Application 2058

Investigation of the water distribution, coupled with current density and temperature mapping

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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 the performance and durability.

Research challenge:

One of the most crucial areas prohibiting the widespread commercialisation of fuel cells is their lifetime performance – amongst the most important, and yet least understood mechanisms of performance loss is uneven water distribution, 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] (see Fig. 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 [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 been investigated [3,4], using neutron radiography, in particular with world-leading work conducted at SINQ. However, if the overall temperature has been altered and its effect on the water content has been measured [5], little is known on the effect of localised water distribution, on the current density and temperature distribution on localised scale; furthermore, the optimum hydration level, on a self-heated cell, leading to the lowest membrane resistance remains unknown. A novel PCB sensor plate has been used, in order to capture the localised current density, temperature and impedance response, and revealed significant distributions in steady state and also through transients in dead ended anode operations (Fig. 2). 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, highly instrumented fuel cell devices.

Proposed experiments:

We will use an air-cooled, open cathode fuel cell stack, with fans providing cooling and oxidant to the air channels. Neutron radiography will be achieved in perpendicular and/or parallel orientations, while the fuel cell is under load, coupled with simultaneous current, temperature and impedance mapping. Two sets of experiments will be achieved: firstly, the water content will be captured from open circuit potential to limiting current density, in steady state condition, in order to capture membrane hydration and dehydration, with respect to temperature and current density. Secondly, transient operations in dead ended anode mode will enable us to capture the evolution of water content, and correlate it with the localised current density and temperature gradients observed in dead ended (Fig. 2). We are requesting three days of beamtime.

Expected Results:

These experiments will enable us to elucidate the changes in water content within air cooled, open cathode fuel cell stack, and to determine the optimum hydration level leading to the lowest localised ohmic resistance. Localised variations of water content directly translates into resistive changes: enabling us for the first time to directly link current density and temperature with water content variations using neutron imaging. Flooded and dehydrated areas will be directly correlated with the subsequent current and temperature profile; this should provide an improved understanding of processes leading to membrane degradations, and enable to optimise future fuel cell generations. This will also be used to validate CFD simulations of PEFC performance.