



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

Adolphsen, Jens Quitzau; Gil, Vanesa; Sudireddy, Bhaskar Reddy; Chatzichristodoulou, Christodoulos

Publication date:
2017

Document Version
Publisher's PDF, also known as Version of record

[Link back to DTU Orbit](#)

Citation (APA):
Adolphsen, J. Q., Gil, V., Sudireddy, B. R., & Chatzichristodoulou, C. (2017). Development of novel High Temperature and Pressure Alkaline Electrolysis Cells (HTP-AEC). Poster session presented at 1st International Conference on Electrolysis , Copenhagen, Denmark.

DTU Library

Technical Information Center of Denmark

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

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

Jens Q Adolphsen (jenqui@dtu.dk); Vanesa Gil, Bhaskar R. Sudireddy and Christodoulos Chatzichristodoulou (ccha@dtu.dk)

Introduction

Background

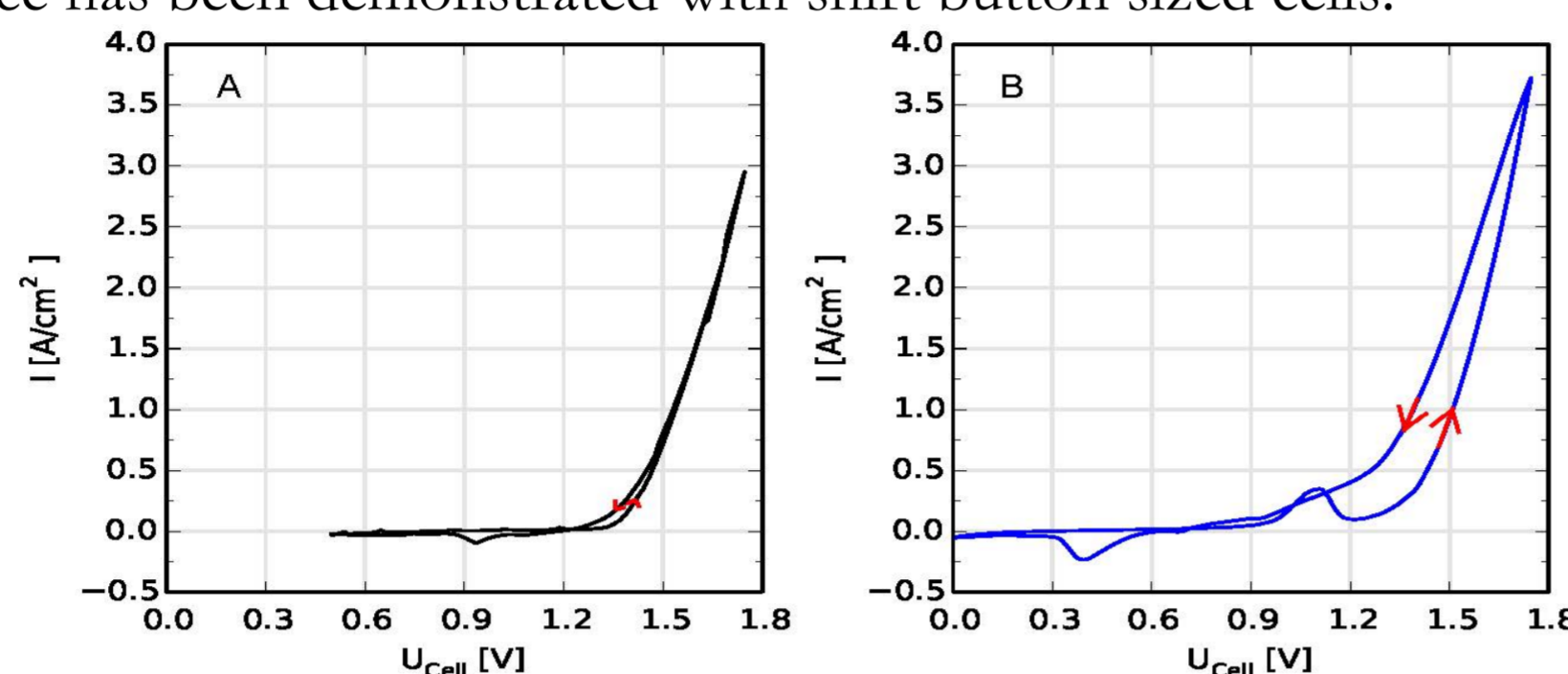
- A HTP-AEC with gas diffusion electrodes (metal foams) and an aqueous KOH electrolyte immobilized in a mesoporous ceramic matrix structure has been developed at DTU Energy.

- Very high current density and performance has been demonstrated with shirt button sized cells:

Record data from earlier work [1]:

3.75 A/cm² at 1.75 V with

$\eta_d = 85\%$ (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

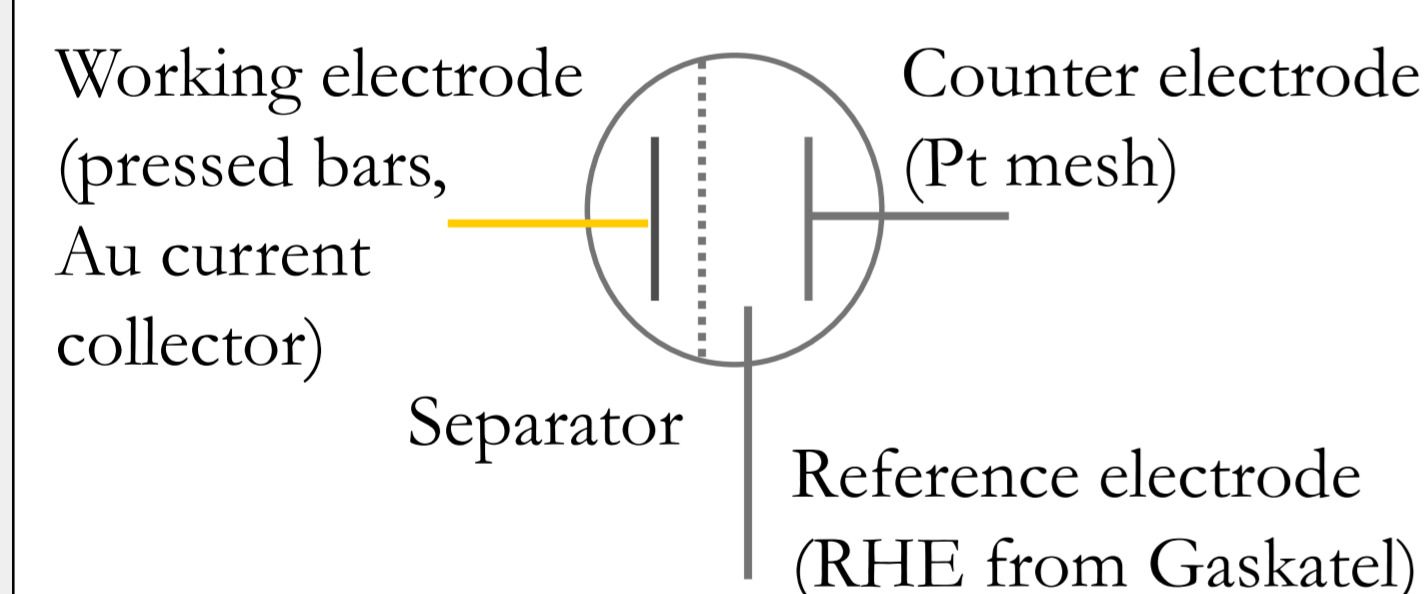
- Corrosion issues at the oxygen electrode. Identification of more stable materials, which also show sufficiently high catalytic activity towards the oxygen evolution reaction.
- Processing of cell layers with optimized microstructure using a low cost & scalable processing method.

The experiments

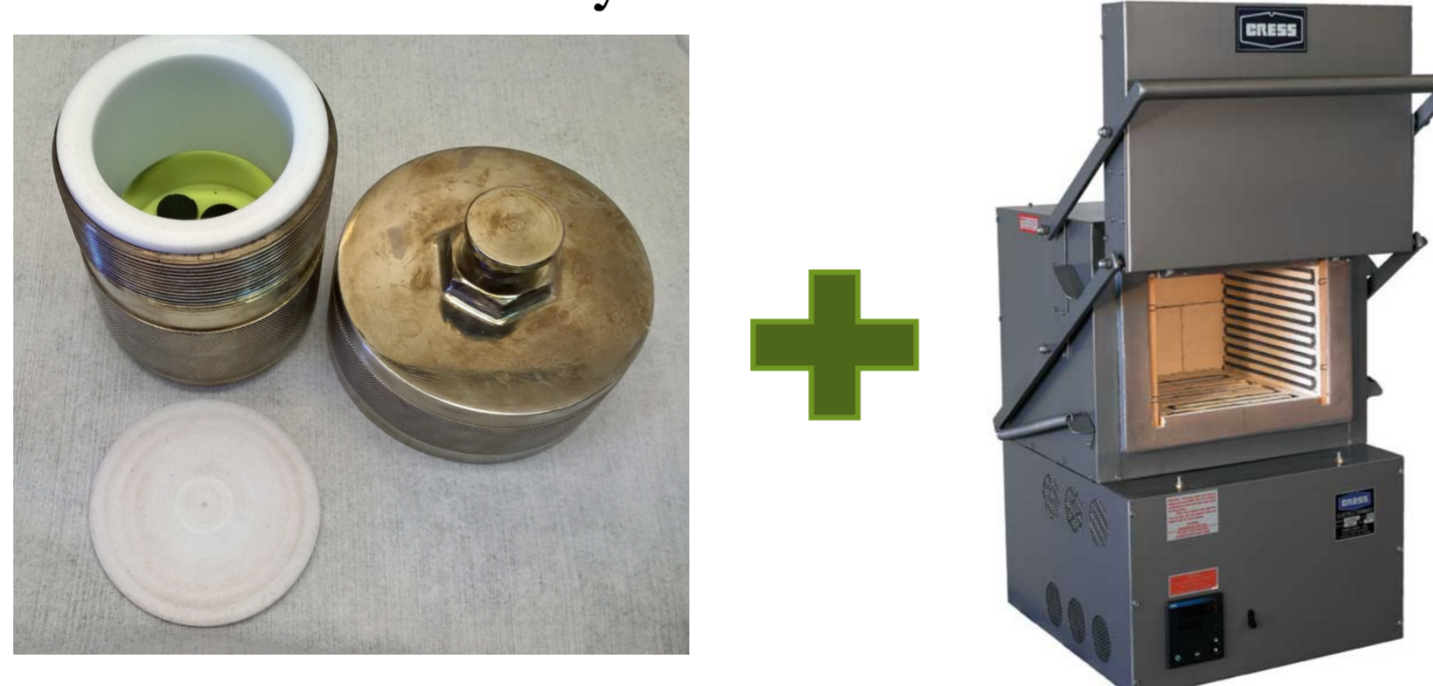
Electrode materials for the oxygen electrode

- Electrode materials (electrocatalysts) based on La, Ni and Fe for the oxygen evolution reaction (OER) have been identified and evaluated.
- The electrochemical activity of the materials has been tested at room temperature and pressure conditions in N₂ atmosphere using densely sintered pellets polished down to 1 μm roughness.
- The chemical stability of the powder, immersed in 45 wt% KOH, and heated in an autoclave to 220°C has been examined comparing XRD patterns before and after.

Three-electrode setup for electrochemical characterization

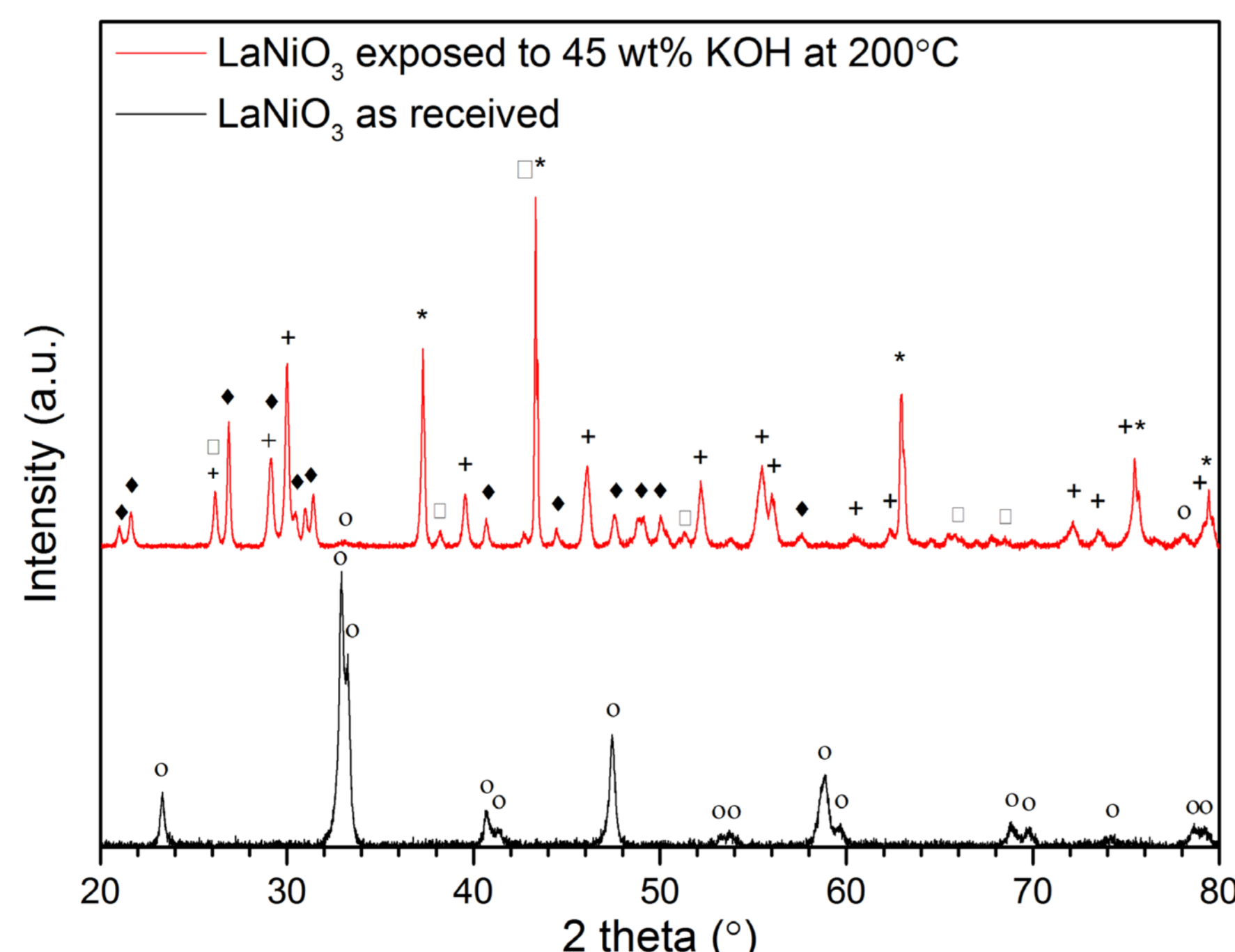
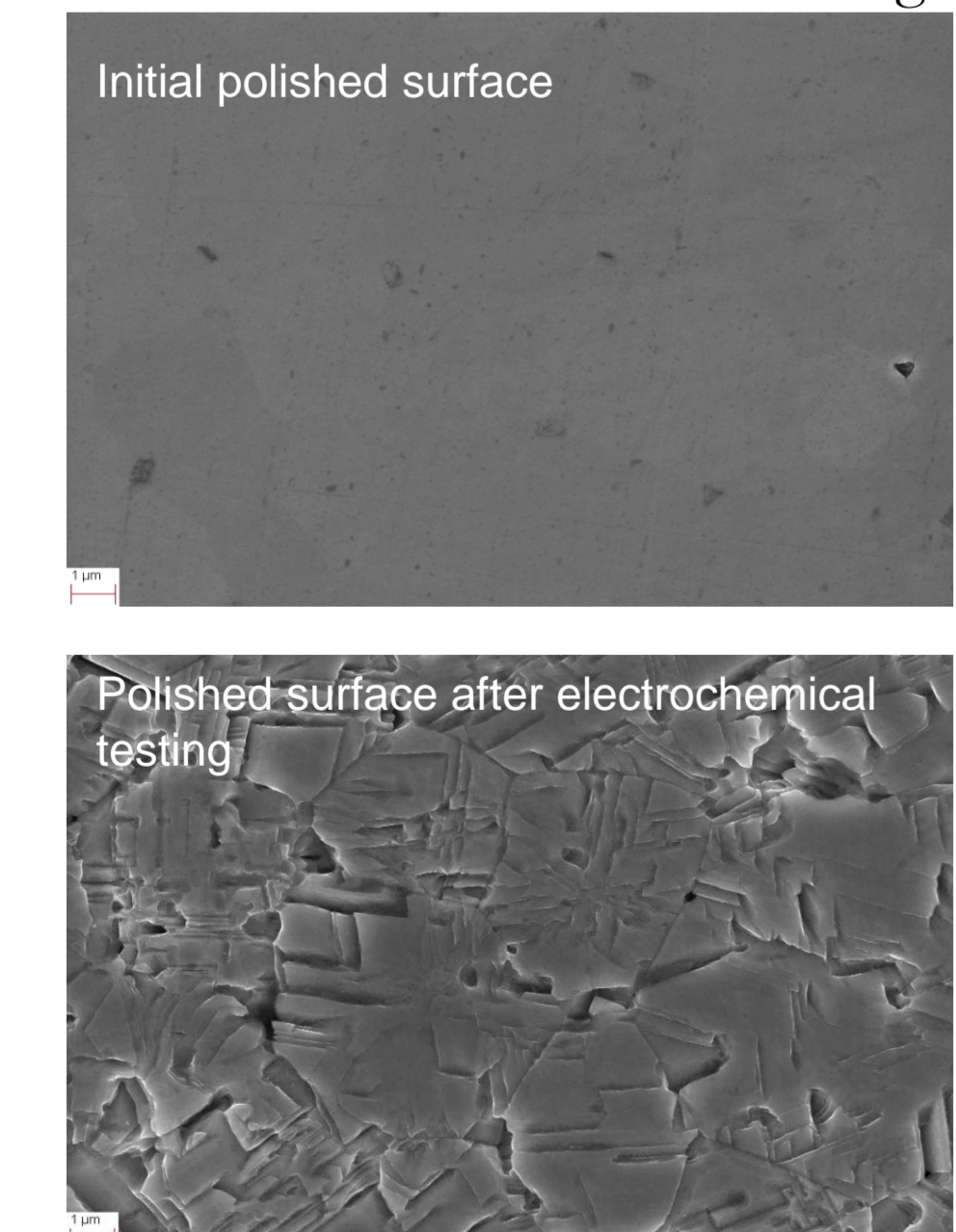


Chemical stability assessment



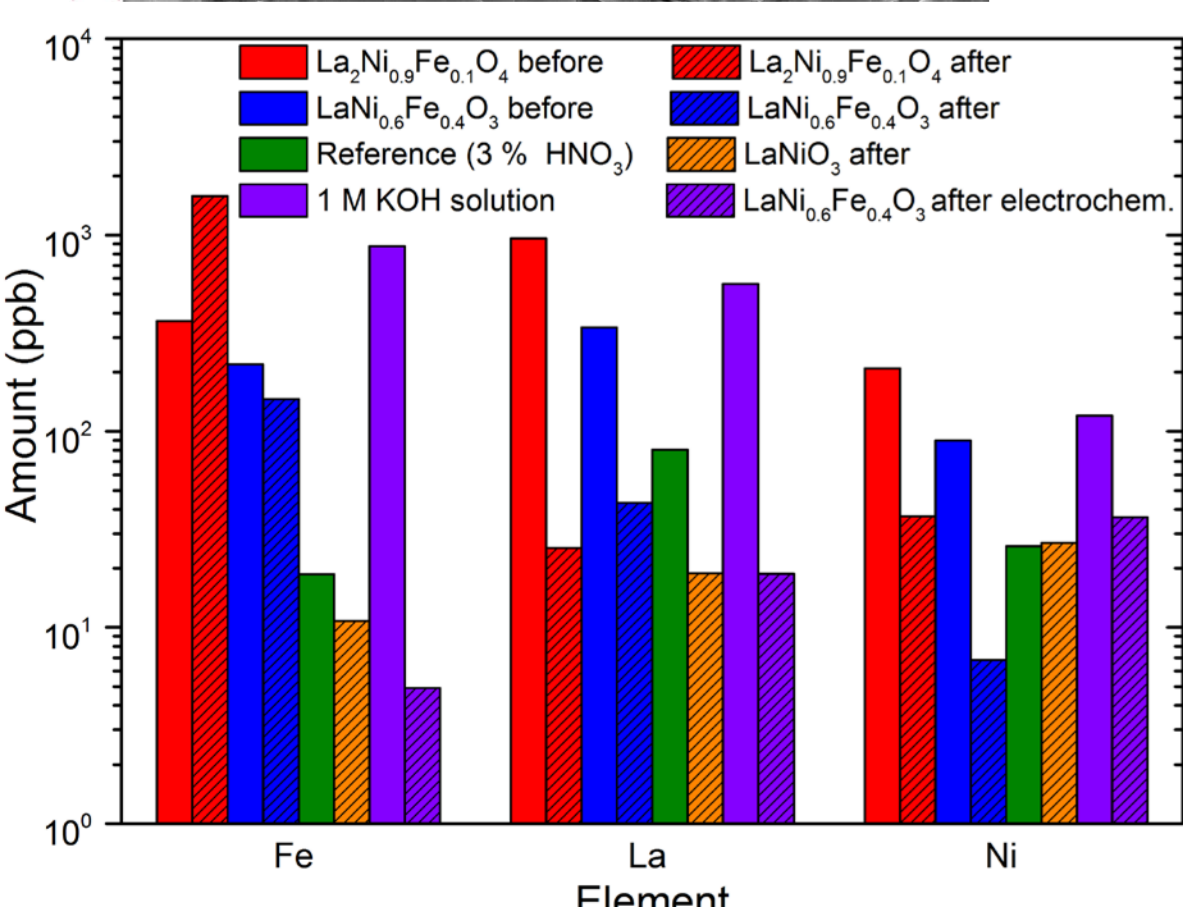
Results – chemical stability

LaNi_{0.6}Fe_{0.4}O₃ pellet surface before and after ~20 h electrochemical testing.

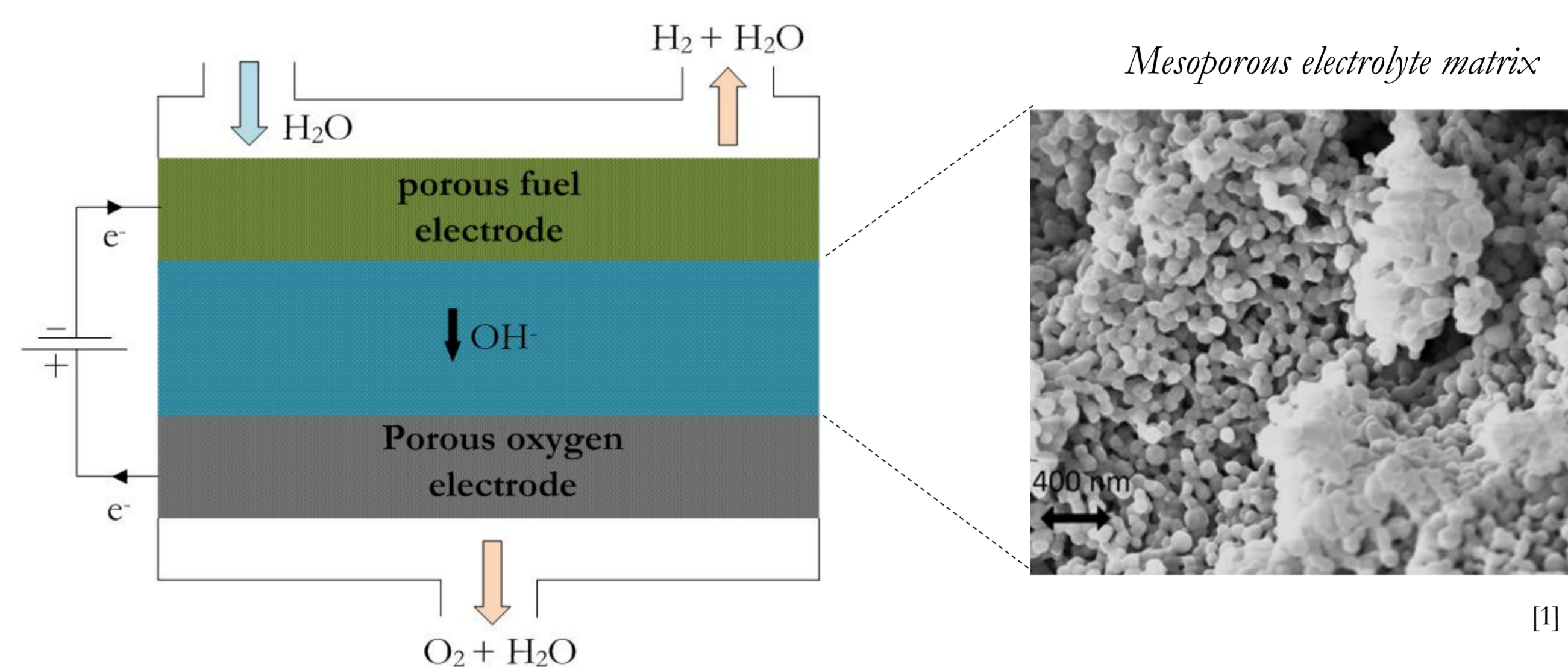


XRD patterns of the as-received LaNiO₃ powder and the same powder after exposure to 45 wt% KOH at 220 °C for 1 week. The symbols represent the following phases: ○ LaNiO₃, ◆ LaO(OH), □ NiO(OH), * NiO. The LaNi_{0.6}Fe_{0.4}O₃ and La₂Ni_{0.9}Fe_{0.1}O₄ powder showed similar decomposition behaviour though 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.

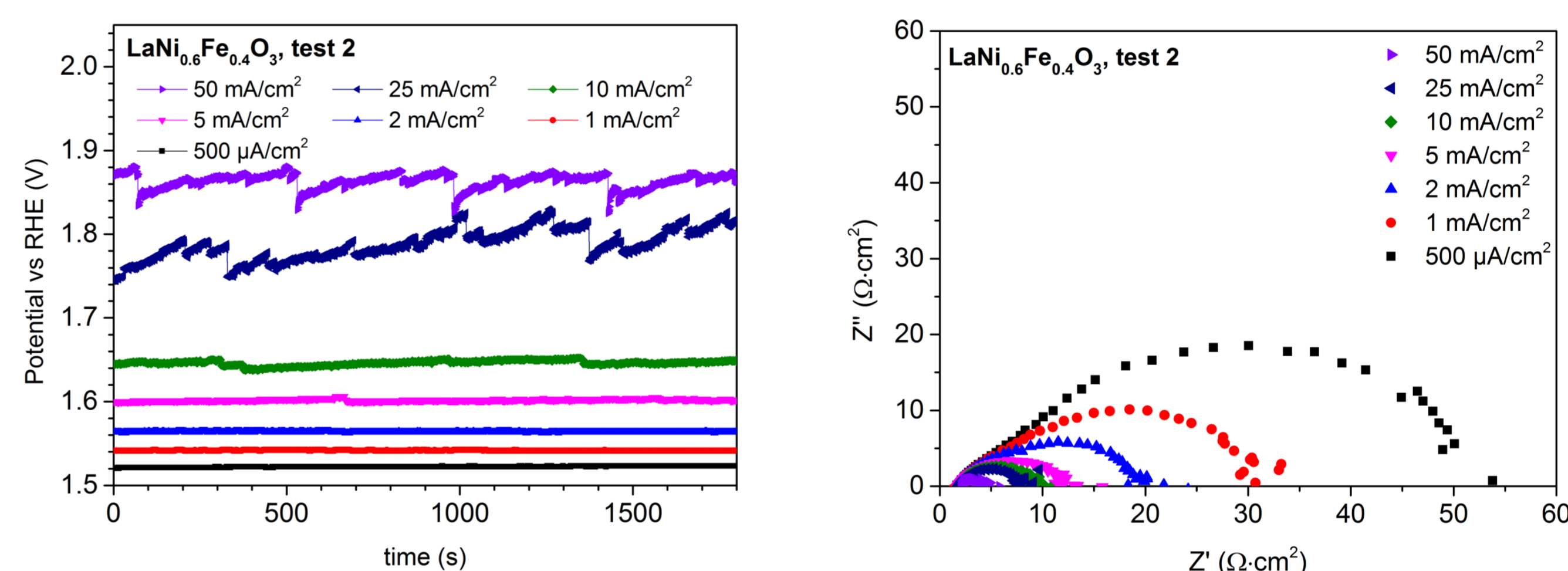


The cell concept

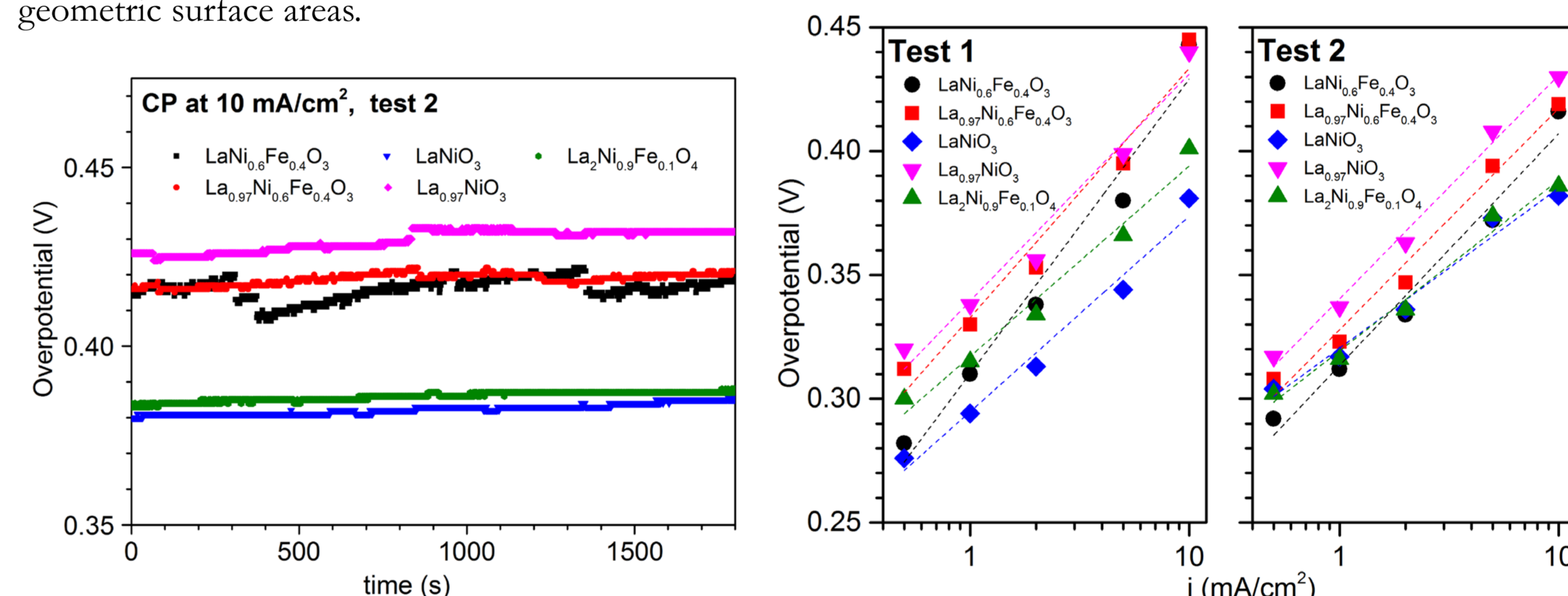


The mesoporous electrolyte matrix contains the KOH electrolyte. The porous electrodes will allow some infiltration of the electrolyte into the electrode to increase the surface area where the electrochemical reactions take place.

Results - Electrochemical activity towards the OER



The iR-corrected chronopotentiostatic measurements of LaNi_{0.6}Fe_{0.4}O₃ and the Nyquist plot of the EIS measurements performed after each chronopotentiostatic measurement. Current densities are based on geometric surface areas.



Comparison of the 2nd set of chronopotentiostatic tests performed at 10 mA/cm². LaNiO₃ could not be sintered dense without decomposition so it is a multiphase of mainly LaNiO₃, NiO and La₂NiO₄.

The tafel plot of the measurements. The fit is from 0.5 – 10 mA/cm². There is a slight increase in the tafel slope above 2 mA/cm² which is then not accounted for.

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

Material	b (V/dec)	a	R ²	η (V) @ 10 mA/cm ²
LaNiO ₃	0.083	0.30	0.97	0.38
La _{0.97} NiO ₃	0.092	0.34	0.97	0.44
LaNi _{0.6} Fe _{0.4} O 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
IrO _x [2]	-	-	-	0.32
Ni _{0.9} Fe _{0.1} O _x [3]	0.030	-	-	0.34
PrBaCo ₂ O _{5+x} [4]	~0.07	-	-	~0.38

Outlook

Processing of porous oxygen electrodes

Based on the electrochemical screening LaNi_{0.6}Fe_{0.4}O₃ 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.