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The Research Council of Norway

Electra

Technology for a better society

Proton conducting electrolytes integrated in tubular segmented-in-series cells for pressurized hydrogen production

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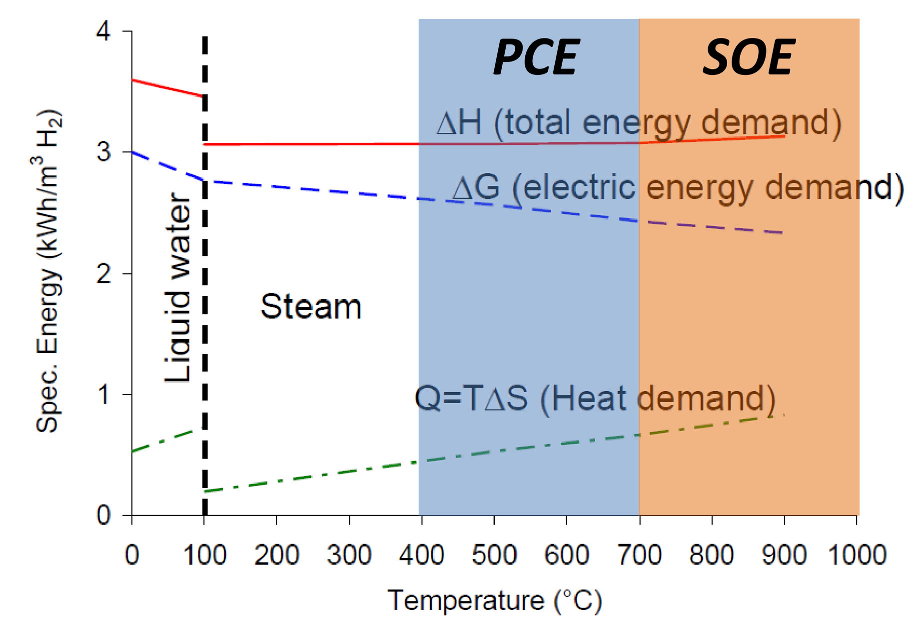
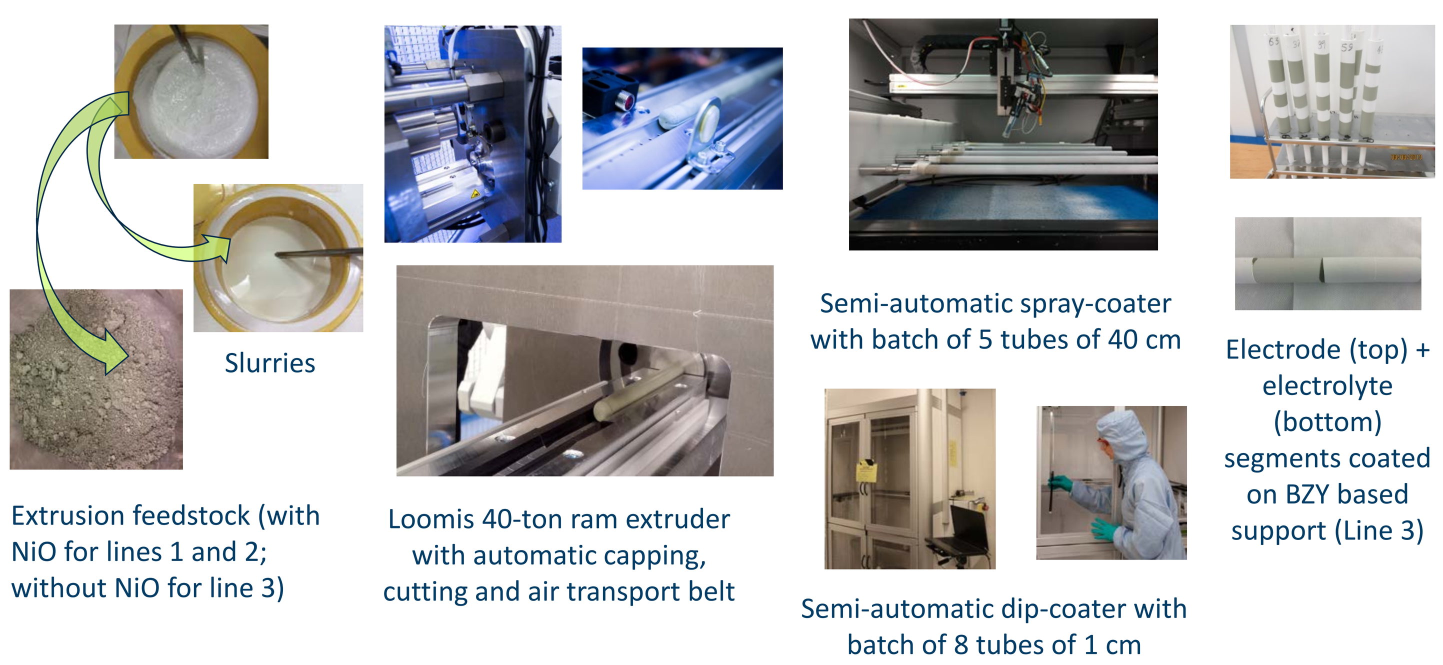
High temperature electrolysis of steam offers high efficiency of conversion of renewable and peak electricity to H_2 and may increase efficiency further by utilising available sources of heat and steam. Solid oxide electrolyser cells (SOE) utilize oxide ion conducting electrolytes, operate around 800 °C and produce hydrogen on the steam feed side. Separation and drying of H_2 costs energy and adds plant complexity and footprint. High temperature proton conducting electrolyte instead pumps protons (H^+) and forms dry H_2, leaving O_2 on the steam side. PCEs thus require less separation process stages and can produce pressurised dry H_2 directly. Protons exhibit lower activation energies than oxide ions, and ceramic proton conductors may thus be able to operate at lower temperatures – 600-800°C – closer to the ideal range for integration with solar and geothermal plants. In ELECTRA scalable fabrication of PCE is pursued along three lines with increasing risks and rewards. All cells consist of a porous Ni-BZCY based cathode for the H_2, a thin dense BZCY-based electrolyte, a porous anode for the H_2O+O_2 side, and a current collector system. Various anode materials were screened for their compatibility with BCZY based electrolyte and stability, including $La_2NiO_{4+\delta}$, LSM, BSCF, $Ba_{1-x}Gd_{0.8}La_{0.2+x}Co_2O_{6-\delta}$ (x = 0-0.5) (BGLC) and LSCF.



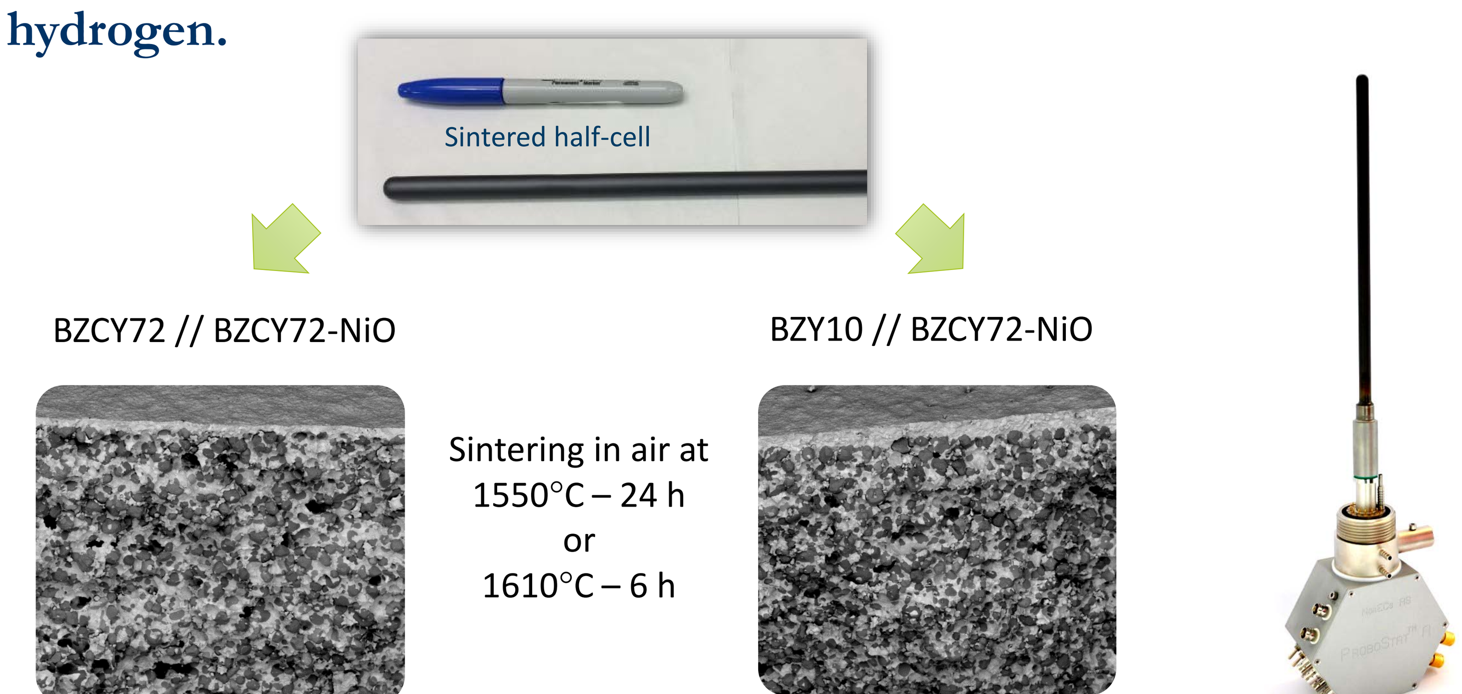
Manufacturing all lines in clean room class 7

Wet milling of SSRS precursors → Extrusion of supports → Spray- or dip-coating of electrode and electrolyte → Solid State Reactive Sintering



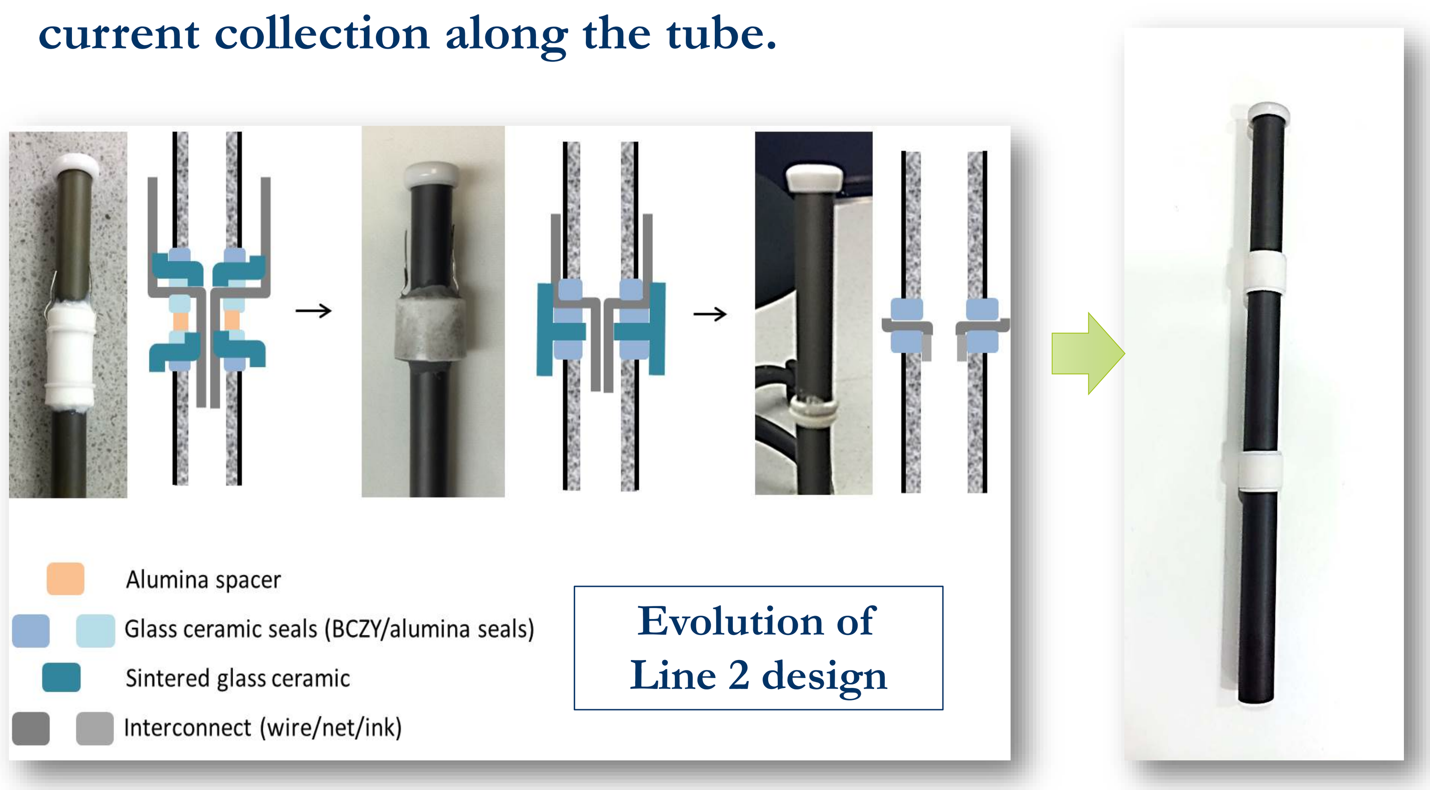
Line 1: Tubular cells

- **Line 1: based on solid state reactive co-sintering of BZY based electrolyte coated on a slip-cast or extruded NiO based composite tube, with subsequent reduction of NiO to Ni in hydrogen.**



Line 2: Segmented-in-series cells by stacking

- **Line 2: based on BZCY tubes, which are cut and stacked in series to build voltage and reduce overall current to improve current collection along the tube.**



Line 3: Segmented-in-series cells by printing

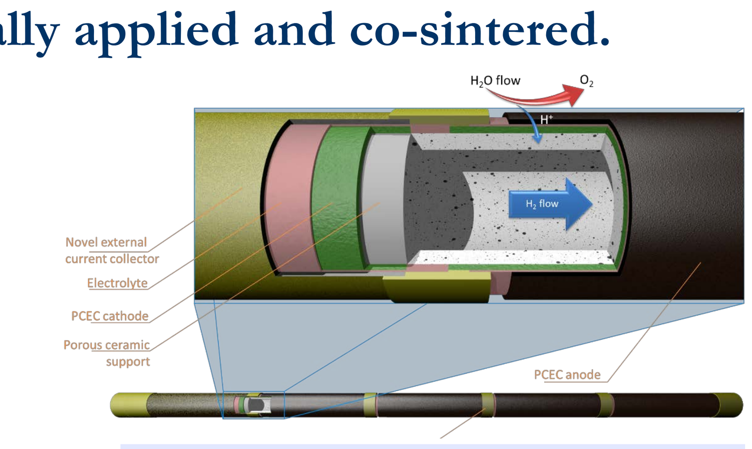
- **Line 3: based on one end-closed porous BZY extruded tube, on which segments of cathode, electrolyte, and interconnect are sequentially applied and co-sintered.**

Investigated materials

Porous supports
- **BZCY72 (SSRS; 20% Ce, 10% Y)) + sintering aid + pore formers**

PCEC cathode
- **BZY10 (SSRS or oxide; 10% Y) + NiO**
- **BZCY72 (SSRS or oxide) + NiO**

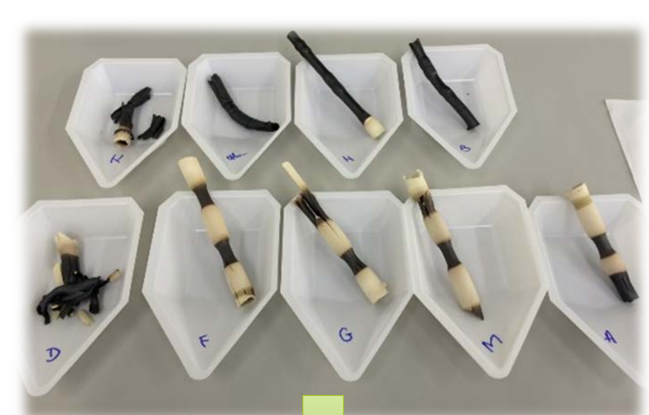
Electrolyte
- **BZCY72 (SSRS or oxide)**
- **BZY10 (SSRS or oxide)**



Novel interconnect materials and PCE anodes are under investigation, and will be applied in a second fabrication step.

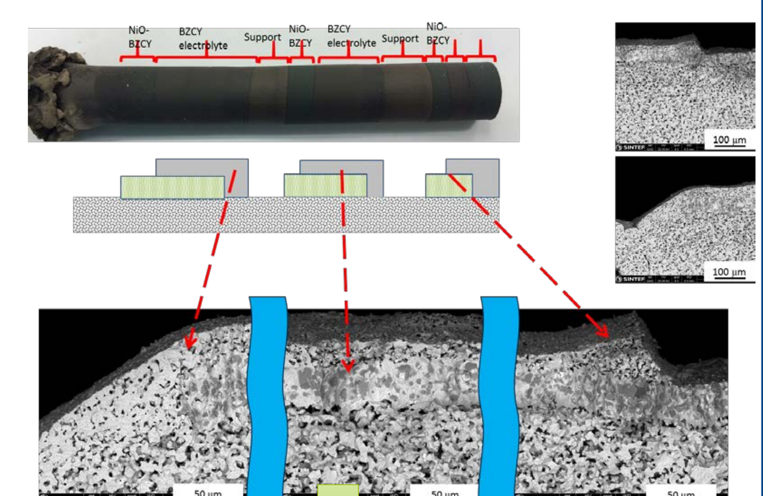
Examples of critical challenges during manufacturing

- ***Differential sintering shrinkage between "coated" and "un-coated segments"***



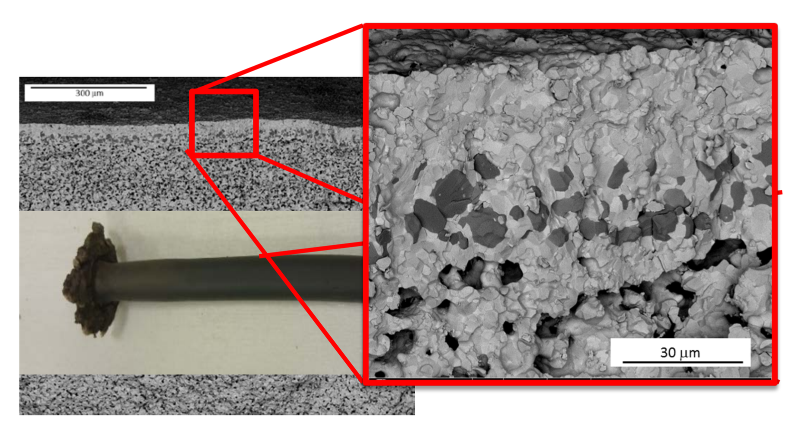
Use of both pore former and sintering aid to adjust sintering shrinkage

- ***Tailoring microstructure of the three layers***



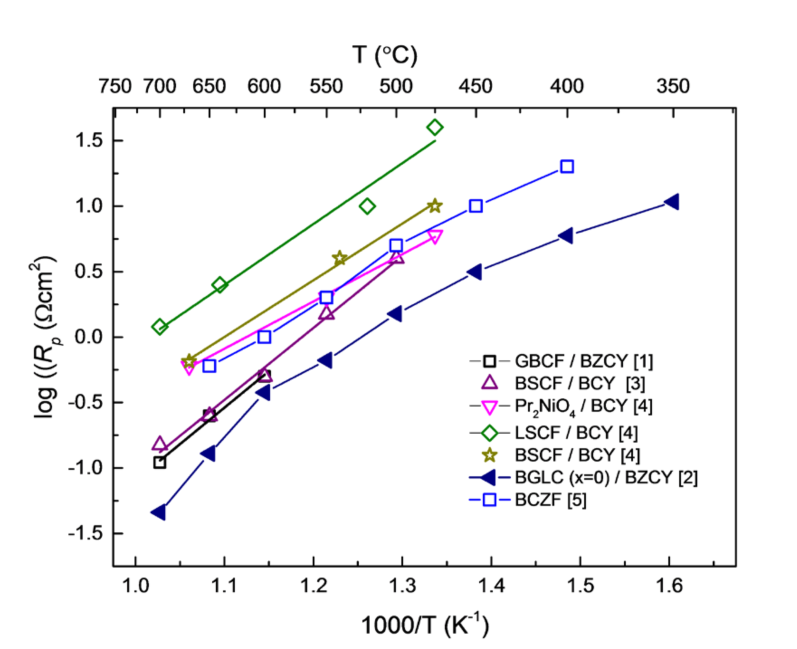
Annealing parameters were adjusted

Segmented-in-series half-cells produced after adjustment of parameters



- ✓ **Dense electrolyte**
- ✓ **Dense NiO-BZCY (porosity will be generated by NiO reduction to Ni)**
- ✓ **Porous BZCY support**

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



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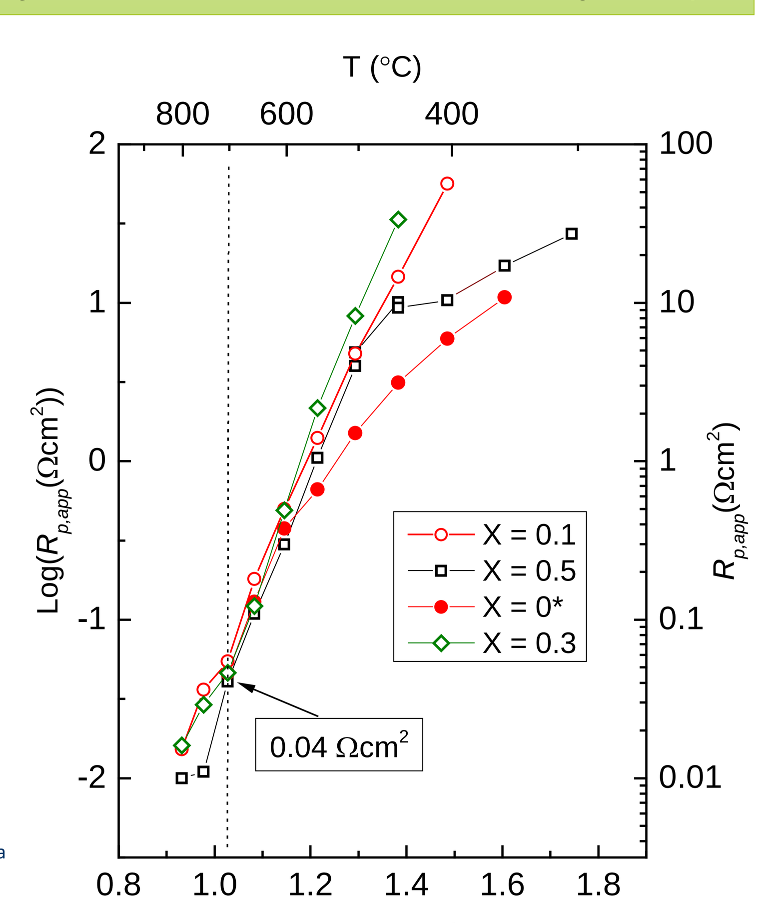

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