Interdisciplinary research for sustainable technologies

› CHEMISTRY
› BIOTECHNOLOGY
› ENERGY
› MATERIALS

DECHEMA
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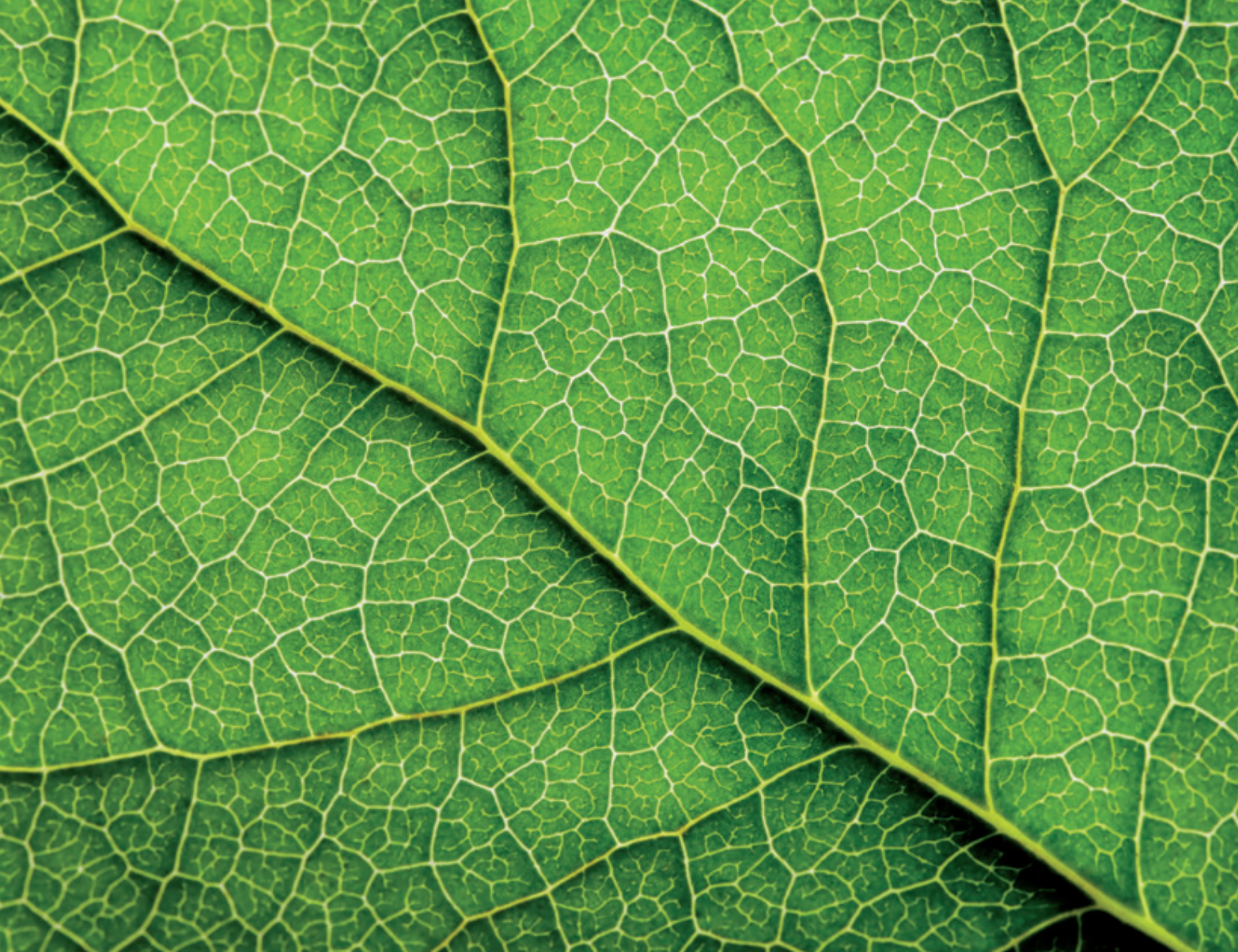

Interdisciplinary research for sustainable technologies

in the fields Energy, Chemistry, Biotechnology and Materials as a contribution to a resources-efficient and environmentally-friendly industrialised society

Future industrialised societies will be dependent on the availability of resources and the general public‘s acceptance of employed technologies. However, natural resources are limited and the technologies implemented today have in many instances reached their limits, both ecologically and politically. Thus, an urgent need exists for the development of alternatives, which can be consolidated under the term Research for Sustainable Technologies. To this effect, considerable potential is associated with the traditional fields of DECHEMA, namely chemical engineering, materials engineering and biotechnology.

In 2012 a number of industrial and private benefactors, who are committed to this socio-political mandate, together with DECHEMA, have established a non-profit, civil law foundation. It bears the name DECHEMA-Forschungsinstitut and builds on the expertise of the former Karl-Winnacker-Institut of DECHEMA. The core competences of this institute in the key disciplines Materials and Corrosion, Chemical Engineering, Electrochemistry as well as Biotechnology were adopted and expanded into a concept of Research Clusters, in which the central problems of future industrialised societies will be transposed into interdisciplinary research focus areas. Hereto, DECHEMA-Forschungsinstitut, together with research partners from industry and universities, contributes its renowned and internationally recognised competence, amassed from over five decades of experience from its predecessor institute. This competence comprises the entire spectrum from fundamental research to application oriented developments and aims to create resources-efficient and ecologically compatible technological solutions for industrial deployment. For this reason, DECHEMA-Forschungsinstitut acts as an important interface in the German and international research landscape.

Interdisciplinary research for sustainable technologies

CHEMISTRY • BIOTECHNOLOGY
ENERGY • MATERIALS

MATERIAL AND RESOURCES FRIENDLY PRODUCTION

INTEGRATED CHEMICAL AND BIOTECHNOLOGICAL PRODUCTION

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RECOVERY OF INORGANIC RESOURCES

MATERIALS SAFEGUARDING

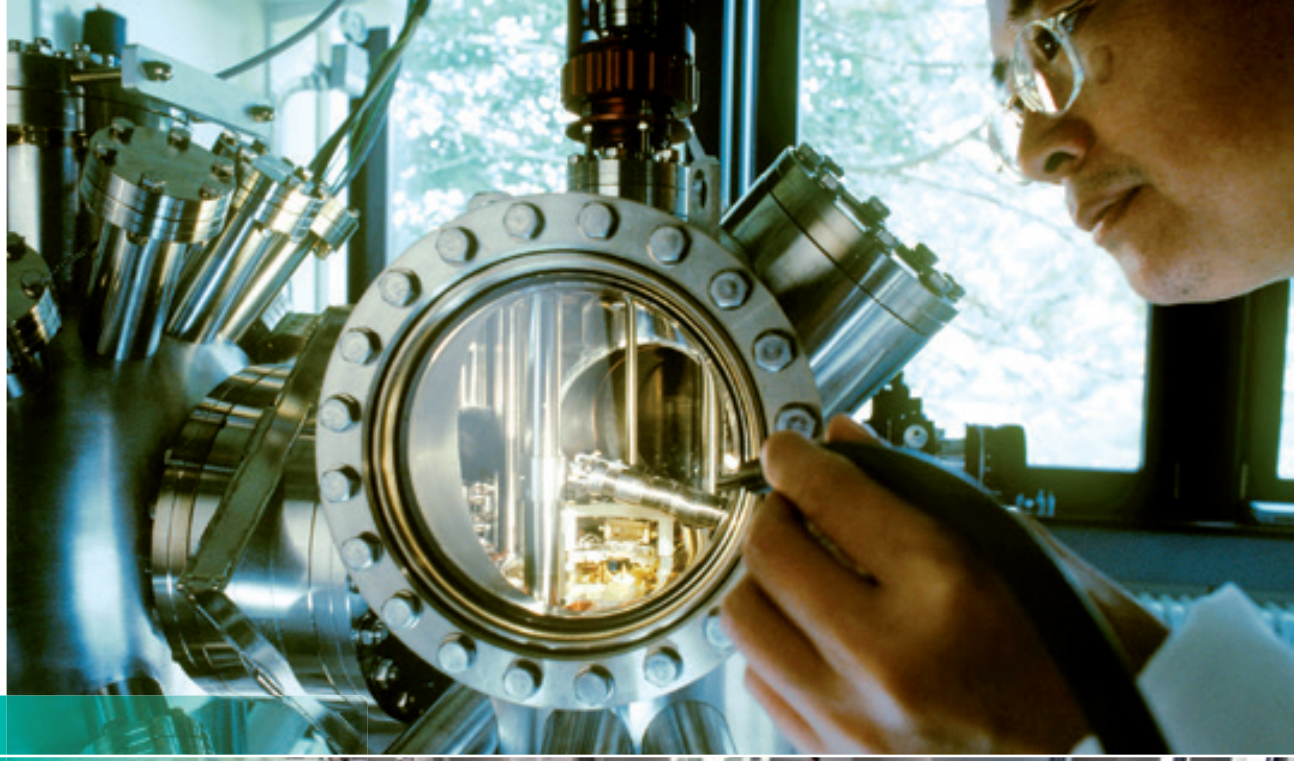
CONCEPT

COOPERATION

INSTITUTE

CONTACT

Objectives of the institute

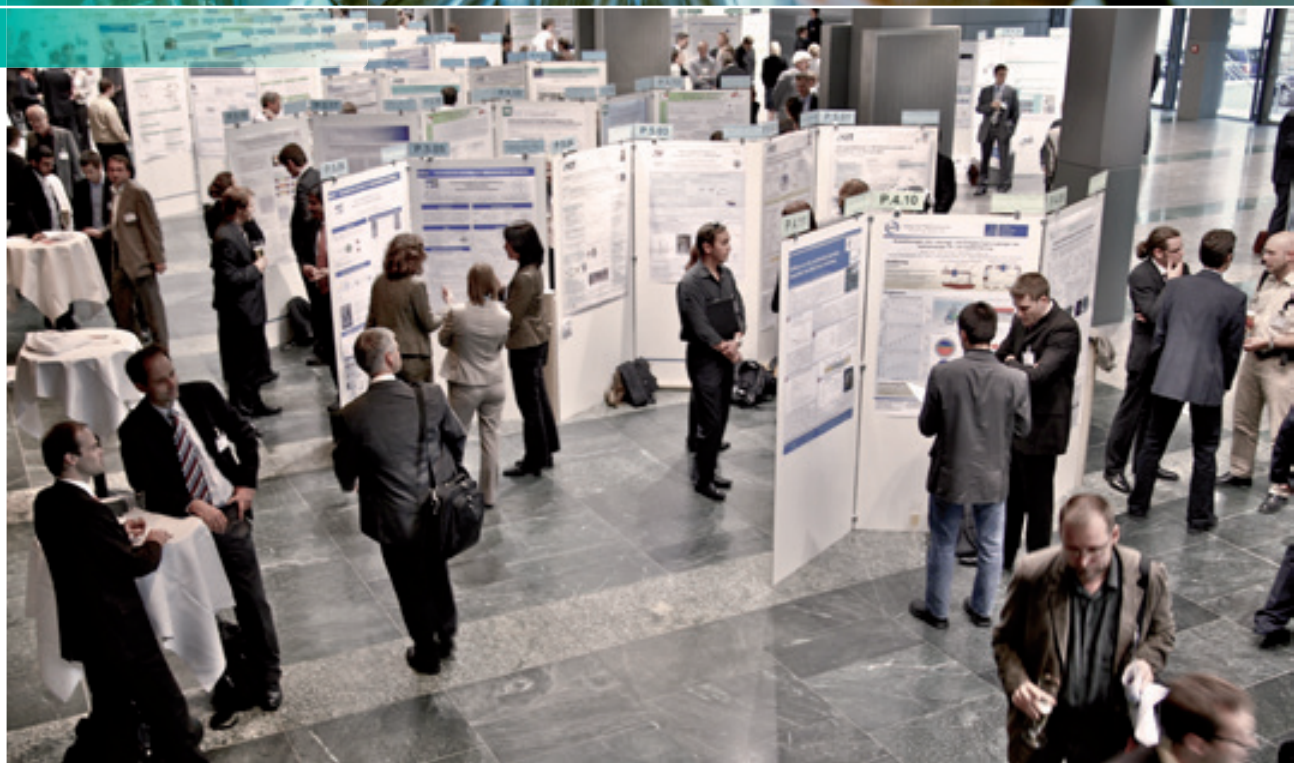


› Industrial contract research with direct financing from industry

› Publicly funded fundamental and pre-competitive practical scientific research

RESEARCH

COOPERATION AND NETWORKING



› Research proposal reviewers for AiF, BMBF, DFG and EU, amongst others

› Scientific involvement in the preparation of research programs

› Cooperation in various panels of DECHEMA e.V. and other organisations (e.g. DIN, ISO, advisory boards)

TEACHING AND TRAINING

› Teaching at universities
by employees of the DFI in their
respective areas of expertise

› Employment of graduate students,
masters and post-graduate students
within the scope of research projects

› Seminars and practical training
for pupils and students

› Vocational training
in the institute workshop

CONTINUING PROFESSIONAL DEVELOPMENT

› Around 50 continuing professional
development courses in process technology
and in the institute‘s areas of expertise
for participants from industry, authorities
and universities

› Highlight: experimental courses
with lectures and self-conducted
experiments

› Development of teaching materials
and cooperation in the publishing
of scientific literature

Research Clusters

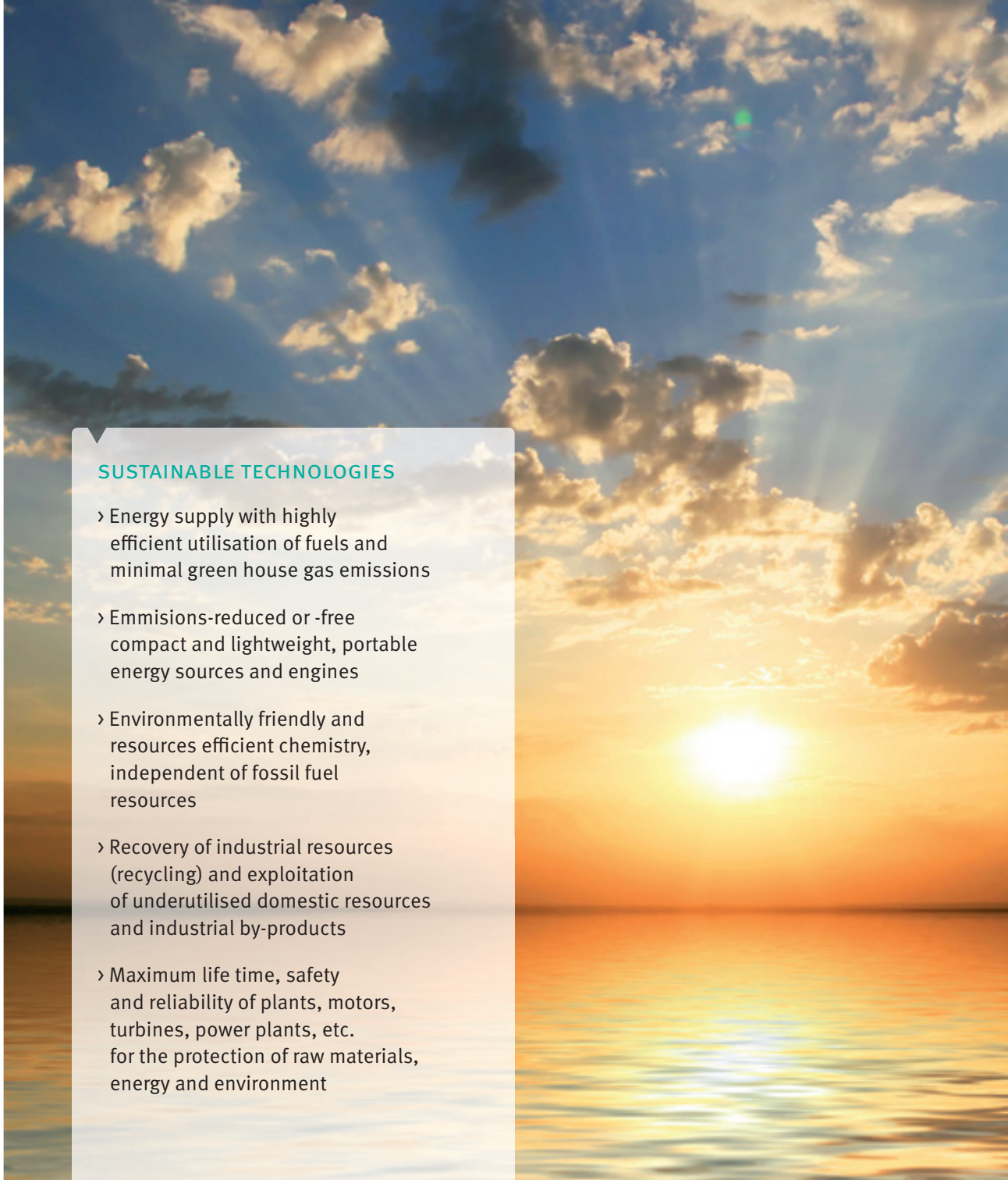
In the research clusters scientists from the different research groups collaborate in order to work on joint issue-oriented projects within the scope of the current interdisciplinary research focus areas.

› Electrochemical Energy Converters and Storage Devices

› Integrated Chemical and Biotechnological Production

› Recovery of Inorganic Resources

› Innovative Corrosion Protection Concepts



SUSTAINABLE TECHNOLOGIES

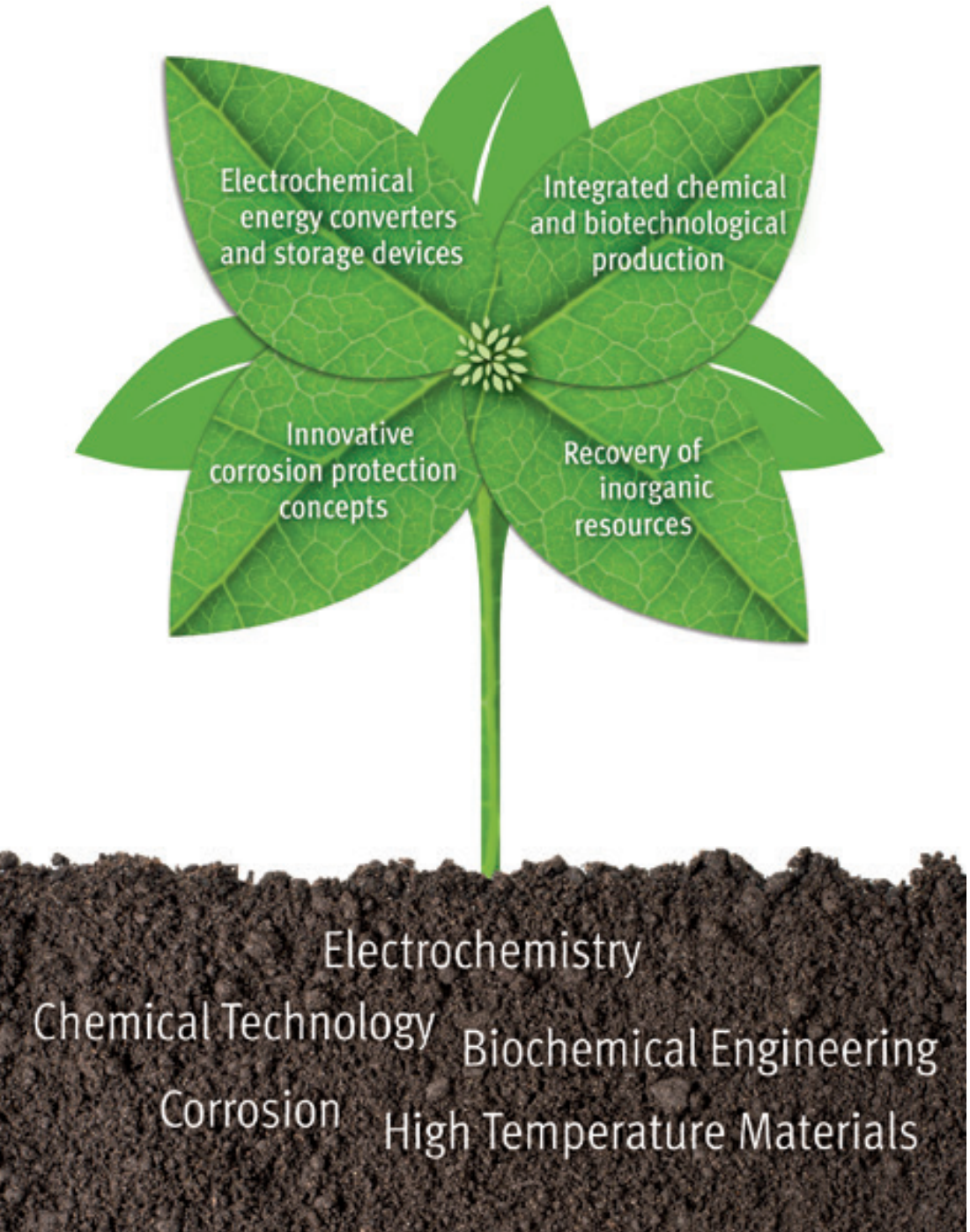
› Energy supply with highly efficient utilisation of fuels and minimal green house gas emissions

› Emmisions-reduced or -free compact and lightweight, portable energy sources and engines

› Environmentally friendly and resources efficient chemistry, independent of fossil fuel resources

› Recovery of industrial resources (recycling) and exploitation of underutilised domestic resources and industrial by-products

› Maximum life time, safety and reliability of plants, motors, turbines, power plants, etc. for the protection of raw materials, energy and environment



Research Groups

The traditional core competences are organised in the form of research groups, each with between 10 and 25 scientific and technical staff members. These research groups manage research projects which command the specific competence of the particular core activity of the group.

› Electrochemistry

› Chemical Technology

› Biochemical Engineering

› Corrosion

› High Temperature Materials

Laboratory cells for the development of metal/air batteries: The active zinc material is placed in the middle of the Plexiglas tube with the air electrode on the left. Both electrodes are electrically contacted with a metal rod.

RESEARCH FIELDS

- Tubular Redox-Flow Battery design with an air electrode
- Catalyst development and characterisation for PEM fuel cells
- Corrosion- and coking-resistant catalysts for direct methane SOFC anodes
- Efficient air electrodes for metal/air batteries
- Optimisation of gas diffusion electrodes
- Protection layers for interconnectors in the SOFC
- New cell design for microbial fuel cell

RESEARCH CLUSTER

Electrochemical energy converters and storage devices

Globally, the demand for energy has increased dramatically. At the same time fossil fuel reserves are limited and power generation from nuclear fission is controversially discussed. Therefore a radical change in the energy mix is expected in the very near future. One of the most important goals of the German government focuses on the expansion of renewable energies up to 60 % of the gross final energy consumption and 80 % of the gross electricity consumption by 2050. In order to better regulate seasonal- and weather-dependent energy production, novel energy storage plants are required. One promising strategy is based on the development of peripheral electrochemical energy storage and conversion plants such as electrolysis and fuel cells for hydrogen production and combustion, double-layer supercaps, as well as redox-flow, lithium-ion and zinc/air batteries.

The actual R&D activities at DFI focus more especially on the development of catalysts and gas diffusion electrodes for fuel cells (DMFC, H2-PEMFC, BioFC & SOFC), metal/air batteries (Al/air & Zn/air) and redox-flow batteries applications. Highly active but also selective and corrosion-resistant materials are required especially towards e.g. hydrocarbon-containing H2-rich fuels such as reformer gas, highly aggressive atmospheres/electrolytes and high electrode potentials during charging/electrolysis process. One of the most challenging topic is related to catalyst/carbon corrosion in the air electrode of DMFC/PEMFC and Metal/Air Batteries (MAB), respectively that use to be evaluated by accelerated chemical and electrochemical degradation tests. Our approach consists on the substitution of Pt and carbon black benchmark compounds by Pt alloys and mesoporous carbon in the PEMFC cathode respectively. For MAB, our strategy is mainly based on the development of so-called bifunctionnal perovskite catalysts for oxygen reduction/evolution and introduction of ionic liquids as electrolyte.

This research cluster aims to bundle together the existing expertise in the different working groups and generate new project ideas around the research focus area »electrodes for energy storage and conversion devices«. Relevant questions and strategies are discussed together with other experts from research and industry in the context of workshops.

RESEARCH CLUSTER

Integrated chemical and biotechnological production

In the 21st century the chemical industry will play a major role in the development of new materials, substances and processes. In the future an increase in efficiency and flexibility of the existing production routes is necessary to reduce material and energy consumption. The integration of biotechnological and chemical reaction steps allows novel processes with improved performances and will address the challenges of climate change and clean energy.

By combining different disciplines such as bio-, electro- and chemo-catalysis, molecular biology and process engineering in the cluster »integrated chemical and biotechnological production« at DECHEMA-Forschungsinstitut novel production routes for the pharmaceutical, cosmetics and chemical industry, agro-chemicals as well as the food area will be developed. The chemo-, regio-and enantioselectivity of enzymatic reactions allow for synthesis routes to be realised that are currently difficult to achieve by chemical processes. The combination of chemo and biocatalysis is a key technology for the efficient use of renewable resources and the development of environmentally friendly and resources-efficient production processes. For this purpose, molecular biology is used to develop enzymes and microorganisms with tailored properties.

The combination of electrochemistry and enzyme reactions to electroenzymatic processes offers a variety of possibilities for advanced production systems. As a novel and highly energy efficient process microbial electrosynthesis are investigated. In microbial electrosynthesis electrons are transferred between electrodes and microorganisms. The electrical energy can be used directly in the metabolism of micro-organisms to produce valuable compounds.

Other research topics in the cluster are the combination of biocatalytic reactions and artificial energy-producing photosynthesis, cascade reactions, and new selective downstream processes.

Prototype of an electrochemical microtiter plate (eMTP) with three electrodes per well, developed at the DFI. An example for eMTP application is the development of environmentally friendly electroenzymatic syntheses for the chemical industry.

RESEARCH FIELDS

- Combined bio-, electro- and chemo-catalysis
  - electroenzymatic processes with oxidoreductases
  - cascade reactions
  - photoenzymatic processes
- Microbial electrosynthesis
- Novel screening systems
- Scalable reactor concepts
- Electrochemical methods for downstream processing of biomolecules

Electronic scrap is a
possible source of raw materials

RESEARCH FIELDS

- Development of unexploited secondary resources *(Urban Mining)* for metallurgy, chemical industry and power generation
- Electrochemical and thermal processes for reclamation of materials
- Recycling of metals from wastewater using modified electrodes
- Combination of *Microbial Leaching* with other processes
- Substitution of inorganic recyclable materials by cost-effective and environmental friendly alternatives

RESEARCH CLUSTER

Recovery of inorganic resources

Numerous raw materials with a wide range of applications for industrial processes have limited availability. Mass-production of consumer items leads to rapid consumption of natural resources. At the same time the modern fast paced society builds an ever-increasing »anthropogenic« stockpile of waste and recyclable materials.

Due to the scarcity of resources these waste and recyclable materials become a valuable source of raw materials. For their development intelligent processes are required, e.g. microbial leaching in combination with electrochemical segregation or high temperature processes.

In the research cluster »recovery of inorganic resources« the competences for this field of research are pooled in an interdisciplinary manner.

The cluster benefits from the interrelation between electrochemistry, technical chemistry, materials science and biotechnology. It aims to develop innovative strategies for prospective industrial cycles and urban mining.

Furthermore, the cluster deals with the possibility of substituting inorganic materials, whose extraction and recovery is expensive and harmful to the environment.

RESEARCH CLUSTER

Innovative corrosion protection concepts

Modern materials technologies are a driving force for innovation especially in branches such as the automotive and aviation industries, medical or energy technologies as well as manufacturing or process systems engineering. Corrosion protection will be of specific importance for the national economy. According to estimates the annual losses by corrosion in Germany are equal to the annual production of a steel plant.

Any decrease of material damage through corrosion due to the application of innovative corrosion protection measures will therefore not only reduce the economic damage but also the need for replacement of metallic compounds. With increased component and plant lifetime the use of raw materials will also be reduced as well as the energy consumption during production.

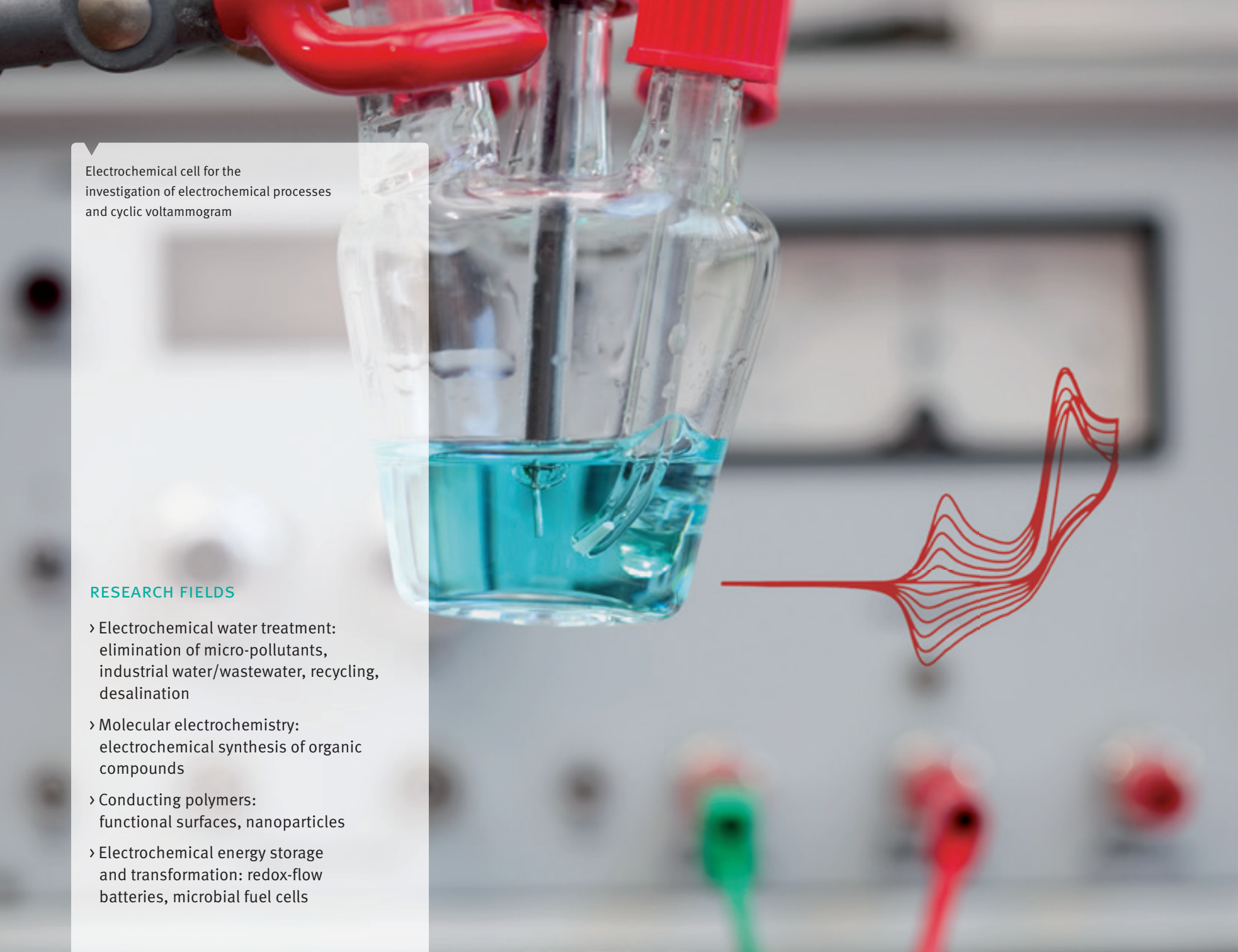
Innovative corrosion protection concepts are not only involved with increased demands on environment and health protection, they may even enable many modern technologies, e.g. in energy production and storage. DECHEMA-Forschungsinstitut has been engaged in corrosion research for over 50 years and therefore offers optimal prerequisites in combining the necessary expertise in electrochemical basics and measurement methods, principles of chemical nanotechnology as well as materials science with a focus on high temperature materials. The research cluster is thereby supported by a unique combination of expertise in electrolytic corrosion, high temperature corrosion, electrochemistry as well as biochemistry.

Nanoparticle based coatings, new anodising methods, protective biopolymer films, oxidation protection layers for intermetallic materials, ceramic thermal barrier coatings or new functional high temperature protection layers are some of the research topics that are the focus of the cluster. As unique selling points, minimally-invasive high temperature corrosion protection as well as coating systems for highly aggressive atmospheres have emerged in recent years.

Scanning Kelvin Probe
for a contactless and space-resolved
measurement of corrosion potentials

RESEARCH FIELDS

- Nanoparticle based coating systems for corrosion/oxidation protection
- Modification of oxidic layers
- Functionalisation of coatings by incorporation of nanocapsules
- Corrosion protection using biopolymer films
- Oxidation protection coatings for intermetallic materials
- Ceramic thermal barrier coatings
- New functionalised high temperature protective coatings
- Minimally-invasive high temperature corrosion protection
- Coating systems and materials for aggressive high temperature atmospheres



Electrochemical cell for the investigation of electrochemical processes and cyclic voltammogram

RESEARCH FIELDS

- Electrochemical water treatment: elimination of micro-pollutants, industrial water/wastewater, recycling, desalination
- Molecular electrochemistry: electrochemical synthesis of organic compounds
- Conducting polymers: functional surfaces, nanoparticles
- Electrochemical energy storage and transformation: redox-flow batteries, microbial fuel cells

RESEARCH GROUP

Electrochemistry

Many technical processes and objects of daily use are based on electrochemistry. The scope of electrochemistry is far beyond batteries and fuel cells. Electron transfer reactions are part of many chemical syntheses. Compared to a chemical synthesis, the electrochemical process uses the current directly, i.e. it is more selective and requires no additives that have to be separated in a purification process. Electrochemistry is applied in surface modification and materials characterisation. Different electrochemical sensors are utilised for monitoring and controlling technical processes. Waste and micro-pollutants can be disposed using electrochemical processes.

The fields of activities of the electrochemistry group cover the whole spectrum from fundamental science to applied developments. A focal point is the development of new organic syntheses and the elucidation of reaction mechanisms. In cooperation with the biochemical engineering group the electron transfer to microorganisms is studied.

A further topic is the development of electrochemical methods for the treatment of process and potable water, e.g. by disinfection, desalination, elimination of micro-pollutants and recycling of resources. Examples are electrochemical switchable ion exchangers, electrochemical elimination of pharmaceutical residues and the development of functional surfaces with electrochemically controllable properties, e.g. membrane coatings with variable separation properties. The electrochemical action is based on the application of conducting polymers. The group has vast experience in fundamental research and the technical application of these polymers. Due to the limitation on resources and legal directives water treatment will also gain importance.

RESEARCH GROUP

Chemical technology

The demand for chemical products is growing at an exponential rate. This tremendous challenge can be met by substantially improving existing strategies and optimising processes in chemical plants. In the past decade, great effort was required to match production efficiency to the needs of the society in view of product selectivity, material and energy costs, as well as environmental protection. In this context, Chemical Technology is a major contributor, transferring fundamental research to improvements and innovation.

The main areas of the research group are sustainable production, reaction engineering, chemical technology, as well as electro-chemical energy storage and conversion. An integral part is the integration of photocatalysis into chemical, electrochemical and biochemical processes. The advantage of photocatalysis lies in the ease of adding the energy in form of photons which is reagent-, contact- and residue-free. Also, clever selection of reactants allows photocatalytic reactions to realise several consecutive reaction steps in a one-pot-synthesis. If sunlight is then used as the energy source to drive the photocatalytic reaction, the process becomes cheaper, sustainable and CO_2-neutral as sunlight is available free of charge and without a carbon footprint.

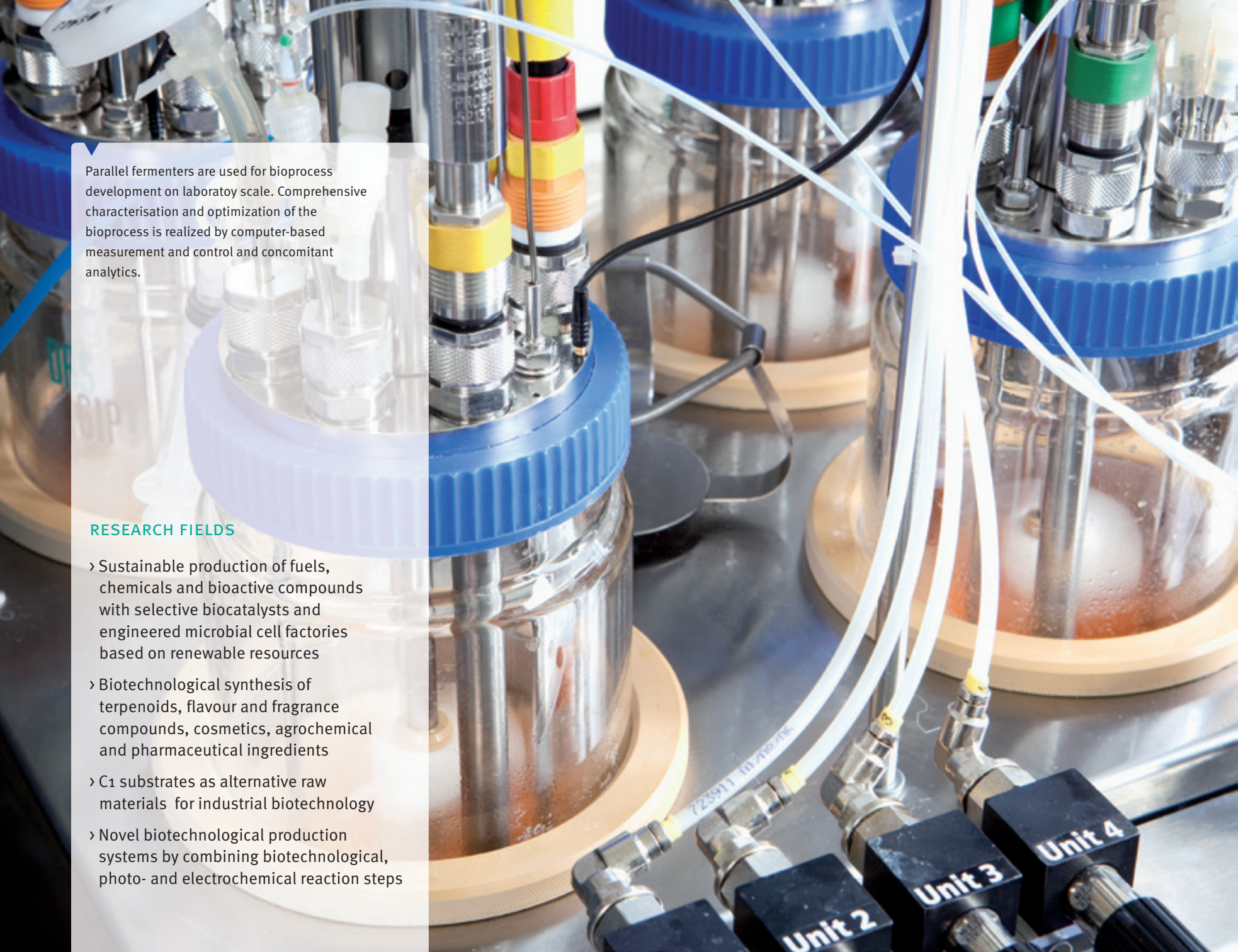
In addition to their uses in synthetic applications the group also explores the oxidative powers of photocatalysts for the abatement of undesired contaminants. Due to the immense oxidation potential of most photocatalysts, e.g. titanium dioxide, these materials are able to mineralise virtually all organic compounds when illuminated with light. This property can be used in water remediation and air pollution cleaning as well as to create actively self-cleaning and self-sterilising surfaces. The group is involved in the development of more efficient and selective photocatalysts as well as improved coating techniques.

Further activities focus on the development and characterisation of gas diffusion electrodes (GDE) and catalysts for polymer electrolyte membrane fuel cells (PEMFC), solid oxide fuel cells (SOFC) and metal/air batteries (MAB). Actual project examples are a low-pressurized direct methanol fuel cell (DMFC), a cooking-resistant direct methane SOFC and an electrically rechargeable Al/air battery.

Downstream processing is an important task, especially when dealing with renewable resources. One attractive possibility is the development and optimisation of integrated concepts.

RESEARCH FIELDS

- Sustainable production of chemicals and synthetic fuels using photocatalysis
- Development of functional surfaces with air-, water-, and surface cleaning properties
- Preparation and characterisation of catalysts & GDE for the PEM & SOFC fuel cells as well as for metal/air batteries



Parallel fermenters are used for bioprocess development on laboratoy scale. Comprehensive characterisation and optimization of the bioprocess is realized by computer-based measurement and control and concomitant analytics.

RESEARCH FIELDS

- Sustainable production of fuels, chemicals and bioactive compounds with selective biocatalysts and engineered microbial cell factories based on renewable resources
- Biotechnological synthesis of terpenoids, flavour and fragrance compounds, cosmetics, agrochemical and pharmaceutical ingredients
- C1 substrates as alternative raw materials for industrial biotechnology
- Novel biotechnological production systems by combining biotechnological, photo- and electrochemical reaction steps

RESEARCH GROUP

Biochemical engineering

The foreseeable limitation of fossil resources is one of the key challenges for modern industrial societies. The chemical industry increasingly seeks to implement sustainable technologies and green production routes in their processes. Here, biotechnology plays a pivotal role as a discipline which enables the development of environmentally benign processes based on renewable resources. The Biochemical Engineering Group focuses on industrial (»white«) biotechnology. In interdisciplinary project teams, biotechnologists, biologists, chemists and engineers work closely together to develop novel biotechnological production strategies and innovative bioprocesses.

Starting with promising basal strains »microbial cell factories« are being constructed enabling the efficient production of valuable chemicals. Here, different methods are employed, such as metabolic engineering, synthetic biology, evolutionary engineering as well as tailor made selection and screening systems. These approaches are complemented by the development of efficient fermentation protocols and the integration of highly selective techniques for in situ product removal to establish powerful bioprocesses.

The potential of isolated enzymes as highly selective biocatalysts for organic synthesis is illustrated by exploiting different oxidoreductases, such as cytochrome P450 monooxgenases and alcohol dehydrogenases. In these systems, electrochemically driven biocatalysis is a major research field, which is conducted in close collaboration with the Electrochemistry Group. This research topic is being deepened further in the interdisciplinary research cluster integrated chemical and biotechnological production.

Concerning their target products, the Biochemical Engineering Group focuses on the natural product class of terpenoids and on functionalised fatty acids. These structurally diverse small molecules are of broad industrial interest as biofuels, bulk chemicals, flavour and fragrance compounds, bioactive food and cosmetic ingredients and as active pharmaceutical ingredients. With respect to the raw materials, the group focuses on C1 sources, such as CO_2, methane, and methanol, as alternative renewable resources for industrial biotechnology. Bioprocesses based on these substrates do not compete with the food industry for cultivable land area.

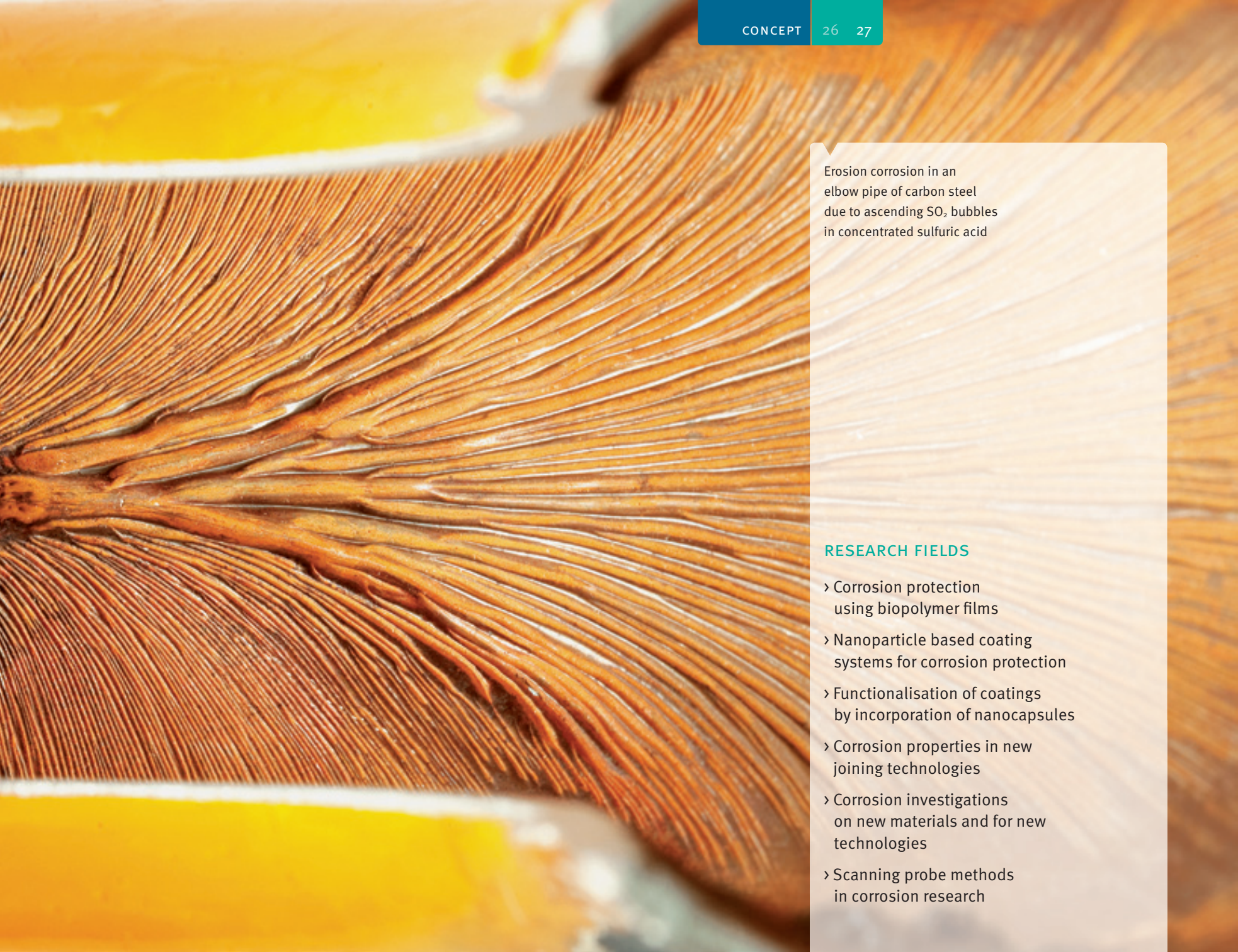
RESEARCH GROUP

Corrosion

Many modern technologies strongly depend on the materials properties of the components in use. However, while in the planning stage much emphasis is placed on mechanical properties, fabrication, availability and materials costs, the role of corrosion is frequently neglected. Corrosion properties are quite often discussed only when initial damage has occurred. This is one of the main reasons for high corrosion costs which have been determined in several studies in this field. Such costs can arise in all fields where metallic compounds are employed: from bridge construction to transport industries, the construction of energy plants through to the aviation industry. Furthermore, many modern technologies will not be realised without adequate or even new corrosion protection concepts. This is especially valid for the successful application of new techniques in energy production.

In order to avoid corrosion damage from the very onset fundamental corrosion research as well as new innovative corrosion protection measures is essential. The corrosion research group is following both paths. Concerning the investigation of corrosion processes themselves, newly developed materials such as improved titanium alloys, innovative joining techniques or other future technologies especially in energy production are involved. A key focal point is the application of new highly resolved scanning probe methods, such as the Scanning Kelvin Probe technique or the electrochemical Atomic Force Microscope.

Concerning corrosion protection the corrosion research group is following new ways for the production of protective layers using nanoparticle based systems or biopolymer films. The work on nanoparticle based systems comprises both the development of inorganic barrier layers from nanoparticulate dispersions and the modification and functionalisation of inorganic coating systems, especially oxidic layers, by the incorporation of nanoparticles. Through integration of nanocapsules such layers may also acquire additional functionalities such as self-healing properties.



Erosion corrosion in an elbow pipe of carbon steel due to ascending SO_2 bubbles in concentrated sulfuric acid

RESEARCH FIELDS

- Corrosion protection using biopolymer films
- Nanoparticle based coating systems for corrosion protection
- Functionalisation of coatings by incorporation of nanocapsules
- Corrosion properties in new joining technologies
- Corrosion investigations on new materials and for new technologies
- Scanning probe methods in corrosion research

Development of materials
for extremely high temperatures

RESEARCH FIELDS

› Gasification atmospheres as well as other aggressive process environments (bromine, chlorine, sulphur, vanadium, carbon, nitrogen, etc.)

› Intermetallic materials (TiAl – high temperature light weight materials, »Beyond Ni-Base superalloys«)

› (Multi)-functional high temperature coatings (anti-adhesive, in-situ depletion sensor, corrosion protection)

› »Minimally invasive« high temperature corrosion protection (halogen effect, catalytic poisoning)

› Diffusion and thermal barrier coatings

RESEARCH GROUP

High temperature materials

The demand for environmentally- and resources-friendly processes as well as higher yields in thermal plants and machinery leads to increasing demands on materials that are employed at these high temperatures. This is particularly relevant with plants used for high temperature processes in the petrochemical and chemical industries, power plants and gasification equipment for fossil fuels, by-products, waste products and biomass as well as combustion engines and land-based as well as aviation turbines. Higher yields in thermal plants and machinery are achieved most notably by higher operating temperatures and in the case of portable applications through the deployment of high temperature light weight materials. At the same time, higher yields constitute a substantial contribution to the conservation of energy resources and a reduction of ecological damage.

With increasing temperatures chemical reactions (high temperature corrosion) between the material surface and the process or operating environment play a deciding role in the component life time, and without appropriate surface protection measures many new approaches for thermal processes are not feasible. For this reason, the working group High Temperature Materials therefore deals with exploring the applicability limits of established high temperature materials under extreme service conditions. A further research area is the development of innovative materials systems in order to extend the operating limits of components and to enable new technologies. In addition, fundamental as well as applied research work in materials properties and mechanisms at temperatures up to 1800°C and in various environments is conducted. The main research activities focus on the development of surface protection systems for innovative intermetallic materials (titanium aluminides, silicides, chromides), the development of life time models and innovative concepts for ceramic thermal barrier coatings as well as the design and development of corrosion protection coating systems for extremely aggressive high temperature atmospheres (chlorine corrosion, sulfidation, metal dusting, vanadate corrosion, etc.) on the basis of thermodynamic and kinetic models. Furthermore, comprehensive work on the development of new functional high temperature protective coatings, e.g., with sensor properties, is also being undertaken.
A research area that has recently developed into a certain unique selling point of the working group has been the concept of »minimally invasive« high temperature corrosion protection.

CONCEPT

COOPERATION

INSTITUTE

CONTACT

BENEFITS

- Minimum red tape enables prompt negotiation and high flexibility, also for intellectual property arrangements and cooperation contracts
- Prompt and intensive consultation for technical solutions and research concepts, rapid initiation of joint research projects
- Large number of experienced researchers guarantees high scientific and technical know-how (long term projects and partnerships)
- Interdisciplinary cooperation allows for integral approaches to R&D projects and consultation
- Vocational training of future scientists for skilled industrial careers
- Continuing professional development courses for personnel from industry
- Institute scientists teach at universities, bringing industrially relevant topics into academia
- Involvement in national and international research networks and committees, to some extent in leading roles (WCO, EFC, NACE, GfKORR, EU, AiF, BMBF, DFG, MTI, ISO, DIN, GDCh, EFCE, etc.)

Research partner for industry

Research at the institute encompasses the complete span from fundamental research to application oriented developments. Fundamental research projects, which are normally financed by public funding, generally have the important goal of industrial implementation of research results. Applied research is for the most part conducted with bilateral cooperation with industry clients. The principal industry sectors addressed by the research of the DECHEMA-Forschungsinstitut are presented below.

In addition, subjects from other sectors (e.g. vehicle manufacturing, aircraft manufacturing, motor and turbine construction, etc.) are also handled, and the specific know-how of the institute for these subjects is also available.

POWER PLANT TECHNOLOGIES

› Specific materials solutions for power plant construction and operation sector

› Development and dimensioning of protective coating systems

› Specific life time prediction concepts taking into account (high temperature) corrosion concepts

› Applications in the thermal energy conversion plant (boiler, heat exchanger, gas and steam turbines, installations, etc.) and renewable energy (off-shore systems, geothermal, etc.) sectors

PLANT ENGINEERING

› Materials solutions for corrosive environments

› Materials solutions for high temperatures

› Materials solutions for complex process conditions

› Assessment of materials suitability and -potential

› Life-cycle engineering concepts

› Support for implementing innovative recycling processes

› Failure analysis and development of solutions

› Supervision and consultancy with design and implementation of plant engineering projects

CHEMICAL INDUSTRY

› Chiral products using efficient bioprocesses (biocatalysis, fermentation)

› Bulk, fine and specialty chemicals from alternative resources using biotechnology

› Cell free bioproduction systems: electroenzymatic syntheses

› Continuous production systems

› Downstream processing using switchable membranes

› Development of electroorganic syntheses

› Specific materials solutions for chemical plant construction and operation

› Support and consultation for process development

FOOD, COSMETICS, DETERGENT, PHARMACEUTICAL INDUSTRIES

› Natural flavours and fragrances from renewable resources using biotechnology

› Bioactive substances using biotransformation and microbial synthesis

› Lubricants and lubricant additives

› Electrochemical disinfection of plants

› Electrochemical water softening

ENVIRONMENTAL ENGINEERING

› Electrochemical decomposition of pollutants and micro-pollutants

› Recovery of resources from aqueous solutions

› Water disinfection

› Thermal methods for urban mining

› Specific solutions for environmental engineering construction and operation sector

Project examples

THE »HALOGEN EFFECT«

› Challenge

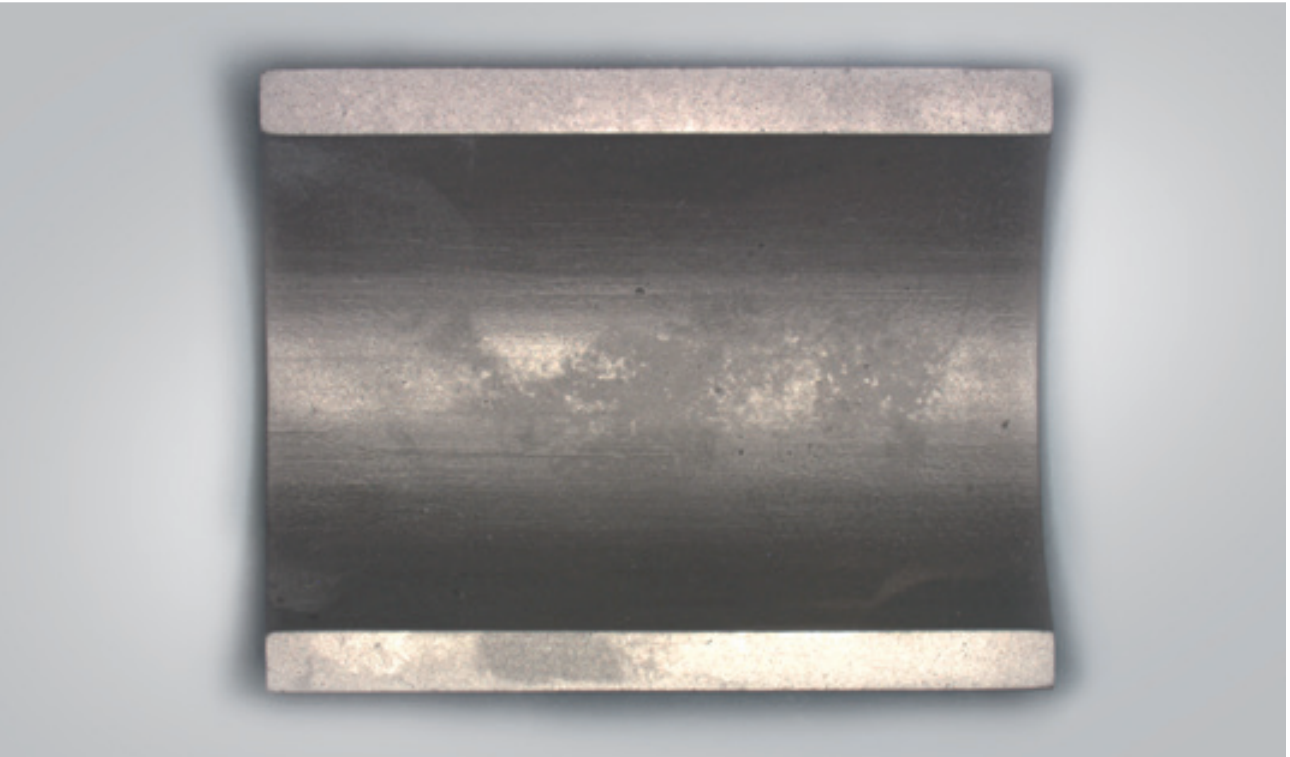
Titanium aluminides (TiAl) are an interesting class of materials for light weight applications at high temperatures, for example for turbo chargers in the automotive industry (Figure on the right). These alloys show an excellent combination of high strength and low density but lack oxidation resistance above 700°C, as they develop a fast growing mixed titanium/aluminium oxide scale.

› Solution

The halogen effect (F, Cl, Br, I) promotes the formation of a protective single phase alumina scale.

› Results

- Increased efficiency
- Decreased fuel consumption and CO_2 emissions
- Noise reduction



INNOVATIVE APPROACH TO AVOID »COKING« AND »METAL DUSTING«

› Challenge

»Coking« and »metal dusting« are two dangerous high temperature degradation mechanisms that can occur in industrial plants with gas atmospheres of high carbon activities and low oxygen partial pressures. Typically thick scales of coke form in the tubes that can lead to a critical decrease of the cross-section or even blockage. This carbon deposition often also results in metal dusting. Metal dusting is a rapid form of metal disintegration by high temperature corrosion in which crystallization of graphite within the supersaturated metal substrate causes internal stresses followed by the transformation of structural components into »metal dust«, i.e. coke and alloy particles.

› Solution

Catalytic inhibition of the initial surface reaction of materials with carbon by tin-containing coatings and thereby the suppression of coking and metal dusting.

› Results

- Increase of service intervals and component lifetime
- Improved performance (Resource economizing, environmental protection)
- Better energy efficiency in fuel cells
- Higher heat exchange in tubes due to the possibility to use metal dusting susceptible alloys protected by the new coating

SELF-HEALING COATINGS FOR CORROSION PROTECTION OF MAGNESIUM ALLOYS

› Challenge

Magnesium is very popular as the lightest construction metal; to protect it against corrosion, so far Cr^{VI}-based coatings have been used. These have self-healing properties, however, Cr^{VI} is toxic and carcinogenic.

› Solution

Encapsulated corrosion inhibitors in an anodic oxide layer:

- Basic protection by the anodic oxide layer
- Rare earth metal compounds as corrosion inhibitors
- Controlled inhibitor release in case of corrosion due to encapsulation

› Results

- Low energy consumption for the anodizing process
- Complying with environmental requirements by abandonment of Cr^{VI}
- Sustainable corrosion protection

PERILLIC ACID FROM LIMONENE

› Challenge

(+)-Limonene is the main constituent of peel oils from citrus fruits. Every year about 50,000 bis 75,000 tons of this hydrocarbon accumulate in the citrus processing industry. Up to now it is regarded as residue and rarely used for the synthesis of valuable products.

› Solution

Selected solvent-tolerant bacteria allow the conversion of hydrocarbons such as (+)-limonene into valuable bioactives in an efficient bioprocess developed at the DFI. A prominent example is the synthesis of antimicrobial (+)-perillic acid from (+)-limonene

› Results

Perillic acid is a promising candidate for the application in cosmetics.
A well known german biotech company is tackling the industrial implementation of this process. Quality control of the biotechnologically produced bioactive and its efficient production on technical scale are of utmost importance.

CONCEPT

COOPERATION

INSTITUTE

CONTACT

Together with around 150 specialists from industry, academia and authorities, institute employees organise around 50 courses annually in Frankfurt am Main and other locations in Germany.

CONTINUING PROFESSIONAL DEVELOPMENT

› Biotechnology
› Electrochemistry
› Corrosion und corrosion protection
› Measurement and control technology
› Patent management
› Soft skills
› Safety technology
› Process and reaction engineering
› Design of experiments

93% of our participants evaluate our training courses as being »good« or »excellent«

GOALS

› to consolidate and expand existing knowledge

› to provide practical skills

› to introduce modern methods

› discussion about the legal framework

› exchange of experiences on an advanced level

› personal development through soft skill courses

GUIDELINES

› limited number of participants

› pleasant learning environment

› continual quality control (course contents, lecturers)

Continuing professional development

Professional excellence is regarded as a prerequisite for every scientist and engineer who wishes to be successful in his long term working life. At the same time, further vocational training of the staff is one of the most important inputs for the sustainability of a company. With its outstanding continuing professional development program in the scientific-technical key disciplines and their interfaces, DECHEMA-Forschungsinstitut contributes by closing knowledge gaps, by calling early attention to cutting edge developments and transferring new methods into industrial practice. Thus, future shortages in skilled workers in local industries will be effectively met by the technological and scientific fields represented by the institute.

The institute not only offers lecture courses, but also unique experimental courses, where the participants conduct supervised experiments themselves in laboratories. Course participants appreciate the particular educational value of this combination of practical exercise with complementary lectures.

Measurement of acustic emission
at high temperatures to evaluate material
damage propagation

Research facilities

MATERIALS AND SURFACE CHARACTERISATION

› Scanning electron microscope (SEM) with energy dispersive analysis (EDX)

› Transmission electron microscope (TEM) with energy dispersive analysis (EDX)

› Electron probe micro analyser (EPMA) with wavelength dispersive analysis (WDX)

› X-Ray diffraction (XRD)

› Atomic Force Microscope (AFM) with equipment for in-situ AFM, Scanning Kelvin Probe Force Microscopy (SKPFM) and SECPM

› Fluorescence microscopy with UV-Vis-spectroscopy

› Classical and interference layer metallography

› Spark emission spectrometer

› Nano-indenter (hardness measurement)

› Dilatometer

› Servo-hydraulic and other mechanical testing machines

› 4 point bending test apparatus (4PB)

› Acoustic emission analysis (AE)

› Thermogravimetric balances (TGA)

› Isothermal and thermocyclic high temperature furnaces corresponding to the newest ISO standards

› Contact angle measuring instrument

› Taber Linear Abraser

› Salt spray chamber

› Confocal Raman microscope

CHARACTERISATION OF POROUS MATERIALS AND CATALYSTS

› Capillary flow porometer

› Chemisorption

› Temperature programmed reduction and oxidation

› BET Isotherms

› Membrane testing facility

CHEMICAL ANALYSIS AND REACTION TECHNOLOGY

› High performance liquid chromatography (HPLC) with UV-Vis/RID/PDA/ELSD/ MS-coupling

› Gas chromatography (GC) with FID/WLD/MS-coupling, enantio-selective GC

› FT-IR spectroscopy

› UV-Vis-NIP spectroscopy

› UV-Vis-Fluorescence microreader

› Fluorescence microscopy

› Atomic absorption spectroscopy (AAS)

› Ion chromatography

› Particle size and zeta-potential measurements using dynamic light scattering

› Rheometer

› Coulombmetric Karl Fischer titration

› Reaction calorimetry

› Determination of organic carbon (TOC)

› Micro-reaction testing equipment

› Autoclaves (-77 to 500°C, 0 to 345 bar)

ELECTROCHEMICAL METHODS

- Current density potential curves
- Cyclovoltammetry (CV)
- Electrochemical impedance spectroscopy (EIS)
- Electrochemical quartz crystal micro-balance (EQCM)
- Rotating ring-disk electrode
- Spectro-electrochemistry (UV-Vis-NIR)
- High voltage-/high current potentiostat for anodising
- Electrode test apparatus
- Battery test system

MANUFACTURING METHODS

› Nd-YAG Laser for micro-manufacturing

› Mechanical precision machining tools

› Single and four source sputtering facility

› Sintering furnaces

› Induction furnaces

› IR-heaters

› Dip coating facilities

› Screen printing machines

› Spraying system with ultrasonic head

› Laboratory hot press

› Vacuum induction melting furnace (up to 2000°C)

› Arc melting furnace (up to 3000°C)

BIOTECHNOLOGICAL METHODS

› Genetic engineering laboratories with security level S1 and S2

› Parallel fermentation systems with computer based measurement and control technology

› Fully equipped laboratory reactors from 150 mL up to 42 L volume

› Microtiter plate cultivation system

› Downstream processing unit operations, e.g. membrane modules for organophilic pervaporation and perstraction (in-situ product removal), cross flow units, freeze drying units

› Complete molecular biological facilities (PCR-machines, gel documentation, electroporator, micro-photometer)

› Diverse rotating incubators including microtiter plate incubators

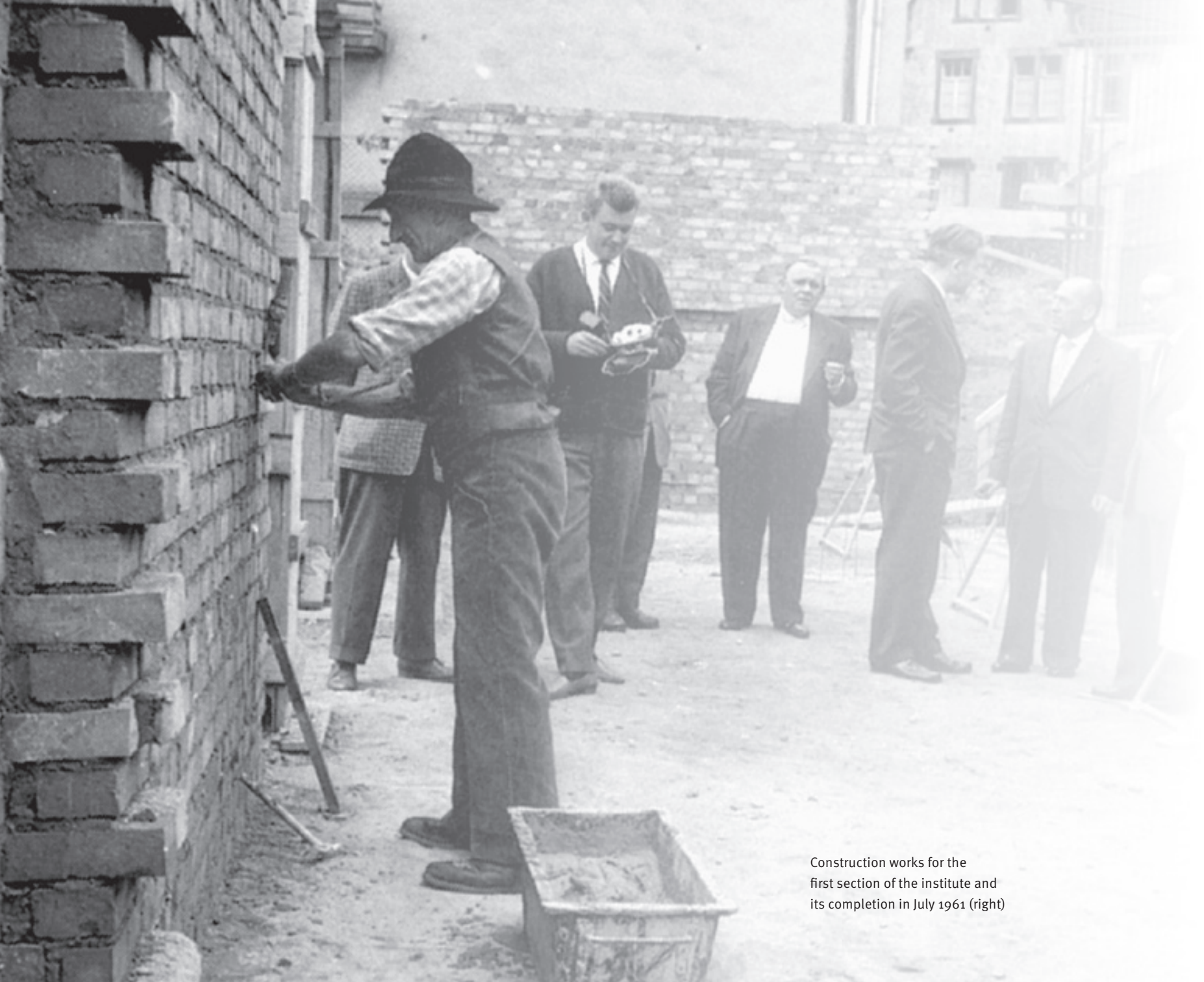
› UV-Vis-spectrometer (sensitivity in the nanolitre range)

› Electroporation

› Liquid chromatography for rapid purification of proteins (FPLC)

› Micro-manipulator

› Fluorescence activating cell sorting (FACS) system



Construction works for the
first section of the institute and
its completion in July 1961 (right)

History

END OF THE 1920'S
Plans for the establishment of a DECHEMA research institute
by Max Buchner (Founder of the DECHEMA e.V.)

1939
Establishment of a research- and information-centre
for plant control as an institute forerunner

1959
DECHEMA executive board resolution under the direction of Karl Winnacker
on 11.12.1959: Establishment of a research institute in the area of reaction engineering

1961
Inauguration of the 1st construction phase by Karl Winnacker. Cost: 2.4 Mio DM

1966
Completion of the 2nd construction phase. Cost: 3.25 Mio. DM. Patrons: VW-Foundation 2 Mio DM,
Hessen State 0.25 Mio DM. 15 scientists, 10 technicians & 3 workshop employees, 5 office staff
Areas of expertise: Technical Chemistry, Electrochemistry, Electrolytic and High Temperature Corrosion,
Materials Engineering. First considerations to employ PhD students

1968
55 Employees, 4 PhD students, 15 third party projects. First projects with AiF and DFG support

1970
Institute acquires the name Karl-Winnacker-Institut. Establishment of the Biotechnology working group

1987
Completion of the 3rd construction phase

2012
Establishment of the foundation and transfer of the institute into the new foundation,
change of name to DECHEMA-Forschungsinstitut

CONCEPT

COOPERATION

INSTITUTE

CONTACT

INSTITUTE STRENGHTS

› Internationally renowned know-how

› Complete span: Fundamental research to application oriented developments

› Experienced partner with industrial contract research

› Unique combination of specialist fields

› Targeted use of interdisciplinary cooperation

› Prompt implementation of new research ideas

› Flexible non-bureaucratic collaboration

› Close networking in the technical and scientific community

› Teaching at renowned universities

› Educating future scientists and extensive vocational training

BENEFACTOR AND SUPPORTER ADVANTAGES*

› Salient patronage: Plaque listing benefactors in DECHEMA-Haus; Internet presence

› One-off benefactor or supporter contribution = long term support of the non-profit goals of the institute

› Invitations to specific events

› Information about the current trends in research and development

› Direct access to competent associates (consultancy, projects)

› Close contact to a particularly interdisciplinary research institute

› Part of the network: DECHEMA-Forschungsinstitut Stiftung bürgerlichen Rechts, DECHEMA Gesellschaft für Chemische Technik und Biotechnologie e.V. and DECHEMA-Ausstellungs GmbH

› Contribution towards the important core competences located in Germany

› Support of practice oriented continuing professional development opportunities

› Support of future scientists through industry relevant training

Become a benefactor or supporter and support the work of DECHEMA-Forschungsinstitut. The institute will happily send you the appropriate documentation. Contributions can be used for tax reduction purposes.

* Benefactor contributions are injected into foundation capital while supporter contributions flow directly into financing the ongoing work of the institute. In addition, equipment donations are also welcome as supporter contributions.

DECHEMA
FORSCHUNGSINSTITUT
Stiftung bürgerlichen Rechts

Theodor-Heuss-Allee 25
60486 Frankfurt am Main
Germany

Phone +49 69 7564 337
Fax +49 69 7564 388

dfi@dechema.de
www.dechema-dfi.de

Executive Board:
Prof. Dr.-Ing. Michael Schütze (chairman)
schuetze@dechema.de

Prof. Dr. Jens Schrader
schrader@dechema.de

Foundation Location:
Frankfurt am Main

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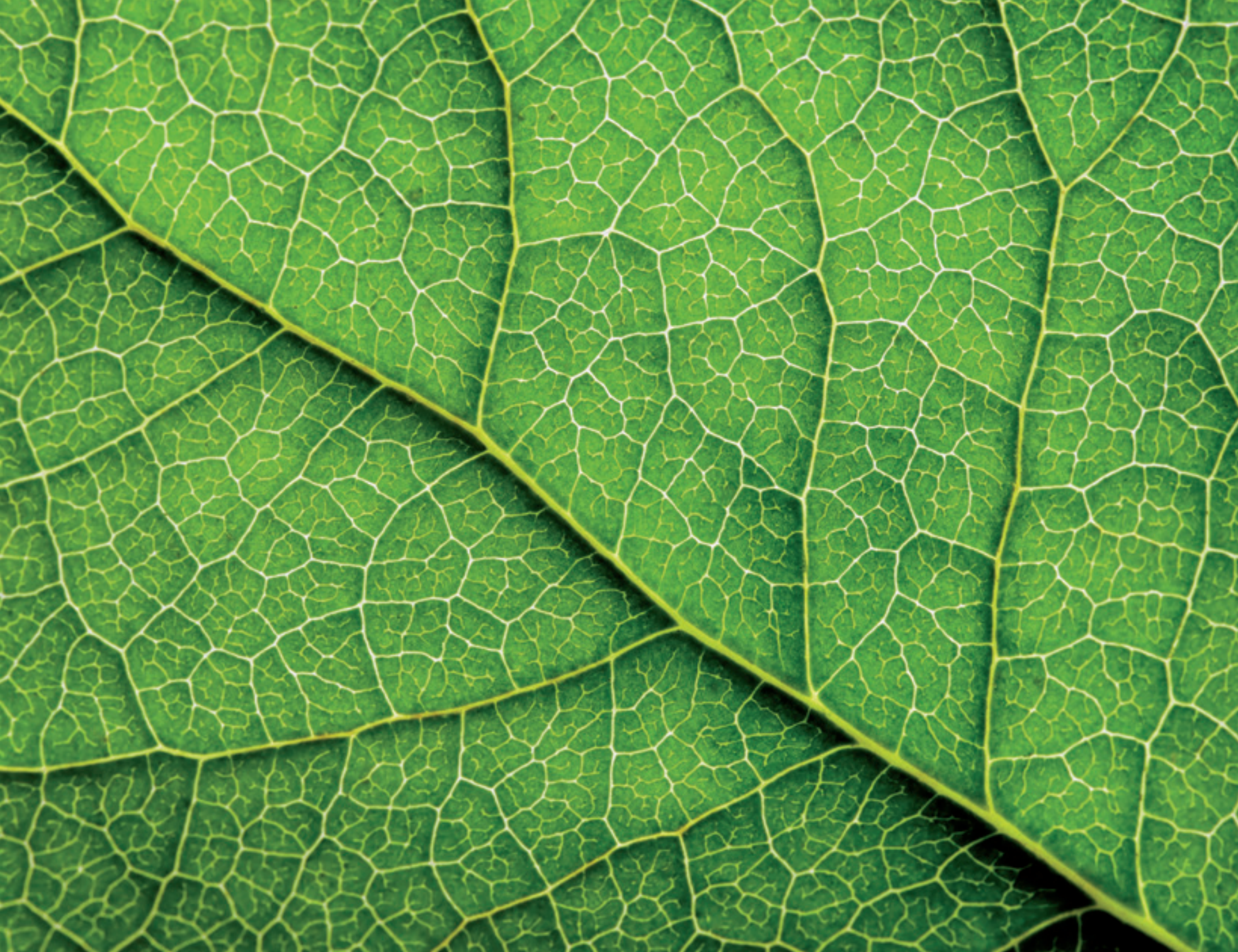

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DECHEMA-Forschungsinstitut
Non-profit civil law foundation

Theodor-Heuss-Allee 25
60486 Frankfurt am Main
Germany

Phone +49 69 75 64 337
Fax +49 69 75 64 388

dfi@dechema.de
www.dechema-dfi.de

RESPONSIBLE FOR THE CONTENT

Prof. Dr.-Ing. Michael Schütze
Prof. Dr. Jens Schrader

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