Development and Characterization of Advanced Cell and Stack Materials for High-Temperature Electrolysis (HTE) Systems

DMREF/HydroGEN EMN Postdoctoral Position

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High-temperature electrolysis (HTE) based on solid-oxide electrolysis cell (SOEC) technology for hydrogen production from steam has significant thermodynamic and kinetics advantages over low-temperature water splitting methods. As a result, electrolyzer efficiencies for HTE are approximately 50% higher than for conventional water electrolysis at typical operating conditions. One reason for this high efficiency is that as the temperature increases, an increasing portion of the total energy requirement for electrolytic water splitting can be provided in the form of heat. Therefore, these systems are utilized best when high-temperature heat is available from sources such as concentrated solar energy or advanced high-temperature nuclear reactors. While the high operating temperature (~800°C) for HTE has advantages, there are also significant materials challenges associated with operation of SOECs at these temperatures, especially in stack configurations. Some of these challenges include delamination of electrodes from electrolytes, inter-diffusion of electrode species at solid-state boundaries, coarsening of porous electrode materials, differential expansion of ceramic and metallic components, etc. These phenomena ultimately contribute to long-term performance degradation of SOECs and stacks, especially when operating at high current density.

Degradation mechanisms can be identified through detailed post-test examination of cells and stacks. Identification of these mechanisms can provide the basis for the development of mechanistic degradation models that, in turn, can lead to identification and development of new materials for electrodes, barrier layers, conduction layers, and interconnects. **The proposed project will focus on development of robust high-current-density HTE cells and stacks through a combination of experiment, post-test examination, and modeling.** We will make use of the INL HTE capability node described on the HydroGEN Advanced Water Splitting Materials website:

https://www.h2awsm.org/capabilities/electrochemical-and-durability-performance-evaluation-high-temperature-electrolysis

INL capabilities include a full HTE laboratory with multiple test stations for support of cell and stack testing from the button cell scale to multiple kW stacks, plus a new 25 kW large-scale HTE test facility. Online diagnostic tools include a full electrochemical impedance spectroscopy (EIS) system, sweep and cyclic voltammetry, reversible operation with power supplies and electronic loads, plus a wide range of supporting instrumentation and hardware. INL also has a significant array of advanced SOEC post-test examination capabilities, including SEM/EDS, Auger electron spectroscopy, Raman spectroscopy, CT scan, Local Electrode Atom Probe microscopy, Positron Annihilation Spectroscopy, Glow Discharge Atomic Emission Spectrometer, and surface profilometry. INL has also supported advanced analytical methods for prediction of the behavior of solid-state materials at the operating conditions of SOECs, including atomistic modeling methods. Small-scale cell fabrication capabilities are also available at INL.