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EXPERIMENTAL COMPARISON OF THE CHARACTERISTICS OF COMMERCIAL SODIUM-ION CELLS

Dimitar Arnaudov*, Krasimir Kishkin

Technical University of Sofia, 8 Kl. Ohridski Blvd, Sofia, Bulgaria,

** Corresponding author: dda@tu-sofia.bg*

Abstract

The paper compares the characteristics of two sodium-ion commercial 18650 cells from two different manufacturers. This paper studies possibility of using impedance spectroscopy for analyzing battery's state of health. In this work, the impedance characteristics of Sodium-ion batteries are compared. The comparisons are made for cells with identical state of charge (SOC). The temperature characteristics in the charging and discharging processes under identical conditions of cells from two different manufacturers are also compared.

Keywords: sodium-ion battery, characteristics, spectral analysis, discharge.

INTRODUCTION

The study of the characteristics of sodium-ion batteries is an interesting area for researchers and various methods have been applied to obtain the characteristics [1, 2, 3, 4]. Based on the obtained characteristics, different solutions are searched and applied to implement Battery Management Systems (BMS). The waveform of the current through the batteries affects the behaviour of the batteries. One of the functions of a BMS is to equalize the voltages across cells (or modules) connected in series by using appropriate equalisation algorithms. Since different types of DC-DC converters, operating at high frequencies, are used in voltage balancing systems, the current waveform with high frequency components affects the behaviour of the batteries [5]. These high frequency components can be used to characterize the state of the batteries. By using the method of electrochemical impedance spectroscopy, the condition of batteries can be analysed [6, 7].

I. CELL DATA FROM MANUFACTURERS

In this paper, two commercial sodium-ion cells in package type18650 have been studied. Different manufacturers provide the cells with equal capacity of 1300mAh but different maximum discharge C-rate. According to the manufacturer's documentation, the C-rates for the cells are 20C (named cell 1) and 3C (named cell 2). Charging and discharging characteristics are obtained as well.

II. EXPERIMENTAL INVESTIGATION

Thermal profile of the cells during the charging and discharging processes has been measured by using thermal imaging camera. When a certain charging level was reached, spectral characteristics were captured using a BODE 100 vector network analyzer.

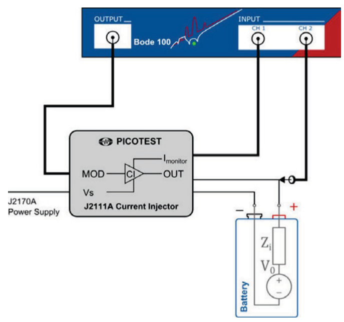

Fig. 1. *Experimental setup for battery impedance measurment*

Figure 1 shows a typical cell connection circuit to a BODE 100 vector analyzer [8].

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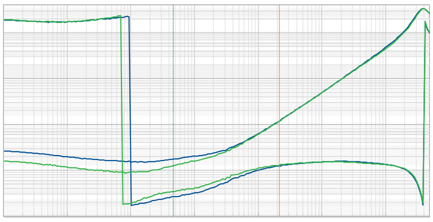

Fig. 2. *Single cell Sodium-ion battery impedance spectrum*

Figure 2 shows the spectral characteristics (impedance and phase) of two cells from different manufacturers (green – cell 1, blue – cell 2). For this case the cells are fully charged. Investigations were made in different charging levels and the characteristics of the same cell at different charging levels were compared. A comparison was also made of the characteristics at the same charge rate but of two cells from different manufacturers (Figure 2).

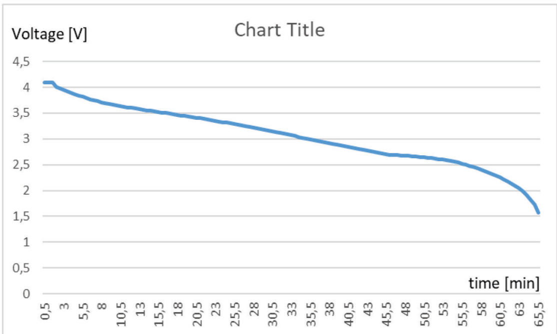

Fig. 3. *Discharge characteristic with current 1C (cell 1)*

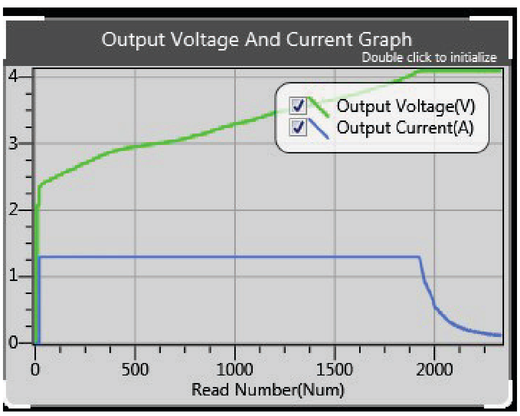

Fig. 4. *Charging characteristic with current 1C (cell 1)*

Figure 3 and Figure 4 show the charge and discharge characteristics of a sodium-ion cell measured at 1C current. (figure 3 and figure 4 – for cell 1). Figure 5 and Figure 6 show the discharge and charge characteristics of cell 2.

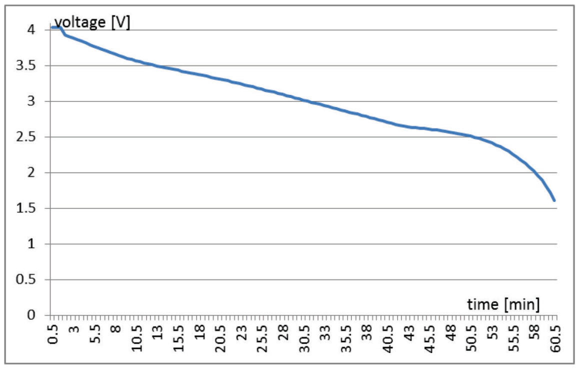

Fig. 5. *Discharge characteristic with current 1C (cell 2)*

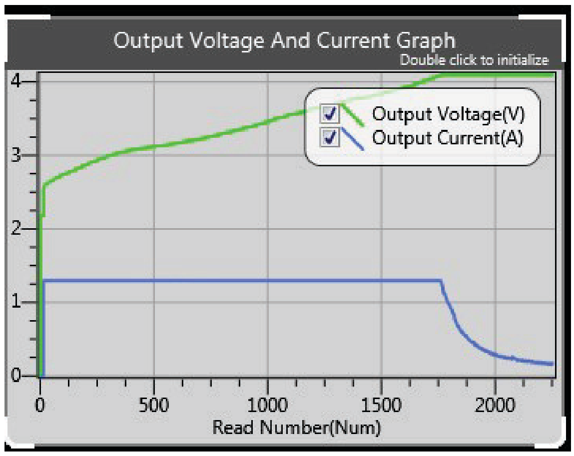

Fig. 6. *Charging characteristic with current 1C* ***(cell 2)***

The cell temperature change during the constant current discharge process were measured and plotted for values of discharge current – 3C-rate (3.9A). When certain temperatures were reached, the spectral characteristics of these cells were taken.

A thermal imaging camera was used to measure the cell temperatures at the time of starting the discharging process - indicated by t - 0 minutes. From the results shown in Figure 7 and Figure 8, it can be seen that the discharge process for both cells starts from the same temperature (23.8 degrees Celsius).

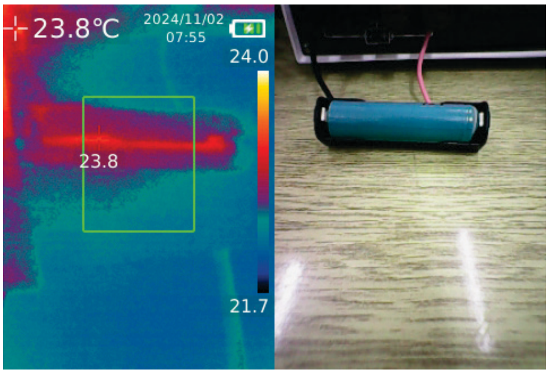

Fig. 7. *Cell 1 temperature 0 minutes*

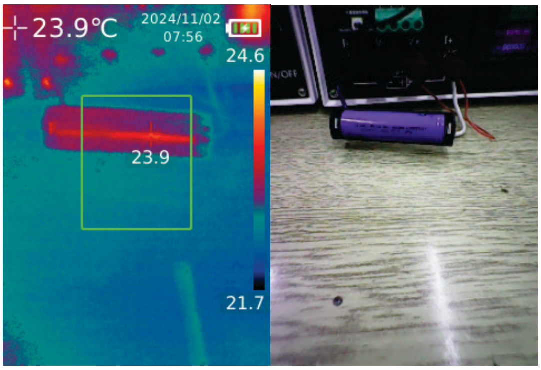

Fig. 8. *Cell 2 temperature 0 minutes*

Two identical electronic loads were used to discharge the cells, by which the same discharge current and the same voltage were set at which to stop the discharge process. Figures 9 and 10 show the results at the end of the discharge process, 20 minutes. From the results it can be seen that the cell with the lower according to the documentation maximum discharge current (cell -2) has a higher temperature.

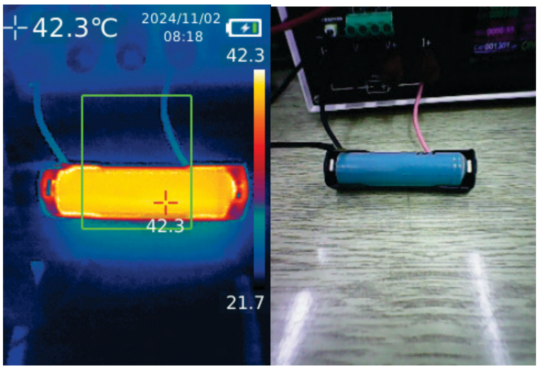

Fig. 9. *Cell 1 temperature at 20 minutes.*

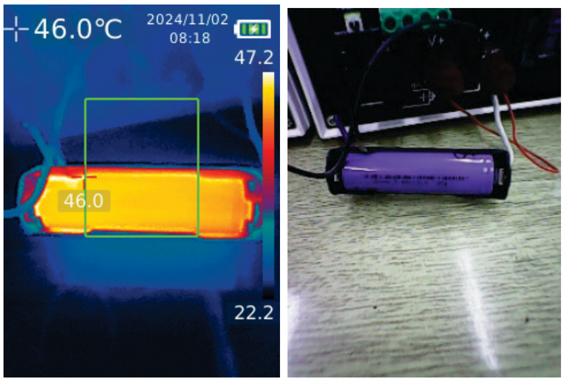

Fig. 10. *Cell 2 temperature at 20 minutes.*

The cells were charged with 1C current, and again the temperature change of two cells was monitored, similar to the above study.

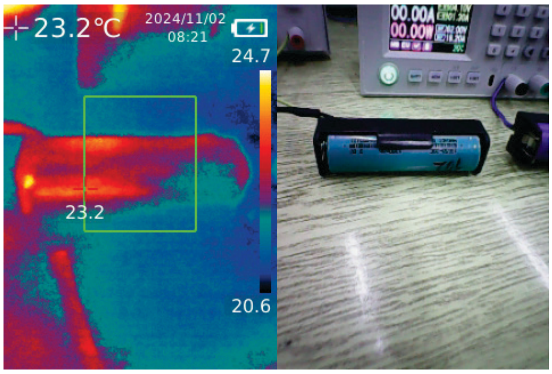

Fig. 11. *Cell 1(charging) temperature 0 minute*

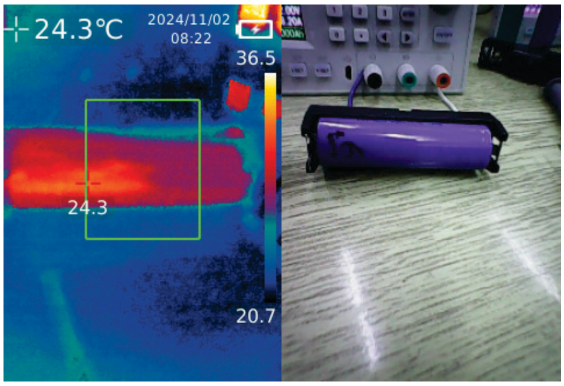

Fig. 12. *Cell 2(charging) temperature 0minute*

Figures 11 and 12 show thermal images of the cells at the beginning of the charging process. Cell 1 starts the process at 23.1 degrees Celsius and cell 2 at 24.3 degrees Celsius.

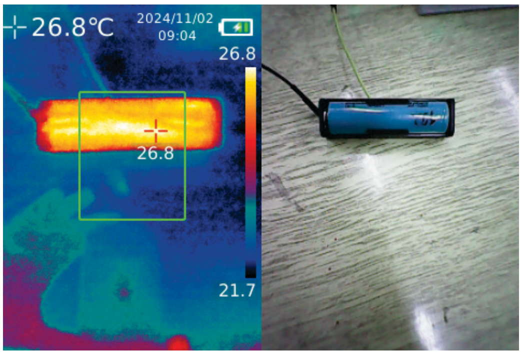

Fig. 13. *Cell 1(charging) temperature 40 minute*

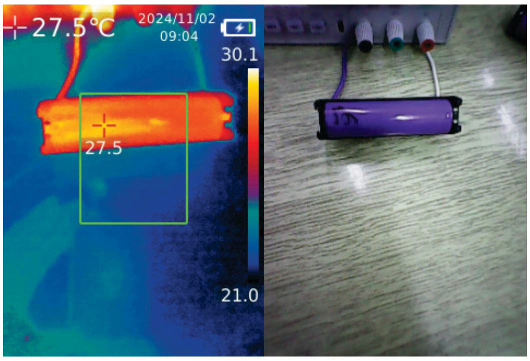

Fig. 14. *Cell 2(charging) temperature 40 minute*

Figures 13 and 14 show the results at the 40th minute of the charging process.

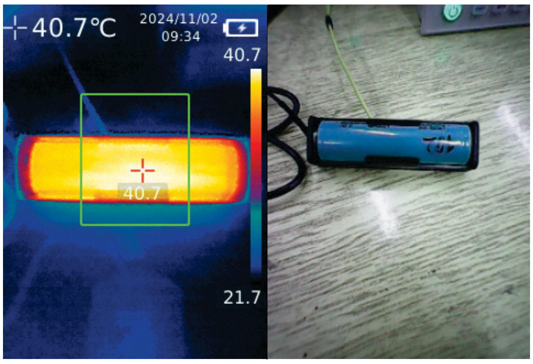

Fig. 15. *Cell 1 (charging) temperature 70 minute*

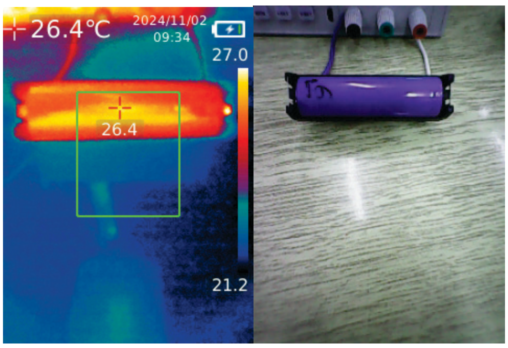

Fig. 16. *Cell 2 (charging) temperature 70 minute*

An interesting result is that the temperature of the cell with the larger allowable maximum discharge current (cell 1) is significantly higher than the one with the smaller maximum discharge current (cell 2).

CONCLUSION

From the investigations made on the spectral characteristics of the two cells from different manufacturers, it is seen that the phase response of one of the cells, independent of the charging rate, always changes its character at a lower frequency relative to the other. From the observation of the cell temperatures during the discharge process, it can be seen that the cell with the higher maximum discharge current according to the documentation has a lower temperature. For the charging process, however, the results are in favour of the cell with the lower maximum discharge current.

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