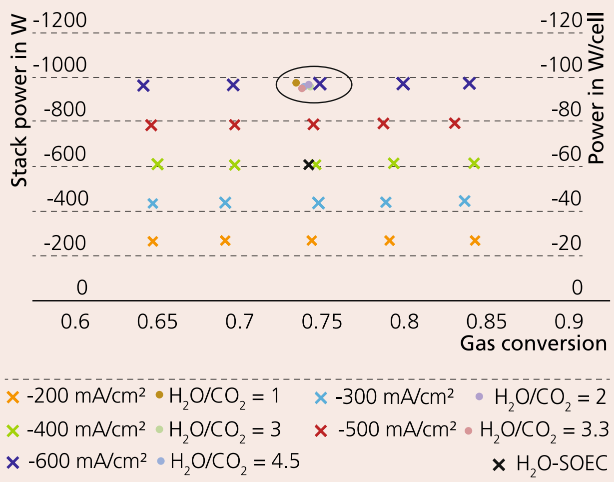

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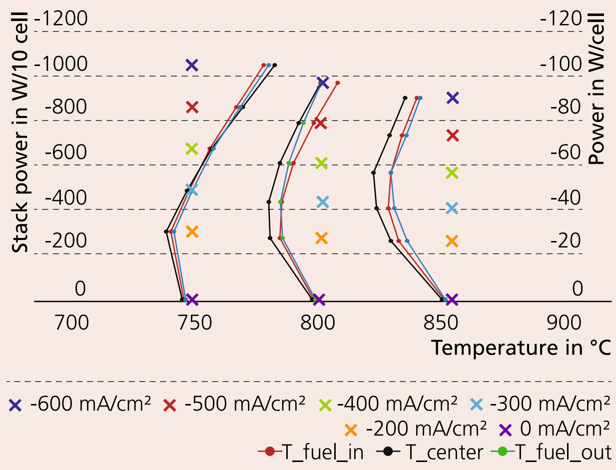

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SOLID-OXIDE CO-ELECTROLYSIS AS A KEY TECHNOLOGY FOR CO_2 UTILIZATION

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SOE technology

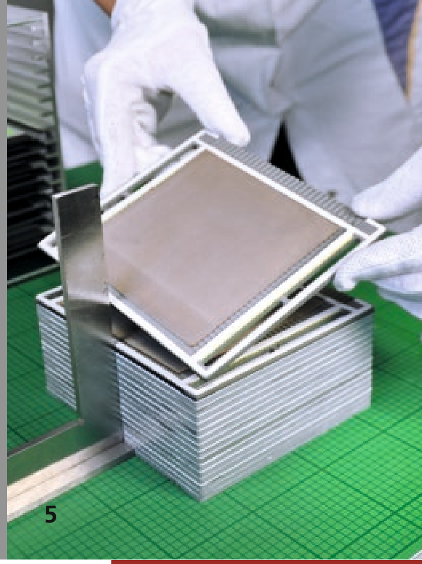
The possibility of substituting crude oil with synthetic hydrocarbons produced from CO_2 and H_2O is of increasing interest worldwide as a way to decrease dependence on fossil resources and to limit CO_2 emissions. The coupling of solid-oxide electrolysis (SOE) technology and Fischer-Tropsch synthesis (FTS) is especially promising for the production of various types of hydrocarbons thanks to the possibility of integrating heat and utilizing by-products.

The reliable operation of solid-oxide cell (SOC) stacks in the co-electrolysis of H_2O and CO_2 is still considered a challenging technical task. Results on cathode-supported cells (CSC) reported in the literature show that operation in steam electrolysis and co-electrolysis modes below 800 °C brings with it considerable degradation rates. In contrast, electrolyte-supported cells (ESC) exhibit higher durability for electrolysis operation. Scientists at Fraunhofer IKTS have devised a CFY stack design that utilizes up to 40 high-power-density ESCs based on scandia-doped zirconia electrolytes. To prove their long-term stability, ten-cell stacks were tested in water electrolysis and co-electrolysis modes. A comparative analysis of the performance depending on operating temperature, feed composition and utilization was conducted for typical gas compositions for FTS ($H_2O{:}CO_2$ = 2) and methanation ($H_2O{:}CO_2$ = 3.3). The stack performance with a gas conversion rate up to 85 % at different temperatures in water and co-electrolysis modes at -600 mA/cm² is visualized in Figure 1. A comparison between water and co-electrolysis modes at similar operating conditions yields similar power consumption figures: at 830 °C and -600 mA/cm², 946 W_{el} are consumed in co-electrolysis mode and 943W_{el} in steam electrolysis mode. A higher Nernst potential of the $H_2O/H_2/CO_2/CO$-containing gas system was identified as the primary reason for the difference.

High-temperature electrolysis is an endothermal process, consuming not only electric energy but also heat. The heat can be provided internally by the cell resistance (i.e. ohmic and electrochemical losses) for thermally self-sustaining operation. The voltage needed for such an operation is called thermoneutral voltage (U_{TN}). In a system context, operating near U_{TN} is beneficial for practical applications. For this reason, the temperature distribution inside the stack in co-electrolysis at a gas conversion rate of 75 % was investigated. Figure 2 shows a performance map and the temperature distribution within the CFY stack. It is possible to conclude, based on the temperature distribution, that at low current densities most of the steam is converted at the stack inlet, acting as a heat sink. At current densities close to U_{TN}, the temperature profile inside the cell is homogenized.

Techno-economic assessment for SOE-based processes

Because of the advantages of SOE technology, such as high electric efficiency and direct formation of syngas from CO_2 and H_2O, the cells and stacks developed at IKTS are applied for system development. Process modeling tools are used to identify the optimal process design for a given production process. Additionally, the calculations allow for the identification of advantageous operating conditions for the SOE stacks in a system context. This feedback allows to deduce development



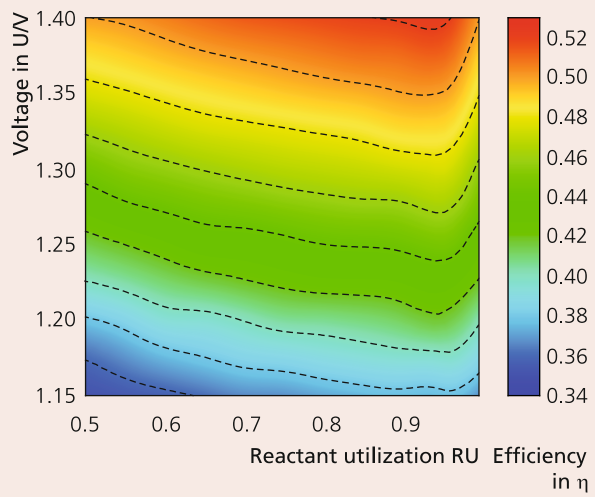
goals for the SOE components, creating a design loop that leads to technological improvements.

One of the processes studied is the coupling of SOE and Fischer-Tropsch synthesis. Not only was the achievable electric efficiency assessed for this process, its economic viability was also evaluated. Production costs for sustainable hydrocarbon products were calculated for different factors, such as costs for SOE production, electricity and CO_2. The results of this study showed that with increasing maturity of the SOE technology and with availability of renewable electric energy at reasonable costs, SOE-based processes look very promising with regard to the sustainable production of chemicals in the future.

Services offered

- Process development for SOE integration in chemical production processes
- Performance of techno-economic feasibility studies for electrolysis-based process concepts
- Design and testing of prototype units as proof of concept
- Design and testing of system components including SOE stacks and modules

Overall efficiency map of a system for wax production with MK352 stacks in SOE operation



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1 Stack performance as a function of gas utilization.

2 Relationship between power and temperature distribution in the stack.

3 Small-scale plant for demonstration of a coupled process for co-electrolysis and Fischer-Tropsch synthesis.

4 Liquid Fischer-Tropsch products.

5 Assembly of an MK352 stack from individual components.

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