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Reducing Electrolytic Hydrogen Cost Through Advanced Electrocatalytic Processes

Prof. A. Kucernak

Department of Chemistry/Energy Futures Lab
Imperial College London
anthony@imperial.ac.uk

Key Topics

01 Vertically integrated approaches to reduce hydrogen cost

02 Improved electrode structure leads to 10-100-fold higher performance

03 Alternative anode reactions lead to significant hydrogen cost reduction

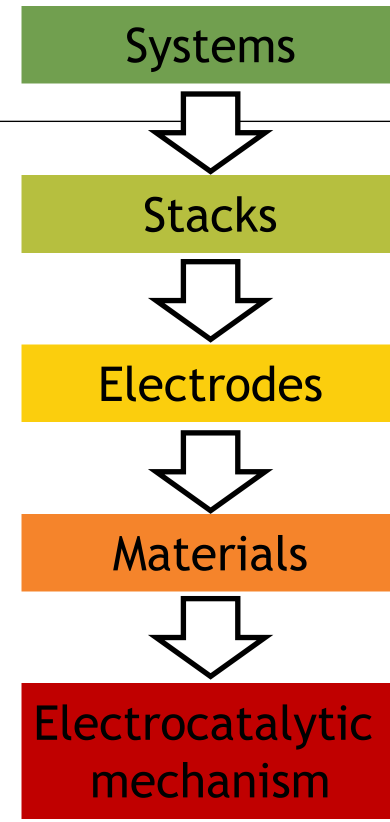
04 Alkaline-PEM approaches

05 Facilities available to perform research

Vertically integrated approaches to reduce hydrogen cost

1

- Ideally want approaches which can be applied across a range of systems
  - Rather than “better material X” → “Improved approach”
  - New approaches lead to conceptual shift
  - Opportunity for valuable innovations is higher
- Opportunities at different scales



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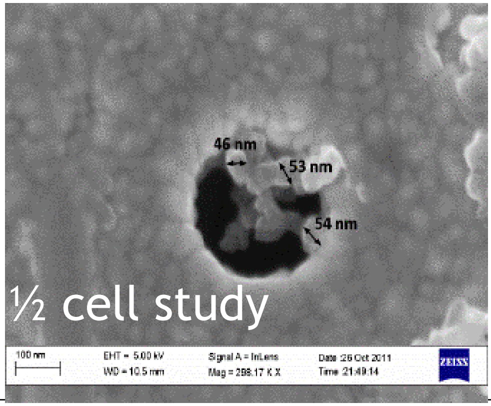
2

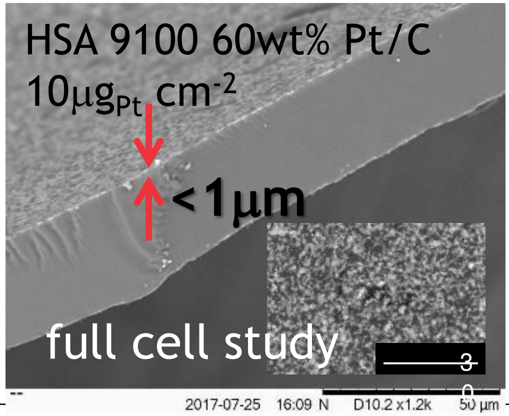
Improved electrode structure leads to 10-100-fold performance improvement

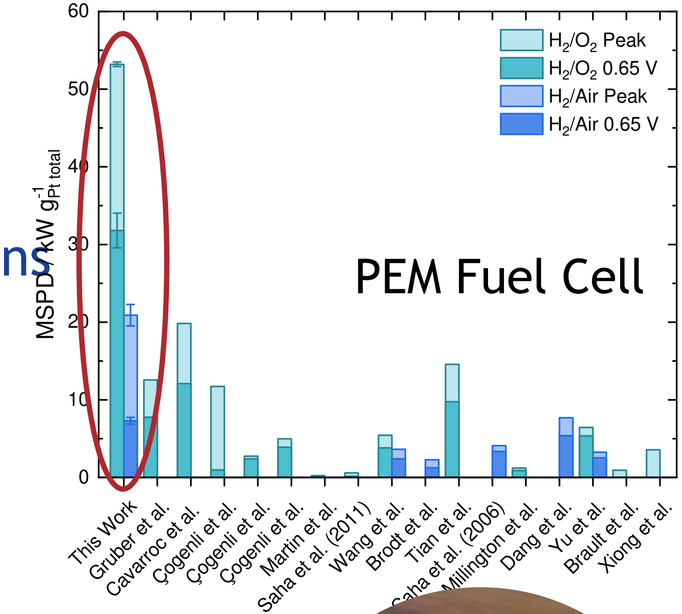
- General approach applicable to any electrolyser electrode structure
- Associated with minimizing transport loses which can be significant
- Poorly researched area

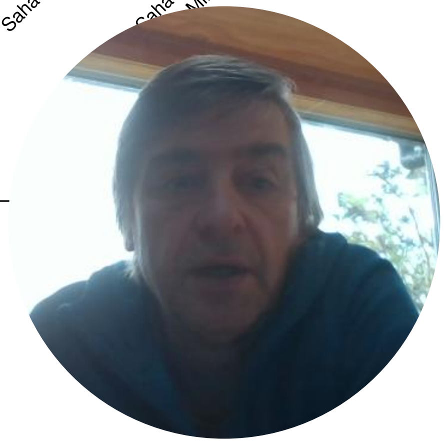
Advanced electrode design (applied to fuel cells)

- Optimise mass transport and ionic conductivity
- Catalyst performs 10-fold better than current designs
- 25-fold reduction in catalyst requirements









[1] C.M. Zalitis, D. Kramer, A.R. Kucernak, Electrocatalytic performance of fuel cell reactions at low catalyst loading and high mass transport, *Phys. Chem. Chem. Phys.*, 15 (2013) 4329-4340. http://dx.doi.org/10.1039/c3cp44431g.

[2] C. M. Zalitis, A. R. J. Kucernak, X. Lin, J. D. B. Sharman, *ACS Catalysis* **2020**, DOI: 10.1021/acscatal.9b04750

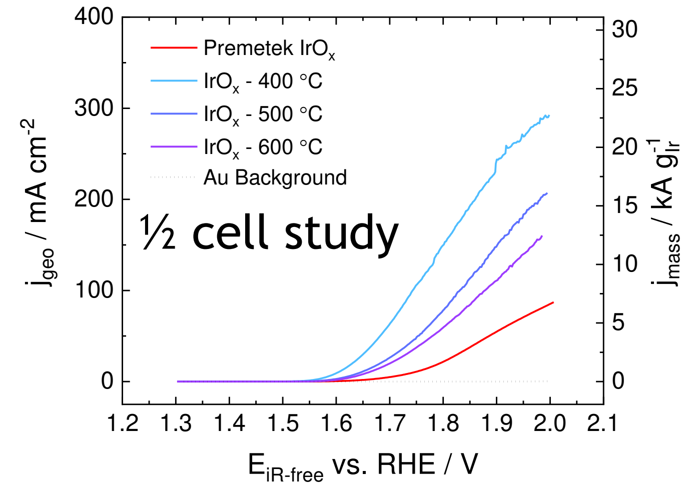
[3] C.M. Zalitis, A.R. Kucernak, J. Sharman, E. Wright, Design principles for platinum nanoparticles catalysing electrochemical hydrogen evolution and oxidation reactions: edges are much more active than facets, Journal of Materials Chemistry A, 5 (2017) 23328-23338. http://dx.doi.org/10.1039/c7ta05543a.

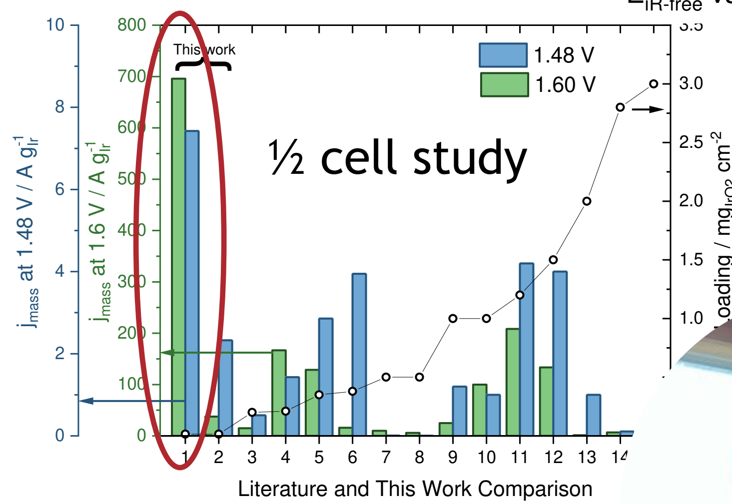
Improved electrode structure – thrifting of Ir

- Initial results showing higher performance than any catalysts in literature
- MSci student applied technique to making electrolyser electrodes

Outstanding issues

- Need electrically conducting buffer layer
- Longevity and degradation
- Understanding loading effects
- ~~Microelectrokinetic model of performance~~



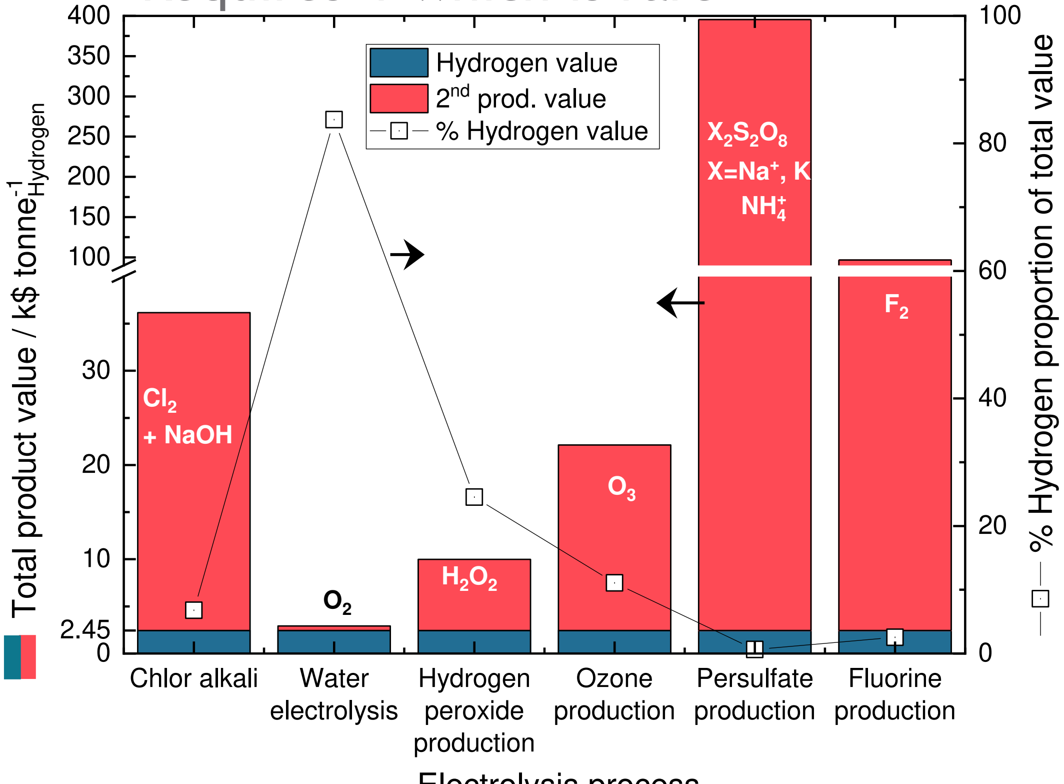


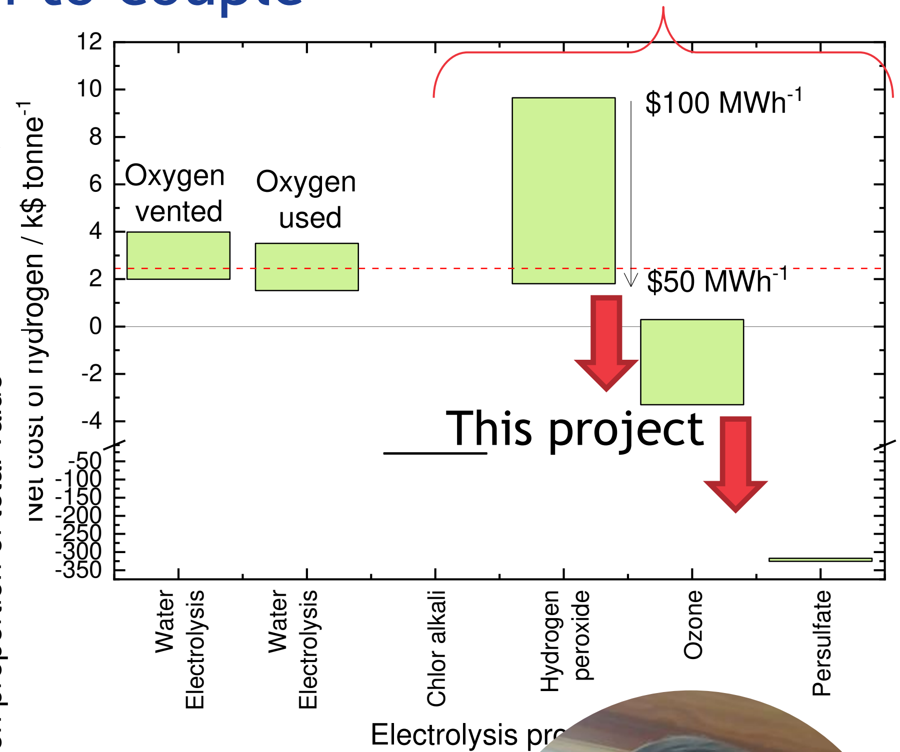
Collaborators: Johnson Matthey, Bramble Energy

3

Alternative anode reactions lead to greater materials efficiency

- Oxygen evolution is a poor reaction to couple to hydrogen evolution
  - Kinetics are poor, requiring significant overpotential
  - Value of oxygen is low
  - Requires Ir which is rare





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Alternative anode reactions lead to greater materials efficiency (and are Ir-free)

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Research methodology

a) Develop electrocatalysts for H_2O_2/O_3 production and incorporate in electrolyser

- Doped tin(IV) oxides are:
  - Corrosion resistant
  - Electrically conductive
  - Electrocatalysts for ozone production

Additional benefit is that these materials will aid 2

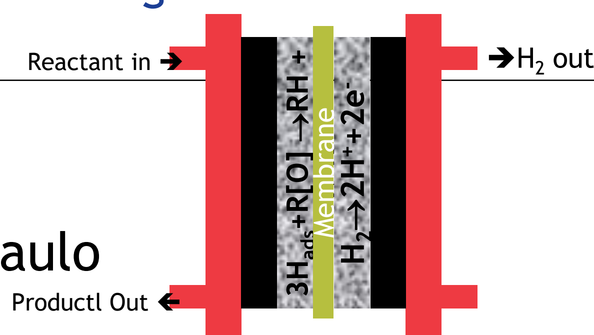
- Long term efficacy is a problem due to de-doping of cationic dopants
- Anionic dopants are much more effective (e.g. F)
- Understand the scale and potential uses for production of H_2O_2 and O_3 at scale

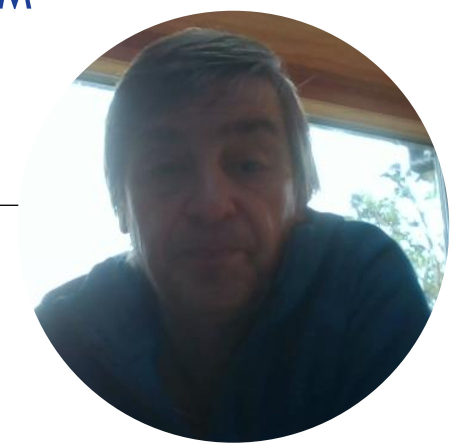
b) Examine use of redox mediators to catalyse useful chemical processes

- Pair Hydrogen evolution with production of oxidative redox mediator

$$M \leftrightarrows M^{+} + e^{-} \qquad M^{+} + \text{Reactant} \rightarrow \text{Product} + M$$

- Mediator = Mn^{2+} and/or N-hydroxyphthalimide
- Reactant = Vinasse or Lignin

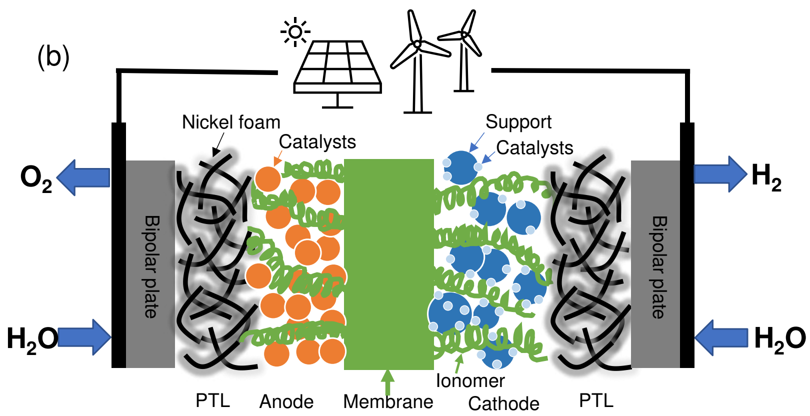


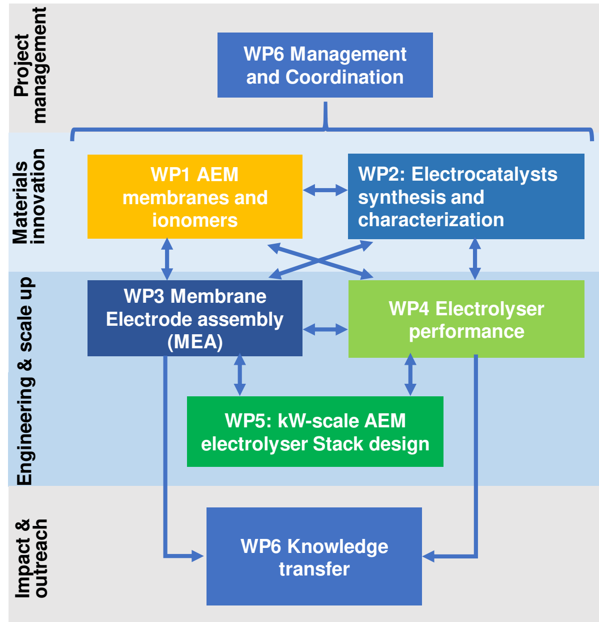


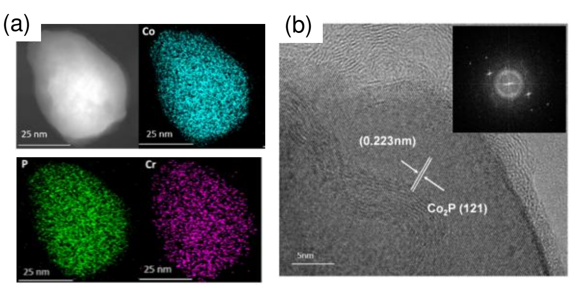
Collaborators:
RFC Power, BP,
University of Sao Paulo

4 Alkaline-PEM approaches

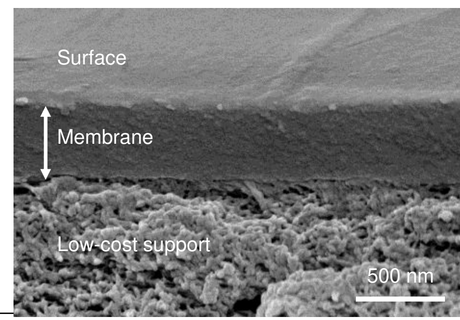
- Development of Alkaline PEM electrolysers with Dr Qilei Song and Prof Nilay Shah



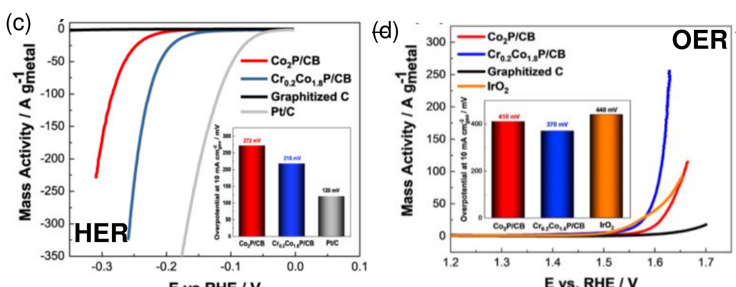




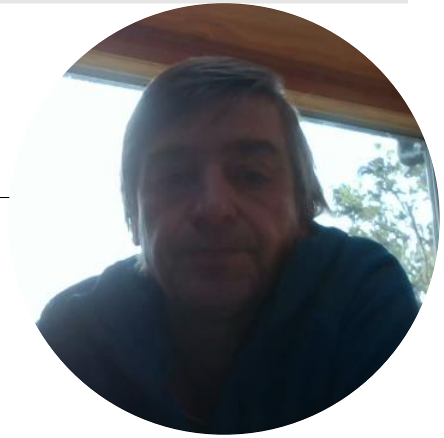
Thin film composite membrane



Asymmetric membrane



Collaborators: Bramble Energy



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Facilities available to perform research

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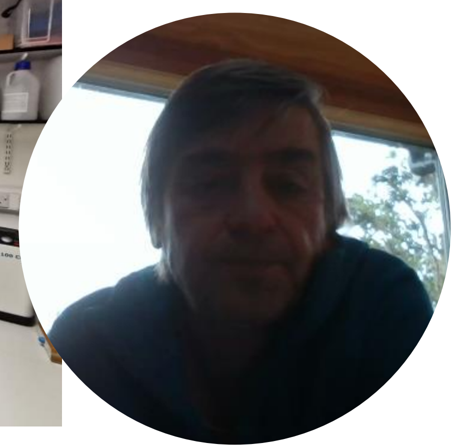
Walk in fume cupboard for large scale testing and materials development including high temperature testing

Fuel synthetic laboratories for materials development

Materials development and characterisation



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Hydrogen safe laboratories (24/7 certified) with multiple test stands. Full gas handling

Post operation teardown and analysis and environmental testing