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IMAGING WATER PROFILES IN ALAKALINE MEMBRANE FUEL CELLS

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* The Alkaline membrane fuel cells (AMFCs) belongs to the family of polymer electrolyte fuel cells (PEFCs) , i.e., it has a pseudo-solid-state electrolyte with the ionic functions being part of the polymer structure , requiring only hydration by deionized water to provide high ionic conductivity . The AMFC is, however, strongly distinguished from the mainstream PEFC technology developed to date , in that it's electrolyte conducts OH- ions , instead of the H+ ionic conduction of the mainstream PEFC ionomers. The main driver for AMFC development is the ability rendered by the benign, mildly alkaline membrane electrolyte, to operate with non-noble electro-catalysts and to use inexpensive metal hardware and membranes. These features make the AMFC technology an important potential key for earlier market entry, particularly in automotive applications. However, while extensive work has been done for more than 20 years on the science and technology of the "mainstream PEFCs" , based on proton conducting ionomers, a significant AMFC technology development effort started only 5 years ago and has been pursued practically exclusively by Cellera Technologies (Caesaria, Israel).

Perhaps the most important roadblock in the development of viable AMFC technology, has been the highly demanding challenge of effective water management in an operating AMFC. Two important distinctive properties in this regard , are: (i) water is generated at the fuel side (anode) of the AMFC, according to: $H2 + 2OH- = 2H2O + 2e$. Consequently, the removal of excess liquid water generated at the anode cannot be done by use of higher gas flow rates which would result in low utilization of the hydrogen fuel and, (ii) the cathode electrochemical process involves water as a reactant , i.e., water is being consumed at the cathode according to:

$1/2O2 + H2O + 2e = 2OH-$ and,therefore, the cathode side of the cell has a strong propensity to dry-out and, consequently , to lose electrode activity. A key for resolving this dual challenge of liquid water buildup on the anode side and , at the same time , water deficiency on the cathode side, can be provided, in principle, by membrane and electrode compositions and structures that enable a high fraction of the water generated on the anode to pass through the cell membrane and into the water consuming cathode . In addition

the gas flow field on the anode side, must be highly effective in removing liquid water, even under very low average flow rates which could secure high fuel utilization.

Developments at Cellera over the last 2 years resulted in significant improvement of the water management in the AMFC , while leaving, however, critical Ł??needs to knowŁ?Ł regarding the actual water profiles in the diffusion media (GDLs) and the flow field channels of an AMFC under some set of operation conditions. Such knowledge is critical for studying and, next, optimizing further key cell components and operation conditions. To date, water imaging in-situ has been performed extensively at the PSI neutron facilities for the mainstream (proton conducting) PEFCs and we propose here a first comprehensive set of experiments where such imaging is to be done for a newly developed type of PEFC Ł?? the alkaline membrane fuel cell.

Great benefits can be derived from upgrading of further AMFC development by the use of detailed knowledge of water distribution in the GDLs and flow channels as function of the most important key operation parameters , including: cell current under stady state and under start-up conditions, stack temperature and temperature distribution as determined by the air cooling mode applied , the nature of GDLs employed, the flow field materials (including surface coats) and overall flow field design , the nature of the ionomeric membrane and thickness and composition of catalyst layers.

Our first specific targets in this proposed neutron imaging project, will be to establish suitability of our metal hardware (no significant problems expected) and next image the water profile as function of steady state cell current, using front view geometry with proper flow field geometries to distinguish between the anode and cathode overlapping water profiles. We would plan to follow next the variation of excess water buildup in the AMFC anode flow channel and GDL , as well as the degree of any liquid water in the cathode GDL, over long cell operation times using our presently preferred flow fields and mode of operation. This latter mode includes operation under dead-ened anode conditions , using only very brief liquid purging perturbations. How effectively the anode can be kept water free in the shorter term as function of the purge duty cycle and , next, over the longer haul with such mode of operation which ensures high fuel utilization, is a key question we hope neutron impaging will help to answer.

In summary, special features of the AMFC technology and recent strong advancements in demonstrated AMFC performance , define it as an important potential key for earlier market entry of fuel cells , particularly in automotive applications. A remaining significant technology barrier is effective water management, challenged particularly badly in the AMFC by the generation of water on the fuel side and consumption of water on the other side of such cells. This barrier stands in the way of raising the power density of the Platinum-free AMFC at the typical temperature of operation (around 60degC) closer to the level obtained with PEFCs based on proton conducting ionomers. Water imaging in the operating AMFC, as proposed here to be done at PSI, should be of great help in climbing this technology development hill , based on work which also has significant additional merit from scientific perspective.

***We request 5 days of beam time for first part of our experiment