Plug-In Hybrid Vehicle and Second-Life Applications of Lithium-Ion Batteries at Elevated Temperature

Arunachala M. Kannan

In improving fuel economy and reducing carbon footprint, hybrid, plug-in hybrid and all-electric vehicles are considered as sustainable modes of transportation in the automotive industry. Here, commercial Li-ion cells (26650 and 18650 with lithium iron phosphate (LFP) and nickel manganese cobalt (NMC) cathodes) were subjected to simulated plug-in hybrid electric vehicle (PHEV) conditions, using the Federal Urban Driving Schedule (FUDS) under charge-depleting mode at elevated temperature (50 °C and <10% RH). The capacity degradation (16% over 800 cycles) under the PHEV test protocol for Li-ion batteries with 26650 NMC cathodes was twice of that using LFP cathodes (8% over 800 cycles) under identical conditions. The Li-ion batteries were also subjected to second-life charge–discharge cycling at C/5 rate after evaluating them under the PHEV protocol (800 cycles for 26650 cells and 1200 cycles for 18650 cells). In addition, the high-frequency resistance measured by electrochemical impedance spectroscopy was found to increase significantly with cycling for both the NMC- as well as LFP-based batteries, leading to power fading. XRD analysis of the 18650 LFP-based battery showed change of phase from LiFePO4 to FePO4, indicating Li+-ion loss. However, the cathode active materials of the Li-ion cells (26650 with LFP and NMC cathodes), examined using XRD, showed no significant phase change in the materials after 800 PHEV cycles and around 200 second-life charge–discharge cycles.