On the development of electrodes for tubular proton ceramic electrolysers for pressurized hydrogen production

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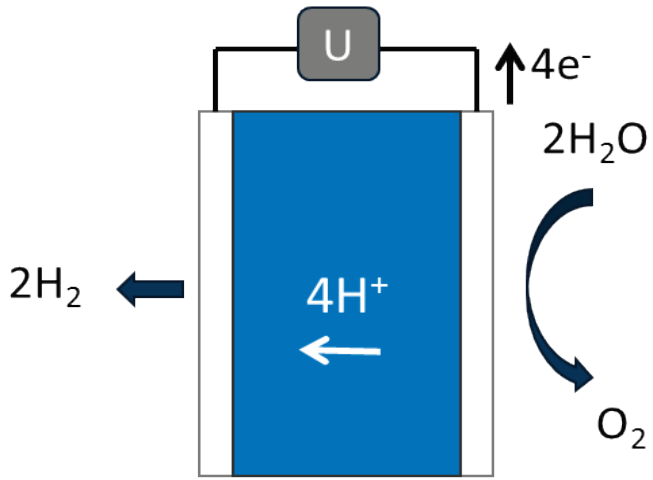
For more information:
SINTEF AS as coordinator
https://www.sintef.no/projectweb/gamer/

GAMER: Game changer in high temperature steam electrolysers

GOAL: Demonstrate high temperature steam electrolysis using proton ceramic electrolysis cell:

- 10 kW system with BoP for thermal integration
- 30 bars dry hydrogen
- 600 °C



ceramic based electrolyte

Partners	Country
SINTEF (coordinator)	Norway
Carbon Recycling International	Iceland
CSIC-ITQ	Spain
Coorstek Membrane Science AS	Norway
University of Oslo	Norway
MC2 Ingenieria y Sistemas SL	Spain
Shell Global Solutions International BV	Netherlands

<u>Advisors:</u> YARA and Air Liquide

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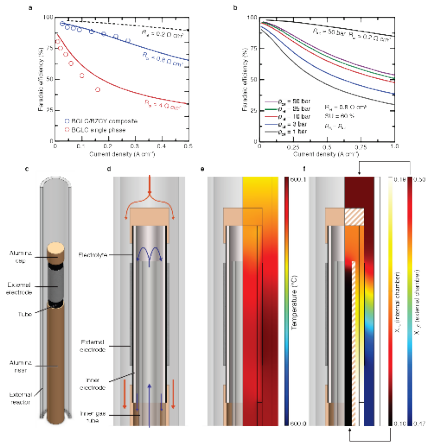
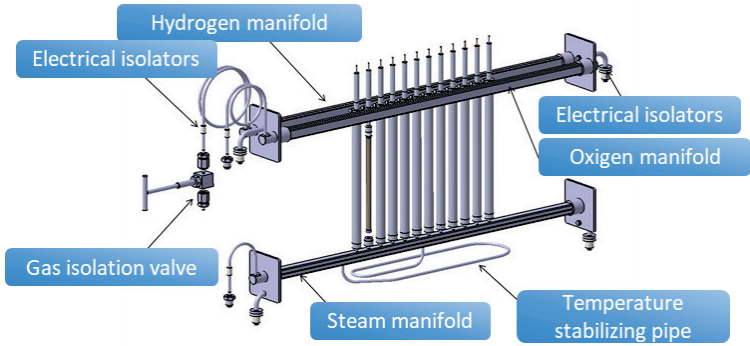
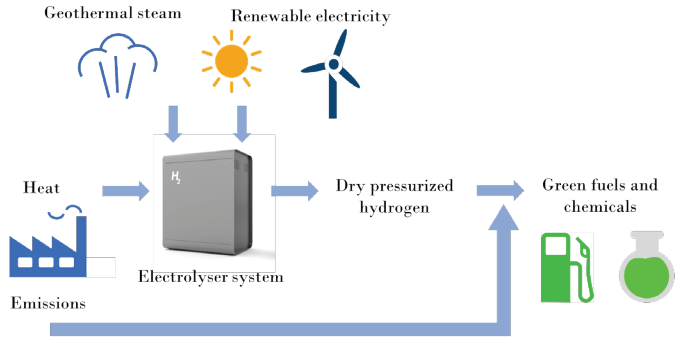
GAMER: 2018-2020



OPTIMISATION OF MATERIALS and CELL DESIGN
(including sealants, manifolds)



INDUSTRIAL PRODUCTION OF CELLS



DESIGN, ENGINEERING, TESTING OF 10 kW SYSTEM

THERMAL INTEGRATION OF ELECTROLYSER IN VARIOUS INDUSTRIAL PLANTS (efficiency, techno economics, LCA)

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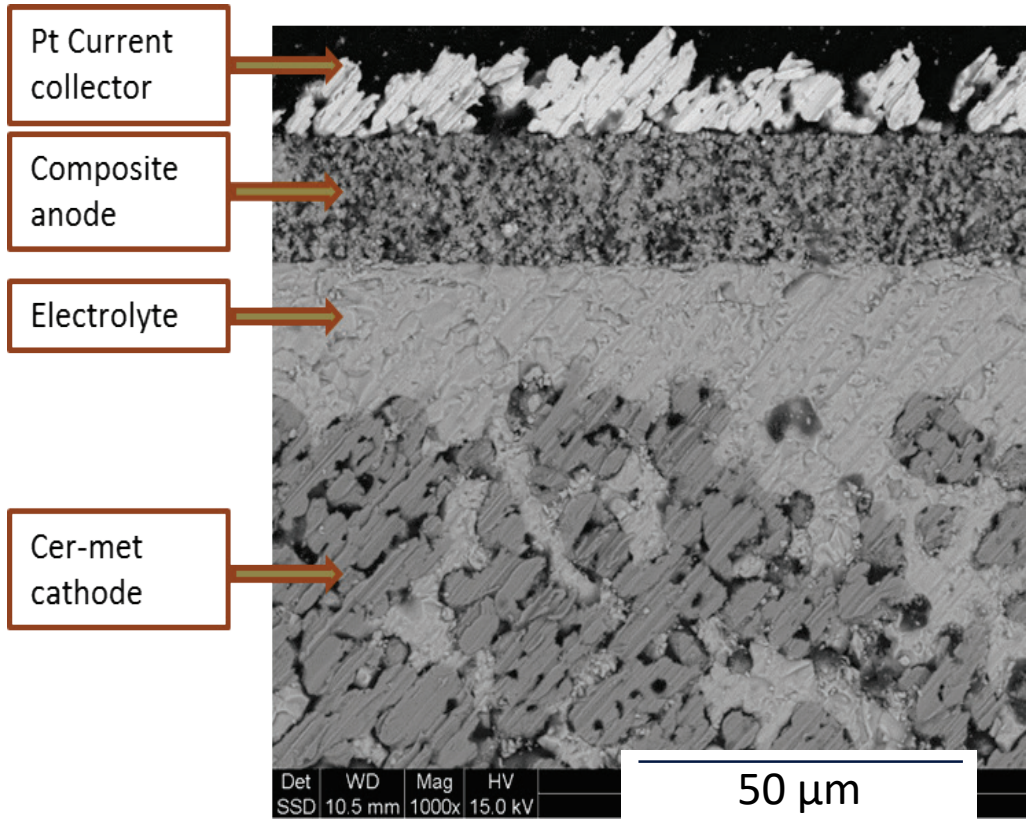
Tubular proton ceramic cells



Electra

10 cm^2

65 cm^2

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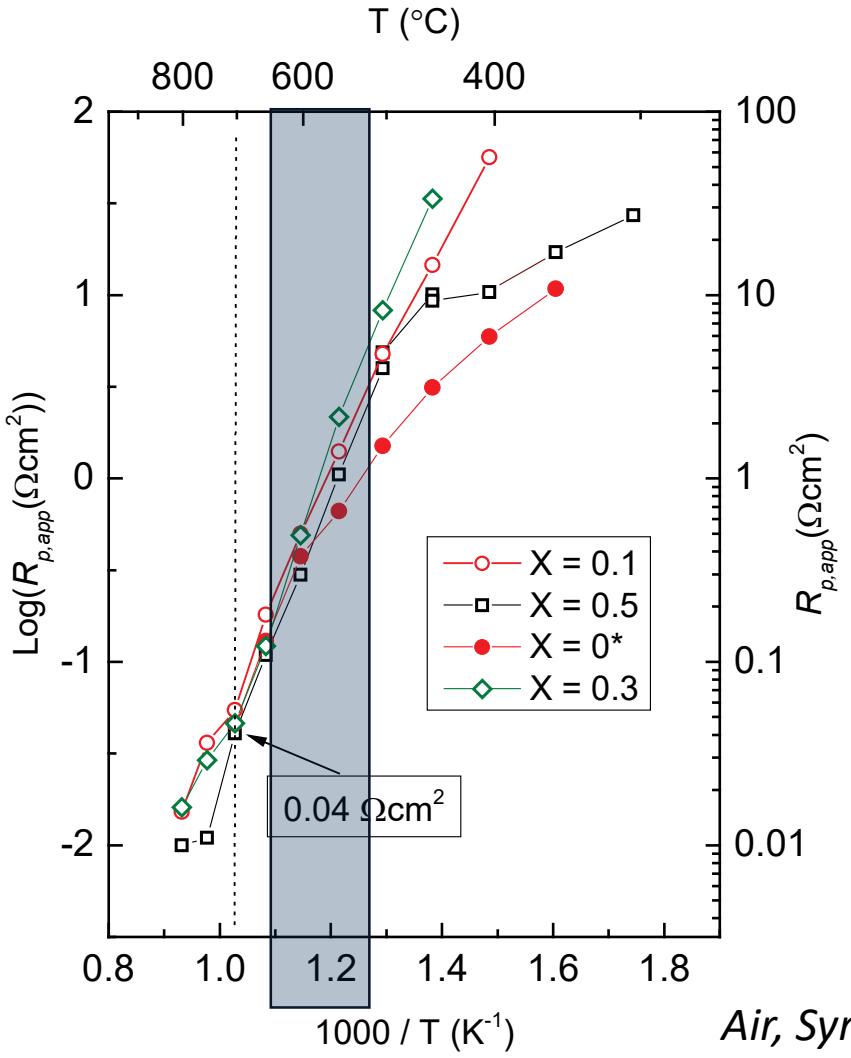
Electrolytes and electrodes

$BaZr_{1-x-y}Ce_xY_yO_{3-\delta}$

- 10-20% Y ; 10-20% Ce

$Ba_{1-x}Gd_{1-y}La_{x+y}Co_2O_{6-\delta}$

- Double Perovskite
- Mixed proton - hole conduction
- X = 0.5 $Ba_{0.5}Gd_{0.8}La_{0.7}Co_2O_{6-\delta}$



Air, Symmetrical cell

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Stability tests

INSTITUTO DE TECNOLOGÍA QUÍMICA

Conditions:

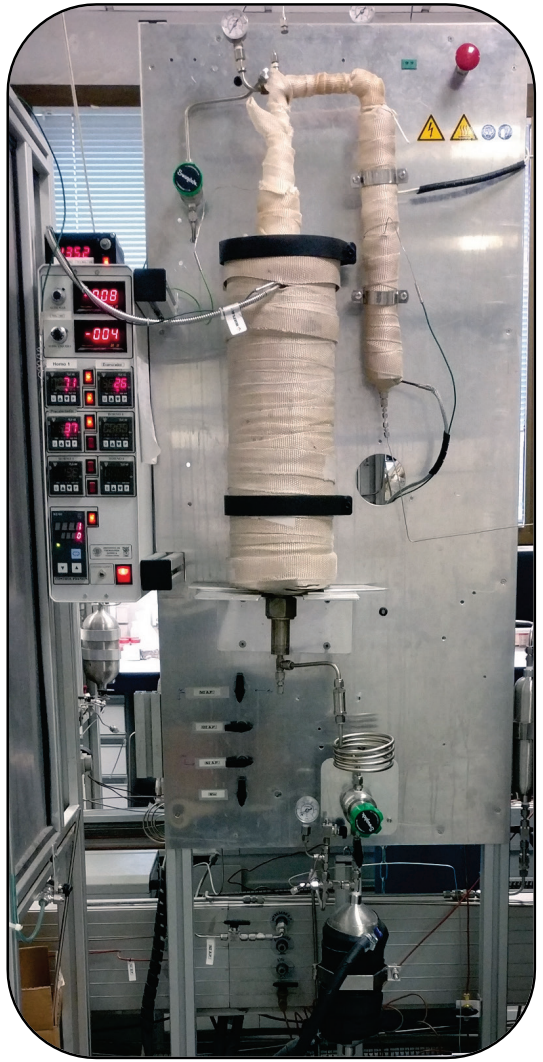
- Temperature = 600°C for 100°C
- Pressure = 29 bar (75% steam + 25% oxygen)

Samples

- BGLC
- BCZY
- Other cell components

Post characterisation

- XRD, SEM-EDS
- Conductivity, etc.



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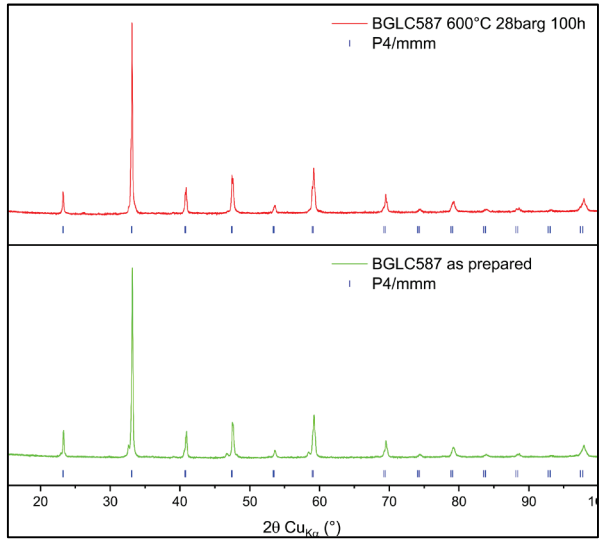
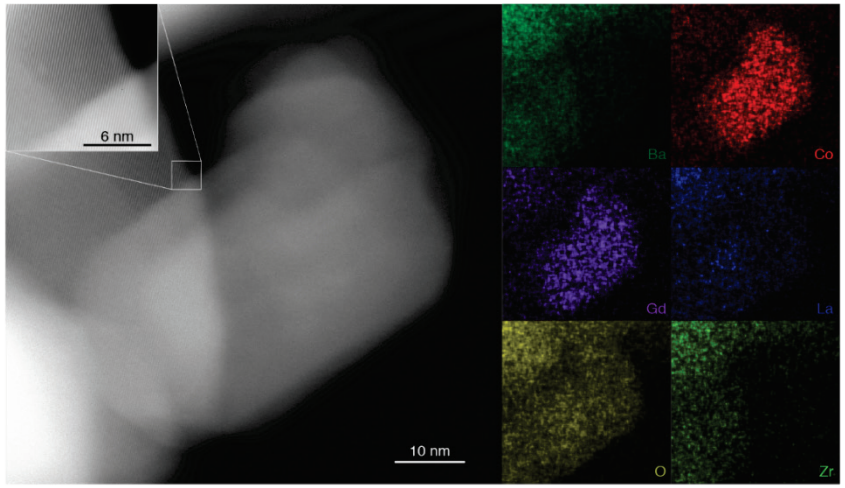
Results

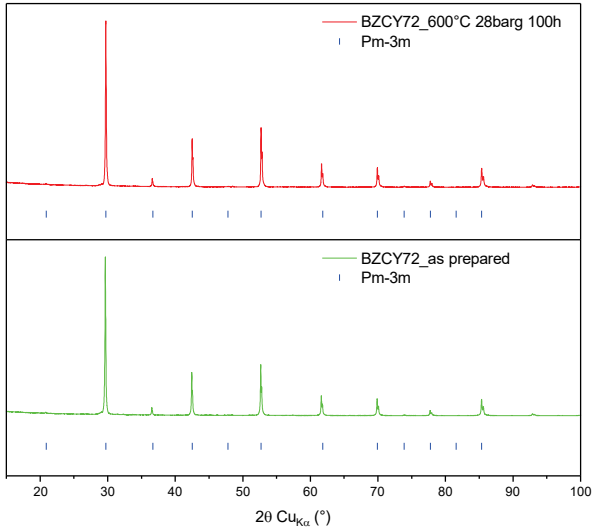
BGLC





"*Mixed proton and electron conducting double perovskite anodes for stable and efficient tubular proton ceramic electrolysers*" , Nature Materials (2019);

BCZY



As prepared:
a=b=c=4.25119 Å
α=β=γ=90°

After treatment:
a=b=c=4.25327Å
α=β=γ=90°

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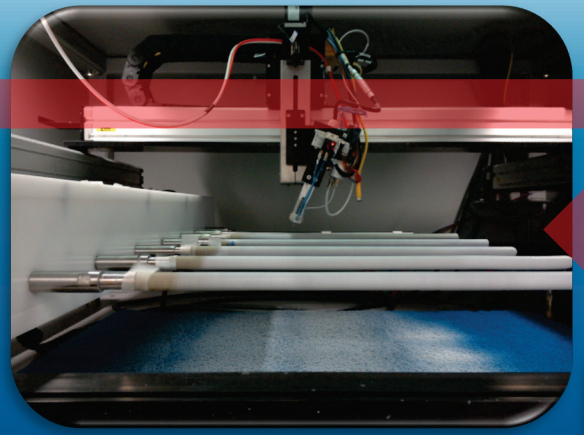
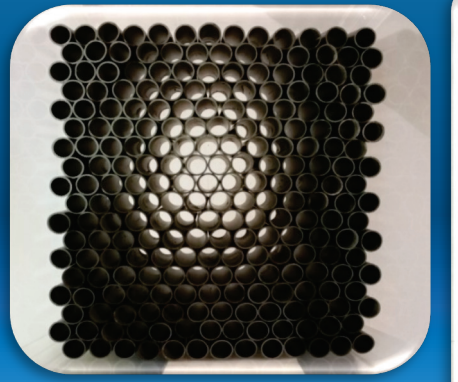
Manufacturing: pilot scale production

1. Extrusion with 40 ton automatic extruder (capping/cutting)

2. Spray-coating with automatic spray-coater

3. Co-sintering of electrode/electrolyte

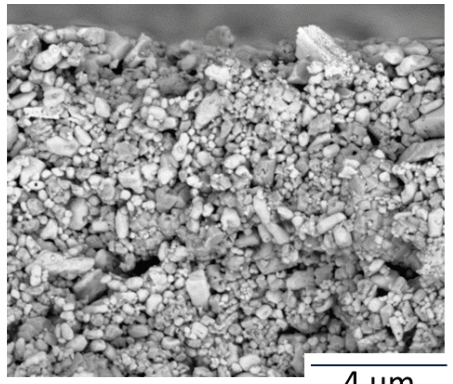




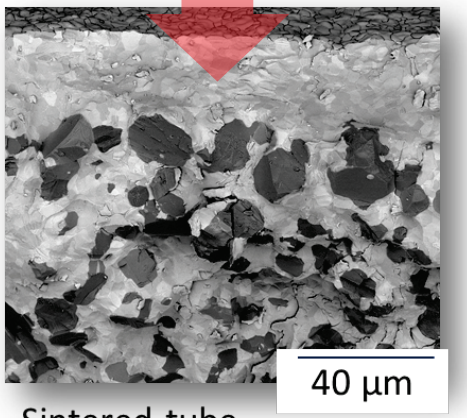
SINTEF

CoorsTek MEMBRANE SCIENCES

100 m² clean room class 7



Precursors mixture



Sintered tube

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Electrode architectures

BGLC

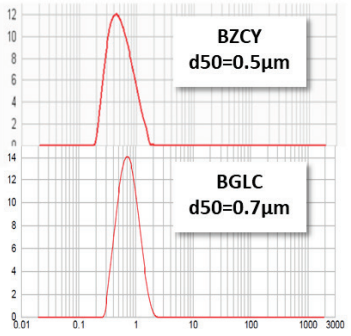
Suspension BGLC powder

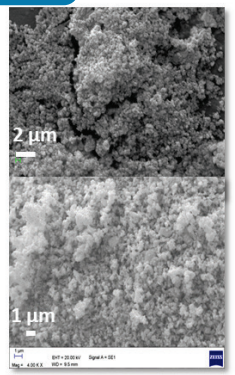
BGLC + BZCY (1 step)

Suspension BGLC + BZCY powder

Coating

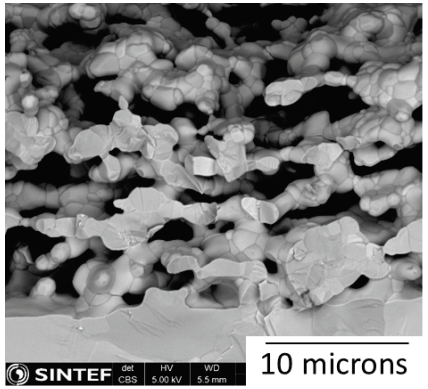
Annealing





BGLC + BZCY (2 steps): infiltrated backbones

BZCY Backbones



BGLC infitration

Suspension preparation ($BaSO_4$, ZrO_2, Y_2O_3, CeO_2)

Dip-coating

Sintering

"Infiltration" step

Annealing

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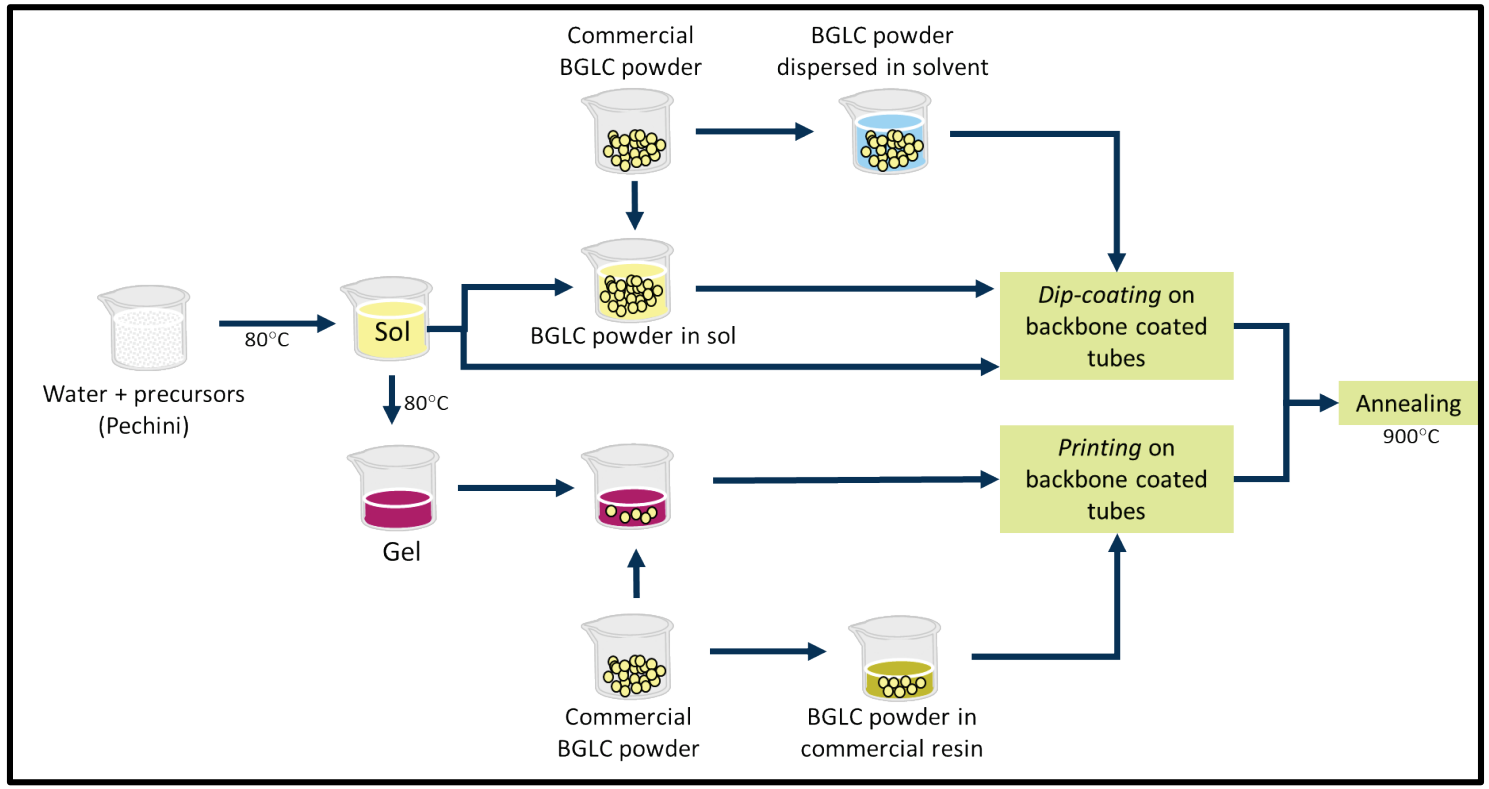
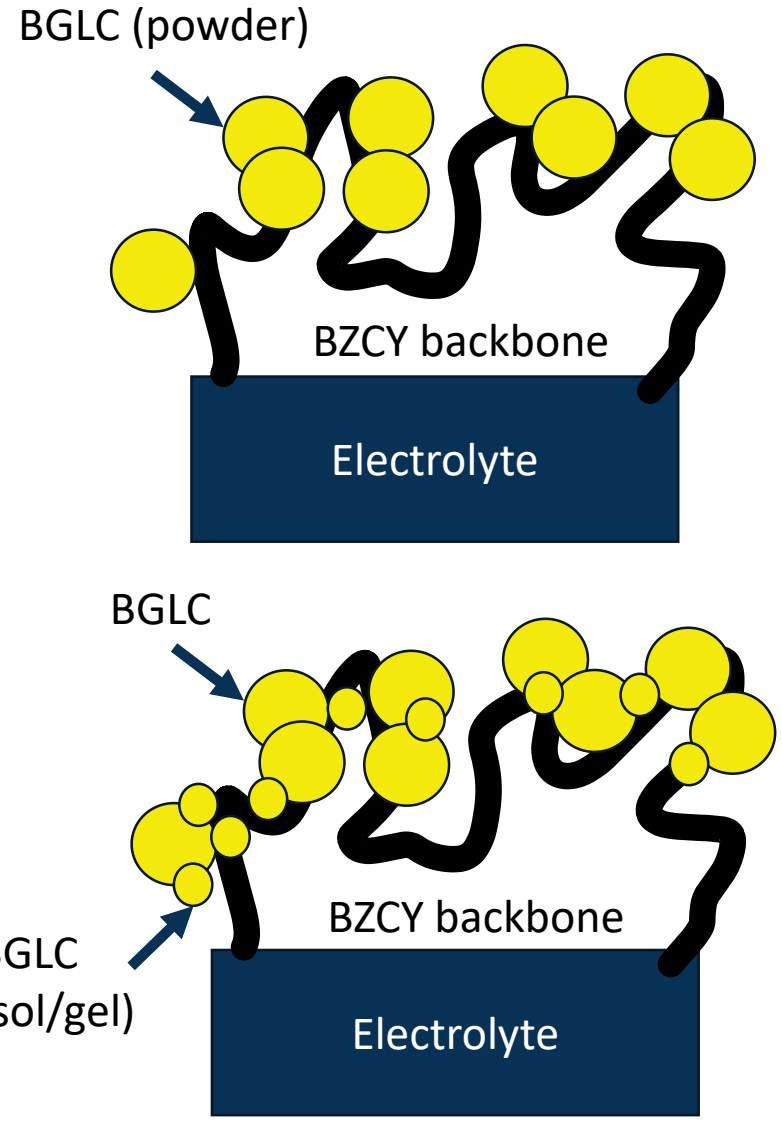
Infiltration in backbones





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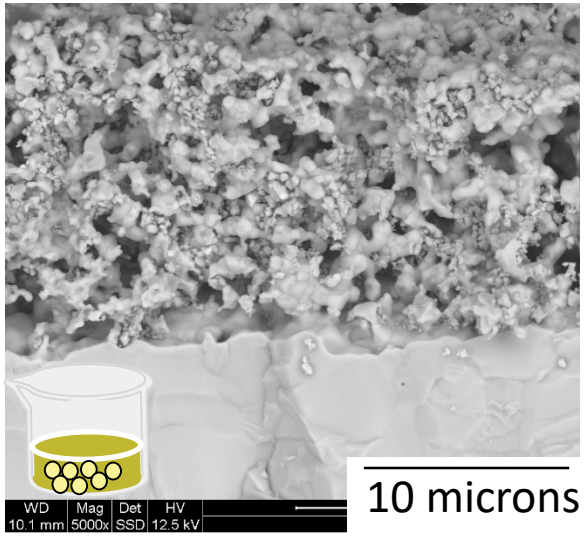
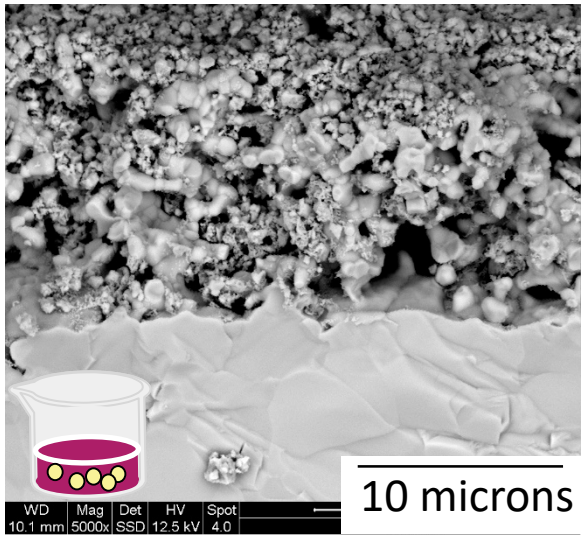
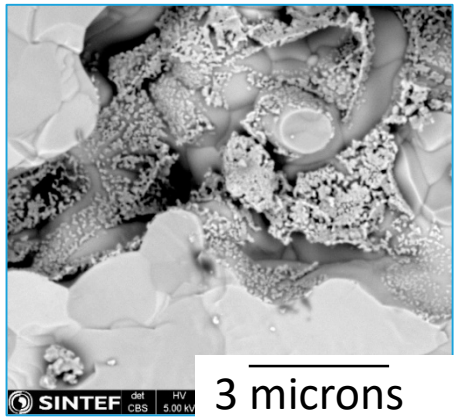
Microstructure

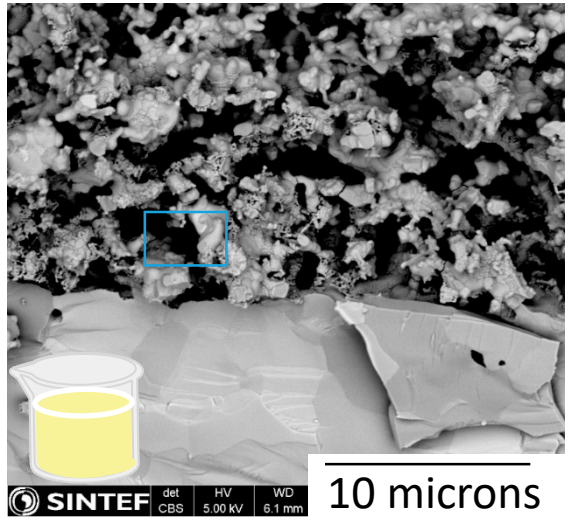


BGLC powder in commercial resin

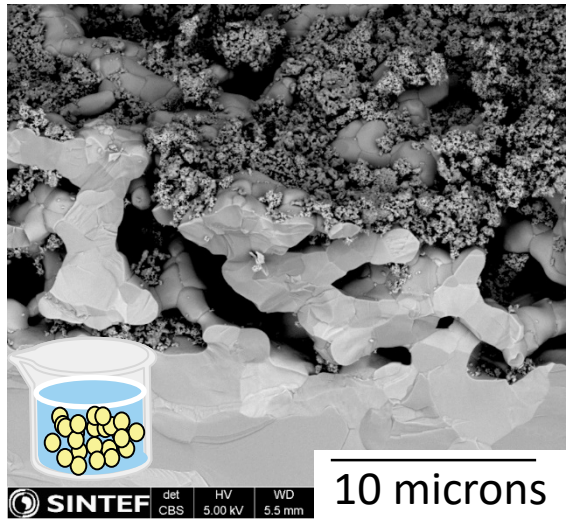


BGLC powder in gel

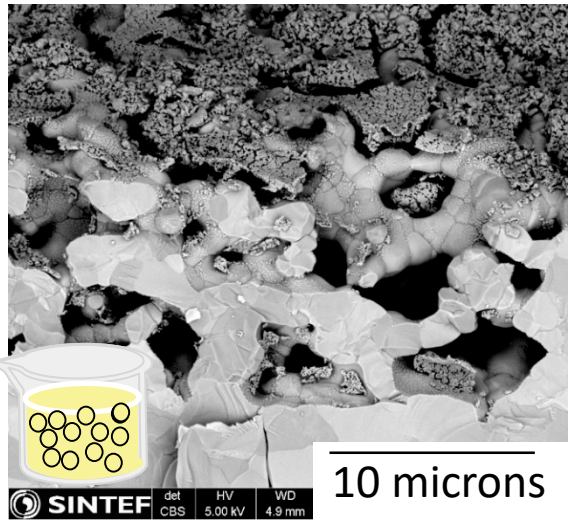




BGLC sol



BGLC powder in solvent



BGLC powder in sol

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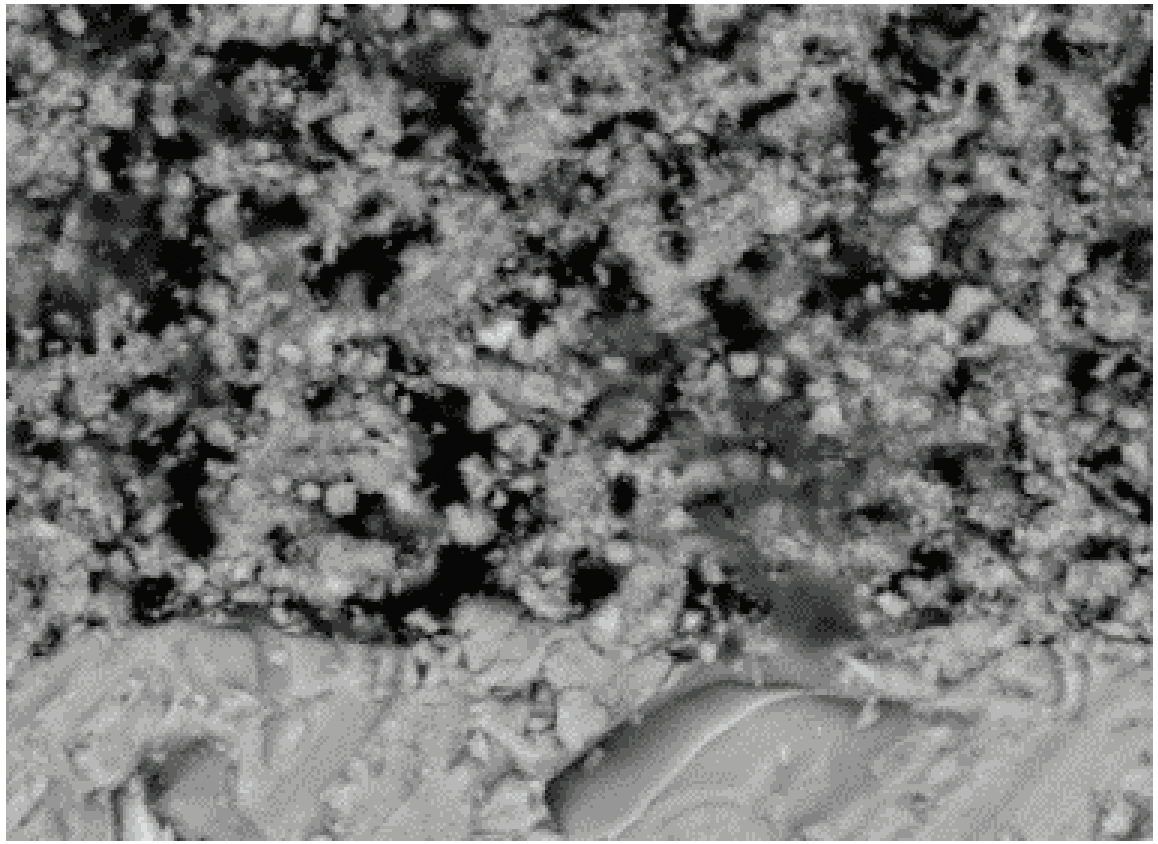
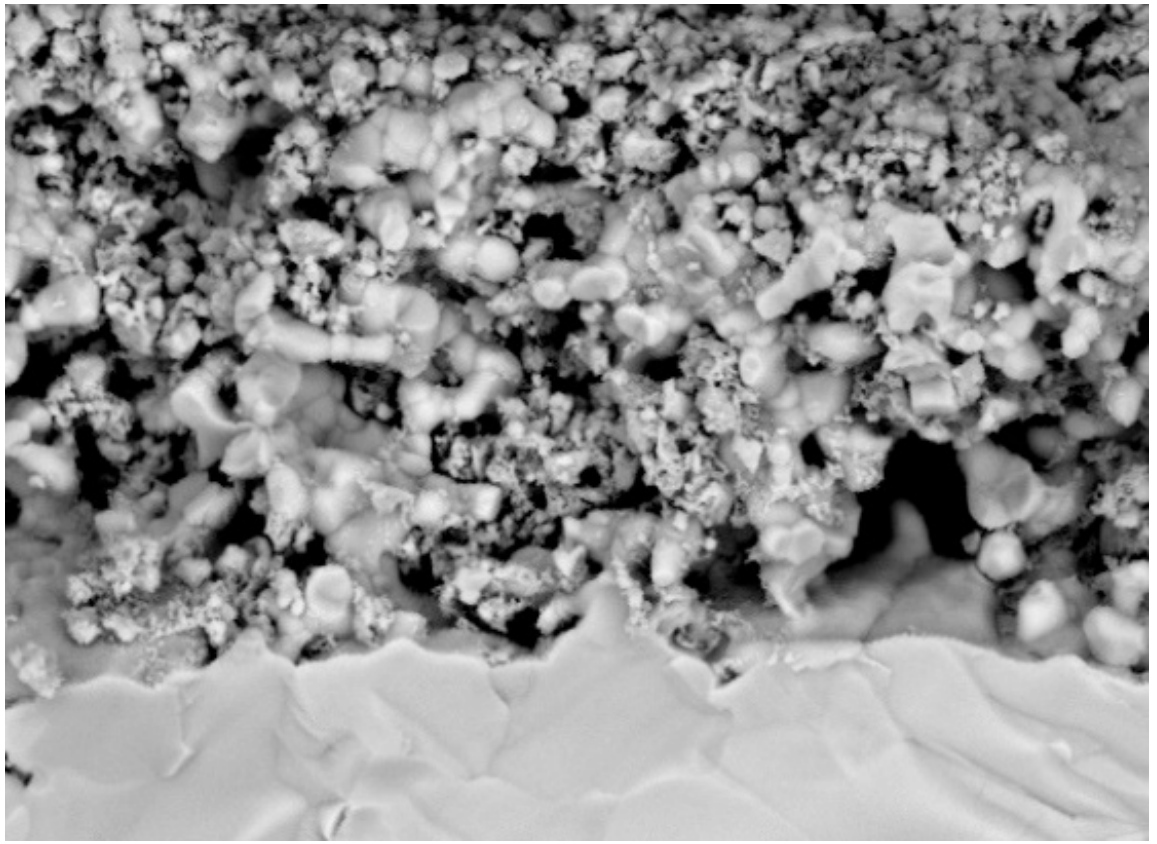
1 step composite



Infiltrated backbone (loaded gel)



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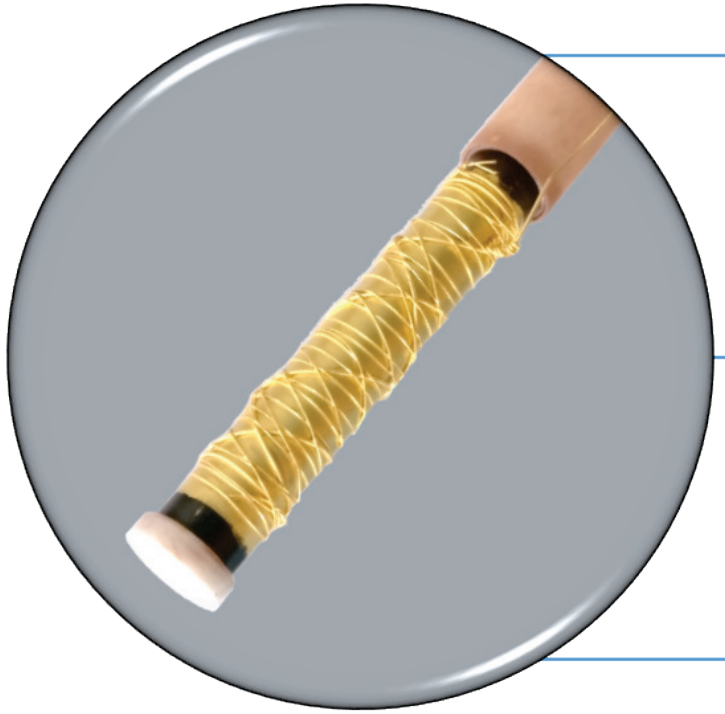
Testing

- Testing in Probostat™
- Cells sealed to alumina riser
- Sealing technology developed by CTMS



Riser

Sample with Au paint and wire

Sealing technology from CoorsTek Membrane Sciences

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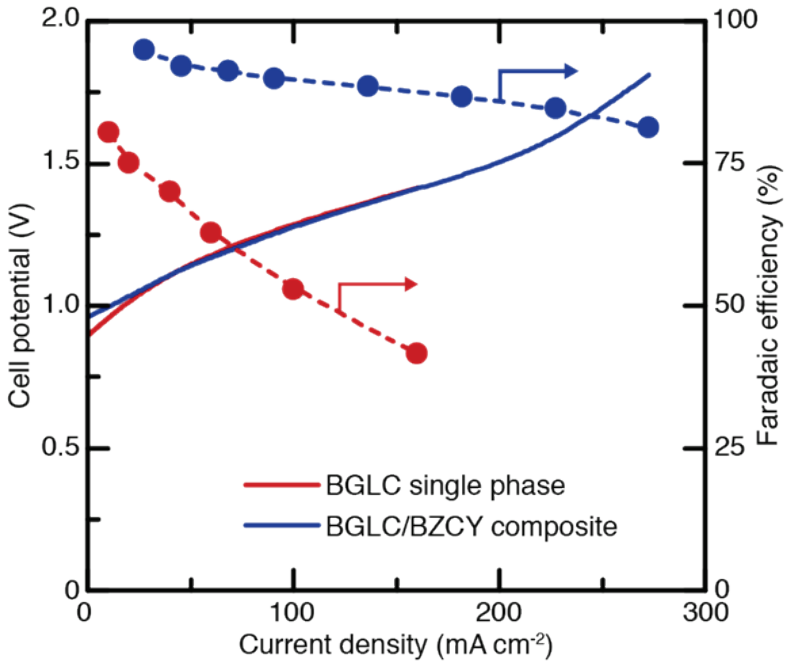
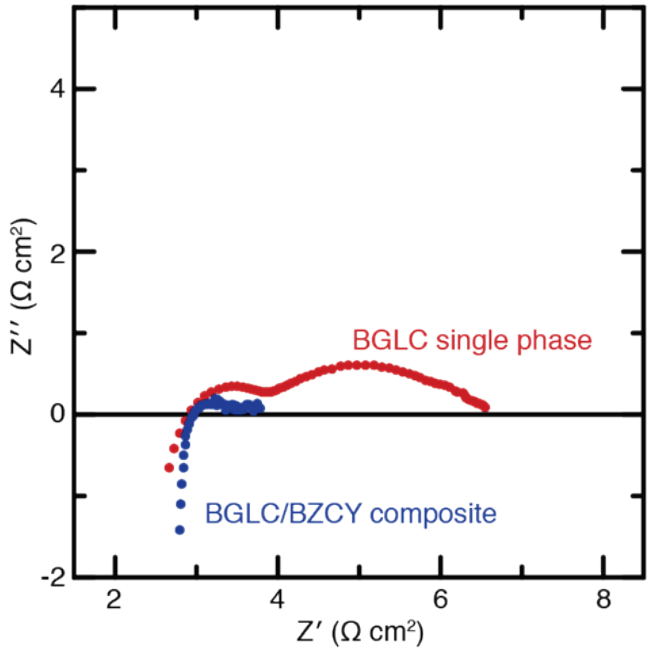
Single phase vs composite electrodes (1 step)

Anode	Current collector
BGLC-BZCY	Pt
BGLC	Pt

Conditions:
Total P= 3 bar
Cell Area: 11 cm^2

1 step composite





"*Mixed proton and electron conducting double perovskite anodes for stable and efficient tubular proton ceramic electrolysers*" , Nature Materials (2019);

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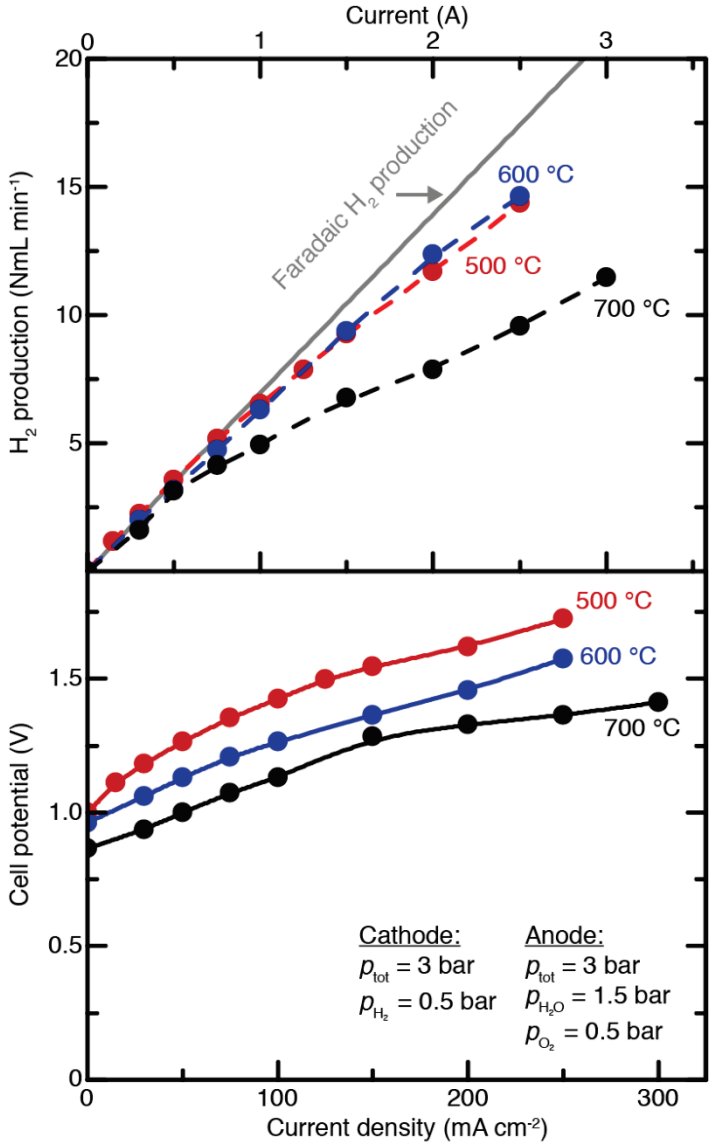
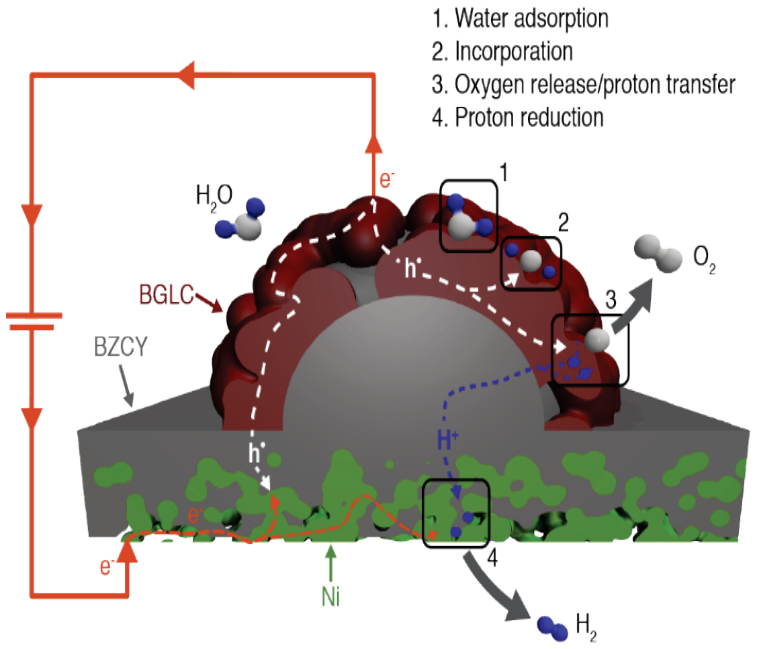
Composite electrodes

1 step composite

Anode	Current collector
BGLC-BZCY	Pt

Conditions:
Cell Area: 11 cm^2





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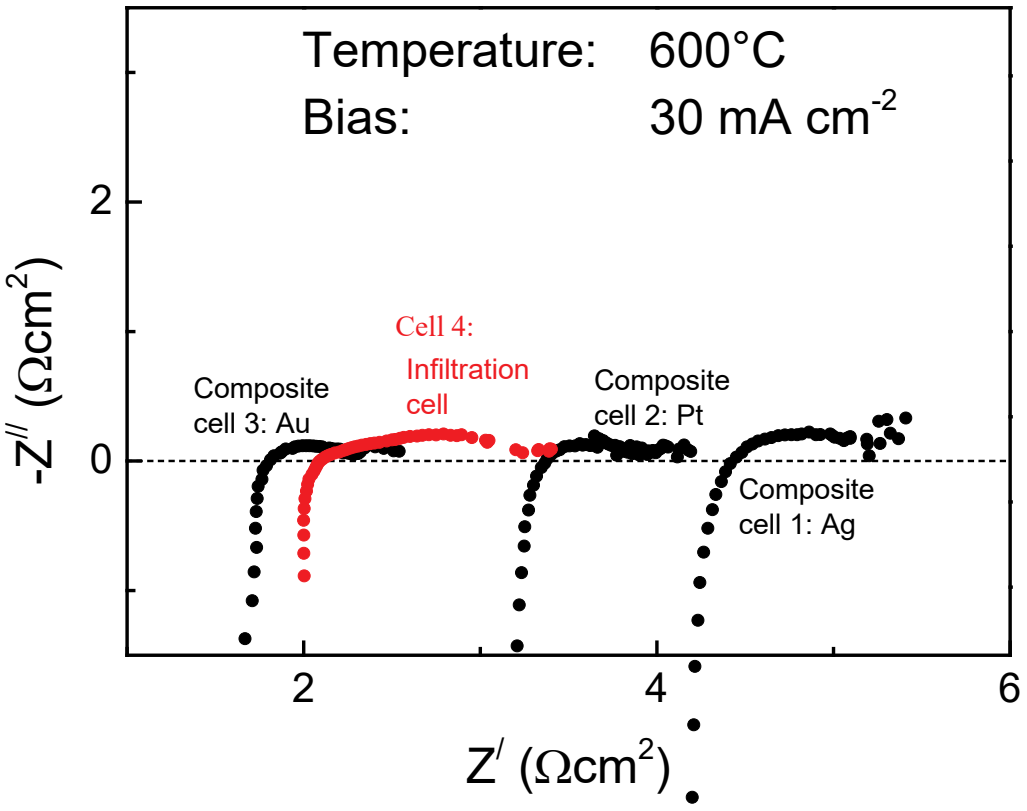
Performance

Anode	Current collector
Cell 1: BGLC-BZCY	Ag
Cell 2: BGLC-BZCY	Pt
Cell 3: BGLC-BZCY	Au
Cell 4: BGLC-BZCY	Au

1 step composite

Backbone infiltrated

Conditions:
pH_2O= 1.5 bar
Cell Area: 11 cm^2



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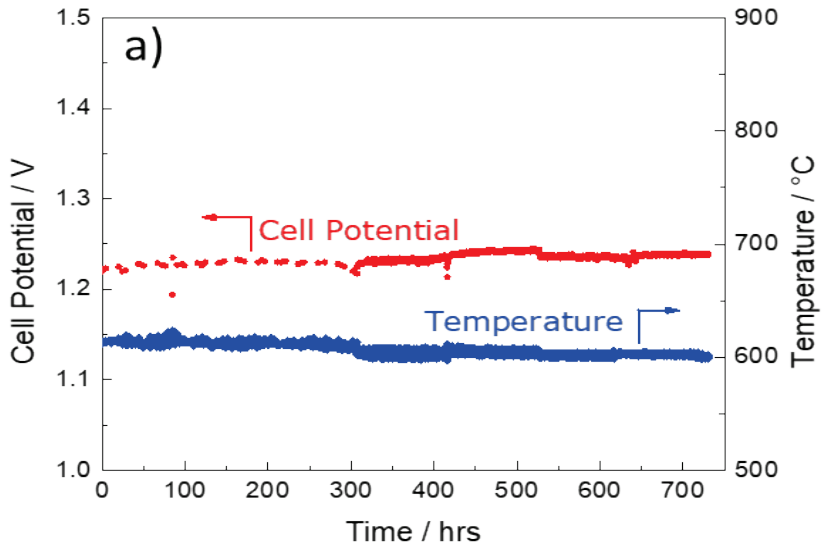
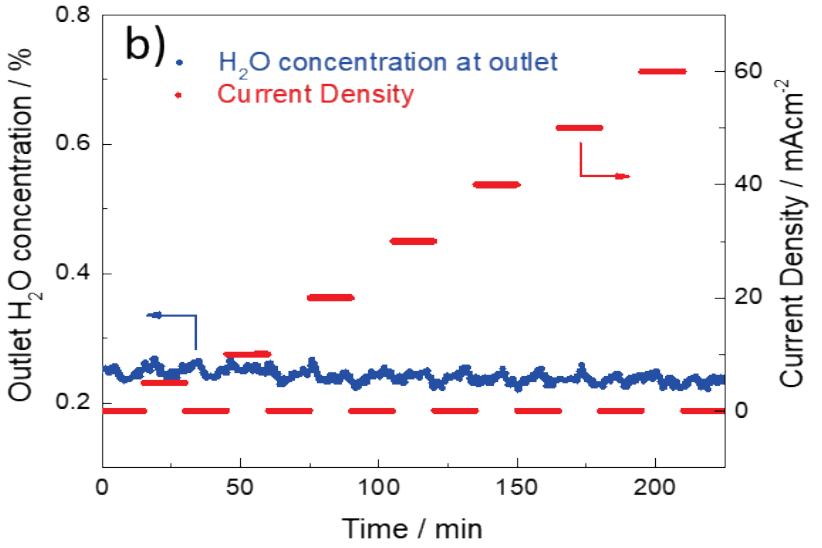
Stability

Backbone infiltrated

Anode	Current collector
Cell 4: BGLC-BZCY	Au

- ✓ 3bar : 50% steam, 20 % oxygen, 30 % argon
- ✓ 65 $mAcm^{-2}$





Nature Materials (2019); https://www.nature.com/articles/s41563-019-0388-2

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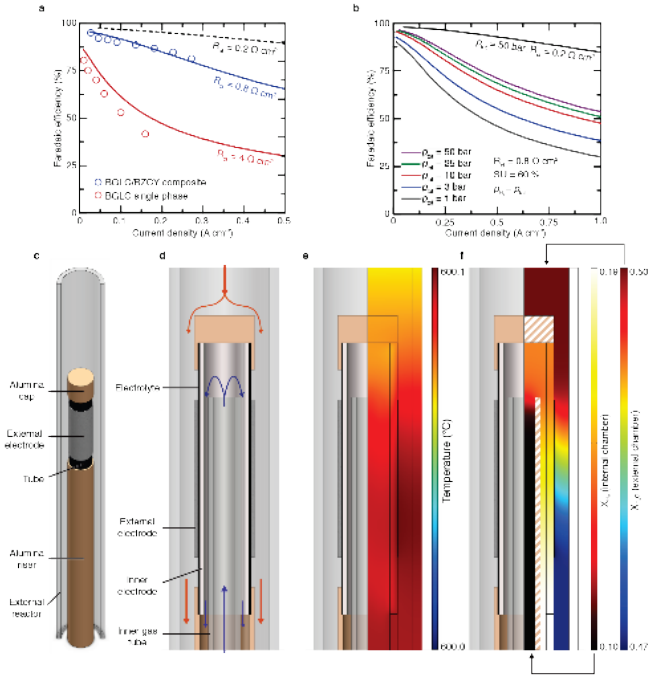
Summary



Correlation faradaic efficiency & electrode performance

Screening of electrode architectures in progress

- H_2 production rate > 10 ml/min at 500°C on short tube
- Cell stability
- Faradaic efficiency 90%

Current collection critical

➡ Currently patenting design of tubular single engineering unit

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Acknowledgments

- Colleagues from GAMER and ELECTRA

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For more information about GAMER:
https://www.sintef.no/projectweb/gamer/