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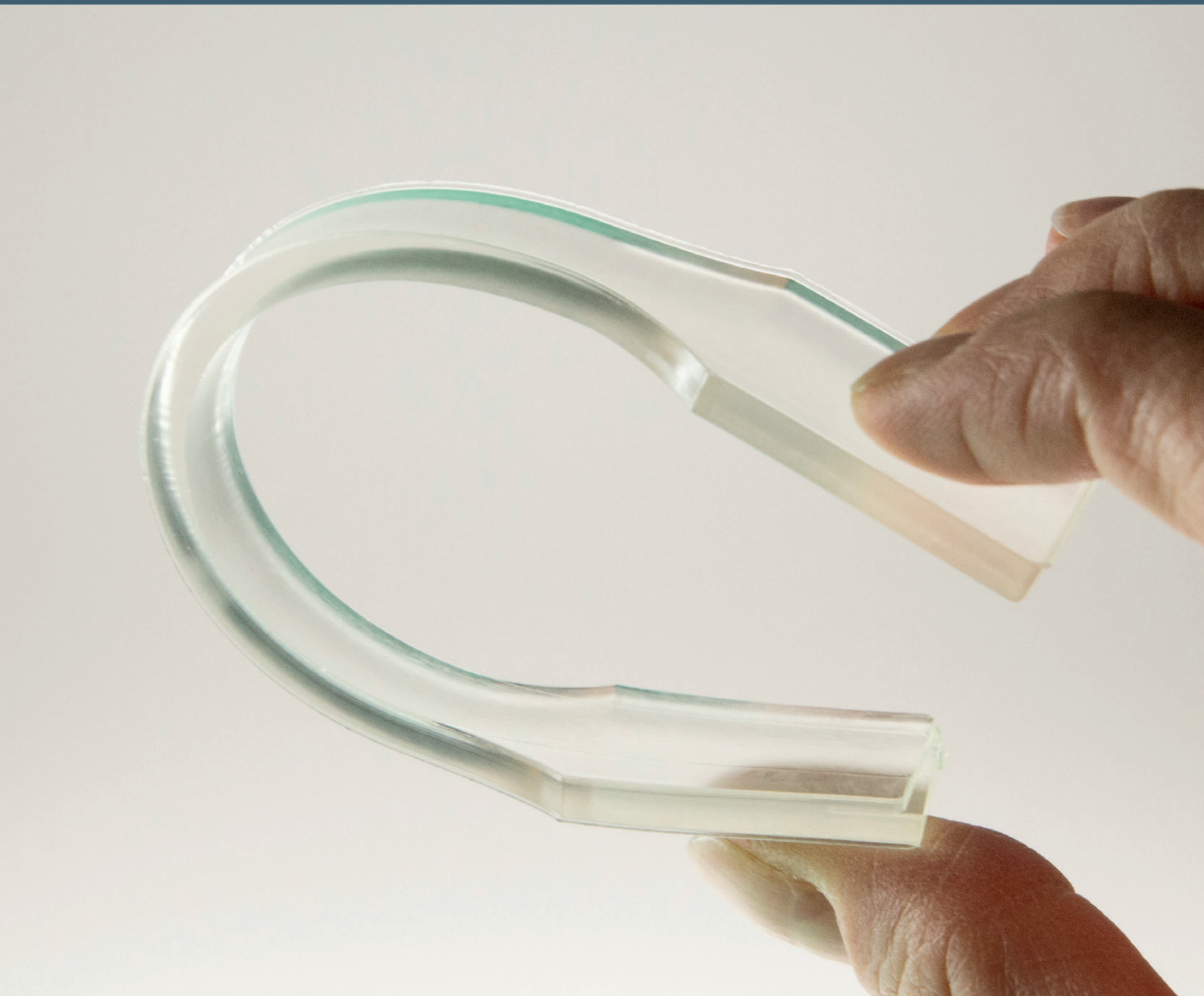
FRAUNHOFER INSTITUTE FOR CHEMICAL TECHNOLOGY ICT

# ENVIRONMENTAL ENGINEERING – POLYMERS AND ADDITIVES



# SUPPORT FROM THE RAW MATERIAL TO THE FINAL PRODUCT AND BACK TO THE RAW MATERIAL

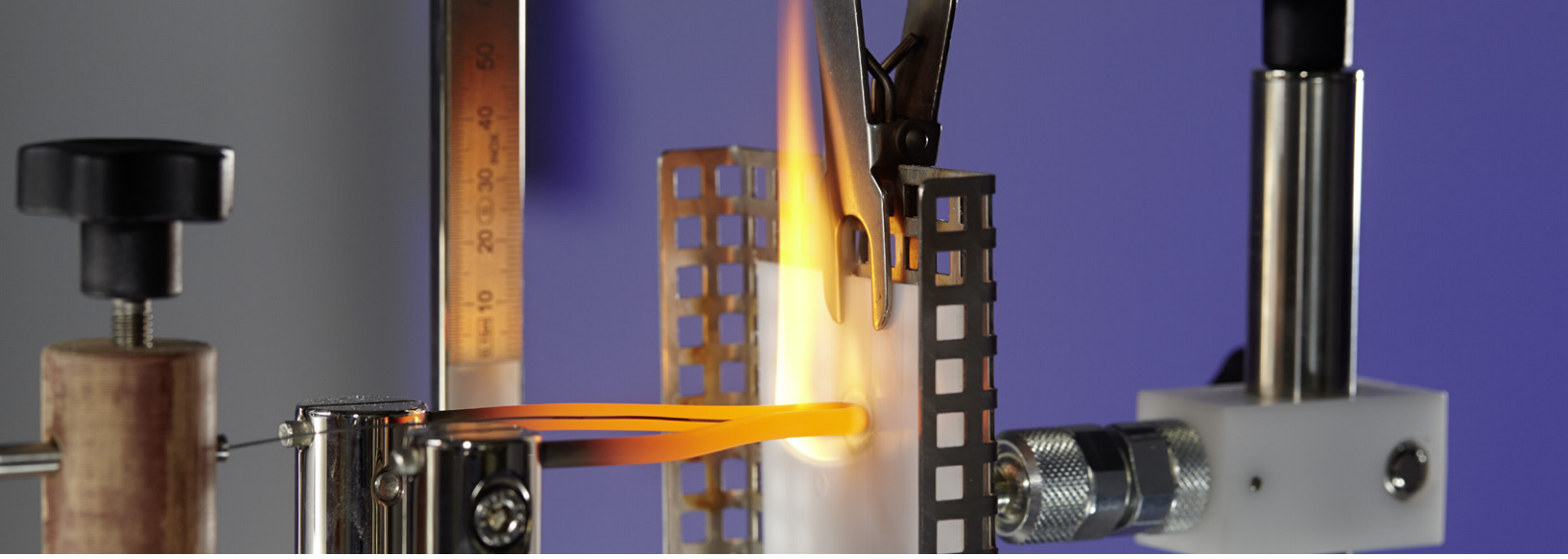
The sustainable and efficient exploitation of resources is one of the core areas of current research, which is supported by politics and increasingly in demand from industry. The aim is to make products and production processes as economically and ecologically efficient and sustainable as possible. The material recycling of by-products and biomasses currently play an important role. The project group for polymers and additives, within the Environmental Engineering Department of the Fraunhofer ICT, investigates and develops components for modern materials based on renewable resources and by-products, which are then tested for potential applications. Furthermore, technical polymer products are chemically recycled and reused on the highest level of the value chain (i.e. material recycling). The research aims to elaborate new, sustainable components and production processes for polymer materials.

## MONOMERS AND ADDITIVES

The use of biomass as a raw material for polymer products is an important factor in the responsible and sustainable use of resources. In order to develop tailored monomers and additives, organic chemical synthesis methods are investigated, and technical reaction processes are tested on a laboratory scale. At the Fraunhofer ICT, monomers and additives have already been obtained from a wide variety of bio-based molecules including fatty acids (FAs) and their derivatives (tall oil, suberin and vegetable oils, amongst others), Hydroxymethylfurfural and fermentation products. The building blocks obtained are mostly multifunctional esters, amines, alcohols or carboxylic acids. Such components can be used as monomers for the production of biopolymers, or as bio-based additives such as plasticizers, surfactants, lubricants or crosslinking agents. It is consequently possible to synthesize various tailored, biogenic constituents which can be applied in different product formulations. Work at the institute involves classic, modern and partially-customized synthesis methods and reaction technologies.

**Practical examples from projects:**

- Extraction and purification of betulins and suberin FAs from birch bark
- Oxidation of furandicarboxylic acid (FDCA) from hydroxymethyl furfural (HMF)
- Metathesis of fatty acids (FAs, e.g. FA tall oil and oleic acid) into long-chain bifunctional esters and various resulting derivatives
- Quantitative breakdown of FAs into azelaic acid and pelargonic acid using ozonolysis
- Synthesis of FDCA-esters and FA-esters as plasticizers for thermoplastics
- Synthesis of FA-based cross-linking agents using Diels-Alder addition
- Amination and reductive amination are current research areas of the Fraunhofer ICT



## FIRE PROTECTION

The development and testing of new, non-toxic and environmentally-friendly flame retardants is an important topic for numerous products. In addition to effective flame retardancy, good material compatibility is also an important requirement. Due to their toxic and mutagenic properties, halogen-containing flame retardants are being progressively withdrawn from the market, while the EU assesses possible legal regulations. Conventional industrial flame retardants such as melamine or ATH are significantly less effective than halogen-containing flame retardants, and this must be compensated by higher loading levels. However, the higher loads alter the mechanical properties of the materials to be processed. For this reason the research group investigates new, effective and compatible flame retardants.

**Practical examples from projects:**

- Incorporation and testing of cyclophosphazene trimers as additives for polyurethane flexible foams and for PA 6 in thermoplastic resin transfer molding (T-RTM).
- Synthesis of phosphoric and polymer flame retardants and testing of their material compatibility and flame retardancy

## CHEMICAL RECYCLING OF POLYMER PRODUCTS

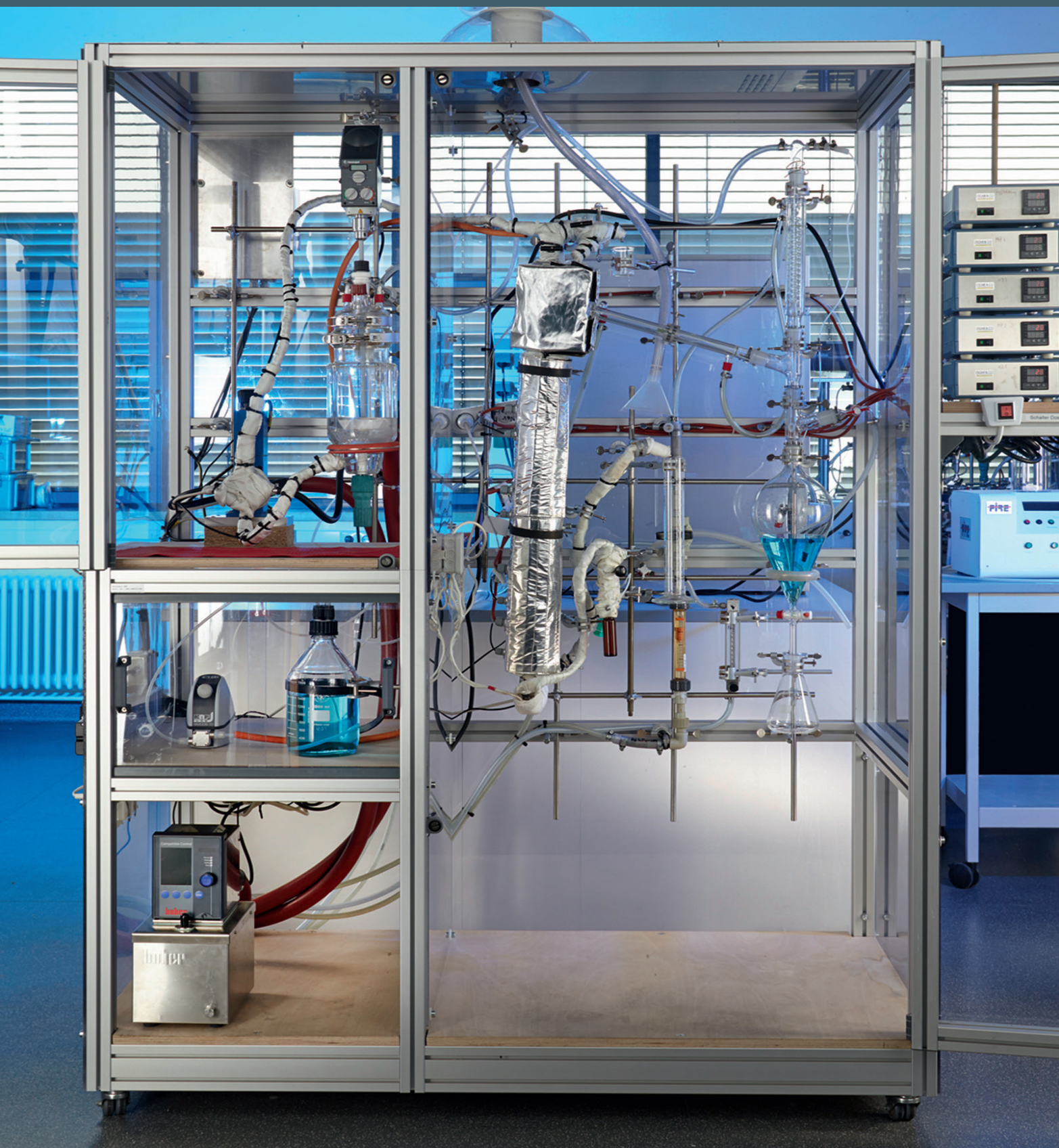
The recycling of polymer by-products is becoming increasingly important for industry and society. One challenge currently under research is the recycling of composites and complex polymer mixtures. The research group for polymers and additives is involved in numerous successful industrial cooperations, which aim to obtain recyclates from polyester and polyurethane products. These recyclates can be used as raw materials for new polymer products. A particular challenge in recycling is the treatment and re-use of heterogeneous and contaminated plastic waste streams. Processes for depolymerization and the purification and re-use of recyclates are under development.

**Practical examples from projects:**

- Extraction of colorless high-purity recyclates from multicolored PET flakes
- Extraction of recyclates and flame retardants from PUR foam products
- Application of recyclates for the production of new products

PHOTOS

*Glow wire test on a thermoplastic demonstrator (above) and tailored set-up of a glass reactor (right).*



# BIOPOLYMERS AND POLYMER PRODUCTS

Bio-based polymers can be obtained from a wide variety of biomass substances. To develop new material sources based on renewable resources it is necessary to synthesize and characterize biopolymers. It is also necessary to carry out process development and the testing of biopolymers in applications and in the final product. Over the past few years a variety of biopolymers have been synthesized and investigated. The aim is generally to obtain polyesters, polyamides, polyurethanes and their co-polymers, which are produced from bio-based monomers and processed to different products such as thermoset coatings, foams and thermoplastics. The focus is on synthesizing biobased components for polyurethane systems, and on evaluating them in different applications. The synthesized components are investigated and characterized by standard methods and incorporated into the mixture. The Fraunhofer ICT has already fabricated thermoplastic PUR, PUR foams, PUR coatings and PUR foam coatings made of bio-based polyols, which are partly produced on site.

**Practical examples from projects:**

- Development of "green" PUR foam pads for aircraft seats, a bio-based flexible foam containing 22 weight % purely biogenic raw materials
- Synthesis of thermoplastic polyesters and polyamides from FDCA
- Synthesis of thermoplastic polyesters, polyester polyols, polyamides, polyurethanes and co-polymer structures based on medium and long-chain FA derivatives
- Development of thin polyurethane foam coatings

# OUR OFFER

- Feasibility studies
- Customized syntheses
- Catalyst and parameter screening
- Reaction and process optimizations on a laboratory scale
- Support in product qualification and the development of mixtures
- Incorporation and testing of new and established flame retardants according to UL 94, FMVSS 302, DIN 4102B, DIN 4589, FAR 25.853, oxygen index and the glow wire test.
- Cooperation with other organizations in bilateral (under non-disclosure agreement, framework contracts) and publicly-funded projects

**PHOTO**

*Granulate and tensile specimens made from bio-based polyamides.*

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