Nanofiber Fuel Cell Electrodes
II. In-Situ Performance and Durability Studies

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Introduction

The hydrogen/air fed proton exchange membrane (PEM) fuel cell is an attractive candidate for zero emission automobile applications due to its high power, portability, and quick start-up. However, two of the major challenges for mass-commercialization are cost and durability due to the usage of Platinum (Pt) and Carbon (C), respectively. Pt on high surface area carbon is still a catalyst of choice for an automotive application owing to their high performance.

Two potential strategies to reduce the catalyst cost are either to significantly lower the loadings of Pt / precious group metals (PGM) by using alloys, core shell catalyst[1] or to use non-precious group metal (non-PGM) catalysts such as metal-nitrogen-carbon catalyst[2]. These technologies are very attractive candidates for cost but may not meet automotive durability targets. Cathodes with low Pt loadings (up to 0.15 mg_{Pt}/cm^2) using conventional Pt on high surface area carbon have demonstrated reasonable performance and durability[3]. The study suggested that lower loaded Pt cathodes are definitely feasible from a power-density perspective but start-stop durability needs to be improved.

Carbon corrosion during start up and shut down can be mitigated at the material level by using graphitized carbon or non-carbon supports. However, due to the lower surface area for these stable materials, fuel cell performance can be compromised in the case of low Pt loaded cathodes.

Another potential strategy to improve the start-stop durability for carbon-based catalysts can be the use of different carbon and catalyst structures such as buckyballs, nanotubes or nanofibers. Nanofiber catalyst layer fabrication using Pt on carbon catalyst by electrospinning technique has been successfully demonstrated earlier[5].

The objectives of this study are to evaluate and analyze electrospun nanofiber electrodes for performance and durability under automotive-relevant durability potential cyclings. Efforts are also being made to evaluate an effect of different carbon supports on durability with nanofiber structure.

Experimental

Nanofiber electrodes with approximately $0.1mg_{Pt}/cm^2$ target loadings were fabricated at Vanderbilt University by electrospinning[5]. Conventional spray-coated electrodes with the same loadings were fabricated separately at Nissan. Membrane electrode assemblies (MEAs) were prepared by hot pressing a spray coated Pt/C gas diffusion electrode (GDE) as an anode, an electrospun nanofiber electrode with gas diffusion layer (GDL) as a cathode, and NRE211 as an electrolyte. After initial conditioning and beginning of life (BoL) iV performance measurements, durability is evaluated using Nissan start-stop cycling (carbon corrosion) and load cycling (Pt dissolution) protocol. CO_2 formation during potential cycling at the cathode is also monitored real-time[6]. The BoL and end of life (EoL) performances of the nanofiber electrodes after durability cycling are compared with conventional spray-coated electrodes.

Results

The BoL iV performance of nanofiber electrode MEAs was found to be slightly less compared with spray-coated cathode MEAs with the same Pt/C catalyst for similar Pt loading. Potential loss analysis showed that the discrepancy in performance is mainly contributed by the larger mass transport losses for nanofiber electrodes under 100% RH condition. In contrast, a significant improvement in EoL performance under 40% RH after start-stop cycling was observed for the nanofiber electrode over the spray-coated electrode as shown in Fig. 1. These results clearly exhibit the durability advantages of the nanofiber structure with less carbon corrosion during start-stop potential cycling up to 1,000 cycles. Corrosion resistance can be further increased by using catalysts with Vulcan support. These encouraging results show that even with the use of the same Pt/C catalysts, the durability of the cathode can be improved with a modified electrode structure such as a nanofiber network.

Additional experiments and more detailed analysis are ongoing. The effect of durable carbon supports will be further explored. Detailed analyses using gas transport resistance measurements will also be performed to understand the gas transport process in nanofiber electrodes[7]. CO_2 formation for nanofiber electrodes with various catalysts will also be detected and quantified during potential cycling.

References

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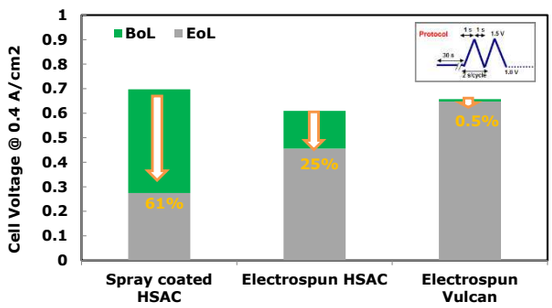

Figure 1. BoL and EoL cell potential @0.4A/cm^2 and % of performance loss comparing conventional electrode and nanofiber electrode MEAs (Cathode loadings are ~$0.1mg_{Pt}/cm^2$) under an accelerated start-stop test (iV measurement condition: H_2/Air, $1bar_g$, 40% RH, 80°C)