Estimation of Active Area Utilization in PEMFCs via Measured AC Impedance High Frequency Resistance

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PEM fuel cell systems for automotive traction applications have stringent requirements of cost, durability, efficiency, power density, and operational robustness. While significant progress towards commercial viability continues, further gains in the area, PGM, and volumetric-specific power densities will likely be required. Along with necessary improvements in the performance, durability and cost of the individual MEA components, improved areal utilization of the expensive membrane electrode assembly (MEA) is likely needed to achieve the longer term targets.

In the subsequent paper, we will present experimental results and simple analysis which suggests that under some operating conditions, the MEA areal utilization can be directly measured via typical AC impedance estimates of the MEA's ohmic (high frequency) resistance, and that decreased MEA areal utilization can be a very significant performance-reducing factor. This result provides insight into the frequent observation that typical Ohm's law correction does not explain the magnitude of the observed performance variation, most commonly observed under substantially subsaturated reactant humidification and attributed to combined increased PEM and electrode resistances and decreased through-plane electrode utilization (1).

Fig. 1 shows H_2/Air polarization curves measured as a function of cell temperature with completely dry gases. As the temperature rose above 75°C, the measured performance decreased and high frequency resistance (HFR) increased. This result was expected qualitatively due to dryout and resistivity increase of the PFSA PEM, as the calculated cell outlet relative humidity varied from 108% at the coolest temperature to ca. 45% at 95°C. Ohmic correction of the polarization curves (IR-Free V) revealed that PEM bulk conductivity decrease alone was insufficient to explain the observed reduced performance, as severe discrepancies between the IR-Free curves remained. After application of the area utilization correction (bottom right), all curves appeared to fall essentially on one line over the entire current density.

In a second example, performance of MEAs containing several different state-of-the-art experimental 3M 825EW PEMs was evaluated, with all other components fixed (Fig. 2) and with ca. 100% calculated outlet RH. Again, the measured ohmic differences between the MEAs were insufficient to explain the performance differences, and application of the area utilization correction resulted in very good agreement between all curves. Fig. 2 also shows that the measured area utilization, based on the ratio of measured HFRs, varies from 90-100% utilization at low current density and decreases to less than 60% at high current density. This analysis suggests that at ca. 1.5A/cm^2 (measured), the "active" region of the MEAs were producing extraordinarily high current densities of 2.5A/cm^2.

The area utilization correction was also applied to literature data for a Pt/C electrode based MEA operated at either saturated or highly undersaturated conditions. Ohmic correction, either taking into account just the PEM or the PEM and electrode resistances, resulted in appreciable residual performance variation, whereas the area utilization correction was largely explanatory.

More detailed discussions on the assumptions and limitations will be discussed.

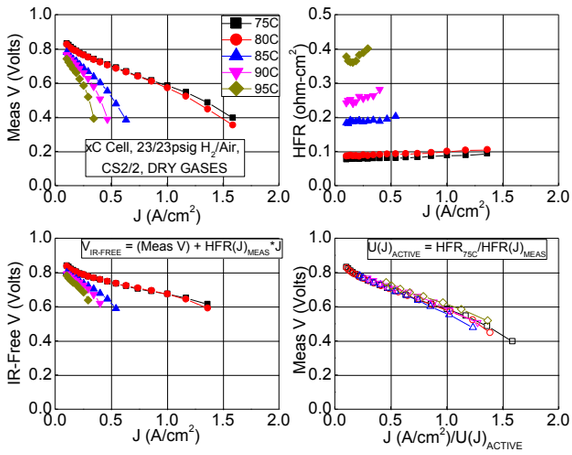

Fig. 1. Area Utilization Correction Applied to Single MEA Operated At Several Temperatures and MEA Humidification States. 0.15Pt/NSTF / 0.15Pt/NSTF, 3M 1000EW 35µm PEM, (2004 Technology).

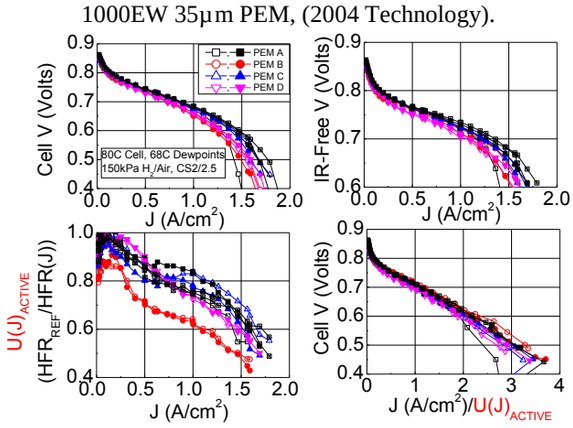

Fig. 2. Area Utilization Correction Applied to Numerous MEAs with Various 3M 825EW 14-20µm PEMs. 0.05PtCoMn/NSTF / 0.10PtCoMn/NSTF, 3M 2979 GDLs (2012 Technology). 4 PEM types, in duplicate.

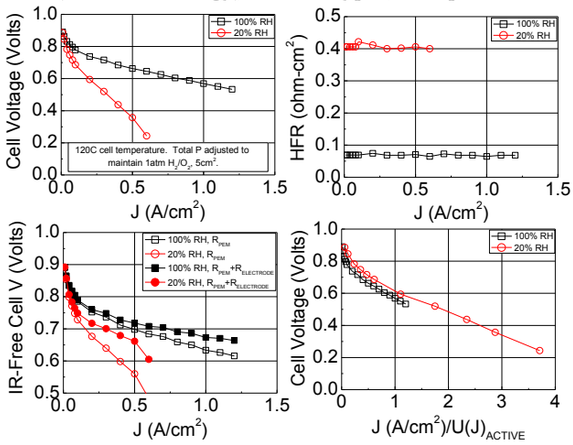

Fig. 3. Area Utilization Correction Applied to Pt/C MEA at Different Humidities (from Xu et al(1)). Ion Power 1.0mg /cm^2 PtRu/C / 0.3mg/cm^2 Pt/C, Nafion^{TM} 112.

REFERENCES

1. Xu et al., Electrochimica Acta **52** 3525-3533 (2007).

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