Modeling of a Laboratory Scale Electrolytic Double Layer Capacitor

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Electrolytic double layer capacitors (EDLC's) achieve high capacitance by using electrodes made of high interfacial area porous materials, such as activated porous carbon, and limiting the charge separation distance to double layer (Debye length) using mobile ions in electrolyte. The present work uses a fundamental transport process based approach to model a EDLC unlike the RC circuit models, already available in the literature (Johnson and Newman (1971) and Srinivasan and Wiedner (1999)). In this work, a 1D transport model is developed for porous activated carbon coated electrodes inserted in an electrolyte solution. The model considers diffusive and convective movement of ions in a straight narrow channel and double layer formation at the electrode-electrolyte interface in response to concentration gradient and electric field. The geometry considered for modeling and simulations is shown in figure 1. Figure 2 shows the reduction of 2D geometry to 1D geometry. The governing equations are solved using COMSOL multiphysics. The model explains variation of anodic and cathodic potentials during (dis)charging, recovery of potential during relaxation phase after high rate of discharge, limiting current densities, and relative contributions from migration and diffusion of ions to the dynamics of (dis)charging process. Figure 3 shows the discharge profiles of cell, anode and cathode potentials at different discharge currents and during relaxation after discharge for 3M electrolyte concentration. The figure shows the initial potential drop during discharge at high currents and recovery of potential during relaxation. The initial drop and recovery of potential are proportional to the magnitude of discharge currents.

The approximations used to obtain 1D model were dropped and simulations were carried with full 2D domain (figure 1) in COMSOL and the simulation results show that 1D model for a SC is quite adequate. The simulation results are in qualitative agreement with the behavior of SC. The model further shows that the constant capacitance assumption for double layer needs to be relaxed to incorporate voltage dependent capacitance to better reflect the nonlinear response of double layers to potential drop across them.

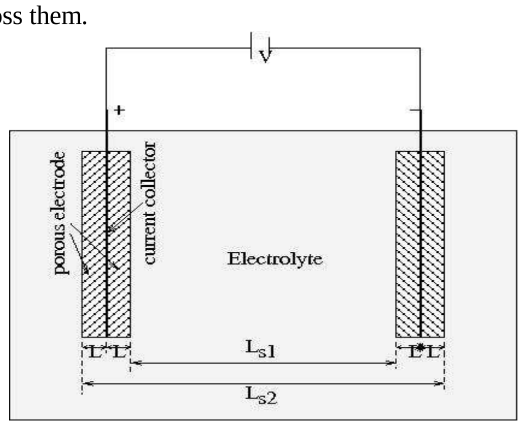

Figure 1: Schematic of laboratory scale EDLC

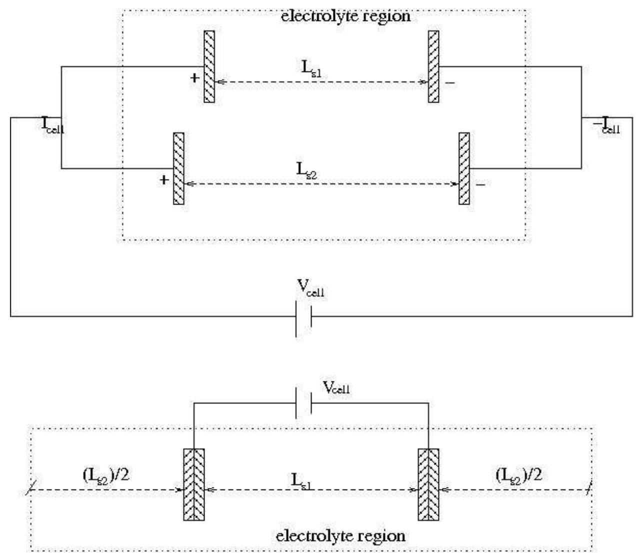

Figure 2: Reduction to 1D geometry from 2D geometry.

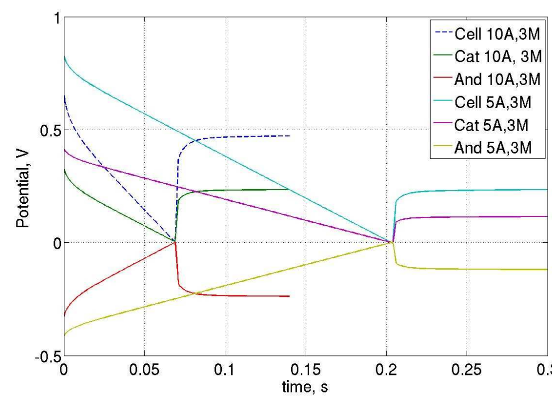

Figure 3: Profiles of Anode, Cathode and Cell potentials with variation in currents during discharge and relaxation at 3M electrolyte concentration.

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