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Electrochemical Performance of Commercial Li-Ion Battery Samsung 25R Cylindrical Type 18650

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Abstract. Samsung 18650 25R lithium-ion battery used as object of reverse engineering study was obtained from commercial market. Samsung cylindrical cell with dimension of 18 mm diameter and 650 mm was tested using a Battery Tester 5V-6A in order to study its Electrochemical performances, such as columbic efficiency, capacity retention, and capacity fading after cycled for 100 times. The cell was charged and discharged with a constant current 1250 mA, and 0.5 C-rate. All these processes were repeated for 100 cycles. The first, fifth and tenth cycles charged and discharged capacity were 2356.18 mAh and 2355.79 mAh, 2342.82 mAh and 2343.62 mAh, 2349.21 mAh and 2343.85 mAh, respectively. It is shown that the real capacity values are little lower than the data label capacity 2500 mAh (99.98%), and there was no significant change in capacity value after 10th cycles. Furthermore, the detail analysis of performance after 100th cycle, showed the charged and discharged capacity downed to 2302.22 mAh and 2302.62 mAh, respectively. There was no significant change in capacity value after 100th cycle. Reflecting to coulombic efficiency, the numbers are stable at more than 99.8%, even after the 100th cycles. Meanwhile, the capacity retention was also remained at 99.95% after the 100th cycle, showing the cyclic ability of this commercial battery was good. The first cycle of the battery gives capacity fading value at 5.77% in respect to the nominal capacity (2500 mAh) and until 100th cycle the value raised to 7.94%, which still in acceptable value (up to 40% capacity fading). It can be concluded that this commercial battery has proved a very stable performance.

INTRODUCTION

Lithium-ion battery has become emerged developing technology with a lot of practical application, from small scale in energy storage system to large storage system in electric vehicles[1] [2]. It is the key to all the electronic device & systems to run well [3]. Various developing technology of this lithium-ion battery mainly concerned to increase the performance in terms of capacity and working voltage window, reliability of usage of the battery in vehicle application, cost-effective manufacture, and the safety concern [4][5].

Recently significant increase of the lithium-ion battery applications in various electronic devices, electric vehicles, drone, military devices as well as for energy storage in the renewable energies [6][7]. Those are followed by the improvement of the battery technology in order to increase performance of the lithium-ion batteries, including the materials of battery components such as cathodes, anodes and electrolytes [8][9]. The current technology of cathodes-based nickel materials, due to their higher capacity and better performance in comparison to the other batteries. The most demanding cathodes in the future market are high rich nickel such as $LiNi_xCo_yMn_zO_2$ (NCM), and $LiNi_xCo_yAl_zO_2$ (NCA) with x + y + z = 1 [10][11][12][13].

There are manufactures that have produced the nickel-based lithium-ion batteries, that commercially available in the market. Some of them are dominant in the markets, such as LG, Samsung, Sony and CATL [7][2][3]. However, there has not been studied that observe the insight and performance of the existing commercial batteries. This could

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be an important issue in order to understand the market, and obtaining the benchmark of the of the best commercial battery in the market. Furthermore, by understanding their battery components and performance, the researchers are able to search for the new and better materials that approaching to the market. Therefore, this paper will comprehensively study and analyze electrochemical performance of the commercial lithium-ion battery Samsung 25R 18650 that available in the market. The insight of the battery components will be discussed separately in another article in this issue.

METHODOLOGY

Samsung 18650 25R lithium-ion battery are used as object of reverse engineering study, which was obtained from commercial market [2]. The cylindrical cell dimension are 18 mm diameter and 650 mm, as shown in figure 1(a). Electrochemical performances of the battery are first analysed using a Neware Battery Tester 5V-6A, as seen in Figure 1(b). The cell was tested through several steps, namely Constant Current Discharge (CC Dchg), where cell was discharged with 0.5 C-rate (1250 mA) until cell voltage dropped to 2.8 V, then it rested for 10 minutes. The Constant Current-Constant Voltage Charge (CCCV Chg) were done, where the cell was charged with a constant 0.5 C-rate (1250 mA) until cell voltage reached 4.2 V and continued charging in a constant voltage until the current dropped to 0.05 C-rate (125 mA). All these processes were repeated for 100 cycles. Detail of the experiment ahs been described elsewhere [6]

After the sample subjected to electrochemical tests, then observation was analysed to the performance of commercial LIB such as the columbic efficiency, capacity retention, and capacity fading after 100 cycles.

RESULTS AND DISCUSSION

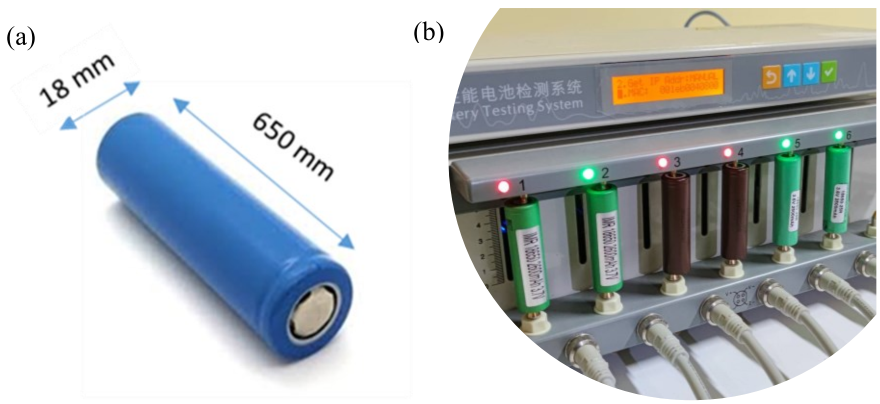


FIGURE 1. (a) Cylindrical cell 18650; (b) Performance Testing of commercial 18650 cylindrical cells during charged and discharged by using a battery testing system.

The commercial battery Samsung 18650 25R lithium-ion battery, that used as object in this study was a cylindrical cell with a dimension of diameter 18 mm and length of 650 mm, as shown in Figure 1(a). The cylindrical cells were then tested by using a Battery Testing with the limitation of 5V-6A, as seen in Fig.1(b). Two cells were tested simultaneously using two battery channels. The cells were discharged with 0.5 C-rate (1250 mA) until cell voltage dropped to 2.8 V, then it rested for 10 minutes. It was followed by the The Constant Current-Constant Voltage Charge (CCCV Chg), with a constant 0.5 C-rate (1250 mA) until cell voltage reached 4.2 V, then continued charging at this constant voltage until the current dropped to 0.05 C-rate (125 mA). All these processes were repeated for 100 cycles.

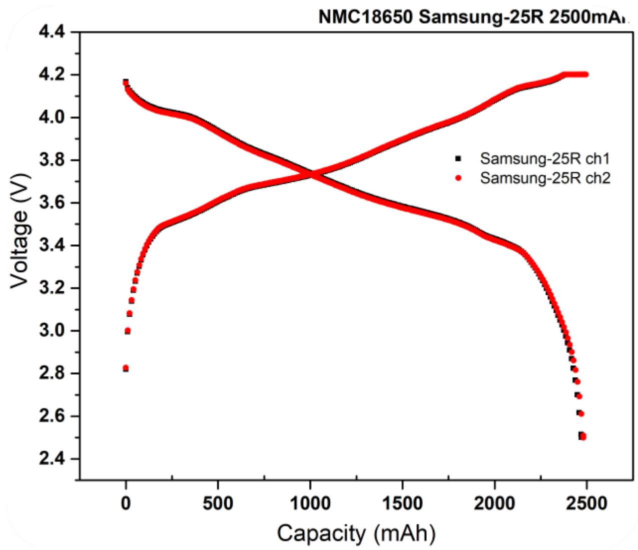


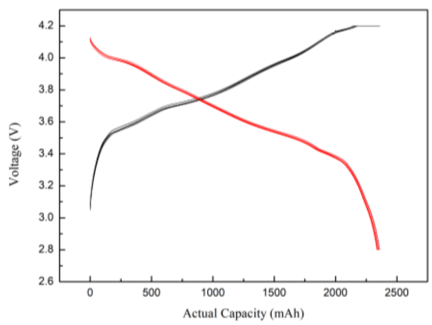
FIGURE 2. Charge and Discharge performances of commercial Samsung 25R cylindrical cell 18650 for 1st cycles measured in two channels of a battery testing.

The first cycle of the two commercial cells from channel 1 and channel 2, whereas both discharged and charged graphs are almost identical is shown in Figure 2. The first measured discharge capacity was 2470.76 mAh and 2355.79 mAh, respectively for cell-1 and cell-2, respectively. Those measured capacity of cell-1 was about 98.83% from the labelled capacity 2500 mAh, while cell-2 was 94.25%. (See Table 1). The actual capacity of the tested battery in first cycle was a bit smaller than the rated capacity stated in the datasheet materials, although the voltage-capacity profile of this type of battery is similar to other performance profile of commercial NMC-cathode battery [6].

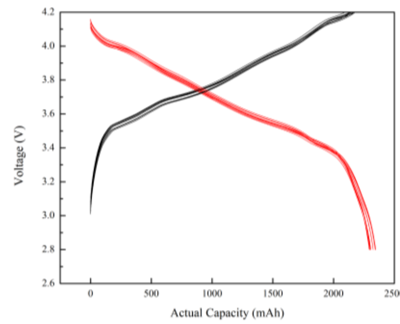
TABLE 1. Measured Capacity of the commercial Samsung 25R cylindrical cell 18650 for 1st cycle

No	Battery Type	Labelled Capacity (mAh)	Measured Capacity (mAh)	% Capacity
1	Cylindrical cell_1	2500	2470.76	98.83%
2	Cylindrical cell-2	2500	2355.79	94.25%

Further analysis the charged and discharged processes were continued for cell-2, with the same condition until 100 th cycles. The electrochemical test performed to the commercial battery were conducted under normal C-rate (0.5C). Figure 3(a) shows the charge and discharge performances of commercial Samsung cylindrical cell 18650 for 1st to 10th cycles, and (b)for 10th to 100th cycles with steps of every 10 cycles measured by a battery testing. The first, fifth and tenth cycles charged and discharged capacity were respectively 2356.18 mAh and 2355.79 mAh, 2342.82 mAh and 2343.62 mAh, 2349.21 mAh and 2343.85 mAh, as listed in Table 2. It is shown that there was no significant change in capacity value after 10th cycles, though the real capacity values are lower than the data sheet capacity. Furthermore, the detail analysis of performance after 100th cycle, showed the charged and discharged capacity were 2302.22 mAh and 2302.62 mAh, respectively as listed in Table 2 and shown in Fig.3(b). The voltage-capacity profile of the battery is in general described in Figures 1and 3 [14]**.** There was no significant change in capacity value after 100th cycle.



(a)



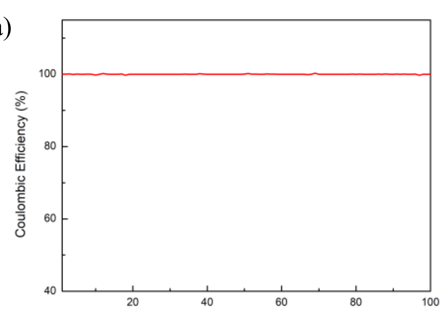
(b)

FIGURE 3. Charge and Discharge performances of commercial Samsung cylindrical cell 18650 (a) for 1st to 10th cycles, and (b) 10th to 100th cycles with steps of every 10th cycle measured by a battery testing.

TABLE 2. Charge & Discharge Capacity after several cycles

n-th Cycle	Cap. Charge (mAh)	Cap. Discharge (mAh)	Coulombic Efficiency (%)	Capacity Retention (%)	Capacity Fading (%)
1	2356.18	2355.79	99.98%	100.00%	5.77%
2	2357.59	2359.03	100.06%	100.14%	5.64%
3	2344.01	2346.12	100.09%	99.45%	6.16%
4	2343.33	2342.15	99.95%	99.83%	6.31%
5	2342.82	2343.62	100.03%	100.06%	6.26%
6	2342.40	2342.29	100.00%	99.94%	6.31%
7	2342.41	2342.35	100.00%	100.00%	6.31%
8	2340.16	2340.83	100.03%	99.94%	6.37%
9	2338.71	2338.84	100.01%	99.92%	6.45%
10	2349.21	2343.85	99.77%	100.21%	6.25%
20	2346.20	2345.47	100.00%	100.02%	6.16%
30	2343.45	2343.84	100.02%	99.93%	6.31%
40	2324.98	2326.14	100.00%	99.95%	7.00%
50	2325.46	2325.07	100.06%	100.01%	6.99%
60	2298.92	2299.49	100.00%	99.96%	8.06%
70	2308.87	2315.79	99.98%	99.58%	7.75%
80	2302.06	2303.14	99.98%	99.93%	7.94%
90	2292.69	2293.13	99.98%	100.00%	8.27%
100	2302.22	2302.62	100.01%	99.95%	7.94%

(a)



(b)

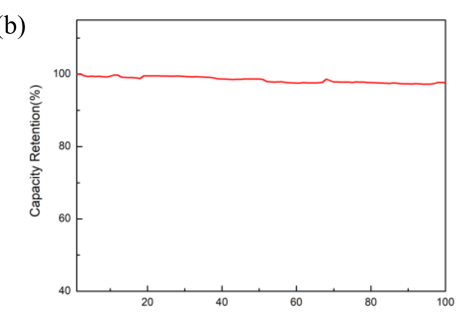


FIGURE 4. The profile of (a) coulombic efficiency, (b) capacity retention of commercial LIB Samsung 25R Cylindrical Cell 18650 from the first to 100th cycles.

The profile of commercial battery's coulombic efficiency and capacity retention, were introduced in Figure 4 (a) and 4(b), respectively. Coulombic efficiency describes the efficiency of transferred electrons during charge-discharge process. Lithium-ion batteries have higher coulombic efficiency rather than other type of rechargeable batteries such as lead-acid and Ni-H batteries [7][15]. However, this parameter can only give the best value at normal current and temperature. Reflecting to coulombic efficiency profile given at Figure 2(a), the numbers are stable at more than 99.8%, even after the 100th cycles, as listed in Table 1. Meanwhile, the capacity retention was also remained at 99.95% after the 100th cycle, showing the cyclic ability of this commercial battery was good. It can be concluded that this commercial battery has proved a very stable performance, where the electron moves back and forth the electrodes with almost similar amounts for every cycle [16]. Figure 5 shows a capacity fading of the commercial Samsung 25R cylindrical battery after 100th cycles. As listed in Table 1, the first cycle of capacity

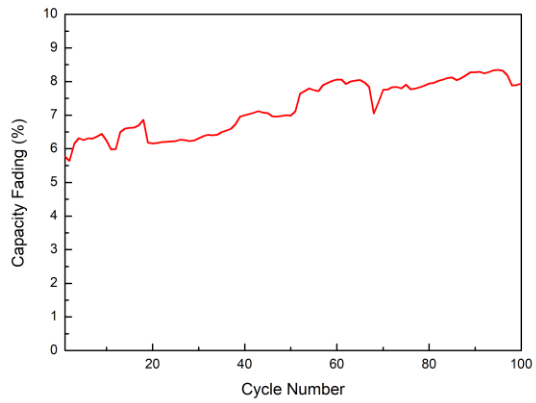


FIGURE 5. Capacity fading of the first 100 charge discharge cycle in 0.5 C-rate fading of commercial LIB Samsung 25R Cylindrical Cell 18650.

Capacity fading or capacity loss is one of parameters that analysed in battery performance. It describes the decrease of capacity or the amount of charge that battery can deliver at the voltage range over time and upon usage, with respect to the initial capacity declared by the manufacturer [5][17]. This parameter appears as a consequence of chemical process that occur inside the battery during cycle usage, where the lithium ions that shuttled back and forth between cathode and anode, interacts with electrolyte and forms Solid Electrolyte Interphase (SEI). This layer causes lithium ion get trapped inside and reducing the amount of ions flow during charge-discharge process. High voltage charge and low voltage discharge could also contribute to the capacity fading as it will damaged the crystal structure of cathode/anode and lowers the lithium occupancy inside the structure. As it seen in Figure 5, the first cycle of the battery gives capacity fading value at 5.77% in respect to the nominal capacity (2500 mAh) and until 100th cycle the value raise to 7.94%, which still in acceptable value (up to 40% capacity fading) [18].

CONCLUSION

The first capacity measured of commercial Samsung was 2356.18 mAh, or about 94.25%, lower than the labelled capacity 2500 mAh. However, it did not significantly change even after 100 cycles. The columbic efficiency and capacity retention after 100th cycles were 99.98% and 99.58%, respectively, which are showing its stability of the cell. Meanwhile the first capacity fading value was at 5.77% in respect to the nominal capacity (2500 mAh), and until 100th cycle the value raised to 7.94%, which was still in acceptable value (up to 40% capacity fading). It is concluded that the Samsung 18650 25R lithium-ion battery has shown good electrochemical performance after charged and discharged for 100 cycles.

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