Charge Transfer and Storage in the Electrochemical Flow Capacitor – A New Concept for Grid-Scale Energy Storage

C. R. Dennison[1,2], M. Beidaghi[2], K. B. Hatzell[2], J. W. Campos[2], Y. Gogotsi[2,*] and E. C. Kumbur[1,*]

[1] Electrochemical Energy Systems Laboratory
Department of Mechanical Engineering and Mechanics
Drexel University, Philadelphia, PA 19104 USA

[2] A. J. Drexel Nanotechnology Institute
Department of Materials Science and Engineering
Drexel University, Philadelphia, PA 19104 USA

[*] Corresponding authors: E. C. Kumbur, eck32@drexel.edu; Yury Gogotsi, gogotsi@drexel.edu

The electrochemical flow capacitor (EFC) is a recently proposed grid-scale electrical energy storage device which has the potential for high power densities and scalable energy capacity (1, 2). The EFC uses a flow-battery-type system architecture (Fig. 1), with flowable carbon-based slurry electrodes as the active material (3). Energy is stored within the slurry by the formation of the electric double layer at the interface between charged carbon particles and the surrounding liquid electrolyte. The charged slurry can then be stored in external reservoirs until it is needed.

Within the flow cell, mobile carbon particles create a conductive network with the current collectors which is changing continuously under the influence of flow. In order for charge to be stored on a carbon particle, it must be connected to this dynamic network. It is hypothesized that the dynamics of flow within the flow channel strongly affect charge transport and storage within the slurry.

Motivated by this, we have investigated the effects of flow channel depth and slurry flow rate on the conductivity and effective capacitance of the slurry in order to gain insight into the variables governing charge transfer and storage in EFC systems. Specifically, the electronic conductivity within the slurry was determined using electrochemical impedance spectroscopy, and found to depend strongly on the flow rate (measured from 0 to 10 ml min^{-1}). Slurry utilization and capacitance were measured at various channel depths from 0.5 to 3 mm (Fig. 2). Very respectable capacitance values of up to ~30 F ml^{-1} (150 F g^{-1}) were obtained during intermittent flow operation. However, utilization of the slurry was found to be low at larger channel depths. The charge transfer resistance across the current-collector|slurry interface was also investigated. This interfacial resistance was found to constitute a large portion of the total cell resistance, and varied considerably as a function of flow rate. Finally, the salt concentration in the slurry was varied and found to affect the electronic conductivity of the slurry.

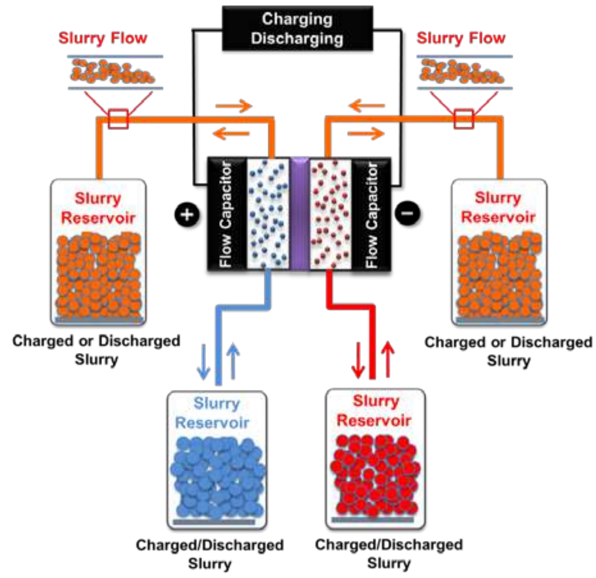

Figure 1. General EFC system architecture (2).

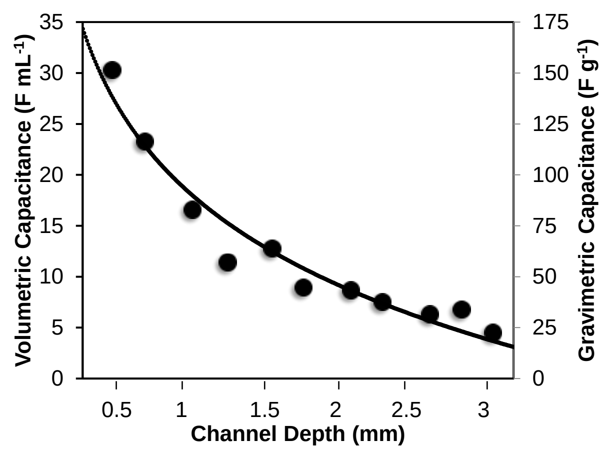

Figure 1. Volumetric and gravimetric capacitance as a function of channel depth. These values were obtained during intermittent flow operation using potentiostatic conditions to charge and discharge the slurry, as described in (2).

References:

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