Development of novel High Temperature and Pressure Alkaline Electrolysis Cells (HTP-AEC)

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Development of novel High Temperature and Pressure Alkaline Electrolysis Cells (HTP-AEC)

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Introduction

Background
- A HTP-AEC with gas diffusion electrodes (metal foams) and an aqueous KOH electrolyte immobilized in a mesoporous ceramic matrix structure has been developed at DTU Energy.
- Very high current density and performance has been demonstrated with shirt button sized cells:
  - Record data from earlier work [1]:
    \[ \text{I} = 1.75 	ext{ A/cm}^2, \text{E} = 1.75 	ext{ V} \text{ vs. } \text{RHE} \]
    \[ \text{I} = 85 \% \text{(200°C, 20 bar)} [3] \]

Motivation
- High temperatures (200°C) increase the activity of the electrodes and the conductivity of the electrolyte significantly.
- A cell that allows for high efficiency and current density simultaneously using non-noble metals.

Challenges
- Corrosion issues at the oxygen electrode. Identification of more stable materials, which also show sufficiently high catalytic activity towards the oxygen evolution reaction.
- Processing of cell layers with optimized microstructure using a low cost & scalable processing method.

Electrode materials for the oxygen electrode
- Electrode materials (electrocatalysts) based on La, Ni and Fe for the oxygen evolution reaction (OER)
- Electrode materials for the oxygen electrode
- The experiments
  - Electrochemical activity of the materials has been tested at room temperature and pressure conditions
  - Electrochemical characterization
  - Chemical stability assessment

Results – chemical stability

LaNi0.6Fe0.4O3 pellet surface before and after ~20 h electrochemical testing.

XRD patterns of the as-received LaNiO3 powder and the same powder after exposure to 45 wt% KOH at 220°C for 1 week. The peaks represent the following phases:
- LaNiO3
- La2O3
- NiO
- La2Ni0.9Fe0.1O4

The calculated Tafel fit parameters (I = a + b log[i]) from the tafel plot together with the overpotential, \( \eta \), at 10 mA/cm². The state-of-the-art, IrOx, and two of the best performing non-noble oxygen evolution catalysts are also included as benchmarking.

Outlook

Processing of porous oxygen electrodes
- Based on the electrochemical screening of LaNi0.6Fe0.4O3, it is going to be used as oxygen evolution electrocatalyst. The microstructure of the oxygen electrode is going to be optimized using the processing method screen printing. An electrode with a bimodal porosity distribution is envisioned to allow for electrolyte infiltration (~10-100 µm pore sizes) and gas diffusion (2-10 µm pore sizes) of evolved oxygen.

Successful fabrication and electrochemical characterization of up-scaled cells (5 x 5 cm²) with the microstructurally optimized oxygen electrode is the expected outcome of the project.

Results - Electrochemical activity towards the OER

Comparison of the 2nd set of chronopotentiostatic tests performed at 10 mA/cm² and LaNiO3 could not be sintered dense without decomposition so it is a multiphase of mainly LaNiO3, NiO and La2O3. LaO(OH), NiO(OH), + La2O3, * NiO. The decomposed products.

The calculated Tafel fit parameters (I = a + b log[i]) from the tafel plot together with the overpotential, \( \eta \), at 10 mA/cm². The state-of-the-art, IrOx, and two of the best performing non-noble oxygen evolution catalysts are also included as benchmarking.

Material b (V/dec) a R² \( \eta \) (V) @ 10 mA/cm²
LaNiO3 0.083 0.30 0.97 0.38
LaNi0.6Fe0.4O3 0.092 0.34 0.97 0.44
La2Ni0.9Fe0.1O4 0.13 0.31 0.95 0.44
LaNi0.6Fe0.4O3 0.11 0.33 0.98 0.45
La0.97NiO3 0.079 0.32 0.98 0.40
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References