Thermally Accelerated Life Testing for Rechargeable
Li-ion Batteries

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Rechargeable batteries that can last for a decade or more are needed for many applications such as medical devices, automobiles, satellites, stationary power and so forth. Battery technologies that demonstrate very low degradation are necessary to meet the demands of such applications. The challenge during development of such systems is how to predict long-term performance from short-term testing, particularly when the rate of degradation (signal) is very small.

We have developed a thermal acceleration methodology and model for Accelerated Life Testing of rechargeable Li ion batteries. The testing involves storage of batteries at elevated temperatures for different durations and measuring performance characteristics periodically. This technique appears to work particularly well for battery resistance for short pulses. Resistance shows increase both with storage time and storage temperature. Our test methodology allowed separation of the time and temperature effects. As shown in figures 1, we were able to determine a "time-adjusted-resistance", which shows near-perfect Arrhenius behavior over a broad temperature range. The model equation obtained has the functional form:

$$R_{dc} = R_{dc0} + \exp(lnA - \frac{E_a}{RT})t^n$$

A comparison of the model predictions with the test data is shown in figure 2. The resistance data (points) and the model predictions (dash lines) show excellent agreement. Independent data-sets were also used to verify the model.

Resistance increase in Li ion batteries is known to often occur due to solid-electrolyte-interphase (SEI) growth. This growth has been reported to follow a parabolic growth model [1]. Our model appears to agree well with this mechanistic approach, yielding a value for the exponent, n, which is very close to the expected value of -1/2. The activation energy we obtained (50 kJ/mol) also appears to agree with the commonly accepted values for Li ion degradation reactions [2].

The model offers a method to obtain data 20-30× faster. This approach provides greater confidence in assessing the reliability and/or design margin of the batteries for long-life applications. The applicability of this approach is dependent on the dominant degradation mechanisms for the chemistry in question and whether these mechanisms can be thermally-accelerated. We have evaluated this approach for two different chemistries, and we will share results which demonstrate both its applicability and limitations.
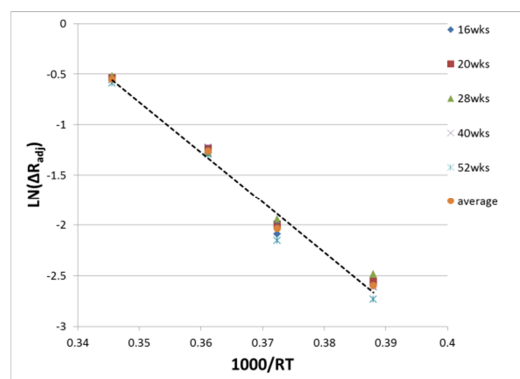

Fig. 1 "Time-adjusted Resistance" as a function of storage temperature shows near perfect Arrhenius relationship
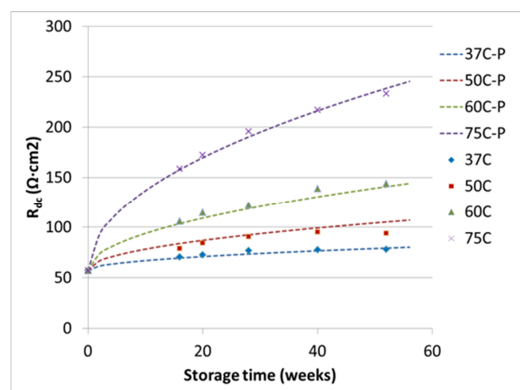

Fig. 2 Resistance prediction curves and actual DC resistance (data points) show excellent agreement over wide temperature range and time points.

Reference
[1] E. Peled, J. Electrochem. Soc. 126 (1979) 2047–2051.
[2] I. Bloom, et al, J. Power Sources, 98-98 (2001) 13-22.