Geometrical optimization of electrochemical flow electrode capacitor via modeling and experimentation

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Abstract:

The Electrochemical energy storage methods are powerful candidate solutions due to their eminent energy density, flexibility, and scalability. The FEA (Finite Element Analysis) based model has been developed for flow-able electrode material. Extended model was used for supercapacitor simulations and measuring charging behaviour of the flow capacitor in terms of Current density. Various geometry shapes were tested to enhance to current density by varying shapes of active layer to electrodes. Our model was suitable for optimization of the energy harvesting and its storage and approved to have potential to be investigated further for high current capacity.

Model Information:

There are two current densities in the model one is due to electrolyte and other is for slurry particles.

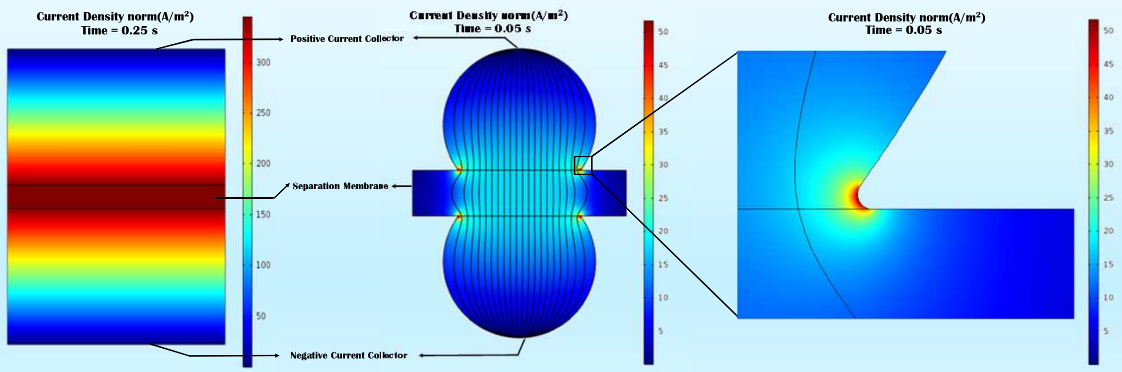
$$J = \sigma E + j_e$$

Where J is the current density, σ is conductivity, E is electric field due to applied potential and j_e is external current Density. Diffusion of Ionic are framed by Nernst-Plank Equation:

$$\frac{\partial c_i}{\partial t} + \nabla.(-D_i \nabla c_i - z_i u_{m,j} F c_i \nabla V) = R_i$$

Where c_i is the concentration of charge specie, D_i is the diffusion coefficient, z_i is electronic charge on specie, F is Faraday Constant, V is potential, $u_{m,j} = \frac{D_i}{RT}$ and R_i is a source term responsible for electric double layer (EDL) on the surface of electrodes

Modeling Results:



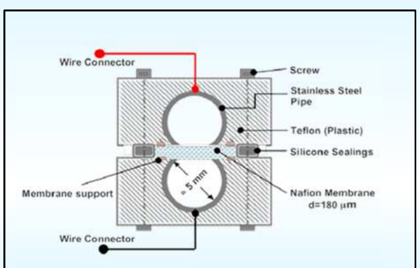
Rectangular Current Collector Model

Circular Current Collector Model

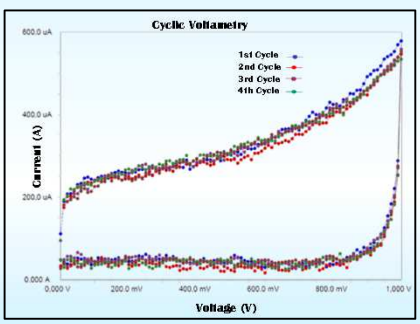
Sharp Corner Between Electrode And Separation Membrane

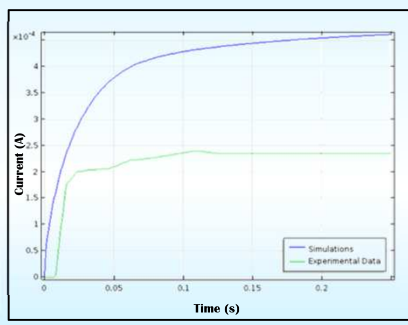
Experimental:

Slurry: 0.1 M Na_2SO_4+ 5mg/ml Carbon Black



Prototype For Experiment





Conclusion:

Finite element method (FEM) was used to study the charging behaviour of Flowcapacitor.
Geometry structures were tested with zero flow rate of slurry.
Modeling results are compatible with the conducted experimentation.

Acknowledgement:

University of Tartu, Estonia.
Institute of Technology, Intelligent Materials and Systems Laboratory, Estonia.
This Work is supported by the Estonian Research Council grant PUT 1149.

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Solid State Ionics
June 18-23 2017