

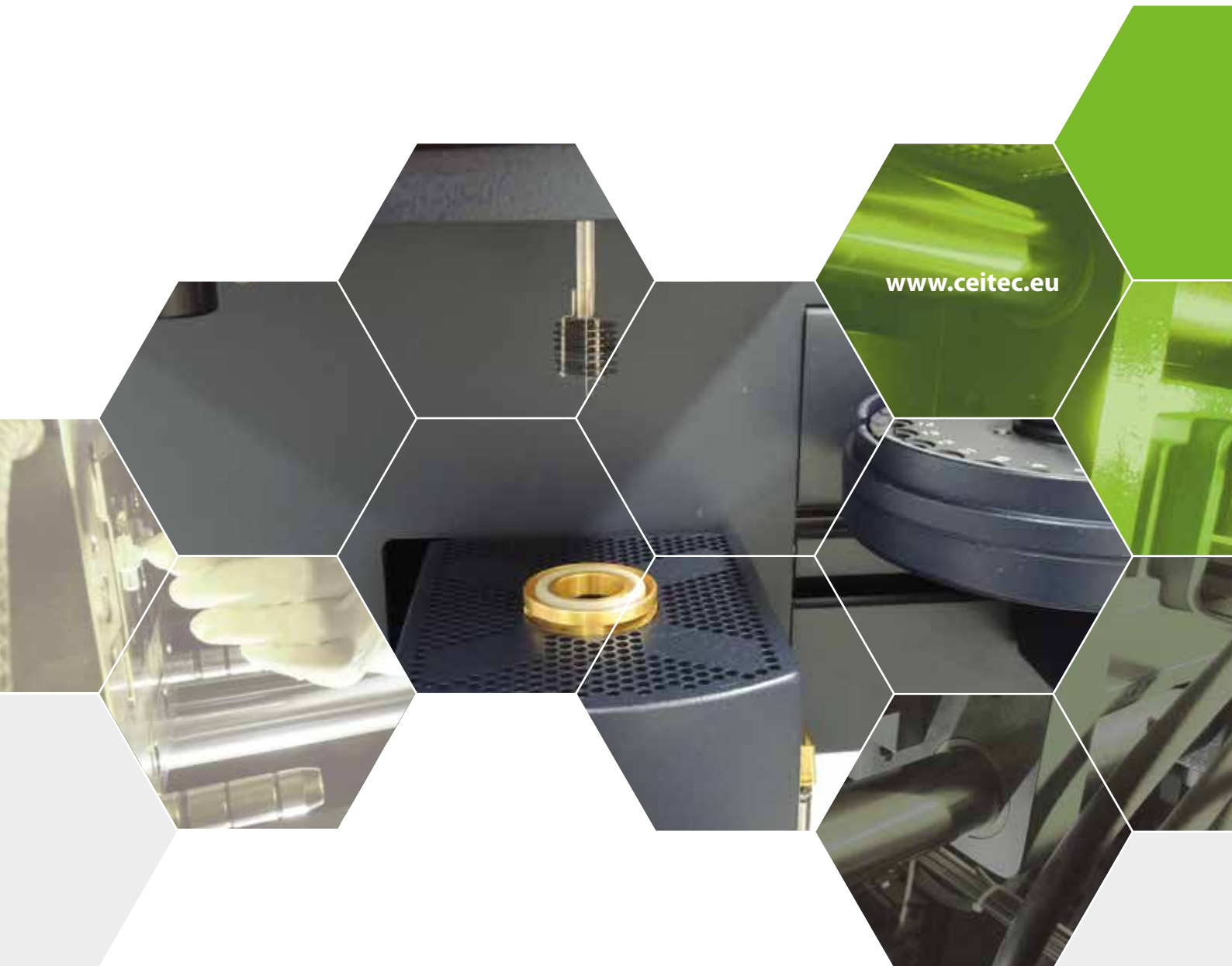


CEITEC

Central European Institute of Technology  
BRNO | CZECH REPUBLIC



# ADVANCED POLYMERS AND COMPOSITES



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# CENTRAL EUROPEAN INSTITUTE OF TECHNOLOGY

CEITEC is a scientific centre in the fields of life sciences, advanced materials and technologies whose aim is to establish itself as a recognized centre for basic as well as applied research. CEITEC offers a state-of-the-art infrastructure and excellent conditions for the employment of outstanding researchers. We are a consortium whose partners include the most prominent universities and research institutes in Brno, Czech Republic: **Masaryk University, Brno University of Technology, Mendel University in Brno, Institute of Physics of Materials of the Academy of Sciences of the Czech Republic, University of Veterinary and Pharmaceutical Sciences Brno** and the **Veterinary Research Institute**. We work closely with the Region of South Moravia and the City of Brno to help increase the local innovative capacity.

## CEITEC BASIC OVERVIEW

- 6 partners
- 7 research programmes
- 61 research groups
- 557 researchers (2015)
- 25 000 m<sup>2</sup> of new laboratories
- 10 core facilities
- total budget of € 208 mil
- project duration 2011 - 2015
- sustainability period 2016 - 2020



## CEITEC BUT PhD programme

CEITEC BUT offers highly motivating environment to carry out specific research and a doctoral degree education in selected programmes. State-of-the-art equipment and the availability of experts provide high quality international environment for study and research. For talented students it provides opportunity to obtain a doctorate in excellent conditions for research under the guidance of the highest quality.

The CEITEC BUT launches two interdisciplinary doctoral programmes, which are composed of particular fields of study:

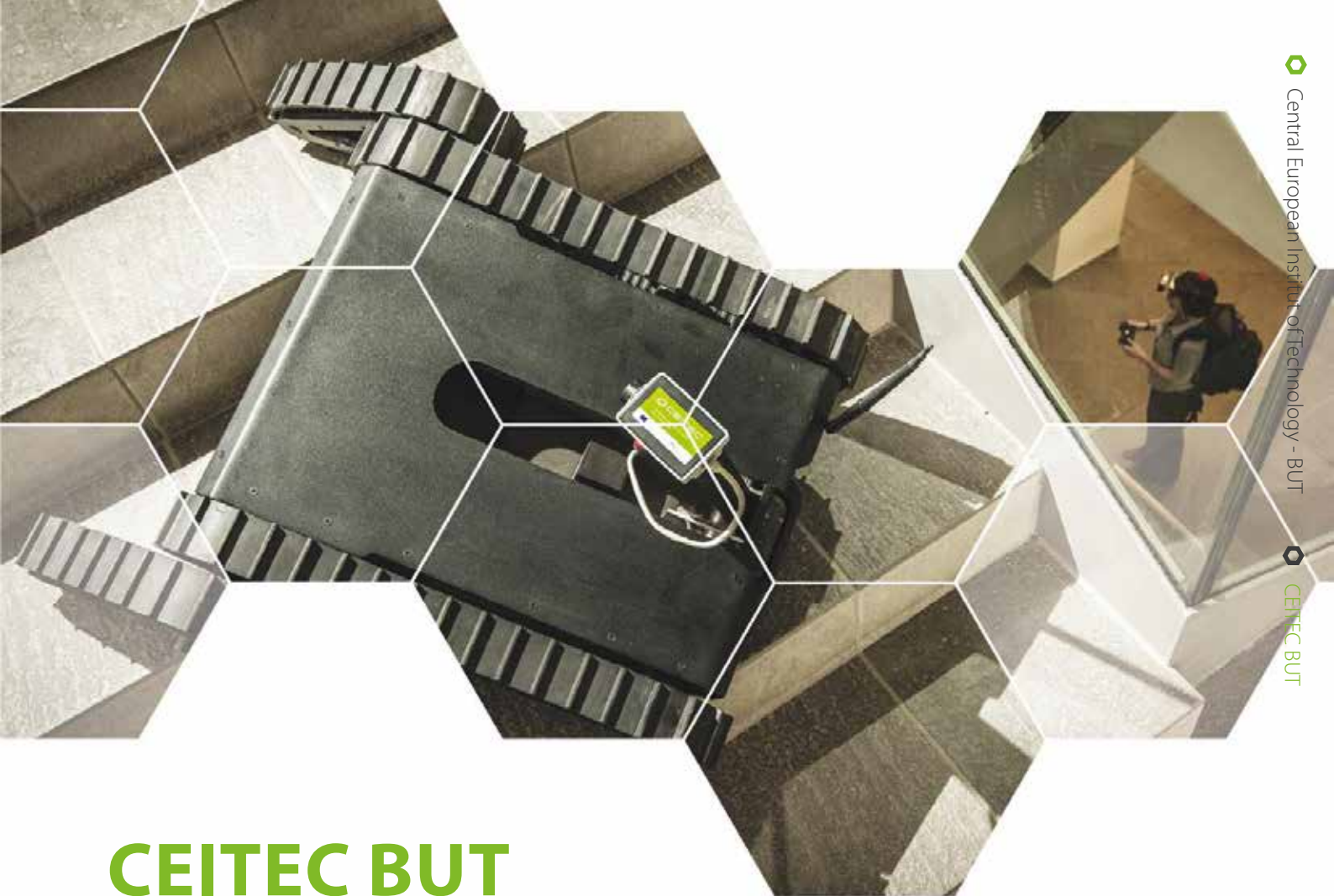
*Advanced Materials and Nanosciences*

- Advanced Nanotechnologies and Microtechnologies
- Advanced Materials

*Advanced Materials meet Life Sciences*

- Biosensing
- Bioengineering
- Quantitative Biology and Cybernetics

more information at: [www.ceitec.eu/phd](http://www.ceitec.eu/phd)



# CEITEC BUT

Central European Institute of Technology – Brno University of Technology (CEITEC BUT) is an independent University institute at Brno University of Technology, which was established under the framework of CEITEC – the Central European Institute of Technology.

CEITEC BUT constitutes a key element of the world-class research infrastructure, built at the University Campus of Brno University of Technology in Pod Palackého vrchem, providing state-of-the-art equipment and ideal conditions for fundamental and applied research, especially in the area of material sciences.

CEITEC BUT priorities include providing an international dimension in research cooperation as well as ensuring its interdisciplinary character. Core facilities as the shared laboratories cover instruments for various research disciplines, as they will create a perfect base for addressing interdisciplinary questions in the fields of advanced nanotechnologies, microtechnologies and advanced materials.

## CEITEC BUT OVERVIEW

- the 2<sup>nd</sup> biggest partner of CEITEC
- 247 researchers (2015)
- 2 research programmes
- 14 245 m<sup>2</sup> of new laboratories
- 8 research groups
- 2 core facilities

# ADVANCED POLYMERS AND COMPOSITES



## THE MISSION

We focus on investigating fundamental relationships between advanced polymer syntheses, preparation controlled structure development and properties of heterogeneous polymer systems and developing and exploiting novel, break through processes enabling their utilization in fabricating synthetic nature inspired hierarchical function specific structures engineered on hierarchically increasing length scales.



## RESEARCH AREAS

Syntheses and characterization of novel multifunctional homogeneous and heterogeneous polymeric materials such as functional macromonomers, polymers, controlled life-time polymers and nanostructured hierarchical polymeric systems with prescribed structure using ATRP, ROMP, living polymerizations, click chemistry and their combination etc. (contact person: Assoc. Prof. Lucy Vojtová, Ph.D.)

### **Multi-scale structure-property relationships in polymers and polymer nanocomposites:**

Physics of heterogeneous polymer systems, reptation dynamics and segmental packing in polymer glasses, nanocomposite viscoelasticity, deformation and fracture phenomena in polymers and composites, self-assembly and forced assembly (contact person: Prof. Josef Jančář, Ph.D.)

### **Stability and degradation of polymers:**

Evaluation of degradation mechanisms of commodity plastics and compounds, the development of new, more stable materials and ways of making reliable predictions of their service life and degradation kinetics of biodegradable materials (contact person: Assoc. Prof. Jiří Tocháček, Ph.D.)

### **Polymer and composite processing:**

Reactive extrusion, compounding, polymer stabilization and additivation (flame retardants, pigments, dyes, fungicide and antibacterial additives, thermo- and photo-chromic compounds), development of master-batches for industry, nanocomposite processing, fiber composite fabrication (contact person: František Kučera, Ph.D.)

### **Structural analysis, rheology and mechanics:**

Laboratory provides instrument and human infrastructure offering thermal, mechanical and structural analysis of polymeric and composite materials using TGA, DSC and modulated DSC, DMA, screw driven and electro-dynamic tensile testers, instrumented impact pendulums, optical and confocal laser scanning microscopy, SEM and AFM, rheometers, FTIR, FTIR microscopy, DLS and GPC (contact person: Petr Poláček, Ph.D. – thermo-mechanics, Radka Bálková, Ph.D. – thermal analysis, Jana Brtníková, Ph.D. – microscopy, DLS)

### **Computer modelling and simulations:**

The development of novel simulation procedures and methods for computer modelling of structure-property-function relationships in heterogeneous polymeric materials and failure in anisotropic polymeric systems to support computer aided material design (contact person: Jan Žídek, Ph.D.).



## TARGETED APPLICATIONS

- Functional biomaterials for regenerative medicine, tissue engineering and drug delivery.
- Novel hydrogels and nanocomposite hydrogels for 3D bioprinting.
- Nature inspired mechanically robust composites for advanced engineering applications.

## CONTACT

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# ADVANCED SYNTHESSES OF SPECIALTY POLYMERS AND MODIFICATION OF BIOPOLYMERS



## RESEARCH STRATEGY

Developing novel syntheses of functional polymers, copolymers, macromonomers, controlled life-time polymers, hydrogels and chemical modifications of proteins and polysaccharides, their structural characterization and use in assembling prescribed hierarchical structure systems employing ATRP, ROMP, RAFT, living polymerizations, click chemistry and their combination.



## RESEARCH AREAS

- “Smart” thermosensitive life-time controlled hydrogels.
- Synthesis of POSS-based polymeric nanocomposites, structural and kinetic study.
- Synthesis and characterization of biodegradable polyurethane films and composites.
- Physical and chemical crosslinking of hydrogels.
- Spinning of functional nanofibers.
- “In-situ” preparation of nanoparticles and core-shell heterogeneous nanoparticles.
- (Bio)polymer-based hydrogels, fibers and scaffolds for tissue engineering.



*Gel chromatography analysis of polymers*



## MAJOR EQUIPMENT

- GPC/SEC Agilent gel chromatography comprising unique Wyatt Detectors (18 angle MALS, DLS, UV, RI and viscometer supplied with both column and FFF separation systems).
- Circular dichroism spectrophotometer JASCO J-1500 with fluorescent and UV-VIS measurement, Calypso-CG-MALS and SDS page Bio-Rad electrophoresis.
- Pilot scale freeze drier Martin Christ Epsilon 2-10D LSCplus (0.7 m<sup>2</sup>).
- Range of all-glass vacuum-lines for advanced polymerizations and syntheses.

- State of the art glove box Jacomex GP (<1 ppm O<sub>2</sub>/H<sub>2</sub>O).
- Perkin Elmer Clarus 680 gas chromatography.

## TARGETED APPLICATIONS

- Scratch resistant transparent nanocomposite coatings for automotive industry.
- Bio- and thermodegradable polyurethane foams for industrial application.
- Injectable hydrogels and composites for drug delivery and bone adhesion/regeneration.
- Amphiphilic nanofibers as a platform for disease modeling and cancer treatment.
- Antibacterial hydrogels with nanoparticles for soft tissue regeneration.
- Highly elastomeric biodegradable polyurethanes for vascular grafts.
- Collagen-based composite scaffolds with blood derivatives for tissue regeneration.
- Novel polymeric materials for 3D bioprinting of soft and hard tissues.



*Polymer composite bone cement*

## CONTACT

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# STRUCTURE-PROPERTY RELATIONSHIPS IN POLYMERS, COMPOSITES AND NANOCOMPOSITES



## RESEARCH STRATEGY

Physics of heterogeneous polymer systems, segmental dynamics and packing in glassy polymers and nanocomposites, rheology of non-newtonian fluids, linear and non linear viscoelasticity, large strain deformation and fracture phenomena, self- and forced- assembly of nanoscale organic-inorganic hybrids, kinetics of phase transitions.



## RESEARCH AREAS

- Interface/interphase phenomena in composites and nanocomposites.
- Molecular reinforcing mechanisms in nanocomposites.
- Microscopic interpretation of large strain deformation response.
- Impact fracture mechanics.
- Rapid hierarchical structure formation.
- Viscoelasticity of hydrogels.

- Rheology of complex non-newtonian fluids.
- Microrheology with 2photon polymerization.
- Additive manufacturing nanotechnology.
- Biomechanics.
- Thermodynamics of phase transitions in homogeneous and heterogeneous polymer systems.

## TARGETED APPLICATIONS

- Mechanically robust hierarchical composites for engineering applications.
- Scratch resistant transparent nanocomposite coatings for automotive industry.
- Flexible ballistic materials.
- Impact resistant composites.
- Hard and soft tissue constructs.
- Functional coatings.

## CONTACT

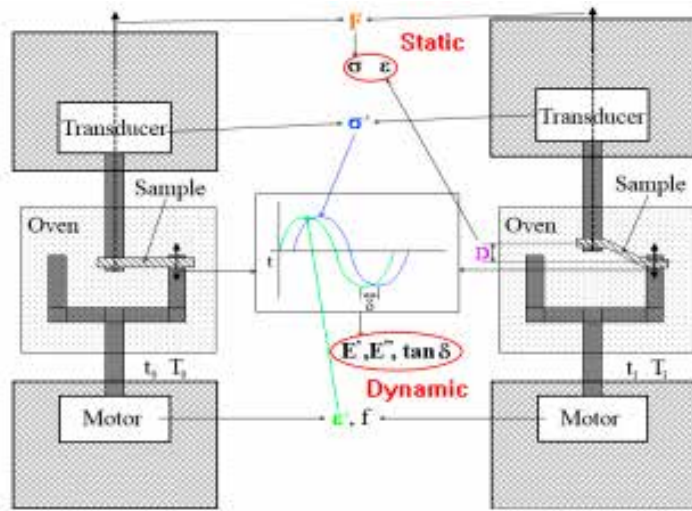
Prof. Josef Jančář, Ph.D.

Research Project Leader

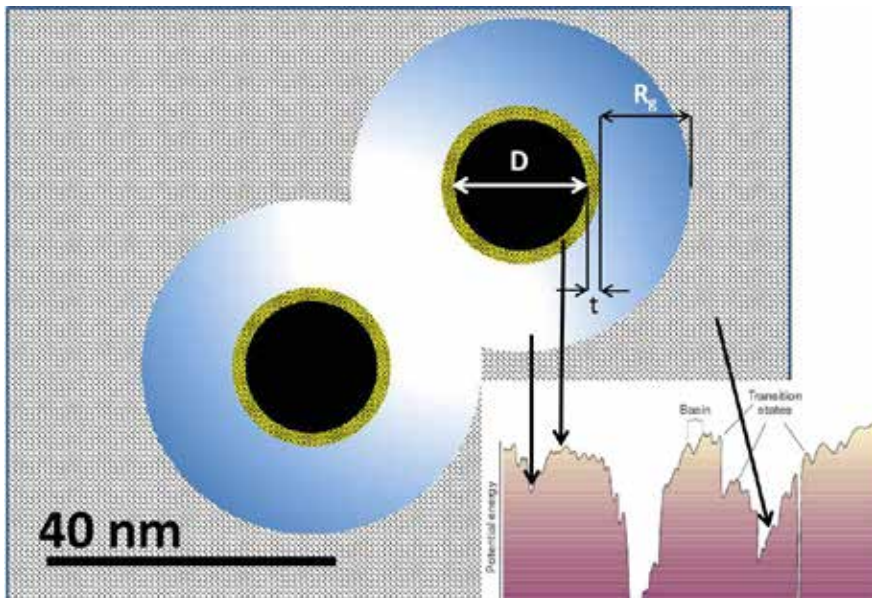
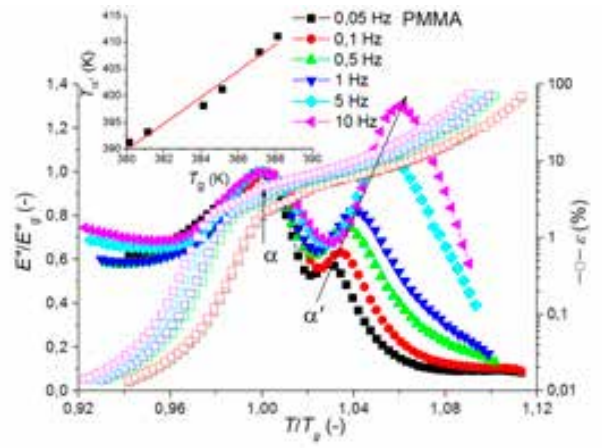
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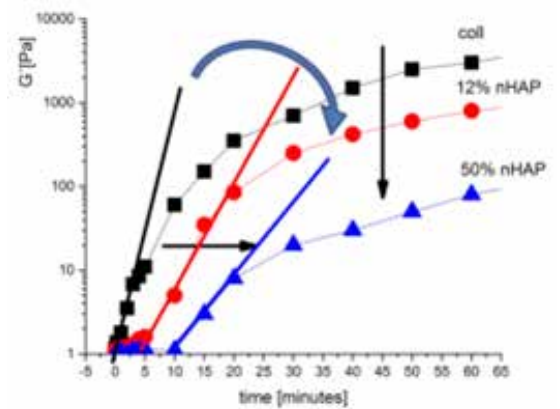
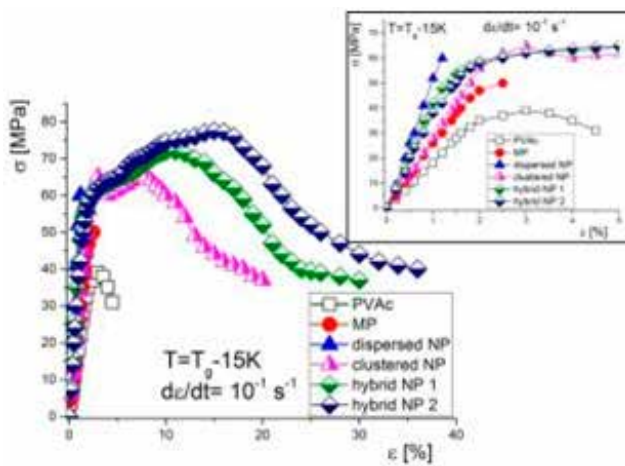




Simultaneous static and dynamic loading



Mechanics of hierarchical nanocomposites



Self-assembly in collagen/HAP nanocomposite hydrogels



# DEGRADATION AND STABILITY OF POLYMERS

## RESEARCH STRATEGY

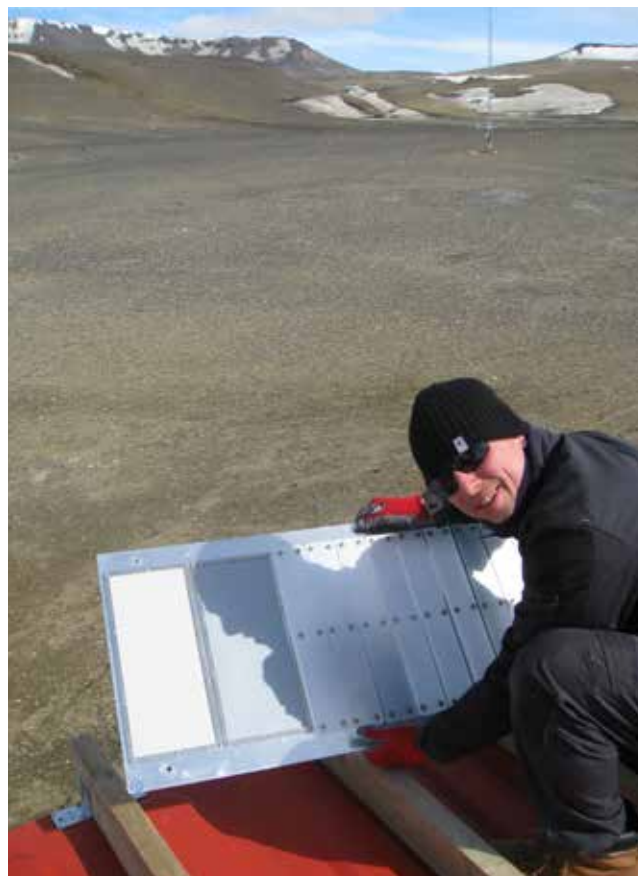
Generating and collecting information on effects of polymer type, morphology, chemical nature and additives on its stability under different conditions of processing, handling, storage and end-application to identify and describe the mechanisms of polymer degradation and design the solutions minimizing the changes in material properties in the course of time.

## RESEARCH AREAS

- Processing stability (kneading, pressing, processing – single/twin-screw/multiple extrusions).
- Thermooxidation stability (long-term heat ageing).
- Photooxidation stability (accelerated, artificial light-sources).
- Weathering (Brno-mid-European climate, Antarctica–specialized).
- Development of polymer stabilizer systems (thermo, UV, hi-energy, processing).
- Polymer additives (peroxides, fillers, flame retardants, antimicrobials, prodegradants).
- Prediction of polymer service-life.
- Troubleshooting for industry.

## MAJOR EQUIPMENT

- HAAKE laboratory extruder including rod, pipe, extruded tapes, melt-filtering and blown-film unit extensions (single screw 19 mm, L/D=30; Thermo Fisher Scientific).
- HORO heat cabinets 200 AVL (air-draft ovens).
- Thermooxidation ageing blocks with natural air-circulation (Liebisch).



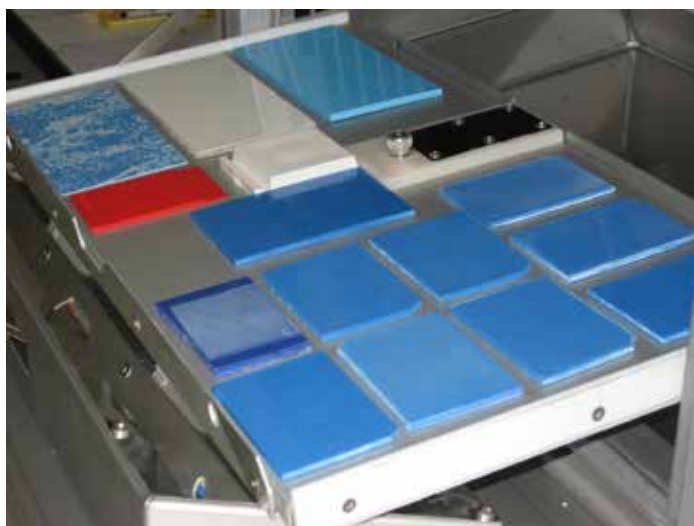
*Plastics outdoor exposure in Antarctica*



*Thermooxidation on synthetic polymers*



- Weather-Ometer Ci 4000, filtered Xe-light source, fully programmable (Atlas).
- Q-Suns Xe-1 test chambers using a filtered Xe-light source with or without exposure chamber conditioning (Q-Lab).
- Outdoor exposure weather station in Brno, CZ (Kipp-Zonen pyranometers, UV-A, UV-B incident radiation data collection).
- Outdoor exposure weather site at J. G. Mendel station in James Ross Island, Antarctica (a cooperation with Masaryk University Brno, CZ).



Plastics irradiated in Q-Sun test chamber

## TARGETED APPLICATIONS

- Evaluation of polymer stability and tendency to degradation.
- Determination of causes of polymer functional failure during processing and application.



- Design of stabilizing protective systems for commodity and specialty plastics and compounds.

## CONTACT

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# RHEOLOGY, THERMOMECHANICS AND COMPOSITE FABRICATION

## RESEARCH STRATEGY

Main effort in investigating fiber reinforced composites (FRCs) is put on research of hybrid reinforcements in respect to the effects of hierarchical spatial arrangement of various fiber and particulate filler types on deformation behavior and hydrolytic stability of FRCs systems for biomedical, aerospace and advanced structural applications. The development of procedures of this material class in the process of their synthesis and preparation is also targeted.

## RESEARCH AREAS

- Hybrid composites (e.g. toughening of particulate filled composite with short deformable fibers).
- Research and development of biomedical composites (e.g. dental FRCs).
- Adhesion between FRCs and particulate filled composites.
- Fiber/matrix interface – surface treatment and modification of glass, ceramic and organic fibers.
- Testing of the thermo-mechanical, visco-elastic, rheological properties and hydrolytic stability of materials.

## MAJOR EQUIPMENT

- Screw driven and electro-dynamic tensile testers with controlled bath designed for testing biomedical specimens.
- Instrumented impact pendulums and 2D impactors.
- High-speed video camera.
- Rheometers.



*Electro-dynamic tensile tester*



## CONTACT

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*Instrumented impact pendulum*





# FTIR, LASER CONFOCAL AND ELECTRONMICROSCOPY

## RESEARCH STRATEGY

Structural characterization of polymeric and bio polymeric materials, composites, ceramics, bones, teeth, polymer substrates for tissue engineering, etc. using microscopic techniques making possible to take images of objects from micro to nano-scale. Imagined is both the surface and internal structure, evaluated is the shape and dimensions (length, diameter, volume, roughness). The field of interest cover imaging of phase interface such as matrix-filler/reinforcement, particles (powders, tubes, short fibers) including distribution, aggregates and defects, fracture surfaces, porous 3D materials, units of supramolecular structure and so on.

## RESEARCH AREAS

- SEM observations in high resolution (micro to nanometer scale) and high depth of focus using multiple detection system (SE, BSE, STEM).
- Fast and highly accurate chemical microanalysis and elemental mapping of a sample surface, qualitative elemental analysis including determination of the distribution of each element and quantitative analysis of the individual elements in a sample.
- Preparation of samples for structural analysis: high vacuum sputtering and carbon coating of conducted layer in a thickness of nanometers, cutting of ultrathin sections ( $\leq 100$  nm).
- 3D imaging of topography and morphology of surfaces of solid materials including particles, fibers and thin films in micro scale using confocal mode.
- 3D nano scale mapping of surface area selected in micro scale using atomic force tip (AFM).
- Evaluation of molecular structure employing FTIR ATR mode.
- Composition and structure mapping of the area up to  $24 \times 24 \mu\text{m}^2$  (phase and interphase analysis, detection of impurities, aggregates etc.).



*FTIR microscope*

## MAJOR EQUIPMENT

- Scanning Electron Microscope (SEM) MIRA3 XMU (Tescan).
- Energy Dispersive Spectroscopy (EDS) Advanced AZTEC ENERGY X-MAX 20 Standard.
- Ultramicrotome Leica EM UC7.

- Sputtering and Carbon Thread Coater Leica EM ACE600.
- Confocal Laser Scanning Microscope connected with Atomic Force Microscope (CLMS-AFM).
- Fourier Transformed Infrared Microscope (FTIR Microscope).



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# THERMAL AND STRUCTURAL ANALYSIS OF POLYMERS AND COMPOSITES

## RESEARCH STRATEGY

Thermal and structural analysis of polymeric materials over a wide range of temperatures using multiple complementary methods providing feedback for establishing quantitative structure-property relationships, elucidating effects of processing and application conditions (temperature, time, pressure, UV) and effects of additives (nucleating agents, fillers, reinforcements, stabilizers).

## RESEARCH AREAS

- Crystalline structure of polymers.
- Kinetics of crystallization.
- Thermal decomposition and kinetics of decomposition.
- Temperature and UV-initiated cure kinetics.
- Composition and phase morphology.
- Chemical structure.

## TARGETED APPLICATIONS

- Homopolymers, copolymers, polymer blends.
- Fillers, reinforcements.
- Composites, nanocomposites.
- Biomaterials.
- Commercial product analyses.

## MAJOR EQUIPMENT

- Benchtop WAXS (Wide-Angle X-ray Diffraction).
- MDSC (Modulated Differential Scanning Calorimetry and Photocalorimetry).
- PDSC (Pressure Differential Scanning Calorimetry).



*Diffraction chamber of Benchtop with the sample of PA12 and particular diffractograms*



*Modulated DSC including Photocalorimeter and endothermic curves of the first and second heating of PA12 with  $\alpha$  and  $\gamma$  structure*



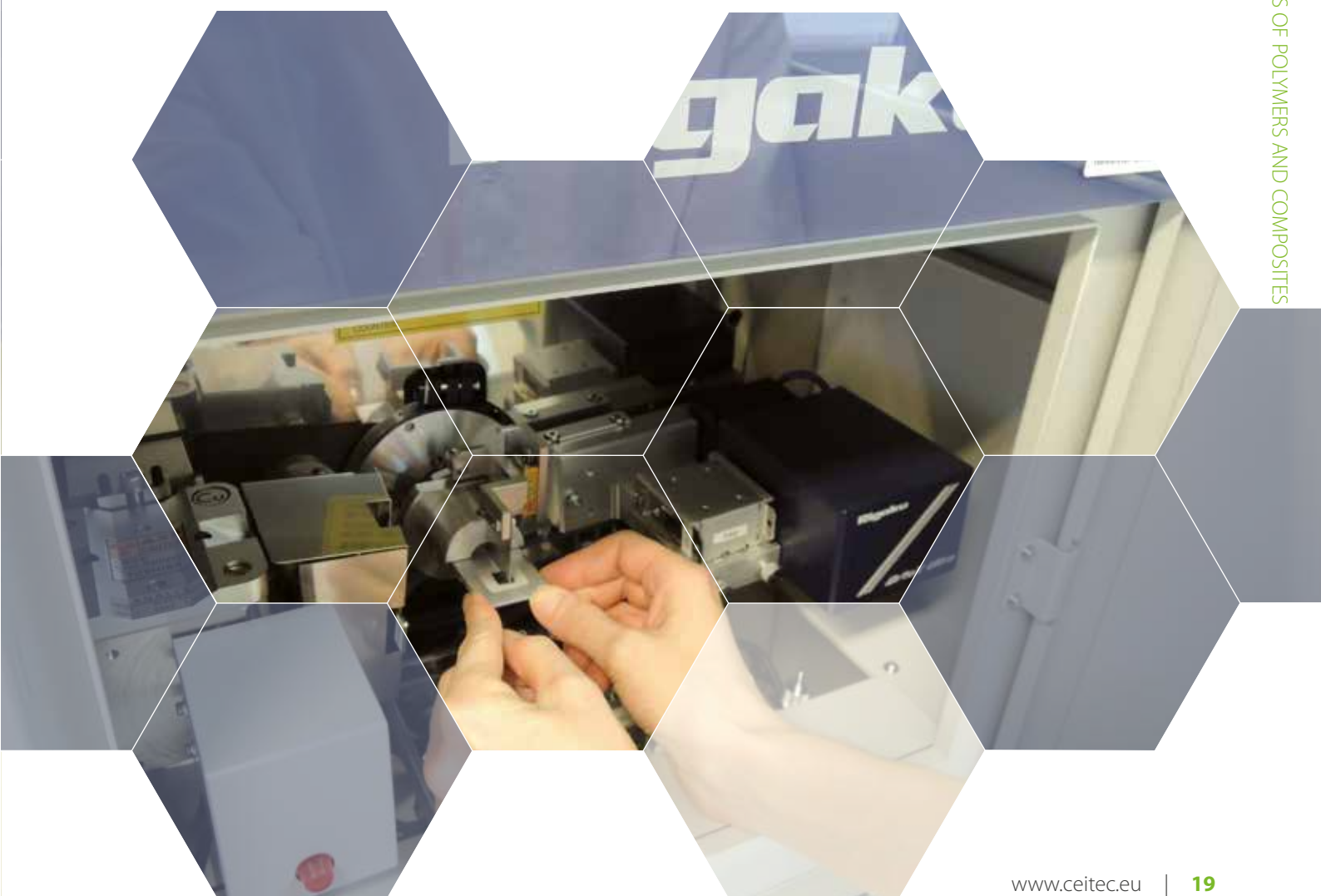
- MTGA-FTIR (Modulated Thermogravimetry combined with Fourier Transform Infrared Spectroscopy).

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# COMPUTER MODELING AND SIMULATIONS



## RESEARCH STRATEGY

Designing advanced computer models elucidating relationships between structure of polymers, biomaterials and hydrogels and their deformation behavior such as viscoelasticity, yielding, strain hardening and plasticity.



## RESEARCH AREAS

- Molecular dynamics simulation of gels and rubbers: Investigation of temperature, and stress responsivity of polymer rubbers and gels. Influence of time scale of deformation on the properties of polymers, prediction of dynamic behavior during yield and post yield deformation.
- Hard spheres models (HSM): In house software AGLOMER. Detection of (nano)particles distribution in the composites, detection of pores distribution in porous materials, structural analysis of heterogeneities in materials.
- 3D Reconstruction of samples from Computed Tomography (CT): Stereoscopic reconstruction of samples and visualization in 3D volume, the reconstruction of structure of tissues and tissue scaffolds.
- Modeling of physicochemical processes: Ab-initio model of fragmentation of molecules, model of chromatographic processes.



## TARGETED APPLICATIONS

- Prediction of rheological properties of hybrid physical/covalent hydrogels by molecular modeling.
- Application of AGLOMER (HSM) software for analysis of viscosity and plasticity of composites.
- 3D CT-reconstruction of heart tissue: recognition of tissue after heart attack.



## PRINCIPAL SOFTWARE

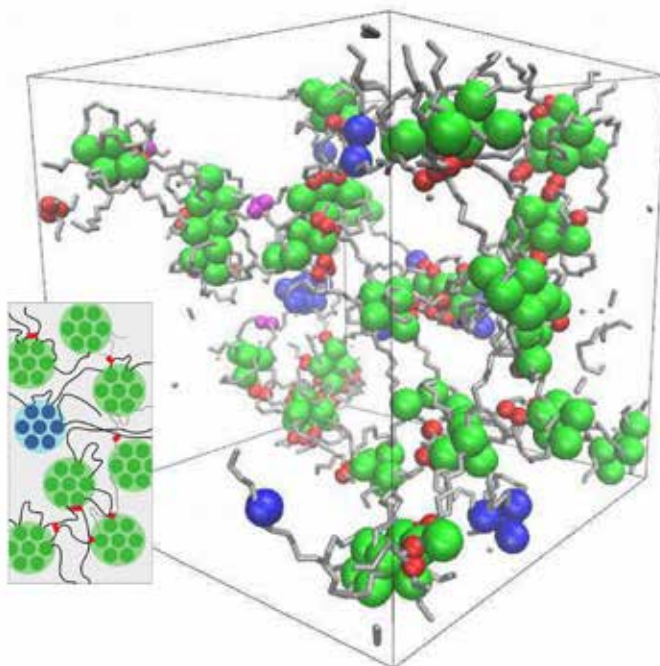
- Materials Studio, GROMACS - molecular dynamics package
- COMSOL- multiphysics simulation
- MeVisLab - 3D visualization
- MATLAB - scripting language
- VMD - visual molecular dynamics

## CONTACT

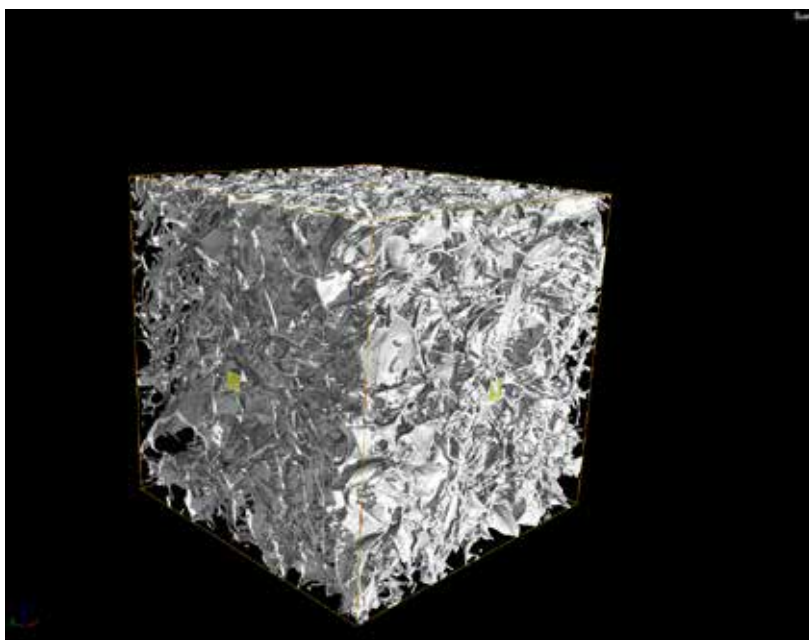
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*Model of the hybrid gel structure*



*Computer Reconstruction of the CT image of collagen tissue scaffold*

# POLYMER AND COMPOSITE PROCESSING

## RESEARCH STRATEGY

The main focus is on research of mechanisms and kinetics of reactions on polymers with specific interest in radical grafting reactions and reactive compounding of polymer blends and composites and on developing application specific multicomponent polymer formulations. Last but not least must be both thermoplastics and thermosets processing trouble shooting service and cooperation with plastic articles producers mentioned.

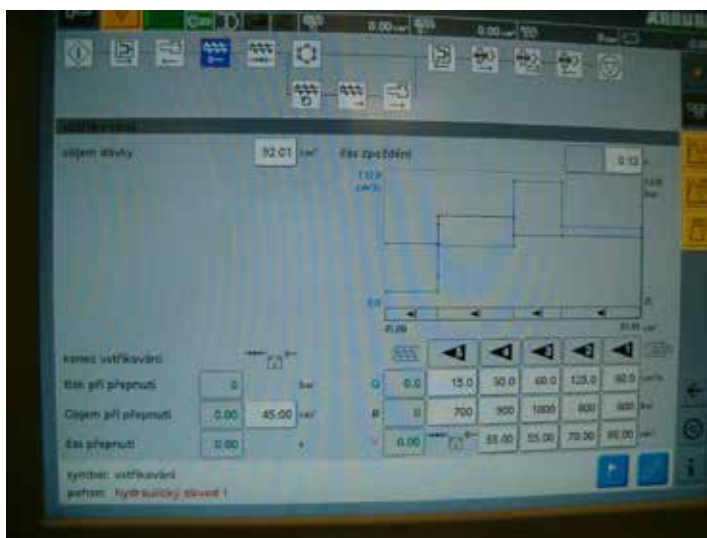


## RESEARCH AREAS

- Reactive extrusion (polymer grafting, end-reactions, cross-linking, vulcanization).
- Formulation and compounding of polymeric materials and blends (additives – e.g. stabilizers, nucleating agents, lubricants, fillers, flame retarders, antimicrobials, electro conductive polymers, photo- active compounds, compatibilizers, etc.).
- Rheological behavior of non-Newtonian fluids (flow curves, rheological additives).
- Morphology of (nano-)composites and (nano-)blends (surface adhesion, phase distribution, stress-strain behavior).
- Technical support for industrial polymer processing.

## MAJOR EQUIPMENT

- Brabender mixer electrically heated (300°C, 25 g PS, torque/time curves).
- Single screw extruder 16 mm L/D=25, tools for pellets, tape and sheet (300°C, torque/time, press).
- Flow reactor equipped with twin screw extruder 19 mm L/D=25-40 and conical side feeder (torque/time, inert atmosphere, vacuum).
- Gravimetric dosing units for all physical form (pellets, powders, flakes, fibers, liquids) of polymers, addi-



tives and reactants (inert atmosphere).

- Micro injection molding machine (max. 14 cm<sup>3</sup>, 2400 bar), mold for dog-bone 1A, 5A, plates.
- Dried air drying of polymers and additives.
- Capillary melt flow viscometer.
- Aquatrac water traces determination.



## TARGETED APPLICATIONS

- Grafted polymers synthesis for innovative applications.
- Development of polymeric materials for engineering applications.
- Technological testing of new polymeric materials.
- Polymer processing troubleshooting-analysis and solutions.



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