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Materials challenges and opportunities in high-temperature steam electrolysis with geothermal heat

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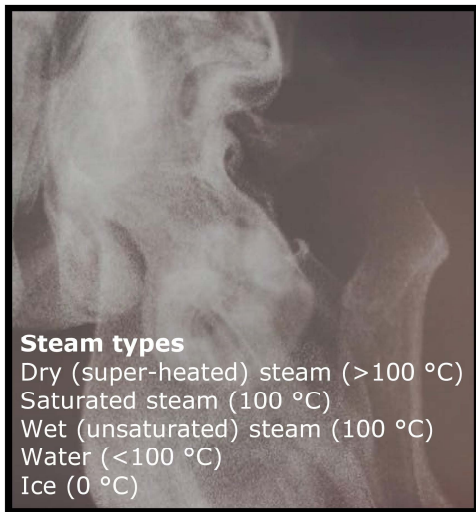
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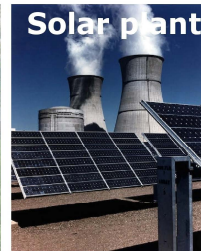
High temperature steam and water

STEAM



Steam types
 Dry (super-heated) steam (>100 °C)
 Saturated steam (100 °C)
 Wet (unsaturated) steam (100 °C)
 Water (<100 °C)
 Ice (0 °C)

APPLICATIONS & OPPORTUNITIES

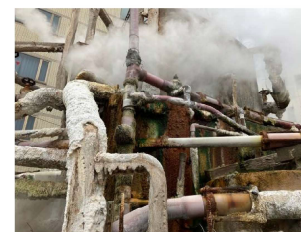


Other examples

- Sugar industry
- Dairy industry
- Paper industry
- Food processing
- Heating
- Sterilisation
- Propulsion
- Atomisation
- Cleaning
- Moisturisation
- Humidification

Temperature ranges of geothermal sources

- **Low-temperature resources:** Below 150 °C (closer to the Earth's surface)
- **Moderate-temperature resources:** 150–200 °C (typically 1–3 km)
- **High-temperature resources:** Above 200 °C, with some reaching 370 °C (regions with volcanic activity)

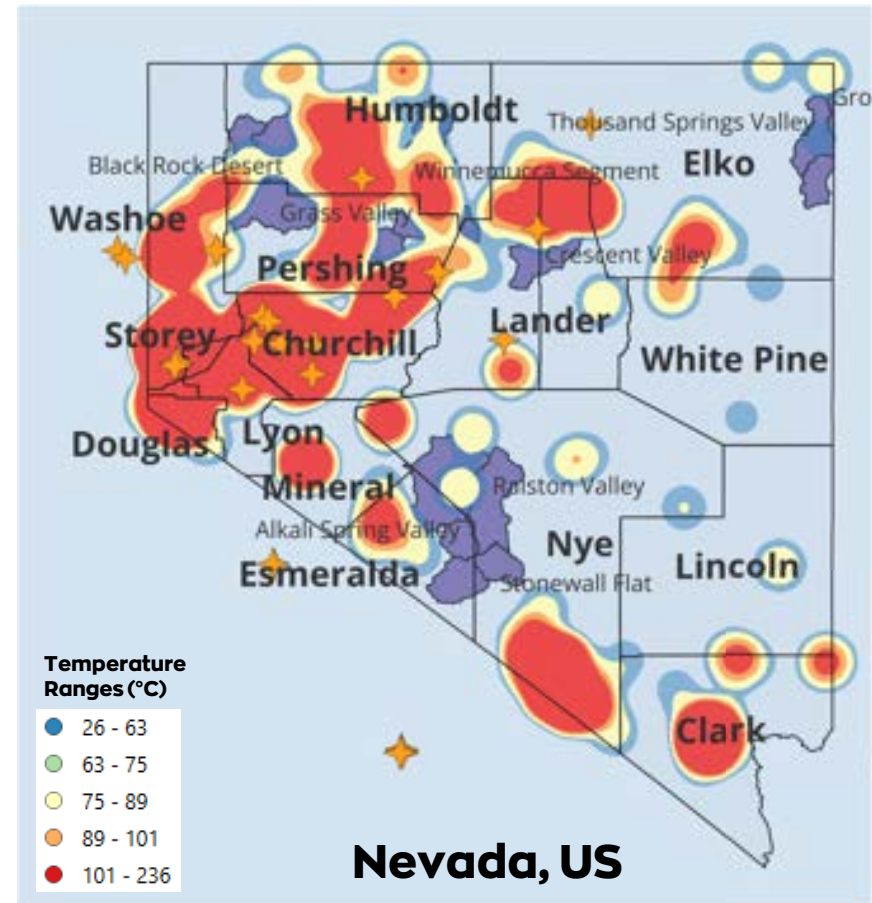
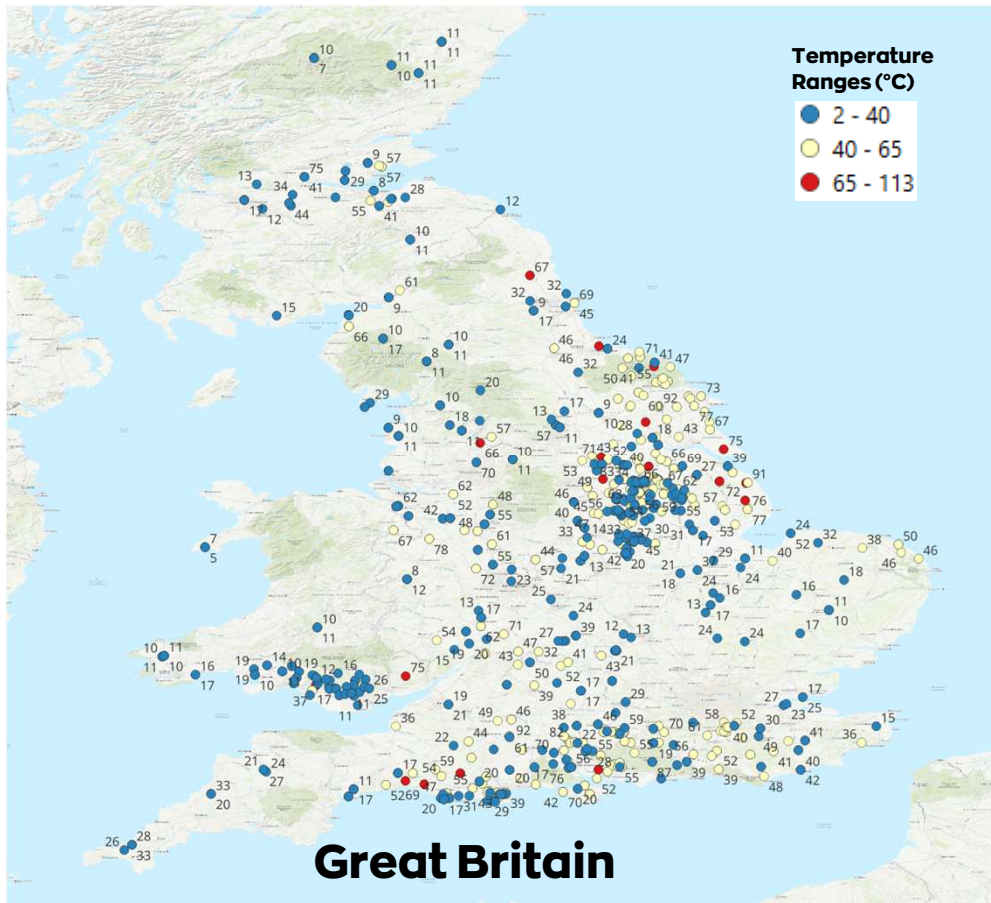


CHALLENGES

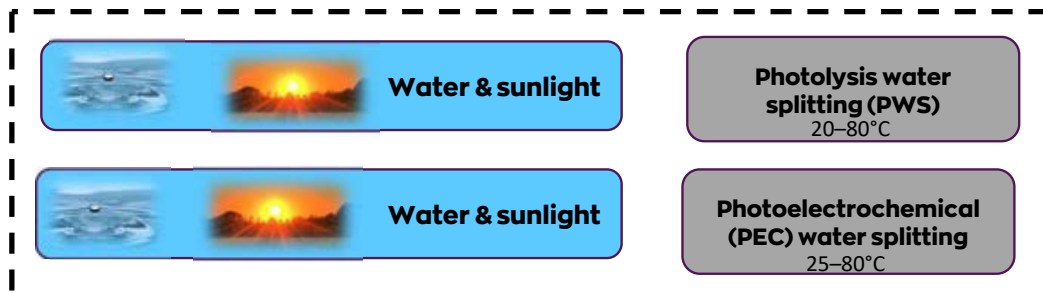
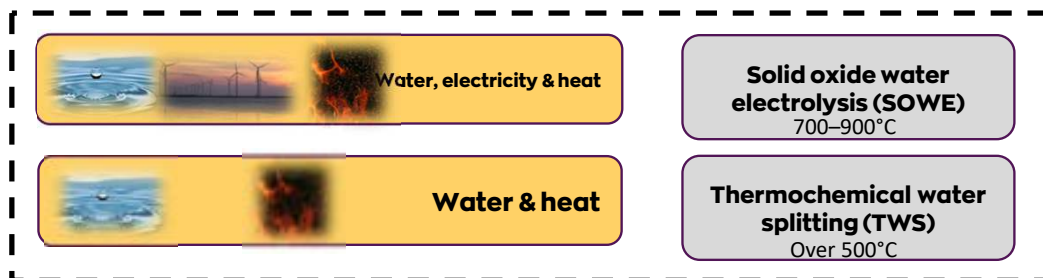
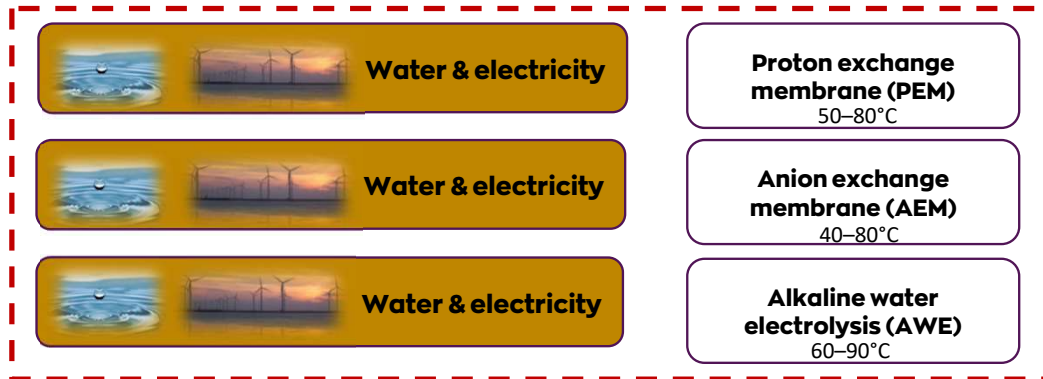
Coating and structural materials degradation



Geothermal GIS – Temperature spread

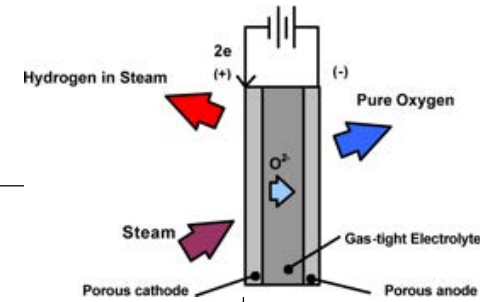


Main electrolyser types

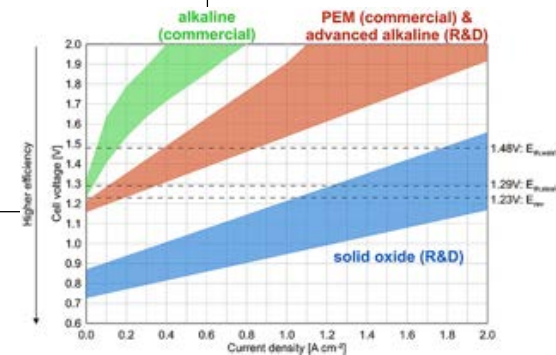
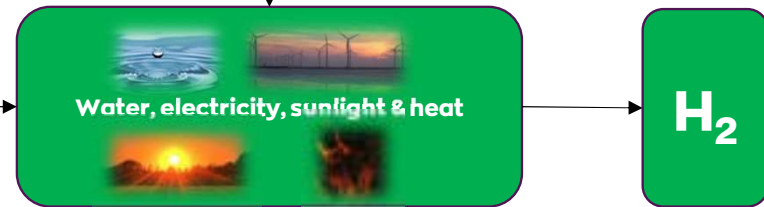


Feedstocks

Technologies (water based)

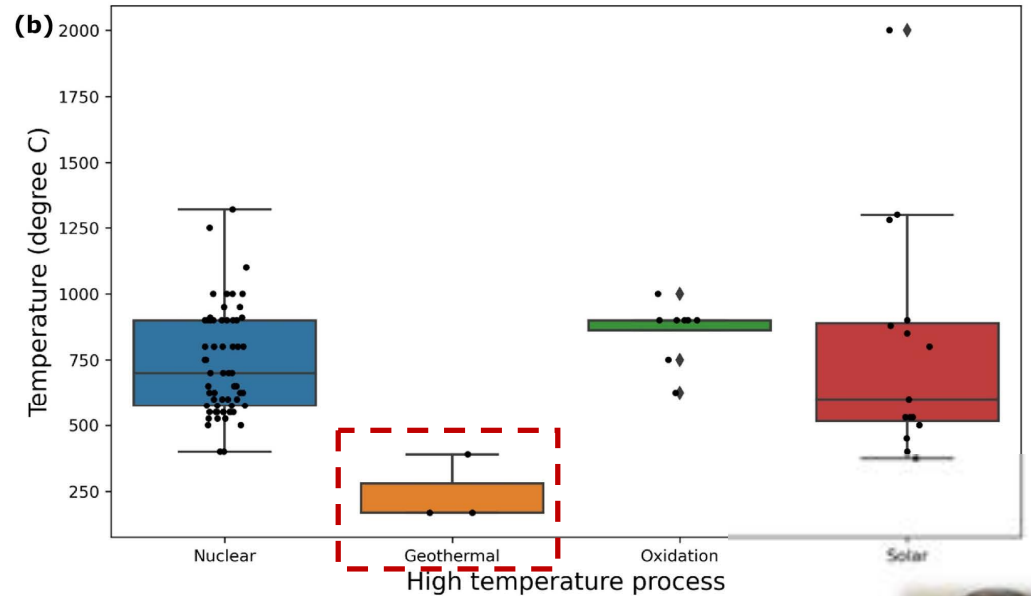
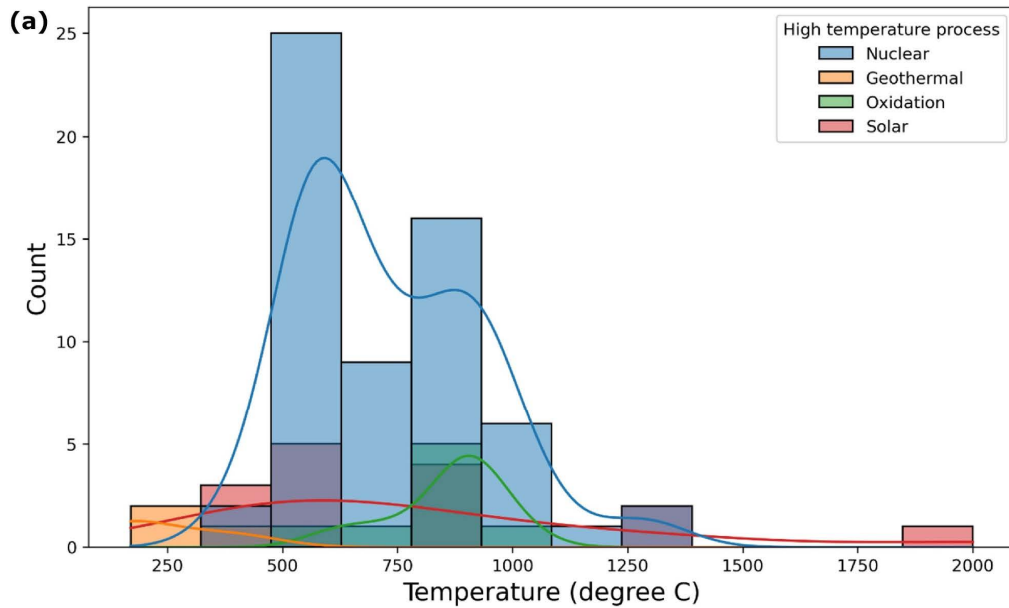


Hydrogen production (water splitting)

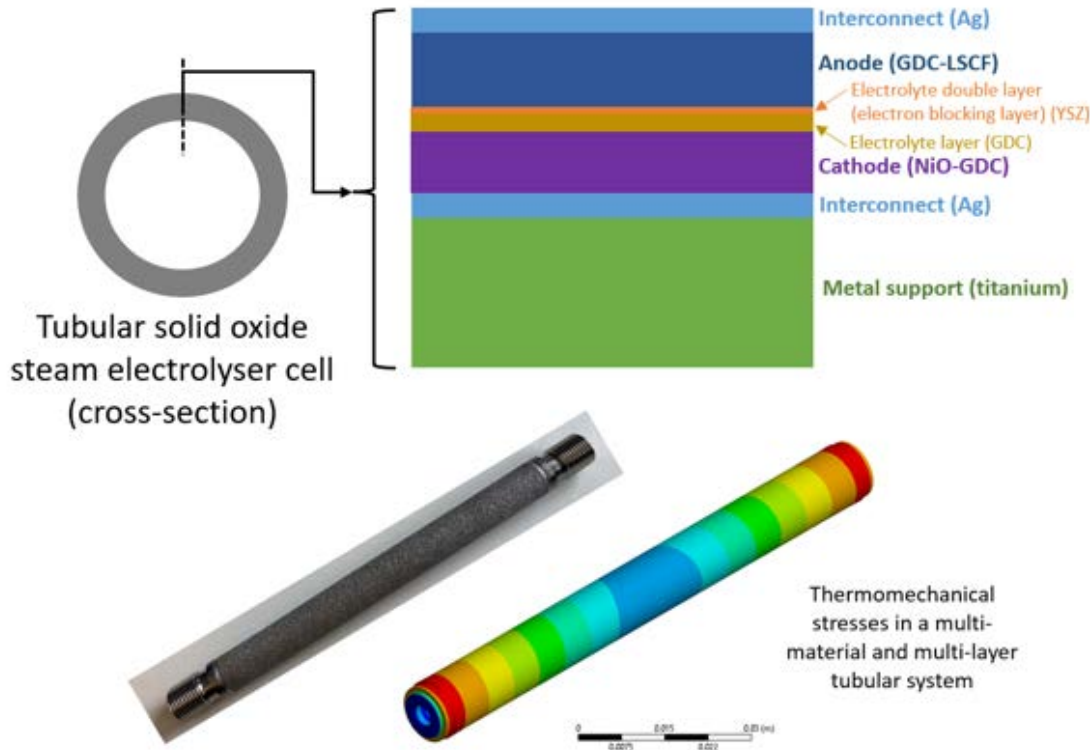


High temperature processes

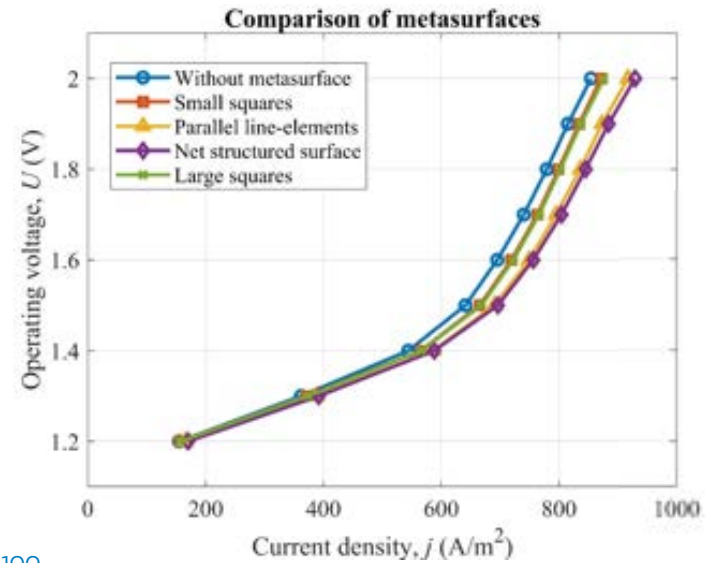
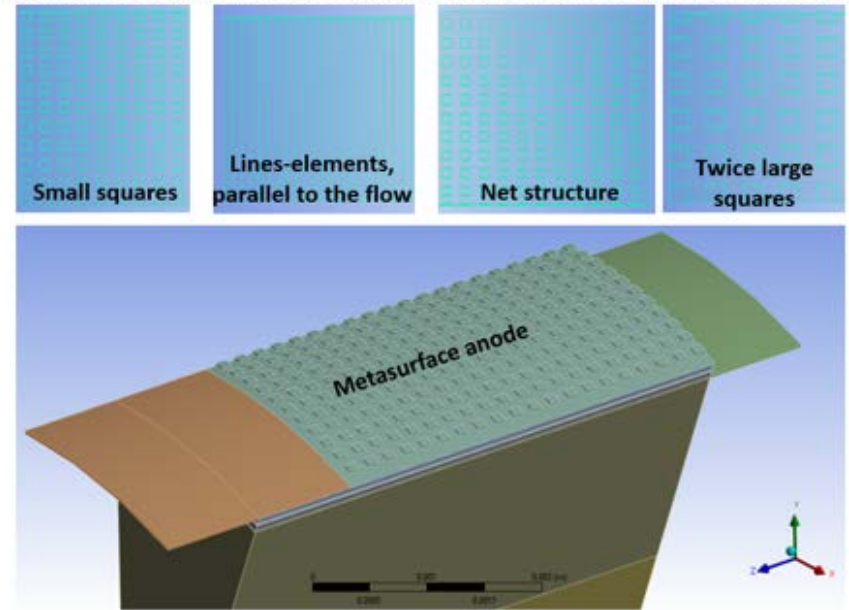
Increase in temperature eliminates the need for expensive catalysts.



Design & modelling



Metasurface patterned anode for enhanced performance of solid oxide electrolyser



Cell fabrication stages



Electrodeposition of silver on SS & Ti tubes



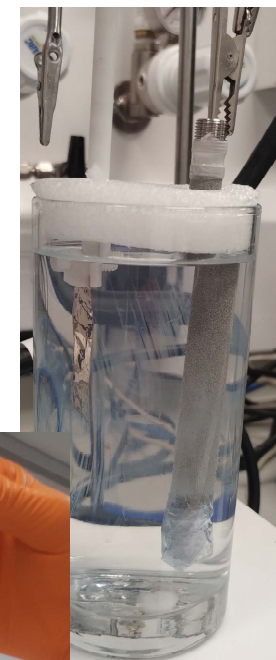
Half cell fabrication (dip coating slurries, current collector & cathode functional layer)



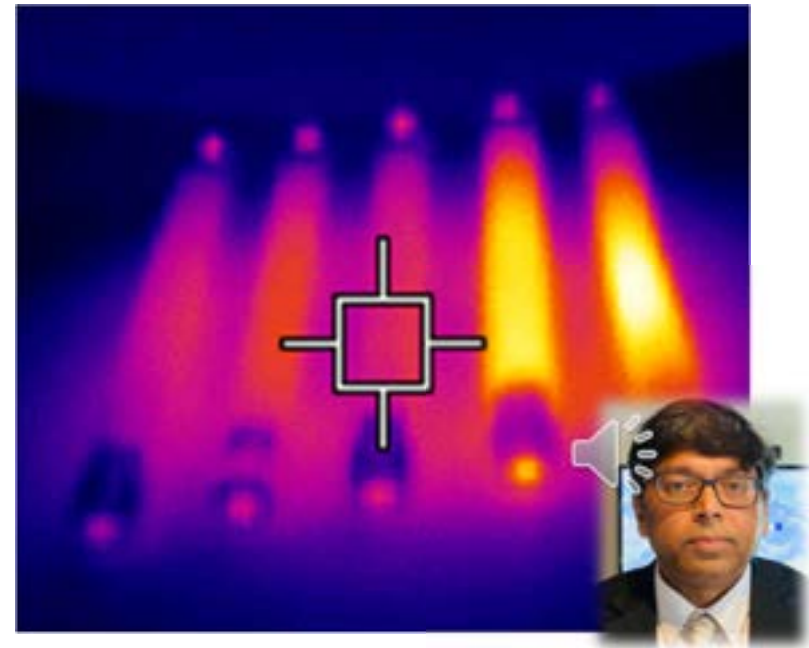
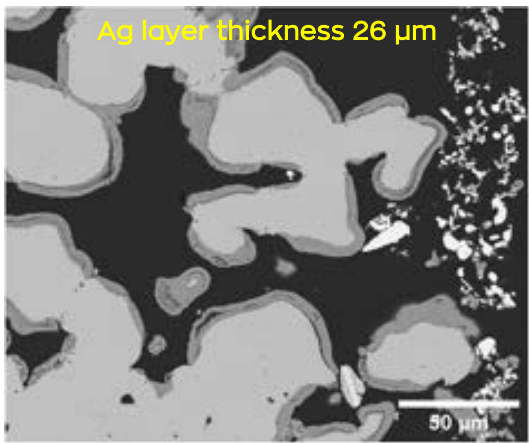
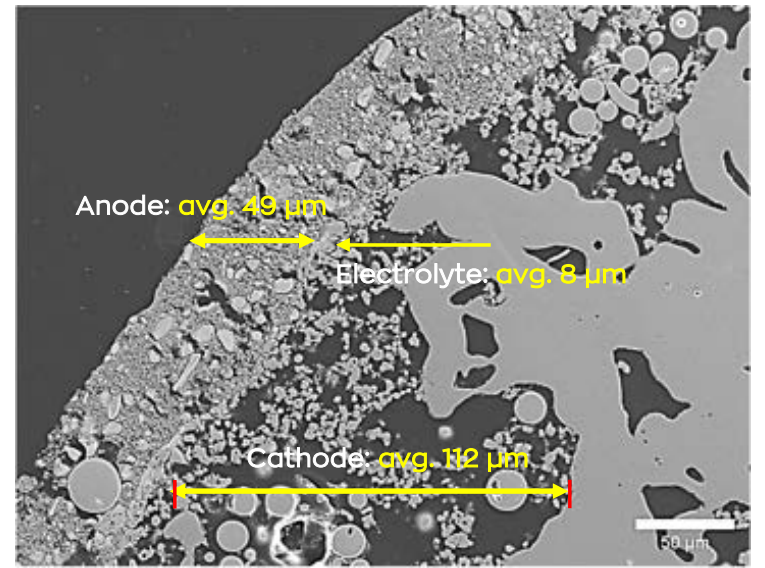
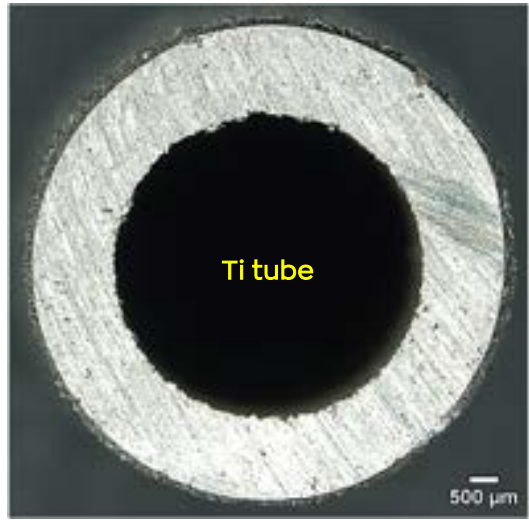
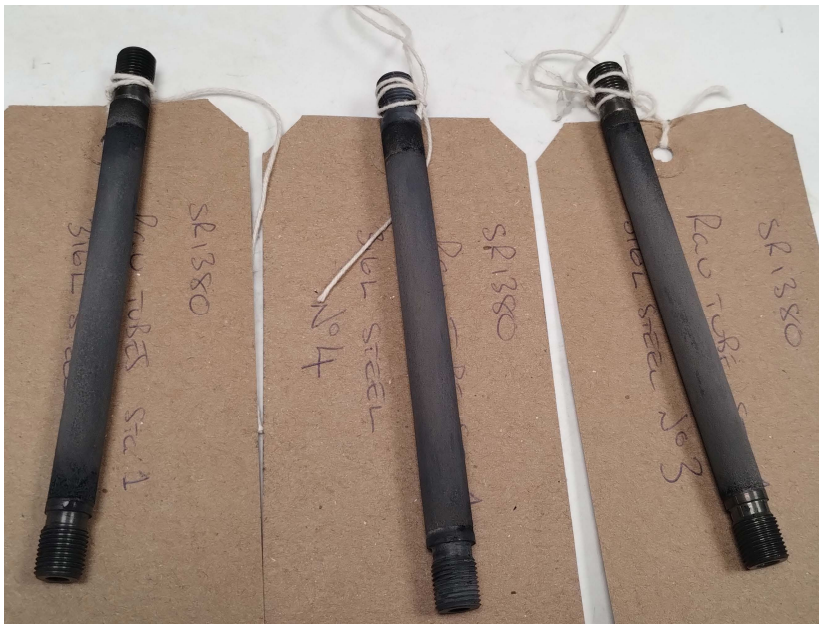
Full cell fabrication (electrolyte and anode layers, anode current collector and sealing)



Ultrasonicated slurries, high-temperature sintering (950-1100 C)



Investigation



Designing steam electrolyzers for geothermal steam applications

- **High-temperature stability**
Thermal expansion mismatch, creep, deformation
- **Corrosive geothermal environment**
Dissolved salts (NaCl, KCl), acidic gases (CO₂, H₂S), mineral deposits (silica, calcium carbonate)
- **Electrolyte materials**
Materials degradation, contamination
- **Electrode degradation**
Nickel oxidation, sulphur poisoning, delamination
- **Durability and longevity**
Thermal cycling, electrochemical degradation
- **Integration with geothermal systems**
Variable steam quality, scaling and fouling in heat exchanges
- **Emerging solutions**
Advanced coatings, new materials, hybrid systems (pre-heating)

