Fraunhofer
IGB

FRAUNHOFER INSTITUTE FOR INTERFACIAL ENGINEERING AND BIOTECHNOLOGY IGB

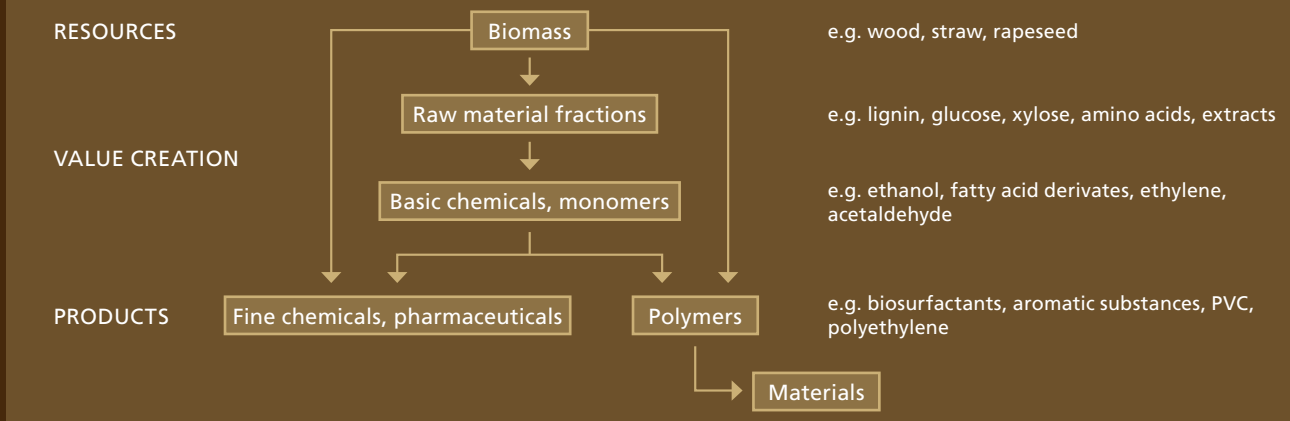
COMBINATION OF BIOTECHNOLOGICAL AND CHEMICAL PROCESSES

CATALYTIC PROCESSES FOR A SUSTAINABLE SUPPLY OF RAW MATERIALS AND ENERGY ON THE BASIS OF RENEWABLE RESOURCES

In view of the worldwide growing shortage of resources, the use of renewable, biogenic and recycled raw materials for the development of sustainable processes and products in industrial sectors such as chemistry and energy has become increasingly important. According to studies of the Verband der Chemischen Industrie (VCI, Federation of the German Chemical Industry) and the Fachagentur Nachwachsende Rohstoffe (FNR, Agency for Renewable Resources), 13 percent of the resources used in the German chemical industry (2010) are renewable. An increase to 20 percent is estimated for the year 2020.

New chemical-catalytic processes as well as processes of industrial biotechnology play a key role in achieving this goal. According to a joint study of the International Energy Agency (IEA), the International Council of Chemical Associations (ICCA) and DECHEMA the increased use of catalysis in the chemical industry provides the means of saving 13 exajoules of energy by the year 2050. This roughly corresponds to the amount of primary energy that Germany requires for one year. At the same time the CO_2 emissions released in the use of this primary energy can be eliminated.

With the Fraunhofer IGB BioCat branch "Catalytic Processes for a Sustainable Supply of Raw Materials and Energy on the Basis of Renewable Resources" in Straubing the Fraunhofer-Gesellschaft is making its contribution to change the raw materials base in the chemical industry.



BIO-, ELECTRO- AND CHEMOCATALYSIS BIOCAT, STRAUBING BRANCH

BioCat develops catalytic processes for a sustainable supply of raw materials and energy on the basis of renewable resources. Here the focus of the work is on the development of new bio- and chemical catalysts and their application in technical processes.

With substrates such as biomass, CO_2 and organic residual matter or waste streams as the starting point, the entire range of catalysis is examined – homogeneous and heterogeneous chemical catalysis, enzymatic and whole cell catalysis as well as combinations of them – with the aim of creating new products from these substrates. The products and/or the corresponding processes are, on the one hand, made available to companies for the production of bulk and fine chemicals, for example monomers for polymer production. On the other, they can be used to store regenerative energy in chemical energy carriers, for example in the form of longer-chain carbohydrates. Here the aim is, in each case, to achieve the best possible value creation from the raw material to the biobased final product.

The recovery of materials from residual matter, which currently is used for the main part thermally, represents an important contribution to the sustainable substitution of petrochemical resources. At the same time this indicates ways of manufacturing technologically high-quality and technically interesting products on the basis of existing renewable forestry resources, taking into account the synthesizing capability of nature.

Here the BioCat branch makes full use of the following competences:

- Chemical (homogeneous and heterogeneous) catalysis
- Biocatalysis (enzymes)
- Screening for catalysts (biocatalysts, chemical catalysts)
- Organic synthesis
- Molecular-biological and technical optimization of enzymes and enzymatic reactions
- Electrochemistry
- Analyses of natural materials and chemical reactions (e.g. high-resolution NMR analytics, high-throughput LC-MS and GC-MS)

Our research work focuses on the following four subject areas:

- Chemical and biocatalysis
- Material use of CO_2, biomass, residual and waste materials
- Specialty and fine chemicals, e.g. aliphatic and aromatic monomers as building blocks, biosurfactants
- Chemical energy storage

Fraunhofer Institute
for Interfacial Engineering
and Biotechnology IGB
Nobelstrasse 12
70569 Stuttgart | Germany

Phone +49 711 970-4401
Fax +49 711 970-4200
info@igb.fraunhofer.de
www.igb.fraunhofer.de

Fraunhofer IGB

The Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB develops and optimizes processes and products in the fields of health, chemistry and process industry, as well as environment and energy. We combine the highest scientific standards with professional know-how in our competence areas – always with a view to economic efficiency and sustainability. Our strengths are offering complete solutions from the laboratory to the pilot scale. Customers also benefit from the cooperation between our five R&D departments in Stuttgart and the institute branches located in Leuna and Straubing. The constructive interplay of the various disciplines at our institute opens up new approaches in areas such as medical engineering, nanotechnology, industrial biotechnology, and environmental technology. Fraunhofer IGB is one of 69 institutes and independent research units of the Fraunhofer-Gesellschaft, Europe's leading organization for applied research.

www.igb.fraunhofer.de

Stay in contact:

EXAMPLES OF PROJECTS

Bifunctionalization of terpenes

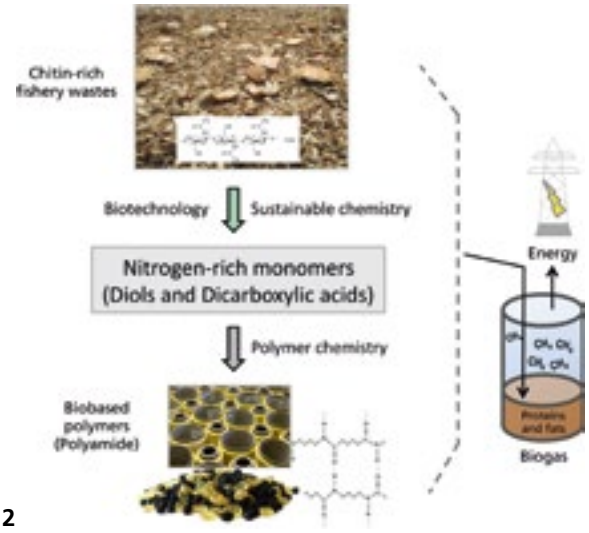
Terpenes represent a separate class of natural substances which are formed as secondary substances contained in plants and which are, for example, the main component of essential oils. They occur as residues e.g. in the form of turpentine oil (mainly pinene and carene) in the pulp and paper industry and as limonene in the processing of citrus fruits. The amount of turpentine oil resulting worldwide from pulping processes alone is estimated to be almost 330,000 metric tons annually.

The primary objective of the project is to produce – from pinene, carene and limonene with just a few chemical and/or biotechnological modifications – bi- or multifunctional molecules (dioles, diamines, dicarboxylic acids, terpene epoxides) that constitute the basis for new types of monomer building blocks for separate kinds of biobased polymers. The market share of sustainably manufactured, biobased synthetics has been significantly increased by utilizing forestry and agricultural residue streams as sources of raw materials.

The innovative approach is not just a matter of using residual plant matter as a substitute for mineral oil and developing new biotechnological-chemical conversion processes. Rather, the aim is to obtain polymers with new properties and to make available more environment-friendly and toxicologically safer synthetic products by means of the special aliphatic-cyclic structure of the terpenes.

1 *Using catalytic processes polymers are produced from renewable raw materials such as straw.*
2 *Conventional harvesting of pine resin for the distillation of turpentine oil.*

1



2

Crab shells as a raw material for chemicals

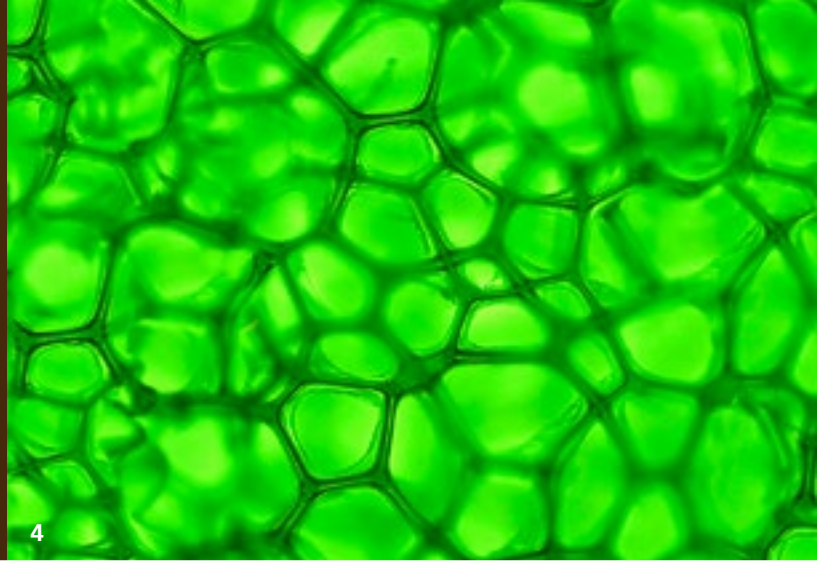
In the "ChiBio" project, which is funded by the EU, the Fraunhofer IGB – coordinated by the Straubinger BioCat branch – is developing in collaboration with an international team new processes for utilizing crab-shell waste as a raw material for chemicals and new materials. The project consortium has opted for an integrated, comprehensive approach. In the manner of a biorefinery various uses will be developed and optimized for the crab-shell waste. This will be reutilized in the form of substances and energy, so that the residual matter is recycled as efficiently and completely as possible.

First of all, the remaining crab meat has to be removed from the shells. The biomass residues consisting of proteins and fats are separated in such a way that they can be directly fermented and used as energy source. The purified chitin can then be split into its monomeric components, the nitrogenous sugar glucosamine, using microorganisms or chitinases that have already been isolated and characterized at the IGB. One of the central tasks is to convert glucosamine into basic building blocks with at least two functional groups, so that they can be linked to form new, biobased polymers. To do this, chemical steps are combined with biotechnological processes. All the biobased by-products resulting from the process chain are then fermented together with the initially separated proteins and fats to produce biogas as an energy carrier.
www.chibiofp7.eu

Aromatic synthetic building blocks from lignin

In the "Lignoplast" project five academic and five industrial partners are working on processes to develop lignin as a source of raw materials for aromatic synthesis components. The required aromatic compounds are obtained by means of hydrolytic degradation of the macromolecular lignins and then functionalized chemically and enzymatically to make adhesives, paints, polyurethanes and epoxides. The lignin-based products are used in trial materials and subsequently characterized in terms of their application technology and compared with conventional systems.

So far, the raw material lignin has only been used to a limited extent in niche products, for example as a concrete additive. A large part of the lignin, which represents the largest natural source of aromatic compounds and approx. 30 percent of the lignocellulose biomass is used to generate energy. The utilization of lignins to produce aromatic synthesis building blocks makes a significant contribution to the sustainable substitution of petrochemical resources. At the same time, this indicates a way of manufacturing high-quality and high-tech products on the basis of renewable resources. A broad range of "green" product classes can be developed by means of the selective depolymerization of the macromolecular lignin and a targeted modification. BioCat investigates how higher molecular solids resulting from the base-catalyzed cleavage of lignin can be further broken down by catalysis.



Coral enzymes for the synthesis of terpenoid pharmaceuticals

Marine ecosystems host a number of unique organisms. However, corals are not only of special interest because of the world-famous reefs. Also, corals are able to form unique natural terpenoid substances that have become indispensable in the field of cosmetics, chemical products and pharmaceuticals. Up till now these substances have been produced mainly by chemical syntheses or by harvesting and extracting the synthesizing organisms. The BioCat branch is therefore working to decode the natural biosynthesis of these substances in order to make the production processes sustainable, utilizing resources economically and in an environmentally compatible way.

Enzymes of central importance have already been identified and made accessible to fermentative production processes. There are two objectives: to enable the fermentative production of the known substances and also, by means of targeted intervention in the catalytic steps, to generate new substances with modified characteristics in order to be able to create new nature-based active ingredients for the medical challenges of tomorrow.

Terpenes as a source of raw materials for new biosurfactants

The aim of the "BioSurf" project is the increased substitution of petrochemically based surfactants by biosurfactants manufactured on the basis of renewable resources. So as to insure sustainable production principles, the chain of value creation in the biosurfactant production is examined in its entirety. The key research objectives are the identification of new biosurfactants and/or new enzymes and microorganisms for new and more efficient biosurfactant production processes, understanding the cellular regulatory processes of the biosurfactant synthesis and consistent metabolic engineering to optimize the production organisms. Within the scope of this project the Fraunhofer BioCat branch has successfully developed enzymatic processes for the production of new terpene-based biosurfactants.

www.biosurf.de

1 *Crustacean shells accumulate in large quantities as waste.*
2 *Process chain in the "ChiBio" project.*
3 *Corals form unique natural terpenoid substances.*
4 *Biosurfactants are excellent foaming agents.*

1


2

The success of the turnaround in energy policy, in the course of which power generation from renewable energies in Germany is to be constantly expanded, depends on an extension of the power networks; however, new technologies are also required to store surplus energy. Thus energy storage systems insure a rapid balancing out of grid loads and make electrical energy available again at a later point in time. In addition to battery storage, chemical energy storage systems can also provide an effective solution.

Center for Energy Storage

The availability of renewable energies such as wind and solar power is subject to natural fluctuations, so that the generation of power is coupled with an insufficient supply or surplus of electric energy. These fluctuations have to be balanced out by starting up and shutting down power stations or, preferably, using suitable energy storage systems.

Since May 2012 the "Center for Energy Storage", funded by the Bavarian Ministry of Economic Affairs and Media, Energy and Technology, has provided assistance to Bavarian industry, the municipalities and policy-makers, and has also been the competent institution to consult about key technologies in the field of chemical and thermal energy storage. The Center, with locations in Sulzbach-Rosenberg (Fraunhofer UMSICHT) and Straubing (Fraunhofer BioCat branch of the Fraunhofer IGB), systematically develops the necessary storage technologies in the medium to long term.

The Center for Energy Storage focuses on the following areas:

- Systems Analysis (UMSICHT)
- Chemical Energy Storage – Catalysis and Processes (BioCat/IGB)
- Chemical Energy Storage – Methods and Technical Implementation (UMSICHT)
- Thermal Storage Systems (UMSICHT)

The focus of the working group "Chemical Energy Storage – Catalysis and Processes" is on the development of processes for the production of liquid and solid chemical energy carriers with the assistance of electrical energy. It is true that there are already several promising ways of producing suitable energy carriers such as the power-to-gas technology. However, these processes need to be adapted for practical applications in such a way that they become processes that are sustainable, easily scalable and can be operated in a decentralized way. To do this, the necessary catalysts or biocatalysts have to be researched and developed so as to generate the required products decentrally and flexibly as regards time schedules.

Initially three processes in particular were defined that can be characterized as "power to gasoline". These will be studied and further developed in the coming years:

- Chemical-catalytic CO_2 fixation and conversion to hydrocarbons
- Microbial CO_2 fixation and fermentative production of hydrocarbons
- Electro-biocatalysis to minimize the energy-related cost of electrochemical reactions

www.centrum-energiespeicherung.de

FACTS

Main research areas

- Polyfunctionalization of natural substances, such as terpenes from plants and residues from wood processing, into epoxides and monomers for the polymer industry
- Production of monomers for conductive polymers from lignin
- Combination of chemical and enzymatic degradation of lignin
- Fabrication of lubricants and biobased surfactants from vegetable oils and fatty acids
- Production of special and fine chemicals from chitin-rich fishing-industry waste
- Production of medium- to long-chain hydrocarbons from methane and/or CO_2

Range of services offered

- Screening of bio- and chemical catalysts
- Molecular-biological and technical optimization of enzymes and enzyme reactions
- Custom synthesis of fine chemicals
- Development of processes for reutilizing residual matter
- Development of procedures for the integration of renewable resources in existing processes
- Studies carried out in the field of renewable resources
- High-resolution NMR spectroscopy (400 MHz) in solution for determining molecular structure, reaction kinetics, deep temperature analytics, and development of methods
- Electroanalytics (e.g. cyclic voltammetry, chronoamperometry, electrochemical impedance spectroscopy)

Equipment and infrastructure

Analytics

- HPLC, U-HPLC with DAD, FLD, MSD (ion trap), ELSD
- GC-MS, GC-FID
- IR, UV spectrophotometer
- Microtiter plate reader (fluorescence, absorption)
- 400 MHz NMR spectrometer

Chemical and bioreactors

- Parallel bioreactors (< 1 liter)
- Various bioreactors up to 40 liters
- Parallel high-pressure chemical reactors (400°C, 250 bar)
- Microwave reactor
- Reaction autoclave
- Continuous parallel reactor system

Other equipment

- Robot units (colony picker, pipetting unit, incubator, centrifuge etc.)
- Preparative chromatography, crossflow
- Distillation units
- Potentiostat

1 *Biological fuel.*
2 *Wind and solar power generation.*
3 *Laboratory building of BioCat project group.*

CONTACTS

Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB
Bio-, Electro- and Chemocatalysis BioCat, Straubing Branch
Schulgasse 11a
94315 Straubing
Germany

Fax +49 9421 187-360
www.biocat.fraunhofer.de

Dr. Michael Hofer
Head of Straubing Site
Phone + 49 172 278-3500
michael.hofer@igb.fraunhofer.de

Dr. Michael Richter
Head of Innovation Field
Bioinspired Chemistry
Phone +49 9421 9380-1020
michael.richter@igb.fraunhofer.de

Dr. Arne Roth
Head of Innovation Field
Sustainable Catalytic Processes
Phone +49 9421 9380 -030
arne.roth@igb.fraunhofer.de

Prof. Dr. Volker Sieber
University and Political Relations Bavaria
Phone +49 9421 9380-1050
volker.sieber@igb.fraunhofer.de