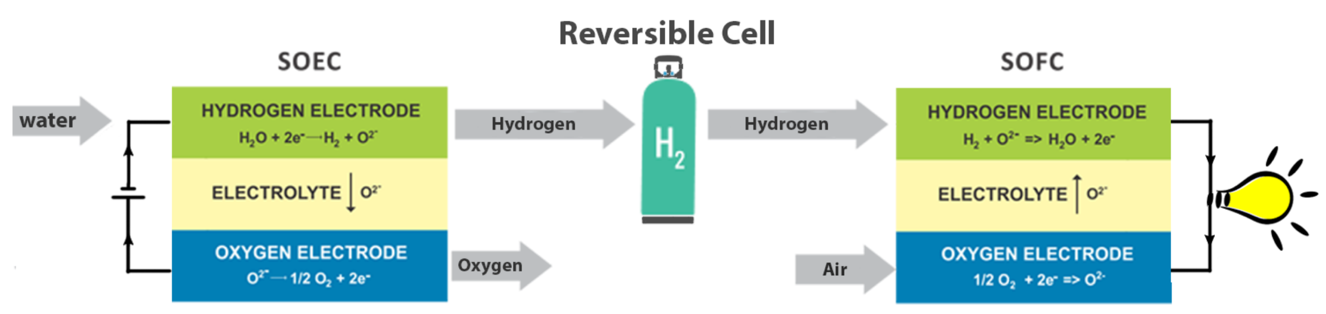
UTILITY-SCALE ENERGY STORAGE: HIGH-TEMPERATURE ELECTROLYSIS

Sajad Vafaeenezhad[1], Dr. Amir Hanifi[1], Dr. Partha Sarkar[2], Dr. Jingli Luo[1], Dr. Thomas Etsell[1]

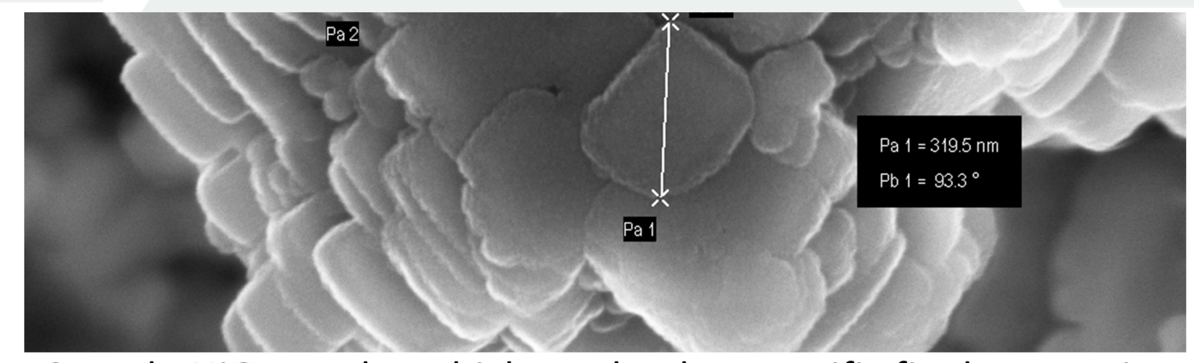
BACKGROUND

- Solid Oxide Electrolysis Cells (SOEC) use electricity to split water molecules into hydrogen and oxygen.
- A reversible cell can use excess electricity (e.g. produced by wind turbines or in the electrical grid) to store hydrogen (SOEC) and produce electricity by using the stored hydrogen at high electricity demand (SOFC)
- The stability of SOEC cell in long term is strongly related to the microstructure of the electrodes. There is a challenge to inhibit metal phase (Ni) migration at high temperatures during the electrolysis operation.



AIMS AND OBJECTIVES

- Studying the effect of different parameters such as raw material properties or process variables on Ni migration and agglomeration.
- Developing an optimized SOEC cell with limited Ni migration and highest Three-Phase-Boundary (TPB) based on the initial characterization results.
- Studying the long-term stability of the cell by introducing accelerated operation conditions such as high steam content, high temperature and high gas conversion ratio.



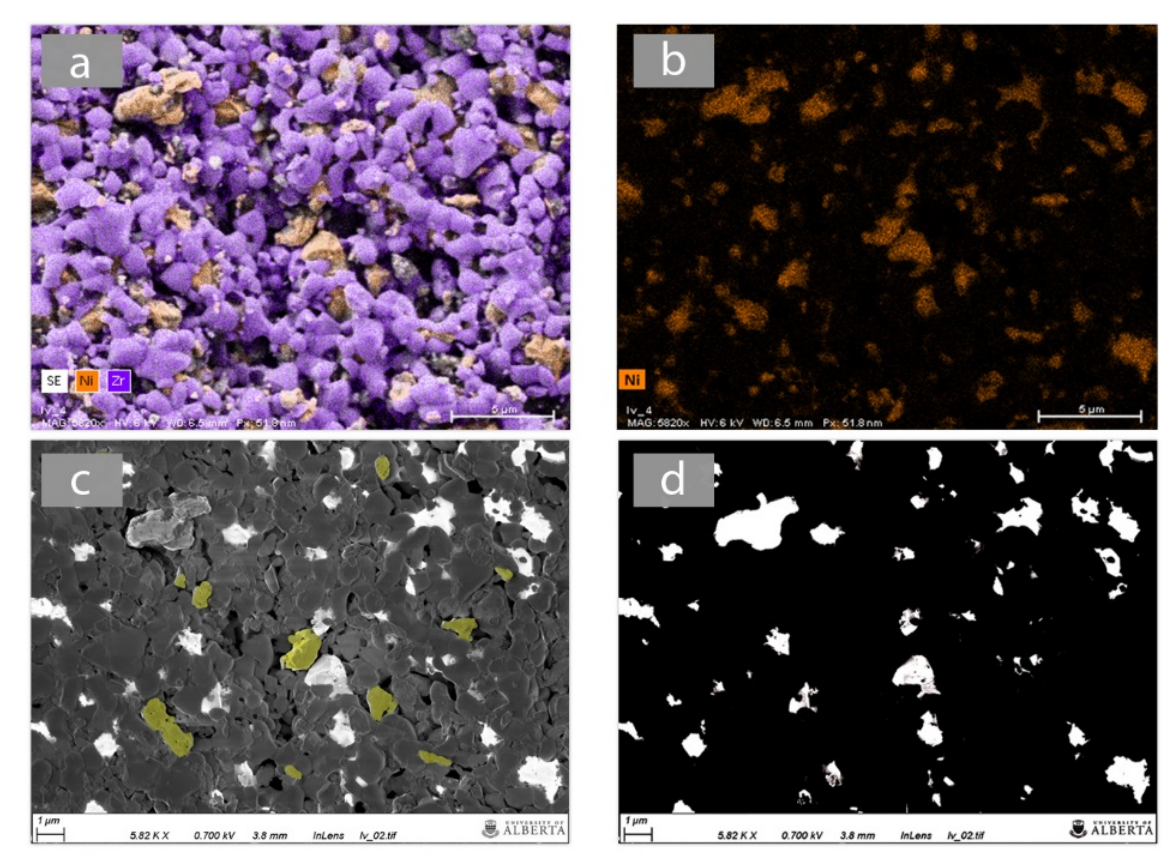
Sample NiO powder which can lead to specific final properties

RESULTS

- Ni and YSZ have similar backscatter coefficient which results in the lack of contrast between two phases. Typical SEM imaging method is changed and optimized at low KV (0.7 – 1 KV) to differentiate between 4 phases: percolated Ni particles, non-percolated Ni particles, YSZ particles and pores. Ni particles tend to migrate or agglomerate during the SOEC operation at high overpotential, high steam content and high temperature. Consequently, electronically connected Ni particles (percolated) turn into isolated Ni particles (non-percolated). The new SEM imaging method enabled us to track Ni particle's evolution and find its relation with the electrochemical performance of the cell.

- Initial crystallite size, impurity, particle size, morphology, and surface area of the raw material to develop the electrodes are measured. This helps us to understand the fundamental reasons how choosing different raw materials or changing the processing parameters can change the final microstructure and performance of the cell. This way we can selectively choose the best combination of raw materials to increase the performance and stability of the cell at high temperatures.

- The supports of the cathode is optimized in term of conductivity, porosity, shrinkage and morphology. The proper composition of the functional layer is going to be coated on top of the support based on the results of the initial raw material characterization.



(a) EDS image of Ni-YSZ composite electrode. (b) Distribution of total Ni particles. (c) SEM image of Ni-YSZ composite. White particles are percolated Ni. Marked yellow particles are non-percolated Ni. Gray particles are YSZ. (d) Distribution of percolated Ni particles.

FUTURE DIRECTIONS

- Maximizing the efficiency of SOECs by considering the influence of electrode microstructure on polarization losses and the required heat balance (Joule heat vs. enthalpy requirements).
- Increasing the efficiency of the cell by using novel catalysts in SOEC mode.
- Developing an optimized microstructure to withstand both SOFC and SOEC operation conditions to be used in reversible cells.
- Scaling up an SOEC device to a multiple cell stack.

PARTNERS

Partha Sarkar, InnoTech Alberta
Fabrication of tubular cells by extrusion, design of inner current collector
Miguel Laguna-Bercero, University of Zaragoza, Spain
Development of new electrode materials, high performance tubular SOECs
Olivera Kessler, University of Toronto
Jian Le, Huazhong University of Science and Technology

FES PROJECT OVERVIEW

- Developing an understanding of previously proposed performance degradation mechanisms in both SOFC and particularly SOEC modes.
- Utilization of the novel catalysts and studying their behavior under SOEC mode which is critical for increasing the reaction rate and decreasing the operation temperature.
- Studying the change in microstructure and performance of the cells in long-term SOEC operation condition.
- A stack of multiple cells will be developed to investigate the effect of stacking on performance of SOEC cells.

[1]Department of Chemical & Materials Engineering, University of Alberta
[2]Environment & Carbon Management, Alberta Innovates-Technology Futures

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