<u>**Application 2072**</u>

Neutron imaging for Air Cooled Open cathode fuel cells

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Background:

Polymer electrolyte fuel cells (PEFCs) are among the most promising energy conversion technologies for a broad range of applications, and in recent years have shown tremendous advances in terms of performance and durability, with wide-scale commercialisation imminent. However, new techniques are sought to optimise performance by understanding the internal workings of these devices. Understanding aspects of thermal and water management is of particular interest as they have a profound effect on both PEFC performance and durability.

Research challenge:

One of the most crucial areas prohibiting the widespread commercialisation of fuel cells is their lifetime performance. Water distribution is amongst the most important, and yet least understood mechanisms of performance loss, creating uneven current density and temperature profiles. Over the past 3 years, the authors have led multiple investigations in PEM fuel cells, coupling impedance and temperature measurements [1], revealing for the first time global membrane dehydration, with an increase of the overall ohmic resistance, at high current density on air cooled, open cathode PEM fuel cell stacks; the authors have also reported increases of the overall temperature and overall ohmic resistance while the stack is operated in dead ended anode mode [2] for an extended period. Temperature and current density are intrinsically interrelated, especially in self-heated systems, and define the electro-thermal performance map (see Fig. 1)[2]. Water distribution has previously been investigated [3,4], using neutron radiography in particular, with world-leading work conducted at SINQ.

In tandem to our ongoing efforts in localised fuel cell measurements, we propose to use the unique benefits of neutron radiography to explore the role of water in creating these distributions, with these bespoke, and highly instrumented fuel cell devices. A recent investigation at PSI has enabled us to reveal the hydration / dehydration of the cell on the air cooled stack (Figs 2-3) as a function of the current density and cooling flow rate, and also highlighted that the cell could be imaged in the in-plane orientation (fig. 4).

Proposed experiments:

In these experiments we will use the same air-cooled, open cathode fuel cell design, with fans providing cooling and oxidant to the air channels tested in the preliminary neutron imaging experiments; however, a number of improvements will be made to enhance the setup. Firstly, to ensure the success of these experiments and offer full visibility of the PEFC active area to facilitate imaging and analysis, isolation of the PEFC current collectors will be achieved using a PTFE sheet (0.25 mm thick) instead of the nylon frame visible in the preliminary neutron imaging results (fig 2). A modified fan cowling will furthermore be constructed to allow in-plane neutron imaging across the cell. Finally, a second S++ sensor plate will be incorporated into the test stack to allow simultaneous mapping of the temperature, current, voltage and impedance distribution of the PEFC under operation for the first time.

The proposed experiments will focus on three aspects not studied (in the first visit):
1. In-plane neutron imaging of the cell behaviour under various current, temperature and purge regimes to elucidate the anode / cathode water balance under the air-cooling channels combined with local cell temperature, current, voltage and impedance mapping to correlate performance with water balance.

2. Through-plane neutron imaging of the cell behaviour under various current, temperature and purge regimes combined with local cell temperature, current, voltage and impedance mapping to correlate performance with water content.

3. Degraded cell condition – neutron imaging of cell behaviour under various current, temperature and purge regimes, having undergone moderately severe degradation of (i) cathode catalyst, (ii) anode catalyst and / or possessing membrane pinhole(s).

Expected Results:

The in-plane study will elucidate the location of the liquid water on the anode / cathode and track down back-diffusion and electro-osmotic drag, particularly in dead-ended operation. Studying the cell, in through-plane, at different stages of its lifecycle will enable understanding of how the water content is affected by material / membrane degradations.

Finally, characterising catastrophic failures, using the localised THDA and impedance to monitor precisely the performance decay, will show how the water content is affected, and also will provide routes to avoid the failure depending on the response (increase / decrease the water content).

This will also be used to validate COMSOL and CFD models of PEFC performance.

References:

1.Meyer et al. J Power Sources, 2014. Submitted, 2. Q. Meyer, et al, J. Power Sources 254 (2014) 1. 3. Kramer D, et al. Electrochim Acta 2005;50:2603–14. 4 Boillat P, et al. Electrochemistry Communications 10 (4), 546-550 5. Oberholzer P, et al. J Electrochem Soc 2012;159:B235.