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:

  1.75 A/cm² at 1.75 V with t_i = 85 % (200°C, 20 bar) [1]

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.

The experiments

Electrode materials for the oxygen electrode
- Electrode materials (electrocatalysts) based on La, Ni and Fe for the oxygen evolution reaction (OER)

Three-electrode setup for electrochemical characterization

Results – chemical stability

LaNi_{0.6}Fe_{0.4}O_{3} pellet surface before and after ~20 h electrochemical testing.

XRD patterns of the as-received LaNiO_{3} powder and the same powder after exposure to 45 wt% KOH at 220°C for 1 week. The symbols represent the following phases:
- ♦ LaNiO_{3}
- ○ LaNi_{0.6}Fe_{0.4}O_{3}
- ♦ La_{2}Ni_{0.9}Fe_{0.1}O_{4}
- ♦ LaO(OH), NiO(OH), + La_{2}O_{3}
- ♦ NiO. The La_{2}Ni_{0.9}Fe_{0.1}O_{4} powder showed similar decomposition behaviour though at a slower rate.

ICP analysis of supernatants from the KOH solution used for the chemical stability testing. If any dissolution is happening the ions seem to be consumed by the decomposed products.

Results - Electrochemical activity towards the OER

Comparison of the 2nd set of chronopotentiostatic tests performed at 10 mA/cm². LaNiO_{3} could not be sintered dense without decomposition so it is a multiphase of mainly LaNiO_{3} and LaO(OH).

The calculated Tafel fit parameters (i = a + b log[i]) from the tafel plot together with the overpotential, η, 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 | η (V) @ 10 mA/cm²
--- | --- | --- | --- | ---
LaO | 0.079 | 0.32 | 0.98 | 0.40
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LaNiO_{3} | 0.13 | 0.31 | 0.95 | 0.44
LaNi_{0.6}Fe_{0.4}O_{3} | 0.11 | 0.33 | 0.97 | 0.45
La_{2}Ni_{0.9}Fe_{0.1}O_{4} | 0.079 | 0.32 | 0.98 | 0.40
IrOx [2] | - | - | - | -
NiO | - | - | - | -
PrBaCo_{2}O_{5+x} [3] | -0.07 | - | - | -0.38

Outlook

Processing of porous oxygen electrodes

Based on the electrochemical screening LaNi_{0.6}Fe_{0.4}O_{3} 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 biodendritic 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.