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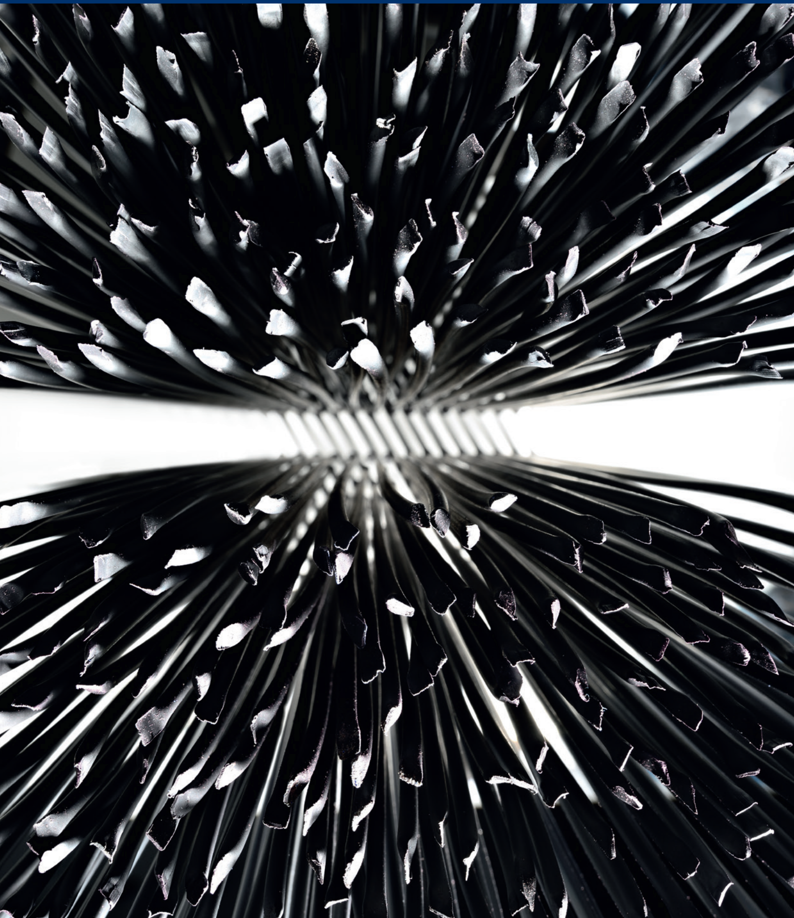
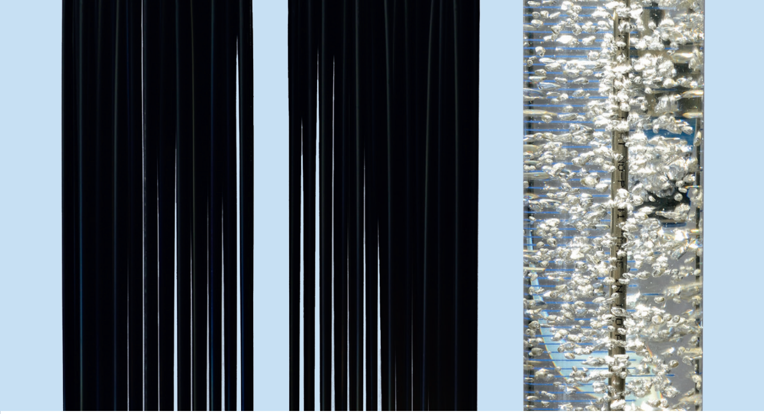
FRAUNHOFER INSTITUTE FOR
CERAMIC TECHNOLOGIES AND SYSTEMS IKTS

DECENTRALIZED OXYGEN PRODUCTION



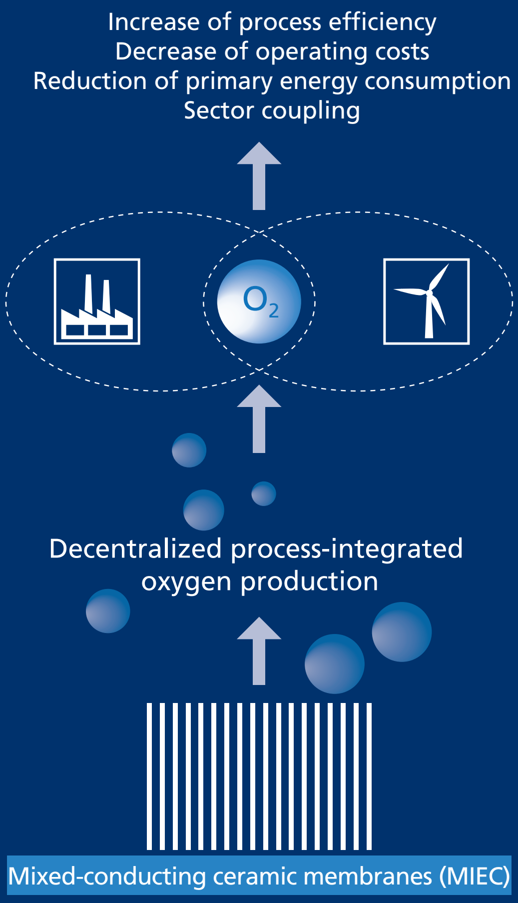


ADVANTAGES OF DECENTRALIZED OXYGEN PRODUCTION

With a worldwide consumption of around 500 million tons per year, oxygen is one of the most frequently required industrial gases. On a large scale, oxygen is produced via cryogenic air separation (Cryo ASU) and usually transported to the customer. The price of oxygen therefore rises significantly for small quantities. Pressure swing adsorption (PSA) or its vacuum alternative (VPSA) is used for local production. However, the O_2 purity is limited to around 93 vol % and the high power consumption strongly impairs the profitability of O_2 use.

For cost-efficient on-site oxygen production, Fraunhofer IKTS develops oxygen-permeable ceramic membranes and corresponding oxygen generators. In addition to a high operating temperature, these so-called mixed ionic-electronic membranes (MIEC) only require different O_2 partial pressures to generate pure oxygen. Therefore, the energy demand of the process is caused by the heat required to maintain the operating temperature and by the compression energy required for gas compression. The operators of these oxygen generators remain independent of gas suppliers.

APPLICATION EXAMPLES



Metallurgy

Combustion with oxygen allows considerably larger amounts of energy to be incorporated into existing furnaces for aluminum, copper, and steel production, thus increasing production capacity. In addition, heat recovery from the waste gas becomes superfluous due to the greatly reduced waste gas volumes. This considerably simplifies the plant design: plant costs, fuel requirements and CO_2 emissions are reduced. Due to the on-site production of oxygen, the associated operating costs are only incurred when the plant is operating at full capacity. They are considerably lower than the oxygen price at delivery. The process also produces concentrated CO_2, the separation of which normally requires a considerable amount of energy. Subsequent processes for sector coupling, i.e. the conversion of electricity into synthetic raw materials or fuels, could benefit immensely from this in the future.

Glass and ceramics industry

The melting of glass and the sintering of ceramics require very high temperatures, which are usually produced by burning fossil fuels. To reduce thermal losses and fuel requirements, the combustion air is usually preheated with exhaust gas. This increases the combustion efficiency. However, high preheating temperatures are usually avoided due to rising NO_x emissions. Alternatively, the level of efficiency can be increased by combustion with oxygen-enriched air or with pure oxygen (oxyfuel technology). Through the integration of oxygen membranes, the required oxy-

gen can be provided directly at the gas-fired industrial furnace as required and a large amount of thermal energy can be conserved, especially at high process temperatures. The additional power required for heating the membranes is only 0.2 kWh/m³ O_2 and thus, only a fraction of the savings. Combustion with pure oxygen can significantly reduce NO_x emissions. Since pure CO_2 is also produced, highly efficient sector coupling is also possible.

Cement and lime industry

Due to their process temperatures and continuous operation, lime and cement production is particularly well-suited for thermal integration of the membrane separation process. The oxygen produced can not only be used to increase the efficiency of combustion, but it also promotes the burnout behavior of difficult substitute fuels. In addition to reducing the fuel requirement and fuel-related CO_2 emissions, oxygen enrichment of the combustion air increases the CO_2 concentration in the exhaust gas and lowers the waste gas volumes. This reduces the effort required for conventional separation of CO_2.

(De)centralized medical care

The oxygen separation process takes place at about 850 °C, so that the oxygen produced is always sterile. Combustible or biologically active substances are completely destroyed and the reaction products potentially produced on the air side do not enter the oxygen. The very high purity of the oxygen produced enables

simple dosage or uncomplicated production of defined gas mixtures. The supply for individual patients is just as possible as that of hospitals or military infirmaries. The oxygen price resulting from the investment and operating costs is noticeably lower than the delivery of oxygen.

Wastewater treatment

Sewage treatment plants account for around 20 % of municipal energy consumption, with about half of this energy being used for the ventilation of the activation basin. Industrial gas producers have already shown that by using oxygen instead of air, the amount of gas to be injected can be reduced to about 4 %, i.e. to 40 liters of oxygen instead of 1000 liters of air. In addition, oxygen can also be used to treat highly polluted industrial waste water or to assist in adapting sewage treatment plants to cope with strongly varying loads. For decentralized oxygen generation, the sewage gas produced in digestion tanks can be used advantageously for heating the oxygen generators. The remaining electrical energy consumption of 0.2 kWh/m^3 O_2 is very low. As the required amount of oxygen is significantly less than the required amount of air, the total electricity consumption can be reduced by more than 60 %.

Aquafarming

In professional fish farming, fumigation with oxygen can improve disease resistance, accelerate feed intake and growth,

and increase stocking density. At water temperatures above 15 °C and decreasing solubility of the gases, oxygen is therefore often introduced. The usual small amounts of oxygen required by small- and medium-sized pond systems or by aquafarming companies come at a high cost due to the complex logistics involved. With oxygen generators based on mixed ionic-electronic conducting membranes, fish farmers can cost-efficiently produce the required oxygen themselves.

PICTURES *left to right*

Oleg Totskyi//Kobets Dmitry/sfam_photo/People Image Studio/Shutterstock.com

PROCESS COMPARISON

While established processes require all energy as electricity, MIEC membranes can be heated by burning of gas or by waste heat from high-temperature processes. The electricity requirement is then only 40 % of a large industrial air separation plant. In addition, there are further significant operating cost savings as the gas price is often only a quarter of the electricity price. Another advantage is the reduction of CO_2 emissions. Conventional electricity production generates significantly more CO_2 per kWh than gas combustion.

Process comparison of energy costs and CO_2 emissions for the production of 1 Nm^3 O_2

Process	kWh_{el} [a]	kWh_{th} [b]	€-Ct.	g CO_2
Cryo ASU	> 0.46		4.9[c]	321[c]
PSA	> 0.90[d]		9.0	508
Vacuum-PSA	> 0.36[d]		3.6	203
Polymer memb.	> 0.35[e]		3.5	197
MIEC membrane plants according to heating method				
a) Electric	> 0.45		4.5	254
b) Gas	> 0.20	0.25	2.6	178
c) Waste heat	> 0.20		2.0	113

[a] 10 Ct/kWh_{el}, 564 g CO_2/kWh_{el}; [b] 2.5 Ct/kWh_{th}, 260 g CO_2/kWh_{th}; [c] incl. transport; [d] < 95 vol % O_2; [e] < 40 vol % O_2

MEMBRANE MANUFACTURING AND PROCESS MANAGEMENT

Fraunhofer IKTS is one of the leading research institutions in the field of separation techniques using ceramic materials. In the area of O_2 separation from air using mixed ionic-electronic conducting ceramic membranes, IKTS is the only supplier of commercially available membrane modules and pilot plants with technically relevant capacities. The device concept and the patented process management are aimed at minimum operating costs and a long service-life.

The ceramic membranes are based on readily available raw materials. By using thin-walled membranes, the required material quantities have already been minimized and the oxygen output increased. The manufacturing process used is extrusion, which has a high potential for further cost reduction for large quantities. Any residual material resulting from the production process is completely recycled.

The membranes incorporated tolerate high heating and cooling rates or thermal stresses, so that membrane systems can be implemented with short start-up times. If required, stand-by operation and a variation of oxygen output of approx. 10 to 200 % compared to normal operation is possible.

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 (Saxony) 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.

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