Quantitative Estimation of Capacity Fade of Sony 18650 cells Cycled at Elevated Temperatures

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Introduction
Capacity fade in Li-ion cells is caused by various mechanisms that depend on the electrode materials, the mode of charging the cells as well as cycling temperature. Elevated temperature can accelerate the degradation of battery materials, which causes a decline in capacity and premature cell death. The increase in the internal impedance of the battery upon cycling has been shown to be the most dominant effect in case of LiCoO₂ based Li-ion cells.

Our capacity fade studies on spinel based Li-ion cells showed us the influence of the charging protocol on capacity fade. Our recent studies on Sony 18650 cells show that rate of capacity loss is higher when cycled at elevated temperatures. Thus it would be possible to propose several reasons for capacity loss depending on the cycling conditions. Our objective is to analyze the capacity loss of LiCoO₂ based Li-ion cells cycled at different temperatures, provide most significant factors that are responsible for capacity loss and estimating the capacity losses quantitatively due to each factor.

Experimental:
Sony US18650S cells with a rated capacity of 1800 mAh were used for these studies. For cycling studies, the cell was charged at a constant current of 1 A until the potential reached 4.2 V. Subsequently the voltage was held constant at 4.2 V until the current drops to 50 mA. The cells were cycled under four different temperatures namely 25, 45, 50 and 55°C.

Rate capability studies, impedance measurements were done for fresh and cycled cells and using T-cell assembly, intrinsic capacity measurements and electrode resistances were estimated for fresh and cycled positive and negative electrode materials. XRD studies were also done for the cycled electrode materials to see for any structural change or any accumulation of new phases with cycling.

Results and Discussion
Capacity fade of the lithium ion cells increases with increase in temperature. Fig. 1 gives the variation of capacity with cycling under four different temperatures. Based on our cycling data and rigorous analysis of variation of charge and discharge curves with cycling, the most significant factors that contribute to capacity losses are: 1. increase in resistance due to electrolyte loss and oxidation of individual electrode materials [Q₁]. 2. Loss due to secondary active material (LiCoO₂/Carbon) [Q₂] and 3. Loss due to primary active material (Li⁺) [Q₃]. Rate capability and impedance measurements were carried out for fresh and cycled cells to estimate the capacity loss due to the first factor stated. Intrinsic capacity measurements of cycled electrode materials using the T-cell assembly with Li foil as counter and reference electrodes can be used to estimate the capacity loss due to the second factor. The third factor can be determined from a charge balance (Q₁ = Q₂ - Q₃) where 'Q' refers to the total capacity loss.

Figure 2 presents the distribution of capacity losses between the three factors we mentioned.

A detailed analysis of the cycling performance and the T-cell studies of the individual electrodes and the quantitative estimation of capacity losses based on the experimental results will be presented.

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References

Fig. 1 Variation of Discharge Capacity of Sony 18650 cells with Cycling at Elevated Temperatures.

Fig. 2 Variation of Capacity Fade factors with cycling for the Sony 18650 cells when cycled at 25°C.