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CoorsTek Membrane Sciences

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Development of Tubular Proton Ceramic Electrolysers (PCEs)

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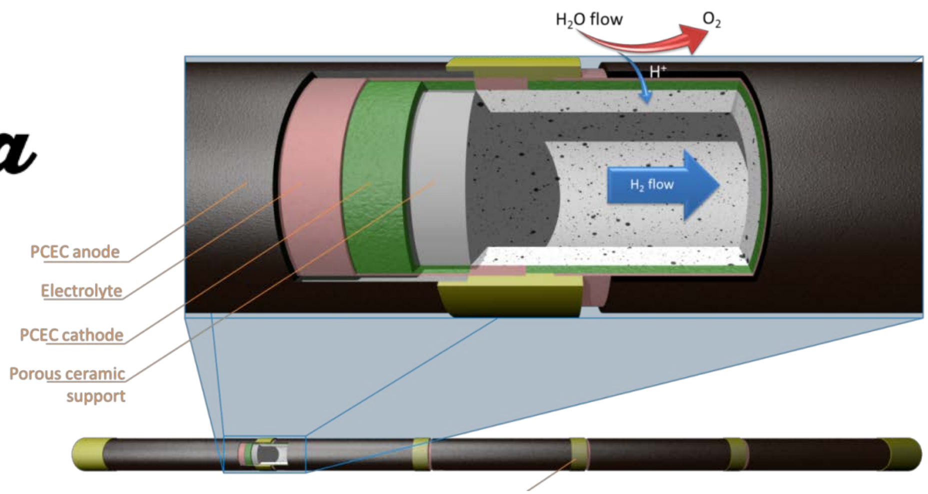
Electra

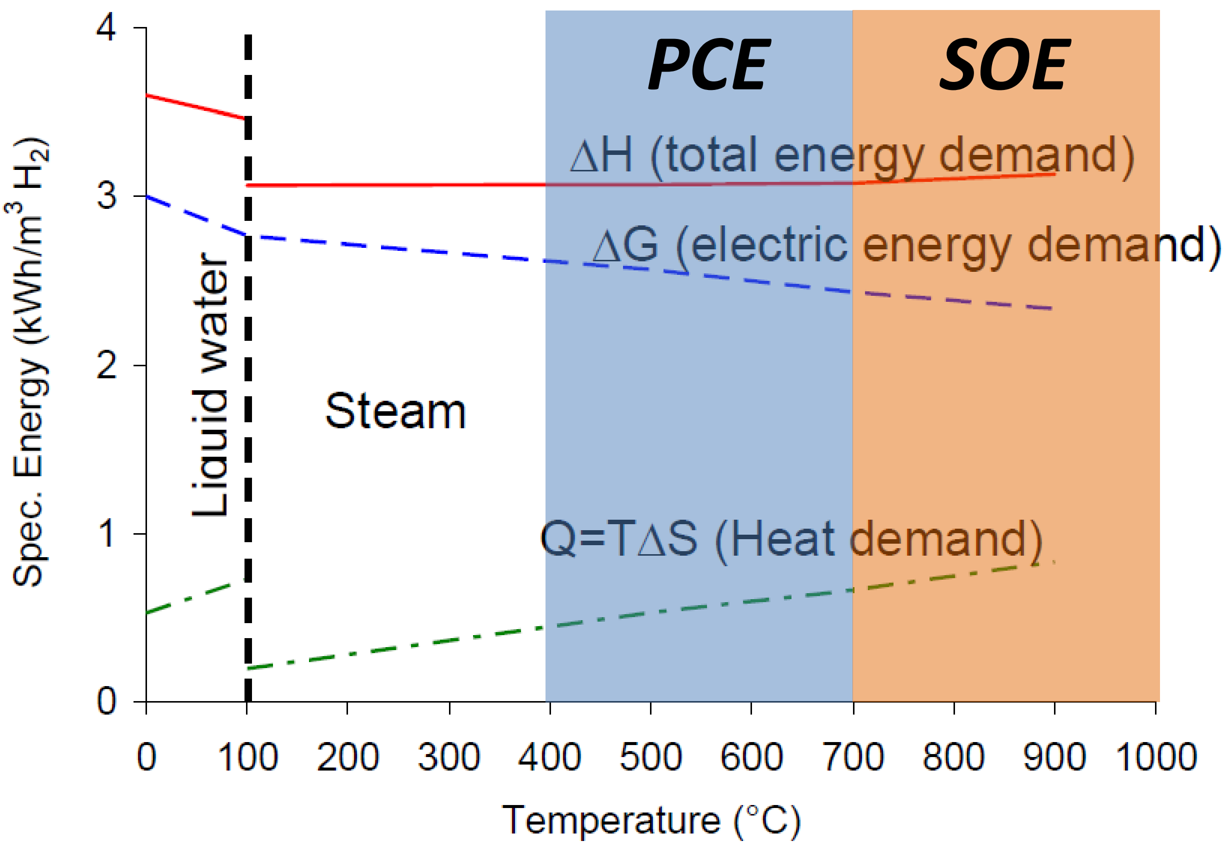
FCH Fuel Cells and Hydrogen Joint Undertaking



- Why PCE?
- Processing & performance
- Up-scaling of tubular PCEs

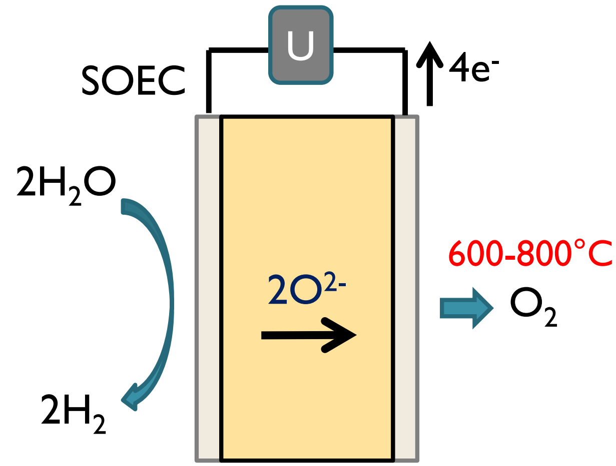
High temperature electrolysis enables utilization of waste heat resources

$$2H_2O \overset{\Delta H}{\Rightarrow} 2H_2 + O_2$$

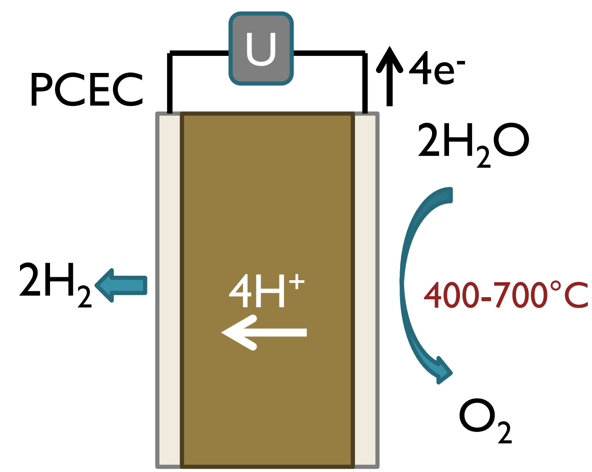


Key differences between SOE and PCE
- advantages and challenges

- Solid Oxide Electrolysers
  - Well proven technology
    - Scalable production
    - High current densities at thermo-neutral voltage
  - Long term stability challenges
    - Delamination of O_2-electrode
    - Oxidation and degradation of Ni-electrode with high steam contents and/or low currents
  - High temperatures



- Proton Ceramic Electrolysers
  - Less mature technology
    - Fabrication and processing challenges
  - Produces dry H_2 directly
  - Potentially intermediate temperatures
    - Slow O_2-electrode kinetics



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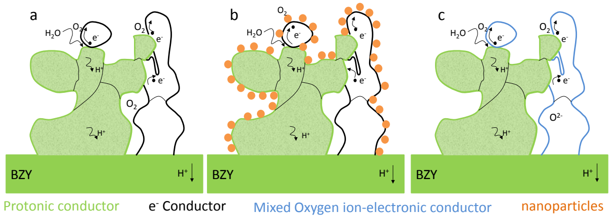
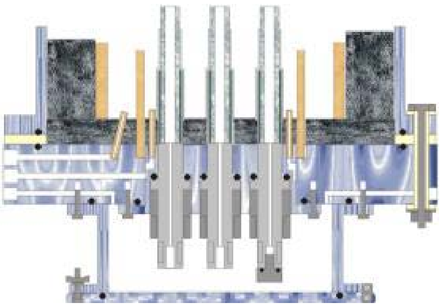
Electra — High temperature electrolyser with novel proton ceramic tubular modules (2014-2017)



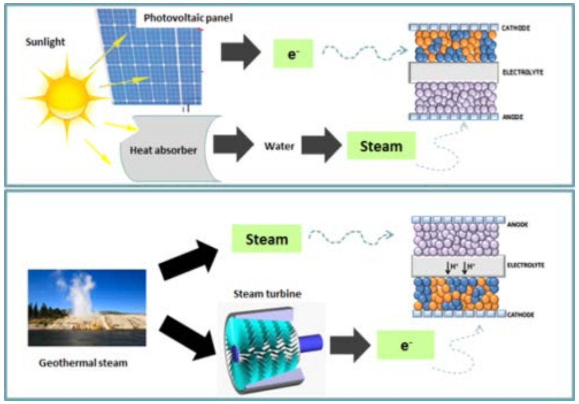
Development of tubular cathode supported electrolyte cell

Development and optimization of anodes and current collection

Single tube module development and testing



Multi-tube module testing
Aim: 1kW demo



Process integration and evaluation

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Tubular half-cell production

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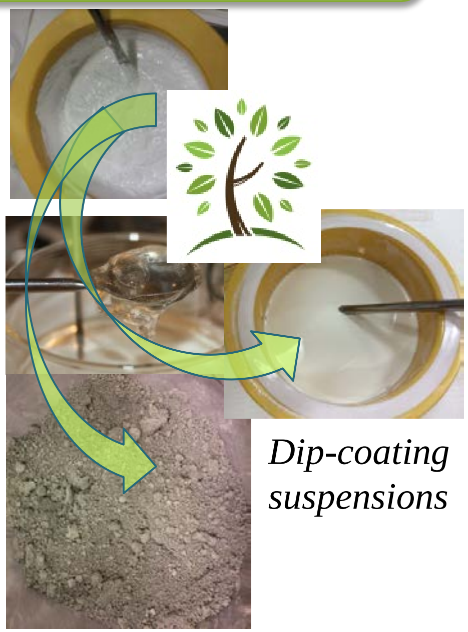
Wet milling of precursors

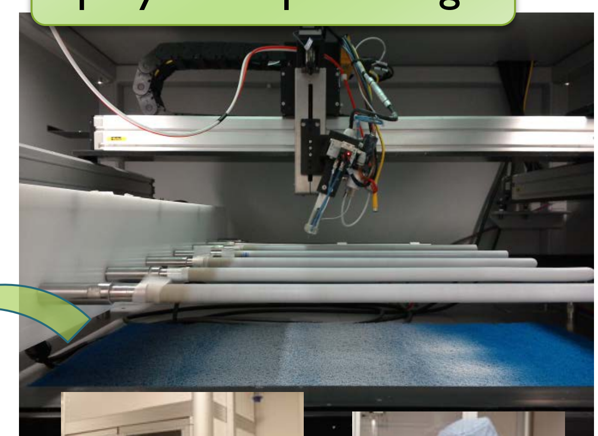


Dip-coating suspensions

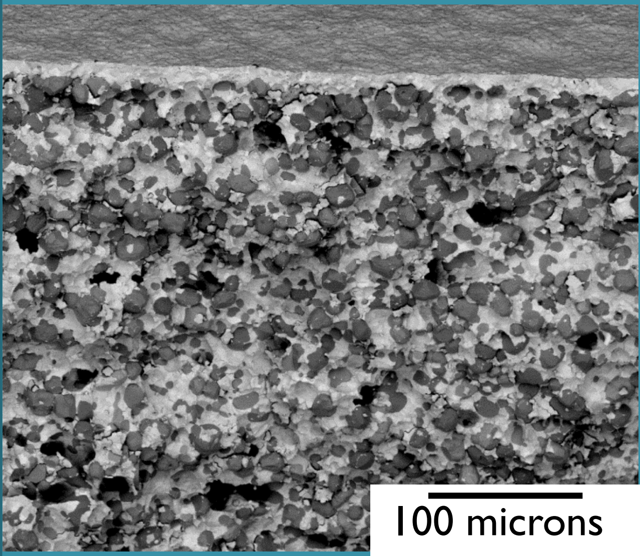
NiO based paste

Extrusion of BZCY-NiO support

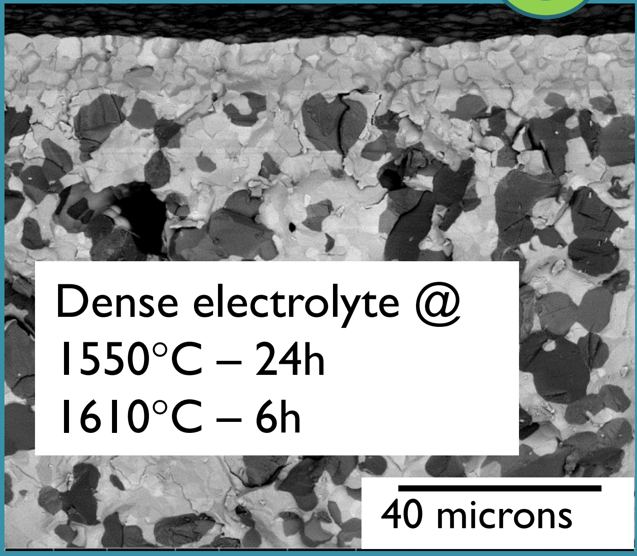
Spray- or dip-coating



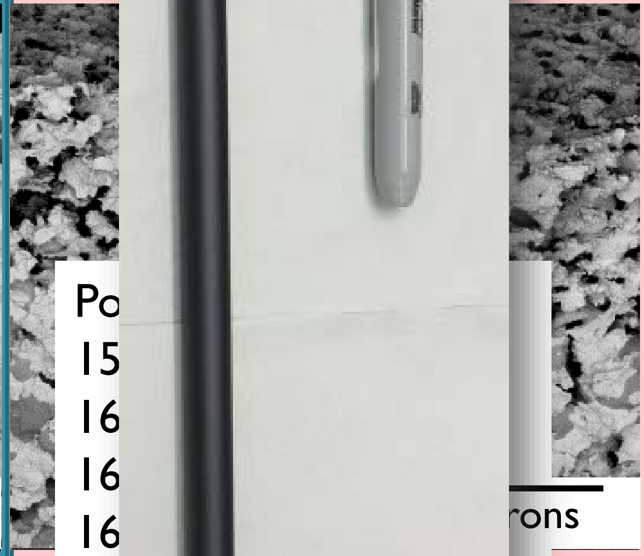
Solid State Reactive Sintering

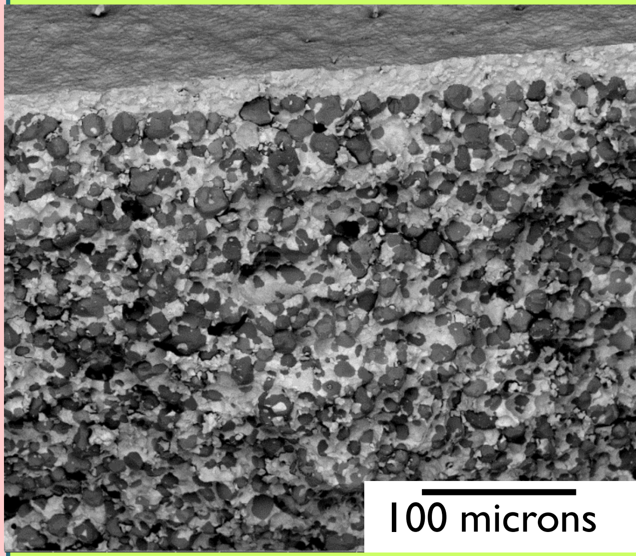


BZCY72 // BZCY72-NiO

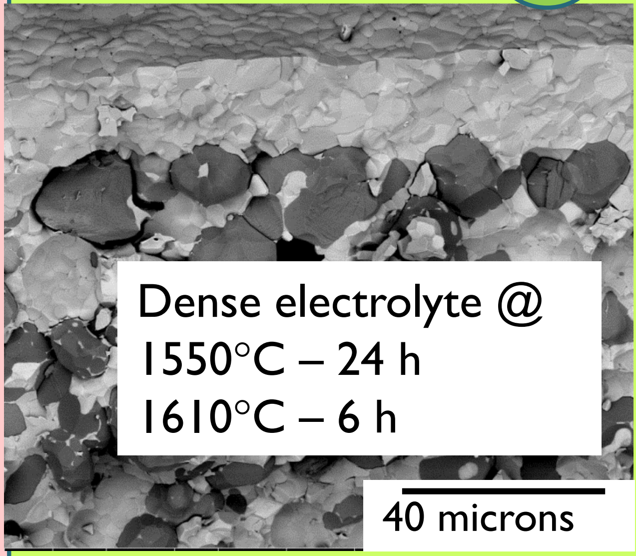


BZY



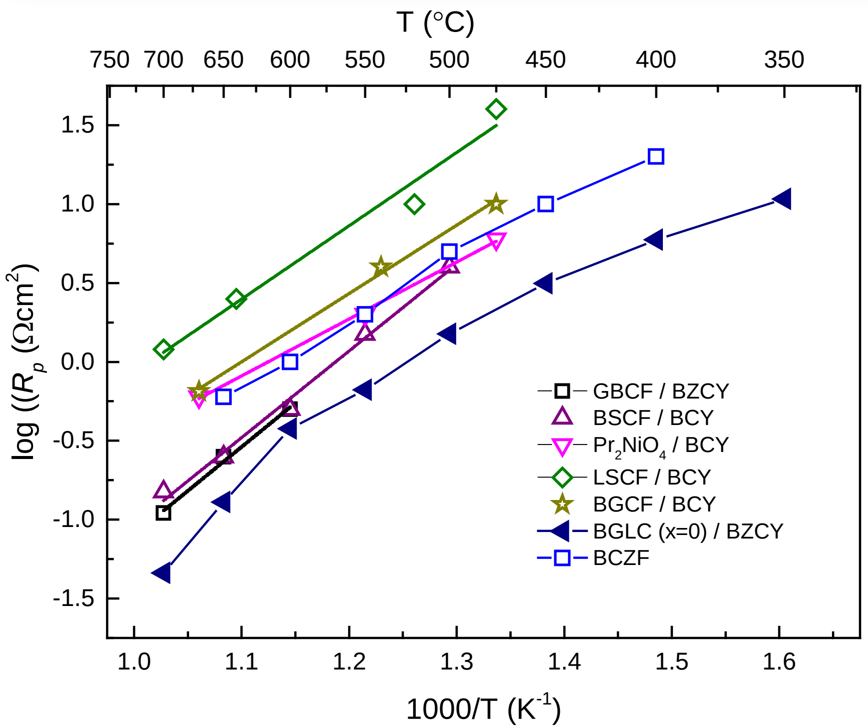


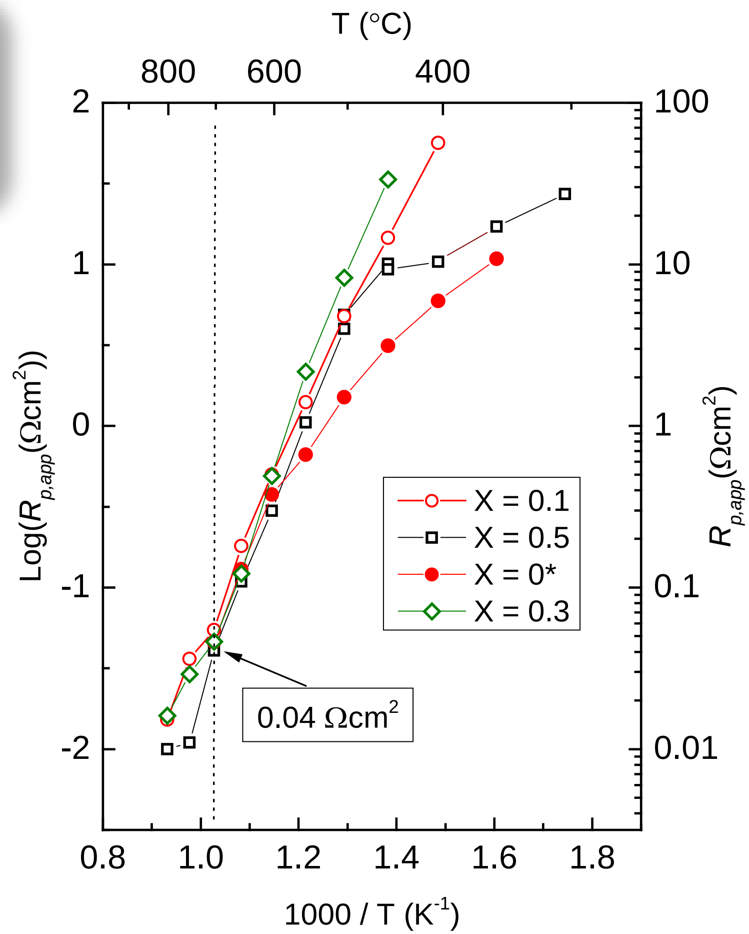
BZY10 // BZCY72-NiO



Development of new anode materials

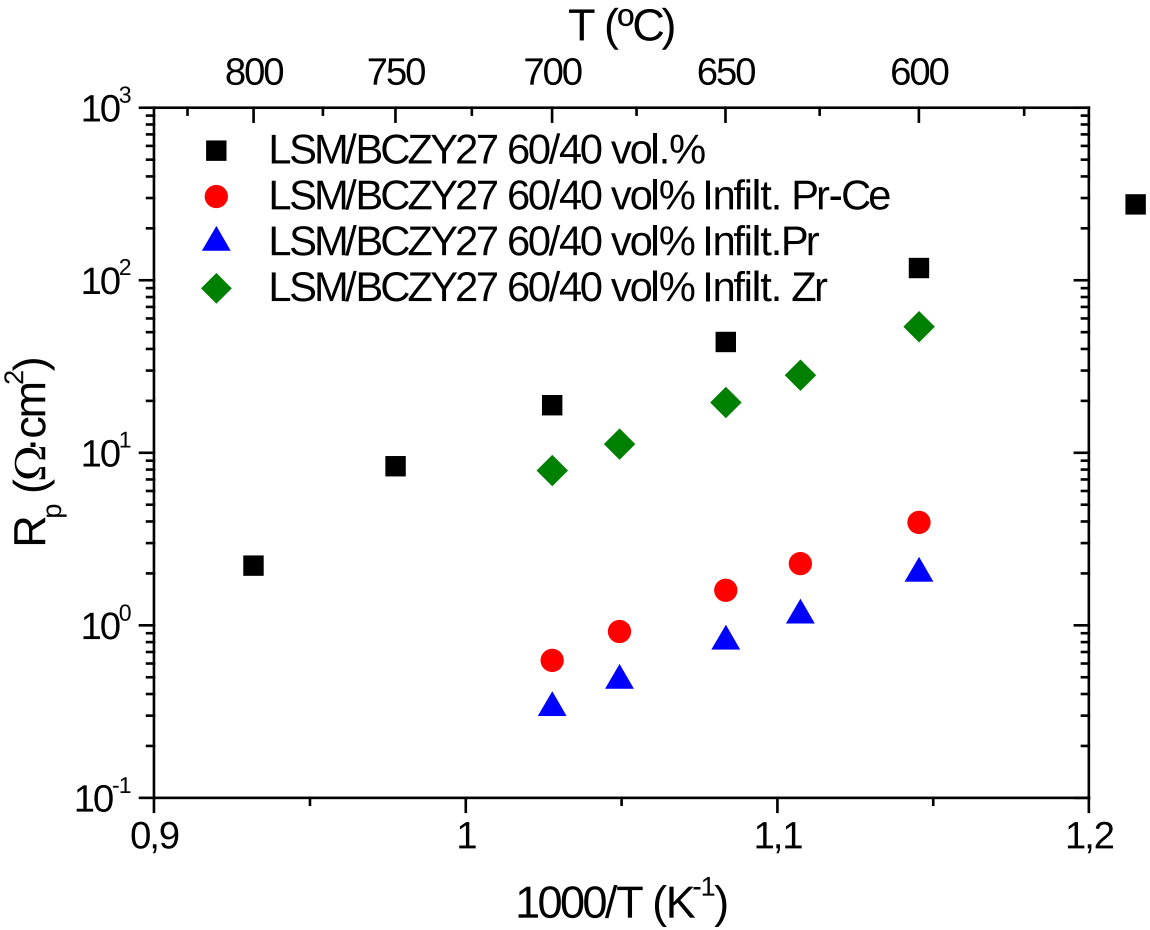
$Ba_{1-x}Gd_{0.8}La_{0.2+x}Co_2O_{6-\delta}$ (BGLC) displays best PCE O_2-H_2O-electrode performance (symmetrical disk samples)





LSM/BZCY composite electrodes

- <u>Symmetrical cell LSM/BCZY 60/40 % vol.:</u>



Conditions:

Total P= 3 bar

Steam 75%

T = 700 °C

Infiltration Pr-Ce

Rp = 0.64 Ω ·cm^2 at 700 °C

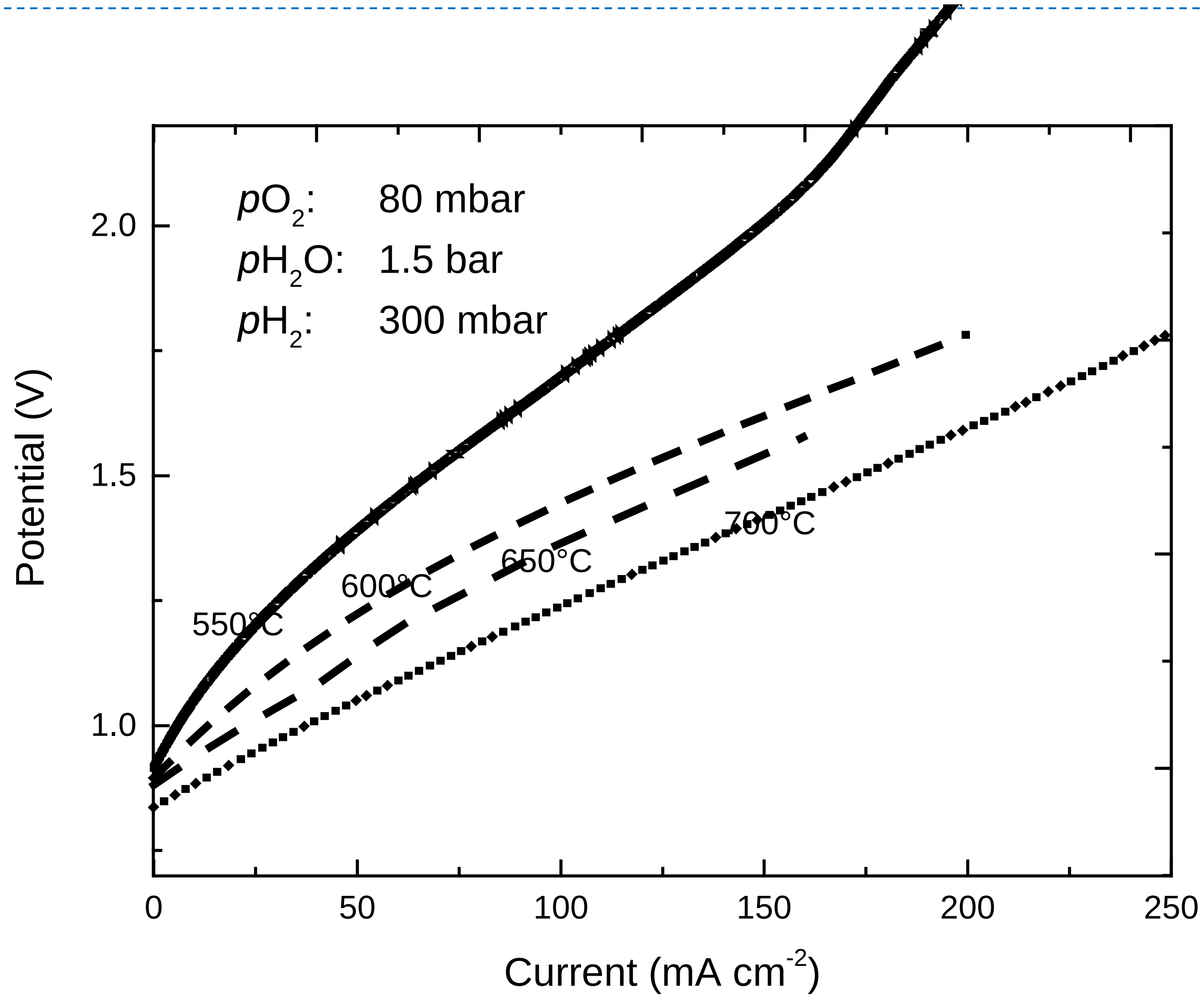
Infiltration Pr

Rp = 0.33 Ω ·cm^2 at 700 °C

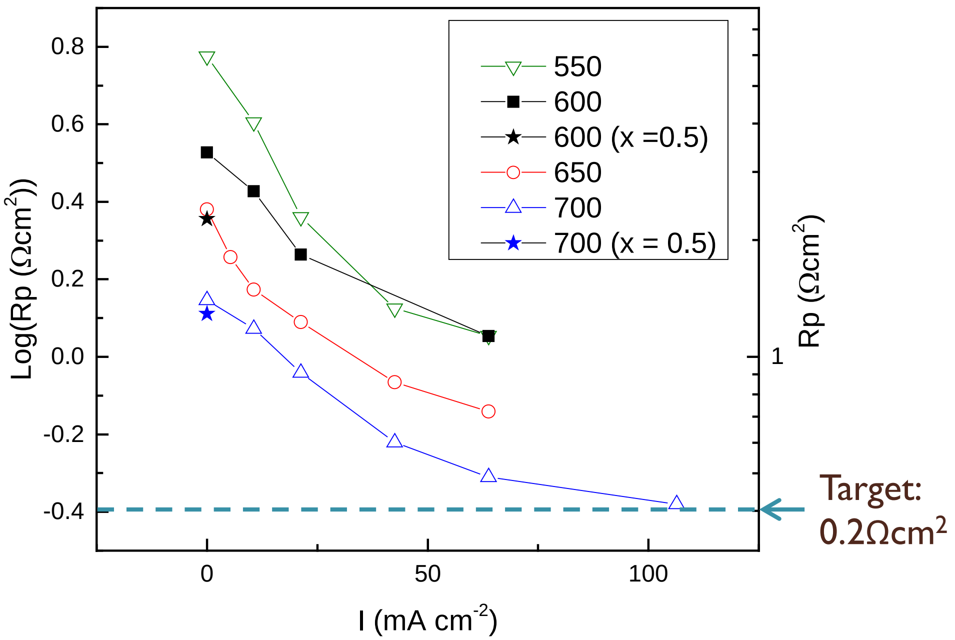
Infiltration Zr

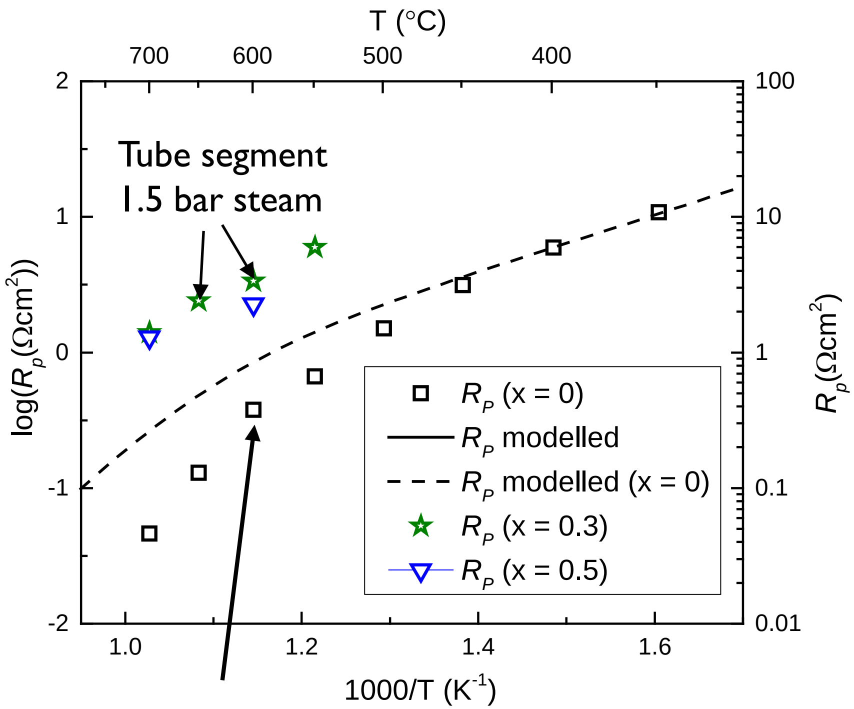
Rp = 7.88 Ω ·cm^2 at 700 °C

Electrolysis tests of single cell



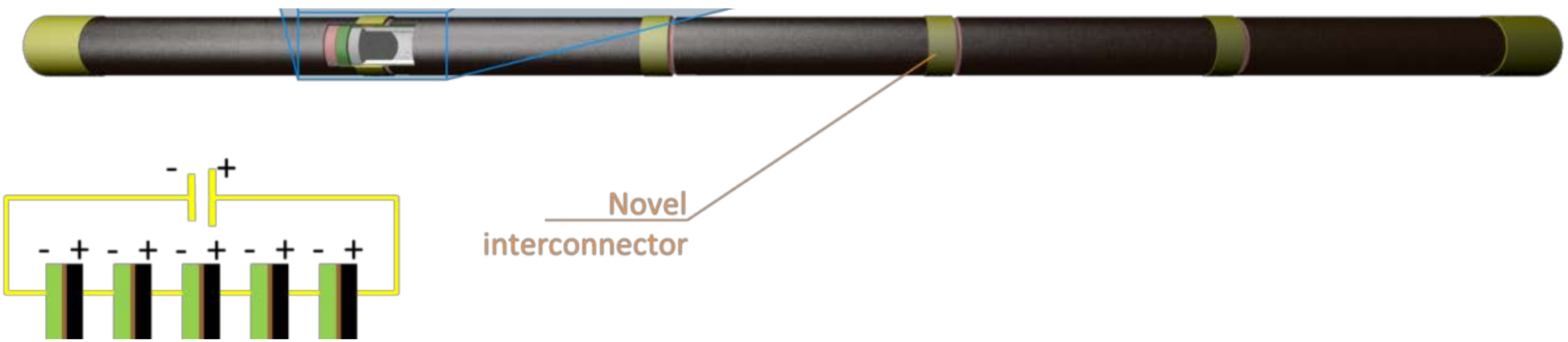
Electrode resistance an order of magnitude higher than expected values from button cell testing



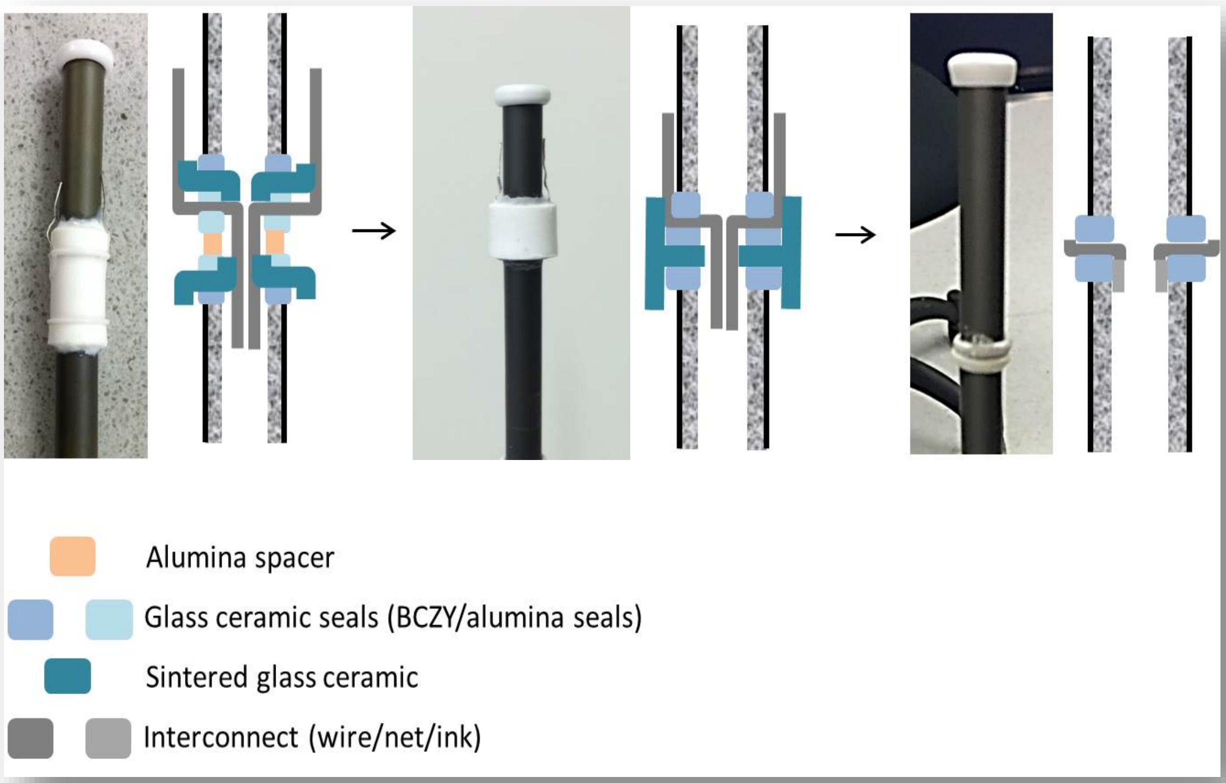


Button cell wet air

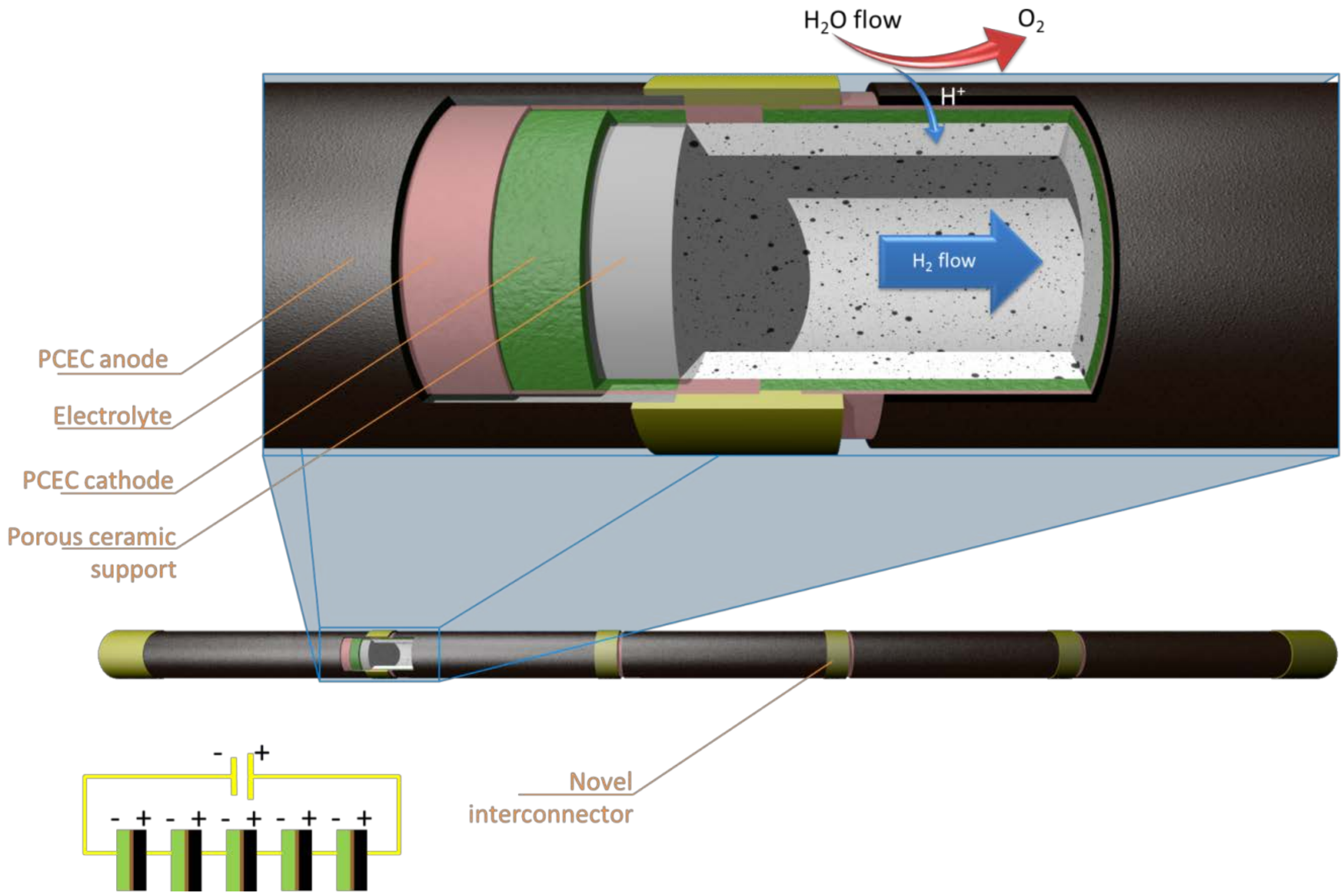
Scaling up – segmented-in-series tubes
Higher tube voltage – lower tube current



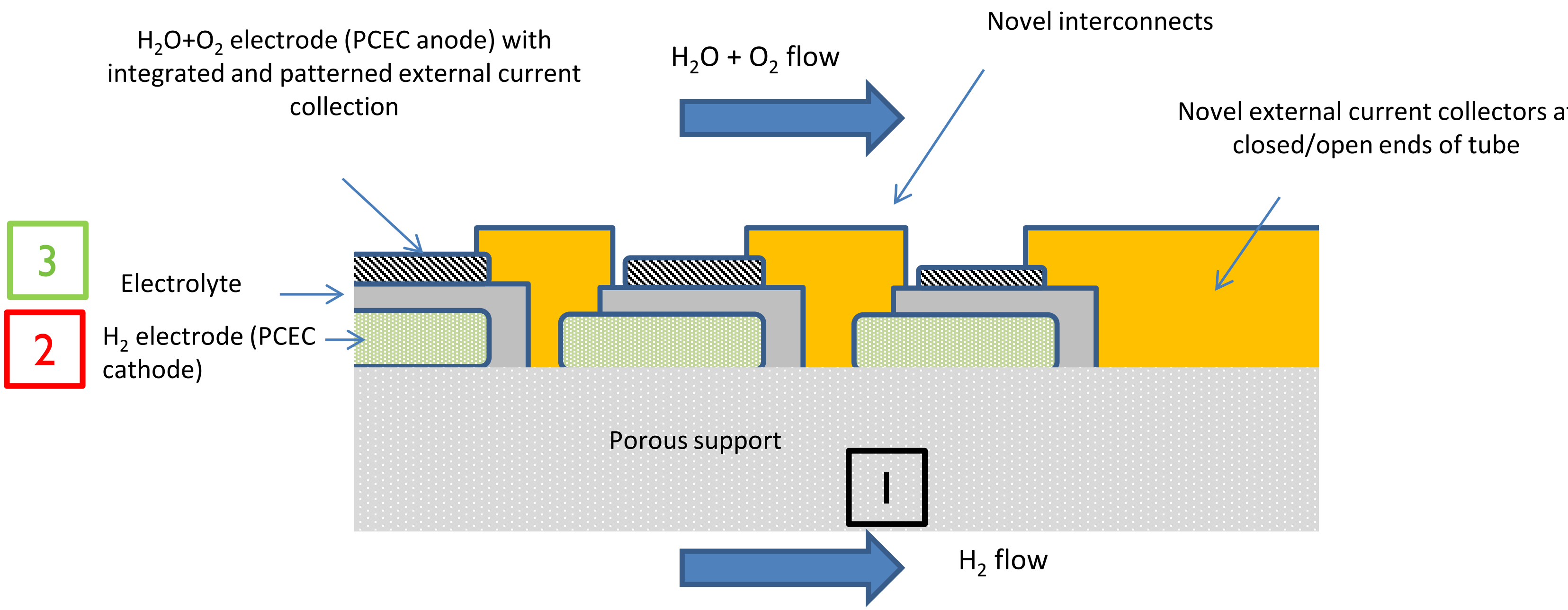
Scaling up – stacking individual segments



Scaling up – "Printing in series"



Segmented-in-series tubular cells



1 – BZCY (SSRS) + sintering aid + pore formers

2 – BZY10 (SSRS or oxide) or BZCY72 (SSRS or oxide) + NiO

3 – BZCY72 or BZY10 (SSRS or oxide)

Manufacturing process

Powder conditioning

- Milling of SSRS precursors and oxide powders
- Drying
- Sieving
- Batching

Pastes preparation

Clean room activities

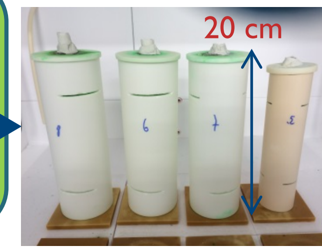
Production of tubes by extrusion and collars

- Drying
- Cutting
- Masking and coating

Dip-coating of tubes

- Drying in air (organic based coating) or at 60°C for water based suspensions

Annealing of tubes (hang-firing)

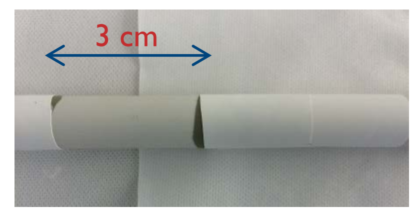


Hang-firing of cells

Slurries preparation

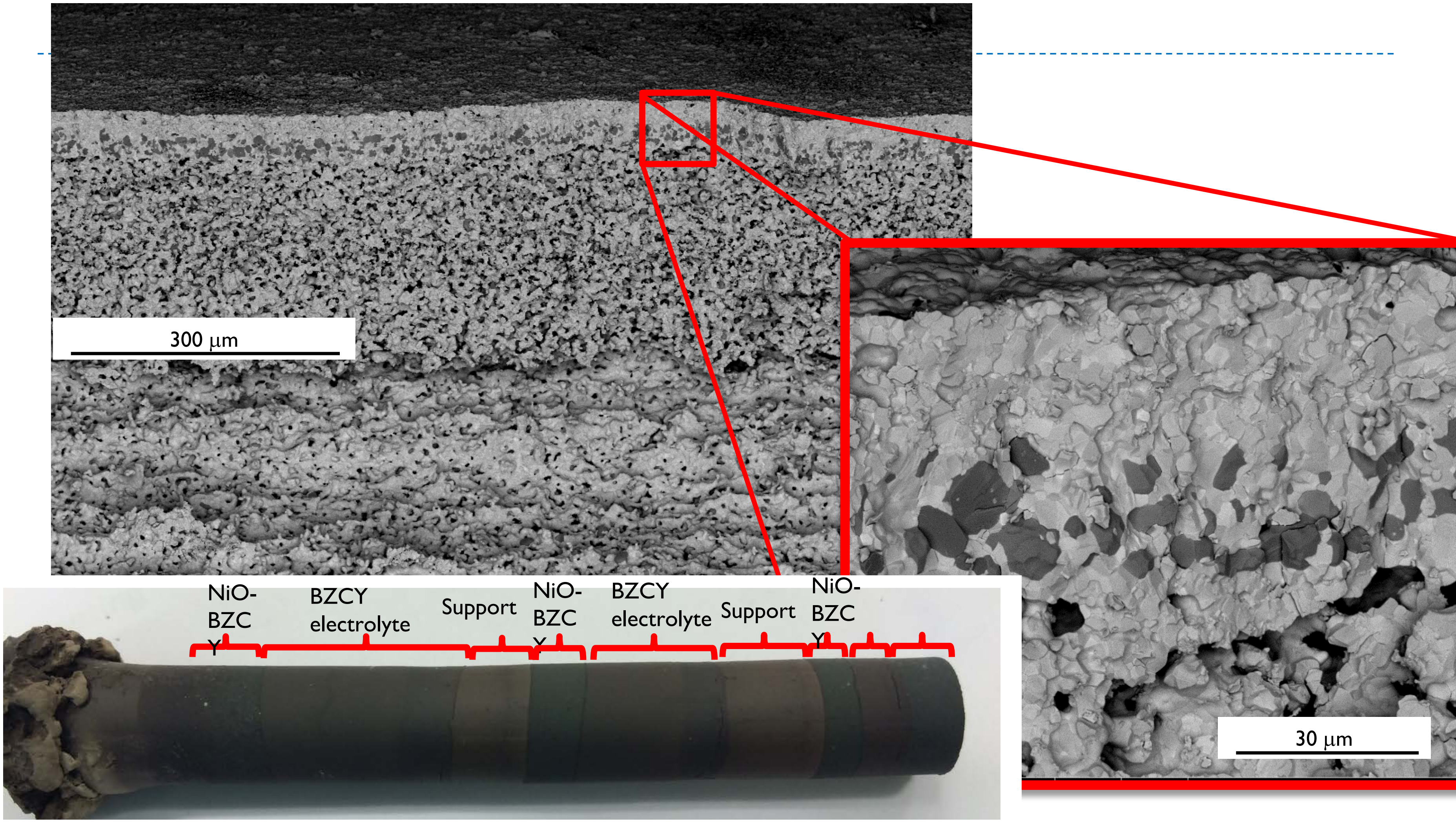
- Water based slurry for SSRS mixtures
- Organic based slurries for oxide mixtures

Green supports with electrodes



Green support coated with cathode (green) and electrolyte (white) layers

Optimized processing parameters for multi-layer sintering



Conclusions

- High temperature proton ceramic electrolysers can produce dry, pressurized hydrogen

- Processing and manufacturing of tubular half cells is now well established

- State-of-the-art electrolyser anodes are developed on button cell scale
  - Deposition and firing protocols for tubular cells currently being developed

- Segmented-in-series tubular cells are needed to reduce total current of tubes in real operational conditions

Acknowledgements

UiO : Universitetet i Oslo

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Carbon Recycling International

Electra

FCH Fuel Cells and Hydrogen Joint Undertaking

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