Current Oscillations in PEFCs Operated with Saturated Anode and Dry Cathode Streams: An Electrochemical and Water Distribution Analysis

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Optimized water management in Polymer Electrolyte Fuel cells (PEFCs) plays a crucial role to achieving improved performance and extended durability. In this work, the transient response of PEFCs operated with saturated anode (RH_a = 100%, condensing conditions) and dry cathode ($RH_c \approx 5\%$) streams is examined by combining electrochemical and water distribution (neutron imaging) measurements. As shown in Figure 1, the cell response is characterized by sharp oscillations of the current (I) and high-frequency resistance (HFR), which are composed of two well differentiated processes. A fast increase of the current (ignition, $\Delta t \sim 10$ s) due to membrane hydration (decrease of HFR), followed by a slower decrease of the current (extinction, $\Delta t \sim 100$ s) due to membrane dry-out (increase of HFR). The experimental results show that such periodic behavior arises from the intermittent shedding of water droplets from the anode inlet chamber. As can be seen from the single-serpentine cell images shown in Figure 2 (counter-flow configuration), the eruption of water droplets into the anode flow field offsets the trend of the membrane to dry from the cathode. The ignition (or activation) front (1340 s < t < 1360 s) takes over from the anode inlet and propagates down the anode channel, increasing gradually the RH up to 100% in the entire anode compartment (and thereby hydrating the membrane). The preference of the system for the high-performance state is lost as soon as the liquid water supply from the anode inlet either stops or decreases significantly. Then, an extinction (or deactivation) front (1360 s < t < 1425 s) propagates from the cathode inlet, so that the membrane dehydrates down the cathode channel. This eventually leads to a low-performance state, which is in turn perturbed when the water input from the anode inlet becomes large enough again.

Figures

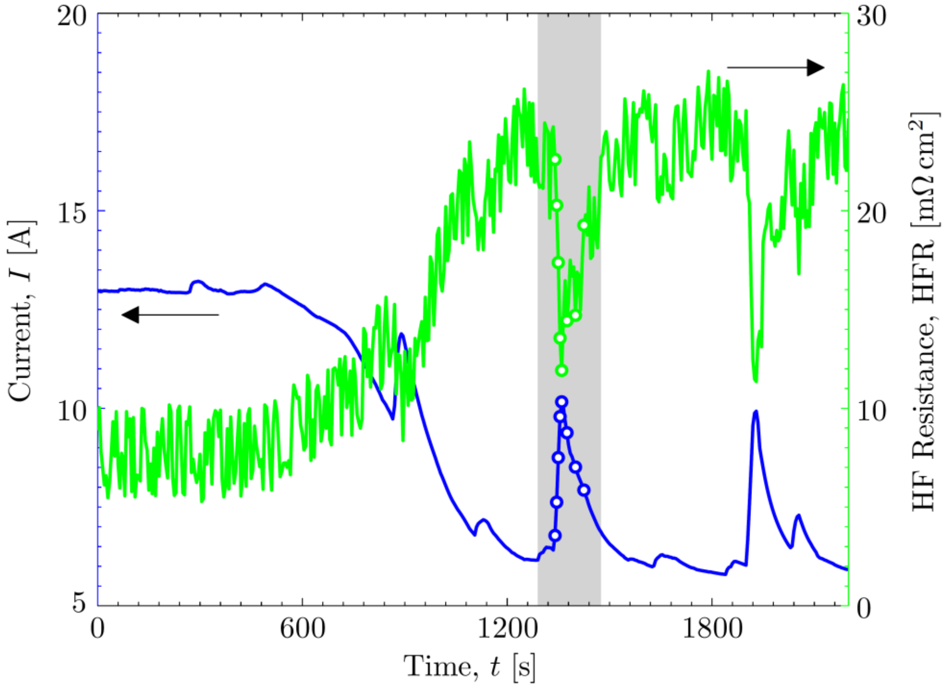

Figure 1: Variation of cell current, *I*, and, high-frequency resistance, HFR, as a function of time, *t*, after a change of relative humidity from $RH_{a/c}$ = 100/100% (c. c.) to $RH_{a/c}$ = 100 (c. c.)/5% at *t* = 0 (c. c. stands for condensing conditions). Components: SIGRACET® 25BC GDL, Nafion® 117 membrane. Other operating conditions: voltage (*V* = 0.6 V), anode/cathode inlet flow rate ($Q_{a/c}$ = 200/1100 ml/min), anode/cathode back pressure ($p_{a/c}$ = 1.5/1.5 bar), cell temperature (*T* = 80 °C), counter-flow configuration. Note that the global decrease of the current (increase of HFR) for *t*<1200 s is due to the initial decay of the water level in the cathode compartment. The data corresponding to the times shown in Figure 2 are indicated by hollow dots.

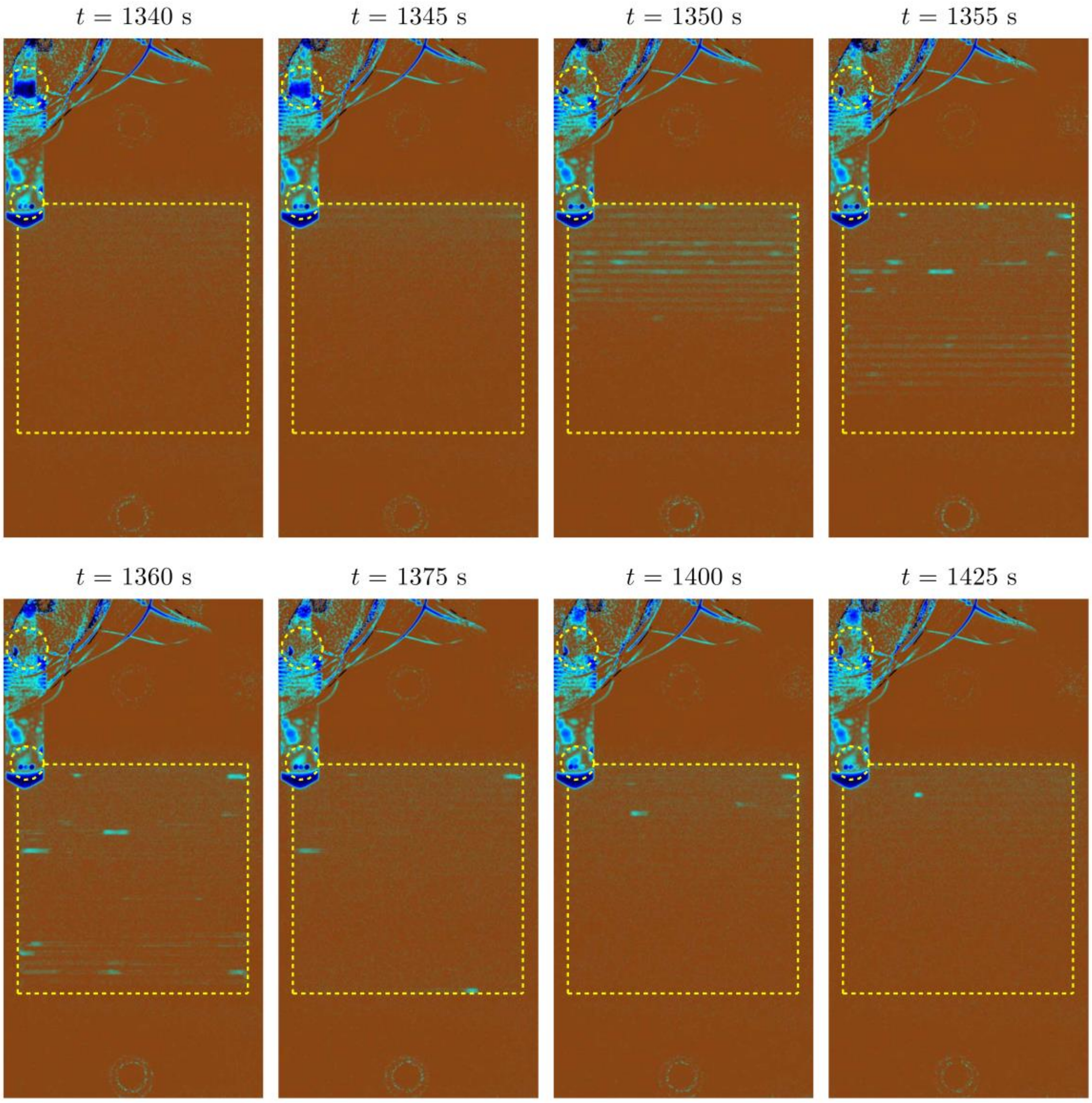

Figure 2: Liquid water distributions at different times during a cell current oscillation, as determined from through-plane neutron imaging measurements. The cell active area (5x5 cm^2) of the single-serpentine cell, as well as regions of interest of the anode inlet chamber from which liquid water is periodically erupted, are indicated by dashed yellow lines. The dry cathode inlet is located at the diametrically opposite corner to the saturated anode inlet. See caption to Figure 1 for details on operating conditions.