State of Charge Effects on the Performance of Vanadium RFBs

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Vanadium Redox Flow Batteries (VRFBs) are now intensively studied with an eye toward commercialization [1-4]. Substantial progress recently has been made toward improving the VRFB performance via modifying electrodes, membranes, electrolytes and cell configuration. In addition, a range of basic studies of electrode kinetics, membrane properties, current distribution and other aspects probing the *in situ* and *ex situ* behavior of components and cells have been reported [5]. The majority of the cell studies reported focused on the behavior under situations corresponding to a high state of charge of the battery.

In this contribution, we move toward descriptions of performance under more realistic operating conditions. A VRFB operating as a grid storage system will likely be maintained at roughly 50% state of charge (SoC) during operation. The extent to which the system can be operated at very low state of charge has a significant effect on system economics. This has led us to begin studies as a function of SoC to isolate additional performance factors in the system.

To begin to illustrate the effect of SoC, in Figures 1 and 2, we show some typical polarization curves obtained with 100% and 50% SoC. Clearly, the SoC has a significant effect on mass transport aspects of the cell performance.

We recently integrated a reference electrode into the VRFB, enabling us to isolate the kinetics of each electrode. Using this approach, we have found that the positive electrode kinetics is strongly affected by the SoC at the compositional extremes. We speculate that this is associated with the presence or absence of a previously identified mixed-valence complex.

In the talk, we will elaborate on these results, using combinations of polarization and ac impedance data to further elucidate the effects of SoC. We will provide a detailed description of the physical causes of the observed effects.

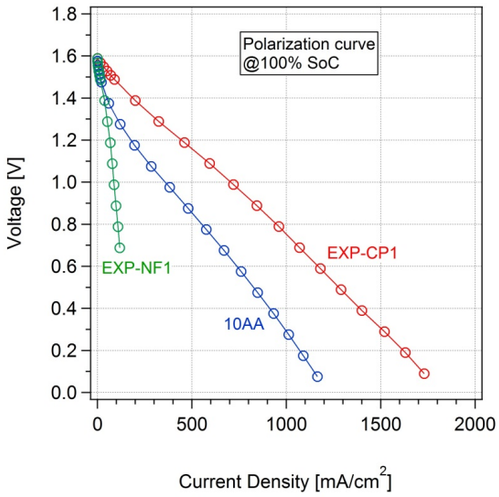

Figure 1. Polarization curve obtained for VFRB using several experimental carbon electrodes at 100% SoC

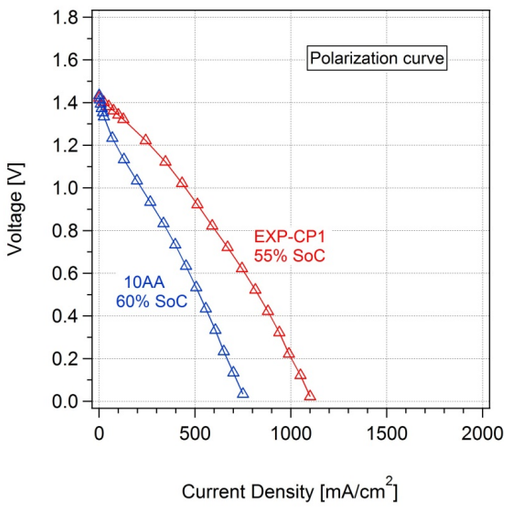

Figure 2. Polarization curve obtained for VFRB using several experimental carbon electrodes at 50% SoC

1. J. Liu, J.-G. Zhang, Z. Yang, J. P. Lemmon, C. Imhoff, G. L. Graff, L. Li, J. Hu, C. Wang, J. Xiao, G. Xia, V. V. Viswanathan, S. Baskaran, V. Sprenkle, X. Li, Y. Shao and B. Schwenzer, *Advanced Functional Materials*, **23**, 929 (2013).
2. A. Z. Weber, M. M. Mench, J. P. Meyers, P. N. Ross, J. T. Gostick and Q. Liu, *Journal of Applied Electrochemistry*, **41**, 1137 (2011).
3. C. Ponce de León, a. Frías-Ferrer, J. González-García, D. A. Szánto and F. C. Walsh, *Journal of Power Sources*, **160**, 716 (2006).
4. Q. Luo, L. Li, W. Wang, Z. Nie, X. Wei, B. Li, B. Chen, Z. Yang and V. Sprenkle, *ChemSusChem*, **6**, 268 (2013).
5. C.-N. Sun, F. M. Delnick, D. S. Aaron, A. B. Papandrew, M. M. Mench and T. a. Zawodzinski, *ECS Electrochemistry Letters*, **2**, A43 (2013).