Title: **Controlled and Tunable Design of Polymer Interface via Polymers and Stimuli-Responsive Particles**

Controlled and precise design of functional polymer interfaces leads to the programmed and rational construction of materials for applications in coatings, adhesives, textiles, emulsions, catalysis, etc. Polymer brushes are particularly attractive systems for the modification of interfaces and tuning their properties. Polymeric brushes consist of polymer chains which are chemically attached by one end to a substrate and they demonstrate stimuli-responsive and adaptive properties caused by environmental changes such as T, pH or light. Further, polymeric brushes are not limited to nanostructured planar molecular 2D brushes; particles grant access to microscale-structured polymer brush scaffolds. Particle-based building blocks provide a large surface area and can be synthesized on large scale in a controlled way. As well, colloidal particles offer excellent opportunities as building blocks for forming functional coatings, as they can be physisorbed and do not require covalent attachment.
In this training course, we will perform the following experiments:

1) Synthesis of silica particles with defined size;

2) Modification of the silica particle surface with polymer brushes of defined grafting density;

3) Characterization of the hybrid stimuli-responsive particles using dynamic light scattering (DLS) and scanning electron microscopy (SEM).

The student will learn

- ➔ how to design pH-responsive hybrid systems in controlled way by varying systematically the grafting density;
- ➔ how to prove the success of the surface modification via DLS and SEM;
- ➔ how to investigate the switchability of the properties.

This knowledge will open you the new horizon towards the development of modern polymeric-based materials! You are welcome to join our group and to learn with us!

Contact person:	Claudia Marschelke	Dr. Alla Synytska
e-mail:	marschelke@ipfdd.de	synytska@ipfdd.de
phone:	0351/4658 403	0351/4658 475

Title: **Semiconducting Nanowires for organic electronics devices**

Organic Electronics is unique next generation electronic devices, which have several advantages: flexibility, light-weight and low production cost. Light Emitting Diodes (OLEDs), Photovoltaics (OPVs) and Field Effect Transistors (OFETs) with organic semiconducting materials have been developed so far. To understand and improve electrical performance, it is important to investigate physical or chemical phenomena inside devices. We are focusing on the research of chemical synthesis and morphology control of semiconducting polymers. During the course, nanowires are fabricated with Anodic Aluminum Oxide templates, which are expected to have better polymer alignment and faster charge transportation.

In this practical course we will perform following experiments

1) Fabrication of semiconducting nanowires by AAO method

2) Characterization of nanowires using scanning electron microscopy (SEM)

3) Fabrication and characterization of organic electronics devices

Student will learn

1) How to fabricate Nanowires

2) How to characterize Nanowires

3) How to prepare organic electronics devices

Contact person: Takuya Tsuda

Email tsuda@ipfdd.de

Title: **Hybrid Hairy Particles as Building Blocks for Design of Surfaces with Reduced Icing Properties.**

The development of surfaces with reduced icing or easy de-icing is of paramount importance for the wind turbine technology as well as automotive and aircraft industries. In fact, inhibition of the ice layer formation allows not only a consequent reduction of costs, but also decreases the number of emergency situations. The commonly used methods for the prevention of icing and promotion of deicing are based either on electrical heating of the surfaces, which results in simple ice melting, or on the use of antifreeze substances, which reduce the water freezing temperature. Nonetheless, the most favorable solution of this problem, which is now broadly explored, is the design of "passive" anti-icing coatings, i.e. polymeric-based coatings that prevent icing or reduce the ice accretion rate, which allows lowering the required power consumption for the ice removal.

In this practical course we will perform following experiments

1) Synthesis of silica particles;
2) Modification of the particles with polymer brushes;
3) Preparation of structured heterogeneous surfaces with controlled ice nucleation and ice adhesion strength;
4) Contact angle, optical microscopy and special freeze/thawing measurements.

The student will learn

- → how to synthesize polymer-modified core-shell particles with controlled chemical composition;
- → how to prepare the functional surfaces based on hybrid particles;
- → how the chemical and topographical design impacts the icing behavior of fabricated layers;
- → how to characterize particle-based systems.

Contact person:	Madeleine Schwarzer	Dr. Alla Synytska
e-mail:	Schwarzer@ipfdd.de	synytska@ipfdd.de
phone:	0351 4658 403	0351 4658 475

Title: **Preparation and Inspection of a Molybdenum thin film on Photoimide, contacted with a conductive adhesive**

Imaging of a polymer samples sometimes can be quite a challenge because of their properties.
One of them is the usually bad electrical conductivity which requires special measures like metal sputtering, whereby one must note not to change the surface properties and topography of the sample. On the other hand polymer samples are often quite sensitive and can be damaged by the electron beam of the SEM. Therefore the imaging parameters of the SEM have to be selected very carefully in order to prevent sample damage during inspection.

In this practical course we will perform the following experiments

1) cross section preparation of a polymer/metal sample by embedding, grinding and polishing
2) metal sputtering with a sputter coater
3) imaging surface and cross section with the SEM
4) studying of the influence of different imaging parameters on the image quality
5) cross section preparation of a polymer/metal sample with the Focused Ion Beam
6) imaging of the FIB cross section and geometrical measurements

Students will learn

- ⇨ how to use the preparation equipment by hands-on learning
- ⇨ get to know the principles of Scanning Electron Microscopy
- ⇨ get to know the principles of Focused Ion Beam Technique

Contact person:

Dr. Rüdiger Rosenkranz, e-mail: ruediger.rosenkranz@ikts.fraunhofer.de Tel. +49 351 88815 529

Title: **Convective Assembly and Printing of Plasmonic Nanoparticles**

Plasmonic nanoparticles represent promising building blocks for novel optoelectronic devices like sensors, low-loss optical waveguides and cost-effective solar cells. Due to the confinement of light-induced electron oscillations to the nanoscopic particle dimensions, the wavelength of absorption can be precisely controlled by varying particle size and shape. Deterministic placement of particles to modify inter-particle coupling enables further tuning of the collective optical response to match the desired application.

We follow a fully e-beam lithography-free approach for array fabrication that provides cost-effective up-scalability and low-loss properties: in a bottom-up approach, readily producible, topographically structured substrates fabricated by laser interference lithography serve as templates for the alignment of wet-chemically produced single crystalline nanoparticles into line or square arrays. By multi-step printing of these assemblies more complex structures are feasible, e.g. wire mesh gratings. In the lab course, a Capillarity-Assisted Particle-Assembly setup is used to *in situ* observe the assembly of nanoparticles at a receding liquid meniscus. This allows reasonable adjustment of external parameters (temperature, withdrawal speed,…) to optimize assembly yield and accuracy.

In this practical course, we will perform following experiments

1) Molding of topographical substrates
2) Arrangement of nanoparticles *via* Capillarity-Assisted Particle-Assembly
3) Multi-step printing of particle assemblies
4) Characterization of templates and assemblies using atomic force microscopy (AFM), scanning electron microscopy (SEM) and UV-vis-NIR spectroscopy

The Student will learn about

- ⇨ Preparation of nano-structured templates
- ⇨ Fundamentals of colloidal self-assembly
- ⇨ Standard characterization techniques of a materials scientist

Contact person: Patrick Probst

e-mail: probst-patrick@ipfdd.de Tel.: 0351/4658 406

Title: **The full-field X-ray microscopy study of the composite materials at the nano-XCT**

The systematic development of new advanced materials with complex structures demands to invent a new or to improve existing techniques for materials characterization. High resolution X-ray microscopy and X-ray computed tomography are suitable techniques for two and three dimensional investigation of structural materials, like composites. The technique allows to analyze the internal structure, without cutting or sectioning of the region of interest, hence it provides non-destructively 3D image data. The 3D volumetric data allows to extract the key morphological and structural parameters of the material such as density variations (fiber, matrix), porous, inclusions at the micro and nanoscale.

This practical course will provide the work at the X-ray microscope to perform tomography data as well as data reconstruction and analysis. The student will lean how to operate with samples for the nano-XCT tool and realize tomography; how to reconstruct and analyze data set; the microstructural characterization of the composite materials.

In this practical course we will include the following activities:

1. Manipulation of the samples and insert them into the microscope
2. Nano-XCT experiment
3. Data analysis.

Students will learn

1. How to use the nano-XCT tool and how to extract 3D tomography data
2. How to reconstruct and analyze the data
3. How to perform a nondestructive nano-scale characterization of composite materials.

Contact person: Kristina Kutukova

0351 / 8881-514

kristina.kutukova@ikts.fraunhofer.de

Title: **Mechanical characterization of materials on nanoscale with help of atomic force acoustic microscopy – special application 50 nm thin films**

Dr. Malgorzata Kopycinska-Müller

Malgorzata.Kopycinska-Mueller@ikts.fraunhofer.de

0351-888-15541

IKTS-MD

Maria Reiche Str. 2

01109 Dresden

1-2 students

Atomic force acoustic microscopy is a method based on atomic force microscopy and basic knowledge in using the AFM in contact mode is of advantage during this practical course. This films are essential and critical components of all electronic devices (among others). Very often, due to their nano-dimensions the mechanical properties of a thin film differ from that of bulk equivalent. As the film thickness decreases, it becomes more difficult to determine their mechanical properties with help of macroscopic method and one must restore to AFM based methods as they offer supreme lateral and depth resolution.

The activities planned for this practical course include:

1. Learning the basics of AFM operating in contact mode
2. Principle of atomic force acoustic microscopy
3. Acquisition of contact resonance spectra on reference materials and thin film samples
4. Data evaluation

The report should include a short description of the principle of the atomic force acoustic method, graphic presentation of the experimental results and summary of the data analysis. The duration time is planned for about four to five days, depending on the previous AFM experience of the student.

The practicum will take place within times specified for the whole course.

Title: **Fabrication of thermoresponsive microgels by droplet-microfluidics.**

An important task that can be performed in microfluidic flow cells is the formation of microdroplets, or the generation of segmented flow in general - as independent reaction vessels and templates in self-assembly processes. On this account, droplet-based microfluidics has emerged as a powerful tool in chemical and biological research as it provides new opportunities for the miniaturization of chemical and biochemical reactions. Libraries of microdroplets are applicable as platforms for high-throughput screening of aptamers and enzymes in drug discovery and protein crystallization studies, for instance, overcoming the limitations of conventional screening techniques in combinatorial chemistry and biotechnology, which usually require large of amounts of consumable materials for performing the same tasks.

In materials science, droplet-based microfluidics is particularly useful for preparing uniform, monodisperse polymer particles with precise control over their size, composition and morphology, e.g. for mimicking the natural environment of cells in 2D and 3D or performing biological functions *in vitro*. Heat, redox reactions and light are most commonly used to initiate polymerization reactions in droplets. A UV-initiated polymerization reaction is generally preferred due to the rapid kinetics that preserves the internal microstructures and the precise spatial and temporal control over the reaction. Various reports have shown UV-initiated polymerization in combination with droplet microfluidics for the fabrication of microspheres and microcapsules.

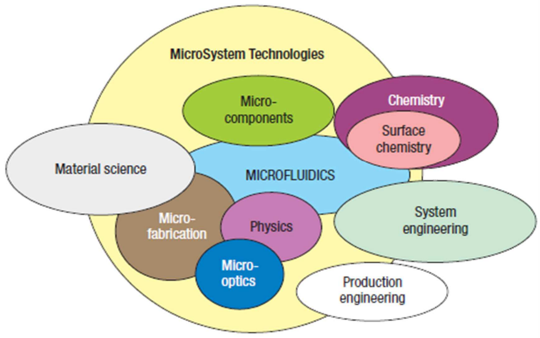


Figure 1: P. Kallio, J. Kuncova, *Microfluidics – TEKES Technol. Rev.* **2004**,

As part of this lab course, polymer particles based on PNIPAM [poly(N-isopropylacrylamide)], approx. 15 to 20 µm in diameter, will be fabricated. NIPAM, a stimuli-responsive polymer with a lower critical solution temperature of 32°C, is widely applied as synthetic monomer e.g. for preparing thermoresponsive valves and switches. The experimental setup requires two high-precision syringe pumps, a microfluidic flow cell with flow-focusing geometry (10 to 15 µm at the droplet-forming nozzle), a simple light microscope and a high-speed camera for single-droplet observations.

In this practical course we will perform following experiments

1) Design and fabrication of microfluidic flow cells by soft lithography and additive manufacturing;
2) Preparation of water-in-oil microemulsions as templates for hydrogel particles;
3) Microgel particle fabrication by UV-polymerization, and their characterization (size, thermo-sensitivity).

Student will learn

- ⇨ How to control and manipulate fluid flows in the picoliter range in microfluidic flow cells;
- ⇨ How to form defined microemulsions as templates for hydrogel particle fabrication;
- ⇨ How to characterize thermoresponsive microgels employing light and fluorescence microscopy.

Contact person: Thomas Heida, Nicolas Hauck

e-mail: heida@ipfdd.de Tel. 0351 4658 566

Title: **Dispersion relation of soft matter with spectral ellipsometry**

We aim to provide a brief overview of both established and novel ellipsometry techniques, as well as their applications. Ellipsometry is an indirect optical technique in that information about the physical properties of a sample is obtained through modeling analysis. Ellipsometry is a powerful method to characterize optically isotropic bulk and/or layered materials. More advanced techniques like Mueller ellipsometry, also known as polarimetry in literature, are necessary for the complete and accurate characterization of anisotropic and/or depolarizing samples which occur in many instances, both in research and "real life" activities.

In this practical course we will perform following experiments

4) Hand on experience with ellipsometer.
5) Basic introduction for ellipsometry software and data analysis.

Student will learn

- ⇨ How to measure film thickness, refractive index, surface roughness, composition etc. of a material.
- ⇨ How to build a model set-up.

Contact person: Vaibhav Gupta, e-mail: gupta@ipfdd.de Tel. 0351 4658 673

Title: **UV-Vis-NIR Absorption and Scattering Spectroscopy of Plasmonic Nanoparticles**

Aim of this practical course is to get insight into the synthesis of bimetallic plasmonic nanoparticles and their optical characterization methods. Utilizing a syringe pump, single crystalline gold nanorods will be overgrown with silver to form a cuboidal shell around the gold rods. During the overgrowth process plasmonic behavior, especially absorption and scattering, changes drastically. This will be observed utilizing a state of the art integrating sphere setup in an UV-vis-NIR spectrometer. Experimental observations can be backed with FDTD calculations.

In this practical course we will perform following experiments

1) Synthesis of bimetallic nanoparticles, consisting of a gold nanorod core and a silver cuboid shell.

2) State of the art absorption and scattering UV-Vis-NIR spectroscopy utilizing an integrating sphere setup.

3) Backing of experimental data with finite-difference-time-domain (FDTD) simulations.

Student will learn

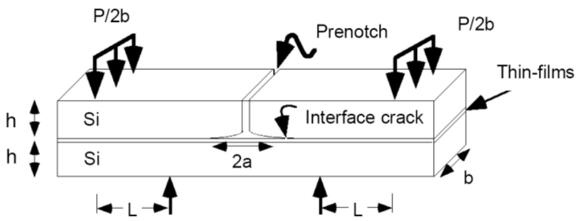
- ⇨ How to synthesize bimetallic nanoparticles, utilizing a syringe pump.
- ⇨ - UV-Vis-NIR spectroscopy with an integrating sphere setup.
- ⇨ - First glimpse into FDTD simulations

Contact person: Anik Kumar Ghosh e-mail: ghosh@ipfdd.de Tel. 0351 4658 289

Title: **Interfacial adhesion measurements of low-k dielectric thin films used in microelectronic devices**

Aim of this practical course is to quantify mechanical properties of dielectric thin films. Nowadays, porous organo silicate glasses (OSG) are widely used in the microelectronic industry as dielectric components in micro integrated circuits. A huge concern in manufacturing dielectrics with low dielectric constants is the low mechanical stability. By inducing pores, the thin films get even weaker and are more prone to mechanical failure and cracking in metal/dielectric-interfaces, which may lead to failure of the electronic device. Therefore, the adhesion or cohesion of these dielectric film stacks has to be investigated and optimized.

A commonly used method for the investigation of the interfacial adhesion in microelectronic devices is the so called 4-point-bend test (4PB). A special specimen with the thin film of interest sandwiched between two Silicon beams has to be prepared for accurate measurements. Figure **1** shows the specimen and the working principle for the 4PB test. The specimen are investigated in the 4PB tool (a mechanical loading frame) and are then mechanically loaded until a crack propagates through the interface of interest. Due to the symmetric crack growth during further displacement, the load reaches a plateau, Figure ***2***. This load value is then used to calculate the critical energy release rate as a measure for the interfacial adhesion of the thin film stack.



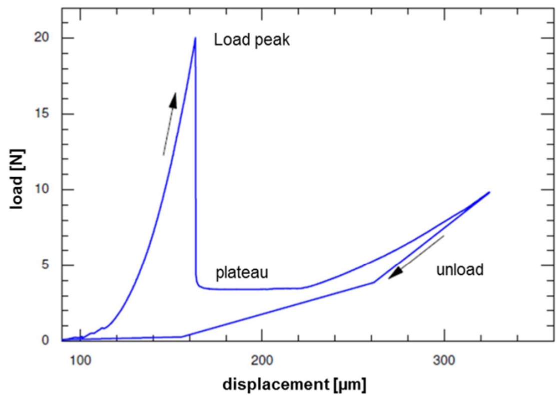


Figure **1**: Sketch of the 4PB working principle

Figure **2**: typical load displacement diagram for the 4PB test

In this practical course we will perform following steps

1) sample preparation for the 4-point-bend test (wafer cleaving, glue&bake) and sample separation with a wafer saw
2) literature review
3) specimen test in the 4-point-bend tool
4) analysis of the fracture surfaces with light microscopy
5) data analysis

Student will learn how to:

- ⇨ handle and dice Silicon wafers and to prepare 4-point-bend samples
- ⇨ test adhesion/cohesion of dielectric thin films
- ⇨ analyze the fractured sample surface
- ⇨ analyze the measurement data and write a report

Contact person: Christoph Sander e-mail: christoph.sander@ikts.fraunhofer.de

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