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Gadolinium doped CeO_2 (GDC) infiltrated Ni-YSZ electrodes for enhanced CO_2/H2O co-electrolysis in solid oxide cells (SOECs)

Aim

The aim of this study is to enhance the electrochemical performance of Ni–YSZ fuel electrodes for high-temperature CO_2/H_2O co-electrolysis by incorporating gadolinium-doped ceria (GDC) via controlled infiltration (10–20 wt%). The project seeks to systematically evaluate the impact of GDC infiltration on mixed ionic–electronic conductivity, oxygen vacancy concentration, charge transfer kinetics, and overall co-electrolysis performance at 750–800 °C. Particular emphasis will be placed on improving triple phase boundary (TPB) activity, reducing polarization resistance, and enhancing long-term electrode stability under co-electrolysis conditions.

Justification

Solid oxide electrolysis cells (SOECs) offer a thermodynamically favorable route for CO_2 and H_2O conversion to syngas (CO + H_2), enabling efficient integration with renewable energy systems and downstream fuel synthesis processes. Compared to low-temperature electroreduction technologies, SOECs benefit from improved reaction kinetics and reduced electrical energy demand due to high operating temperatures.

Despite these advantages, conventional Ni–YSZ electrodes exhibit several limitations under co-electrolysis conditions:

- Limited oxygen ion conductivity within the metallic Ni network
- Restricted triple phase boundary (TPB) length
- Insufficient oxygen vacancy concentration for rapid redox kinetics
- Elevated charge transfer resistance during CO_2/H_2O reduction

Gadolinium-doped ceria (GDC) is a well-known mixed ionic–electronic conductor (MIEC) with high oxygen ion mobility and enhanced oxygen vacancy concentration due to Gd^{3+} substitution in the ceria lattice. Incorporation of GDC into Ni–YSZ electrodes via infiltration can:

- Extend electrochemically active TPB regions
- Improve charge transfer kinetics
- Reduce polarization resistance and enhance electrode durability by distributing reaction sites more uniformly

Therefore, GDC infiltration represents a targeted materials engineering strategy to overcome intrinsic limitations of conventional Ni–YSZ electrodes and improve co-electrolysis efficiency and stability.

Program

The proposed work aims at Followings;

- Controlled infiltration of GDC precursor solutions to achieve 10–20 wt% loading.
- Calcination and reduction treatments for microstructural stabilization.
- Phase analysis, Morphology and microstructural evaluation
- Electrochemical testing (750-800ºC) [(I–V) characterization under CO_2/H_2O co-electrolysis, Electrochemical impedance spectroscopy (EIS) to determine polarization resistance and charge transfer resistance, Analysis of syngas production rates and Faradaic efficiency].

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