Materials Science and Engineering Thesis Defense

Analyzing the performance of Lithium-ion batteries for Plug-in Hybrid Electric Vehicles and Second-life applications

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abstract

The automotive industry is committed to move towards sustainable modes of transportation through electric vehicles to improve the fuel economy with reduced carbon footprint. In this context, battery operated hybrid, plug-in hybrid and all-electric vehicles are becoming commercially viable throughout the world. Lithium-ion batteries with various active materials, electrolytes and separators are currently being used for applications in electric vehicles. Specifically, lithium-ion batteries with Lithium Iron Phosphate ($LiFePO_4$ - LFP) and Lithium Nickel Manganese Cobalt Oxide ($Li(NiMnCo)O_2$ - NMC) cathodes are being used mainly due to higher cycle life and higher energy density values, respectively. In the present work, 26650 Li-ion batteries with LFP and NMC cathodes were evaluated for Plug-in Hybrid Electric Vehicle (PHEV) applications, using the Federal Urban Driving Schedule (FUDS) to discharge the batteries with 20 A current in Arizona simulated weather conditions (50 ^{0}C & <10% RH) up to 800 cycles. In addition, 18650 lithium-ion batteries (LFP cathode material) were evaluated under PHEV mode with 30 A current to accelerate the ageing process, and to monitor the capacity values and material degradation. To offset the high initial cost of the batteries used in electric vehicles, second-use of these retired batteries is gaining importance, and the possibility of second-life use of these tested batteries was also examined under constant current charge/discharge cycling at 50 ^{0}C.

The capacity degradation rate under PHEV test protocol for batteries with NMC based cathode (16% over 800 cycles) was twice as compared to batteries with LFP based cathode (8% over 800 cycles), reiterating the fact that batteries with LFP cathodes have a higher cycle life compared to other battery chemistries. Also, the high frequency resistance measured by electrochemical impedance spectroscopy (EIS) was found to increase significantly with cycling, leading to power fading for both the NMC as well as LFP based batteries. The active materials analyzed using X-ray diffraction (XRD) showed no significant phase change in the materials after 800 PHEV cycles. For second-life tests, these batteries were subjected to a constant charge/ discharge cycling procedure to analyze the capacity degradation and materials characteristics.

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