Capacity Fade Analysis of a Battery/Supercapacitor Hybrid and a Battery under pulse loads

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Introduction:

A lithium ion battery-supercapacitor hybrid system exhibits better rate capabilities over a lithium ion battery at high rates of discharge due to the higher power density of ultracapacitor (~10^6 W/kg) as compared to that of a lithium ion battery (~100 W/kg). In modern electronics the cells may be discharged under temperature that may range up to 60^0C.The capacity fade of batteries are expected to be higher at an elevated temperature than at room temperature[1]. In this work the capacity fade of battery and a battery-super capacitor hybrid system cycled up to 400 cycles under three different pulse protocols at an elevated temperature of 55^0C has been studied in detail. A comparison will be presented between the cycling performances of a hybrid and a battery in terms of capacity fade and rate capability.

Experimental:

Full-cell studies: A Sony US 18650 Lithium -ion cell with a rated capacity of 1500mAh in parallel with two 100F Maxwell PC super -capacitors in series was used as the hybrid. The hybrids were cycled at an elevated temperature of 55^0C by charging them to 4.2 V using constant current –constant voltage (CC-CV) protocol. The hybrids were discharged at pulse rates with amplitudes of 5C, 3C, 1C respectively. Duty ratio and pulse frequency were fixed at 0.1and 1Hz respectively. Electrochemical Impedance Spectroscopy (EIS) were done for both the fully charged and fully discharged states of the battery. Rate capability analysis were done for both fresh and cycled cells by charging them using a CC-CV protocol and then discharging at C/8, C/4, C/2, C, 2C, 3C rates. Cyclic voltammetric(CV) studies were also carried out at both high scan and low scan rates. These experiments were also carried out on a single Sony US 18650 lithium ion cell for comparison.

Half cell studies: T-cell experiments were also performed for the individual electrodes taken from the fresh batteries and also from the batteries that were cycled (both from single battery and also as part of the hybrid).

Results and discussions:

Figure 1 represents capacity fade(%) vs. cycle number for different cases. The capacity fade for hybrids were mostly higher than battery at 55^0C .After 200 cycles of operation the battery cycled at 1C rate showed the maximum capacity fade. In hybrids, the capacity fade at 1C was always higher than at 3C and 5C rates. The capacity fade was lesser for hybrids cycled at 5C than at 3C up to 200 cycles and then the situation reversed at higher cycle numbers. Hybrids cycled at 1C rate showed a capacity fade of 28% at 200 cycles whereas those cycled at 5C and 3C rates showed 14.9% and 16.3% respectively. Capacity fade differed significantly between 1C on one hand and the 5C and 3C rates on the other hand after 100 cycles. The capacity fade of a battery cycled at 3C rate was significantly higher than a battery at 5C rate. At 200 cycles the battery showed an 8% capacity fade at 3C rate, whereas when cycled at 5C rate it was only 9% even at 400 cycles. It differed greatly between 3C and 5C rates after 100 cycles. Cyclic Voltammetry and Impedance results could also be correlated with the discharge capacity results seen above. At high cycle numbers, the battery cycled at 5C pulse rate had better rate capability than the hybrid at higher discharge rates. The average ohmic drop in a pulse discharge is much lesser for hybrids than for a battery.

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References:

1.P.Ramadass et al., J. Power Sources 112(2002)606.

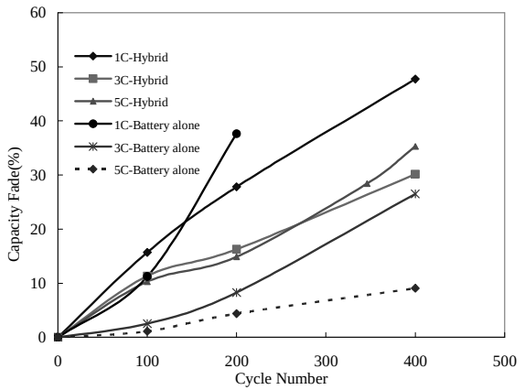

Fig1.Capacity fade (%) in a hybrid and a battery under pulse discharge