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FRAUNHOFER INSTITUTE FOR
CHEMICAL TECHNOLOGY ICT

PRODUCTS MADE FROM SUSTAINABLE RAW MATERIALS

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The rapidly growing global population and increasing scarcity of resources mean that it is extremely important to use renewable raw materials in a meaningful, efficient and sustainable way.

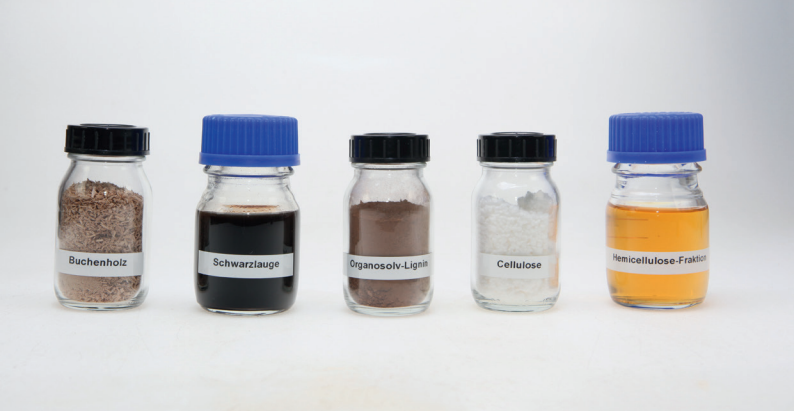
The Environmental Engineering Department of the Fraunhofer Institute for Chemical Technology ICT has for many years been investigating various renewable resources which do not compete with food production. The overall objective is to extract individual components and to process them into high-quality base chemicals, chemical products and polymers.

FRACTIONATION OF WOOD

The three key components of wood are

- Cellulose
- Polyoses (hemicelluloses)
- and Lignin.

For the fractionation of wood or wood waste and lignocellulose-containing biomass the Fraunhofer ICT has developed the ethanol-water Organosolv pulping process, which, in contrast to the established Kraft process used by paper factories, does not use sulfurous chemicals and consequently generates sulfur-free products. Depending on the targeted fraction, this method can be optimized in terms of higher yields of sulfur-free lignin and low-lignin cellulose. After these two fractions have been separated, polyoses (hemicelluloses) in the form of monomer and oligomer sugars remain in the aqueous fraction and can be used as carbon sources for fermentations.



PRODUCTS MADE FROM CELLULOSE AND POLYOSES (HEMICELLULOSE)

Both the polysaccharide cellulose and polyoses can be broken down to monomer carbohydrates through chemical and enzymatic hydrolysis. The decomposition of cellulose mostly produces glucose. Besides hexoses such as glucose, mannose and galactose, hemicelluloses mostly produce pentoses, in particular xylose and small amounts of arabinose. At the Fraunhofer ICT, platform chemicals can be obtained from glucose and other hexoses or pentoses through a number of different processes, and used as initial raw materials for various polymer products such as:

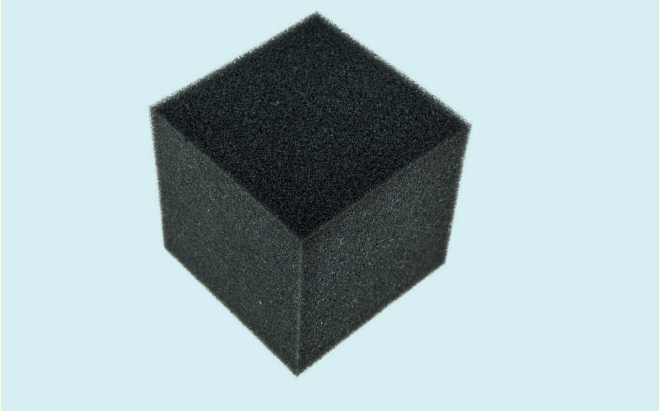
- **Olefins for polyolefins** | By using fermentation, glucose derived from renewable raw materials can be processed to form, for example, ethanol, isopropanol or butanol. The related alkenes are produced from these alcohols by catalytic dehydration in a specially-designed high-pressure testing unit. These alkenes – in particular ethylene and propylene – are important platform chemicals for the production of plastics. They can be processed to form polyethylene (PE), polypropylene (PP) and numerous chemical intermediate products.

Sugar alcohols as polyols for polyurethanes | In a continuously operated tube reactor, glucose and other sugars such as xylose or fructose can be hydrogenated to form the sugar alcohols sorbitol or xylitol, or mannitol / sorbitol. The sugar alcohols obtained by this method have already been successfully used as ingredients in formulations for hard polyurethane foams.

Furan derivatives for polyesters and polyamides | Hexoses, especially fructose, can be transformed into furan compounds such as 5-hydroxymethylfurfural (5-HMF). Researchers at the Fraunhofer ICT have also developed a method for the quantitative transformation of 5-HMF to furandicarboxylic acid (FDCA). FDCA is currently considered an alternative to terephthalic acid and can be used as an acid component for the production of polyethylene furanoate (PEF) or for polyfuranamides. PEF can be obtained from biogenic raw materials only and is the bio-based counterpart of the polyester PET. Xylose, which is a pentose obtained from wood polyols, can react to form furfural – an industrially important platform chemical used for the production of furan compounds, thermosetting resins, plastics, organic solvents, varnishes, pesticides etc.

Hydrogen and/or alkanes | The generation of hydrogen and alkanes from sugars – in particular sugar alcohols – via aqueous phase reforming (APR) could be successfully shown for both batch and continuous tube reactor operations. Depending on the reaction conditions and the catalyst used, the reaction can be influenced so that either hydrogen or alkanes are generated.

Products made from lignin | Lignin is an aromatic macromolecule composed of phenolic components, which makes it a very attractive option as a natural source of aromatics. Research at the Fraunhofer ICT also includes investigation of the base-catalyzed depolymerization of lignin (BCD). The lignin breakdown products obtained in this way can be incorporated into formulations for specialized applications (adhesives, paints, brake pads, grinding disks, thermosetting materials, foams), enabling the complete or at least partial replacement of oil-based components. Additional efforts are made to selectively produce certain compounds in order to achieve a higher added value.



PRODUCTS MADE FROM OILS

Other raw material sources are vegetable oils and fats – preferably those that are by-products of industrial processes and unfit for human consumption, for example tall oils from wood-based industries.

The Fraunhofer ICT has already investigated and developed various methods for the production of polymer components for polyesters, polyamides and polyurethanes. These investigations focused especially on medium- and long-chain polymer components such as 1,9-nonanedioic acid, 1,18-octadecanedioic acid and their derivatives. They have already been tested for a number of different polymer products. Long-chain polyesters are well suited for elastic thermoplastic products. They are also suitable for application in foils, coatings and hot-melt adhesives. Furthermore, bio-based polyester polyols have been produced and incorporated into polyurethane foam formulations and thermoplastic polyurethanes. In addition, fatty acids have been processed to form bio-based additives such as plasticizers (mostly in combination with carbohydrates and derivatives such as FDCA) and crosslinking agents, and tested in polyurethane products.

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