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Our Mission

The Leibniz Institute of Polymer Research Dresden e. V. (IPF) is one of the largest polymer research facilities in Germany. As an institute of the Leibniz Association, the IPF is committed to carrying out application-oriented basic research and receives its base funding in equal parts from the federal and state governments.

The focus of activities at the IPF is directed toward the expansion of basic scientific knowledge for the development of functional polymers and polymer materials with new or improved characteristics. In addition, emphasis is also put on combining material development with innovative and sustainable production and processing technologies. Advanced materials are absolutely necessary and create a driving force for the development of new technologies and system solutions in medical engineering, modern communication technology, data storage and processing, and transport and energy technology. In their endeavours, the researchers at the IPF work towards understanding the effects of interfaces and the utilization of interface design in material development, in which nanotechnological aspects as well as interfaces to biosystems are of great importance.

The combination of competences in natural and engineering sciences, for which the IPF is known, as well as state-of-the-art technical equipment, allow a holistic approach to material science research. This extends from synthesis and modification of polymer materials to characterization, theoretical studies, processing, and testing to controlling properties of polymer materials, biomaterials, and composites by selective interface design. In this way, it is possible to deal with problems and requirements on new and improved polymer materials until they are transformed into an industrially utilized product.

Networking and Cooperations

Solidly anchored at the Dresden research site and closely networked with research groups worldwide – this is how the position of the IPF may be aptly described in the global research landscape.

The capital of Saxony has an extraordinarily high density of research facilities, including the Technische Universität Dresden (TUD) and the institutes of the Leibniz Association, the Max Planck Society, and the Fraunhofer Gesellschaft. All together, these institutes help to make Dresden a leading research site, particularly in the fields of material research, microelectronics, and biotechnology. Competence and capacity in the field of materials are merged into the Materials Research Network Dresden, in which 20 facilities from both inside and outside universities are affiliated. These facilities currently have a combined workforce of about 2000 employees.

The IPF maintains close connections to the TUD, and the directors of the institutes of IPF, the head of the theory workgroup (since 2006), and the head of the research area Biofunctional Polymer Materials (planned for 2007) are, by joint appointments, professors at the university and closely involved in teaching. Students from various backgrounds, including interns, graduate students, and PhD students, participate in research projects at the institute. The Max Bergmann Center of Biomaterials (MBC), jointly created by the IPF and TUD, merges under one roof the activities of both institutions in the field of molecular bioengineering. Several collaborative research centres, priority programmes, and research units of the Deutsche Forschungsgemeinschaft (DFG) have also been jointly initiated and managed. Furthermore, the IPF is associated through honorary professorships and lecturing activities with other universities and technical colleges.

The excellence cluster 'From Cells to Tissues to Therapies' and the 'Dresden International Graduate School for Biomedicine and Bioengineering' represent the dynamic development of life sciences and biotechnology. They have been founded within the scope of the excellence initiative of the federal government, with the help of which the TUD and its partners are able to expand the activities of the DFG research centre "Regenerative Therapies" (established in 2006). Here, the IPF is an important partner, in particular with its activities at the MBC.

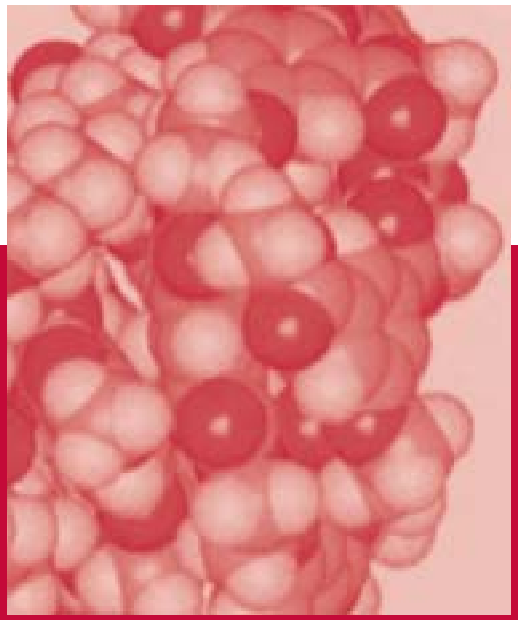
The combination of material research and life sciences results in a unique synergy and potential for international cutting-edge research as well as highly interesting application perspectives. A similar statement may be made for the cooperation of Dresden material researchers with the microelectronics industry, which together have developed 'Silicon Saxony'.

With its application-oriented research based on a broad understanding of fundamentals, the IPF is a sought-after partner in projects with industry. Funding in the amount of more than Euro 1.5 million is obtained directly from industry annually. This is approximately 25 % of third-party funding of the institute. Currently, two start-up enterprises have already been established for the direct commercial exploitation of research obtained at the IPF. The institute also offers advice to the polymer-producing and plastics-processing industry, and its efforts in establishing these contacts and technology transfer are supported by regional and nationwide networks.

Cooperation with facilities around the globe has been a long-time feature at the IPF. Guest scientists from up to 30 countries are working at the institute at any given time for various time periods and IPF staff members travel abroad to partners regulary.

The participation in several research associations promoted by the European Union serves as evidence of the international recognition of the institute and helps to open up new forms of cooperation in Europe. From the network of excellence "Nanostructured and Functional Polymer Based Materials and Nanocomposites" (NANOFUN-POLY), the European Centre for Nanostructured Polymers (ECNP) was founded in 2006 in order to allow the research networking in this field to continue on a permanent and sustainable basis.

Multifunctional Polymer Architectures



Modern technologies require materials with exactly-defined, new characteristics and functionalities. Here, polymers offer huge a potential; they can be tailor-made for a vast number of applications. A prerequisite, and at the same time a challenge, is the exact control of the polymer architecture, functionality, and nanostructure in polymer materials through the synthetic strategy as well as a complete understanding of the correlation between chemical structure or architecture and material properties.

For example, researchers are striving for polymer materials which have a multifunctionality that optimizes materials as highly effective additives or those which are selectively addressable on a component of a microscopic or nanoscopic level. Other important properties are high selectivity and quick response times of stimuli-responsive polymers for sensors, actors, and catalytic or biologic active polymers as well as a high and long-term stable biocompatibility or optimized bioactivity of synthetic polymers and biohybrids for medical applications.

A broad range of methods for the controlled synthesis of polymers is available for the creation of such multifunctional polymer architectures, for example, anionic and controlled radical polymerization, metallocene polymerization, but also high temperature polycondensation complemented by sophisticated polymer analytics.

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Defined Polymer Architectures: Multifunctional and Biofunctional Polymers

Various approaches are undertaken for the synthesis of complex, multifunctional polymer systems with adapted characteristic profiles for specific applications:

Branched Polymer Architectures

- Application of new synthesis methods to build up branched architectures in one or more steps, precise adjustment of branching density and nature of end groups
- Exploitation of characteristic profiles determined through branching and increased functionality in applications such as reactive formulations (e. g. in coatings), as functional materials in thin films or for the build up of nanohybride materials

Functional Hydrogels

- Selective setting of characteristics, including amphiphil, stimuli-responsive, or even molecularly shaped character made possible by copolymerization and combination of synthesis methods.
- Immobilization and application of functional hydrogels and copolymers, for example, in bioactive layers with the utilization of various surface anchoring methods

Optical and Thermal Sensitive Polymer Materials

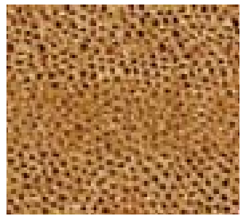
- Creation of copolymers with optical and thermal sensitive functionalities and switchable characteristics by methods including incorporation of photolabile protecting groups in suitable monomers
- Application of functional (co)polymers on surfaces or interfaces as thin lateral structurisable layers, e. g. in microelectronics, microsystems technology, and in sensors

Bioactive and Biofunctionalized Polymers

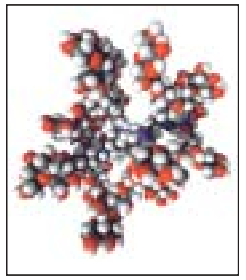
- Synthesis of polymers and hydrogels with covalently or physically bound bioactive and biological components and studies on their application in bioactive surfaces to be used for cell cultivation, in hemocompatible coatings and for prevention of biofouling (cooperation with groups in the Max Bergmann Center of Biomaterials)
- Preparation and development of water-soluble multifunctional biohybrid structures and bioactive polymer systems with (oligo-) saccharide units used as carrier and polyelectrolyte systems; Investigation of the interactions with proteins, cell membranes, and DNA molecules

Non-covalent Interactions

- Utilization of non-covalent interactions for the precise inclusion of new material characteristics in polymer construction and modification and the production of composites and hybrids
- Incorporation of internal superstructures in polymer material as well as fixation of functional components (e. g. dyes, conductive or optical active nanoparticles) through acid-base and ionic interactions or through the formation of hydrogen bonds



Phase morphology in a thin film (20 nm) prepared from a block copolymer based on orthogonally protected p-hydroxy styrene segments by controlled nitroxide-mediated radical polymerisation



Spheric molecule shape of a second-generation poly(propylene imine) dendrimer with 16 maltose units

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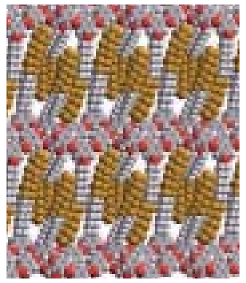
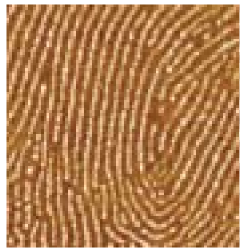
Control of Nanostructure and Morphology



General model of the structure of semifluorinated polymers

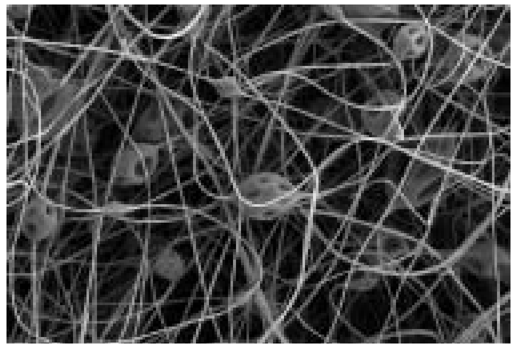


Cylindrical structure of a nanophase-separated methacrylate-based diblock copolymer

The main goal of the work is to control the nanostructure and morphology of new polymer architectures in solid state and in thin films (on surfaces) by means of chemical structure and supramolecular structure, as well as polymer synthesis strategies. The cooperation of synthesis and characterization work is aimed at understanding of resulting macroscopic properties and structure-property relationships. Thus, several types of polymers are currently developed:

Nanostructured Block Copolymers

- Controlled synthesis of nanophase-separated di- and triblock copolymers, segmented block copolymers, and graft copolymers, partially with inline-monitoring techniques
- Experimental determination of nanophase separation supported by mean field modelling
- Investigation of the influence of nanophase separation on macroscopic properties, particularly wettability: The macroscopic wetting behaviour of polymers determines significantly the applicability in microelectronics, nanolithography, as templates etc.



Electrospun fibres made of phosphorus-containing aromatic polysulphone (Image: T. E. Long et al., Blacksburg, USA)

Laboratory equipment for high temperature polycondensation reactions in melt and solution

Polymers with Specific Surface Properties

Application of demixing concepts in the nanometer scale:
- nanophase separation in block- and graft copolymers
- self organization
- surface segregation

to develop polymers with specific surface characteristics:
- hydrophilic/polar
- hydrophobic/non-polar
- laterally demixed polymers

Nanocomposites and Nanohybrids

- Development of polymers with high polarity to enhance the interaction between object and polymer matrix (phase adhesion) in polymer hybrids and composites
- Chemical modification of inorganic nanoobjects and fillers
- Synthesis of additives for multifunctional nanocomposites and nanohybrids with tailor-made properties, such as optical and electrical characteristics

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(Poly)Reactions in Melt and During Processing

Microscopic investigation of the morphology of polymer blends

The objective of chemically oriented activities in the area of reactive processing, as well as in polymer preparation and modification in the melt, is the target-oriented utilization of melt reactions for the preparation of multifunctional polymers. Here, it is of vital importance to take into account the peculiarities of melt reactions, such as high viscosity, occurrence of secondary reactions at high reaction temperatures, and evacuation of potential condensates. Reactions should be controlled with the highest possible definition in order to tailor the structures of multifunctional polymers in a way similar to reactions in solution.

Multifunctional Coupling Agents

- Synthesis of multifunctional coupling agents with at least two different reactive groups which react selectively and independently of each other
- Use of compounds, such as reactive compatibilizers in polymer blends, in the synthesis of segmented block copolymers and for the functionalization of interface layers
- Gaining of knowledge regarding the occurring reactions as a basis of new methods for variable polymer modification in the melt

Reactive Polymers

Synthesis of reactive polymers and their use in multicomponent systems as well as examination of the extent of their chemical reactions and their effect on multifunctionality

Multifunctional Polycondensates

Preparation of multifunctional polycondensates with reactive or selectively interacting groups by various processes of melt polycondensation and variable setting of functional characteristics by means of end-group modification reactions or preparation by specific interactions with low-molecular weight compounds

Influence of the rubber reactivity on the phase morphology in blends of rubber and epoxy resin top: blend containing non-reactive rubber, bottom: blend containing reactive rubber

Well equipped laboratories permit complex preparative work

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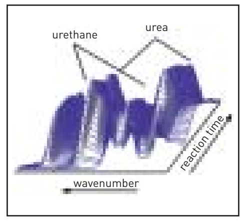

Monitoring of the synthesis of highly branched poly(urethane ureas) by means of *in situ* IR spectroscopy

Extensive experience in methodology as well as necessary modern technical equipment are available for characterization of the molecular and supermolecular structures of newly synthesized or modified polymer systems. Methods are applied individually or in combination, while activities for the adaptation and advanced development of methods corresponding to the actual analytical terms of reference are also in progress.

Primary and Secondary Structure Clarification of Complex and Functional Polymer Architectures in Bulk and in Thin Films

- Clarification of the chemical structure of monomers and polymers, chain conformation and configuration, degradation and cross-linking phenomena, and molecular and super-molecular interactions in various media completed with spectroscopic (NMR, IR, Raman), chromatographic (headspace and pyrolysis GC/MS), and thermoanalytical (TGA, TGA/IR, DSC) methods as well as elementary analysis
- Studies of reactivity, functionality, phase behaviour, order, and orientation
- Optimization of vibrational spectroscopic and spectral ellipsometric characterization (*ex situ* and *in situ*) of thin homogenous and heterogenous/microstructured organic films on metallic and dielectric solid surfaces

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In situ spectral ellipsometry of "switchable" hydrogel layers in a temperature-controlled solid-liquid cell

Analysis of volatile products during heating of polymers by coupled thermogravimetry/IR- spectroscopy

Structural Examination/Determination of Molar Mass of Multifunctional Polymers in Solution

- Characterization of dissolving behaviour, molar mass, and molar mass distribution of linear and differently branched polymers by combination of analytical techniques (incl. size exclusion chromatography (SEC) with various detector combinations, semipreparative fractioning) with application of dynamic molecular simulations
- Molecular characterization of polyolefines and analogue polymer systems by means of high-temperature gel permeation chromatography (GPC)

In-line Monitoring of Polymer Reactions

- Tracking of polymer syntheses and polymer analogue implementations in the melt and in solution on a lab and technical-school scale by means of *in situ* ATR-IR and Raman spectroscopy in combination with off-line NMR and SEC
- Qualitative (mechanism, secondary reactions) and quantitative (yield, kinetics) evaluation with application of chemometric methods
- In-line process analytics of polymer systems (composites, blends, polymer/additive systems) in processing by means of UV/VIS, NIR, Raman, and ultrasonic spectroscopy

Functional and Nanostructured Polymer Interfaces

Polymer materials characteristics are not only determined by chemistry and general materials properties. Interfaces and inner structures frequently play a decisive role and are determined by preparation and sample treatment. Consequently, better physical and chemical understanding of interfaces and structure on a nanoscopic level is a prerequisite for control and optimization of properties of polymer materials. The aim is to achieve a description and targeted design of interfaces, structures, and resulting properties based upon comprehensive characterization of interfaces and nanostructures,.

The main focus of activities is directed towards the manufacture and characterization of functional and nanostructured polymer thin films, surfaces, and nanohybrids, including nanoscale functional elements. In these investigations, main emphasis is put on a basic understanding of correlations between structure and properties from single molecules to super-molecular structures and from self-organized structures to macroscopic interface-determined properties.

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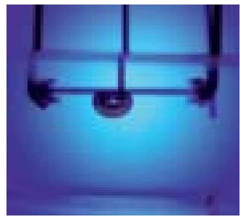
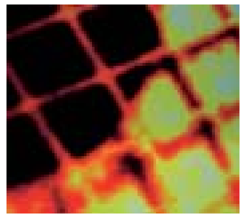
Functionalization and Characterization of Interfaces

Measurement of particle sizes and zeta potential in suspensions



Temperature-controlled liquid cell for measurement of wetting by inverse drops profile analysis (captive bubble): bubble at a hydrophilic surface



Imaging XPS: Image of the Ag 3d peak of a silver grid for electron microscopy

Macroscopic phenomena, such as wetting, adhesion, and adsorption processes can be explained on a molecular level by employing comprehensive characterization techniques to study the chemical composition, reactivity, and morphology of surfaces as well as through the study of forces between interacting phases. With knowledge of the molecular mechanisms and morphological changes in interphases, it is possible to control the macroscopic interface phenomena by specific surface functionalization reactions. The fundamental studies serve as a basis for the development of optimised technologies and materials, for example, in finishing processes, ultra-hydrophobic coated metal or polymer surfaces, formation of hybrid and composite materials, plastic recycling, dispersion and coagulation processes, procedures used in textile refinement, and processes in microelectronics.

Creation of Functionalized Surfaces

- Chemical modification of surfaces by thin polymer films
- Surface structuring on a micro- and nano-scale
- Controlling surface properties by adsorption of surfactants and polyelectrolytes and their subsequent reaction with reactive polymers

Development and Combination of Special Methods for the Characterization of Interfaces

- *In situ* measurements to determine surface tension and wetting of polymers (also of reactive multicomponent systems)
- Coupling of *in situ* methods (ADSA-TRIS), e. g. to study the adsorption of surfactants and proteins
- Combination of electrokinetic measurements with direct-force measurements (AFM colloid probe technique) and wetting measurements

Water droplets repelled by an ultrahydrophobic aluminium substrate (Picture: K. Tittes, Nehlsen Flugzeug-galvanik GmbH)

Methods

- Surface spectroscopy (X-ray photoelectron spectroscopy, XPS)
- Direct force measurements on a molecular level through atomic force microscopy
- Wetting and surface (interface) tension measurements by drop profile analysis and Wilhelmy technique, including determination of the surface (interface) tension of polymer melts
- Determination of charges in solid/liquid interfaces (electrokinetics) by streaming current, streaming potential, and electrophoresis measurement; electro-kinetics in suspensions with high particle concentration by acoustophoresis
- Particle size analysis by means of dynamic light scattering and acoustic damping
- Characterization of surface morphology (roughness) through atomic force microscopy and optical methods (chromatic aberration)
- Determination of the specific surface and pore analysis by low-temperature gas adsorption
- Adsorption and desorption of vapours, e. g. water vapour, vapours of organic liquids
- Inverse gas chromatography (determination of surface free energy and characterization of the Lewis acid-base properties)
- Null ellipsometry to measure the thickness of adsorption layers

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Nanostructured Interfaces and Thin Films

Polymeric double layer with two-dimensional gradient structured by UV light for application in self-rolling microtubes

Processes of self-organization as well as manipulation of single molecules are used to prepare nanostructured interfaces, thin films and structures on various size scales.

Ordered Block Copolymer Nanostructures

Ordered nanostructured thin films of block copolymers are used for the preparation of magnetically and optically active films:

- Creation of self-organized and aligned block copolymer nanotemplates
- Loading with active materials (metals or nanoparticles) for the production of nano-materials
- Use as lithography masks or for the production of ordered functional nanostructured films
- Copolymer structures for the production of ordered magnetic nanohybrids or composites

Single Molecules

Study and manipulation of adsorbed, single polymer molecules on surfaces with the objective of being able to generate special functions on a molecular-length scale

- Basic studies of adsorbed single molecules on interfaces
- Production and characterization of nanoelectronic components (transistors, etc.) with single polymer molecules

Polymer Brushes

Functional switchable or adaptive interfaces based on the use of mixed polymer brushes and copolymers

- Preparation and study of adaptive surface functions (partly with characteristics gradients), for example, for the control of wetting and adsorption
- Switching of surface properties with temperature, solvent, pH-value, ion strength
- Control of interaction of functional polymer layers with nano- and microparticles and (bio) polymers, for example, for sensors and bio-adsorption

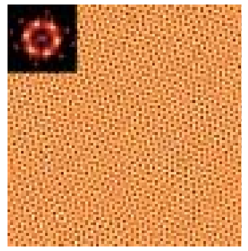
Nanotubes Made from Multilayers

Rolling up of polymer multilayers in selective solvents to form functional nanotubes

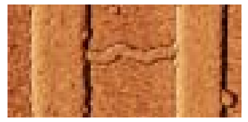
- Manufacture of micro- and nanoubes with functionalization of the inner surface
- Nanotubes for nanodroplet generation as well as nanonozzles for ink jet printers

Methods

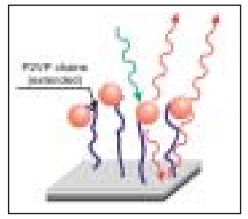
- Atomic force microscopy for the visualisation of single molecules and nanostructures
- *(In situ)* ellipsometry for the determination of layer thickness and adsorption
- X-ray methods (SAXS, WAXS, reflectometry) for multiscale determination of structures
- Combination of X-ray techniques with stretching devices, rheology, annealing
- Synchrotron techniques (XPEEM, USAXS, GISAXS, scanning X-ray microscopy) for the determination of surfaces and bulk structures (with BESSY, HASYLAB, and ESRF)
- Transmission electron microscopy for the determination of morphology (with TUD)
- Microfluidic sensor for the analysis of adsorption and flow in a microfluidic cell
- Fluorescence microscopy for the analysis of nanoparticle adsorption and kinetics



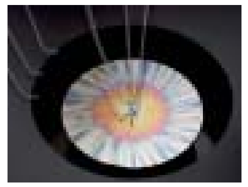
AFM picture of a porous block copolymer nano-template (1 x 1 µm²)



Electrically conductive nanowire (50 x 100 nm) prepared from a single polymer molecule



Nanoparticles at brushes for application as optical sensors



Preparation of thin polymer films from solution by means of a spin coater (cover picture)

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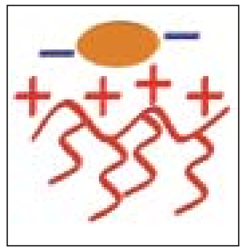
Charged Polymer Systems in Contact with Water

Needle-like polyelectrolyte complex particles made of poly(maleic acid-co-propylene) and poly (L-lysine) in the α-helical conformation (length: 150-230 nm)



Electrostatic interaction as driving force for the sorption of small molecules at polyelectrolytes

The interplay between electrostatic and dispersive interaction is utilized in order to adjust the bonding capabilities of proteins and active ingredients in dispersions and on solid surfaces. Another use of these interactions is to alter the stability of dispersions as well as the selectivity and separating characteristics of membranes. The surface characteristics necessary for this purpose are dominantly influenced by electrostatic and hydrophobic interaction, which are conveniently adjusted by polyelectrolytes, polyelectrolyte multilayers, and polyelectrolyte complexes. The research is focused on polyelectrolyte complexes and dispersed systems as well as polyelectrolyte multilayers and membranes. For the characterization of the materials, dedicated spectroscopic methods, particularly NMR, are developed.

Synthesis of New Polymers and Polyelectrolytes

- New polymers for membrane applications and model polyelectrolytes are synthesized and characterised.
- Membranes for fuel cells and water treatment are tested.

Preparation of Polyelectrolyte Multilayers and Complexes

- Polyelectrolyte complexes permit high tolerance to the surrounding medium for the adjustment of surface properties and the stability of dispersions. Stable polyelectrolyte complex nanoparticles are prepared with a narrow size distribution.
- From polyelectrolyte multilayers, switchable surfaces for protein adsorption and antifouling treatment of membranes are generated.

Radiation Modification

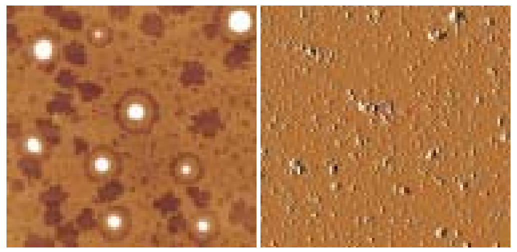
The variation of reaction conditions and atmosphere during electron beam irradiation and plasma treatment generates reactive groups on otherwise inert fluoropolymers.

Comprehensive Characterization of Systems

- Determination of hydrodynamic size in solution and dispersion (Angström to millimetre, by optical methods and pulsed field gradient NMR)
- Measurement of zeta potential in layers and particles

Probehead for electrophoresis NMR, developed at the IPF. Electrophoresis NMR allows to determine the charge of molecules and complexes

- Determination of the charge of molecules and complexes by electrophoresis NMR
- Characterization of dynamic complexes and ligand binding with NMR methods
- Spectroscopic (IR and NMR) determination of stoichiometry, degree of dissociation, hydrogen bonding, conformation, order, and superstructures
- Determination of morphology and particle shape in dispersions
- Analysis of solid content in dispersions
- Characterization of membranes and restricted diffusion



AFM pictures of adsorbed polyelectrolyte complexes made of maleic anhydride copolymers with different hydrophobic comonomers. The particle shape is influenced by the hydrophobicity of the comonomers

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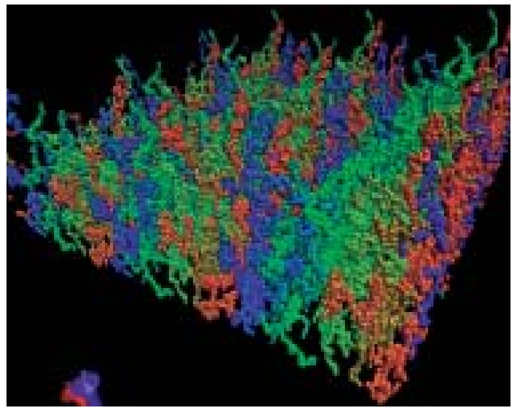
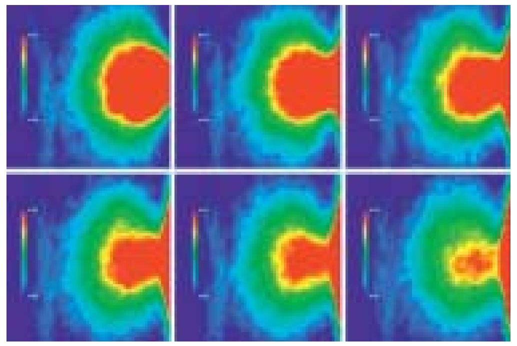
Theory of Polymers



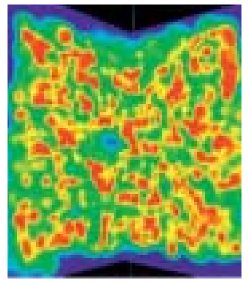
Snapshot of a polymer brush. All chains are bound to the surface by a terminal monomer. The different colours serve to distinguish the individual chains

In close collaboration with experiments we explore the structure-property relations and dynamics of polymer systems using both analytical and numerical methods. In particular we apply large-scale computer simulations. The following are major points of interest:

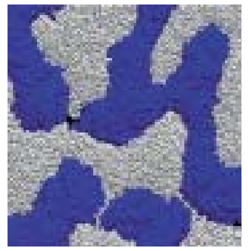


Density profiles of a polymer chain at different stages of an irreversible adsorption process (from left side top to right side bottom)

- Investigation of the effects of interaction between polymers and surfaces and among different polymer chains in order to understand various mechanisms of phase separation and dynamic structure formation, including possible applications for the preparation of thin polymer films as templates for nanostructures or biofunctionalized surfaces
- Mathematical description of polymer layers and interactions between adsorbing surfaces and interfaces and numerical calculations of the static and dynamic behaviour of polymers on nanostructured substrates
- Time-resolved simulations and dynamic theory of polymer brushes using molecular dynamics simulations in order to understand the processes of pattern formation in binary polymer brushes and their response to changes of ambient conditions
- Analysis of the topology of cross-linked polymers and the description of highly branched polymers using analytical models and computer simulations
- Study of the crystallization behaviour of polymers using analytical models and computer simulations



Frozen density fluctuations in a network: averaged density distribution of a swollen polymer network (colours: local density; extension of the inhomogeneities about 30 nm)



Formation of nanostructures in a binary polymer brush. The interaction between the monomers of different species causes separation processes (pattern formation) on the nanometer scale

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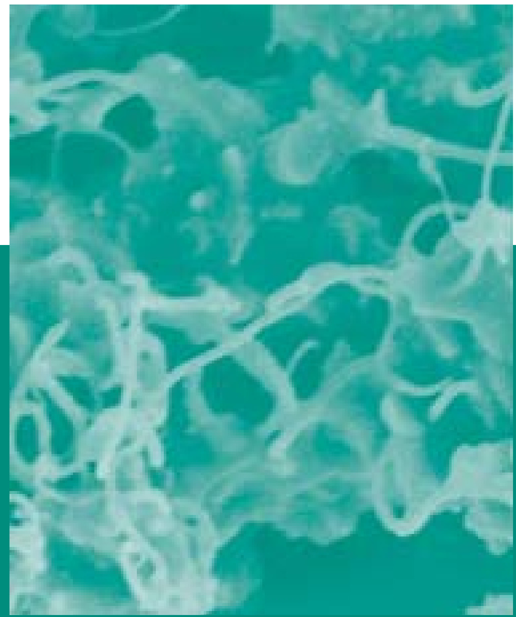
Functional Polymer Materials



Currently, the development of new polymer materials as engineering and functional materials for special applications is based predominantly on already established polymers and their modification by suitable functionalization and coupling. Here, a challenge faced by researchers is the elaboration of an overall scientific concept encompassing the entire scale from molecules to components.

With interdisciplinary collaboration of natural scientists and engineers, an approach is being pursued that regards material design, material production and processing, engineering technology, in-line monitoring, comprehensive characterization, and polymer material modelling as integrated entities.

The influence of physical and chemical parameters on morphology, and thus the characteristics of materials and their processing behaviours, is examined on heterogeneous or multiphase polymer materials such as fibre composites, blends, and filled elastomers.

The merger of fundamental studies and processing trials under conditions close to those encountered in industry has created a very fruitful interaction. Together with the competence in the fields of reactive processing, melt spinning of polymers and glass, radiation modification of polymer materials, and *in-line* monitoring, these interactions open up a great variety of opportunities for material and processing innovations.

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Reactive Processing

Pilot plants for plastics processing allow investigations under industry-relevant conditions

Development, adaptation, and application of chemical reaction principles in technical processes for the development of new materials, improvement of characteristics of commercial plastics, and (advanced) development of processes. Particular uses include the following:

Thermally Controlled Reactions in and with Technical Polymer Masses

- Development of deformation-stable powder coating formulations for the coating of semi-finished products and for the logistic redesign of processes
- Development of low-temperature, cross-linking powder coatings for wood materials
- Development and adaptation of powder coating systems for the coating of sheet moulding composites (SMC)

Interface-Reactive Processes to Increase Composite Bonding

- Examination of quick reactions on the interfaces of polymer melts, including modelling and simulation
- Surface-active injection moulding for in-situ surface modification in the forming process for subsequent coating, bonding, or metallising
- Interface-active injection moulding to increase composite adhesion
- Composites of precoated and deformable or deformed metal parts (sheets) with thermoplastics by interface-reactive injection moulding

High-Temperature Electron Radiation of Thermoplastics and Rubber

- Clarification of reaction mechanisms, and changes in structure and properties after electron beam treatment at high temperatures
- Coupling of plastics processing and electron beam treatment to form one continuous modification process

Melt Modification Reactions: Chemical Coupling of PTFE with Polymers

- (Advanced) development of chemically coupled (high performance) plastic PTFE materials, particularly for tribological applications
- Development of specially modified PTFE nano- or micropowders as additives for chemically coupled material systems as well as additives for special lubricants
- Development of (bonded coating) lubricant systems for deformation processes

In-line and On-line Process Analysis Methods – Development of Sensors for Microphotometric Purity and Particle Analysis in Flowing Plastic Melts

- Close to real-time detection of inhomogeneities (pinholes, gel particles, blisters, streaks, granulate and powder residue, agglomerates) in transparent melts
- Adaptation of such sensors on extruders and injection moulding machines on a lab and industrial scale for close to real-time process and product control

Powder-precoated aluminium sheet after deep drawing shaping test. The new uretdione powders are curable at moderate temperatures above 120 °C resulting in weather-resistant and highly flexible films

Particle monitoring sensor adapted to the strand die unit of a single screw extruder

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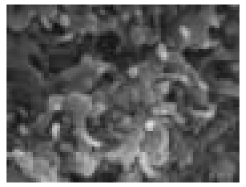
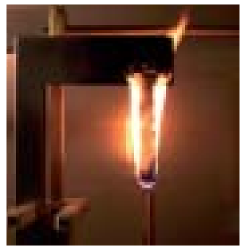
Nanocomposites and Blends



Composite of polycarbonate and multi-walled carbon nanotubes (master batch with 15 weight-%). The nanotubes are wetted by the polymer and therefore well separated from each other



Flammability test UL 94 of a nanocomposite of polypropylene and layered silicate (filler content: 5 wt.-%)

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Adjustment of both defined material properties and combinations of characteristics can be achieved through the use of multi- and nanoscalability of functional filler materials and selective control of morphologies, the latter of which is based on the deeper understanding of morphology formation during processing.

Nanocomposites

- Studies on the spatial distribution and alignment of carbon nanotubes in polymer composites and their effects on electrical, rheological, and mechanical properties
- Clarification of the influence of alignment, exfoliation degree, and distribution of layered silicates on diffusion characteristics
- Combination of flame retardation and other properties, such as reinforcement or UV resistance with modified layered double hydroxides (LDH)

Organically modified layered silicate in polypropylene grafted with maleic anhydride. The picture shows coexistence of completely exfoliated, intercalated and cluster species

Sampling from a pair of extruder screws removed from the barrel

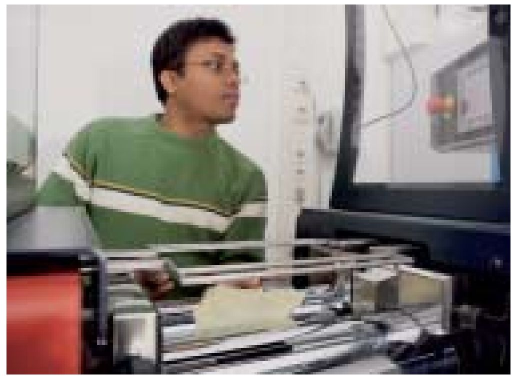
Blends

- Selective setting of phase morphologies in multiphase polymer blends during melt mixing processes by varying material conditions and exploiting various mechanisms to promote compatibility
- Introduction of functionalities (e. g.conductivity) in interface layers or phases of multicomponent polymer blends by multifunctional couplers (e.g. functionalized polypyrroles) or nanocomposite phases

Morphology Development and Elucidation

- *In situ* process control of polymer/nanocomposite systems (nanohybrids) during extrusion with UV/VIS, NIR, RAMAN, and ultrasound spectroscopy for the determination of dispersion, distribution, and morphology
- Clarification of complex structures composed of heterogeneous materials by means of solid-state NMR

Elastomers and Physics of Polymer Materials



Preparation of elastomer blends using a rolling mill

The activities here are directed to the adjustment of defined elastomer properties by exploitation of multi- and nanostructuring and chemical modification of both industrially available "and" novel, functional, reinforcing fillers. This is based on the understanding of physical properties of filled and entangled polymer networks and melts under relevant service and processing conditions. Emphasis is put on combination of problems of application of materials with physical fundamental approaches within a concept of polymer soft matter engineering (PSME).

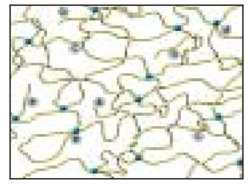
Elastomers

- Development, compounding, vulcametric, and physical characterization of novel elastomeric nanocomposites mainly for application in automotive industry with the aim of frequency-selective and temperature-selective improvement of dynamic-mechanical materials performance
- Development of scientific fundamentals of fracture mechanical concepts for filled elastomer blends, combination of different experimental techniques with multiscale methods of modelling heterogeneous elastomer materials (DFG Research Unit FOR 597)
- Characterization of physical surface and interface properties of polymer and filler constituents in elastomers, development of methods for the prediction of the dispersibility of fillers in polymers
- Development of coupled elastomer-PTFE materials, particularly for tribologic applications
- Service, elastomer and tyre consulting

Physics of Polymer Materials

- Analytical theory and statistical mechanics of filled polymer networks
- Dynamic-mechanical spectroscopy of elastomer materials
- Physics of hysteresis and adhesive friction of rubber materials at heterogeneous interfaces
- Physical and nonlinear rheological characterization and modelling of entangled polymer-nanocomposite melts
- Physics of car tyres

Estimation of the visco-elastic properties with a dynamic-mechanical rheometer



Visualization of a polymer network

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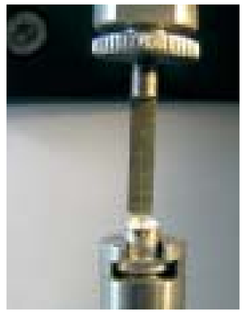
Composite Materials

AFM height profile of a sized glass fibre (sizing compatible for polypropylene matrix, 0.4 weight-%) with single walled carbon nanotubes



Cyclic loading in tension and compression of a glass fibre embedded in epoxy resin matrix (micro fatigue test)

Selected approaches from fibre to component are pursued and mechanisms are studied for the development of multifunctional, surface-modified reinforcing fibres and new composite materials.

Surface Modification of Reinforcement Fibres

- On-line surface modification of special glass fibres in the continuous spinning process for the creation of highly resistant surfaces tailor-made for special polymer and inorganic matrices
- Healing of surface defects of reinforcing fibres by nanostructured surface modifications to increase strength and to improve capabilities as well as longevity in composite materials
- Creation of multifunctional, nanostructured fibre surfaces by special sizing as well as polymer coatings
- Selective control of morphology/transcrystallinity of interfaces by concentration of nanofibres as well as nanoparticles during fibre surface modification

Interface Characterization

- Advanced development of quasistatic micromechanical test methods
- Expansion of measuring ranges of cyclic micromechanical methods
- Atomic force microscopic characterization of interface morphology as well as local interface characteristics relating to fibre-matrix adhesion
- Atomic force microscopic characterization of fracture surface morphology according to micromechanical examinations to clarify the connection between geometric and adhesive characteristics

New Composite Technologies

- On-line spinning of hybrid yarns of polymer and glass filaments for the manufacture of continuous fibre reinforced thermoplastics
- *In situ* composite formation and polymer build-up reactions
- Long-fibre and continuous-fibre reinforced thermoplastics with improved aging resistance
- Textile-reinforced concrete
- Fibre and interface design with polymers

Novel equipment for online spinning of hybrid yarns (glass and polymer filaments) developed by the departments Composite Materials and Structure and Mechanics

Tailored Fibre Placement

Advanced development of tailored fibre placement for load-related component reinforcement, particularly for carbon fibre heating elements and for textile carrier structures in medical applications

Manufacture of preforms for stress-field aligned reinforcement of components by means of a modified embroidery technology

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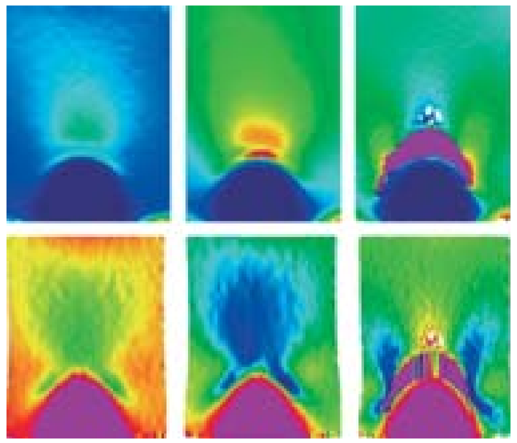
Structure, Mechanics, and Fibre Formation

Arrangement of the mini tensile rig under a microscope

Determination of Structure and Interface-Determined Material Properties Using Miniaturized Samples

Mechanical properties of polymers are strongly dependent on processing and the structure created during processing. Morphology and morphological changes in correlation to mechanical properties during deformation and fracture are studied, and microscopic processes are clarified in order to obtain reliable data for material modelling.

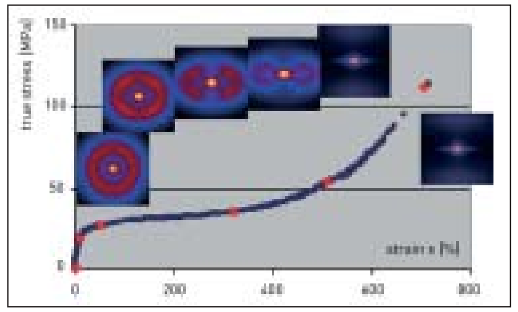
- Investigation of small (mm-and sub-mm-size) test specimen
- Recording of local deformation behaviour of the entire specimen by means of grey-value correlation analysis
- Structure examination by means of on-line X-ray scattering



2D strain fields of a bicomponent specimen PMMA-TPE with curved interface (top: parallel, bottom: perpendicular to tensile direction)

Modelling of Deformation and Fracture of Multiphase Polymer Materials

Characterization of adhesion phenomena at interfaces between components, analytical and numerical (finite-element method, ANSYS software) simulation of the macroscopic behaviour on the basis of continuum mechanics



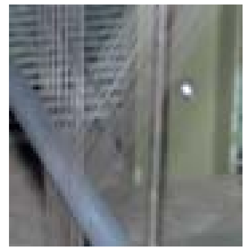
True stress-strain-curve of a PE specimen with SAXS patterns at characteristic positions of the curve

Melt Spinning of Thermoplastics in Special Applications

The structure and properties of polymers can be influenced selectively in melt spinning as a shaping process with extreme cooling and deformation speeds.

- Basic research on melt spinning of polymers with spinning speeds up to 6000 m/min
- Theory of fibre formation and modelling/simulation of the melt spinning process
- Rheology and spinnability of new polymers
- Spinning of biologically compatible and degradable polymers for medical applications
- Spinning of bicomponent, ultrafine and profiled cross sections (profiled, hollow) filaments
- On-line spinning of hybrid yarns of polymer and glass filaments

Industrial style equipment (extruder spinning and drawing systems, 2.5 kg/h throughput, up to 6000 m/min spinning speed), as well as a lab piston spinning system (10 g material usage), are available for melt spinning.



Commingling of glass and polypropylene filaments at the online hybrid melt spinning device (diameter of filaments 12 and 25 µm, resp.)

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Biomimetic Surfaces and Matrices

Biomimetic materials utilizing structures and functions of living matter define a key challenge for materials research and play an increasingly important role in various innovative technologies. Synthetic polymers represent the most important basis for biomimetic materials as they provide a wide variability in chemical and physical properties and options to create architectures with specific affinities for biomolecules.

Biomaterials research of the IPF is performed within the Max Bergmann Center of Biomaterials (MBC), a joint interdisciplinary initiative co-founded with the Institute of Materials Science of Technische Universität Dresden. The core competences of IPF groups within the MBC are:

- Charge and structure of biointerfaces: unravelling electrostatic characteristics and supramolecular assembly of surface-confined polymers
- Hemocompatible coatings: exploring mechanisms of the interactions between blood and materials to enable the development of blood compatible devices
- Matrix engineering: mimicking cellular microenvironments for *in vitro* and *in vivo* tissue engineering

The MBC is one of the pillars of the Dresden Cluster of Excellence for Regenerative Therapies and the Graduate School for Biomedicine & Bioengineering.

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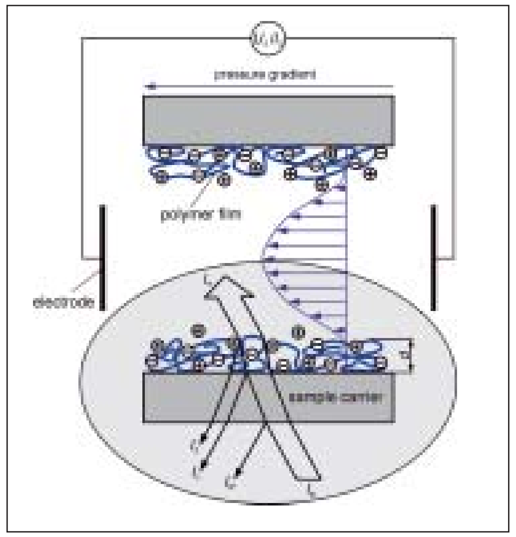
Charge and Structure of Biointerfaces

Microslit electrokinetic set-up

Charge Formation Processes at Solid Interfaces in Aqueous Media

Unravelling charge formation at biointerfaces in aqueous electrolyte solutions, as well as the interplay between ionisation and structure of polymers at interfaces, is a prerequisite for the rational design of biomimetic materials and the development of advanced bioanalytical tools and methods.

- Electrostatic interactions of (bio)polymers at interfaces
- Charge formation by unsymmetrical ion adsorption
- Electrokinetic phenomena in membranes and in microfluidic transport
- Combination of streaming potential/streaming current measurements with complementary interface-sensitive methods

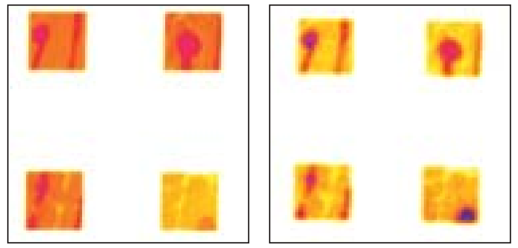


Combined electrokinetics and reflectometric interference spectroscopy provides insights into electrostatic switching of biopolymer layers

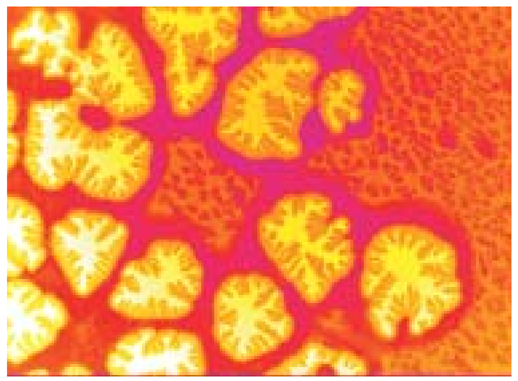
Structure Formation at Microheterogeneous Surfaces

The design of surfaces or intefaces compatible with biological entities requires a detailed understanding of basic physico-chemical interactions responsible for structure formation at surfaces. In particular, wetting, dewetting, and self-assembly processes at surfaces including crystallisation are addressed. As chemically heterogeneous surface become more and more important in surface engineering for biological and bioanalytical applications, the focus is on:

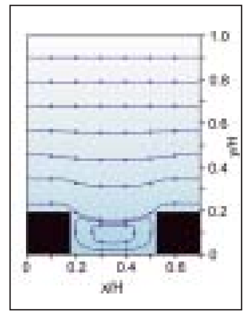
- Preparation of microheterogeneous surfaces applicable for bioimmobilization by soft- and electron beam lithography
- Realization of liquid/liquid phases and interfaces on microheterogeneous templates
- Self-assembly processes at micropatterned surfaces including crystallization in ultrathin films and in confined geometries
- Photopolymerizable diacetylene systems at soft-matter interfaces (vesicles, multilayer aggregates, liquid/liquid phase boundaries)



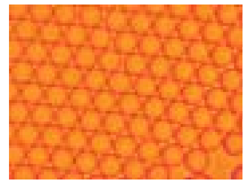
Micropatterned PEO layers immobilized by electron beam lithography. Different morphologies imaged by SEM (left) reveal different surface reactivities detected by fluorescence microscopy (right) (colour-coded images)



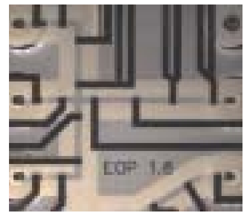
Complex surface structure of aminoterminated PEO with different morphology dependent reactivities for bioimmobilisation (colour-coded SEM image)



Simulation of hydrodynamic and electrokinetic transport at heterogeneous interfaces



Self-organized µ-droplets prepared by liquid flow in a microsystem



Microchannel with electrodes for electroosmotic liquid transport

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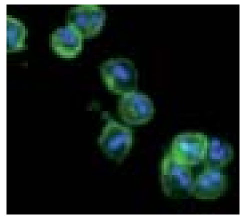
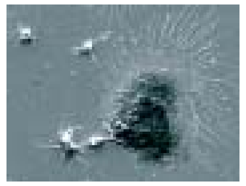
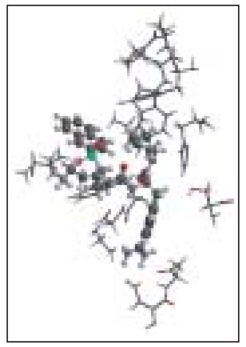
Hemocompatible Interfaces



Adherent granulocytes (blue: cell nucleus DAPI labelled, green: CD11b FITC labelled; confocal laser scanning microscopy)



Surface adherent cells after blood incubation (leukocyte, thrombocytes; scanning electron micrograph)



Orientation of a synthetic thrombin inhibitor to amino acid residues in the active site of thrombin

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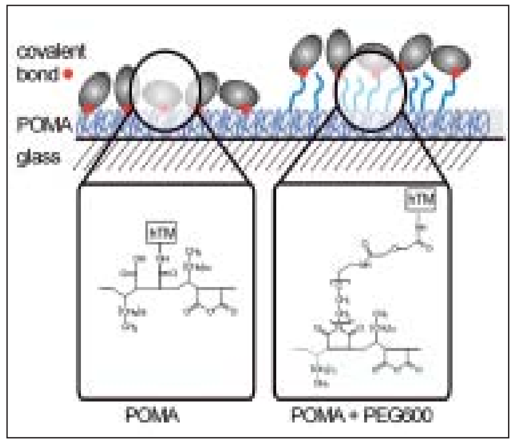
The prevention of coagulation processes and immune reactions at the interface of blood and biomaterials is a key requirement in the process of enhancing the hemocompatibility of biomedical products (e. g. cardiovascular implants, catheters, medical membranes). With this objective, strategies for coating technologies which utilize synthetic or naturally occurring coagulation inhibitors are being developed.

Systematic analyses of the interaction of human whole blood with model substrates serve to clarify the molecular and physical-chemical factors which trigger the humoral and cellular immune defense. These analyses further support the development of blood-compatible polymer coatings by quantifying the inhibitory effect of immobilized substances.

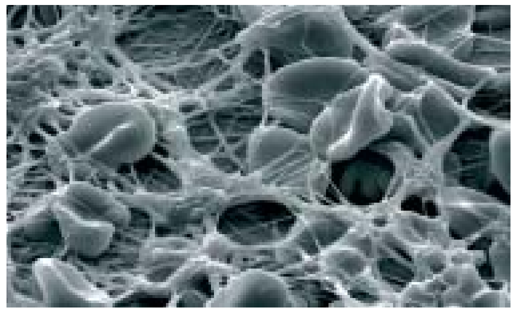
Project lines

- Correlation of physical-chemical interface characteristics with the activation of blood coagulation and immune reactions
- Influence of competitive plasma protein adsorption on blood coagulation (Vroman effect)
- Anticoagulant coatings on the basis of naturally occurring blood coagulation inhibitors (e. g. thrombomodulin), synthetic coagulation inhibitors (benzamidine and guanidine derivatives), and persulfated structures with inhibitor characteristics
- Development of test systems and methods for the characterization of blood compatibility of materials by incubation of human whole blood *in vitro* under flowing or steady conditions



Immobilization scheme for the natural thrombin inhibitor human thrombomodulin (hTM) with or without PEG spacer onto poly(octadecene alt maleic anhydride) thin films

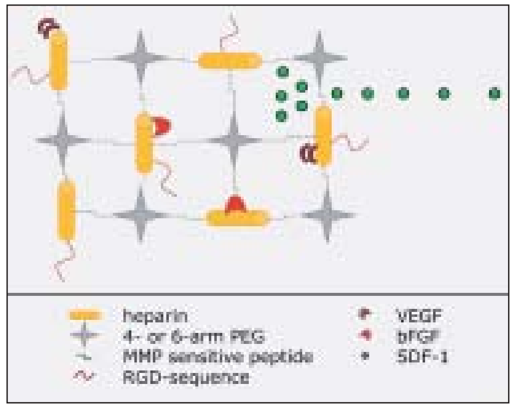
Human whole blood is filled into the screening incubation chambers for hemocompatibility assessment



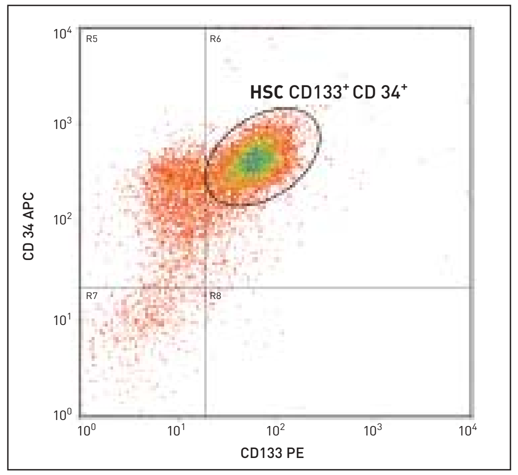
Fibrin network on a surface after blood contact (scanning electron micrograph) incorporating blood cells (erythrocytes, leukocytes, thrombocytes)

Matrix Engineering

Polymer matrices with temporally and spatially tuned cell signalling characteristics are developed for *in vitro* or *in vivo* tissue engineering. For this purpose, the physical and molecular stimuli of cellular microenvironments are systematically imitated using reconstituted biopolymer assemblies (consisting of collagen I, fibronectin, and other components of the extracellular matrix), supported lipid bilayer membranes, as well as synthetic and biohybrid hydrogels. Several projects are aimed towards the utilization of stem cells in new therapeutic strategies by creating combinations of exogenic signals for the control of self-renewal and differentiation of these cells – the "stem cell niche". Accordingly, the molecular understanding of cell-matrix adhesion, the effect of physical stimuli (micro- and nanostructure, elasticity of matrices), and biomolecular cues (chemokines and growth factors) are prioritized resarch tasks.



Biohybrid hydrogel for sequential release of growth factors and chemokines

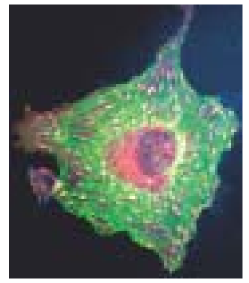


Analysis of hematopoietic stem cell differentiation by flow cytometry

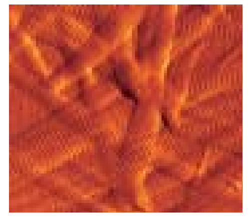
Project lines

- Modulation of the functionality of biopolymers and assemblies of the extracellular matrix as well as growth factors, chemokines, and membrane proteins through the kind of coupling to material surfaces
- Biophysical aspects of cell-matrix adhesion to biomimetic materials with gradated property profiles
- Cellular and cell-free reconstitution of supramolecular (multicomponent) structures of the extracellular matrix (fibrillar networks based on collagen I and glycosaminoglycans, collagen IV and laminin (basallamina), or fibronectin)
- Synthetic and biohybrid matrix imitates for *in vivo* tissue engineering applications (injectable, functionalized gels)
- Biomimetic interface design of biologically degradable polymer materials (polyhydroxyalkanoates)

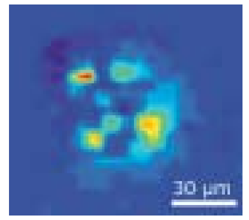
Hematopoietic stem cells on matrix coated support



Endothelial cell (adhesion receptors and cytoskeleton) with self-assembled fibronectin fibrils



Composite fibrils of collagen I and heparin



Traction field measurement of adherent cells on matrix coated support

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Research Technology

CNC machining of an aluminium plate: cut-out of a meander structure for a cooling system

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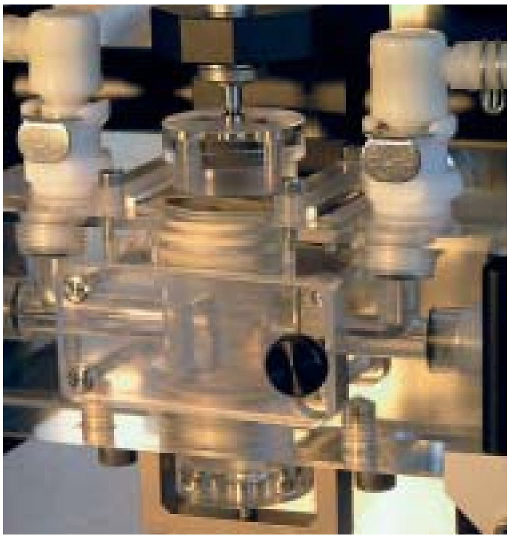
In experimental research, technical expenditures increase with the demand for ever more precise and comprehensive measuring data. The industry is already offering innovative technical solutions for many established measuring methods. However, since research continually enters new territory, there is a continual demand for new processes and measuring methods as well as special technical equipment.

The solutions for individual cases are being developed and realised by technical research staff in collaboration with scientists.

Advantages

- Professional equipment tailored to individual needs
- Optimised solutions through close cooperation of scientists and engineers of various technical fields
- Balanced parallel development of mechanics, electronics, and software through close interlocking of the disciplines
- Innovation by new development of technical devices
- Continuity in further development of devices and methods

Rheometer control unit for an NMR spectrometer: An example of the development of electronic systems from the layout of a printed circuit board to the complete control instrument



Flow cell made of PMMA with adjustable gap width for measurement of electrokinetic effects

Performance Range for Device Development

- Engineering: designing of mechanical components and system parts with 3D-CAD (Inventor)
- Measuring and automation technology: development of mainly computer-based measuring and control systems (e. g. with LabView)
- Electronics: development and fabrication of electronic circuitry and devices (e. g. for HF, LF, HV systems)
- Production: workshop with CNC, NC, and conventional processing technology