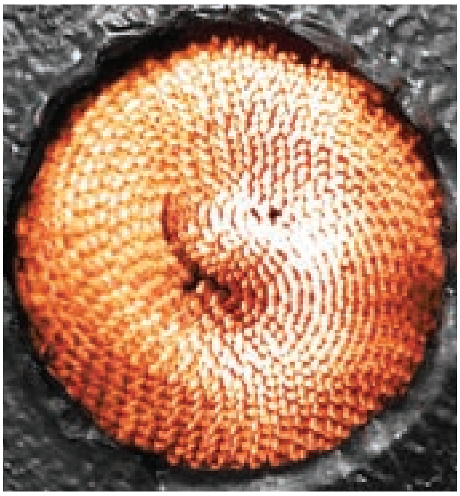
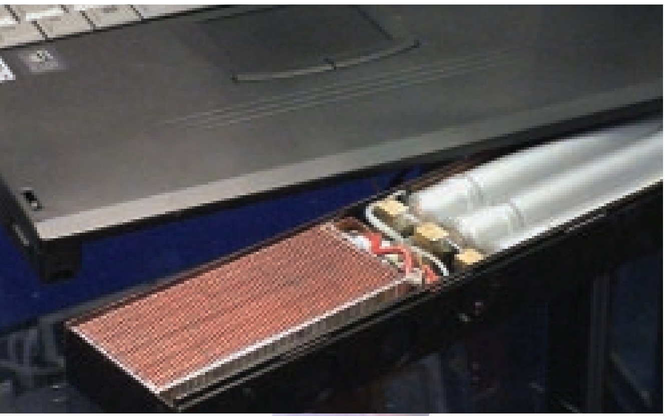
  

Hydrogen Technology

Fraunhofer Institut
Solare Energiesysteme



Fuel cell system integrated into a laptop.
Prototype commissioned by LG Catex, Korea.

Self-Sufficient Solar House Project (1992-95) with solar heat generation, photovoltaic energy supply and electrical energy storage consisting of a battery and a hydrogen system including a fuel cell, electrolyser, hydrogen and oxygen tanks, hydrogen air pre-warming and hydrogen cooker.

Hydrogen – The Energy Source of the Future

In the reaction between hydrogen and air-oxygen, useful energy is released. In a fuel cell hydrogen is converted into electricity in a controlled and highly efficient process, whereby the generated heat produced by the reaction can also be used. Since hydrogen is not found in its pure form in nature, it must be extracted from its chemical compounds, e.g. by electrolysis of H_2O using electricity generated by regenerative energy or by reforming of biogenic and fossil fuels. For a long time, researchers and engineers have been working intensively to realise energy generation with zero-emission through hydrogen technology.

In the field of Hydrogen Technology at Fraunhofer ISE, we research innovative technologies for the production of hydrogen as well as for the conversion of hydrogen into electricity. In co-operation with our partners in the fields of industry and research, we develop entire hydrogen systems as well as single components in the interest of an economical and environmentally friendly energy economy.

We build reformers for the conversion of liquid or gaseous fuels and construct electrolysers of up to 2 kW for producing hydrogen by electrolysis. To convert hydrogen into electricity, we prefer fuel cells based on polymer electrolyte membranes (PEM). These fuel cells are efficient, environmentally friendly, quiet, low-maintenance and are particularly suitable as a portable energy supply. Furthermore, we are investigating the catalytic conversion of hydrogen for heating or cooling purposes.

In addition to the development of fuel cell systems and components, we are working on the integration of higher-level systems, whereby we plan and develop the electronics including power conditioning and safety engineering. Thus, the foundations are established for a marketable hydrogen industry which includes hydrogen supply stations, fuel cell co-generation plants for the combined production of electrical and heating energy, autonomous power supplies for off-grid applications and micro-systems to serve as a portable energy supply.

Hydrogen Generation by Reforming / Gas ProcessingTechnology

At Fraunhofer ISE we develop and build compact units for steam reforming, autothermal reforming and for the partial oxidation of gaseous and liquid hydrocarbons. Reformers can be employed in stationary power stations, domestic and industrial buildings, ships, cars and even in airplanes. With micro-reformers, the large energy density of hydrocarbons can also be utilised for portable applications.

Even when hydrogen is not available in its pure form, the catalytic conversion of easily accessible fuels into hydrogen enables the use of fuel cells. In addition to reforming fossil fuels such as natural gas, gasoline, diesel, kerosene or heating oil in PEM fuel cell systems, we research ways to use regenerative energy supplies through the use of biological fuels such as gas produced from municipal sewage or urban refuse, methane, bio-alcohol, rape seed oil or wood.

We supply components and complete systems which are individually adapted to suit our customer's needs. These include reformers, gas processing, control systems and safety engineering.

Hydrogen Generation by Electrolysis

Hydrogen and oxygen can be produced effectively and with a high degree of purity by electrolysis. For this purpose we develop electrolysers based on polymer electrolyte membranes (PEM).

Hydrogen can be produced using regenerative energy such as hydropower, wind power or solar energy. We can either develop complete systems or offer consultation in this area. For reliable operation we construct bipolar plates for the electrical energy supply and the exhaust gas. Further, we coat the membranes with optimised catalyst compounds. The electrolyser is integrated with the water inlet and processing units, the gas separation, gas drying and storage components and the safety engineering to form a complete hydrogen system. For the temporary storage of hydrogen, pressure electrolysers with up to 30 bar operating pressure are used.

PEM electrolysers are suitable for producing hydrogen or oxygen in laboratories and in the field of medical engineering as well as for the operation of fuel cells. The capacity ranges from just a few Nl/h to several Nm^3/h of hydrogen.

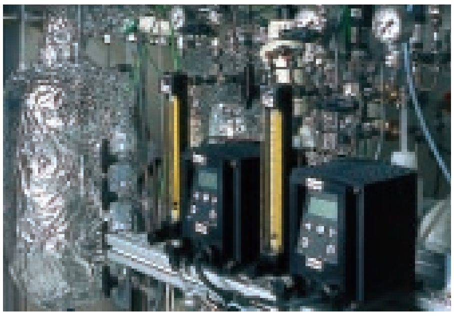
Membrane Fuel Cells for Electrical Energy Generation

Due to their high efficiency, reliability and the low environmental impact, fuel cells are optimally suited as a decentralised energy supply.

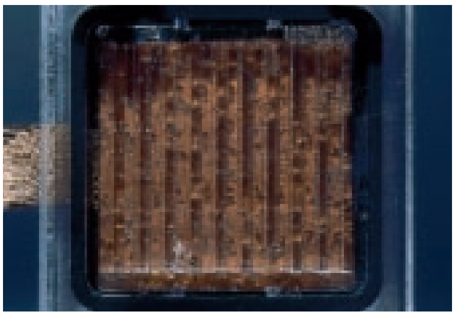
We concentrate our research on membrane fuel cells for portable and stationary systems. According to the customer´s demands, we develop fuel cell systems for operation with either hydrogen or methanol. For optimisation, we perform simulations in the areas of electrochemistry, thermodynamics and computational fluid dynamics. To verify the simulation models, we perform experiments using a wide variety of available equipment at our Institute.

A main emphasis of our research is increasing the lifetime, i.e. minimising degradation and increasing the tolerance to CO contamination. This leads us toward developing a fuel cell that can be fed with product gas directly from a reformer.

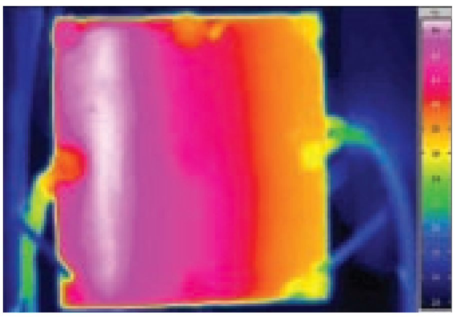
Together with our partners, we develop system solutions based on the individual application and offer consulting services.



Kerosene reformer for a solid oxide fuel cell (SOFC) with a power of 25 kW and integrated de-sulphurisation.



Hydrogen production in a miniature electrolyser.



Temperature distribution in a miniature PEM fuel cell during start-up.

Micro-Energy Technology Micro Fuel Cells

To meet the steadily increasing energy demand of electronic devices distributed world-wide, innovative concepts must be developed. Whether it be mobile phones, laptops, organisers or off-grid measurement or signal systems, a reliable and miniaturised power supply is desired.

For the power range of up to 200 W, we develop membrane fuel cell systems, based on hydrogen or methanol, as an alternative or as a supplement for batteries and rechargeable batteries.

Since the electrical energy supply and the fuel cell storage are separate, the energy supply can be ideally fitted to the required specifications of the system. The modularity of the fuel cell allows for great flexibility in the construction design. Based on computer simulations and experimental results, we develop control electronics for the air and the fuel inlets as well as the heat recovery and the water management. Additionally we develop high efficiency DC/DC converters. (See "Off-Grid Power Supply")

Characterisation and Simulation

The scientific investigation of the physical, chemical and electrochemical reactions on the microscopic scale constitutes the basis for an optimised design of hydrogen systems.

In the field of reformer technology, we carry out individual catalyst tests specifically fitted to the system application and the fuel. We evaluate the different catalyst formulations and carriers. Regarding bulk materials, we vary the pellet dimensions, and in honeycomb materials, we vary the geometry.

In order to constantly improve the process design, we employ simulation tools and develop detailed theoretical models. By comparing the simulation results with those of our experimental investigations, we ensure the reliability of our process design.

The core of a PEM fuel cell or PEM electrolyser is the membrane electrode assembly (MEA). We coat membranes with pure or substrated catalyst coatings. To determine the MEA characteristics, we use techniques such as impedance spectroscopy for spatially resolved measurements.

By performing an intensive test series on long-term measurement equipment, the system management of fuel cells is constantly being improved. Wide-ranging characterisation options allow us to observe the behaviour of individual fuel cells under different operating conditions. In addition to standard test procedures, a test cell has been developed in order to perform spatially resolved measurements of key parameters such as current density, resistance and temperature.

The safe design and construction of fuel cell systems are based on detailed simulation calculations. Using CFD programs, we model the coupled parameters such as spatially resolved current density, oxygen partial pressure, flow rates on the anode and cathode side respectively, temperature and membrane humidity. Further, we use dynamic simulation models to design control systems.

Packaging of a miniature fuel cell system with a power of 10 W including the system components.

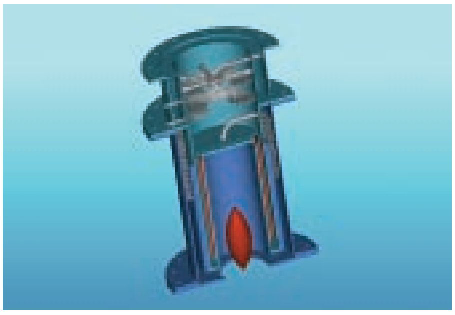


Diagram of a steam reformer used to produce 6 Nm^3/h hydrogen from natural gas.

Test cell for spatially resolved measurement of key parameters.

Selected Projects

Innovative Domestic Energy Supply

In an environmentally friendly and highly efficient process, fuel cells can generate electrical energy from hydrogen. The heat resulting from this process can be used externally to heat buildings. We develop reformers which process hydrogen from natural gas. The systems we design at the Institute are for the power range of 1-2 kW_{el}. The first stage of the process, the reforming reactor, generates a hydrogen-rich gas mixture through the conversion of natural gas and steam. Two downstream catalytic reactors convert the remaining carbon monoxide (10% volume) into carbon dioxide and hydrogen. The CO fine purification (e.g. selective oxidation of carbon monoxide) reduces the amount of carbon monoxide to the ppm range. With this process, the gas quality is acceptable for membrane fuel cells. The fuel cell co-generation plant including the control system allow for remote access. Therefore, the optimisation of the operation is carried out under an economical as well as ecological standpoint.

The first world-wide installation of a fuel cell as a small co-generation plant was realised in 1992 by the Fraunhofer ISE in the project “Self-Sufficient Solar House”. Hydrogen produced by solar energy served as energy storage for both electricity and heating energy for the building (see photo page 2).

Electric Car Powered by a Fuel Cell

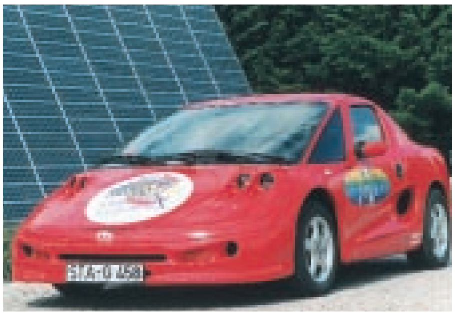
As a first in 1997, Fraunhofer ISE constructed a fully regenerative energy supply for a car using hydrogen generated by solar energy. The vehicle, which has been approved by TÜV (German Technical Control Board), is the first car powered by a fuel cell.

Micro-Fuel Cell for Camcorder

In a demonstration project within the Fraunhofer Initiative Micro Fuel Cells headed by Fraunhofer ISE, the rechargeable battery in a modern camcorder was replaced with a fuel cell system. The power of 10 W is realised with a voltage of 8 V. 15 bipolar plates are stacked on top of each other and bonded. The hydrogen is supplied under controlled conditions from a hydride storage capsule. The simple ventilation with ambient air is sufficient for the oxygen supply. In the Fraunhofer Initiative Micro Fuel Cells, partners from seven Fraunhofer Institutes develop innovative power systems based on portable micro fuel cells. The newest developments in the areas of system simulation, electronics or controls, material development, production and assembly technologies are considered here.

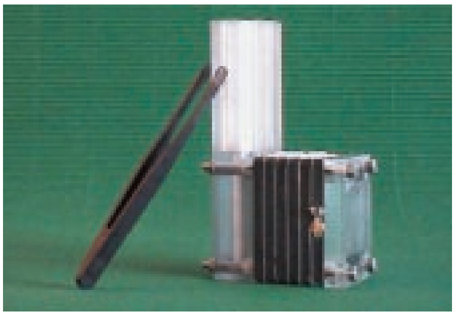
Miniature Electrolysers for Switchable Windows

The light transparency of gaschromic windows is reduced when a hydrogen-enriched carrier gas interacts with a tungsten-oxide layer. To neutralise the colour, the carrier gas is oxygenated. The oxygen reacts with the hydrogen to form water, and the glazing becomes fully transparent again. The water is then available for subsequent electrolysis. For this process we have developed a miniature electrolysis unit with a hydrogen production of 4.2 Nl/h and a power of 18 W. This unit can be integrated in the window frame.



System with solar hydrogen generation by electrolysis, pressurised hydrogen storage and a fuel cell powered car.

Demonstration system of a fuel cell co-generation plant.



Miniature electrolyser for use in gaschromic windows.

Fuel cell system with a power of 10 W for a digital camcorder. A development of the Fraunhofer Initiative Micro Fuel Cells.

Give us a call!

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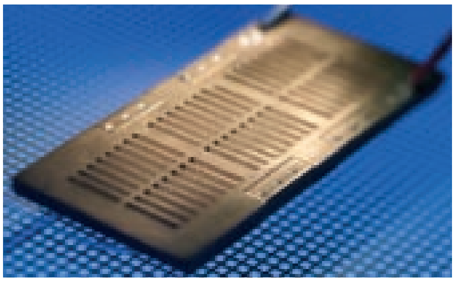
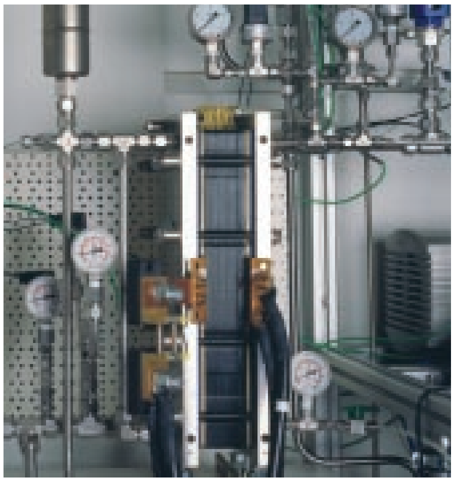
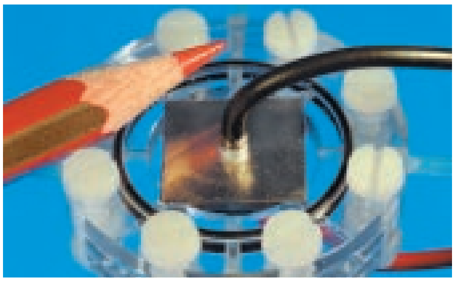
Illustrations titelpage (left to right):
Honeycomb catalyst for reforming liquid fuels.
Drying unit of a PEM electrolyser.
PEM fuel cell system as a power supply for a digital camcorder.



Planar fuel cell with a power of 1.2 W. The series connection of three fuel cells is carried out by printed circuit board technology.



Test stand of a 3.3 kW_{el} fuel cell stack with a Siemens fuel cell.



Micro fuel cell with a power density of 1 W/cm^3. Development in co-operation with the Institut für Mikrosystemtechnik IMTEK of the Albert-Ludwigs-Universität in Freiburg.

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October 2002