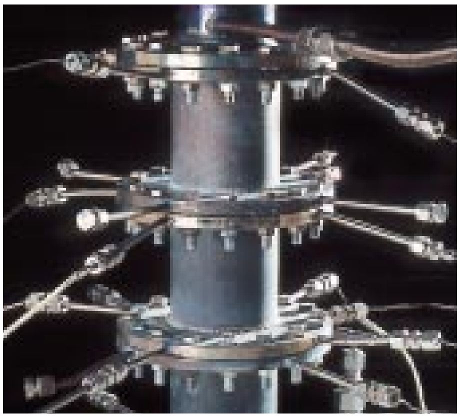
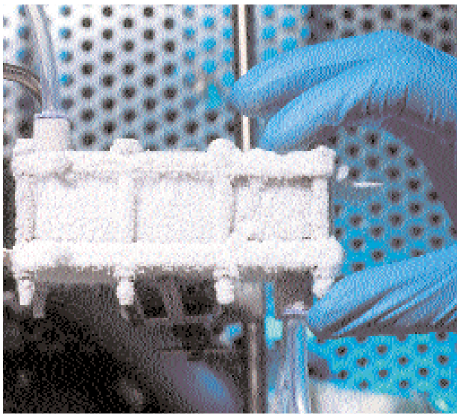
  

Hydrogen Technology

ISE

Fraunhofer Institut
Solare Energiesysteme

Prototype of a fuel cell system, developed at Fraunhofer ISE, for use with professional film and television cameras. The system has twice the volumetric energy density as compared to a Li-ion secondary battery of similar size.

Rappenecker Hof, a Black Forest guest house which is situated far from the public utility grid. In 2003 a PEM fuel cell was installed into an existing photovoltaic/hybrid system and operates under real conditions in the guest house.

Hydrogen – The Energy Carrier of the Future

Due to 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 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 renewable energy or by reforming of biogenic or fossil fuels. Sustainable and zero-emission energy conversion by means of hydrogen technology is considered as a promising part of a solar power industry.

In the business area 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.

To produce pure hydrogen, we develop water electrolysers with a power of up to 2 kW. To generate hydrogen-enriched synthesis gas, we develop processes and systems for the reforming of liquid and gaseous hydrocarbons. To convert hydrogen into electricity, we prefer, for the most part, fuel cells based on polymer electrolyte membranes (PEM). These fuel cells are efficient, environmentally friendly, quiet, low-maintenance and are particularly suitable as an energy supply in the low power range.

Furthermore, we integrate the fuel cells, electrolysers and reformers which we develop into complete systems. Here we design and realise the electronics including power conditioning and safety engineering. With the development of auxiliary power supplies, 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 portable power supplies, we are establishing the foundations for a marketable hydrogen energy industry.

Competences

Hydrogen Production by Reforming

At Fraunhofer ISE we develop prototype reformer systems that convert fossil and biogenic fuels in gaseous or liquid form such as natural gas, propane, petrol, diesel, kerosene or ethanol into hydrogen. The system includes the reforming reactor, and depending on the type of the fuel cell connected, it also includes a gas processing step to increase the hydrogen concentration and purity in the product gases. We have mastered the three conventional reform processes – steam reforming, autothermal reforming and partial oxidation. Therefore, we are able to choose the most suitable procedure for each application.

In our developments we pick up on over ten years of experience in reaction technology, heat and mass transport, heterogeneous catalysis, process simulation and safety technology. With our experience gained from the successful operation of numerous systems, we have attained valuable knowledge in the integration of reformers and fuel cells into complete systems. The area of application of these systems ranges from stationary fuel cell co-generation plants to auxiliary power units (APU) and portable energy supply systems.

Hydrogen Production by Electrolysis

Hydrogen and oxygen can be produced effectively resulting in a high degree of purity by means of electrolysis. Renewable hydrogen can be produced using renewable energy, e.g. hydropower, wind energy or photovoltaics. For this purpose, we develop electrolysers based on polymer electrolyte membranes (PEM) as well as optimise single components. To more deeply understand the electrochemical processes at the electrodes, we perform various characterisation methods. Pictures taken with the Scanning Electron Microscope (SEM) relay information about the structure of the electrodes. Revelations about the electrochemical surface are obtained from cyclic voltammetry measurements. To optimise the membrane electrode units, we apply procedures from the field of statistic experimental design.

We develop complete systems or offer personal consulting services. For the efficient buffer storage of hydrogen, we concentrate on the pressure electrolysis system. We optimise the peripherals of the process technology with respect to efficiency, costs and reliability.

Membrane Fuel Cells for Electrical Energy Conversion

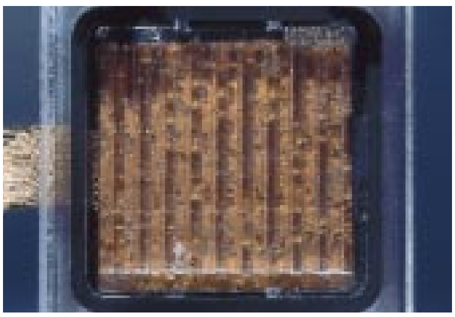
Due to their high efficiency, their reliability and last but not least their low environmental impact, fuel cells are ideally suited for the decentralised energy supply.

Our research concentrates on membrane fuel cells for portable and mobile systems. According to the customers´ 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 equipment available at our Institute.

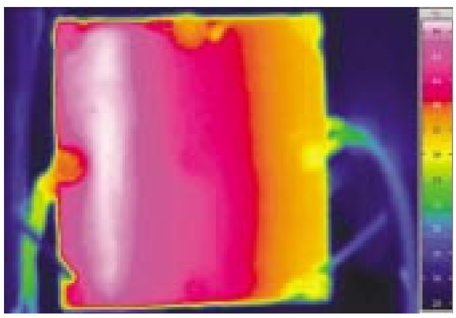
One main area of emphasis is to increase the lifetime of the fuel cell stack by analysing the causes for degradation or by increasing the tolerance for CO impurities.

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

The steadily increasing energy consumption of miniature electronic devices requires that innovative power supply concepts be developed. Whether it be mobile phones, laptops or off-grid measurement or signal systems, a reliable power supply with a high energy density is desirable.

For the power range of up to about 400 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 offers a wide range of constructive freedom. Based on computer simulations and experimental investigations, we develop control electronics for the air inlet and the fuel inlet as well as for the heat recovery and the water management.

Additionally we develop high efficiency DC/DC converters. (Refer to the Area of Business "Off-Grid Power Supply".)

Characterisation and Simulation

The scientific investigations of the physical, chemical and electrochemical reactions on the microscopic scale constitute 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. 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 cyclic voltammetry and impedence spectroscopy for spatially resolved measurements.

By performing series of intensive tests 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 measuring cell has been developed in order to perform spatially resolved measurements of key parameters such as current density, resistance and temperature.

The profound design and construction of fuel cell systems are based on detailed simulation calculations. Using Computational Fluid Dynamics 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.

Development of a new type of procedure for the residue-free vaporisation of liquid hydrocarbons.

Measuring cell for spatially resolved measurement of key parameters.

Selected Projects

Innovative Domestic Energy Supply
The first world-wide installation of a fuel cell as a small co-generation plant was realised in 1992 by 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. In the years following, we developed reformer systems for converting natural gas into a hydrogen-enriched synthetic gas for fuel cell/co-generation units. The two newest system prototypes are combined with PEM fuel cells and are operating successfully since 2003.

Auxiliary Power Unit of the Future
For auxiliary power units on ships, reformer/fuel cell systems offer several advantages over conventional combustion/generator systems. The low emissions and the low noise level are significant advantages, especially in the harbour. A further benefit of fuel cell based systems is the higher electric efficiency. Because diesel is used as fuel on ships, it must first be converted into a hydrogen-enriched gas mixture in a reformer and then converted into electricity in a high-temperature fuel cell.

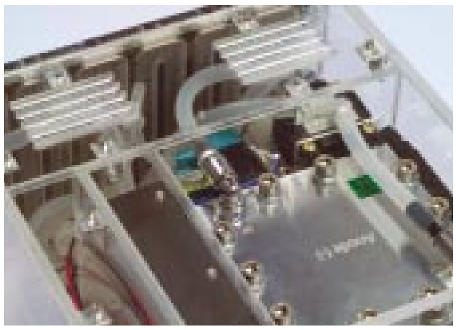
Within the framework of a co-operation with the Italian company Ansaldo Fuel Cell SpA (AFCo) in Genova, we developed a system that converts diesel into a synthetic gas by means of autothermal reforming. The power of the system is 100kW (with respect to the heating value of the diesel.) We operate the system for more than 500 hours in order to gain information on the long-term performance of the catalyst.

Electric Car Powered by a Fuel Cell
As a first in 1997, Fraunhofer ISE constructed a fully regenerative energy supply for an automobile using hydrogen generated by solar energy. This is the first vehicle which is powered by a fuel cell and has been approved by TÜV (German Technical Control Board).

Mobile Power Box
Together with the company Masterflex, Fraunhofer ISE developed a PEM fuel cell with a steady state power of 50 W. The so-called Power Box offers a portable power supply for electronic devices. The system which operates using hydrogen convinces through its performance with excellent reliability and high power density. In the application, a large degree of flexibility is reached due to the coupling of different storage dimensions. The air supply is realised by a micro-pump. Through a newly developed control based on a microprocessor, a very stable behaviour is achieved during start-up, operation and shut-down.

Miniature Electrolysers for Switchable Windows
The light transparency of gasochromic 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. This unit can be integrated in the window frame.

View of entire system for autothermal reforming of diesel. The reactor is in the left upper part of the system.



Direct methanol fuel cell system with 30 W steady state power. The system operates with pure methanol.

Give us a call!

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We develop components and complete systems for hydrogen production by means of reforming or electrolysis as well as for fuel cell systems which are customized for our clients. Additionally, we simulate and design the overall systems as well as the automatic control and the safety technology.

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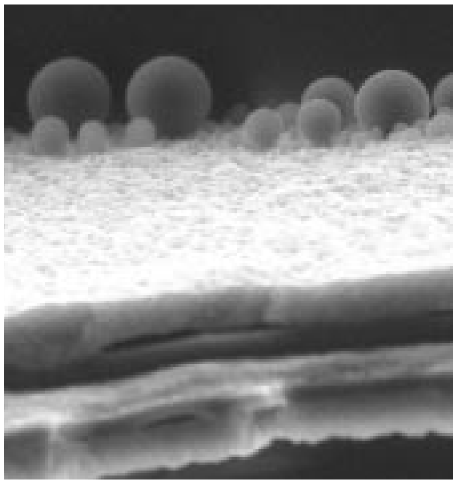
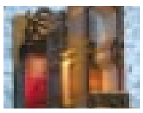
Planar fuel cells with a peak power of 8 W. The series connection of three fuel cells is realised in printed circuit board technology.



Picture of water droplets on a hydrophobic electrode made from an electron microscope. This investigation was carried out as part of a long-term study on catalyst morphology.

Fuel cell system suitable for outdoor use in the temperature range of -20°C to +40°C.

Title page (from left to right):
Miniature electrolyser for use in gasochromic windows – free-standing view of reforming reactor with thermal elements – fuel cell stack during a low temperature test.

April 2005