COMSOL Modelling for Li-ion Battery Ageing

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Introduction: Recently, Li-ion battery is being widely used as power source for various applications. The performance and cycle life of Li-ion battery are becoming gradually important issues especially for dynamic power applications (EVs, HEVs). To create a better control over the performance and cycle life of a Li-ion battery, accurate modelling for battery ageing is essential. We are investigating a non-invasive method for Li-ion battery ageing based upon magnetic field probing [1]. During a battery lifetime, its health tends to deteriorate slowly due to irreversible physical and chemical changes like: internal impendence rise, excess out-gassing, internal temperature rise, electrolyte decomposition and electrodes' cracking [2]. The scope of this research work is to develop a Li-ion battery model with applied magnetic field to induce above parameters for battery ageing and predict its future age.

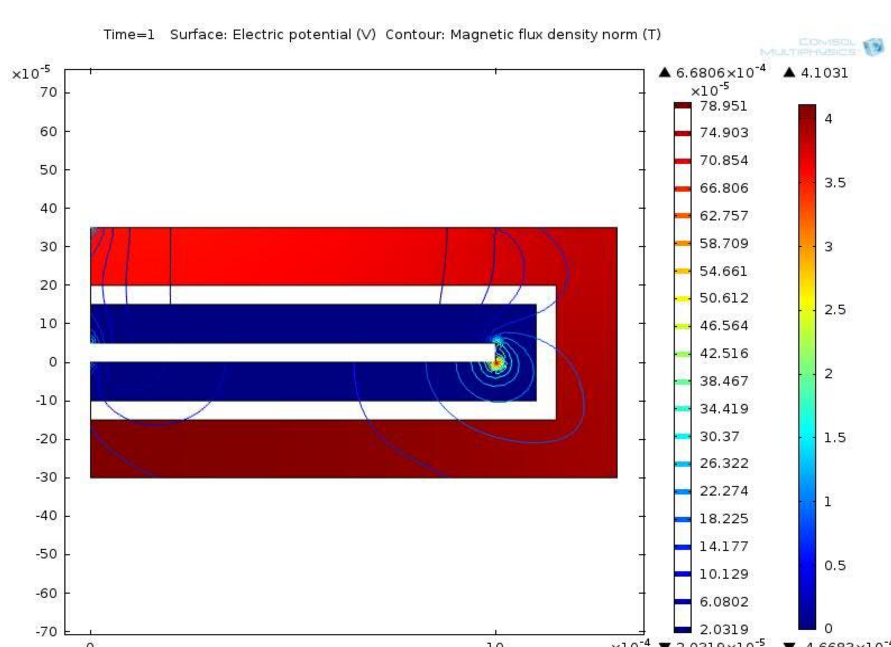

Figure 1. 2-D Modelling of Li-ion battery with Magnetic Field

Computational Methods: We design and simulate a 2D model based on pseudo two dimensional (P2D) modelling which is coupled with magnetic field (mf) physics. Following equations and parameters are used for solving the model. A detailed analysis has been performed to evaluate the response of applied magnetic field on the domains of Li-ion battery [3, 4].

Battery Electrode/Electrolyte Domain Equations

$$\frac{\partial C_1}{\partial t} + \nabla . N_l = R_i$$

$$\nabla . i_l = Q_l$$

$$\nabla . i_s = Q_s, i_s = -\sigma_s \nabla \phi_s$$

$$i_l = -\sigma_l \nabla \phi_l + \frac{2\sigma_l RT}{F}\left(1 + \frac{\partial nf}{\partial \ln C_1}\right)(1 - t_+)\nabla \ln C_1$$

$$N_l = -D_l \nabla C_1 + \frac{i_l t_+}{F}$$

$$\phi_l = phil, \phi_s = phis, C_1 = cl$$

Magnetic Field Domain Equations

$$\sigma \frac{\partial A}{\partial t} + \nabla \times \left(\mu_0^{-1} \mu_r^{-1} B\right) - \sigma V \times B = J_e$$

$$\sigma \frac{\partial A}{\partial t} + \nabla \times H = J_e$$

$$B = \nabla \times A$$

Parameters	Name	Expression	Description
	rp_neg	12.5e-6[m]	Particle radius Negative
	rp_pos	8e-6[m]	Particle radius Positive
	epss_pos	1 - epsl_pos - 0.259	Solid phase vol-fraction Positive
	epsl_pos	0.444	Electrolyte phase vol-fraction Positive
	epss_neg	1 - epsl_neg - 0.172	Solid phase vol-fraction Negative
	epsl_neg	0.357	Electrolyte phase vol-fraction Negative
	cs0_neg	14870[mol/m^3]	Initial Negative State of Charge
	cs0_pos	3900[mol/m^3]	Initial Positive State of Charge
	mf.H0x	100[A/m]	App. Magnetic field, x component
	mf.H0y	100[A/m]	App. Magnetic field, y component

Table 1. Parameters used in the modelling

Results: The simulation results provide behaviour of battery ageing parameters with the applied magnetic field. We get the magnetic field response in each domain and determine the behaviour pattern of each domain. The Figure 2 shows that the electric potential (phis) in domain 3 increases with magnetic flux density and figure 3 shows the magnetic field response with insertion particle concentration (liion.cs_average). Magnetic flux density decreases with the increase of insertion particles concentration. We will also investigate the impact of magnetic field on other ageing parameters like:

- The MFR (Magnetic Field Response) vs. loss of capacity due to the ageing
- MFR with respect to charging/discharging behaviour of the Li-ion battery
- MFR with respect to change in internal impedance of the Li-ion battery

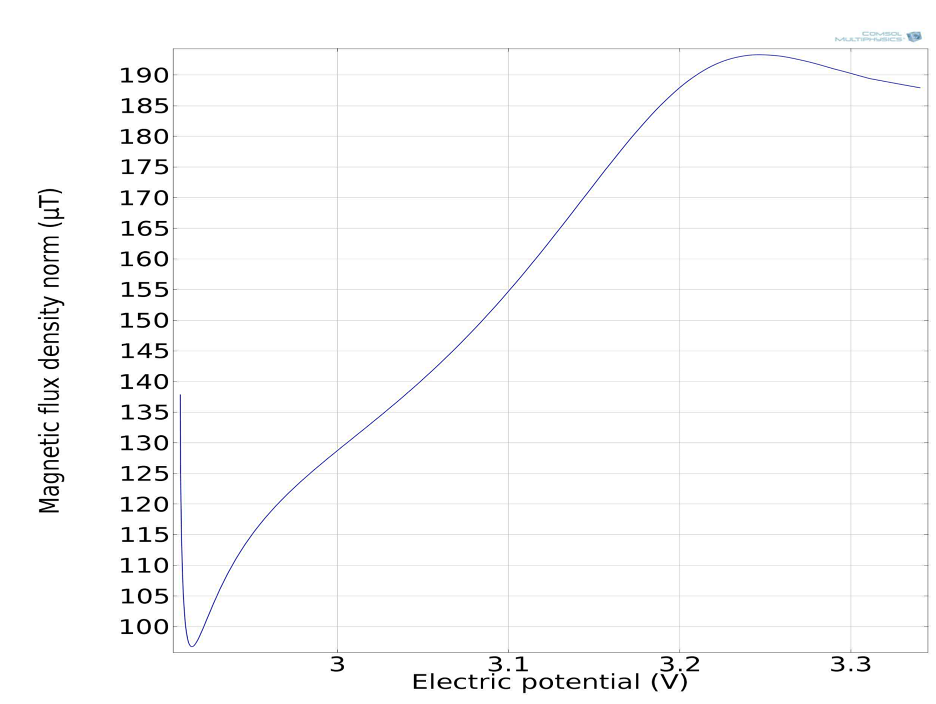

Figure 2. Electric potential of Li-ion battery Vs. Magnetic field response

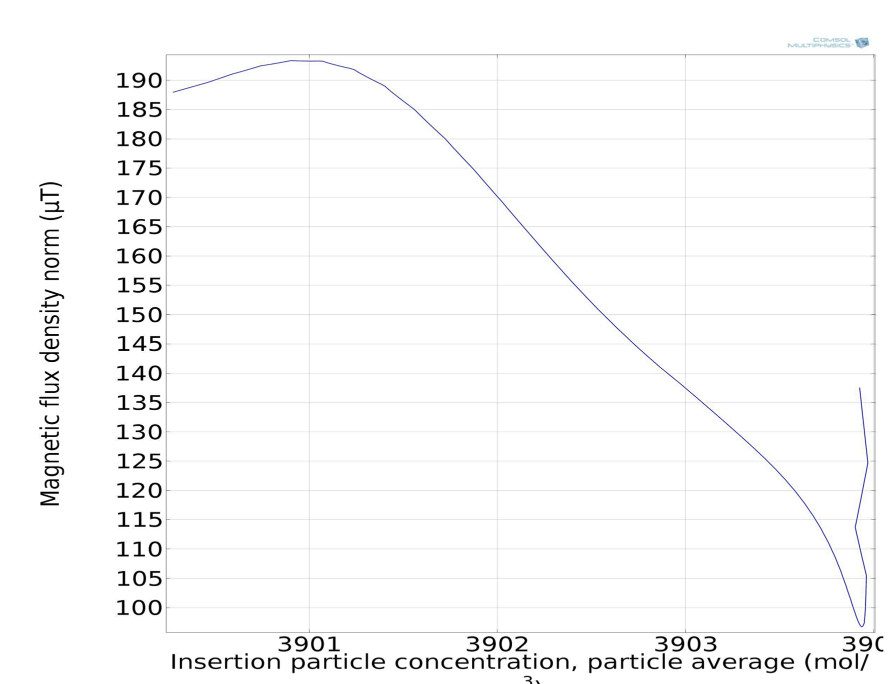

Figure 3. Insertion Li-ion particle concentration Vs. Magnetic field response

Conclusion: Early results and simulation indicate that **COMSOL Multiphysics®** has potential to support this studies and help in modelling MFP interfaced with Li-ion battery to predict ageing in battery. This model is also help to design a prototype for real time aging prediction for Li-ion Battery.

References:

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