Measuring the Open Circuit Heat Rate of a Li-ion battery in the TAM III Macrocalorimeter

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Introduction

The Macrocalorimeter for the TAMIII is the largest calorimeter manufactured by TA Instruments and can measure heat rates from sample volumes up to 100 mL (Figure 1A). The reference cell is accessed from the underside of the calorimeter (Figure 1B). This accessibility allows the instrument operator to match the thermal mass of the reference to the thermal mass of the sample. In addition to measuring large samples, the Macrocalorimeter is designed for measuring heat rates during charge/discharge or self-discharge of batteries. Samples are contained in either a 100 mL screw-top glass ampoule (Figure 1C), or a battery holder (Figure 1D).

Methods

To illustrate the functionality of the TAM III Macrocalorimeter, the open circuit heat rate at 25°C for a rechargeable, lithium-ion 18650 battery was determined with the 18650-battery holder (Figure 1D).
The reference side of the calorimeter contained an 18650-battery holder without the battery. A blank-control experiment was done to determine a baseline heat rate. The sample used in the blank experiment consisted of dried sand, equal in mass to the 18650 battery, and contained in flame-sealed glass ampoules positioned in the 18650-battery holder.

Figure 2. The open-circuit heat rate for a 2600mAh Li-Ion 18650 3.7V battery (Blue) and Blank-Control (Black) at 25°C. The fit to calculate mean and standard deviation for the Li-Ion 18650 Battery and Blank-Control is overlaid with each raw data set (straight line). The variation in the Blank-Control data is caused by variation in room temperature. Data and graphic analysis performed with the TAM Assistant software package.
Results & Discussion

Heat flow data and room temperature data were collected for 48 hours (Figure 2). Room temperature data were collected to determine the effect of the external environment on calorimeter noise. Calorimeter data were fit to the Linear-Constant Model to determine the average heat rates for the Li-Ion 18650 Battery (54.3 ± 0.74 µW) and the blank-control experiment (0.80 ± 2.09 µW) (Figure 2). The open circuit heat rate (53.5 µW) was calculated from the difference between average heat rates, and is proportional to the rate of battery self-discharge.

The Macrocalorimeter has performance characteristics for accurately conducting either the self-discharge or the more dynamic charge-discharge cycling battery evaluations with a dynamic range of ±340 mW, a baseline drift of <6 µW over 24 hrs at a stable room temperature range of ±1°C, and short term noise (peak to peak) of 0.5 µW. For best results from the Macrocalorimeter, the laboratory temperature fluctuation in the room housing the TAM III should be ±1°C/24 hrs or less. The 61 mm diameter x 72 mm high (210 mL total volume) sample chamber is large enough to provide the necessary volume to accommodate a wide variety of shapes and sizes of battery holders. The TAM III Macrocalorimeter provides maximum flexibility and performance for self-discharge and charge-discharge cycling battery evaluation experiments requiring larger sample sizes and adds a powerful battery testing tool to the already existing TA Instruments 20 mL calorimeters used for testing smaller cylindrical and coin-shaped batteries.