Thermal Characterization of 18650-type Non-flammable Sodium-ion Cells

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Lithium-ion/sodium-ion batteries (LIBs/NIBs) generate heat during the cycling operation as a result of various polarization processes leading to rise in temperature of the cell. Such a rise in temperature due to high internal resistance can sometimes trigger unfavourable exothermic reactions causing thermal runaway [1]. Hong et al. [2] quantified heat generation in 18650-type LIBs through calorimetric studies in terms of reversible and irreversible heat contributions. Manikandan et al. [3] reported in detail, the heat generation and internal resistance of various 18650-type commercial LIBs made of different cathode materials against graphite anode.

Although thermal studies are reported on many LIB chemistries, to the best of our knowledge, there are no thermal studies on commercial type NIBs except a few reports on improving thermal safety of its anode and cathode materials. Zhao et al. [4] performed Differential Scanning Calorimetry (DSC) tests to evaluate the thermal stability of hard carbon anodes. Rudola et al. [5] investigated the flammability of different electrolytes used in NIBs by DSC and burn tests. Xia and Dahn [6] investigated the thermal stability of $Na_{0.5}CrO_4$ cathodes using Accelerating Rate Calorimetry (ARC). In the present study, we investigate both heat generation and internal resistance of 18650-type cells comprising sodium vanadium phosphate, $Na_3V_2(PO_4)_3$ (NVP) cathode vs. hard carbon (HC) anode using 1M $NaBF_4$ in tetraglyme non-flammable electrolyte. Both the irreversible heat generation arising due to internal resistance and the reversible heat generation caused by entropic changes in the electrode materials are elucidated. While the total heat generation is determined using ARC, the reversible heat generation in these 18650 cells is determined using entropic coefficient measurement. The internal resistance contributing to the irreversible heat generation is estimated by both Galvanostatic Intermittent Titration Technique (GITT) and Electrochemical Impedance Spectroscopy (EIS). Moreover, variation in the individual components causing internal resistance across different depths of discharge (DODs) is determined by fitting the impedance data to an equivalent circuit model. Lastly, we demonstrate that aliovalent substitution of NVP has improved energy density of the NVP vs. HC 18650 cell due to substantial reduction in the internal resistance and the consequential heat generation.

References:

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