Investigating Effects of Number of Layers on Thermal Behavior of Lithium Ion Batteries

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Abstract

In last few decades, growing popularity of Electrical Vehicles (EVs) and Hybrid Electrical Vehicles (HEVs) associated with environmental concerns over oil-based transportation infrastructure, has attracted many research attentions over rechargeable Lithium-ion batteries (LIBs)1. Their high capacity, high energy density and stability make LIBs a promising alternative energy source for both EVs and HEVs. However; problems such as safety, high cost and poor low temperature performance hinder utilization of these batteries in the battery packs of EVs and HEVs2. Studies showed that even small temperature gradients have remarkable effects on performance of the battery packs3 Commercial Li ion cells are composed of several electrochemical layers each consisting a negative-current collector, a negative electrode, separator, a positive electrode, and a positive current collector. Numerous researchers have studied the electrochemical and thermal behavior of the Li-ion batteries but effects of number of layers inside the pouch cells on thermal behavior of the cells have not been fully investigated. Distribution of heat generating sources in Li cells affect thermal issues in lithium ion cells such as thermal runaway, number of hot spots, power and energy losses, and reaction kinetics. Therefore, we propose that single-layer approach is not sufficient for simulating thermal and electrochemical behaviors of the lithium ion batteries and by comparison with the experimental results, our model shows that multilayer approach is providing more precise and reliable thermal behavior of the Li-ion batteries.

In this work, we used Batteries and Fuel Cells Module of COMSOL Multiphysics® to study the electrochemical and thermal behavior of LiFePO4 battery. Developed model is used to investigate the effects of number of layers (single layer, 4 layers, 8 layers, 16 layers, and 20 layers) inside the cell on temporal and spatial temperature profile and heat generation rates. Each cell having a copper negative current collector, graphite negative electrode, LiPF6 w/EC:DEC (1:1) electrolyte, LiFePO4 positive electrode and aluminum current collector is modeled exactly the same with the purchased commercial 20Ah LiFePO4 batteries. The model results for voltages and surface temperature change on cells are validated at ambient temperature of 30˚C and for various discharge rates (1C, 2C, 3C, 4C, and 5C). Total heat dissipation at cathode and anode are compared and results showed that the total heat dissipation was significantly higher in cathode part than anode during discharge. Our simulation results show that the thermal behavior of lithium ion batteries is significantly dependent on the number of layers inside the cell; and temperature non-uniformity increases with the increase in the number of layers inside the cells. The obtained results for thermal behavior of the Li-ion batteries are believed to be promising for designing an efficient thermal management system.

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Figures used in the abstract

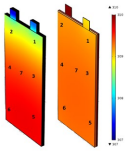

Figure 1: Comparison of simulated: (left) 20-layer cell and (right) single layer cell 3D temperature profiles.