Secondary Battery System (Vol. 9) : Cost Evaluation of a Lithium-ion Battery Using Next-Generation Electrode Active Material

Summary

An attempt was made to predict future changes to higher specific energy and lower costs of lithium-ion batteries (LIBs) by calculating the manufacturing costs of LIBs while taking into account recent technological levels. Incorporation of next-generation electrode active material into LIBs was designed, and the manufacturing cost of a LIB was estimated. While the manufacturing cost of the current model (year 2020) is from 11.9 to 23.2 JPY/Wh, it was found in the estimation that the manufacturing cost of the future model may be reduced to 5.1 JPY/Wh at the lowest. On the other hand, to accomplish the short-term targets of energy density (500 Wh/kg or more) and manufacturing cost (10,000 JPY/kWh per battery pack) for EV applications, etc. by 2030, about ten years of development period remain, and therefore research for that end should be encouraged and promoted.

Proposals for Policy Development

- As specific measures for attaining high-performance low-cost secondary batteries, a proposal was made to replace the current positive and negative electrodes with a next-generation positive-electrode active material and a Si negative electrode, respectively, or alternatively with S positive-electrode active material and a metal Li negative electrode, respectively. It was shown in a quantitative manner that the replacement of these electrodes is technically feasible.
- With the technology development and implementation under current development investment, it is predicted to be able to accomplish the targets after 2040. To accomplish new targets in the future, it is essential to make urgent, concentrated investment in terms of equipment, budget, and human resources through close cooperation between industry, academia, and government.

1. Secondary battery design specifications for evaluation

The structure of the secondary battery for evaluation was such that a stacked cell, in which several single cells were stacked, was sealed by the enclosure of a pouch material (Fig. 1). Dimensions were selected by referring to LiBs on the market. Table 1 shows the configuration of electrode active material and the battery voltage. In the case of References 1 through 4, electrode active materials (conventional materials) used in LiBs on the market were employed. In the case of Examinations 1 through 9, materials other than conventional materials were employed for one or both of positive and negative electrode active material ([1] - [5]).

2. Estimated manufacturing cost

Fig. 2 shows the estimated manufacturing cost and energy density of secondary batteries for evaluation batteries (References 1 through 4 and Examinations 1 through 9 in Table 1) for several groups classified by combination of different electrodes.

3. Future prospects

To reduce the manufacturing cost and to improve the energy density, it will be necessary to replace positive and negative electrodes with next-generation electrode active materials.

For the estimation of the energy density and the manufacturing cost, the following settings were assumed: For the short-term targets (from year 2030 to year 2040), replace either or both positive or negative electrode with next-generation positive-electrode active material and a Si negative electrode, respectively. For the medium-term targets (year 2050), replace positive and negative electrodes with next-generation positive-electrode active material and a Si negative electrode respectively, or alternatively with S positive-electrode active material and metal Li negative electrode, respectively. Specific energy and manufacturing cost were estimated by referring Fig. 2.

Current group (G1): 277 Wh/kg, 11.9 JPY/Wh

Short-term targets group (G2, G3, and G5):
300 Wh/kg or more, 11.6 JPY/Wh or less

Medium-term targets group (G4, G6, and G7):
300 Wh/kg or more, 10.0 JPY/Wh or less

Note, however, that it is estimated that more time will be needed for practical realization because both positive and negative electrodes should be changed to accomplish the medium-term targets (year 2050).

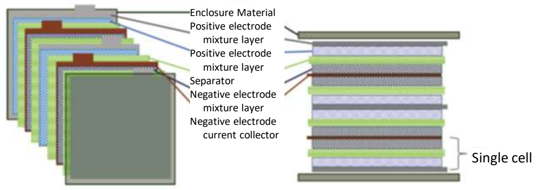

Fig. 1. Conceptual Configuration Diagram of Secondary Battery for Evaluation
(Left: Exploded Perspective View, Right: Cross Section)

Table 1. Configuration of Electrode Active Material and Battery Voltage of Secondary Batteries for Evaluation

	Positive Electrode			Negative electrode			
	Active material	Capacity [mAh/g]	Capacity utilization	Active material	Capacity [mAh/g]	Capacity utilization	Battery voltage [V]
Reference 1	$LiNi_{0.8}Co_{0.15}Al_{0.05}O_2$	196	0.72	C_6	353	0.95	3.6
Reference 2	$LiNi_{0.33}Mn_{0.33}Co_{0.33}O_2$	169	0.61	C_6	353	0.95	3.6
Reference 3	$LiFePO_4$	165	0.97	C_6	353	0.95	3.3
Reference 4	$LiMn_2O_4$	110	0.74	$Li_{4/3}Ti_{5/3}O_4$	165	0.94	2.24
Examination1	$Li_{1.2}Ti_{0.4}Mn_{0.4}O_2$	300	0.76	C_6	353	0.95	3.3
Examination2	$Li_2Mn_{1/2}Ti_{1/2}O_2F$	320	0.70	C_6	353	0.95	3.3
Examination3	$LiNi_{0.5}Mn_{1.5}O_4$	135	0.92	C_6	353	0.85	4.55
Examination 4(a)/4(b)	$LiNi_{0.8}Co_{0.15}Al_{0.05}O_2$	196	0.72	Si	1,007/ 4,197	0.24/ 1	3.3
Examination 5(a)/5(b)	$LiNi_{0.3}Mn_{0.33}Co_{0.33}O_2$	169	0.61	Si	1,007/ 4,197	0.24/ 1	3.3
Examination 6(a)/6(b)	$Li_{1.2}Ti_{0.4}Mn_{0.4}O_2$	300	0.76	Si	1,007/ 4,197	0.24/ 1	3.0
Examination 7(a)/7(b)	$Li_2Mn_{1/2}Ti_{1/2}O_2F$	320	0.70	Si	1,007/ 4,197	0.24/ 1	3.0
Examination 8(a)/8(b)	$LiNi_{0.5}Mn_{1.5}O_4$	135	0.92	Si	1,007/ 4,197	0.24/ 1	4.25
Examination9	S	1,508	0.9	Metal Li	2,895	0.75	2.15

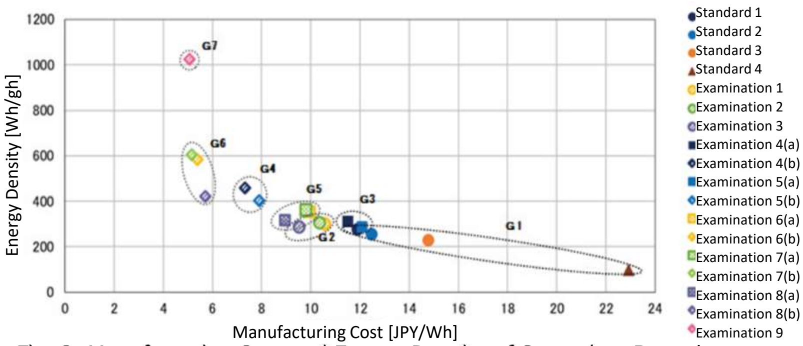

Fig. 2. Manufacturing Cost and Energy Density of Secondary Batteries for Evaluation (References 1 through 9 and Examinations 1 through 9) by Group Classification

* Group classification into G1 through G7 (Table 1 classification in parentheses)
G1: Conventional positive-electrode active material/ conventional graphite negative electrode (References 1 through 4)
G2: Next-generation positive-electrode active material/ conventional graphite negative electrode (Examinations 1 through 3)
G3 (future 2L): Conventional positive-electrode active material/ Si negative electrode (Examinations 4a and 5a)
G4 (future 2H): Conventional positive-electrode active material/ Si negative electrode (Examinations 4b and 5b)
G5 (future 3L): Next-generation positive-electrode active material/ Si negative electrode (Examinations 6a, 7a, and 8a)
G6 (future 3H): Next-generation positive-electrode active material/ Si negative electrode (Examinations 6b, 7b, and 8b)
G7 (future 4): S positive-electrode active material/ metal Li negative electrode (Examination 9)

[1] Naoaki Yabuuchi et al, “Origin of stabilization and destabilization in solid-state redox reaction of oxide ions for lithium-ion batteries,” Nature Communications, vol. 7, no. 13814, 2016.
[2] Jinhyuk Lee et al., “Reversible Mn2+/Mn4+ double redox in lithium-excess cathode materials,” Nature, vol. 556, pp. 185-190, 2018.
[3] “Development of Lithium-Ion Battery Active Material and Electrode Material Technology,” Science & Technology Co., Ltd., pp. 42-52, 2014
[4] “Battery Handbook,” Edited by the Committee of Battery Technology, the Electrochemical Society of Japan, Ohmsha, Ltd., p. 410-413, 201
[5] LCS, Proposals for Planning of Innovation Policy, “Secondary Battery System (Vol. 6),” February 2019