It implies measuring the change in polarization of the light reflected from the sample. The experimental results are interpreted through the intensity ratio of the S and P polarization components, which provides access to the material properties. This method enables precise characterization of several parameters including layer composition and thickness, optical constants, crystallinity, anisotropy, uniformity and surface roughness. In general, ellipsometry is a technique that is used daily in basic research as well as on the industrial level to manufacture semiconductors, flat displays, windows, energy storage devices, biosensors, etc.

This practical course includes the following experiments:
1) Sample preparation by the spin-coating technique.
2) Sample characterization by the spectral ellipsometry.

What one can learn during this course:
1) How to use the spin coating method for the preparation of thin films? What parameters affect the quality of the sample?
2) How to perform ellipsometry?
3) How to build a model of the studied sample and fit experimental results?
4) How to evaluate the results and extract meaningful parameters, such as optical constants, thickness or roughness of the surface?

Literature:
1) Handbook of ellipsometry, Tompkins and Irene, eds., William Andrew Publishing, 2007
2) A User's Guide to Ellipsometry, H.G. Tompkins, Academic Press, 1993
3) https://www.jawoollam.com/resources/ellipsometry-tutorial/what-is-ellipsometry

Topic 2: **High throughput microfluidics in parallised devices**

Droplet microfluidics focuses on the generation of monodisperse droplets inside microchannels. Conventionally, Poly(dimethylsiloxan) (PDMS)-based microfluidic devices are fabricated using a combination of photo- and soft lithography. However, this technique has several drawbacks. Photo- and soft lithographapy are time-consuming and require experienced users and a nearly dust-free environment for their successful fabrication. An alternative manufacturing method is the fabrication of microfluidic devices using digital light processing (DLP). This is a layer-by-layer printing process with high print resolution. The use of 3D printed microfluidic devices allows the processing of high flow rates within the mircochannels. Through additional parallelisation of a number of channels, the production of emulsion droplets within the droplet-based microfludic can be increased. The emulsion droplets serve as a template for the resulting polymer microgels. Afterwards, the polymerisation of the microgels in the emulsion droplets can be initiated, for example, by means of UV light.

This practical course includes the following experiments:
1) Spot light test as material test for the determination of the printing parameters of the resin (resulting digram: layer thickness as a function of exposure energy)
2) Printing and post processing of a parallelised microfluidic device
3) Preparation and testing of different surfactant concentrations to stabilise the emulsion droplets
4) Evaluation of the droplet size and standard deviation as a function of the flow rate ratio of the aqueous disperse phase to the oil phase (methods: bright field microscopy, ImageJ)
5) Evaluation of the influence of UV intensity on microgel formation at high flow rates

What one can learn during this course:

Student will learn the manufacturing process of 3D printed mircofluidic devices and the use of droplet-based microfluidics for the production of monodisperse emulsions and polymer microgels.

Topic 3: **Adsorption of Heavy Metall Ions onto Bio-Adsorbers Starch Modified by Chitosan**

The removal of heavy metal ions from surface water using environmentally friendly and biodegradable biopolymers is an intriguing scientific challenge. Due to its low cost and widespread availability, starch is highly intriguing as a biopolymer to solve these issues. Starch, a natural component of plants, it composed of two main components amylose the linear chain and amylopectin the branched chain. The adsorption of heavy metal ions from water is very low, that is why it is necessary to modify starch in order to increase it adsorption capacities.
The presence of the high O-H groups onto the starch chain facilitates to form ionic bonds with other biopolymers such as chitosan. Chitosan, a biopolymer produced from crustacean shells, has a high ability to adsorb heavy metal ions owing to the presence of the amino groups.
The adsorption capacity of modified starch depends on a number of parameters: deacetylation degree of chitosan, molecular weight, particle size and charge.

In this training course, we will perform the following experiments:
1) Synthesis of modified starch;
2) Determination of particle size using morphologie 3D, and charge using PCD (Particle Charge Detector);
3) Determination of the adsorption isotherms for each metallic ions in a batch system.

What one can learn during this course:
1) how to modify starch;
2) how to determine the functional groups, which can be active in the adsorption process using the PCD;
3) how to determine the particle size of the samples;
4) how to fit the adsorption isotherms.

This knowledge will open you the new horizon towards the development of biopolymers!

Topic 4: **Contact Angle Measurement Experiments Using Optical Tensiometer**

Wettability is the determining factor in many applications ranging from coatings to enhanced oil recovery and medical implants to pesticides. Due to a wide range of applications, the measurement of wettability, i.e., the contact angle measurement can be done by using optical methods. Contact angle, θ (theta), is a quantitative measure of wetting of a solid by a liquid. The contact angle is geometrically defined as the angle formed by a liquid at the three-phase boundary where a liquid, gas, and solid intersect. Depending on the application, static and dynamic contact angles can be measured on different hydrophobic and hydrophilic substrates.

Contact Angle Measurement
Optical tensiometers are utilized to measure static, dynamic contact angles. The main components of the optical tensiometer are a camera, dispenser to dispense a drop, sample stage and the light source to illuminate the drop on the sample stage. Optical tensiometers range from completely manual systems to fully automated instruments.

Static contact angle
Static (i.e. sessile drop) contact angles are measured when the droplet is sitting on the surface and the three-phase boundary is not moving. Static contact angles are by far the most measured wettability values. It is most suitable for relatively smooth and homogenous surfaces. Static contact angles are

also used to define the surface free energy (i.e. surface tension of solid) of the substrate. Static contact angle offers a quick, easy and quantitative measurement of wettability. Static contact angle measurement is based on Young's equation which assumes that interfacial forces are thermodynamically stable. In practice, a droplet is placed on the solid surface and an image of the drop is recorded. The static contact angle is then defined by fitting Young-Laplace equation around the droplet, although other fitting methods such as circle and polynomial can also be used.

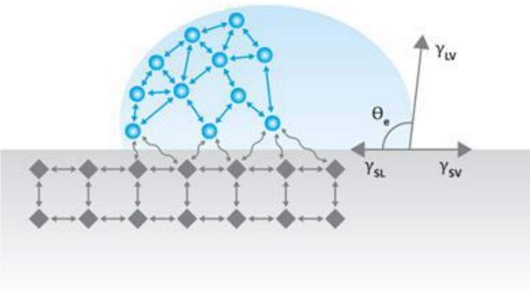

Figure 1 – A schematic of static contact angle.

A surface is hydrophobic if the contact angle with water is greater than 90º. Intuitively, as θ angle increases, there is less contact surface between the spherical droplet and the surface, thus making the droplet slip on the surface without adhering. A hydrophilic surface is identified by a static contact angle with water smaller than 90º. A hydrophilic surface will tend to absorb or attract water, in other words, it is more wettable.

Dynamic contact angle, contact angle hysteresis

When the three-phase boundary is moving, dynamic contact angles can be measured, and are referred to as advancing and receding angles. As the terms imply, advancing contact angle is measured when the droplet front is advancing and receding when the droplet front is receding. On an ideal surface, these two values are close to each other. However, most often, the measured contact angle depends on the direction on which the contact line is moving. Contact angle hysteresis is the difference between the advancing and the receding contact angles. Contact angle hysteresis arises mostly from the chemical and topographical heterogeneity of the surface, solution impurities absorbing on the surface, or swelling, rearrangement or alteration of the surface by the solvent. For Dynamic contact angle measurements with optical tensiometer by using the needle in the drop method, a small droplet is first formed and placed on the surface. The needle is then brought close to the surface and the volume of the droplet is gradually increased while recording the contact angle at the same time. This will give the advancing contact angle. The receding angle is measured the same way but this time, the volume of the droplet is gradually decreased. This method is especially utilized to measure dynamic contact angles on superhydrophobic surfaces.

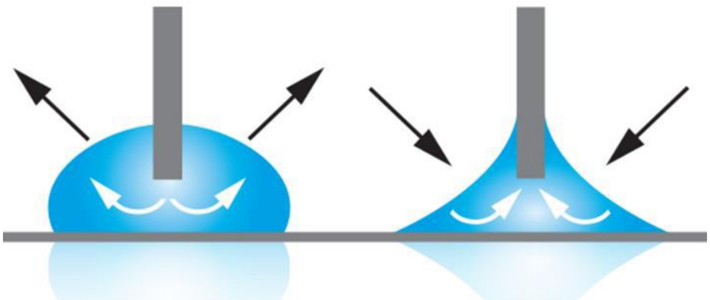

Figure 2 – A schematic of advancing and receding contact angles.

What one can learn during this course:

1) Static Contact angle measurement

2) Dynamic contact angle measurement
Advancing / Receding / Hysteresis
3) Preparation of samples with special wetting properties for contact angle measurement experiments.
Hydrophobic / Hydrophilic

Reference: Certain parts of the text have been adapted from Biolin Scientific's company website, which is available for further reading (biolinscientific.com). As a result of this knowledge, you will gain a new perspective on the wetting phenomenon!

Topic 5: **Decontamination of non-radioactive europium as Model element for Radioactive elements**

Since the invasion of the Ukraine, decontamination agents for nuclear relevant substances are in highly sought. However existing solution damage the skin barrier that can lead to an uptake of those substances through the skin. Therefore, innovative solutions are necessary. At IPF Jonas Schubert and co-workers developed a gel that can remove nanoparticles from the skin, which is part of the spin-off DermaPurge. Your task is to evaluate if nano-ex is also suitable for the decontamination of Lanthanides. For this, we will use Europium as a model substance for radioactive substances. The advantage is that Europium is chemical similar to e.g. uranium but not radioactive. Furthermore, it exhibits fluoresce and can be tracked with simple methods.

This practical course includes the following experiments:
1) Preparation of a measurement protocol for Europium via fluorescence spectroscopy
2) Decontamination experiments and determination of the decontamination efficiency.

What one can learn during this course:
1) How to perform decontamination experiments.
2) How to measure and evaluate fluorescence data.

Literature:
1) GUIDELINES ON STABILITY TESTING OF COSMETIC PRODUCTS: https://www.cosmeticseurope.eu/files/5914/6407/8121/Guidelines_on_Stability_Testing_of_Cosmetics_CE-CTFA_-_2004.pdf
2) Kumar V, Goel R, Chawla R, Silambarasan M, Sharma RK. Chemical, biological, radiological, and nuclear decontamination: Recent trends and future perspective. J Pharm Bioall Sci 2010; 2:220-38.

Topic 6: **Biophysical methods – Practicals at CMCB Campus**

Practical project (day1): Super-resolution stimulated emission depletion microscopy (STED) Students will learn how stimulated emission is used to break the diffraction barrier in fluorescence microscopy. They will perform measurements on control samples (beads) to determine the scaling law how spatial resolution and STED laser power are connected. And they will see the benefits of super-resolution imaging compared to diffraction limited imaging on biological test samples.

Practical project (day2): Active volume regulation in cells
A human cell line will be used to quantify and analyze cell volume regulation during mitosis.

Practical Project (day3): Deciphering forces down to the single molecule level -AFM force spectroscopy Students will get an introduction to an atomic force microscope and learn about the principles of single cell measurements and different modes of the device (e.g. imaging and force spectroscopy.
Practical Project (day4): Single-molecule FRET to reveal conformational changes on the molecular level

The practical will introduce Förster resonance energy transfer (FRET) and the concept of a molecular ruler. We will use a biological model system to illustrate how conformational changes, kinetics and distances can be monitored and extracted using smFRET. The participants will measure and analyse data and report about their findings.

Practical day 5 will be used to analyze data and provide a protocol for each method.
Each group submits one protocol (2-4 pages, pdf file format) via email to the advisors within two weeks after participation in the practical course. The protocol should include a brief introduction, describe the performed measurements, and focus on data evaluation and interpretation.