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FRAUNHOFER INSTITUTE FOR
CERAMIC TECHNOLOGIES AND SYSTEMS IKTS

MEMBRANE TECHNOLOGY

MEMBRANE TESTING IN LABORATORY, PILOT AND FIELD TESTS

At Fraunhofer IKTS, ceramic membranes for separation processes in liquid, vaporous and gaseous media are developed. These developments usually aim at improving the separation efficiency and selectivity of membrane and process. For process evaluation, technical data are collected in a multistage process. Basic experiments in laboratory scale provide first qualitative results for the planned membrane process. The following tests with industrial scale membranes on a pilot plant (in lab or on site) are used to capture reliable performance data.

The field test plants of IKTS can be used in different modes ranging from batch, feed-and-bleed to continuous mode. They can be refilled automatically or integrated in an industrial plant. They can also be individually designed for various applications.

Membrane systems in the laboratory and pilot scale are available for the following processes: pervaporation, vapor permeation, gas permeation, microfiltration, ultrafiltration and nanofiltration as well as organophilic filtration.

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MEMBRANE PROTOTYPES

Membrane development at Fraunhofer IKTS ranges from small lab-scale geometries like mono channel tubes and plate discs to industrial scale multichannel tubular membranes with a length of up to 1.2 m and a filtration area of up to 1.3 m²/tube. An important step towards industrial application is the upscaling of membrane production to membrane geometries offering a high active membrane area. For various membrane prototypes, pilot membrane production lines were established. Here, membranes samples of industrial scale geometry are synthesized. This step is necessary to develop manufacturing processes and methods for later industrial membrane production. In the pre-industrial membrane production phase, membranes for plants are offered to test and prove the application of the membrane for a certain process on large scale.

Microfiltration, ultrafiltration, nanofiltration and zeolite A membranes are available as prototypes on industrial scale. At laboratory scale, zeolite ZSM-5 membranes and carbon membranes are available.

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MEMBRANE CHARACTERIZATION

Membranes developed at IKTS have to be characterized in order to follow membrane development steps and to evaluate mass transfer. Multilayered membrane structures and pore sizes ranging from the micrometer to the sub-nanometer scale require special test procedures. So, for example, pore size and pore size distribution are determined and layer quality is analyzed (before and after application). These methods can be applied with lab samples, industrial scale membranes with a length of 1.2 m as well as with customer-specific membranes. The main methods that are used for membrane characterization are the following:

- Permporometry
- Bubble-point method
- Permeation measurement/cut-off determination
- Burst pressure testing
- Clear water flux determination
- Contact angle measurement
- Determination of acid and alkali stability

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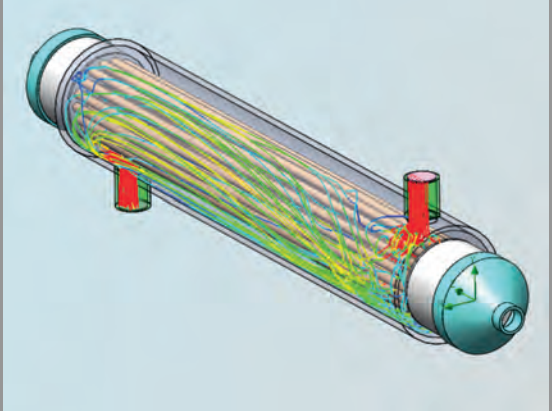

SIMULATION OF MASS TRANSFER

Performance and efficiency of a membrane process are highly influenced by membrane flux and relevant process conditions. The membrane flux is not only affected by the active separation layer, but also by the membrane support and the supporting layer structure. Therefore, simulation of mass transfer is an important tool for the development and characterization of ceramic membranes and membrane processes.

The most meaningful result of simulation is the permeance that can be expected for the whole membrane. Considering the whole membrane module, the flow conditions within the membrane housing also play an important role. This is of special interest for complex membrane geometries, e.g. capillary or hollow fiber bundles, as well as for optimizing mass transfer. Furthermore, questions on heat transfer and pressure stability of certain membrane geometries have to be answered. The latter, for example, is of great importance for high-pressure applications, such as nanofiltration, with highly selective ceramic nanofiltration membranes.

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NANOPOROUS MEMBRANES

Nanoporous membranes are filters with pores in the nanometer and sub-nanometer range. Nanoporous ceramic membranes allow the separation of liquid, vaporous and gaseous mixtures by filtration using different sizes, shapes or adsorption behaviors. In membrane development, various membrane materials, like amorphous oxides, zeolites, carbon and carbon containing non-oxides, MOFs, CNTs and polymer/ceramic-mixtures are synthesized by sol-gel technology, hydrothermal crystallization, CVD or tape casting. Tubular as well as flat membranes can be prepared. Current research is focusing on hollow fiber bundles and honeycombs as support structures.

Nanoporous membranes can be used for effective separation in environmental engineering, food, chemical, pharmaceutical and fuel industry. Furthermore, the technologies and methods of membrane preparation are used for sealing, modifying and functionalizing surfaces in the building sector as well as for vehicle components, medical products, tools, optical components, electronic devices and household appliances.

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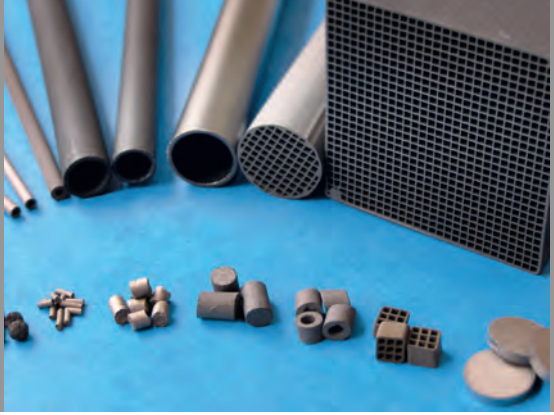

HIGH-TEMPERATURE GAS SEPARATION AND CATALYSIS

At Fraunhofer IKTS, gas separation at high temperature and heterogeneous catalysis are based on mixed oxides crystallizing in perovskite, fluorite or spinel structure. These materials realizing promising combinations of physical properties can be used as catalysts substituting noble metals, as mixed conducting oxygen membranes and as oxygen storage materials. Based on selected materials and on their adjustment for specific applications, Fraunhofer IKTS develops ceramic components suited for easy integration in pilot plants and optimized for high packaging density and gas throughputs. Besides, new technical processes are developed and further optimized to reduce energy consumption and so to minimize total costs for industrial applications.

Accordingly, our development aims at saving resources and energy as well as at the integration in industrial processes, e.g. for intensified combustion, gasification without nitrogen, carbon capture and storage, waste gas cleaning and a higher yield of chemical reactions.

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ELECTROMEMBRANE PROCESSES

Fraunhofer IKTS is also developing electromembrane processes typically based on polymeric ion exchange membranes. Starting with the appropriate selection of ion exchange membranes for the desired reaction conditions, the IKTS offers a broad portfolio of services. These comprise e.g.:

- Selection of economically preferable electrode material or coating, electrode testing
- Cell development
- Process design and optimization
- Process scale-up
- Development, construction and maintenance of testing equipment

The scientists are experienced in areas like electrochemical water treatment, detoxification, recycling of rare and precious metals, and conditioning of mining effluents as well as of radioactive wastes. In addition to lab-scale development, Fraunhofer IKTS also carries out pilot-scale tests.

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COOPERATION MODELS

One-off contracts
The classic model of cooperation: A company perceives a need for research or development. A discussion with Fraunhofer identifies possible solutions and clarifies the form the partnership could take and the estimated cost.

Large-scale projects with multiple partners
Some challenges are so complex that they require multiple partners to develop a solution. Clients in this situation have access to the full range of Fraunhofer Institutes. It is also possible to incorporate external partners and additional companies.

Strategic partnerships and innovation clusters
Pre-competitive research which starts off without any ties to specific development contracts often results in long-term partnerships with companies on a regional and international level.

Spin-offs
Fraunhofer researchers often take the step towards independence by founding their own company. Fraunhofer itself only participates in these kinds of start-ups up to a certain extent. Sometimes the customer who commissioned the new development is interested in taking a stake in the spin-off company itself.

MEMBRANE TECHNOLOGY BY FRAUNHOFER IKTS

FRAUNHOFER IKTS

The Fraunhofer Institute for Ceramic Technologies and Systems IKTS conducts applied research on high-performance ceramics. The institute's three sites in Dresden and Hermsdorf (Thuringia) represent Europe's largest R&D institution dedicated to ceramics.

As a research and technology service provider, Fraunhofer IKTS develops modern ceramic high-performance materials, customized industrial manufacturing processes and creates prototype components and systems in complete production lines from laboratory to pilot-plant scale. Furthermore, the institute has expertise in diagnostics and testing of materials and processes.

The institute operates in eight market-oriented business divisions to demonstrate and qualify ceramic technologies and components as well as non-destructive test methods for new industries, product concepts and markets beyond the established fields of application.

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