

# Efficient and stable oxygen reduction and oxygen evolution electrodes for alkaline zinc-air flow battery



UCT PRAGUE



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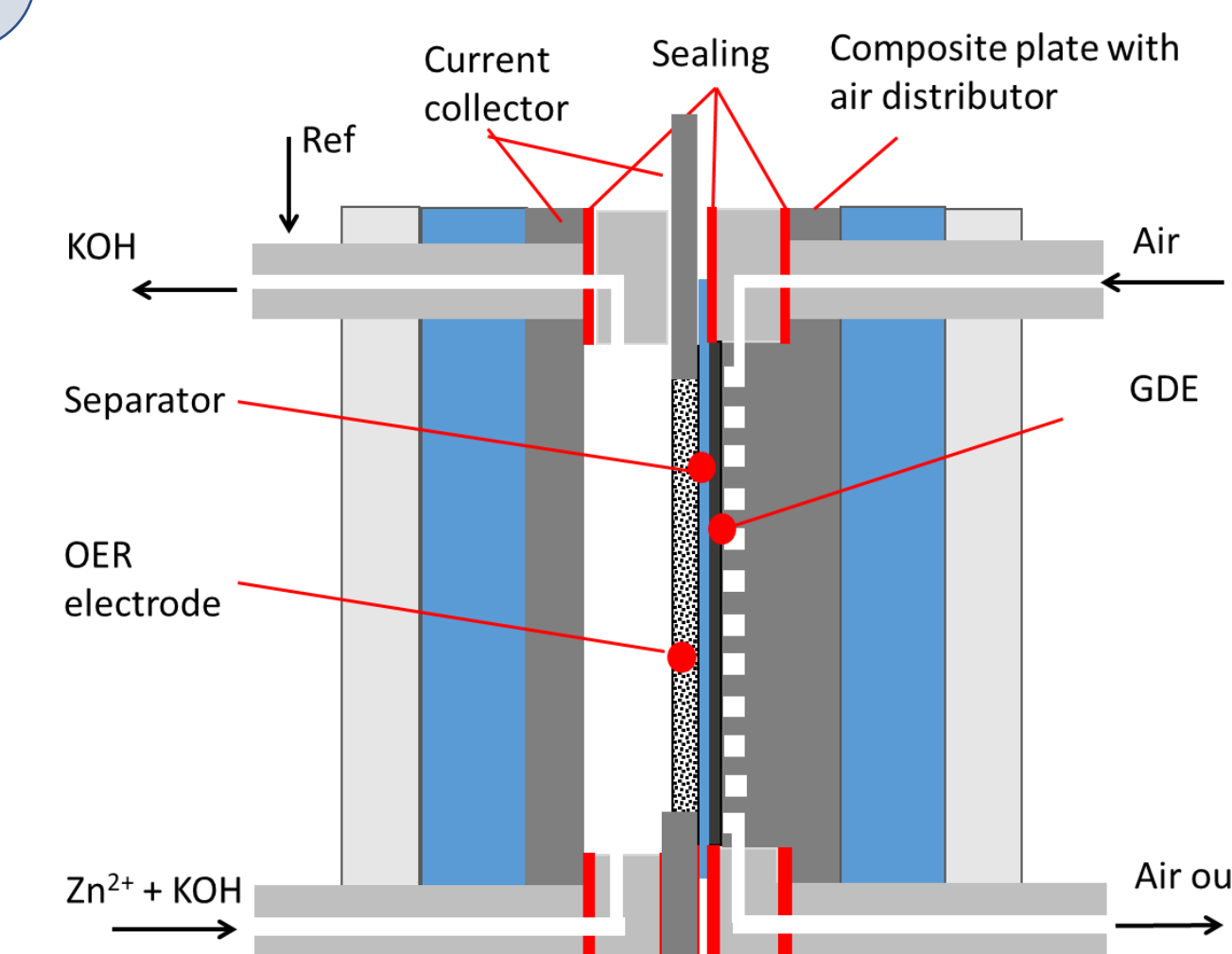


## Motivation:

- Zinc– air flow battery (ZAFB) is a promising eco–friendly, safe and cost– effective stationary energy storage technology
- Limitation of technology by dendritic growth of zinc electrode and sluggish kinetic of oxygen electrodes reactions

## Aims of study:

- Developing stable and efficient electrodes for oxygen evolution reaction (OER) and oxygen reduction reaction (ORR)
  - OER electrode: nickel-based electrodes, catalytically activated forms of them, **laser structured** electrodes.
  - ORR electrode: preparation series of oxygen reduction electrodes with different content of **PTFE (10-80 %)**
- Improvement of performance of ZAFB



**Figure 1:** Scheme of three electrode zinc–air flow battery.

## Development of OER electrodes:

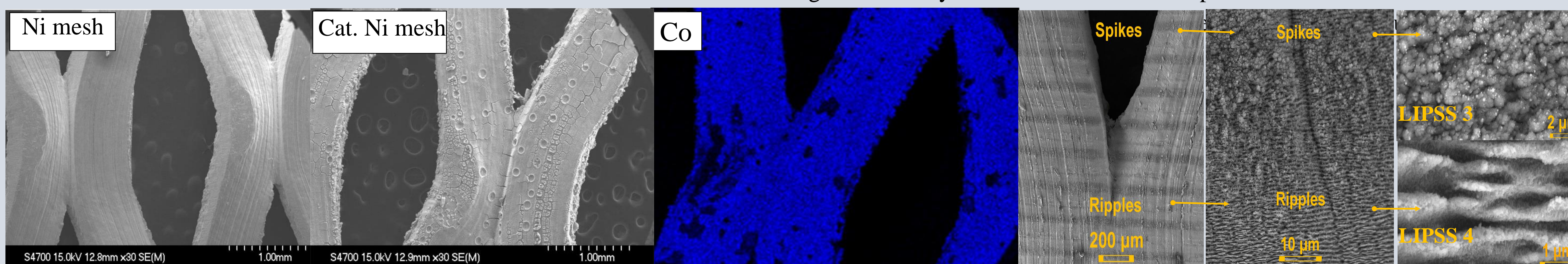
**Prepared electrodes:** nickel foam, catalytically activated nickel foam, expanded nickel, catalytically activated expanded nickel

**Process of catalytic activation:** Electrochemical assisted precipitation in solution of  $(\text{Ni}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O})$  and  $(\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O})$ . Followed by calcination and creation of  $\text{NiCo}_2\text{O}_4$  catalytic layer.

**Characterization of prepared electrodes:** SEM- characterization of surface morphology, EDS- representation of Ni, Co, O

XRD-detection of Ni and nickel cobaltite  $\text{NiCo}_2\text{O}_4$

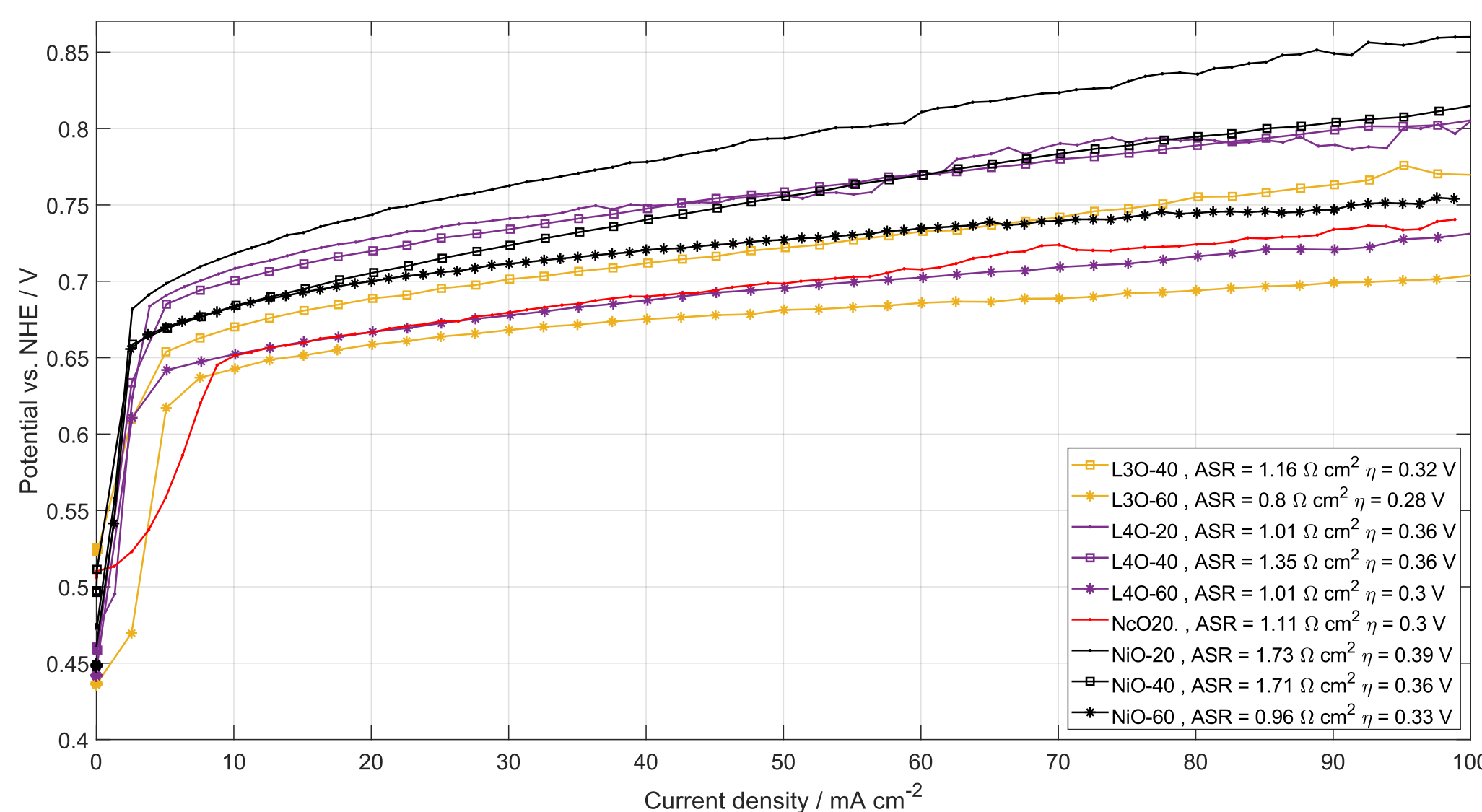
EIS and load curves in non-flow arrangement: catalytic activation decrease of polarization resistance



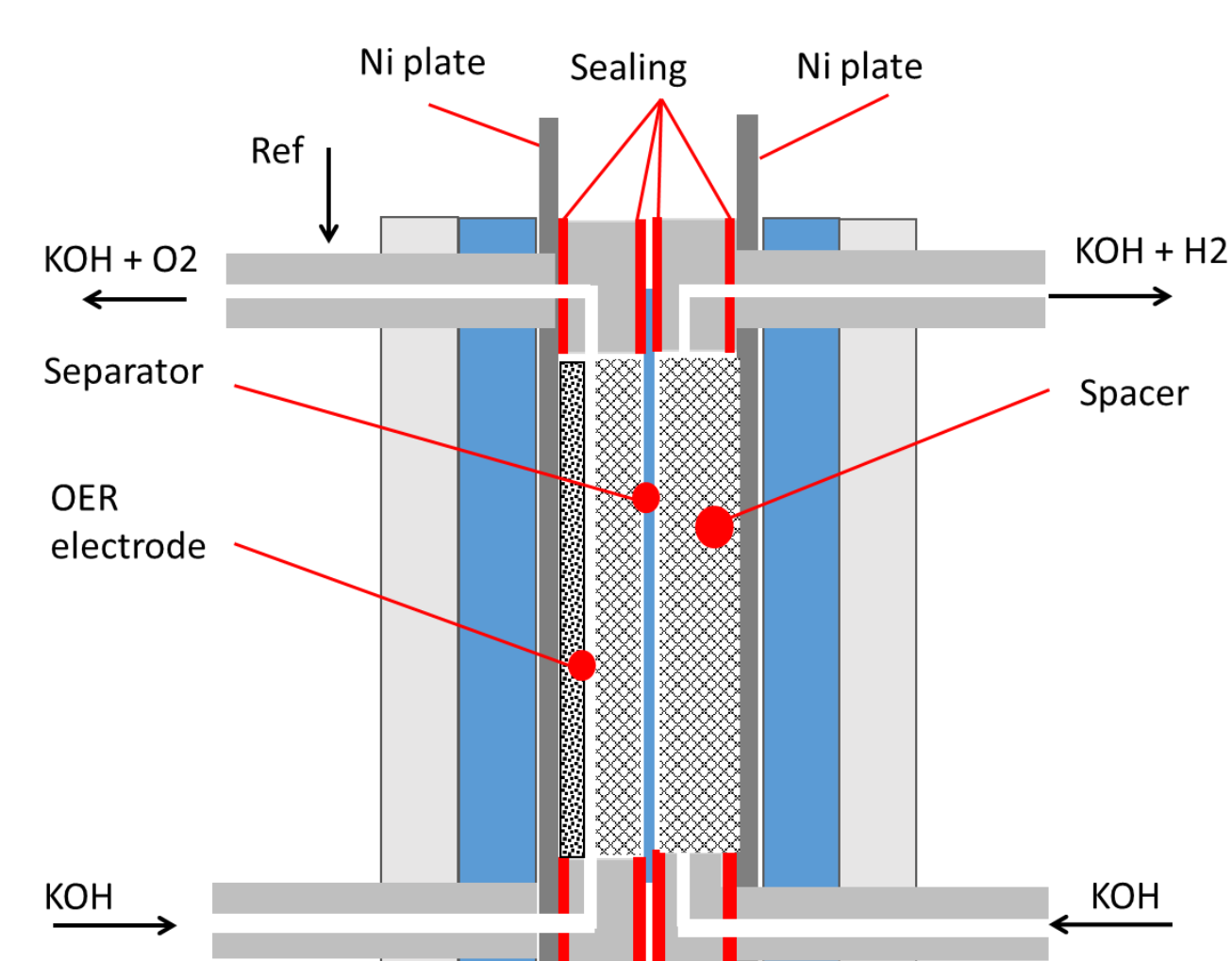
**Testing in flow battery:** 8 M KOH electrolyte, separated electrodes by membrane, counter reaction  $\text{H}_2$  evolution, increased flow speed of electrolyte

EIS, load curve measurements ( $0-100 \text{ mA cm}^{-2}$ ,  $1.25 \text{ mA cm}^{-2} \text{ s}^{-1}$ ), constant galvanostatic load ( $50 \text{ mA cm}^{-2}$ , 6 hours), 25 repetitions, change of electrolyte after 25 repetitions

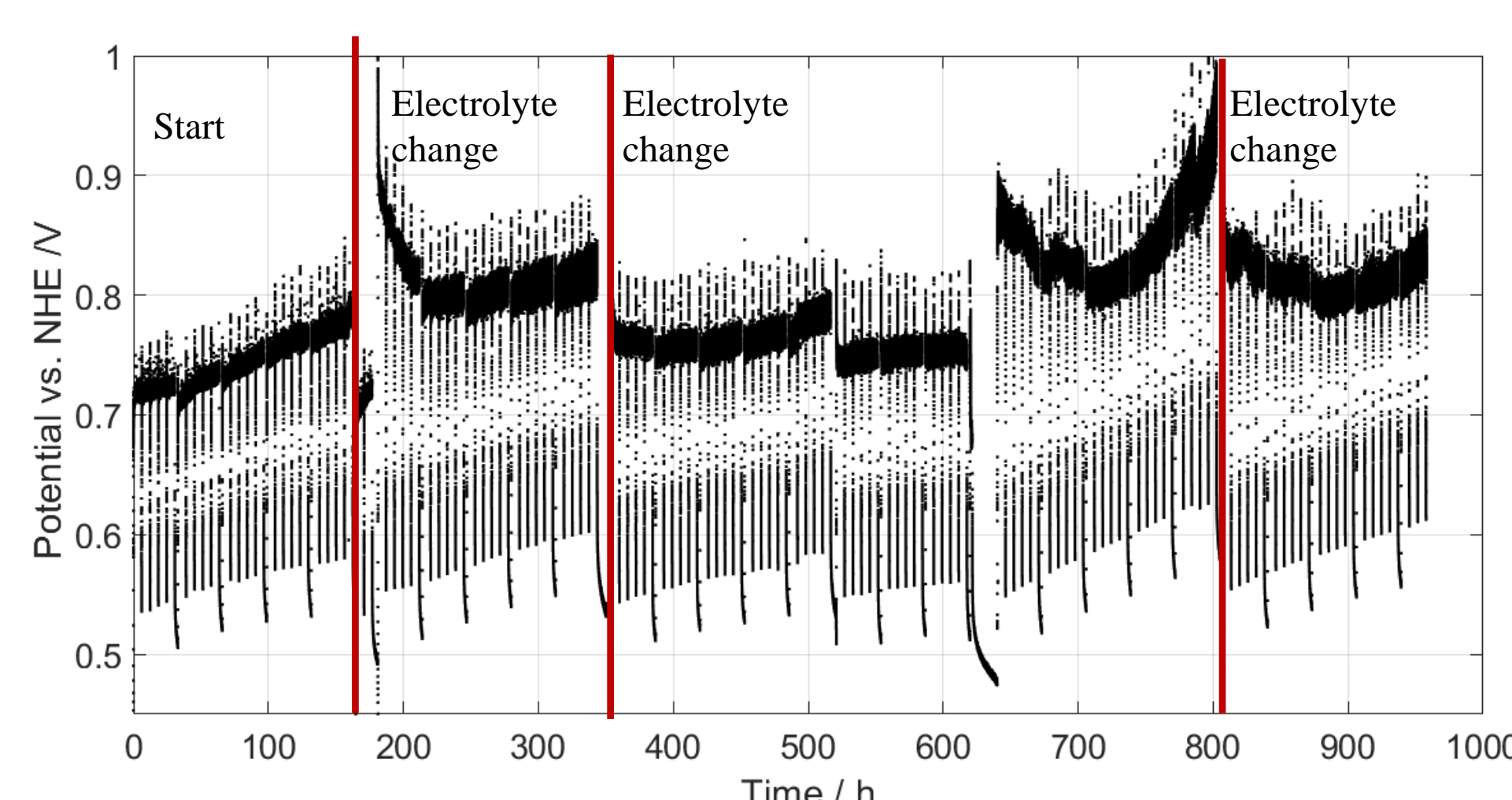
## Results:



**Figure 2:** Load curves ( $0- 100 \text{ mA cm}^{-2}$ ,  $1.25 \text{ mA cm}^{-2} \text{ s}^{-1}$ ), 6<sup>th</sup> cycle. Ni- pristine electrode, NC- cat. electrode, L3- lipss+spikes, L4 lipss electrode. ASR area specific resistance (from load curve slope),  $\eta$  overpotential at  $50 \text{ mA cm}^{-2}$ .

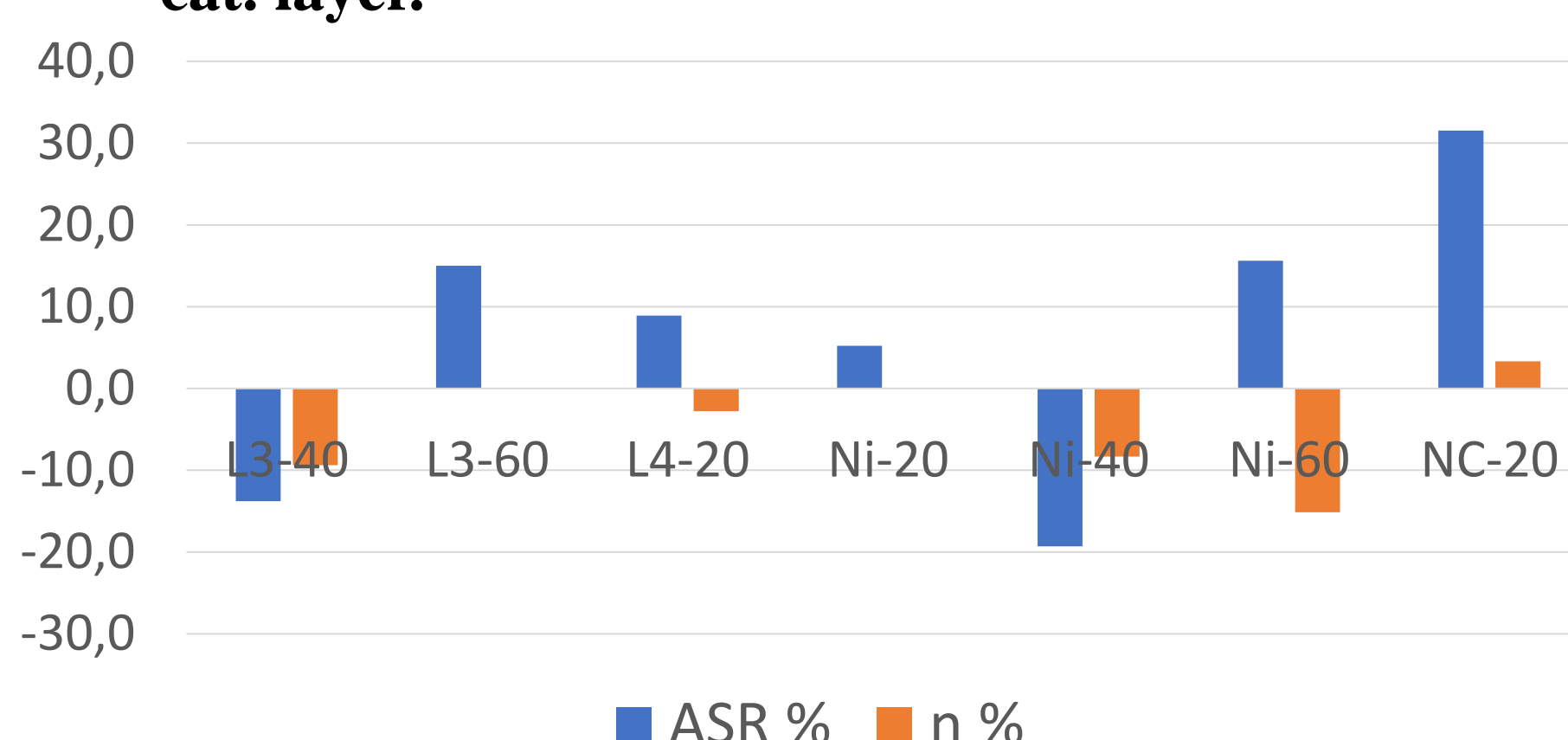


**Figure 5:** Scheme of single flow cell for oxygen evolution.

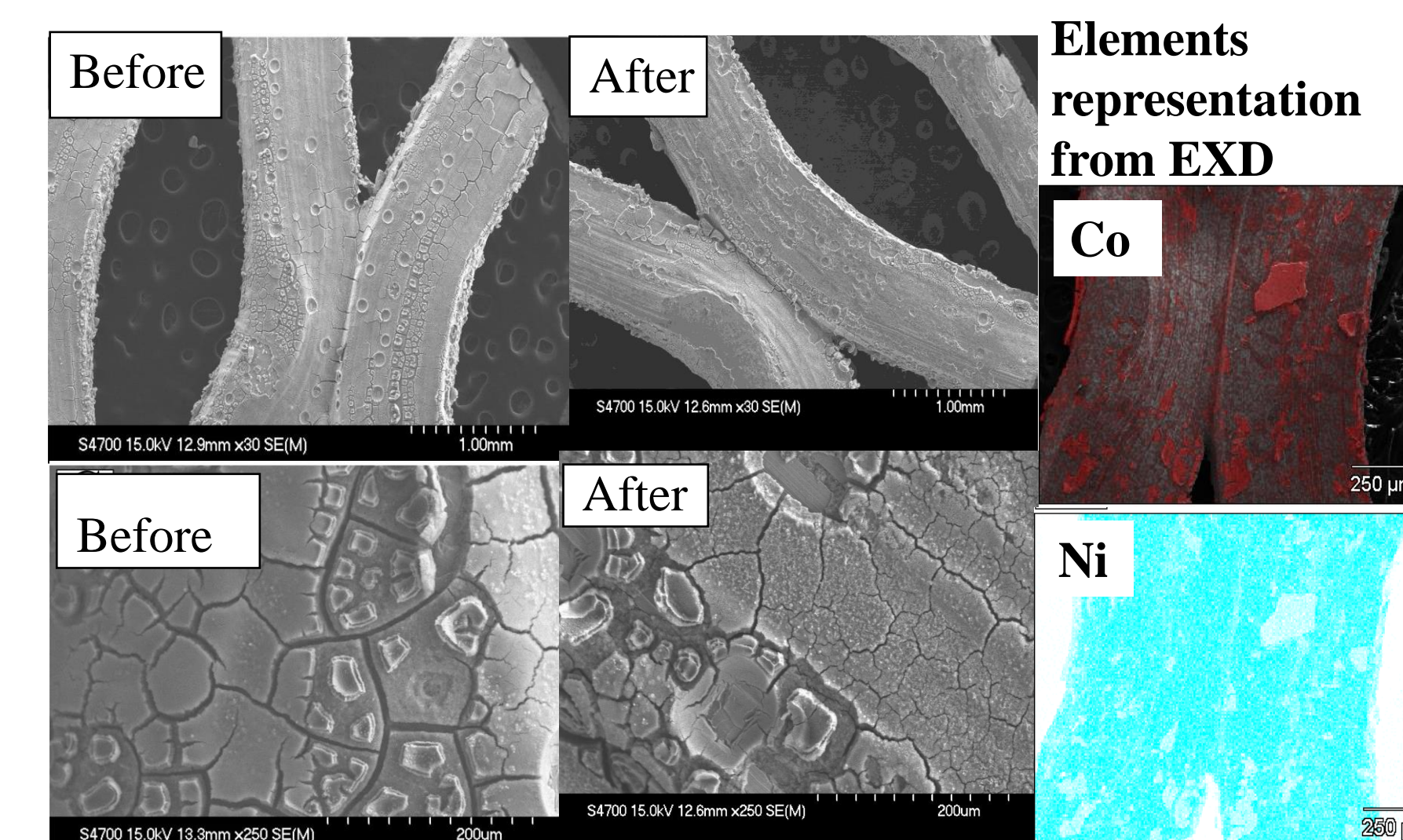


**Figure 3:** Potential of catalyzed nickel mesh (vs. NHE) in long term experiment.

- **Increase of potential of cat. Ni mesh in first experiment (start part)**, caused by change of electrolyte composition: local acidification and flow through the membrane (won't happen in final battery). In longer term lost of most of cat. layer.

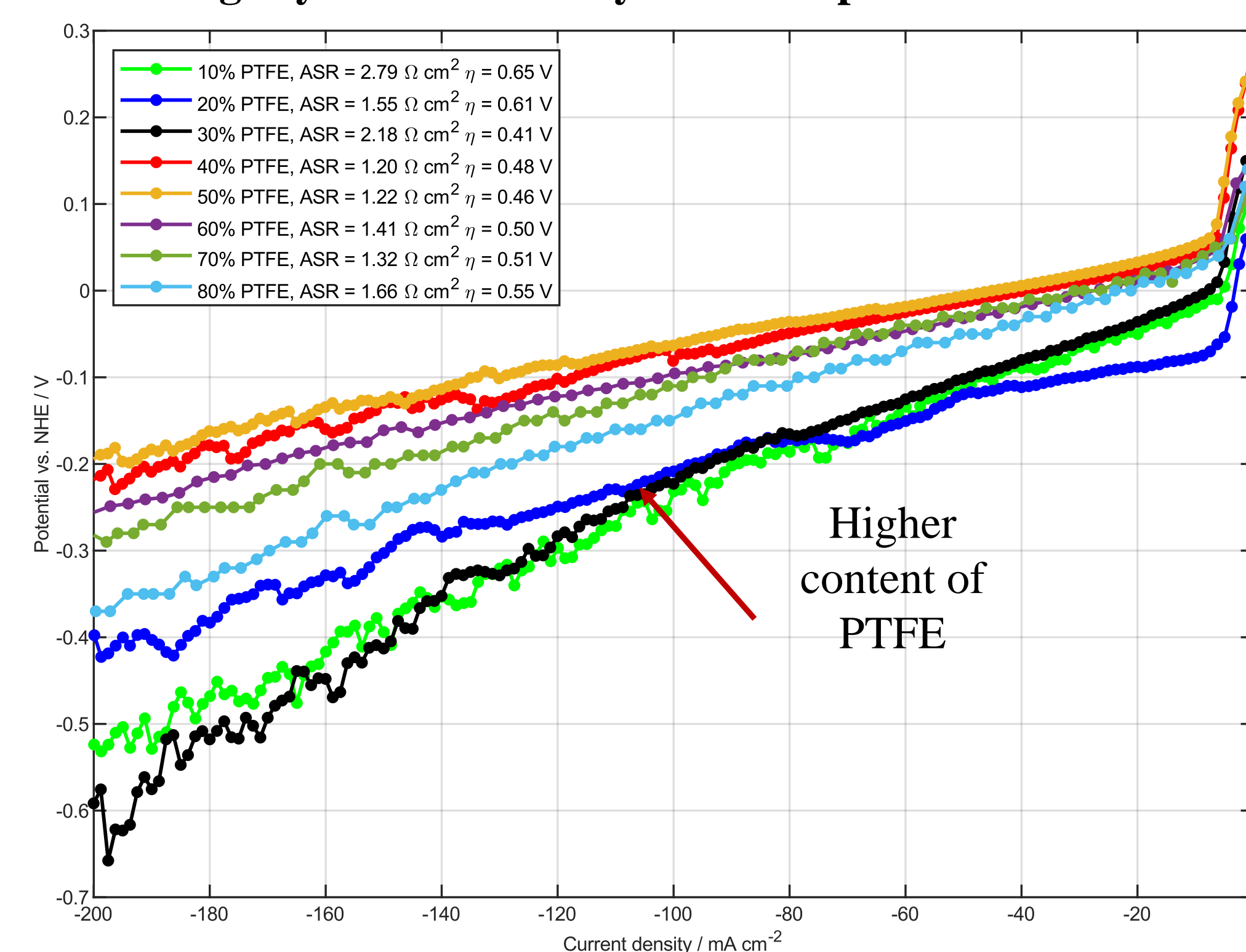


**Figure 6:** ASR change for old and new electrolyte (from load curves) and overvoltage change (at  $50 \text{ mA cm}^{-2}$ ) during OER electrodes experiments for each electrode.



**Figure 4:** Before use and post-mortem SEM images of catalytic layer of OER electrode. Cobalt and nickel representation from EDX after long term test

- **Slightly cracked cat. layer after experiments.**



**Figure 7:** Load curves ( $0- 200 \text{ mA cm}^{-2}$ ,  $1.25 \text{ mA cm}^{-2} \text{ s}^{-1}$ ), second cycle. Different content of PTFE in catalytic layer (Pt catalyst). ASR area specific resistance (from load curve slope),  $\eta$  overpotential at  $50 \text{ mA cm}^{-2}$ .

## Conclusion:

- Developed catalytically activated OER electrodes: decrease of overvoltage → increase performance of OER
- Laser structured electrodes → promising way to decrease overvoltage
  - more stable with compared to catalyst.
- Content of PTFE about 60 %wt. in ORR electrodes → lower ASR, lower overpotential.
- Further investigation of promising electrodes in zinc-air flow battery

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