Tubular high temperature solid oxide steam electrolysis cell

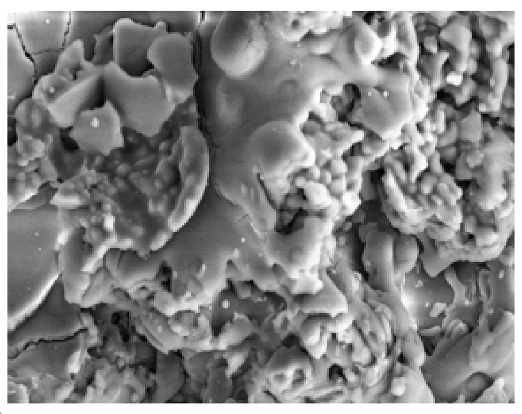
Opportunity

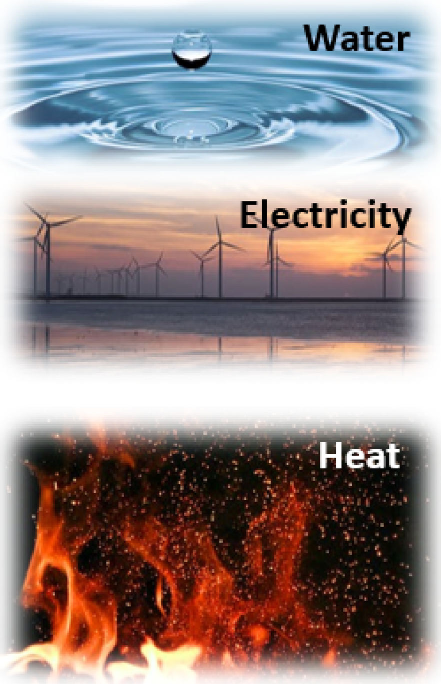
- Hydrogen has been considered to the energy vector to meet the target. The UK government has set an ambitious target of reaching net-Zero by 2050.
- One of the most promising new avenues for green hydrogen production is to combine the development of a highly active electrode layers for high temperature solid oxide steam electrolysis (HT-SOSE) with the waste steam generated from nuclear power plant.
- This project is developing an advance solution for zero emission hydrogen production by designing, fabricating, and testing thermally sprayed novel metasurface coatings of electrodes (tubular cell design) for solid oxide steam electrolysis (SOSE).
- While metasurface design for electrode is new, the tubular cell design has received increased attention in recent years, and among the different geometric design of electrode, the tubular design offers several advantages (e.g., alleviates issues associated with high temperature sealing as seals can be placed outside of high temperature zone, can have high active surface area, can be robust against thermal cycling, etc).

Nuclear reactor heat & steam

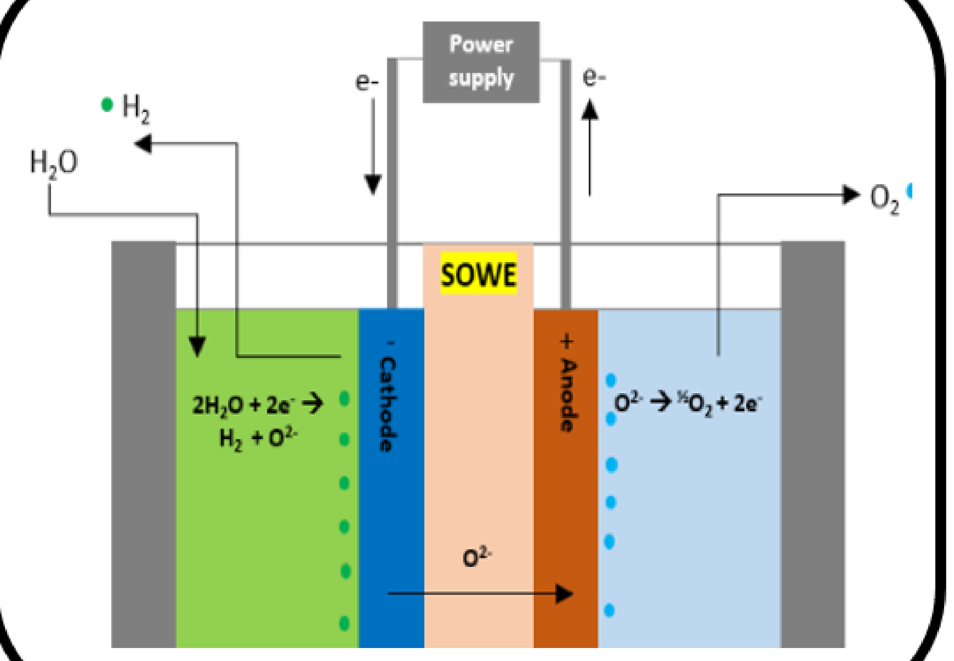
Electrode & feedstocks for electrolysis

High temperature electrolysis cell (metamaterials, manufacturing)



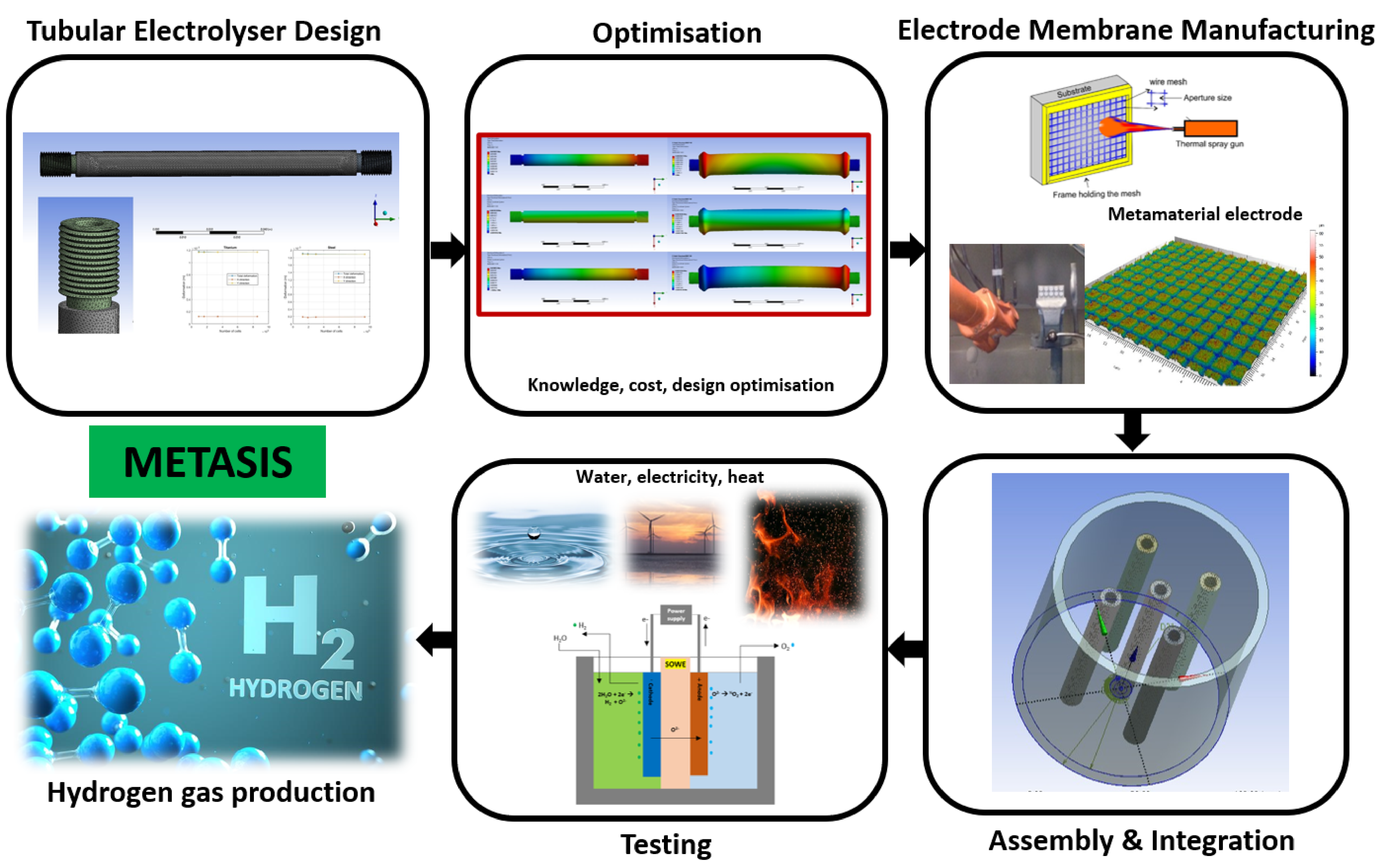


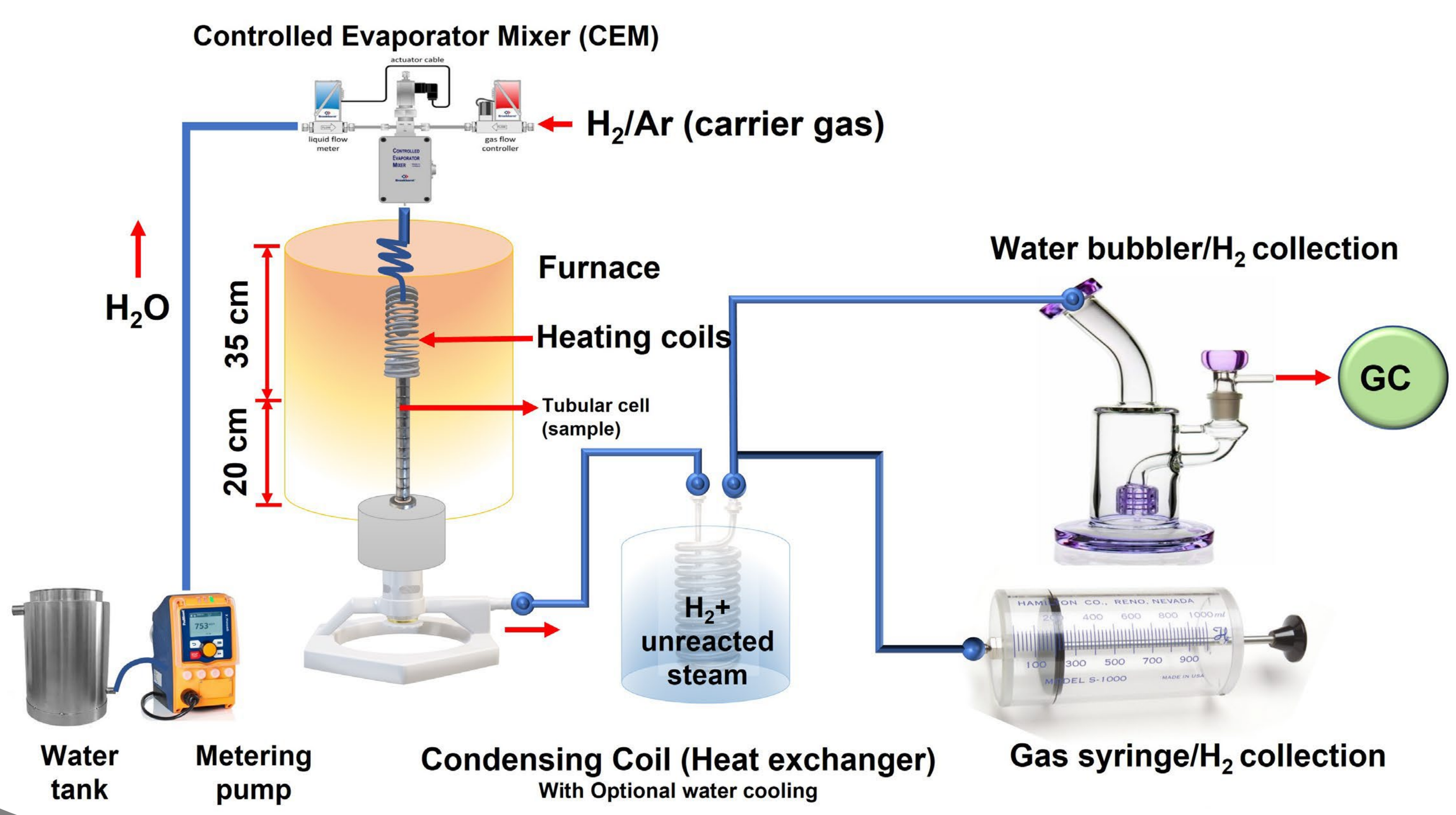
Electrolyser & hydrogen production



Plans & Progress

- Analysis and optimisation of the tubular SOSE cell should balance the following design requirements: a) mechanical stability of the cell during high temperature operation; b) electrochemical efficiency of materials, used for functional layers, where oxidation/reduction reactions take place; c) increased surface area of the fluid – electrode interface; d) efficient circulation of fluid species in gas channels; e) convenience of manufacturing.
- To achieve the goals, analysis of the tubular cell includes thermomechanical simulations of high temperature conditions and computational fluid dynamics (CFD) with the unresolved electrolyte model, species transport, laminar flow and porous materials.
- Thermomechanical simulations are verified in terms of the total and directional deformation. Considered design operation conditions are: maximum expected 10 bars pressure; effect of fixed-fixed, fixed-free, fixed-elastic end conditions; temperatures of 600, 800, 1000°C; variation of the initial substrate porosity from 20% to 40%.





Results

- Thermomechanical steady-state simulations were performed for steel and titanium substrate tubes used as a mechanical support for the designed tubular cell.
- In this study, analysis for steel tubes, reveals a substantial deformation in the longitudinal direction leading to significant alterations in the geometry at bounds of the central section.
- These changes are expected at a high temperature bandwidth and are important to account for, if fixed-fixed conditions apply.

Summary

Developing electrolyser cells with enhanced hydrogen production and their scalable manufacturing can play an important role in enabling not only eco-friendly development but also cost-effective, reliable, and sustainable opportunities. Thermomechanical assessments of expected deformations at high temperature bandwidth for two types of materials, used as a cell metal support were performed. Revealed changes to geometry, especially, at fixed-fixed conditions provide a basis to estimate the overall cell stability, optimise the fluid dynamics component and electrochemical performance.

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