APPLICATION**NOTE**

Measuring Operation Performance of 18650 Cell by Isothermal Cycling

Isothermal Calorimetry for Advanced Battery Testing

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Introduction

Lithium ion batteries are used across many consumer and industrial markets where portable and/or back-up power is required. The performance of these cells, high power density and no memory effects has enabled many technologies in ways that would not have been possible otherwise. More recently, Lithium ion batteries are now the foundation of electric vehicles. Lithium ion technology has many advantages but one significant drawback is the potential for thermal runaway. Also given some of the newer applications and their associated demand on the technology, it is not clear how well these cells and packs will perform over years of use in different environmental conditions and how this may impact safety. Thermal Analysis and Calorimetry have been used to study battery materials and full cells. This information is useful for understanding the chemistry and to design inherently safer batteries. Calorimetry, in particular isothermal Calorimetry, in conjunction with charging/discharging in normal and exaggerated conditions is critical for thermal management studies and to estimate long-term effects. This note will show the application of isothermal calorimetry performed on accelerating rate calorimeter. 18650 lithium ion battery was used as an example.

1 NETZSCH ARC® 254

Instrumentation

The Calorimetry used in this note was the NETZSCH ARC® 254 system (Figure 1) equipped with the battery cycler interface kit and the 18650 cell *VariPhi*™ sensor. The ARC® 254 is an accelerating rate calorimeter designed specifically for adiabatic operation. However, by incorporating the *VariPhi*™ sensor, the user is able to run true isothermal Calorimetry experiments.

Using the patented *VariPhi*™ technology, one can run the ARC to get isothermal and heat capacity data. Furthermore isothermal calorimeters are generally not designed to handle the potential risk of thermal runaway and explosion but using the *VariPhi*™ and the ARC together, one has the advantage of running the isothermal test in a robust ARC calorimeter. This is a unique feature of the NETZSCH ARC product.

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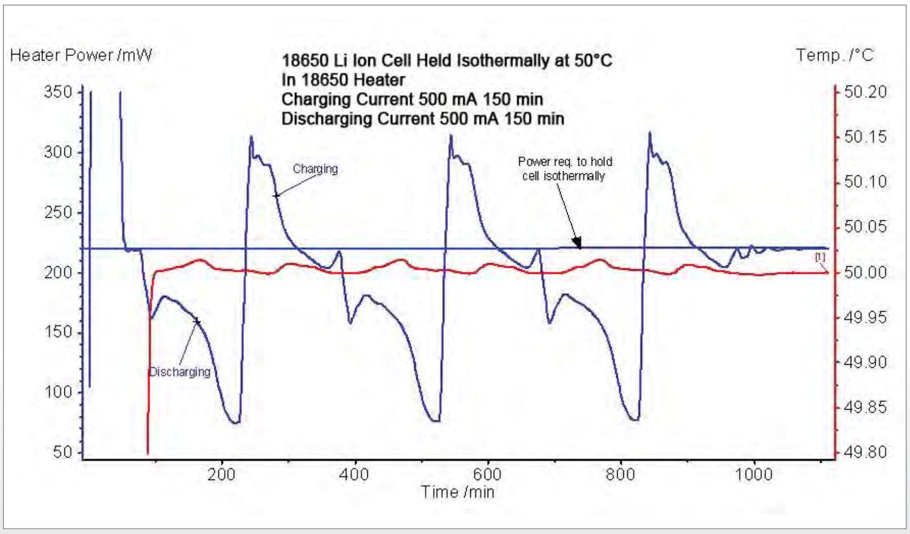
The *VariPhi*™ technology has been introduced over 5 years ago and is described in several publications. The development of the 18650 sensor assembly is recent and works with the existing *VariPhi*™ systems. The inner diameter of the cylindrical sensor is specifically designed to prove a good fit with a standard 18650 cell. A photo of the sensor is shown in Figure 2.

2 18650 cell and its *VariPhi*™ sensor

Results

A series of tests were conducted using a commercially available 18650 cell to gauge the performance of the system. One example showing the temperature and heater power versus time is depicted in Figure 3. In this test, the cell was held constant at 50°C while the cell was being charged and discharged at 500 mA. It is easy to see that the isothermal condition was well maintained at 50°C with only a slight diversion of 0.02°C during times when the instrument was switching between charging and discharging modes. The battery was charged/discharged three times and then the system was held constant, without cycling, to establish a baseline. This baseline is a function of instrument condition and the self-discharge rate of the cell. Using this baseline, one can calculate the overall heat gained or lost during cycling simply by integrating the peaks. It is evident that discharging is exothermic and charging is endothermic. As can be seen, the endotherm for any given cycle is smaller than the exotherm. The reason for this is more clearly illustrated in test sequence summarized in Figure 5. In this test series, the current for charging and discharging was increased after each cycle. In the first few cycles, the power is more or less a step pattern. However, with increasing current we see that the power curve becomes distorted. This occurs because the cycler is trying to charge the battery beyond its capacity. This can be associated with the Li-ion "pressure" increasing due to mass transfer limitations at the interfaces. The sample power is just the inverse of the heater power. The heater power is plotted with current as a function of time in Figure 4. The heater power is directly proportional to the current as can be expected. When the current is decreasing, the rate of the endothermic reaction also decreases which leads to a decrease in the power needed to keep the battery at isothermal temperatures.



3 Cell heater power and cell temperature versus time for an isothermal 18650 battery cycling test at 50°C

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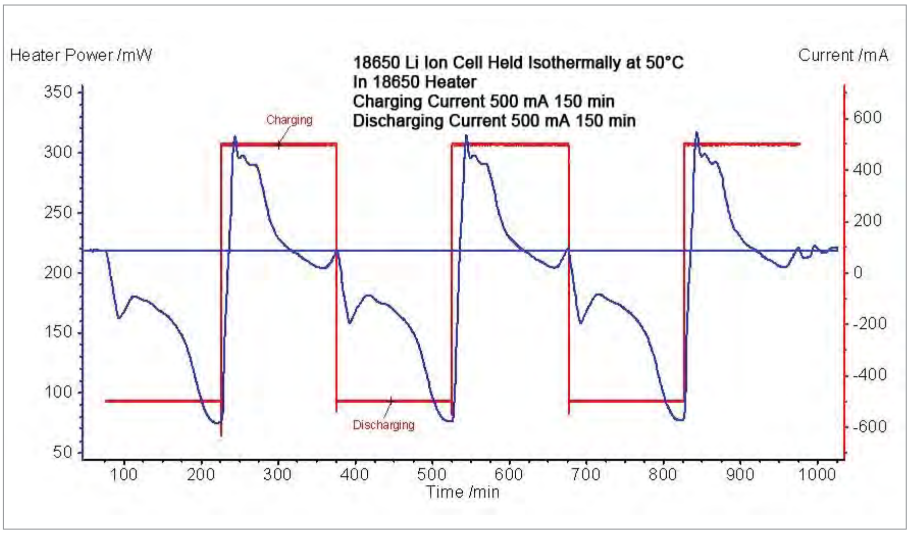
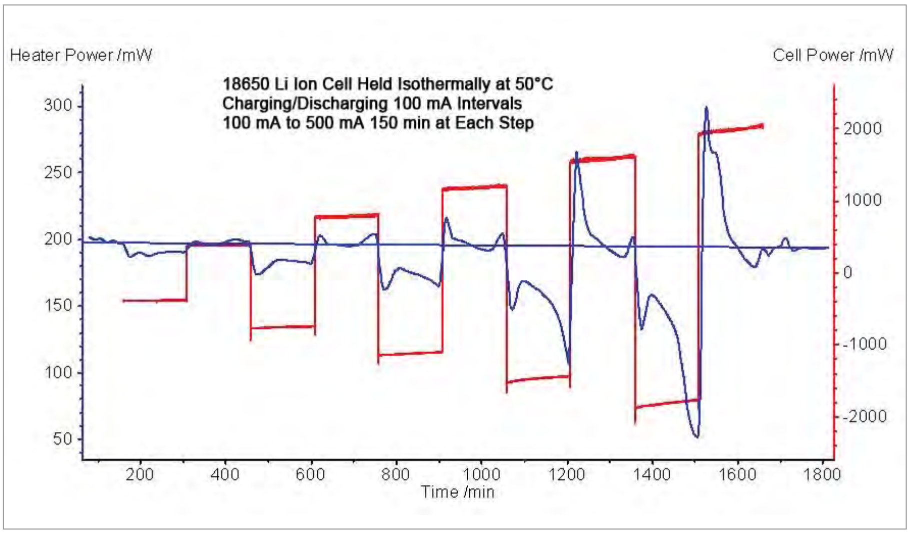


4 Cell heater power and cell current versus time for an isothermal 18650 battery cycling test at 60°C



5 Cell heater power and cell current versus time for an isothermal 18650 battery cycling test at 50°C with increasing current

Conclusion

18650 lithium ion battery is commonly used in laptop battery pack and flashlight. The information from isothermal charging/discharging test is very useful for battery thermal management, safety and lifetime. Since the isothermal cycling is performed inside a robust NETZSCH ARC 254® calorimeter, it is quite possible to perform isothermal cycling tests at temperatures close to or even beyond the stated operating temperature to get a better understanding how the cell will behave in a variety of conditions. For large cells, this could conceivably lead to power output which outpaces the cooling capability of the calorimeter. In such cases, thermal runaway and explosion are likely to occur so testing must always be done at a level which is meaningful and also safe. The unique combination of adiabatic and isothermal testing in a single unit provides the user with the necessary flexibility and safety to run a comprehensive testing program.

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