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Fraunhofer Institute for Ceramic Technologies and Systems IKTS

Membrane technology – enabling separation

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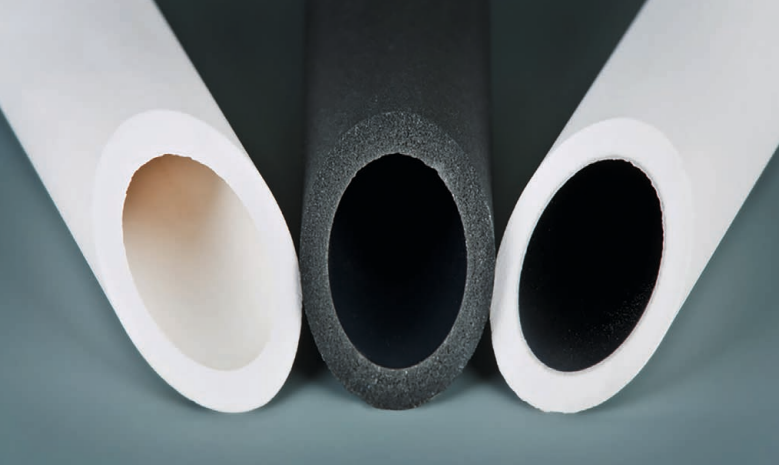

Nanoporous membranes

Nanoporous membranes are filters with pores in the nanometer and sub-nanometer range. By targeted adjustment of the pore size, polarity and surface properties, nanoporous membranes can be used to separate at the molecular level in liquids, gases and vapors.

Depending on the application, membranes can be synthesized from amorphous metal oxides, zeolites, carbon including carbon nano tubes (CNT), graphene and graphene oxides, metal organic frameworks (MOFs), metal components (Pd, Pd alloys), polymers and mixtures of polymer and inorganic components (mixed-matrix membranes) and scaled up to industrial scale.

Flat, tubular (single and multi-channel tubes), capillary and honeycomb geometries are used as membrane elements.

Continuous processing, low energy requirements, modular construction, short start-up times, no chemical additives are hallmarks of nanoporous membrane technology.

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Supports and prototypes

Membrane development at Fraunhofer IKTS ranges from small lab-scale geometries like mono-channel tubes and plate discs up to industrial-scale multi-channel tubular membranes with a length of up to 1.2 m and a filtration area of up to 1.3 m^2 per tube. In the pre-industrial membrane production phase, membranes for plants are offered to test and prove the application of the membrane for particular processes. 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 are available.

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. Upon request, filtration membranes can be provided with hydrophobic properties.

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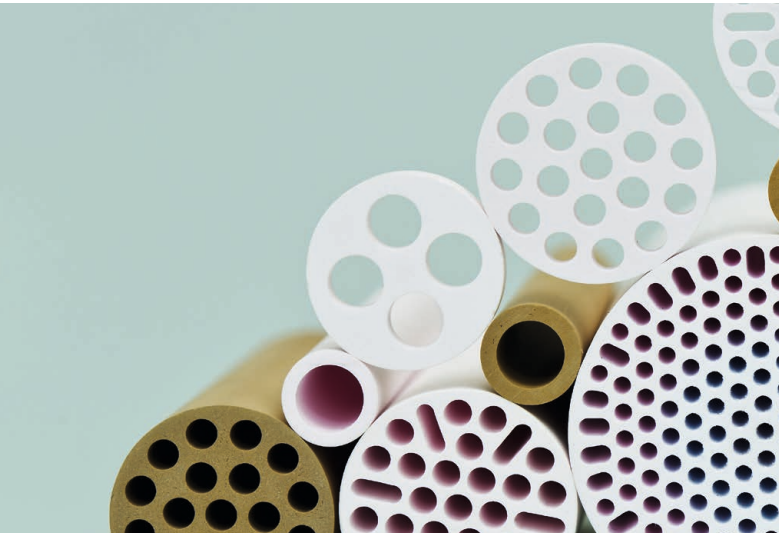

Testing, characterization and simulation

Fraunhofer IKTS has extensive expertise in membrane testing and characterization. Multi-layered 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.

Mechanical robustness of membrane supports is verified using burst pressure testing, whereas mass transfer calculations help optimize streaming properties and minimize pressure losses. Integrity of intermediate layers is evaluated by the bubble point method. Pore sizes and retentions are proofed by perm-porometry and cut-off determination measurements.

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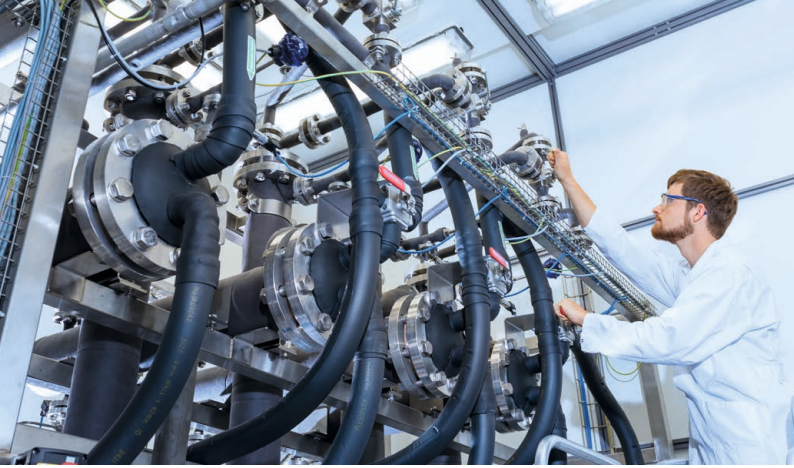

Process engineering and pilot units

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: liquid filtration (microfiltration, ultrafiltration, nanofiltration), pervaporation, vapor permeation and gas permeation

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Membrane applications

Our developments in the field of membrane technology target topics of highest relevance such as: water, hydrogen, CO_2 or green fuels. Our membranes are used in a wide variety of industries such as water management, chemicals, pharmaceuticals, raw materials (steel, lime, cement), agriculture, food, fuel, energy supply etc. Basic operations are:

Liquid filtration

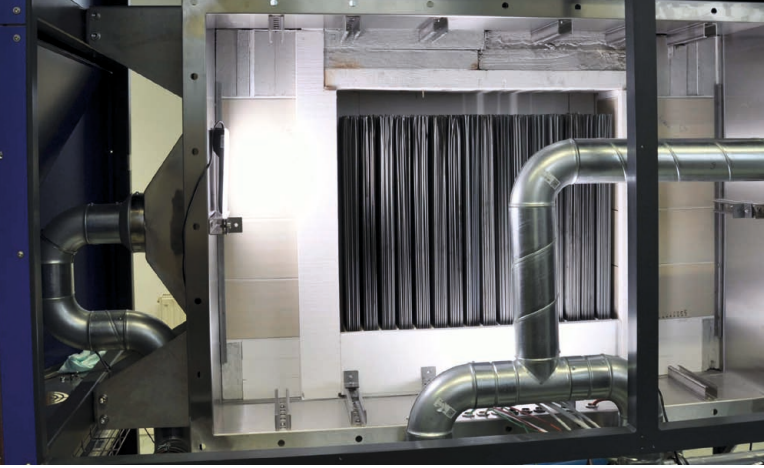
Micro-, ultra- and nanofiltration in cross-flow in aqueous and organic environments | Cleaning waste water for recycling, treatment and maintenance of process water

Membrane contactors

Membrane distillation and membrane extraction | Membrane-assisted chemical adsorption | Treatment of saline water in the field of wastewater treatment, seawater desalination, salt extraction (e.g. Li) | Treatment of polluted waste water | Extraction of valuable materials | Extraction of CO_2 from exhaust gases

Membranes support the avoidance, separation and utilization of CO_2 and thus make a significant contribution to climate protection.«

Prof. Ingolf Voigt
Deputy Institute Director,
Fraunhofer IKTS



Pervaporation and vapour permeation

Drying of alcohols for biofuel production (ethanol, methanol, butanol) | Drying of organic solvents for chemicals, pharmaceuticals, microelectronics and food | Separation of water from desiccants used in natural gas and hydrogen processing | Separation of organic solvents from aqueous solutions for food, chemicals, pharmaceuticals and fuels

Gas separation

Decentralized generation of oxygen to supply oxidation processes | H_2 separation from synthesis gases and other gas mixtures | CO_2 separation from bio, natural and flue gas | Drying of gas streams | Paraffin/olefin separation | Separation of isomers

Membrane reactors

Separation of products or dosing of educts from or in chemical equilibrium reactions | Increase in conversion and yield in the synthesis of methane, methanol, higher hydrocarbons from green hydrogen and CO_2 (Power-to-X) | Miniaturization of chemical apparatus by coupling reaction and product separation in one step | Heat integration of reaction and separation

Polymer and mixed-matrix membranes

Polymer and mixed-matrix membranes are developed at Fraunhofer IKTS for various applications in material separation. These polymer-based membranes represent a cost-effective alternative to the highly stable inorganic ceramic membranes at lower temperatures. Also, specially synthesized polymers are used as precursors for carbon, silicon carbide as well as nitride membranes.

Mixed-matrix membranes are produced by incorporating nanoporous fillers, such as zeolites or so-called MOFs, into the polymers. This effectively increases flow rates and enhances selectivities of the polymer-based membranes. Further chemical modifying of the polymers or fillers leads to a high compatibility of the different materials leading to defect-free mixed-matrix membranes.

For further adaptation of our membranes to special separation tasks of gases and, in particular liquids, the membrane surfaces are functionalized using different physical and chemical methods.

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High-temperature membranes

Fraunhofer IKTS develops energy-saving high-temperature gas separation processes and the necessary membrane materials and catalysts. The metal-oxides-based materials, which realize a promising combination of physical properties, can be used as catalysts substituting noble metals, as mixed-conducting oxygen or hydrogen membranes or as oxygen storage materials. In parallel, metallic Pd membranes are being developed for the hydrogen economy. Based on selected materials and on their adjustment for specific applications, Fraunhofer IKTS develops ceramic, metallic and composite (cermets) components, i.e. tubular membranes or capillaries, suited for easy integration in pilot plants and optimized for high packaging density and gas throughputs.

Accordingly, our development aims at saving resources and energy as well as at the integration in industrial processes by reducing the total costs, 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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Fraunhofer IKTS

For more than 30 years, Fraunhofer IKTS has been demonstrating the potential of ceramic materials in a steadily growing range of applications. Our development work is derived from the needs of the nine market-oriented business divisions – supplemented by strategic preliminary research at the highest scientific level.

We actively contribute our expertise in membrane technology, for example, in the areas of CO_2 separation, water treatment, decentralized oxygen production, and hydrogen production and utilization.

It is our goal to develop complete system solutions and services, but also to solve specific challenges within the processes of our partners from industry and science. Our expertise in characterizing materials, components and systems along their life cycle provides us with a unique data pool to carry out new developments more efficiently and faster.

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