Investigation of Water Transport in Perforated Gas Diffusion Layer by Neutron Radiography

Zijie Lu[1], James Waldecker[1], Xingbing Xie[2], Ming-Chia Lai[2], Daniel S. Hussey[3], and David L. Jacobson[3]
[1]Ford Motor Company, Dearborn, Michigan 48124
[2]Wayne State University, Detroit, Michigan 48202
[3]National Institute of Standards and Technology, Gaithersburg, Maryland 20899

The gas diffusion layer (GDL) with integrated microporous layer (MPL) plays a pivotal role in fuel cell water management and gas transport. A number of works have demonstrated that the cracks in the MPL serve as the preferential water transport paths and improve water management. However, these cracks are not engineered, but are randomly formed during the drying process. In this study, a laser perforation technique is applied to engineer holes with controlled size and pattern in the GDL, particularly in the MPL. The specific perforation pattern reported in this work is the square lattice distribution, which comprises 100 µm diameter holes spaced 1 mm apart, and which penetrate only the MPL. The effects of the perforation treatment on water transport and fuel cell water accumulation are investigated.

Water breakthrough in the baseline and perforated GDLs were visualized by neutron radiography in a specially designed breakthrough cell. In this cell the GDL edge was sealed with Rose's metal which has low melting point (100 °C) and is transparent to neutrons. The neutron images were recorded while the water (capillary) pressure increases till breakthrough occurs. In the non-treated GDL, water breaks through cracks in the MPL, leading to the irregular water breakthrough due to the random distribution of MPL cracks (Fig. 1). On the contrary, the regular distributed perforation in the treated GDL produce a more uniform water breakthrough (Fig. 1). The perforated GDL also showed much lower breakthrough pressure, 9.5 kPa for perforated GDL compared to about 25 kPa for the baseline, due to the lower resistance for water transport in the perforated holes. This uniform water breakthrough induced by GDL perforation is expected to have positive effect on fuel cell water transport and thus performance. For example, the water accumulation at the catalyst layer/MPL interface due to the high resistance for water transport in the MPL, which has been recognized as a major source of mass transport loss, could be significantly reduced by the engineered paths.

The in-situ fuel cell water distribution was measured in the NIST high resolution fuel cell under neutron beam. The perforated GDL was employed only on the cathode where the performance decrease due to liquid water blockage and the resulting insufficient oxygen concentration is more pronounced. The perforated GDL displayed higher performance at both cool, wet condition (T_{cell} = 40 °C and RH = 100%) and hot, dry condition (T_{cell} = 90 °C and RH = 100% (an)/ 30% (ca)) (Fig. 2a). The water thickness in different fuel cell components under each channel was calculated to quantify the water distribution variation over the entire component. Fig. 2b shows that the laser perforated GDL produces more uniform water distribution in the CCM than the baseline GDL does (Fig. 2b). This might be related to the change of water breakthrough behavior caused by the laser perforation. Also significant from Fig. 2b is that the perforated GDL leads to less water accumulation in GDL. This is important because less water accumulation in GDL implies more open access for oxygen to diffusion through to reaction sites. The combination of uniform CCM water distribution and less GDL water accumulation indicates better water management in the laser perforated GDL and thus accounts for higher performance.

ACKNOWLEDGEMENT
The authors thank Dr. Jason Siegel for his assistance in experiment preparation and image analysis, Dr. Anna Stefanopoulou for her useful discussion and Mr. Eli Baltic for his assistance conducting the experiments at NIST. The work was supported by US Dept. of Commerce, NIST Radiation Physics Division, Director's Office of NIST, the NCNR, and DOE interagency agreement DE-AI01-01EE50660.

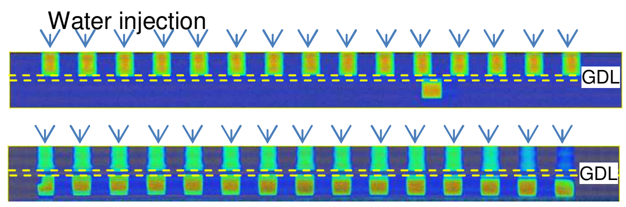
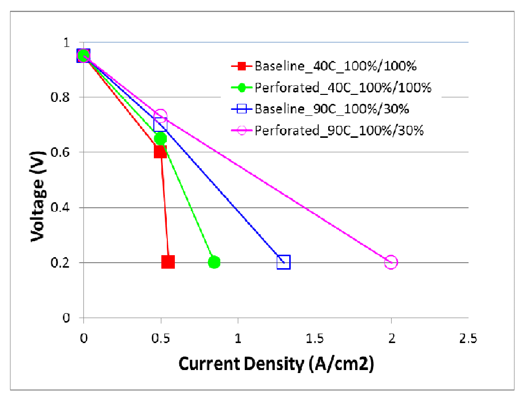
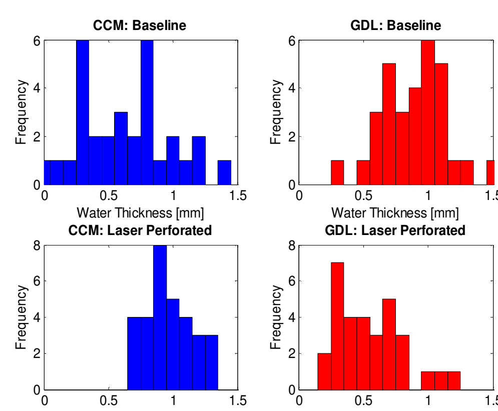


Fig. 1 Neutron radiographs of water breakthrough in the baseline GDL (upper image) and the laser perforated GDL (lower image).



(a)



(b)

Fig. 2 (a) Polarization curves of the baseline and laser perforated GDLs inside the NIST high resolution cell hardware; (b) Histograms of water distribution in CCM (left row) and GDL (right row) in fuel cells associated with baseline and perforated GDLs at current density of 0.5 A/cm^2 under 40 °C and 100% RH.