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Application Segmented Cell for In-situ Detection and Controlling the Stability of PEM Fuel Cell

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Water plays a critical role on the PEMFC performance, stability and lifetime. On one hand, water is needed to guarantee good proton conductivity of the membrane and active layers; on the other hand, the presence and accumulation of liquid water in the flow-field channels and/or electrodes gas porosities resulted in flooding of the electrodes [1-5]. A subtle equilibrium has to be controlled between membrane drying and liquid water flooding to prevent degradation and guarantee a stable performance of fuel cell.

At DLR, printed circuit boards (PCBs) with segments and internal measurement resistances have been developed to measure current density distributions both of single cells as well as stacks [5, 6]. Through investigation of current density distributions, the correlations between the current activities and humidity of fuel cell would be found. In the present work, we applied the segmented cell to find the correlations between the current instabilities and humidity of fuel cell. Thus, the countermeasure for optimization of water management of fuel cells would be found. Through controlling the humidity of anode (RHa) and cathode (RHc), the stability and performance of fuel cell would be improved.

Fig.1 shows the performance of PEM fuel cell at potentiostatic operation conditions at 80 °C. The humidification temperature of fuel cell is also set at 80 °C. Time-dependent oscillations of current would also appear. It is due to less water was produced and transported by electro-osmotic drag. Water electro-osmotic drag or low humidity operation caused a positive spike in cell current with respect to a stationary value, which may indicate a temporary improved performance. Increasing the humidity of anode and/or cathode to the optimal condition (increasing the humidification temperature to 85 °C in this case), the performance would improve and become stable. Furthermore, it was found if the humidity of the cell went back to the starting unfavourable condition, the performance became unstable again. Through controlling the humidity of fuel cell, the stability of that could be efficiently improved. The performance is reversible if adverse humidity conditions are temporarily applied. Similar phenomenon would be found at higher temperature (120 °C, Fig.1). The performance irreversibly changed when the humidity conditions of the fuel cell was modified. In this case, returning to favourable humidity conditions made the performance stable but an irreversible degradation associated with the adverse humidity conditions was observed. It may be due to the severe drying conditions, which caused irreversible membrane degradations.

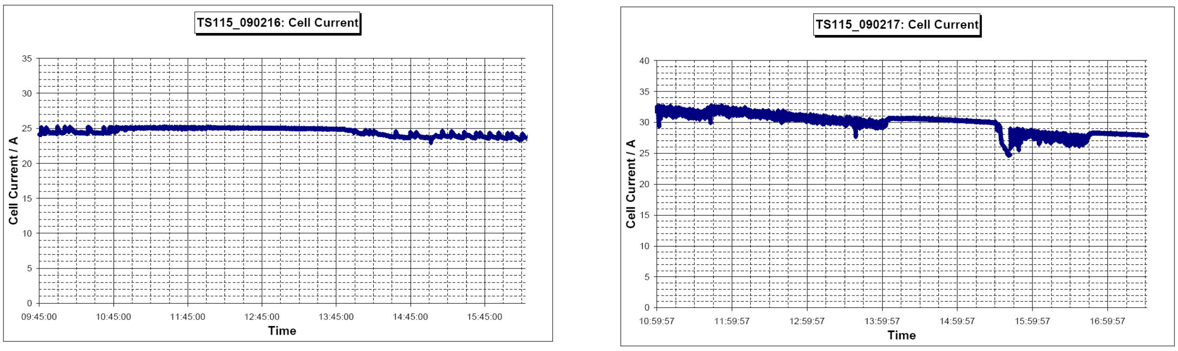

Figure 1: Improvement the stability of fuel cell at 80 °C (on the left side) and 120 °C (on the right side) by adapting humidity and observed irreversible degradation.

The stability of the fuel cell system was also dependent on the forced cell voltage, which was shown in Fig. 2. The cell was operated at 100 °C. At 700 mV, current was at lower value and no current peaks appeared (not shown in the figure). At 600 mV, the current showed variations in the range of 5 minutes. Decreasing the voltage to 500 mV, the current became unstable and the performance changed from the top to the bottom in less than one minute. It was apparently that water balance of the cell was affected by the forced voltage. The amplitude and the frequency of current peaks compared to the reference value were affected by the cell voltage. The lower the forced voltage, the higher rate of water would be produced. So it was difficult to stabilize the performance at higher current densities and fast change of performance would occur, which led to a higher fluctuation of current frequency.

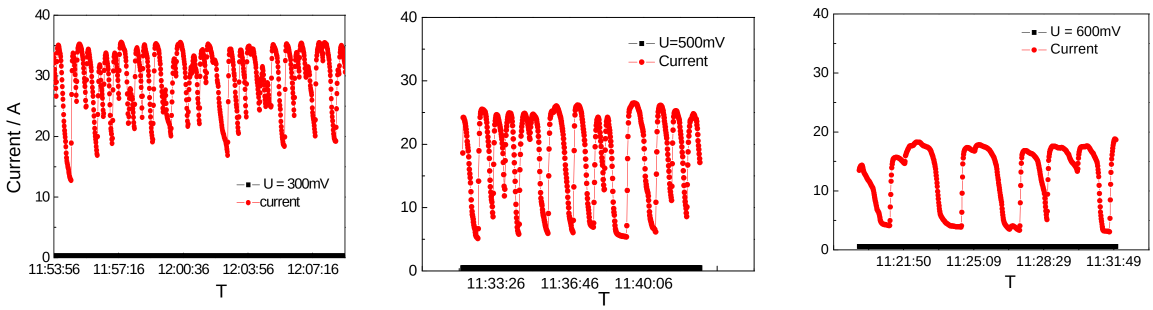

Figure 2: Frequency of current peaks increased with voltage decreased (under potentiostatic state). T cell = T humidification air = T humidification H_2= 100 °C; Pair = PH_2 = 2 bar.

Fig. 3a was the mapping of current density distributions at different stages (baseline or peak top) of the positive spike of the current. At different stages of current, the contour plot of current density distribution was similar (Fig. 3b). In the case of operating conditions where water flooding was expected, negative spikes in cell current compared to the stationary reference value was observed (Fig. 4a). The contour of current density distribution during the negative spike in cell current was much different to the one before and after the negative spike in cell current (Fig. 4b). In different stages of negative spikes of current, their current density distributions differed greatly. It might be due to the case that the flooding of water in the channel occurred and the liquid water accumulated in different location of the flow field, which would greatly affect the local current density distribution. When the operating conditions allow the liquid water to accumulate to some extent, severe water flooding occurred. The gas flow path would be temporarily blocked, giving rise to a negative spike in cell current [4]. The periodic build-up and removal of liquid water in the cell caused the observed fluctuations in cell performance. It was also found that at the stage current peaks up or current peaks down, the homogeneity of current density was less than the one at the stationary reference.

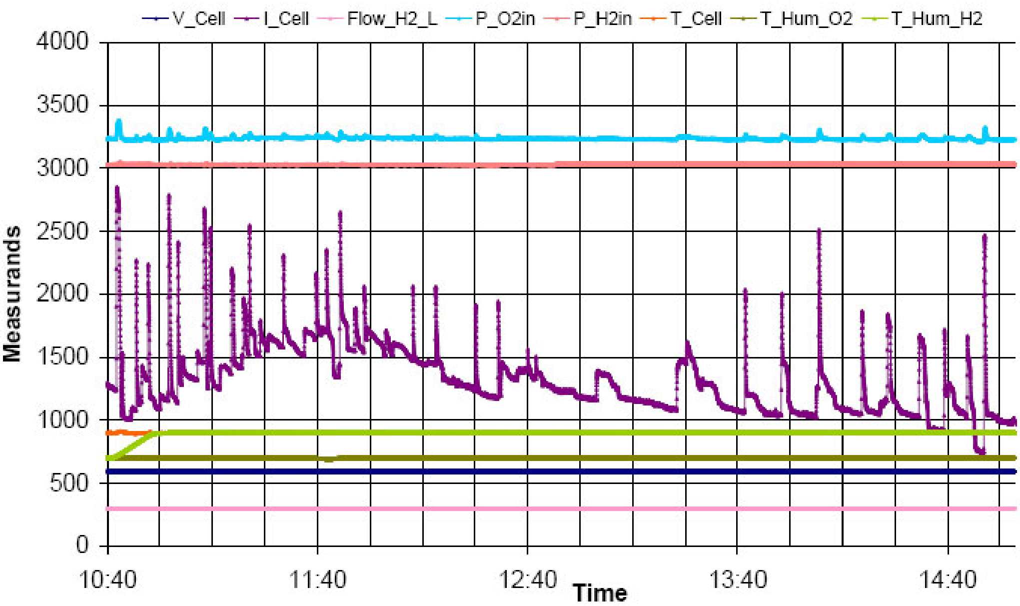

Figure 3a: Overview of operation parameters for the current peaks up.

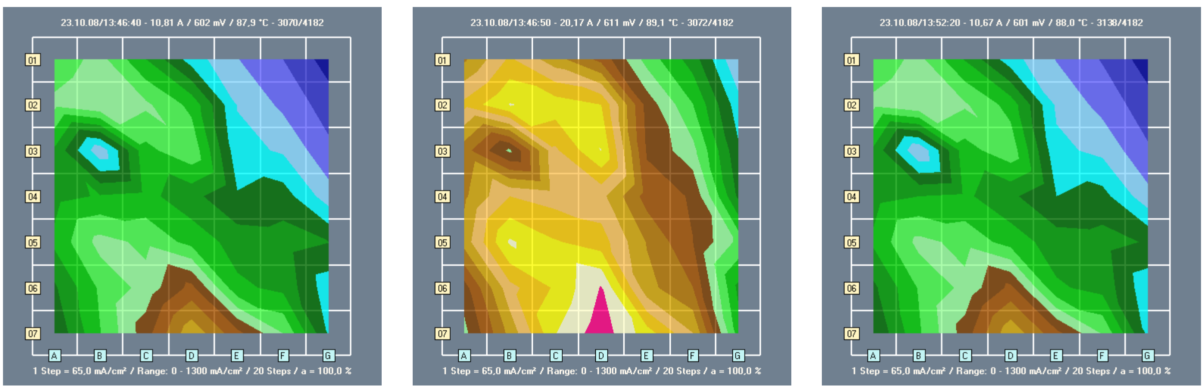

Figure 3b: Current density distribution of PEM fuel cell, before, during and after current peaks up.

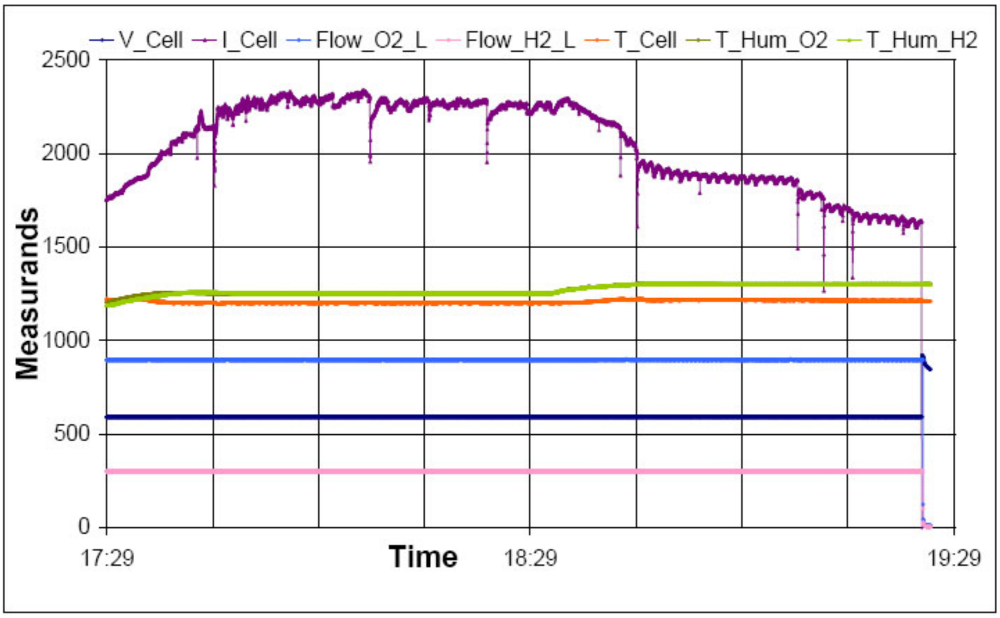

Figure 4a: Overview of operation parameters for the current peaks down.

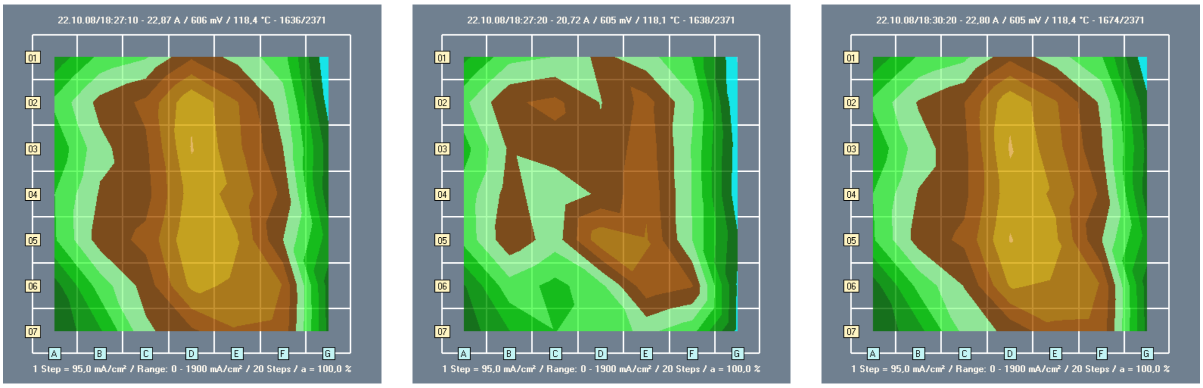

Figure 4b: Current density distribution of PEM fuel cell, before, during and after current peaks down.

In a summary, in certain operating conditions, the time-dependent oscillation of current (potentio-static state) at fixed voltage would appear. The periodic build-up and removal of liquid water in the cell caused fluctuation of the cell performance (positive or negative spike of current compared to the stationary value), causing unstable, unreliable and inconsistent cell performance. In the present work, we applied in-situ segmented cell technology to detect the current density distributions of fuel cell and thus found the correlation of that with the humidity of fuel cell. Controlling the humidity of fuel cell, the stability of fuel cell would be efficiently improved.

The stability of the fuel cell system was also dependent on the input voltage. The amplitude and the frequency of current peaks up are affected by the applied of voltage.

The current density distribution maps were similar in different stages of the spike up of current. But during the flooding stage, their current density distributions differed greatly. This behaviour was interpreted as indicating flooding in different locations of the flow field.

References

[1] Effects of hydrophobic polymer content in GDL on power performance of a PEM fuel cell, Chan Lim, C.Y. Wang, Electrochimica Acta 49 (2004) 4149-4156

[2] A review on PEM voltage degradation associated with water management: Impacts, influent factors and characterization, N. Yousfi-Steiner, Ph. Moc otéguy, D. Candusso, D. Hissel, A. Hernandez, A. Aslanides, J Power Sources 183 (2008) 260–274.

[3] J. Zawodzinski, C. Derouin, S. Radzinski, R.J. Sherman, V.T. Smith, T.E.Springer, S. Gottesfeld, J. Electrochem. Soc. 140 (1993) 1041.

[4] H. Li, Y.H. Tang, Z. W. Wang, Z. Shi, S. H. Wu, D. T. Song, J. L. Zhang, K. Faith, J. J. Zhang, H. J. Wang, Z. S. Liu, R. A. Abouatallah, A. Mazza, J Power Sources, 178 (2008) 103-117.

[5] Transient analysis of polymer electrolyte fuel cells, Y. Wang, C.Y. Wang, Electrochimica Acta 50 (2005) 1307-1315.

[6] Diagnostic tools for in-situ and ex-situ investigations of fuel cells and components at the German Aerospace Center, M. Schulze, E. Gulzow, K. A. Friedrich, P. Metzger, G. Schiller, ECS Transactions, 5(2007) 49-60.