Fraunhofer ICT

Reactive Extrusion

Continuous polymer production/modification using co-rotating twin-screw extruders

Reactive extrusion is continuous, chemical polymer modification or polymer synthesis in an extruder. It enables polymer-analogous reactions to be carried out without the use of a solvent. It also allows polymers to be further processed, mixed with other polymers (blended) or introduced directly into the component in an injection molding process, directly after modification.

Top: Starch-based materials produced by reactive extrusion

Bottom: Pilot-scale co-rotating twin screw extruder (left) Twin screw extruder in operation (right)

Advantages of reactive extrusion

- Cost savings through elimination of solvent
- Handling of higher viscosities up to 10^6 Pa·s
- Optimal mixing and heat transfer conditions through adjustment of screw and barrel design
- Cost and energy savings due to fewer processing steps
- Improved material properties, as exposure to thermal stress is minimized

Reactive extrusion: experience and applications at Fraunhofer ICT

1. Bulk polymerization from a monomer/low-molecular-weight prepolymer:
→ e.g. ring-opening polymerization of PLA, polycondensation of PGA, repolymerization of PET oligomers, step-growth polymerization of TPU

2. Functionalization and grafting reactions through linking of monomers/oligomers to polymer backbone
→ e.g. radical grafting of anhydride onto polymers

3. Interchain copolymerization between two or more polymers with copolymer formation
→ e.g. modification of thermoplastic starch by copolymerization with anhydride-grafted biopolymers

4. Coupling or branching with poly-functional coupling agent to increase the length of the homopolymer chain
→ e.g. PET chain extension with difuctional anhydride

5. Degradation reactions decreasing the molecular weight of the polymer
→ e.g. degradation of PET with ethylene glycol, devulcanization of rubber

Equipment available at Fraunhofer ICT

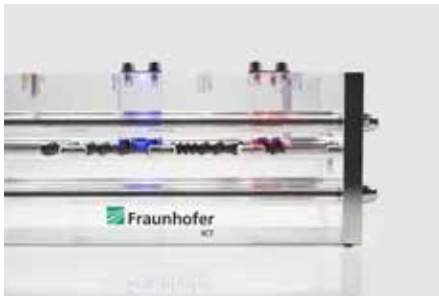
- Mini-scale extruder (batch compounder):
  - twin-screw with backflow channel
  - capacity of 6-10 g
- Lab-scale extruders (limited flexibility):
  - screw diameter of 12-16 mm
  - throughput below 2 kg/h
- Pilot-scale extruders (tailored process setup):
  - screw diameter of 18, 27, and 32 mm
  - processing length 36-60 L/D
  - throughput of 0.2-100 kg/h depending on the processed material
- Flexible dosing for granules, powders, fibers, liquids & gases (supercritical) in a wide range of throughputs
- Vacuum technology
- Downstream equipment for pelletizing, shaping, foaming

Online analytics

Besides standard techniques, at Fraunhofer ICT on-line viscometry and multi-position online NIR technologies are also available for the effective characterization of reactive extrusion. Especially for reactions involving a large change in viscosity, on-line viscometry is a versatile measurement to evaluate the process efficiency. In the early stage of research, multi-position NIR analysis generates a very detailed process understanding, including information about where reactions or side reactions occur in the extruder. At a later stage, NIR can be utilized for tracking the quantity of a selected additive or for a quick and simple quality control of the produced material.

Our offer

- Adjustment of the reaction system and the formulation, with all necessary safety precautions
- Optimization of process control
- Analysis and quantification of the reaction, and characterization of the materials
- Development of the process chain from material selection and dosing to material processing and certification



Top: Transparent extruder demonstration of spectroscopic measurements

Bottom: Screw elements from laboratory to industrial scale

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