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High Temperature PEM FCs Based on Advent TPS® Technology

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High Temperature PEM Fuel Cells (130˚C-200˚C) offer the distinct advantages of high CO tolerance, enhanced kinetics on both electrodes, easier thermal management and the ability to use cell stack waste heat to boil water for the fuel processor increasing electrical efficiency substantially compared to conventional PEM Fuel Cells. The selection of the components of a fuel cell stack is very critical for the efficiency and durability of the final product. Especially for stationary applications-for example distributed CHP (combined heat and power) systems- a lifetime of at least 40,000 hrs with minimum degradation, is required.

Fuel cell components such as electrocatalyst, catalyst support, microporous layer, membrane, gaskets, bipolar plates are of great importance. The MEA is the core part of the stack and should have specific properties to withstand the strong conditions during the fuel cell operation. The polymer material should possess good mechanical, thermal, chemical and oxidative stability, high glass transition temperature and high proton conductivity while the MEA should possess good mechanical stability, long term chemical stability under continuous operation and cycling conditions and small voltage drop [1-3].

Advent Technologies has developed high temperature polymer membranes based on aromatic polyether polymers and copolymers bearing pyridine units based on the idea of creating acid-base interactions so as to acquire high proton conductivity (~10^{-1}S/cm) at temperatures ranging between 150° and 200°C [4-6].

The aromatic polyether backbone was chosen for its high mechanical, thermal and chemical stability while the incorporation of polar pyridine groups aids in the retention of phosphoric acid. High temperature polymer condensation polymerization is used while the insertion of pyridine groups into the polymer backbone was accomplished using pyridine containing diols which are designed and synthesized for this purpose.

Advent Technologies technical team has succeeded in developing different kinds of high temperature electrolytes, combining different monomers that result in tailor-made polymeric materials. All polymer characteristics are pre-screened in terms of their compliance to the desired properties and then MEAs are studied under cell conditions. At the same time, much work has been done towards the optimization of the electrode and the enhancement of electrode electrolyte interface. So far, Advent TPS® MEAs count two generation products which are the outcome of this chemistry and electrochemistry development efforts.

First generation Advent TPS® MEAs use main chain pyridine polymer as electrolyte.

These MEAs show excellent performance and chemical and mechanical stability at operating conditions for temperatures up to 200^{o}C using oxygen or air as the cathode feed gas. A power output of 0.125 W/cm^2 was measured at 0.2 A/cm^2 at 180^{o}C with H_2/air. In addition, excellent tolerance to 2% CO present in the hydrogen feed was also found.

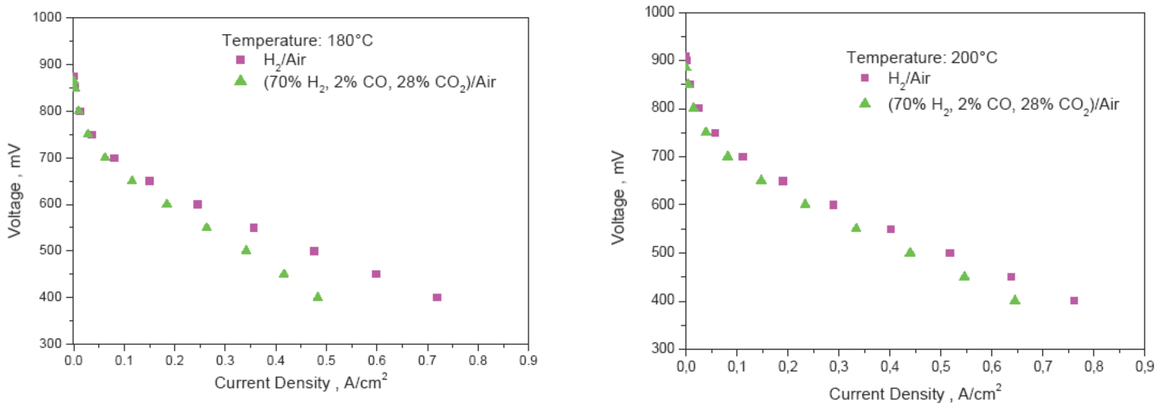

Figure 1: **Polarization curves of first generation Advent TPS® at 180^{o}C and 200^{o}C with H_2 or reformate gas and air, under ambient pressure.**

Finally, initial long term stability tests have shown extremely stable performance to more than 4000 hrs and 100 thermal cycles.

In the next generation Advent TPS® MEAs, side chain pyridines are inserted in the polymer backbone while optimized electrodes have been used.

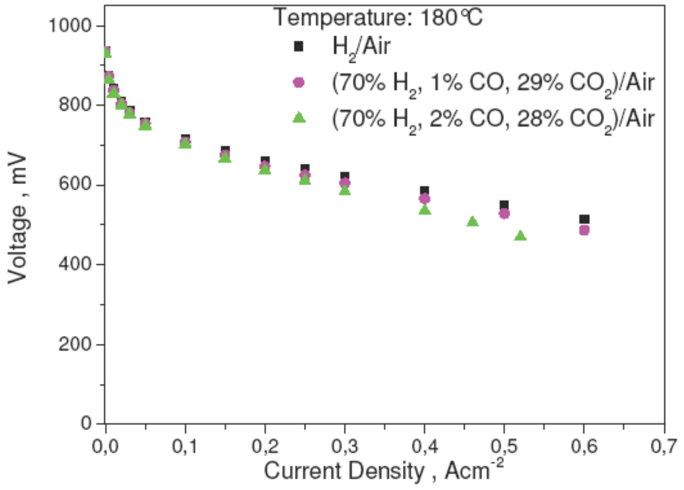

Figure 2: **Polarization curves of next generation Advent TPS® at 180^{o}C with H_2 or reformate gas and air, under ambient pressure.**

The presence of side chain pyridine has resulted in higher amount of H_3PO_4 retained in the membrane, while new electrodes improve the electrode/electrolyte interface. Those MEAs show decreased ohmic and polarization resistances that result in higher performance compared to the first generation products. A power output of 0.136 W/cm^2 was measured at 0.2 A/cm^2 at 180^{o}C with H_2/air.

Long term stability tests have shown equally stable performance to first generation Advent TPS® and over 130 thermal cycles.

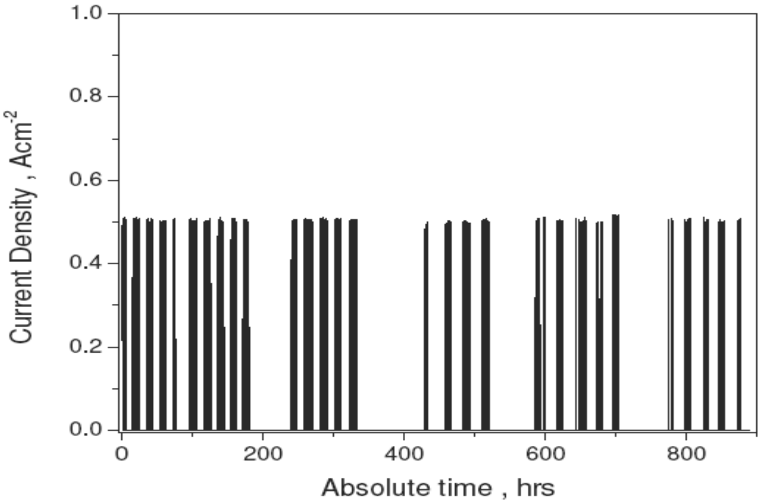

Figure 3

Additional alterations have been also made to the MEAs so that they meet the requirements of different reformate streams and applications. As an example, the absence or the percentage amount of humidity strongly affects the electrode and MEA performance. So custom made MEAs are designed and tested in order to fulfil the feed specification and be compatible with the stream coming from the fuel processor in each case.

Overall, Advent TPS® products show certain advantages compared to the competition due to the high mechanical integrity of the polymer membranes, their oxidative stability as well as the relatively low acid doping level proving them to be a reliable solution for HT PEM stacks for CHP applications.

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