

# Polarization Behavior and Power Capability of Metal Hydride Electrodes and Cells at Low Temperatures

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## Introduction:

There has been an increase in demand for batteries having high power capability not only at normal room temperatures but also at cold temperatures down to  $-30^{\circ}\text{C}$ . Specific power levels of 1000-2000 W/Kg at normal ambient temperatures and 300 W/Kg at a temperature of  $-30^{\circ}\text{C}$  at 10 seconds pulse are required for future hybrid vehicle and 42V ISG automotive applications where the batteries must provide power not only for traction but also for starting the car. Significant improvement in power and rate capability of nickel metal hydride (NiMH) batteries was reported by OBC in the last few years<sup>(1-3)</sup>. To further improve the power capability of NiMH batteries, we studied the polarization behavior of the metal hydride electrodes with an emphasis on low temperature behavior. In this paper we will present the results on low temperature power from a cell basis, with particular emphasis on the polarization behavior of the MH electrode.

## Results and Discussion:

The polarization behavior of the metal hydride negative electrode at different temperatures is shown in figure 1. The ohmic free polarization curves shown in the figure are fitted to the polarization data using a model which included activation polarization ( $\eta_{act}$ ) and pore polarization ( $\eta_{pore}$ ), which is the ohmic polarization in the pore;

$$\eta = \eta_{act} + \eta_{pore}$$

At the current densities used in the figure (up to 1 A/g), concentration polarization is small and was therefore not taken into account.

Figure 2 shows the polarization contributions of the pore and activation components to the total polarization at  $-30^{\circ}\text{C}$ . At low polarization currents, the activation overpotential dominates the polarization of the negative electrode. At higher currents, the contribution due to ionic resistivity in the pores of the electrodes increases. This behavior occurs due to the fact that the activation polarization behaves in an exponential way at higher currents (Tafel behavior), while the ionic pore polarization has a linear dependency on current (ohmic behavior). The contribution due to the pore resistivity becomes even more pronounced at lower temperatures. Figure 3 summarizes the contribution of the different polarization components to the electrode polarization at different polarization currents and at different temperatures. The reason that the pore polarization becomes the dominant polarization at low temperatures is the different dependency of the two components; activation and pore polarization. At higher currents, the pore polarization increases faster with decreasing temperature compared to activation polarization. Examples will be shown where modification of the metal hydride alloy and to the electrode construction resulted in

a significant decrease in activation and pore polarization, which lead to significant improvement in cells power and low temperature performance.

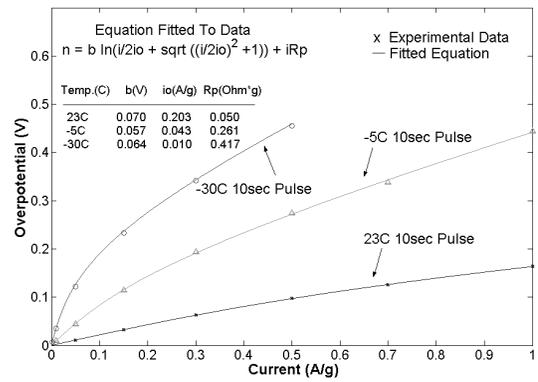


Figure 1: Overpotential Vs. Current at 80% SOC of AB5 negative at 23C, -5C, & -30C showing experimental data and Butler-Volmer fitted with the addition of pore resistance.

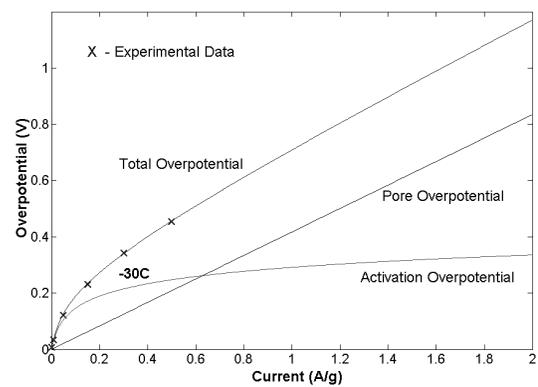


Figure 2: Overpotential contributions due to activation and pore resistance for AB5 electrode at  $-30^{\circ}\text{C}$  for a 10sec pulse.

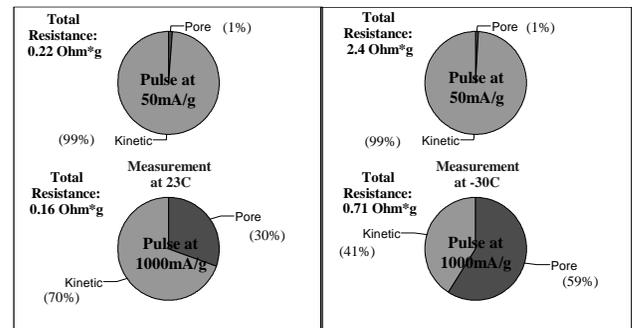


Figure 3: MH electrode pore resistance & kinetic resistance at different temperature & current using a 10sec pulse at 80% SOC.

## References:

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