RMIT University Melbourne hydrogen storage and transport R&D project:

Presentation to ARENA Hydrogen R&D Roundtable

Professor John Andrews

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ELDOR CORPORATION

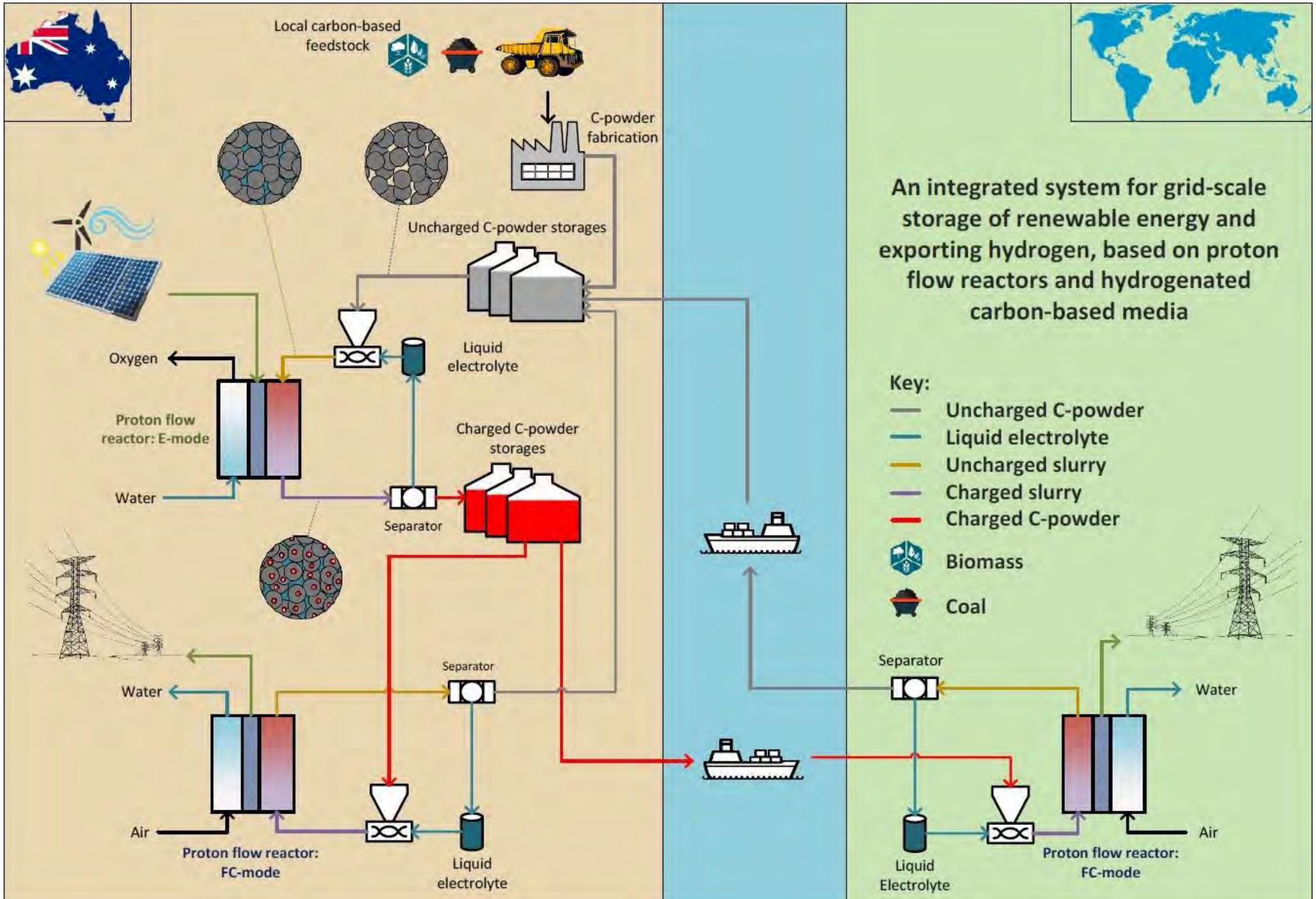
I²CNER International Institute for Carbon-Neutral Energy Research, Kyushu University

RMIT UNIVERSITY

A proton flow reactor system for electrical energy storage and bulk export of hydrogenated carbon-based material

- Aim: to develop an integrated system for storage of electricity from renewable energy, and/or export the stored energy as hydrogen within hydrogenated carbon-based powder
- Continuous charging of a carbon slurry/paste with hydrogen in a flow electrochemical reactor – a scaled-up extension of RMIT's innovative proton battery concept
- Bulk storage and transport as dry powder
- Reconstituting slurry/paste again for discharging in separate reactor to produce electricity when and where needed
- A zero-emission and environmentally-benign solution

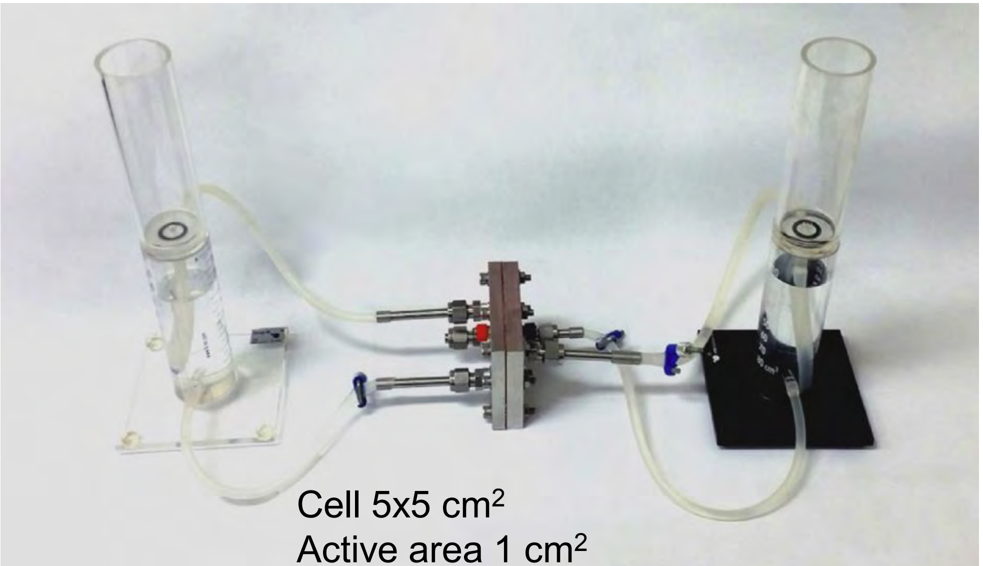
Process map of the proposed system



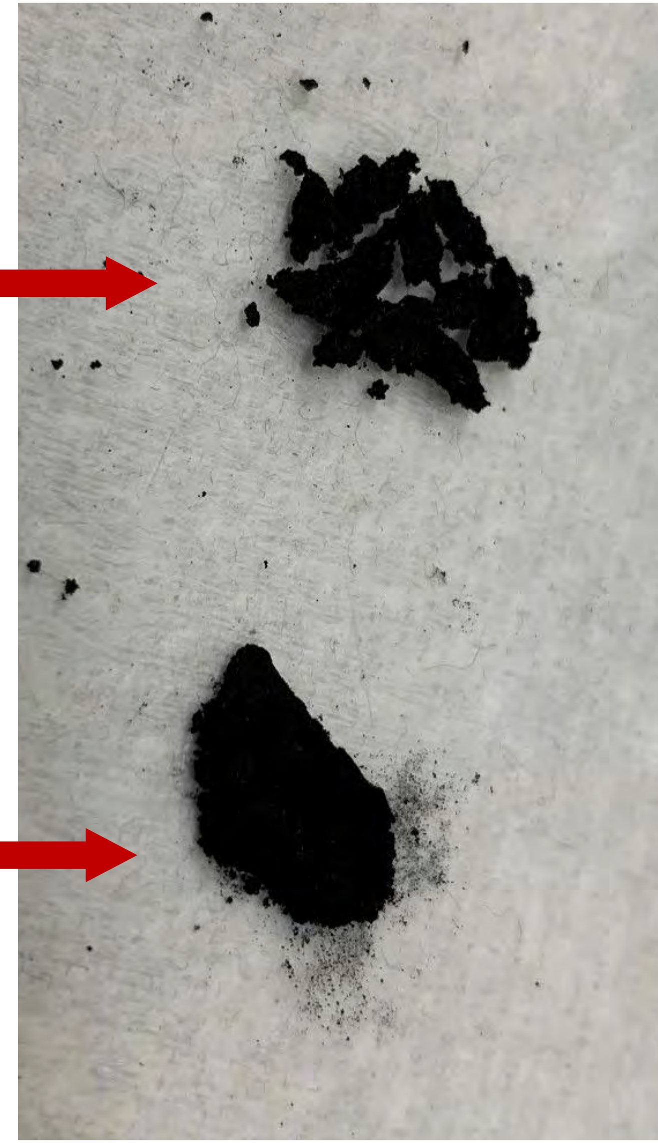
A. The system has been experimentally demonstrated in a proton reactor with a paste electrode

- Paste electrode made by mixing activated carbon from phenolic resin particles in a 1 M sulphuric acid electrolyte - limiting case of a slurry electrode with a near maximum density of suspended particles.
- Paste electrode was charged with hydrogen in a proton reactor at 1.8 V
- Paste dried by blowing argon through for 30 min it so that it returned to near powder consistency, and left in dried state for nearly a day.
- Liquid acid added again to return the electrode to a paste
- Proton reactor was discharged to produce electricity.

Storage of H in dried powder



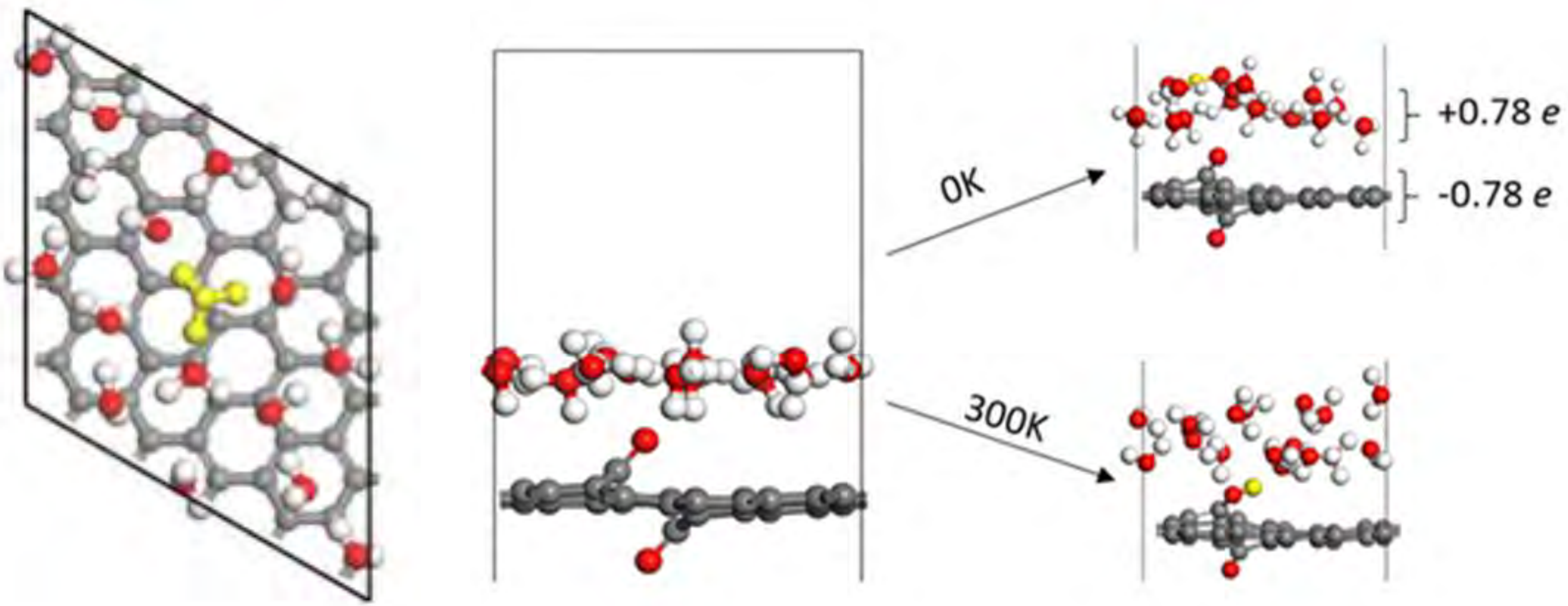
- Around 60% of the hydrogen stored in the electrode after charging was recovered.
- Approx. 20-25% of the H storage in the form of electric double layer capacitance that would not be retained after liquid electrolyte removal
- Hence, overall retention of hydrogen was 75-80%, a promising initial result.



Dried powder

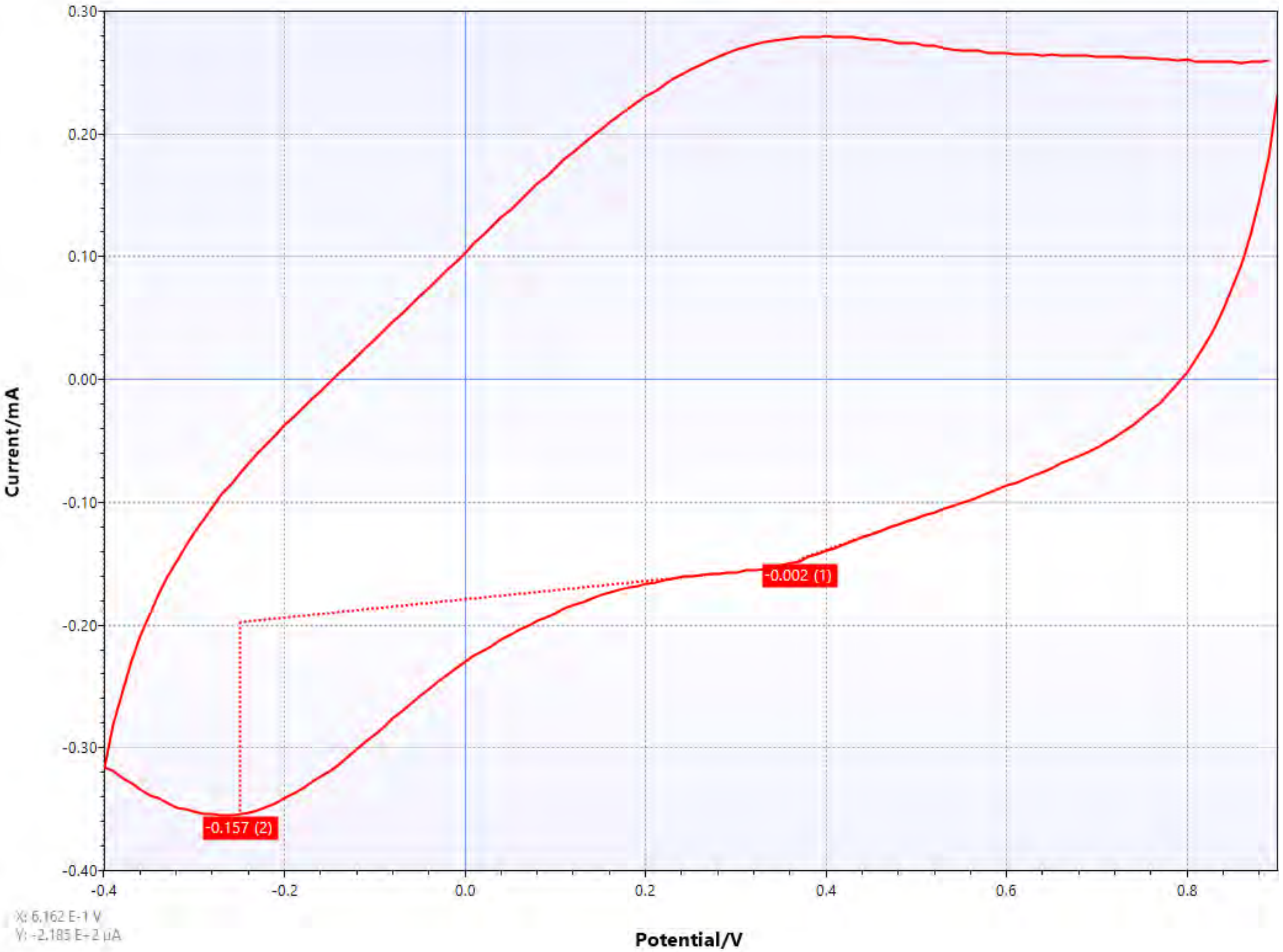
Original powder

B. Molecular modelling (DFT) has shown C…H bonds when hydronium reacts with negatively- charged carbon surfaces



- Carbonyl group on graphene (-1e) with H_3O+ atop
- Also occurs with epoxy group, and graphene surface without O

C. Cyclic voltammograms of activated carbon from phenolic resin in acid electrolyte have shown clear signs of C…H bonding



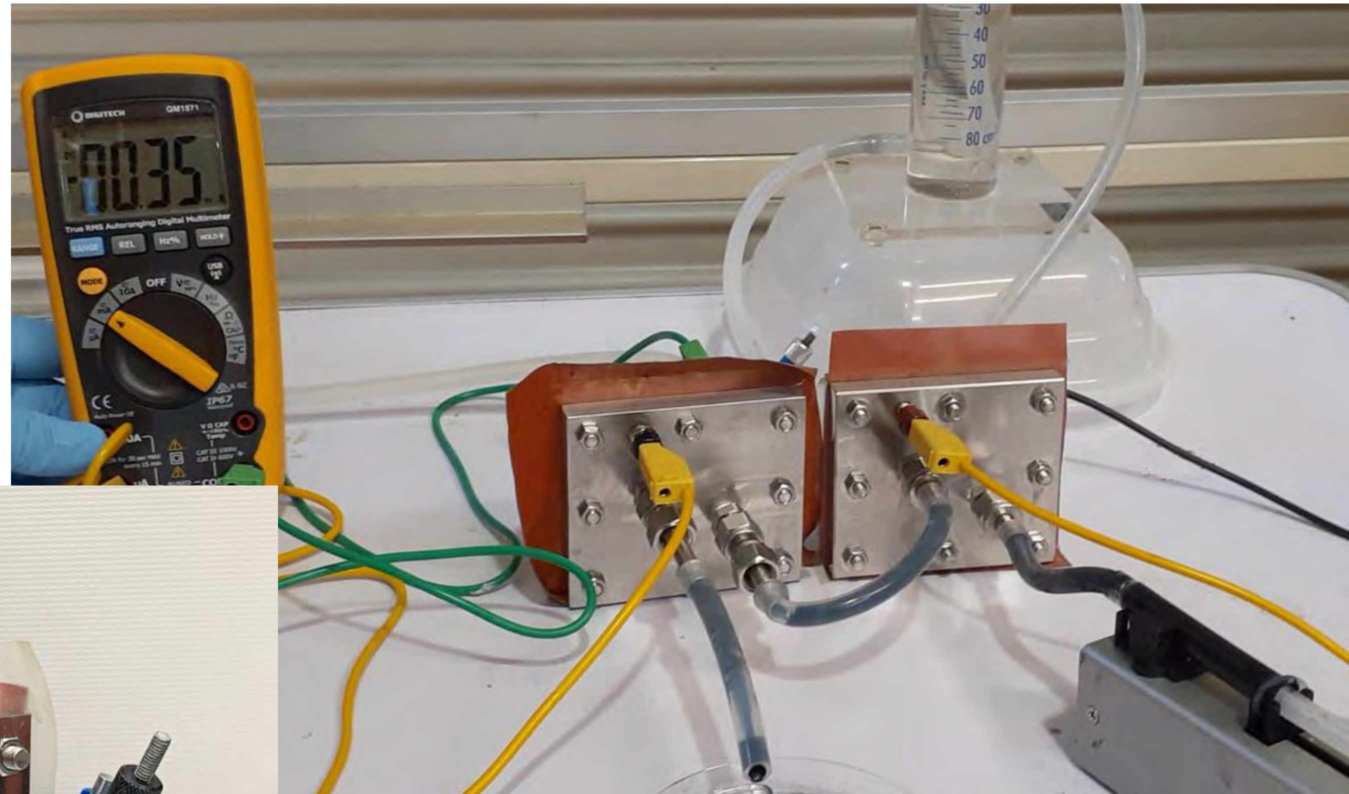
Scan rate 2 mV/s
1 M H_2SO_4 electrolyte

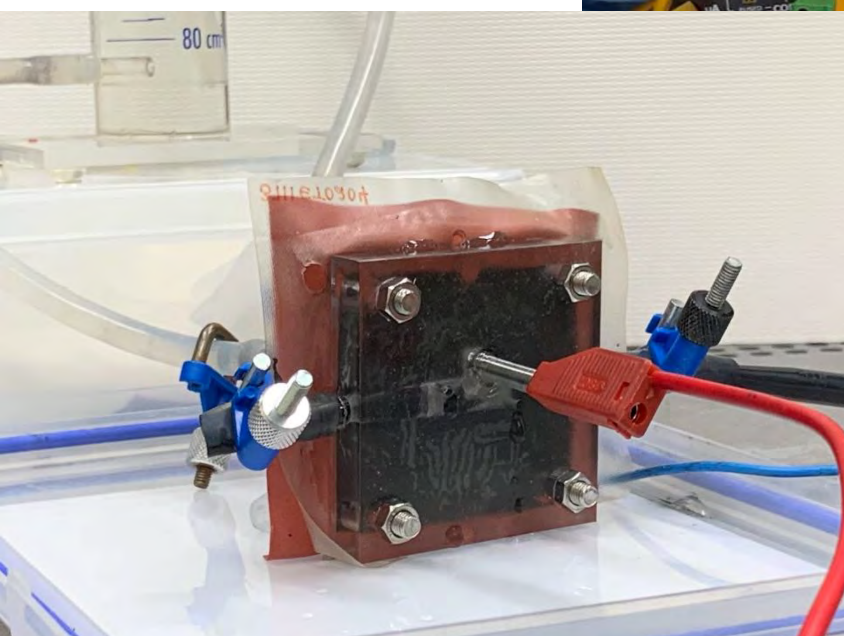
Next steps

Experiments on aC PR to identify form(s) of C…H bonding

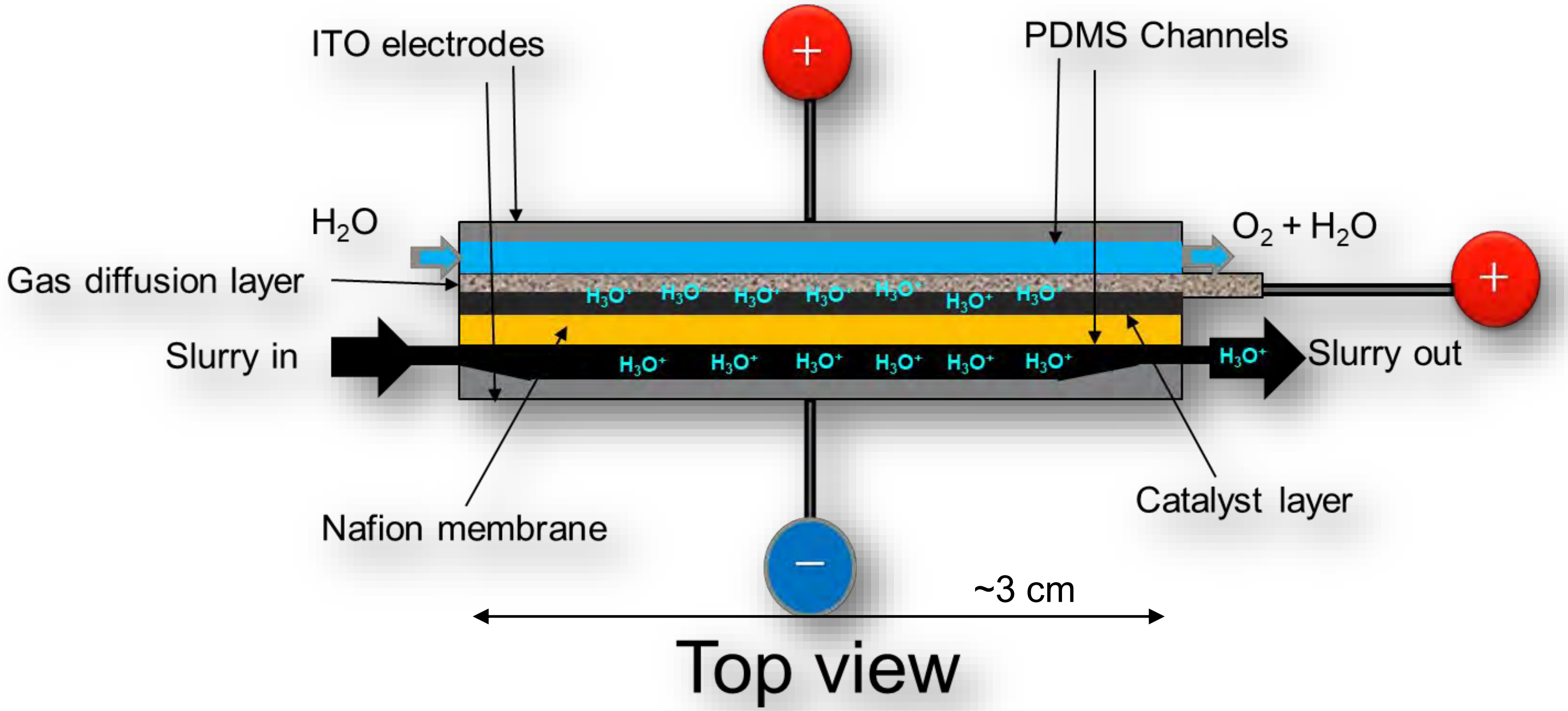
- Key questions:
  - Are oxygen functional groups involved? If so, which ones?
  - Is there any direct C-H bonding?
- Techniques being used:
  - Elemental (CHNO) analysis
  - X-ray photoelectron spectroscopy (XPS)
  - Raman spectroscopy
  - Temperature Programmed Desorption

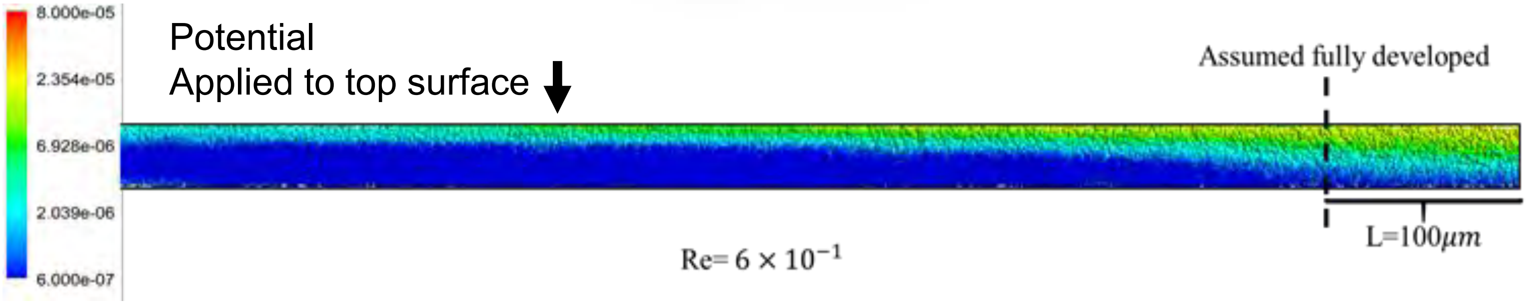
Design and testing of flow-in and flow-out proton flow reactor with paste electrode





Design and testing of microfluidic proton flow reactor





Electric potential distribution at different Reynolds numbers, for a 10 vol.% slurry.
Different colours represent the magnitude of obtained electric potential (V). FLUENT+DEM simulation

Final milestone

- Aiming for experimental demonstration of technical feasibility of all main processes in the proton flow reactor system
- Convert Provisional patent (Australia) for the Proton Flow Reactor System

Provisional Number	**2020902128**
Priority (Filing) Date	25 June 2020
Title	Proton Flow Reactor System
Applicant(s)	Royal Melbourne Institute of Technology

  to full patent before end of project

- Milestone 3 (Final): due 19 August 2021