Storing electricity and CO2 as synthetic hydrocarbon fuels by high temperature electrolysis

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Storing electricity and CO₂ as synthetic hydrocarbon fuels by high temperature electrolysis

Carbon capture & storage (CCS)

- Conversion of fossil energy
- Hydrocarbon fuel
- CO₂
- Fossil carbon
- H₂O
- Sequestered carbon

Today's major sustainable energy efforts are (i) reduction of CO₂ emissions and (ii) increasing the share of renewable energy. One way of CO₂ emissions reduction is CO₂ sequestration, which can be pursued independently of renewable energy. Another way is CO₂ utilization, which at large scale means conversion of CO₂ into synthetic hydrocarbons for use in existing infrastructure. This conversion must be driven by energy sources that do not produce CO₂ emissions, e.g. renewable or nuclear energy sources. Advantageously, using renewable energy to convert CO₂ to fuels also helps increase the share of renewable energy because the most abundant renewable sources, solar and wind, provide fluctuating energy supplies which must be stored. Synthetic hydrocarbon fuels are excellent energy storage media. Solar energy can be used to convert CO₂ and H₂O into fuels in a variety of ways. The most common way is by electrolysis.

Carbon capture & recycling (CCR)

- CO₂ air capture
- CO₂
- Solid oxide electrochemical cell
- Gasoline, diesel, etc.

We anticipate significant improvements in cell performance and degradation minimization though further studies are needed. We are continuing to improve the basis for safe operation of SOECs by understanding the possible degradation mechanisms, the large effort in materials design that has been undertaken for many years has brought 5-10 year operating lifetimes with reach. SOEC research therefore entails a combination of fundamental studies of materials with long-term testing of pre-commercial devices for thousands of hours, as well as investigating integration into the larger energy system to test relevant intermittent operating profiles.

Cell performance

- PEM (commercial) & advanced alkaline (R&D)
- wider optimal operating conditions
- lower capital cost

Compared with conventional low temperature electrolysis, operating at high temperature has several advantages that lead to higher efficiency as well as potentially lower capital cost. First, high reaction rates are achieved without expensive electrocatalysts such as platinum. Second, the electrolysis reaction becomes increasingly endothermic with increasing temperature and the inevitable resistive losses in the cell can be used as heat in driving the reaction. The combination of these two advantages enable operation at high temperature (1150°C) instead of the lower temperature (100-200°C) typically used in low-temperature electrolysis systems. Operating the SOEC at high temperature allows for more efficient operation and reduces the amount of heat that needs to be transferred to the system.

Long-term stability

However, there are challenges to achieving high temperature operation. For example, the high temperature environment can lead to degradation of materials, which can affect the performance of the cell over time. To address these challenges, researchers are conducting long-term testing on pre-commercial devices to evaluate the stability of the materials over extended periods of operation.

Outlook

Production of synthetic hydrocarbon fuels from CO₂ and renewable electricity using SOECs is feasible. State-of-the-art cells developed at our lab can now run with minimal degradation below 1 A/cm². Recent cell improvements and careful control of cell operation has led to nearly stable performance at 1 A/cm² at the thermoelectric voltage (200°C) and in ambient conditions. Further improvements can be made to achieve commercial viability. We are continuing to improve the basis for safe operation and degradation minimization though further studies are needed. We are also investigating integration into the larger energy system to test relevant intermittent operating profiles.

Our group at the Technical University of Denmark (formerly Risø National Lab) has been researching high temperature electrolysis of CO₂ and H₂O using solid oxide electrolysis cells (SOECs) for more than 10 years. The ceramic cell technology that was developed most actively for fuel cell application (solid oxide fuel cells) can be simply run in the reverse by applying electrical energy. Besides using the cells optimized for fuel-cell mode operation, new types of cells optimized for electrolysis mode operation are also under development.

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