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Recent Advances and Remaining Challenges for Automotive PEM Fuel Cell Membrane Electrode Assemblies and Components

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PEM fuel cell systems employed as the primary power source for automotive applications provide the most challenging demands for the membrane electrode assembly (MEA) and its constituent components. Targets for performance, lifetime and cost for widespread adoption of the technology are well-established [1-2]. MEA power density performance is crucial but current targets of 1.0 Wcm^{-2} are now being attained at cell and stack demonstration level through a combination of advanced components, such as the use of very thin (<20 µm) reinforced and highly conducting low equivalent weight (<800EW) perfluorosulphonic acid membranes, and elevated pressure operation. OEMs are now pushing to extend peak power density out towards 1.5 Wcm^{-2} at >0.6 V. At the same time costs need to be reduced, and in particular platinum loadings per cell need to be reduced from current practical levels of around 0.4 – 0.5 $mgcm^{-2}$ down to around 0.15 - 0.2 $mgcm^{-2}$, to meet the target of around 10g Pt for a PEMFC-powered vehicle. Improved cathode (oxygen reduction) catalysts are required that are some four-times more active on a mass basis (>0.44 Amg^{-1}Pt) than conventional carbon black supported nano-particulate platinum catalysts [3] to meet these targets.

Several catalyst design approaches have recently been reported to have kinetic mass activities in the range of 0.5 – 1.0 Amg^{-1}Pt - significantly higher than the established target. However, these catalysts have typically either been synthesized as model materials in tiny quantities and evaluated in the RDE, or at best prepared in a more practical form as a dispersed supported catalyst in very low quantities and evaluated in low area single cells. As yet none of these exciting new materials have found their way into practical MEAs. It is now of the utmost importance to move forward from a materials invention activity to exploiting these new catalysts in the real-world practical environment. Project INSPIRE, initiated in 2016 and funded by the FCH JU, has the challenging objective of taking several world-leading catalyst design developments, many funded by earlier FCH JU projects, and determining how best to incorporate these into catalyst layer structures that can deliver on their potential by operating at high current densities with minimal mass transport losses, and additionally scaling the best materials to sufficient quantities to provide material for MEA manufacture for multiple full-size stack demonstrations. Progress in INSPIRE on the further development of proven high activity materials, including nano-particulate Pt/alloy catalysts, de-alloyed Pt/Ni catalysts and extended thin film Pt and Pt/Ni core-shell catalysts, will be presented.

To meet the stack lifetime requirements of 6,000 hours operation with <10% peak power degradation over an operationally-relevant drive cycle, the MEA has to be robust to real-life situations, in particular to cell reversal, extensive start up/shut down cycles, operation over a wide range of temperature and relative humidity, rapid freeze-start and trace levels of carbon monoxide in the hydrogen fuel. Recent progress in MEA design to address these issues, through the use of more corrosion resistant catalyst supports, the incorporation of oxygen evolution reaction catalysts into the catalyst layers and improved catalyst layer and GDL design, will also be presented.

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