Fraunhofer ICT

Fraunhofer Institute for
Chemical Technology ICT

Polymer Engineering

Expertise in polymer engineering and composite materials

Fostering material and process innovation

Material and process innovations lead to the development of advanced products. Long-standing experience in material and process development makes our institute an expert partner for application-oriented research and development in polymer and composite technology - from the initial idea and concept development through to the manufacture of prototypes. Our researchers in the working groups for

- material development and compounding technologies,
- foam technologies,
- additive manufacturing,
- injection and compression molding,
- structural composites
- microwave and plasma technology, and
- material characterization and failure analysis

develop materials, processes and methods for our customers in the automotive, aerospace, construction, packaging, toy and leisure industries. In addition to individual topics along the value chain, we also provide solutions to long-term social challenges, in particular sustainable mobility, the circular economy, hybrid lightweight construction and the digitalization of process chains.

Networking

We strengthen our expertise through participation in Fraunhofer-wide thematic alliances and innovation clusters, and through our close scientific collaboration with the Karlsruhe Institute of Technology KIT, including in the Karlsruhe Research Factory for AI-Integrated Production.

With our two Fraunhofer Innovation Platforms for Composites Research in Canada and South Korea, we offer our customers an international research and development environment. Excellent contacts on a national and international level help to solve complex, interdisciplinary problems and address different markets and their requirements.

Possibilities for cooperation

Pre-competitive development tasks are mainly carried out together with our cooperation partners in national or international collaborative projects. Individual solutions are mostly developed in direct bilateral cooperation with our customers on a contractual basis.

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Pultrusion profiles with a thermoplastic matrix made of polyamide 6.

Our lead topics

what motivates us...

Sustainability

Efficient recycling and optimized material cycles have become a key topic in global economic and social advancement. Whenever new processing chains are developed, an essential consideration is how to close the material cycles. For example, we are developing improved material formulations based on secondary raw materials, biobased and recyclable material systems, energy-efficient processing and biobased, self-reinforced composites.

Flexible manufacturing technologies

Industrial manufacturing requires increasing flexibility to enable product individualization. Economically viable implementation can only be achieved through shorter development and production times, greater production agility and the efficient use of resources. We are meeting these challenges in the development of modular and adaptable manufacturing technologies and process chains, and in the further development of additive manufacturing.

Artificial intelligence

Using artificial intelligence to optimize products, processes and materials is one goal of digitalization. Drawing on our core expertise in polymer and composite materials technology, we are using machine learning methods and accompanying simulation to enable new processes and optimize existing ones. The development of digital twins of plastic processing methods and materials, and their connection to a virtual production process, are a current research priority.

Lightweight construction

Lightweight construction conserves resources, energy and the climate. The sector-specific design and construction of lightweight solutions determines the material selection and manufacturing processes. At Fraunhofer ICT we develop polymer-based fiber composites and efficient process chains for their manufacture. Key research topics include long- and continuous-fiber-reinforced polymers with a thermoset and thermoplastic matrix, and their functionalization. With regard to recyclability, self-reinforcing plastics - so-called monomaterial systems - are also the focus of research in this area. In close collaboration with the KIT we develop methods, processes and materials.

Material innovation

Modern materials need to meet both structural and functional requirements. Their targeted development requires a profound understanding of material behavior, as well as a great deal of experience in material formulation. Current research emphasizes functional materials which, in addition to their structural properties, have functionalities such as electrical or thermal conductivity, improved acoustic properties, scratch resistance or antibacterial properties. Programmable materials produce a targeted reaction to changing environmental conditions or stresses. Sustainability considerations along the value chain have high priority. Our research therefore focuses on biobased material systems, material formulations based on recycled components, and novel recycling concepts.

Material development and compounding technologies

The research group for material development and compounding technologies has many years of expertise in the development of formulations for thermoplastic compounds, and in the development of innovative compounding processes.

Material development – tailored formulations

When manufacturing high-quality products from plastics, crucial aspects include the selection of the right ingredients and optimal process design. Based on many years of experience and the latest scientific findings, we develop material formulations in cooperation with our partners. Depending on the desired property profile, we can incorporate powders, granules and fibers, and dose low and high-viscosity liquids or gases, also in supercritical state.

The addition of functional fillers and additives enables targeted adjustments to the properties of plastic compounds. Stabilizers, for example, often enable the production and processing of compounds in the extrusion process without degrading the material. Reinforcing fibers provide the requisite mechanical properties of the component.

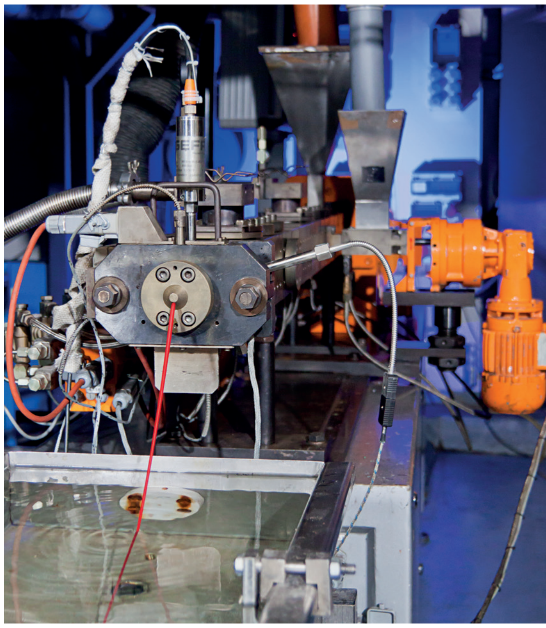
Process development – continuous mixing processes

Process development includes all tasks from the optimization of a screw configuration through to the development of material-specific extruder configurations including the necessary dosing and pelletizing strategies. Besides the optimization of conventional compounding processes, we also develop completely new process variants for twin-screw extruders. Examples include extractive compounding or reactive extrusion processes.

Our expertise in material and process development

- General compounding tasks
- Biopolymers and natural-fiber-reinforced polymers
- Reprocessing/re-formulation of recyclates
- Purification/odor reduction/emission reduction
- Functional compounds
- New materials for additive manufacturing methods
- Polymerization and polymers
- Modification by reactive extrusion
- Online process control
- Safe handling of reactive materials and nanomaterials in extrusion

Fraunhofer ICT has a fully equipped and flexible extrusion pilot plant. Extruders with various diameters and processing section lengths enable the demonstration of different processing concepts. The incorporation of alternative energies such as microwave heating or ultrasound, and the use of supercritical fluids in compounding technology, significantly expand the processing window. A comprehensive range of dosing and pelletizing technologies enables the visualization of complex processes.



Compounding line for the manufacture of functional polymer compounds.

Polylactide pellet: starting material for the production of mono-material systems.

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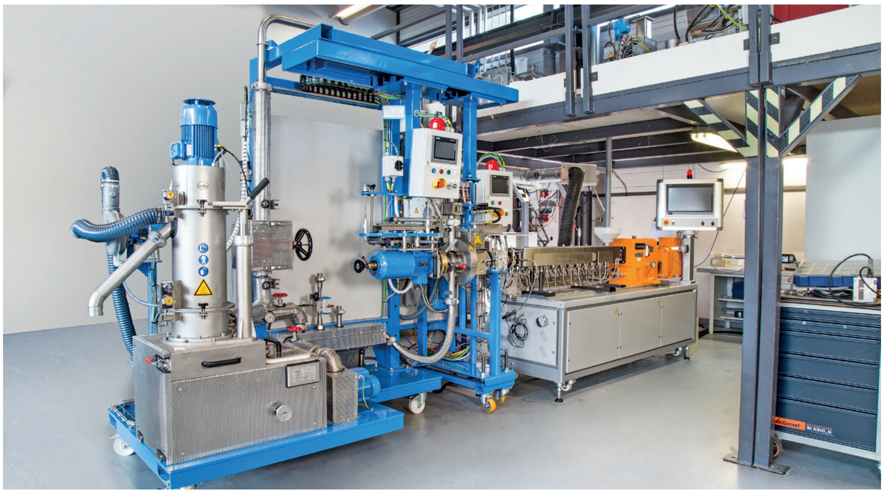
Foam technologies



Particle foam line for the continuous production of particle foams.

Foamed materials are increasingly used for transport packaging, heat insulation of buildings and also in the automotive sector. The goal in developing new foamed materials is, for example, to optimize mechanical properties, temperature stability and recyclability.

Material development for thermoplastic foams

Foams with tailored properties have attracted increasing attention in the field of material development. At Fraunhofer ICT, emphasis is placed on the development of foamable polymers in the extrusion process, based on renewable or recyclable resources and on the targeted use of functional additives. This can improve the mechanical and thermal properties, for example, or enable environmentally friendly fire protection. Additional trends include the development of high-performance foams from technical polymers, and the hybridization of foams, for example in sandwich processes.

Material development for innovative particle foam components.

Process and material development for extrusion foams

For the development of extrusion-foamed semi-finished products, sheets and foils, Fraunhofer ICT has a cutting-edge Schaumtandex laboratory unit, which consists of a twin-screw and a single-screw extruder. This production line makes it possible to test and further develop new material and blowing agent formulations while limiting the use of resources. In our development work we draw on our extensive material and process know-how in the field of foam extrusion.

Process and material development for particle foams

Fraunhofer ICT offers the following development services and expertise in the field of particle foam technology:

- material development and optimization of the foam structure in the extrusion and autoclave process,
- development of foamed granules, or granules containing a blowing agent, by extrusion and subsequent underwater pelletizing,
- investigations into the foaming of granules to generate foamed particles in the laboratory pre-foamer,
- investigations into molding processes based on steam and radio frequency,
- testing of foam properties in our own test laboratory.

This complete process chain forms the basis for successful cooperation with our partners. New material mixtures can be quickly characterized in terms of their processability and component properties, for example insulation properties.

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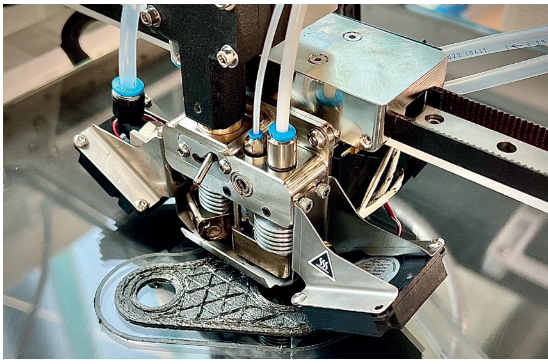
Additive manufacturing

The development of new materials and processing technologies is the core task of the research group for additive manufacturing. In order to exploit the significant potential of additive manufacturing processes in industrial applications - including design freedom, production flexibility and product individualization - we are researching new material options and possible material combinations as well as the influence of the printing strategy and parameters on the properties of the final component.

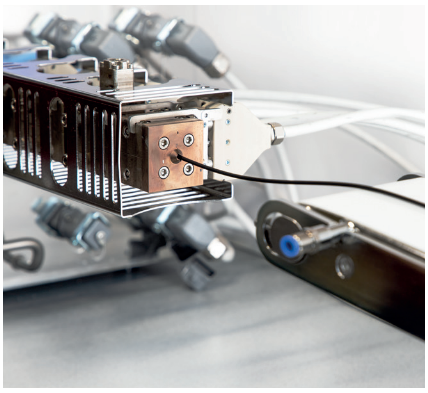


Printing process of a continuous-fiber-reinforced component.

Material development and functionalization

Depending on the application, experts select thermoplastic matrices and suitable (functional) fillers. In general, any commercially available plastic can be used as a matrix material for extrusion-based additive manufacturing. Biobased and biodegradable polymers (for example PLA, PHB) are produced, modified and optimized for the processes. High-performance thermoplastics (for example PEEK, PPS, PPSU) reinforced with short glass or carbon fibers are suitable for demanding applications in cases where conventional engineering thermoplastics cannot be used. Metals or carbon-based materials can be used as fillers, for example in electrically conductive composites.

Extruder for filament production.



Processability, in particular the melt viscosity of the composite, also plays an important role. The technical equipment for material development ranges from various small mixers, kneaders and extruders through to pilot plants in which the composite material is compounded into granules. A filament extrusion line is also available for the production of thermoplastic filaments with diameters of 1.75 mm and 2.85 mm.

Process development and prototyping

The targeted properties of the printed parts depend on the entire production chain, from polymer compounding through to filament production and printing. Our specialists monitor the entire production chain and carry out technological and economic optimizations to both the material composition and the production processes. With our cutting-edge filament manufacturing and additive manufacturing equipment, we can tailor the material and process to meet our customers' requirements.

By combining conventional short-fiber-reinforced or unreinforced polymers with continuous glass- or carbon-fiber reinforcements, the mechanical properties of additively manufactured parts can be significantly improved. We are researching the integration of continuous fibers on both desktop and industrial scales, in order to qualify additively manufactured parts for new applications. Process development in additive manufacturing includes the extrusion-based additive manufacturing processes ARBURG Plastic Freeforming, with a two-component freeformer 200-3X, and one- and two-component fused filament fabrication (FFF). Accompanying technologies are also available, such as plasma processes for the pre-treatment of printable substrates, microwave processes for the post-treatment of additively manufactured components, and the characterization of materials and components in our test laboratory.

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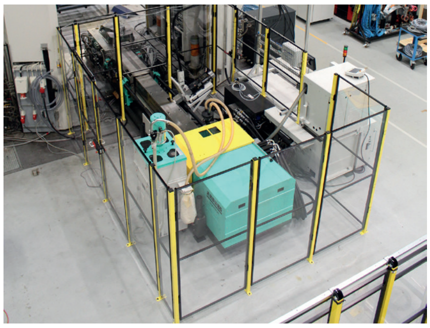
Injection and compression molding

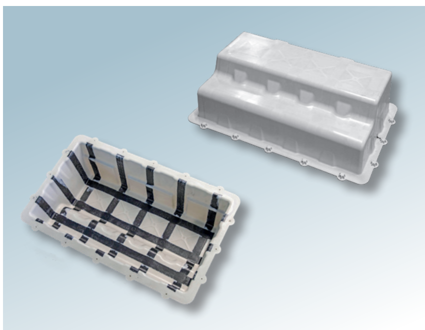
The research group for injection and compression molding specializes in the development of large-series processing technologies for flowable material systems. In addition to standard injection and compression molding processes, work is focused on single-stage, resource- and energy-efficient direct processes, tailored local continuous-fiber reinforcement, and the functionalization of monomaterial systems.



Modular long-fiber injection molding unit combined with a 3,600 ton press.

Injection molding

Thermoplastic and thermoset material systems are processed using cutting-edge, high-volume technology. The focus is on the processing of high-performance plastics, and on hybridization technologies and thermoplastic foam molding. Together with our partners we develop material compositions and processes for foamed components using both chemical and physical (Mucell®) blowing agents. In comparison to conventional thermoplastics, thermoset polymers and high-performance thermoplastics have advantages in terms of media and temperature stability. This makes them attractive for demanding applications, allowing them to be used, for example, as substitutes for aluminum diecast material.



Traction battery housing made of SMC (white) with local unidirectional continuous-fiber reinforcement (black).

Sheet molding compound (SMC)

The thermoset composite sheet molding compound (SMC) enables lightweight construction solutions in application areas that are characterized by stringent requirements regarding mechanical, chemical and thermal load. Activities at Fraunhofer ICT include formulation development, the use of novel resin systems and reinforcing fibers, and the development of an optimized process control. Here, both conventional thermoset and thermoplastic resin systems are further developed, for example for applications in the automotive and commercial vehicle industries.

Direct processes with in-line compounding in injection and compression molding

When compounding technology and molding are combined into a single process, plastic processors gain new, innovative options to improve the mechanical properties of components while saving energy and material costs. By incorporating fibers directly during the material processing, longer fiber lengths can be achieved than with conventional processes based on semi-finished products. This technology offers particular flexibility due to the multiple possible combinations of the matrix materials and reinforcing fibers, such as standard, natural and recycled fibers.

Selective use of unidirectional fiber reinforcements

We achieve maximum lightweight construction potential for components through the selective and resource-efficient use of continuous-fiber reinforcements in areas exposed to high loads. By introducing unidirectional fiber reinforcements into the matrix, the specific properties of flowable material systems can be further improved to enable structural application. 3D skeleton winding technology (3DSW) and the use of local UD prepregs offer large-scale solutions for local continuous-fiber-reinforced components in injection and compression molding.

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Structural composites

The structural composites group is specialized in the development and optimization of materials and processes for the manufacture of high-performance lightweight structures. The highest component strengths can be achieved through the targeted use of continuous fibers.

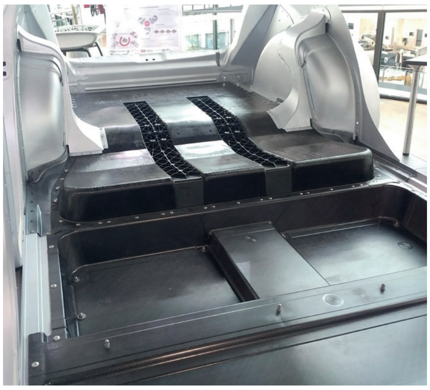
Material development

Many raw materials and semi-finished products can be used to manufacture fiber composite structures. We support our customers in the development and selection of the right matrix and fibers, as well as semi-finished products to achieve the best material properties and at the same time enable efficient manufacturing. We work with both thermoplastic and thermoset matrix systems using the available fiber types and production processes suitable for series production. The functionalization of materials and combined processes plays a major role in our work.

Process development

Our large portfolio of manufacturing processes allows us to efficiently manufacture fiber composite structures on an industrial scale.

Lightweight vehicle underbody demonstrator.



Our expertise lies in a holistic approach to the entire process chain and the optimization or enhancement of individual processes to meet the required quality and production rate. One of our core competences is the validation of the manufacturing processes and the plant technology in an industrial environment within our own facilities.

Benefit from our expertise

- Consulting on process and material selection, optimization of manufacturing concepts and process chains for continuously fiber-reinforced composite structures
- Production of samples for material characterization
- Commissioning and implementation of customer-specific molds
- Fully equipped test setups to characterize the deformation behavior of dry and wet semi-finished textiles
- Preforming: Automation and optimization of the subprocess steps of cutting, handling, draping, and trimming
- RTM/HP-RTM: Reactive thermoset and thermoplastic processing with injection pressures of up to 200 bar
- Equipment for the processing of epoxy resin systems, polyurethanes and caprolactam (in-situ polymerization)
- Wet compression molding and prepreg compression molding: Characterization and further development of the processes and their derivatives
- Automated thermo-forming or compression molding of thermoplastic and thermoset fabrics and laminates

Hybrid seat back manufactured on a modular production line.

- Tape laying on industrial scale, energy-efficient consolidation of fiber-reinforced semi-finished products and their combined processing, for example by compression (LFT-D) or injection molding
- Manufacture of profiles by pultrusion (open bath pultrusion and pultrusion with injection chambers; with thermoset and thermoplastic matrix systems)
- Process data acquisition and evaluation for documentation and simulative validation

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Microwave and plasma technology

In the field of microwave and plasma processing technology, our team of experts focuses on the development of production and measurement technologies. The numerical simulation of microwave and plasma processes designed specifically for this purpose often enables the rapid development of processing solutions.

Microwaves

The thermal processing of non-metallic materials such as plastics, glass or natural materials is usually carried out using contact heating or infrared radiators. These processes heat up the surface of the material, and the heat diffuses into the material until the desired temperature is achieved. The low thermal conductivity of these materials makes this process rather time-consuming.

Microwaves are non-ionizing electromagnetic waves. They are absorbed by polar and magnetic materials, and by materials that are poor conductors of electricity. With their long wavelength, microwaves have a high penetration depth into many non-metals. The quick, contact-free volumetric deposition of heat deep inside the material can therefore be achieved independently of the thermal conductivity. Our work focuses on the development of processes, production lines and material formulations for the industrial use of microwave technology. Current development areas include microwave-assisted chemistry, desorption processes, pultrusion, de-bonding and the RTM process.

Microwave plasma unit, large-scale

Plasmas

Plasma coating methods such as PECVD (plasma enhanced chemical vapor deposition) can equip the surfaces of various materials with thin functional layers that significantly improve the properties or application suitability of the components. The coated surfaces have properties that often cannot be achieved using conventional coating methods. Plasmas generated with microwaves protect the surface and achieve high coating rates. Together with our partners, we develop new coating methods and transfer them to industrial processes. Developments include a highly efficient new method of coating polycarbonates with a scratch-resistant coating, and an extremely effective corrosion protection for metals such as high-strength steels or aluminum alloys. A new nanoporous adhesive layer significantly improves the adhesion of polymers or adhesives in hybrid components, for example metal-polymer composites. Both vacuum and atmospheric pressure plasmas are used.

Corrosion-resistant layer on Damascus knife, as an example of a corrosion-resistant layer on metals.

Simulation

Simulation technologies already facilitate and accelerate the design and the construction of technical systems in many areas. Using commercial software and models developed in-house, we calculate electromagnetic fields in microwave plants and the related heat or plasma generation, and use this information to support production technology and process development.

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Material characterization and failure analysis

In our testing laboratory we carry out comprehensive investigations into polymer materials along the entire processing chain, from the raw material through to the component. We generate material data for structure and process simulation and, in the event of failure, we offer a systematic analysis of the causes and influences.

Sample manufacture

Test results can only be used to draw comparisons if the methods applied in the sample production and preparation of the different materials are identical. The following standardized sample production methods are available in Fraunhofer ICT's technical centers and laboratories:

- Injection molding for thermoplastics and free-flowing thermosets
- Production of sheet material for the manufacture of test samples by compression molding
- Mechanical separation processes and hot wire cutting
- Tab strip preparation
- Conditioning of samples in climate chambers

Mechanical testing in the material testing laboratory

- Tensile test with measurement of lateral contraction
- 3- and 4-point bending test
- Interlaminar shear strength test (for example ILSS, tensile shear test, shear edge test, etc.)
- Compression test, e.g. for fiber composites or foams
- Impact strength/notched impact strength (Charpy) and puncture test
- Bond strength test (for example lap-shear test)
- Heat distortion temperature and Vicat softening temperature
- Dynamic mechanical analysis (DMA)
- Characterization of the deformation behavior of semi-finished products

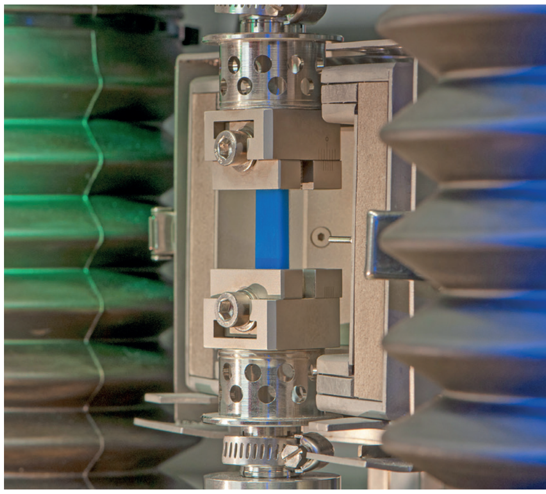
Rheological and supplementary testing methods for plastics

- Shear viscosity measurement (high-pressure capillary viscometer and plate-plate rheometer)
- Elongational viscosity of plastic melt (Rheotens)
- Melt index test (MFR/MVR)
- Measurement of specific volume as a function of pressure and temperature (pVT measurement)
- Measurement of fiber content and length
- Measurement of moisture content
- Shore-hardness (Shore A and Shore D)
- Density measurement (immersion method)
- Colorimetry
- Measurement of wetting angle/ measurement of interfacial energy
- Thermal analysis (DSC, TGA, TG-MS etc.)
- Spectroscopy (FTIR, UV-VIS)
- Thermal conductivity measurements
- Aging and weathering

Microscopy and preparation methods

We offer comprehensive know-how in the preparation and microscopy (LIM and REM) of plastic and fiber-reinforced plastic samples, such as:

- Crystallinity of polymers
- Visualization of cavities/pores, fiber impregnation
- Fiber and particle distribution in polymers
- Morphology of polymer blends
- Measurement of layer thickness of surface coatings



Dynamic mechanical analysis (DMA) under tensile stress.

Series extraction, for example to measure residual monomer content.

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Our pilot plant technology

Fraunhofer ICT has cutting-edge facilities and equipment to meet the requirements of application-oriented research and development.

Material development and compounding technologies

- Various twin-screw extruders
  - Screw diameter: 16-40 mm
  - Processing section length: 36-60 D
- Film production line up to 200 mm film width
- Various gravimetric feeders for the dosing of pellets, powders and flakes in the range of a few grams to more than 250 kilograms per hour
- Dosing technology for special processes
  - Dosing feeders for milled/cut fibers
  - Gas dosing station for nitrogen, hydrocarbon and carbon dioxide
  - Dosing systems for liquid and highly viscous media
  - Liquid dosing for suspensions of nanoparticles
- Gas-tight melt filter that can operate with constant pressure
- Application of ultrasound and microwaves in extrusion
- Process integration of inline analysis methods (viscosity, Raman, NIR, pressure, temperature, residence time)
- Strand pelletizing, underwater pelletizing (also for the production of microgranules) and hot die pelletizing, for variable use in all extruders
- Various dryers for pellets
- Various vacuum pumps based on water rings or rotary vane technology for up to 1 mbar
- Laboratory press for the production of test samples
- Analytical methods for dispersion conditions
- Measuring station for surface and bulk electrical conductivity
- Various production lines for filaments used in 3D printing
- Safety facilities and extraction systems for working with nanomaterials and hazardous substances in the extruder

Foam technologies

- Particle foaming technology
  - Two particle foam lines with twin-screw extruders and underwater pelletizing
  - Compounding technology for gas-loaded granules
  - Production technology for directly foamed particles
  - Prefoamers and pressure loading
  - Laboratory steam chest molding machine
  - Steam chest molding machine on an industrial scale with a freely-programmable control system
  - Radio-frequency-based laboratory-scale molding machine
  - Various mold geometries for components
  - Variotherm mold technology for particle foam processing
- Foam extrusion
  - Tandem foam extruder for foamed semi-finished products, sheets, and foils
  - Wide slot, hole and annular gap nozzles
  - Several gas dosing stations (two membrane pumps and a compressor station for liquid and gaseous blowing agents, HPLC pumps, etc.)
- Autoclave technology
  - Various autoclaves up to 15 l volume
  - Dosing of various blowing agents

Additive manufacturing

- Production lines for filled and fiber-reinforced filaments with 1.75 mm and 2.85 mm diameter, including equipment for process monitoring of diameter and roundness

Injection molding compounder.

- 2-component printer for standard plastic granules based on Arburg Plastic Freeforming:
  - Arburg freeformer 200-3X
  - Build volume 154 × 134 × 230 mm
  - Build plate and build space temperature max. 120 °C
- Several 1-component printers for standard filaments based on fused filament fabrication (FFF)
- Industrial robot with 50 kg manipulation weight and an experimental print head for the production of continuous fiber-reinforced skeletal structures
- Several 2-component printers based on fused filament fabrication (FFF), including:
  - German RepRap X500 for processing filled, functionalized and short-fiber-reinforced filaments
    - Build volume 500 × 400 × 450 mm
    - build plate temperature max. 120 °C
    - build space temperature max. 80 °C
    - extruder temperature max. 400 °C
  - Anisoprint Composer A3 for processing continuous-fiber-reinforced filaments
    - build volume 420 × 297 × 210 mm
    - build plate temperature max. 150 °C
    - build space temperature max. 100 °C
    - extruder temperature max. 350 °C

Injection and compression molding

- Compression molding technology
  - Parallel-operating hydraulic compression molding machines with clamping forces of 6,300 and 36,000 kN for the processing of thermoplastic and thermoset fiber composites
- Dieffenbacher LFT-D inline compounder comprising two 40 mm twin.screw extruders with up to 150 kg/h throughput
  - Gravimetric dosing of polymer, masterbatch and additives
  - Direct fiber roving intake for glass and carbon fiber
  - Plate molds for material characterization (400 × 400 mm²)
  - Various demo structures (ribbing and beading, overmolding of continuous-fiber reinforcement, warpage)
- SMC technology
  - SMC production line with glass and carbon fiber cutting unit for widths of up to 1.600 mm
  - Vacuum unit for evacuating molds
  - Mixing laboratory with various dissolvers, twin-screw extruders
  - Measurement technology (Brookfield viscosimeter, plate-plate-rheometer)
  - Testing technology (DSC, TGA, plastometer, qualisurf, mechanical testing, etc.)
  - Extrusion compression molding rheometer with in-mold pressure sensors
  - Various molds for testing and prototype production
- Injection molding technology
  - Clamping force: 600-36,000 kN
  - Equipment suited to high processing temperatures
  - Specialized technologies: LFT-D-IM, FDC, TSG, MuCell®, LFT-D foams, expansion foams, multi-component injection molding, mono sandwich, counter-cycle injection molding, cascade injection molding, injection embossing
  - 7,000 kN injection-molding compounder with a 40 mm twin-screw extruder (48 D)
  - 5.500 kN injection molding unit with a fully-automated manufacturing cell for the processing of thermoplastic and thermoset polymers

- 36.000 kN injection press with bolt-on injection molding units:
  - 80 mm FDC injection unit
  - 90 mm standard injection unit
- Various production and sample molds with integrated sensor systems for process monitoring
- Hybrid technologies
  - Robot-based 3D filament winding technology for the manufacture of complex skeleton structures
  - Metal-plastic hybrids
  - Back-injection of planar laminates
- Heating technology: IR-heating panels, contact heating table, and various heating cabinets

Structural composites

- Thermoplastic prepreg processes
  - Automated thermoplastic tape-laying process
  - Radiation-induced vacuum consolidation of laminates
  - Consolidation of (sandwich-) laminates
  - Fully-automated production cell for the forming of semi-finished products with a 3,600 t press
  - Overmolding of laminates using LFT-D or an injection unit
- Pultrusion
  - Pultrusion with reactive thermoplastics and thermoset matrices
  - 2C dosing systems for caprolactam and polyurethane
  - Caterpillar puller with 8 t pulling force and 3 m/min
  - Recording of process and material parameters, energy consumption, CO_2 emissions, etc. in central database
  - Various dies with and without injection and impregnation chambers
  - Diverse sensor and measurement technology
  - Bobbin racks for glass and carbon fibers with external and internal winding
- RTM/WCM technology
  - High-pressure RTM in various process variants (IRTM, CRTM, PC-RTM)
  - Thermoplastic RTM (caprolactam)
  - Dosing systems with 2 to 3 components (EP, PUR, PA6)
  - Recording of RTM and compression molding parameters in a central database
  - Prepreg compression molding
  - Various master and sample molds
  - Temperature-controllable universal test stand for (sequential) draping
  - CNC cutting table

Microwave and plasma technology

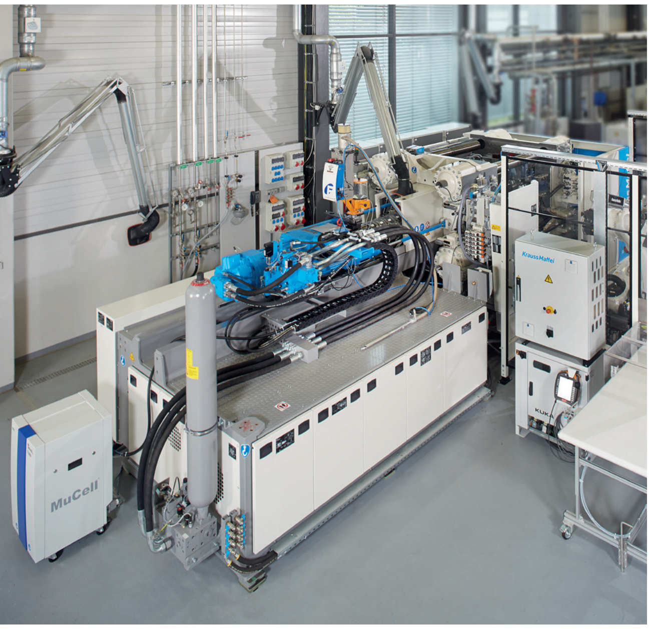
- Microwave plants
  - Generators (including semiconductor generators) with an output of 1.2 to 6 kW at 915 MHz, 2.45 GHz, and up to 5.8 GHz
  - Directional coupler for impedance measurement, leakage radiation meters
  - Lab facilities for measurement of dielectric properties

Schaumtandex extrusion line (left) and high-pressure RTM processing unit consisting of a hydraulic press and a high-pressure injection unit for the production of high-performance fiber composites (right).

  - Production technology for large-area and local resin curing
  - Pyrolysis unit for the recovery of carbon fibers from composites
  - Microwave-based sensors for process monitoring
- Plasma technology
  - Low-pressure area plasma, 500 × 1.000 mm application area, 8 × 2 kW power
  - Low-pressure plasma line, 8 gas channels, ECR plasma, 1000 mm plasma length
  - Atmospheric pressure plasma system, 2 plasma nozzles for coating, 500 × 500 mm coating area
- Simulation
  - FEM software for the solution of multiphysical tasks
  - Hardware with 512 GB RAM and 64 processor cores

Material characterization and failure analysis

- Mechanical testing
  - Universal testing machine (50 kN and 5 kN) with fixtures for bending, tensile and compression testing, and optical and mechanical extensometry
  - Impact pendulum and drop weight impact test
  - HDT/Vicat device
  - Dynamic mechanical analysis (DMA)
- Rheological characterization
  - High-pressure capillary viscometer
  - Rheotens® device for the measurement of extensional viscosity
  - Melt index testing device
  - Rotating or oscillating viscometer (plate-plate, cone-plate)
- Interface characterization
  - Contact angle measurement device
- Thermal analysis
  - Differential scanning calorimetry (DSC)
  - Thermogravimetry TG-MS, pyrolysis-GC-MS
  - Macro-TGA and microwave ashing to determine the fiber content
  - Thermal conductivity measurement
- Microscopy
  - Light microscopy (incident light and transmitted light), polarization
  - Scanning electron microscope with element analysis (SEM-EDX)
  - (Cryo-)microtome, grinding and polishing machines
  - White light interferometer
  - Fiber length measurement (FASEP®)
- Spectroscopy
  - FTIR with ATR attachment, IR microscope
  - UV-VIS and NIR
- Flame tests
- Climate chambers
- Outdoor weathering test unit



Injection molding production cell for processing free-flowing, thermoset materials and thermoplastic injection molding pellets (left) and Fiberforge system for fully automated processing of unidirectional fiber-reinforced thermoplastic tapes (UD tapes) (right).

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