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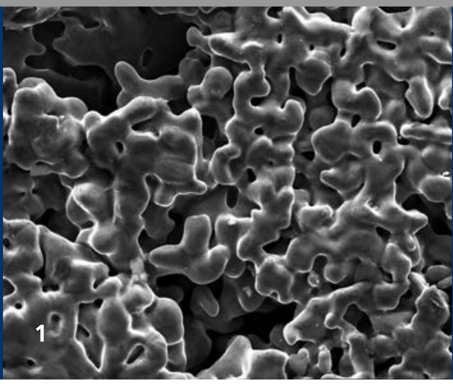
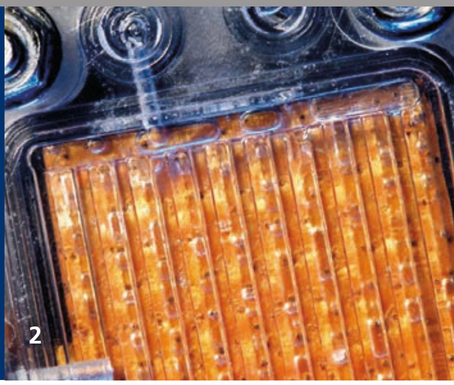
FRAUNHOFER INSTITUTE FOR SOLAR ENERGY SYSTEMS ISE





1 *Image of a porous transport layer as used in PEM electrolysis cells and stacks.*
2 *Gas evolution in an electrolysis cell designed for gasochromic windows.*
3 *Side view of a 4000 ampere test rig to characterize electrolysis stacks for power to gas applications.*

HYDROGEN PRODUCTION BY PEM WATER ELECTROLYSIS

The electrochemical splitting of water in electrolyzers is a clean and efficient process to generate hydrogen and oxygen. If electricity from renewable energy sources is used, green hydrogen can be generated as a universal fuel that can be stored easily and utilized as required in different applications of the energy economy, transport sector or the chemical industry. Given the strongly fluctuating and steadily increasing supply of electricity from renewable energy sources, hydrogen can promote a reliable energy supply and even enable long-term or seasonal storage in future energy systems.

In particular, PEM water electrolysis, which applies a proton exchange membrane (PEM), is well suited for combination with renewable energy sources. This process offers very good efficiency values at high current densities and can be operated at high pressure and very dynamically in a wide operating window, i.e. also under partial-load or overload conditions.

Our Offer

Fraunhofer ISE has worked for more than 25 years on component and system development as well as the integration of PEM electrolyzers in higher-level energy systems. With our wide-ranging expertise gained in many R&D projects we can offer:

- screening and evaluation of new cell components, cells and stacks for PEM water electrolysis
- investigation of degradation mechanisms and development of accelerated stress tests
- cell and stack development by means of fluidic and structural-mechanical calculations
- development of coating strategies for bipolar plates and porous transport layers
- system design and BoP optimization
- development of operating controls and implementation on embedded systems
- characterization of complete prototypes up to the three-digit kW range

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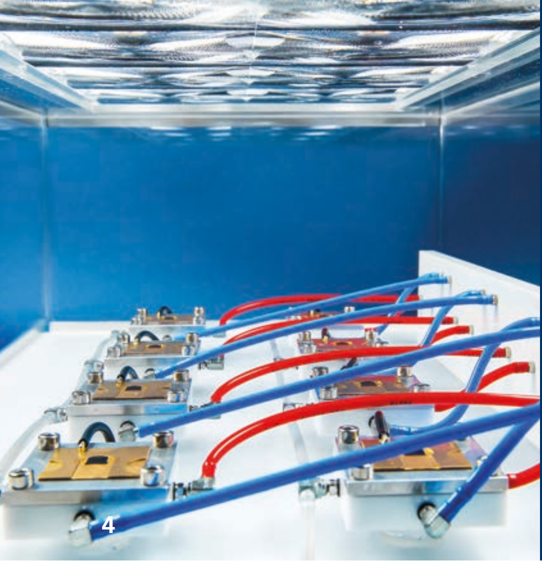

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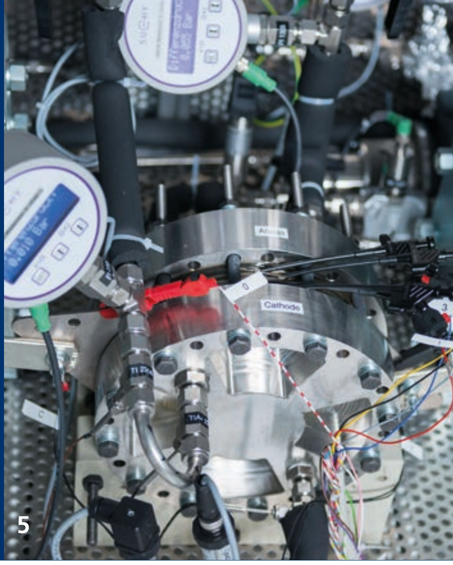

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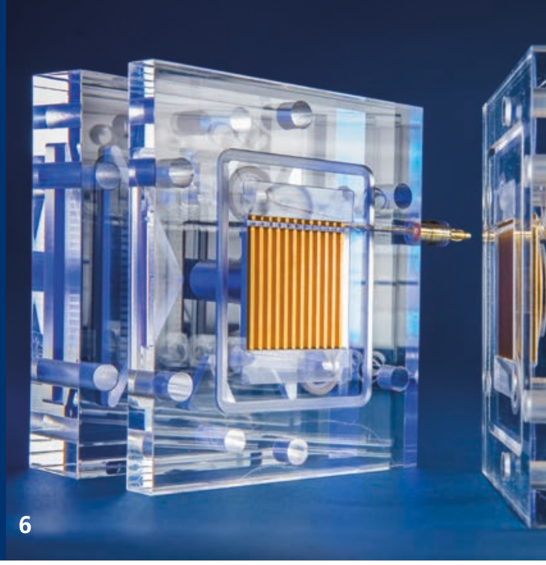

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New facility for PEM water electrolysis

In order to meet the current R&D demand in upscaling stack size and capacity for PEM water electrolysis, the institute has set up a new electrolysis center in Freiburg. Unique are the two test benches for investigating PEM cell stacks with electrical currents up to 4000 amperes, operating pressures up to 50 bar and temperatures up to 80 °C. The larger of the two test rigs allows DC voltages of up to 250 VDC to be applied, so that stacks up to 1 MW can be operated. The maximum hydrogen outflow is specified as 200 standard cubic meters per hours. This rig is accompanied by a smaller test bench for stacks with fewer cells (up to 50 VDC). Sophisticated measurement equipment and a very flexible process management system enable the comprehensive characterization of PEM electrolysis stacks for Power to Gas applications.

In addition, the facility has several test benches, designed and built in-house to characterize single cell and small short stacks up to 10 kW. These fully automated test benches are equipped with script-based measuring programs. Diverse ex-situ measurement analyses with 3D x-ray tomography, porometry and electron microscopy as well as interfacial contact resistance and corrosion measurements are performed.

Fraunhofer ISE offers a broad range of R&D services and supports customers worldwide in developing efficient, high performing and durable PEM water electrolyzers.

In-situ characterization of components for PEM water electrolysis

- cell component screening over a broad operating window from ambient conditions up to 50 bar, 80 °C and 200 amperes in single cells and 500 amperes in short stacks
- electrochemical characterization techniques such as polarization curves (performance and efficiency), electrochemical impedance spectroscopy (mass transport limitations) and cyclic voltammetry (electrochemically active surface area)
- evaluation of anodic and cathodic overpotentials in single cell measurements using segmented flow field with electrically insulated areas as reference electrodes
- long-term performance investigation and degradation analysis with combined in-situ and ex-situ measurements, e.g. high frequency impedance, gas crossover and impurity measurements
- accelerated stress tests of membrane electrode assemblies and other cell components according to customer or international test protocols

4 HyCon protoype for generating hydrogen directly from solar energy by water electrolysis. The module consists of eight III-V solar cells, each of them directly coupled with a PEM water electrolysis cell. This enables hydrogen to be generated directly with a very high efficiency of 19.8%.

5 Long-term characterization of a laboratory PEM water electrolysis stack operated under pressure.

6 Model of an electrolysis test cell to investigate new cell components for PEM water electrolyzer.

Ex-situ characterization of components for PEM water electrolysis

- corrosion current measurements to investigate oxide layer formation and passivation, using a 3-electrode setup with stressor test cells made in-house for this purpose
- electrical conductivity measurements to analyze interfacial contact resistance of bipolar plates and porous transport layers (PTL)
- environmental scanning electron microscopy (ESEM) to investigate surface characteristics, and energy dispersive x-ray spectroscopy (EDS) to determine surface composition and contaminates
- x-ray tomography to analyze 3D structures, porosity and pore size distribution of porous transport layers
- mass spectrometry using inductively coupled plasma (ICP-MS) to analyze water contaminates
- porometry and in- and through-plane permeability measurements of PTLs to determine fluid transport properties