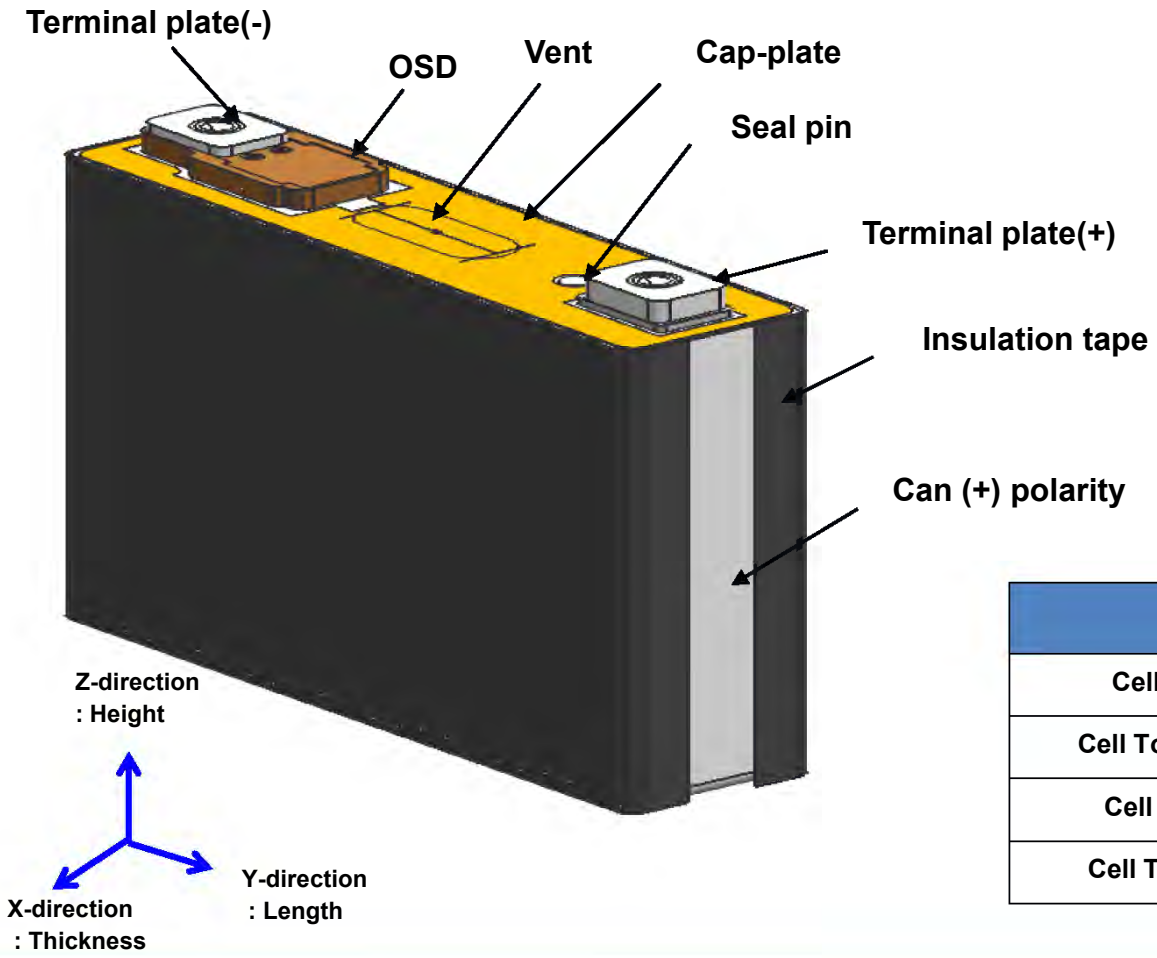
Introduction of Samsung SDI's 94Ah cells

31th Dec. 2015

SAMSUNG SDI

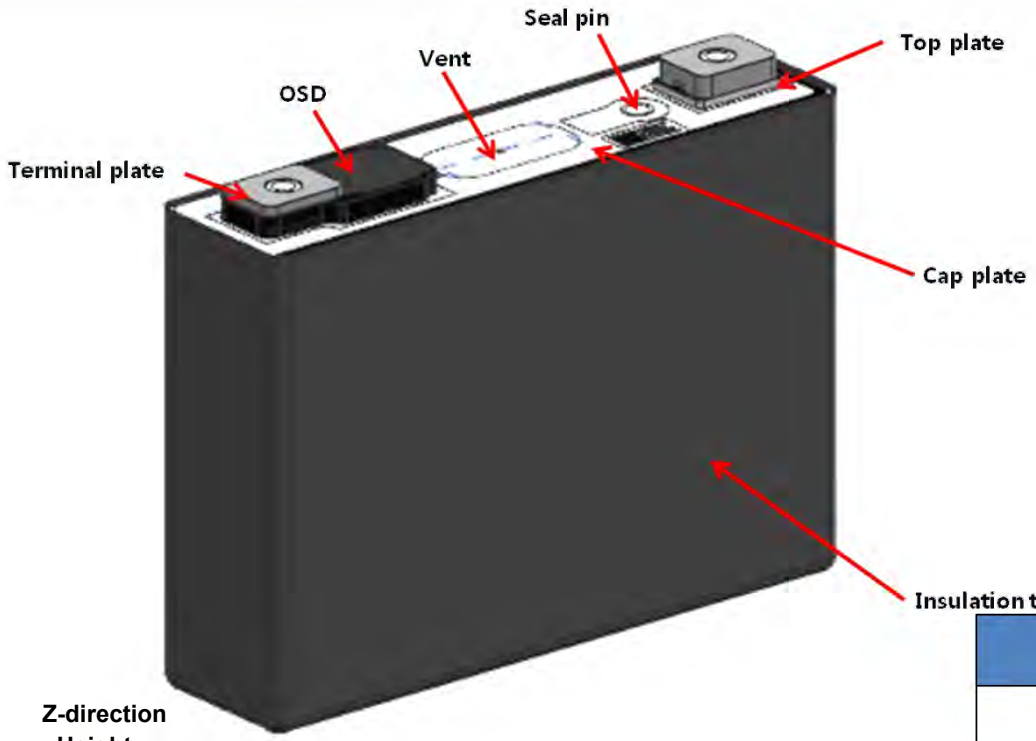
Contents

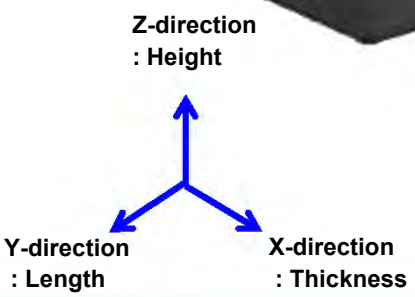
Cell Appearance
94Ah(1)



Items	Characteristics
Cell Height (Z)	125mm
Cell Total height (Z)	133mm (Rivet)
Cell Length (Y)	173mm
Cell Thickness (X)	45mm

Cell Appearance
94Ah(2)_ 5 side taping





Items	Characteristics
Cell Height (Z)	125mm
Cell Total height (Z)	133mm (Rivet)
Cell Length (Y)	173mm
Cell Thickness (X)	45mm

Summary of cell performance

Cell type					94Ah cell
Energy	Capacity (min.)		1/3C rate, 25°C, Discharge	Ah	94
	Energy (min.)		1/3C rate, 25°C, Discharge	Wh	345
	Specific energy (min.)			Wh/kg	165
General information	Nominal voltage		-	V	3.68
	Size		Width x height x Thickness	mm	173 x 125 x 45
	Cell weight (max.)		Bare cell	kg	2.1
	Operating voltage		-	V	2.7 ~ 4.15
	Operating temperature		-	°C	-40 ~ 60
Operation current	Discharge	Continuous	25°C	A	150
		Peak	25°C	A	409
	Charge	Continuous	25°C	A	72
		Peak	25°C	A	270
Power capability	5sec discharge	Resistance	RT, 50% SOC	mOhm	0.75
		Specific power capability	RT, 50% SOC (at V_min)	W	3,500
	30sec discharge	Resistance	RT, 50% SOC	mOhm	0.99
		Specific power capability	RT, 50% SOC (at V_min)	W	2,600
Life	Cycle life		0.5C/1C, RT, EOL80%/EOL70%	cycles	3,200 / 5,200
			1C/1C, 45°C, EOL80%/EOL70%	cycles	1,500 / 2,500
	Calendar life		SOC100%, 25°C, EOL80%/EOL70%	years	17 / 26
Swelling force	Max. force at EOL		0.5C/1C, RT, rigid jig	N	< 25000
China homologation			GB/T certificate	PASS	PASS estimation
Transportation			UN 38.9	PASS	PASS estimation

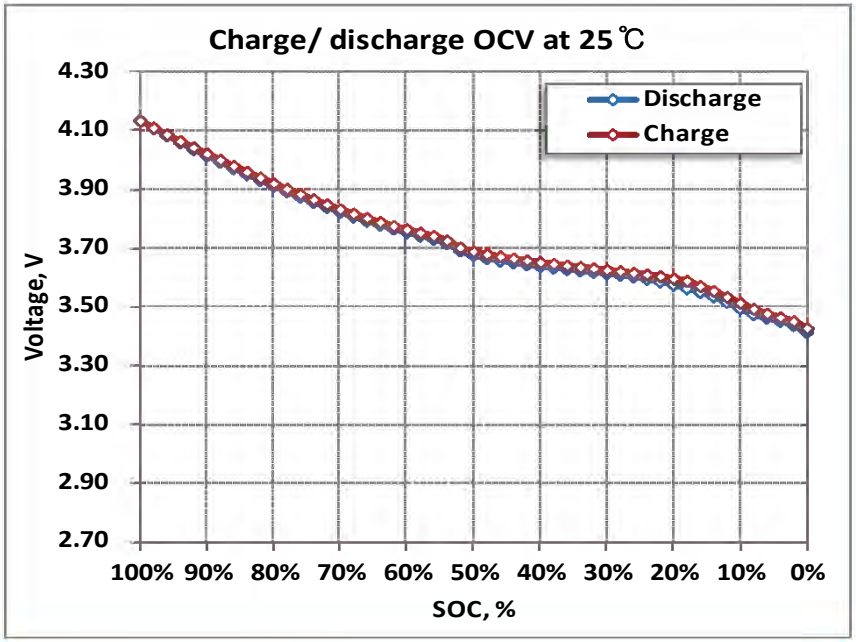
Performance Test

OCV, Rate Capability, DC-IR and Power

SAMSUNG SDI

Charge and discharge OCV

2% interval at 25℃



- **Discharge method**

1. Standard charge at RT (SOC = 100%), rest 3 hr
2. Adjustment of SOC: Discharge by 2% SOC with 1/3C , rest 3 hr
3. Repeat step 2 until SOC=0% or until to meet limit voltage

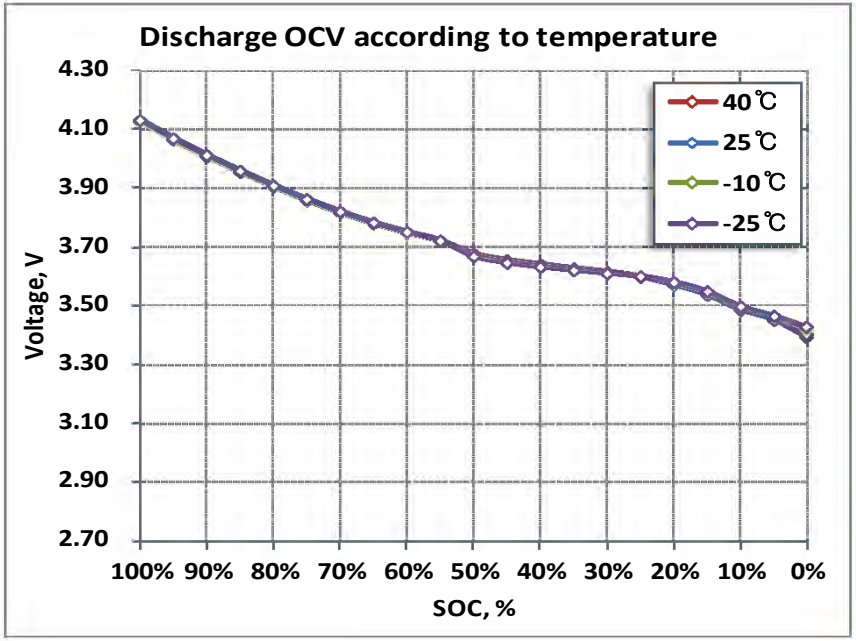
- **Charge method**

1. Standard discharge at RT (SOC = 0%), rest 3 hr
2. Adjustment of SOC: Charge by 2% SOC with 1/3C, rest 3 hr
3. Repeat step 2 until SOC=100or until to meet limit voltage

OCV	Discharge @ 25℃	Charge @ 25℃
100%	4.136	4.133
90%	4.016	4.022
80%	3.913	3.921
70%	3.825	3.833
60%	3.756	3.765
50%	3.678	3.690
40%	3.641	3.653
30%	3.615	3.627
20%	3.579	3.598
10%	3.499	3.517
0%	3.420	3.433

Discharge OCV

5% interval at 25℃/ -25℃



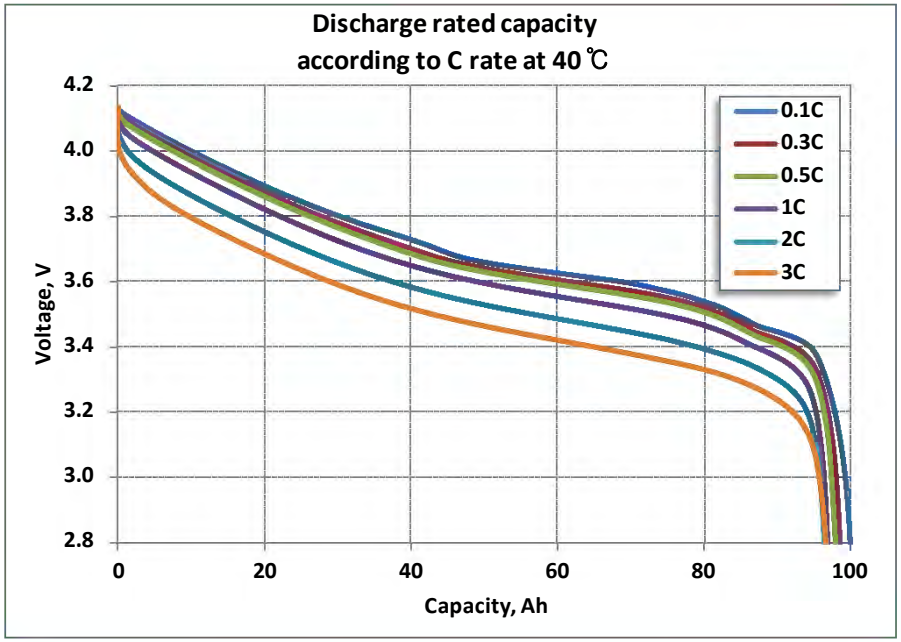
- **Discharge method**

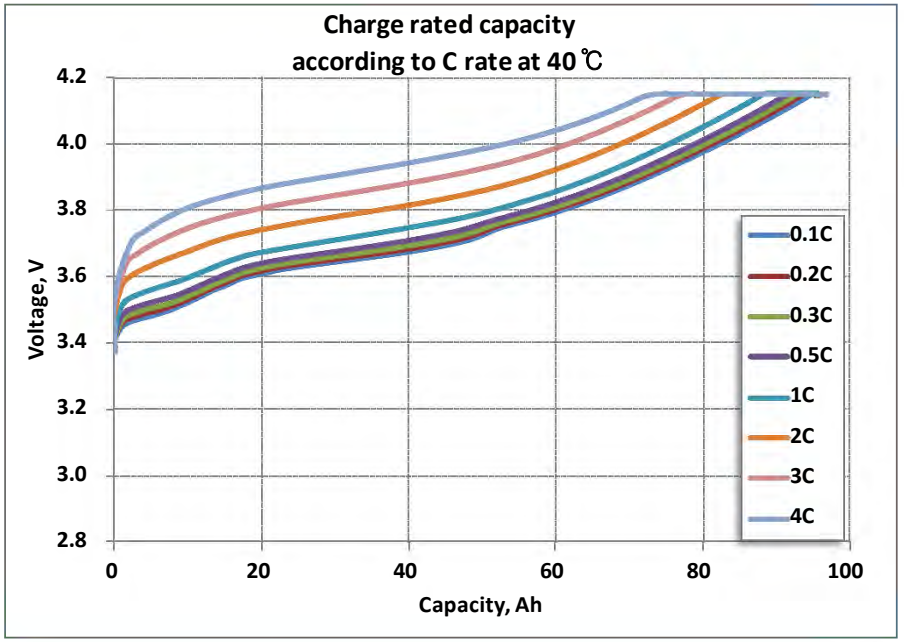
1. Standard charge at RT (SOC = 100%), rest 3 hrs
2. Temperature change (25℃ to -25℃)
3. Soaking(5h), rest 1hr
4. Room Temperature Change (-25℃ to 25℃, soaking 2hrs)
5. Adjustment of SOC: Discharge by 5% SOC with 1/3C , rest 3 hrs
6. Repeat step 2~5 until SOC=0% or until to meet limit voltage

OCV	Discharge @ 40℃	Discharge @ 25℃	Discharge @ -10℃	Discharge @ -25 ℃
100%	4.129	4.129	4.131	4.132
90%	4.009	4.010	4.012	4.013
80%	3.9076	3.907	3.909	3.910
70%	3.818	3.819	3.820	3.821
60%	3.750	3.751	3.751	3.752
50%	3.677	3.676	3.671	3.669
40%	3.641	3.641	3.634	3.647
30%	3.616	3.614	3.611	3.611
20%	3.572	3.574	3.579	3.581
10%	3.452	3.490	3.496	3.499
0%	3.395	3.404	3.422	3.429

Rated Capacity

0.1C ~4C rates @ 40℃





C-rate		0.1C	0.3C	0.5C	1C	2C	3C
Discharge	Capacity	100.2 Ah	98.8 Ah	98.1 Ah	97.0 Ah	96.6 Ah	96.9 Ah
	% (vs.1/3C)	101.40%	100.00%	99.30%	98.20%	97.80%	98.10%
	Energy (Wh)	370 Wh	363 Wh	360 Wh	352 Wh	345 Wh	339 Wh
	% (vs.1/3C)	101.80%	100.00%	99.00%	97.00%	94.90%	93.40%

C-rate		0.1C	0.2C	0.3C	0.5C	1C	2C	3C	4C
Charge (CC/CV)	Capacity	95.5 Ah	95.4 Ah	95.5 Ah	95.6 Ah	95.7 Ah	95.8 Ah	95.9 Ah	96.9 Ah
	% (vs.1/3C)	100.00%	99.90%	100.00%	100.10%	100.20%	100.30%	100.40%	101.50%
Charge (CC)	Capacity	94.8 Ah	93.7 Ah	92.4 Ah	91.6 Ah	88.2 Ah	81.8 Ah	76.5 Ah	72.2 Ah
	% (vs.1/3C)	102.60%	101.40%	100.00%	99.10%	95.40%	88.50%	82.80%	78.20%

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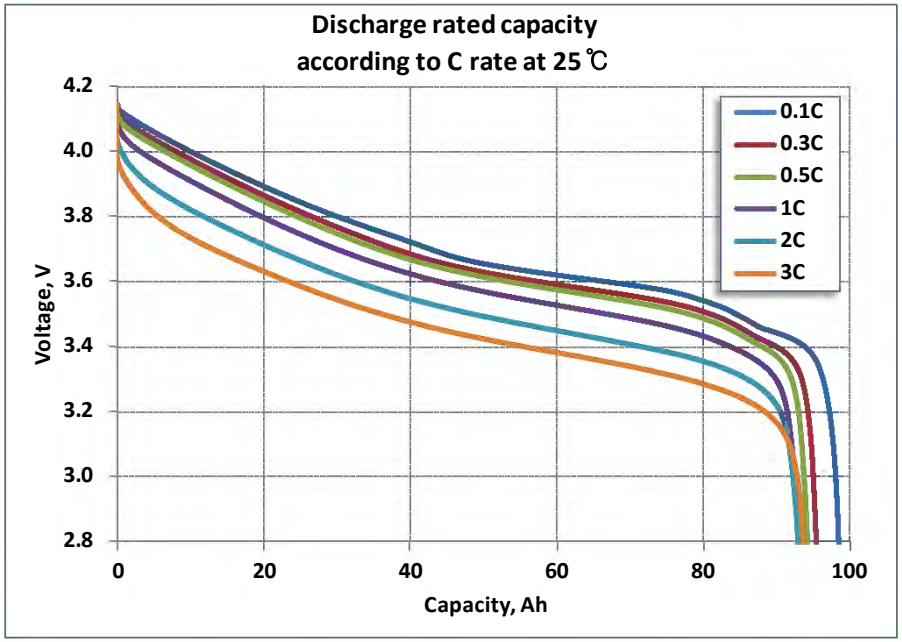
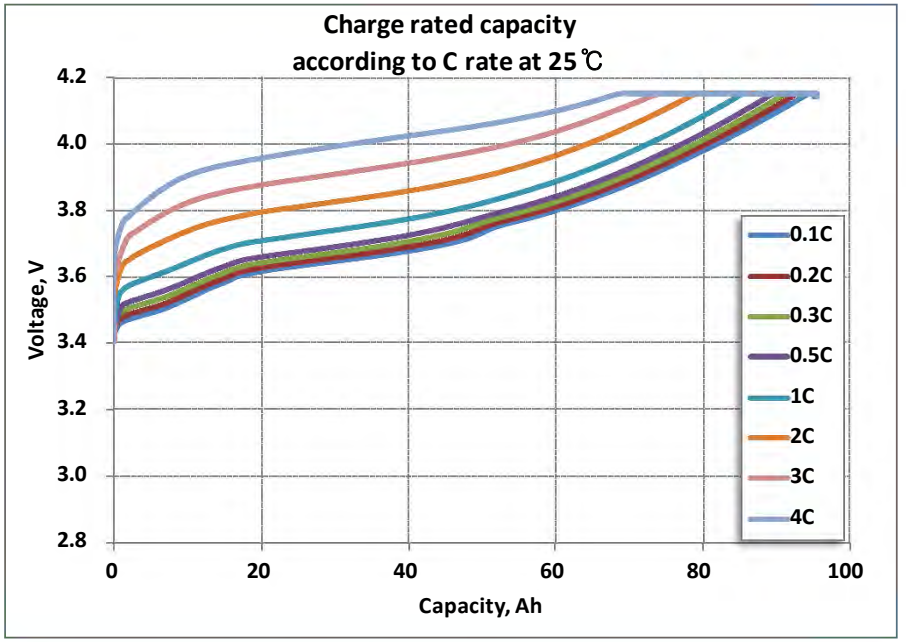
Rated Capacity

0.1C ~4C rates @ 25℃





C-rate		0.1C	0.3C	0.5C	1C	2C	3C
Discharge	Capacity	98.6 Ah	95.5 Ah	94.4 Ah	93.1 Ah	93.2 Ah	93.9 Ah
	% (vs.1/3C)	103.30%	100.00%	98.80%	97.50%	97.60%	98.40%
	Energy (Wh)	365 Wh	351 Wh	346 Wh	337 Wh	330 Wh	326 Wh
	% (vs.1/3C)	103.80%	100.00%	98.40%	95.90%	94.00%	92.80%

C-rate		0.1C	0.2C	0.3C	0.5C	1C	2C	3C	4C
Charge (CC/CV)	Capacity	95.3 Ah	95.1 Ah	95.1 Ah	95.1 Ah	95.2 Ah	95.3 Ah	95.5 Ah	95.6 Ah
	% (vs.1/3C)	100.20%	100.00%	100.00%	100.00%	100.00%	100.20%	100.40%	100.50%
Charge (CC)	Capacity	94.2 Ah	92.4 Ah	90.8 Ah	89.2 Ah	85.0 Ah	78.6 Ah	73.3 Ah	68.0 Ah
	% (vs.1/3C)	103.70%	101.80%	100.00%	98.30%	93.60%	86.60%	80.70%	74.90%

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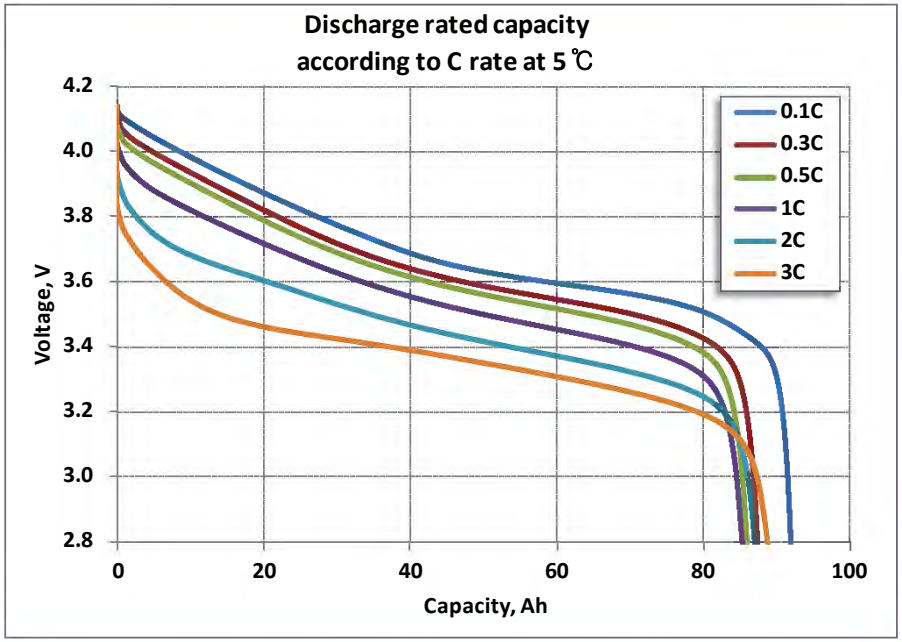
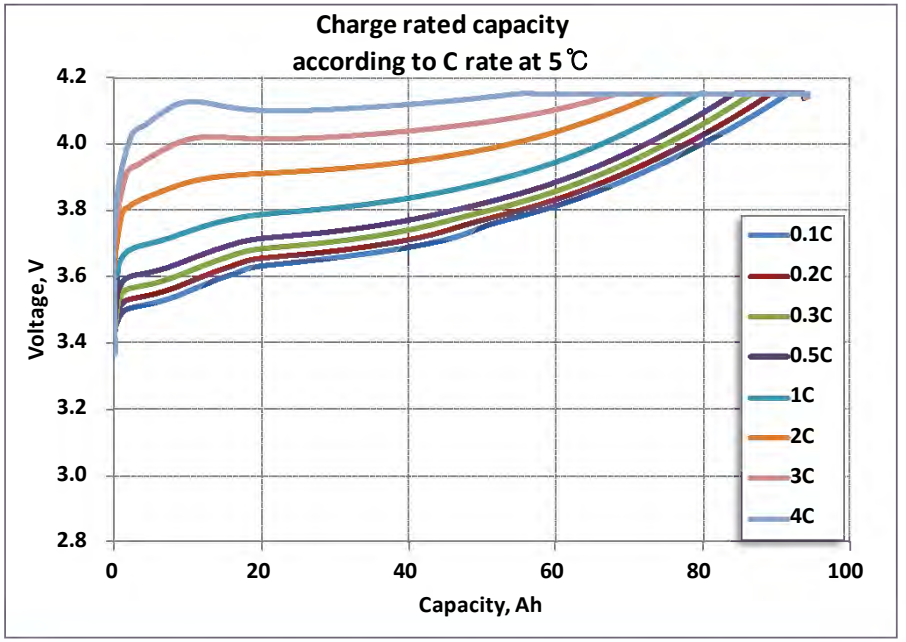
Rated Capacity

0.1C ~4C rates @ 5℃





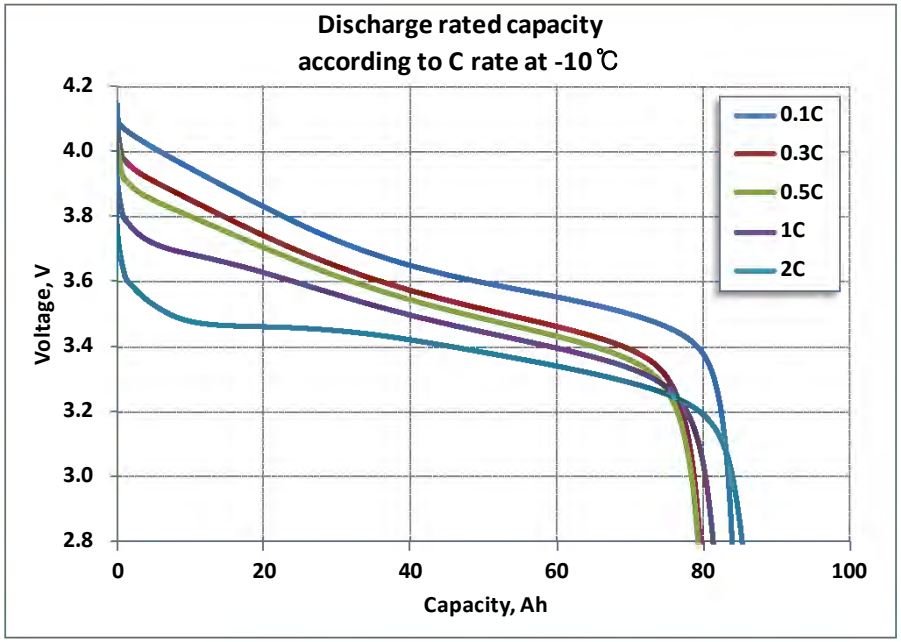
C-rate		0.1C	0.3C	0.5C	1C	2C	3C
Discharge	Capacity	92.1 Ah	87.5 Ah	86.2 Ah	85.6 Ah	87.5 Ah	89.2 Ah
	% (vs.1/3C)	105.30%	100.00%	98.60%	97.80%	100.00%	101.90%
	Energy (Wh)	340 Wh	320 Wh	313 Wh	305 Wh	303 Wh	301 Wh
	% (vs.1/3C)	106.50%	100.00%	97.90%	95.50%	94.80%	94.00%

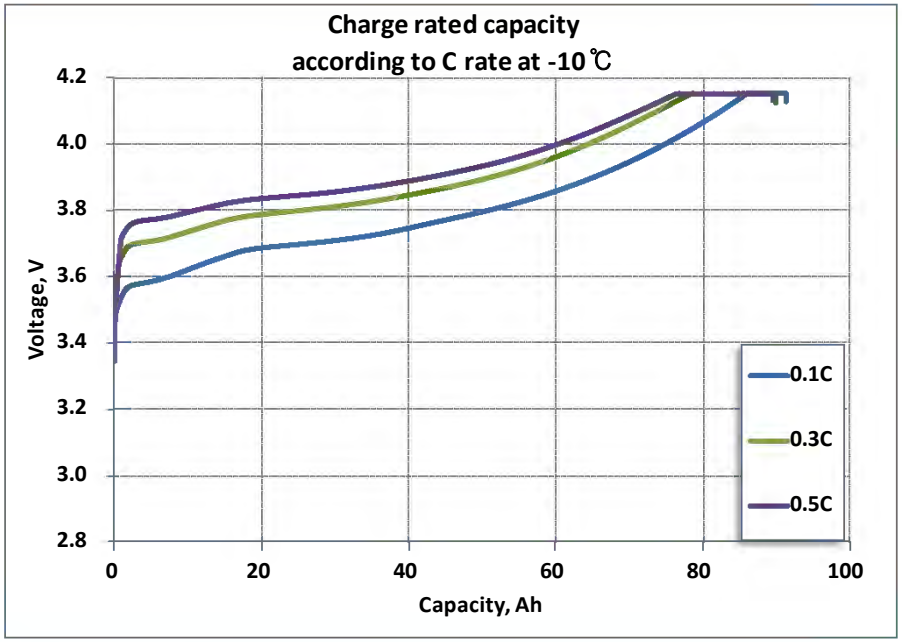
C-rate		0.1C	0.2C	0.3C	0.5C	1C	2C	3C	4C
Charge (CC/CV)	Capacity	93.8 Ah	93.7 Ah	93.7 Ah	93.7 Ah	93.8 Ah	94.0 Ah	94.3 Ah	94.3 Ah
	% (vs.1/3C)	100.10%	100.00%	100.00%	100.00%	100.00%	100.30%	100.60%	100.60%
Charge (CC)	Capacity	91.6 Ah	88.9 Ah	86.6 Ah	84.0 Ah	79.1 Ah	73.3 Ah	65.3 Ah	53.1 Ah
	% (vs.1/3C)	105.80%	102.70%	100.00%	97.10%	91.40%	84.70%	75.50%	61.40%

SAMSUNG SDI

Rated Capacity

0.1C ~2C rates @ -10℃



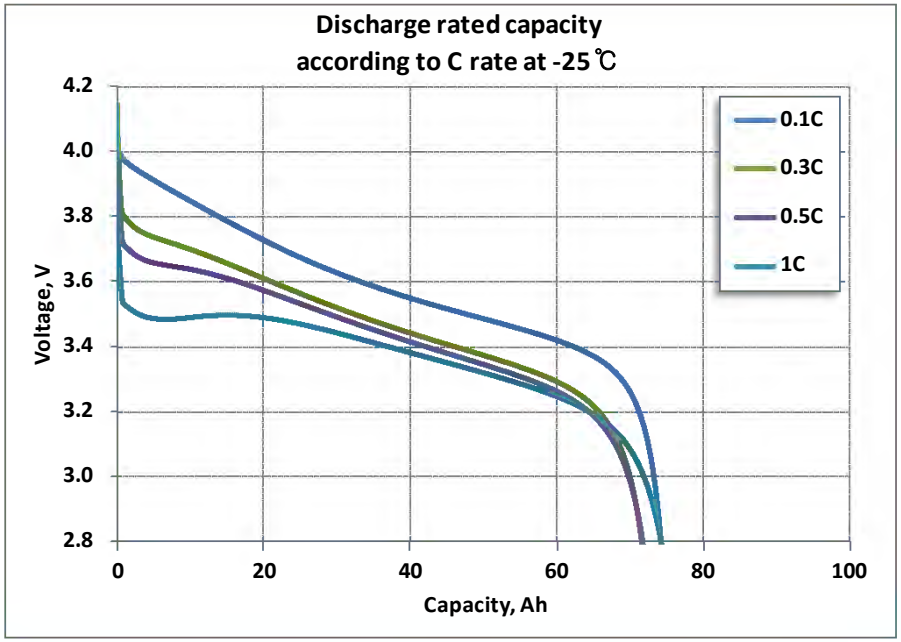


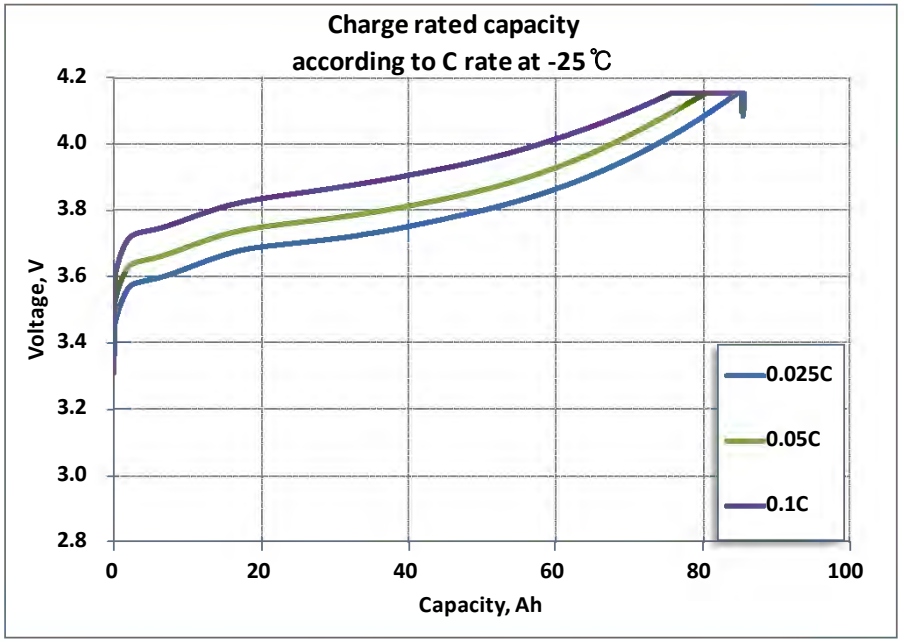
C-rate		0.1C	0.3C	0.5C	1C	2C
Discharge	Capacity	84.2 Ah	79.9 Ah	79.7 Ah	81.7 Ah	85.7 Ah
	% (vs.1/3C)	105.40%	100.00%	99.80%	102.20%	107.30%
	Energy (Wh)	309 Wh	287 Wh	283 Wh	285 Wh	289 Wh
	% (vs.1/3C)	107.70%	100.00%	98.90%	99.40%	101.00%

C-rate		0.1C	0.3C	0.5C
Charge (CC/CV)	Capacity	91.4 Ah	89.9 Ah	89.5 Ah
	% (vs.1/3C)	101.70%	100.00%	99.60%
Charge (CC)	Capacity	86.0 Ah	77.9 Ah	75.8 Ah
	% (vs.1/3C)	110.50%	100.00%	97.30%

Rated Capacity

0.025C ~1C rates @ -25℃



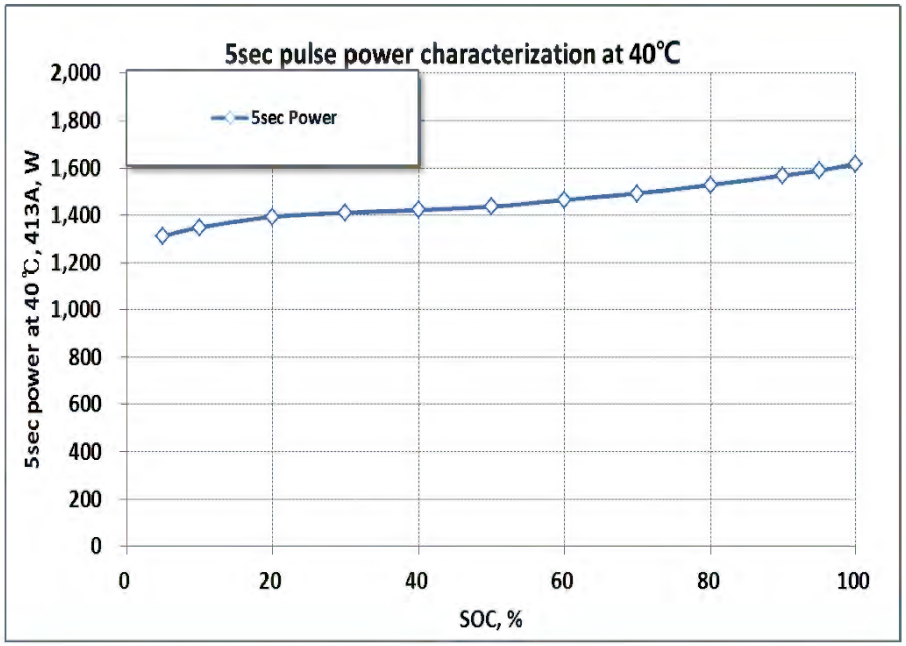


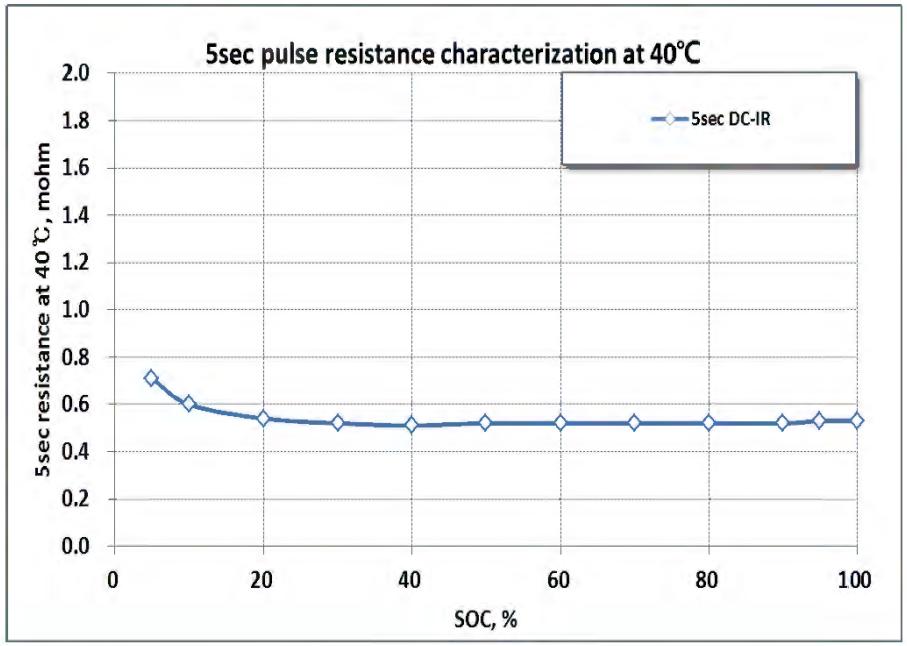
C-rate		0.1C	0.3C	0.5C	1C
Discharge	Capacity	74.6 Ah	72.0 Ah	72.3 Ah	75.0 Ah
	% (vs.1/3C)	96.50%	100.00%	100.40%	104.10%
	Energy (Wh)	267 Wh	250 Wh	248 Wh	252 Wh
	% (vs.1/3C)	93.40%	100.00%	99.30%	100.80%

C-rate		0.025C	0.05C	0.1C
Charge (CC/CV)	Capacity	85.5 Ah	85.3 Ah	85.6 Ah
	% (vs.1/3C)	113.40%	113.00%	100.00%
Charge (CC)	Capacity	84.7 Ah	80.4 Ah	75.4 Ah
	% (vs.1/3C)	112.30%	106.50%	100.00%

Power and DC-IR

@ 5sec discharge, 40℃, 413A

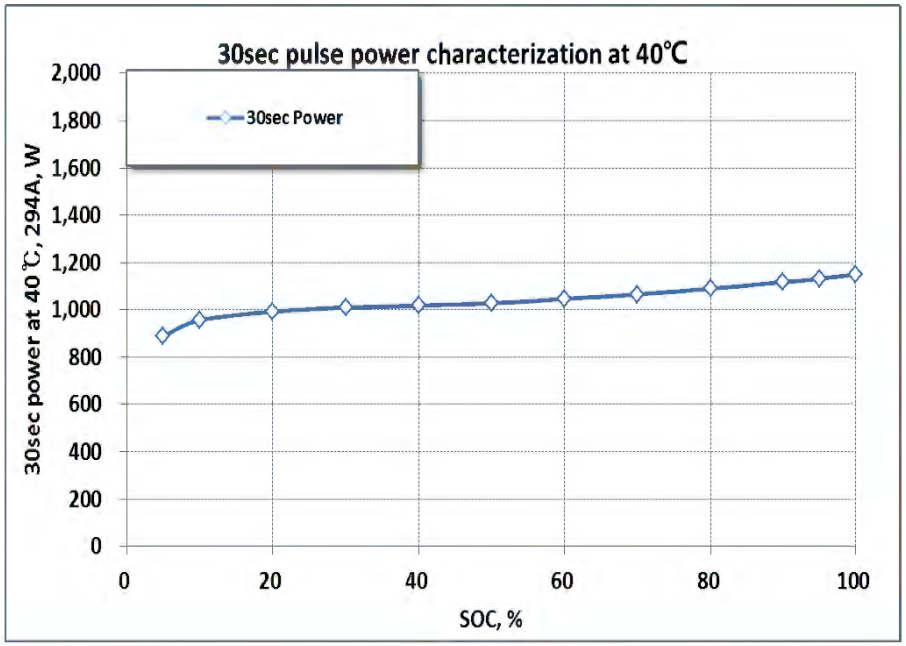


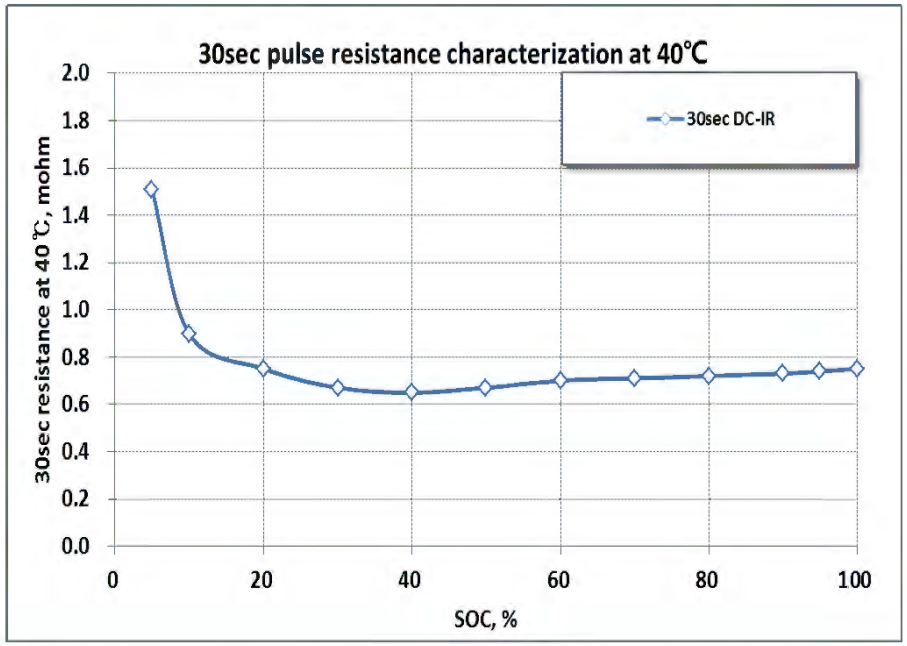


	SOC (%)	100	95	90	80	70	60	50	40	30	20	10	5	Max current
Discharge	Resistance (mΩ)	0.53	0.53	0.52	0.52	0.52	0.52	0.52	0.51	0.52	0.54	0.60	0.71	413 A
	Power (W)	1617	1589	1568	1528	1492	1465	1436	1422	1410	1393	1348	1312	

Power and DC-IR

@ 30sec discharge, 40℃, 294A

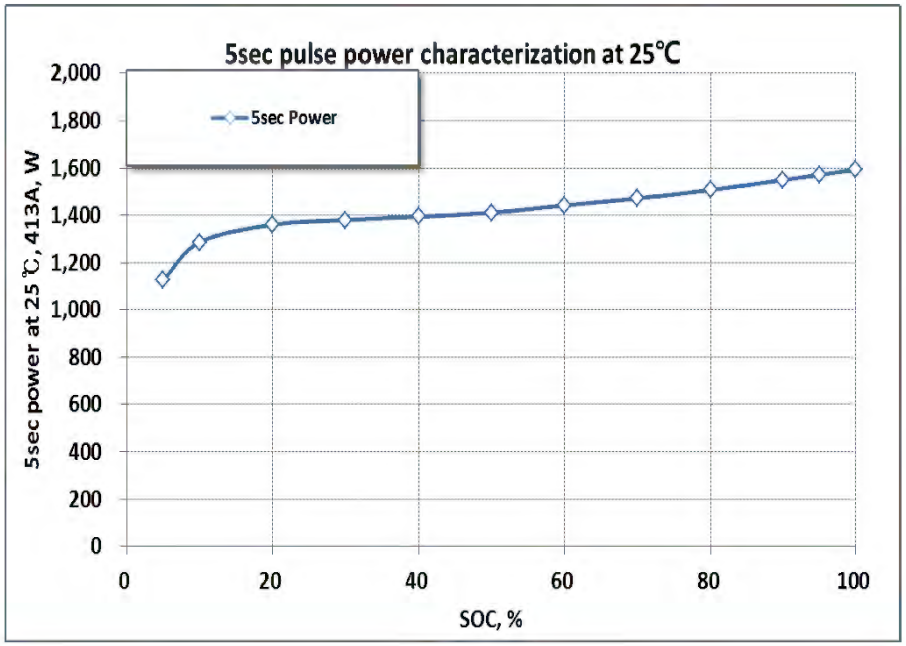


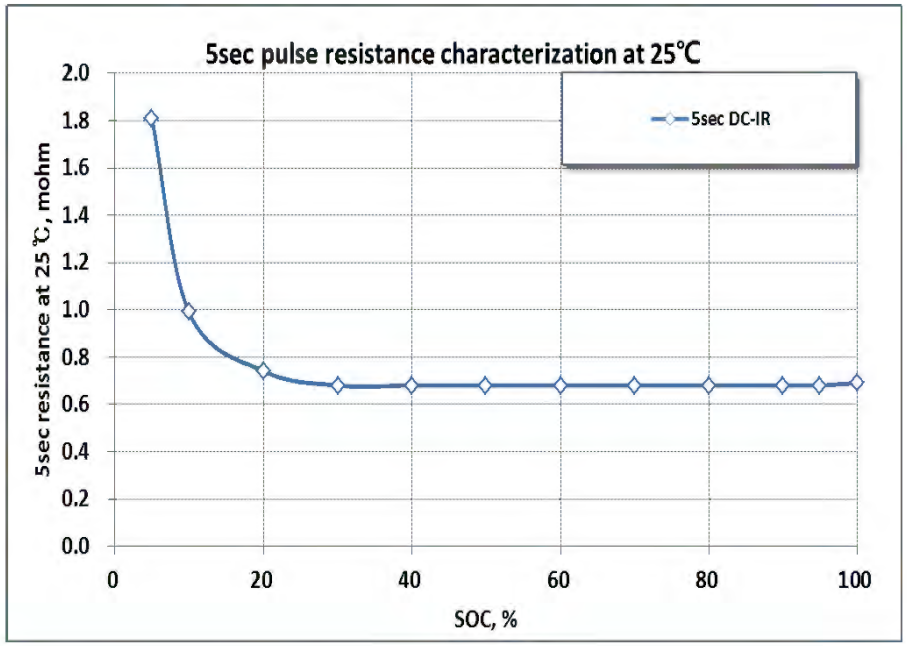


	SOC (%)	100	95	90	80	70	60	50	40	30	20	10	5	Max current
Discharge	Resistance (mΩ)	0.75	0.74	0.73	0.72	0.71	0.70	0.67	0.65	0.67	0.75	0.90	1.51	294 A
	Power (W)	1151	1131	1117	1089	1065	1046	1027	1018	1009	992	955	889	

Power and DC-IR

@ 5sec discharge, 25℃, 413A

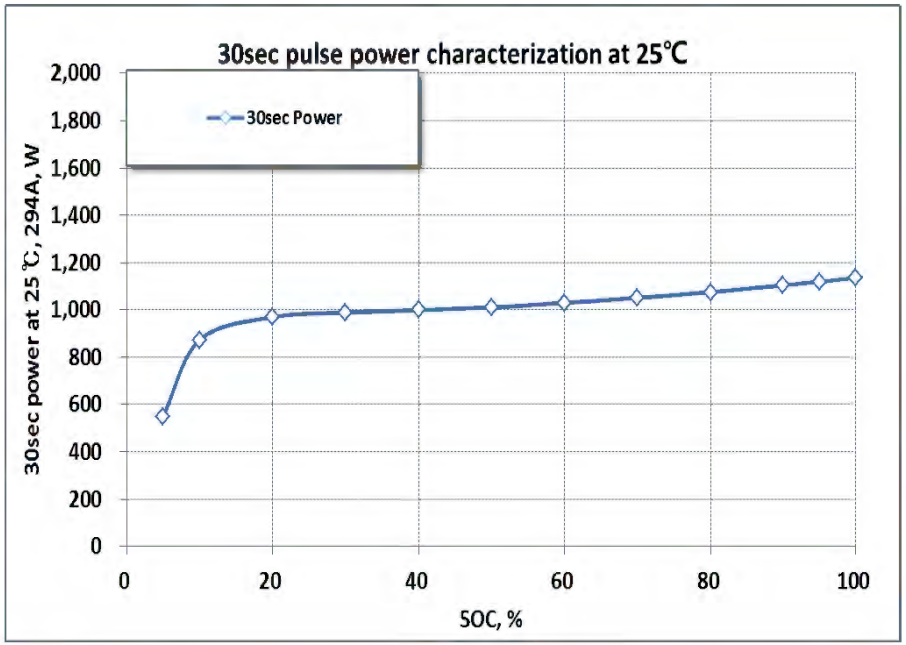


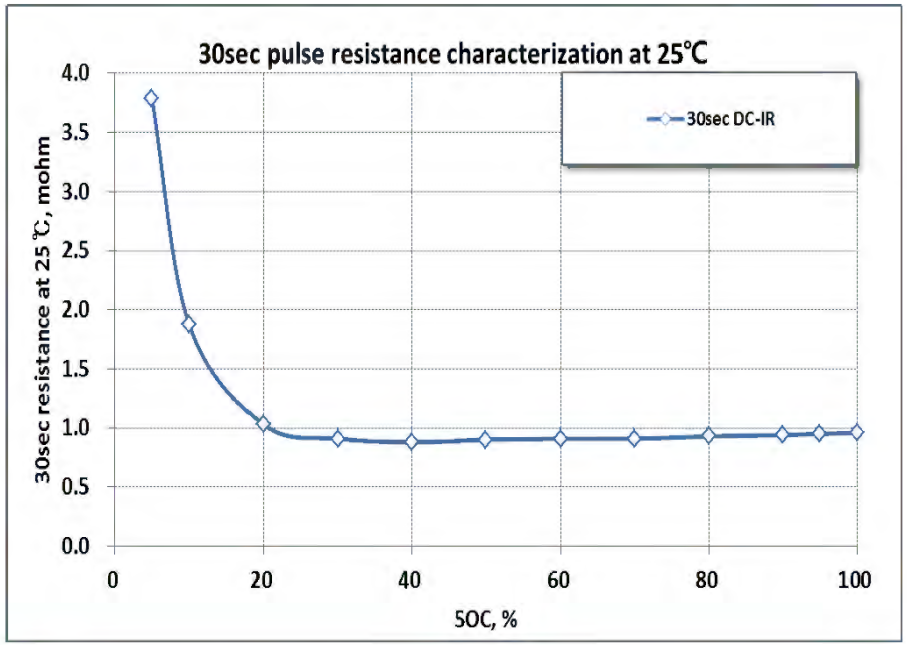


	SOC (%)	100	95	90	80	70	60	50	40	30	20	10	5	Max current
Discharge	Resistance (mΩ)	0.69	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.74	0.99	1.81	413 A
	Power (W)	1593	1571	1549	1507	1471	1442	1411	1394	1380	1360	1286	1125	

Power and DC-IR

@ 30sec discharge, 25℃, 294A

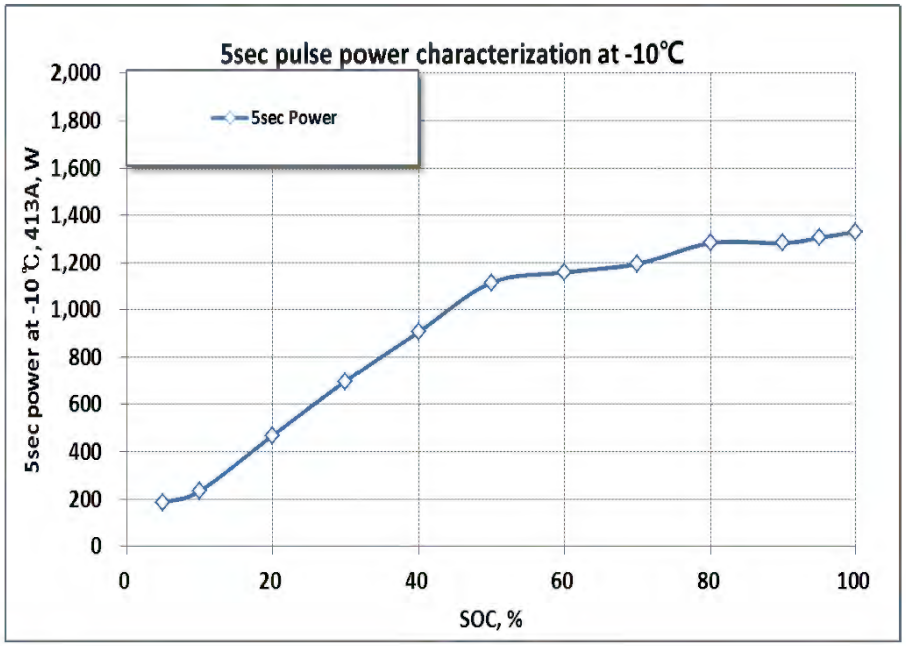


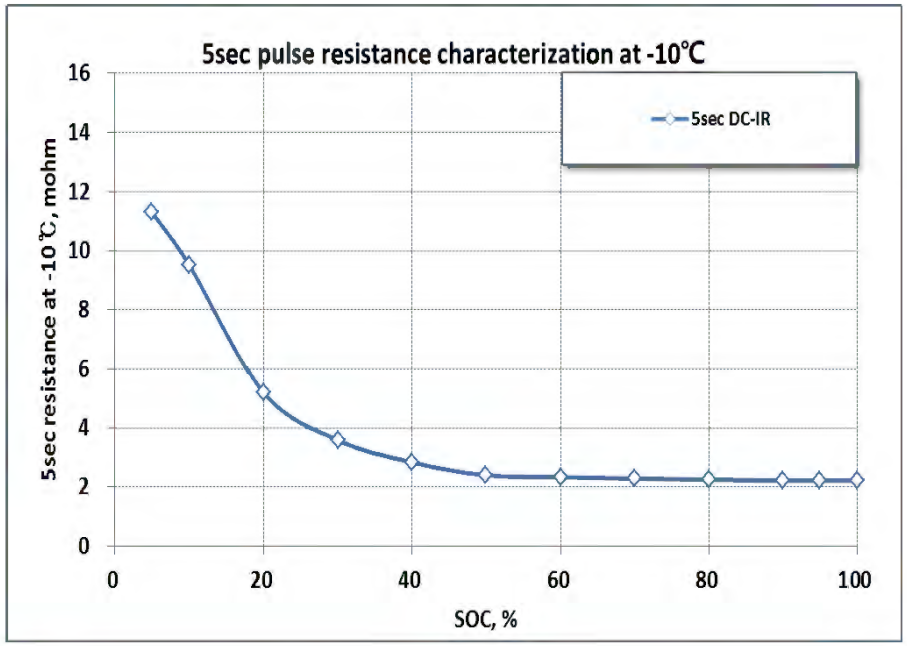


	SOC (%)	100	95	90	80	70	60	50	40	30	20	10	5	Max current
Discharge	Resistance (mΩ)	0.96	0.95	0.94	0.93	0.91	0.91	0.90	0.88	0.91	1.03	1.88	3.79	294 A
	Power (W)	1135	1119	1104	1075	1050	1030	1010	999	988	969	873	550	

Power and DC-IR

@ 5sec discharge, -10℃, 413A

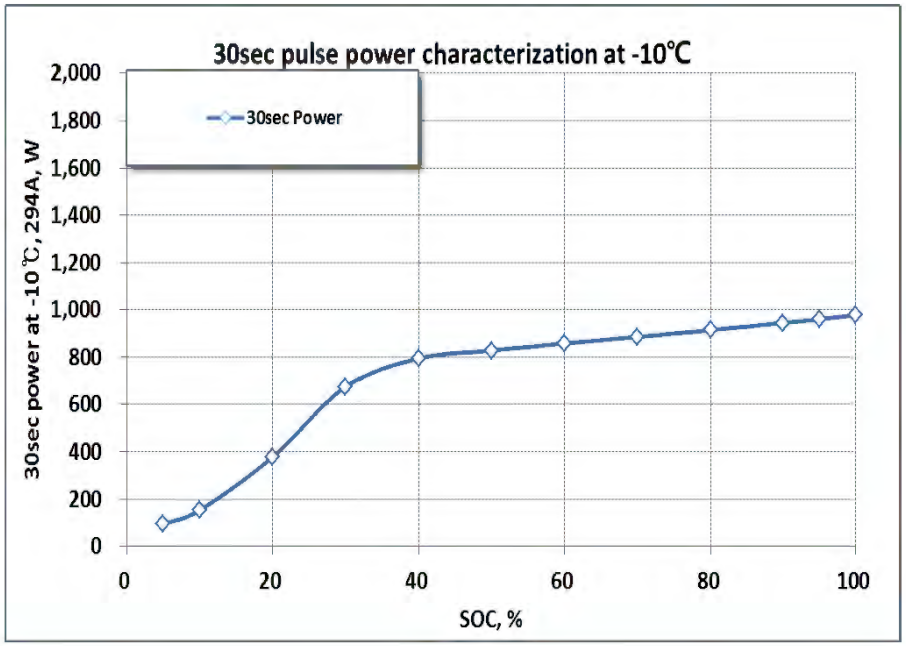


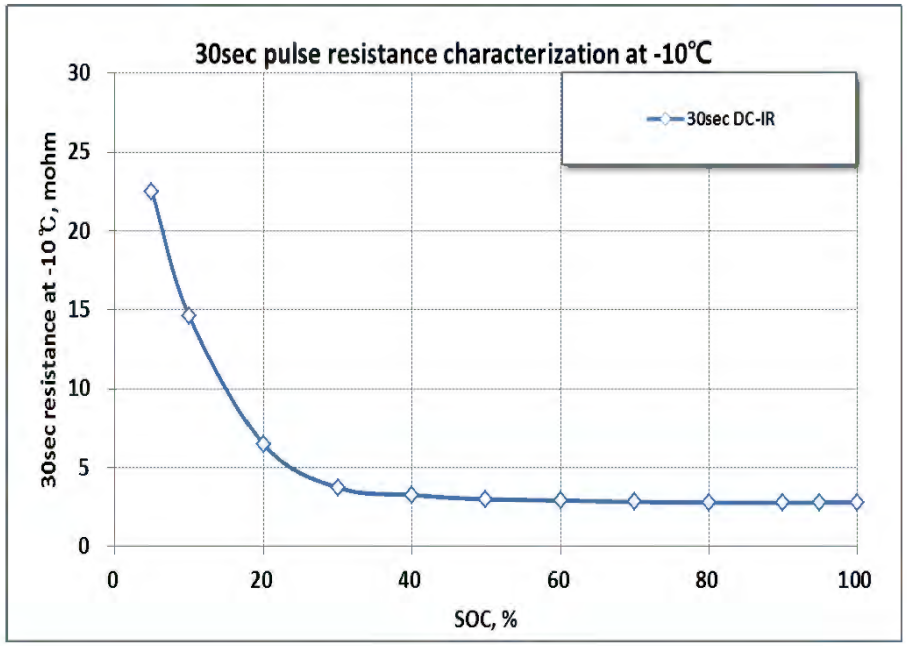


	SOC (%)	100	95	90	80	70	60	50	40	30	20	10	5	Max current
Discharge	Resistance (mΩ)	2.22	2.22	2.22	2.25	2.29	2.34	2.40	2.84	3.59	5.20	9.53	11.30	413 A
	Power (W)	1330	1305	1282	1282	1194	1158	1115	906	697	467	233	185	

Power and DC-IR

@ 30sec discharge, -10℃, 294A

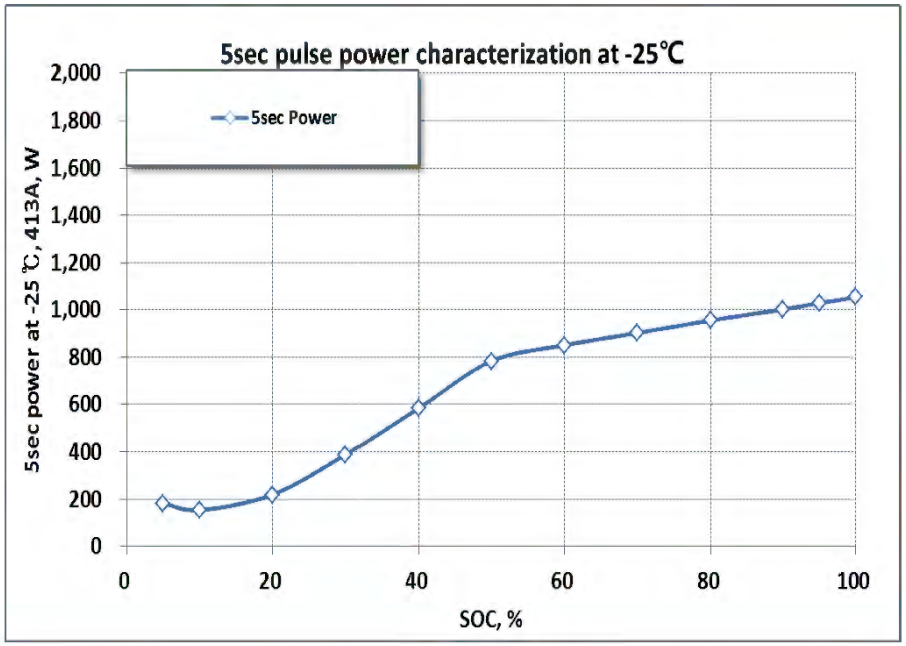


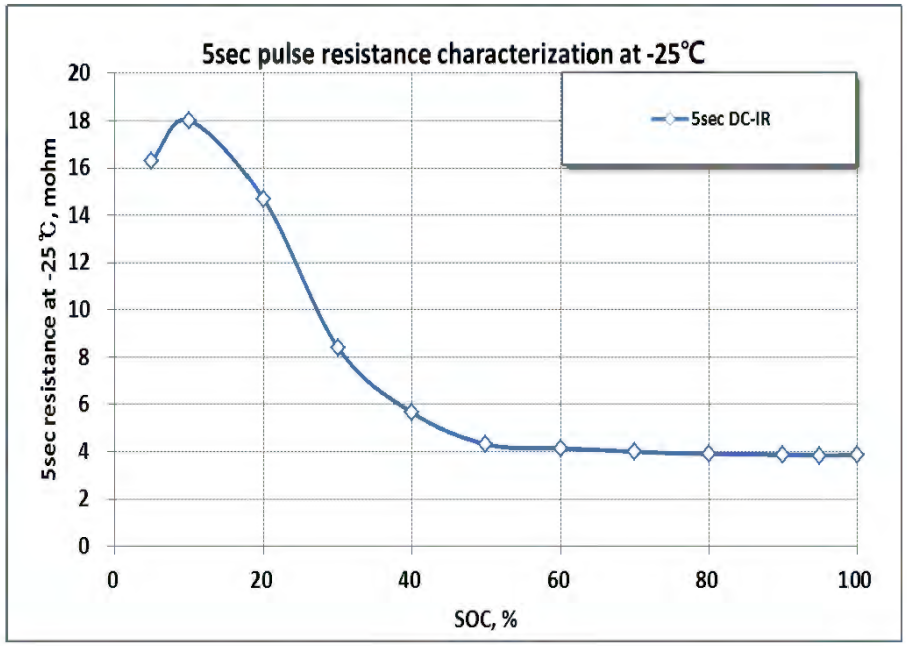


	SOC (%)	100	95	90	80	70	60	50	40	30	20	10	5	Max current
Discharge	Resistance (mΩ)	2.77	2.77	2.76	2.77	2.81	2.89	2.98	3.24	3.72	6.47	14.63	22.52	294 A
	Power (W)	978	960	945	914	885	858	828	794	673	376	152	93	

Power and DC-IR

@ 5sec discharge, -25℃, 413A

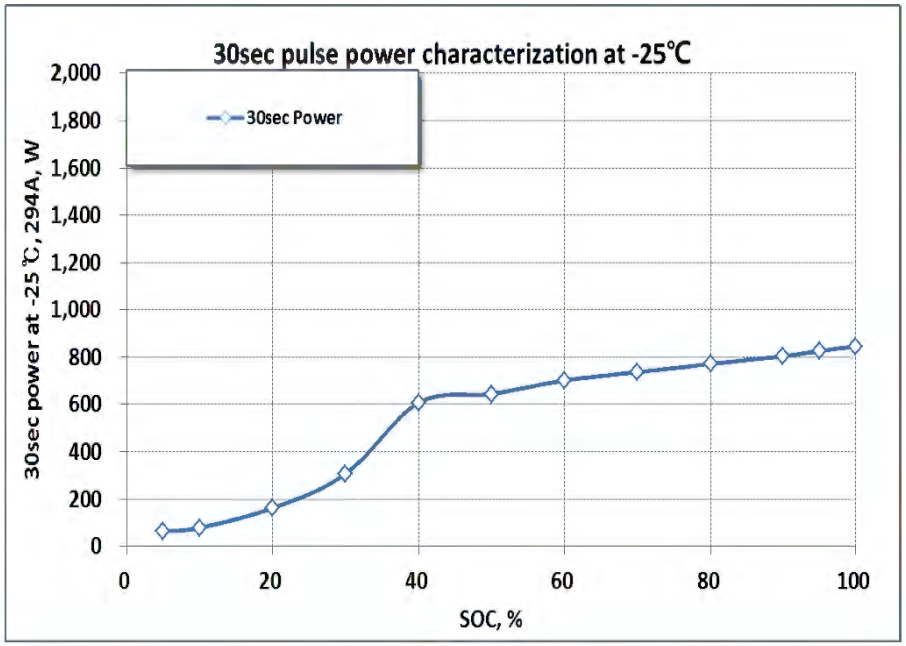


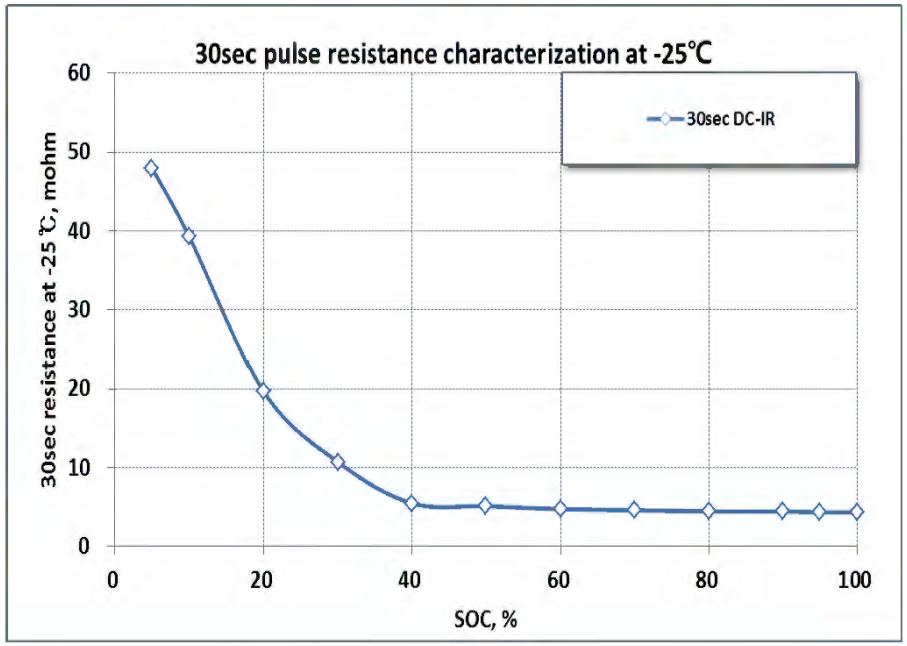


	SOC (%)	100	95	90	80	70	60	50	40	30	20	10	5	Max current
Discharge	Resistance (mΩ)	3.85	3.84	3.87	3.90	4.00	4.14	4.32	5.66	8.41	14.68	18.01	16.31	413 A
	Power (W)	1053	1029	1002	955	902	850	783	584	387	218	153	181	

Power and DC-IR

@ 30sec discharge, -25℃ , 294A





	SOC (%)	100	95	90	80	70	60	50	40	30	20	10	5	Max current
Discharge	Resistance (mΩ)	4.29	4.31	4.39	4.42	4.54	4.71	5.09	5.44	10.69	19.61	39.36	48.00	294 A
	Power (W)	846	826	804	771	736	701	644	607	305	161	78	62	

Additional Parameter Test
I-V plot

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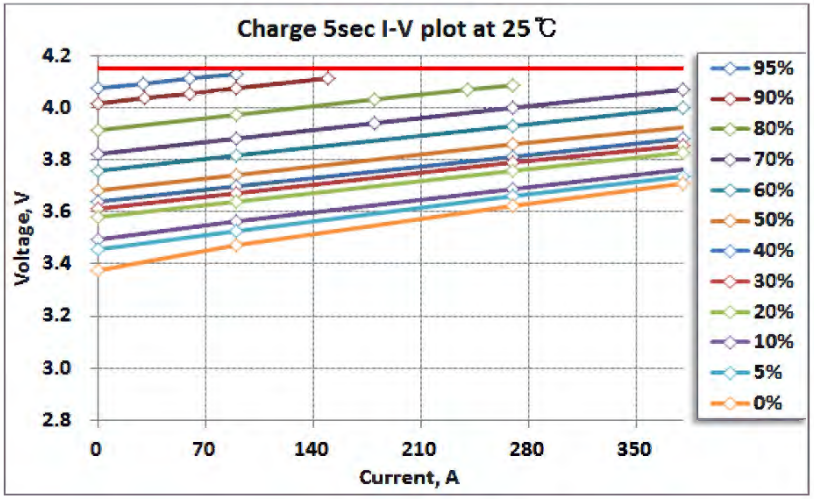
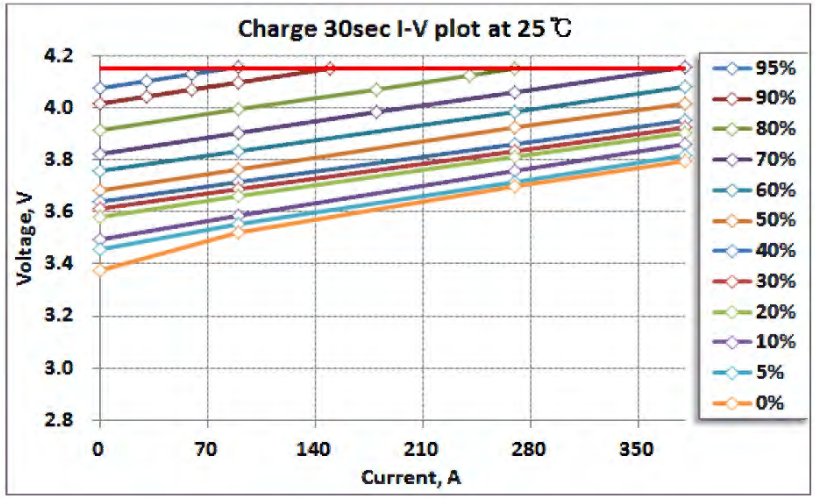
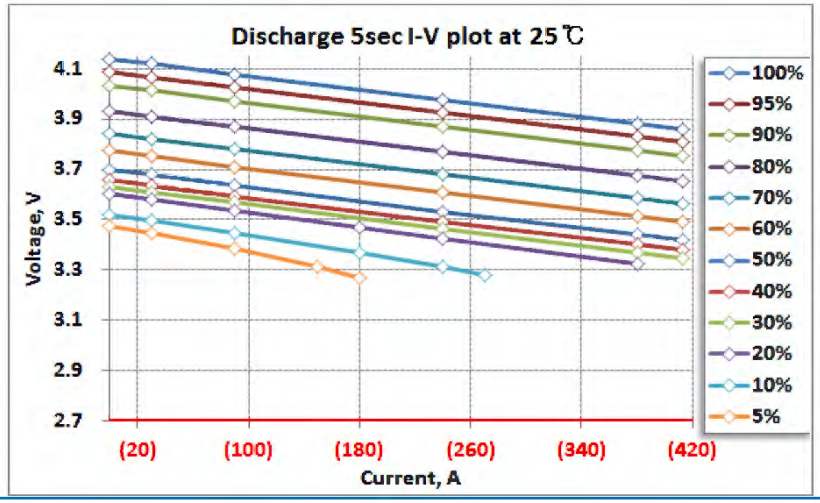
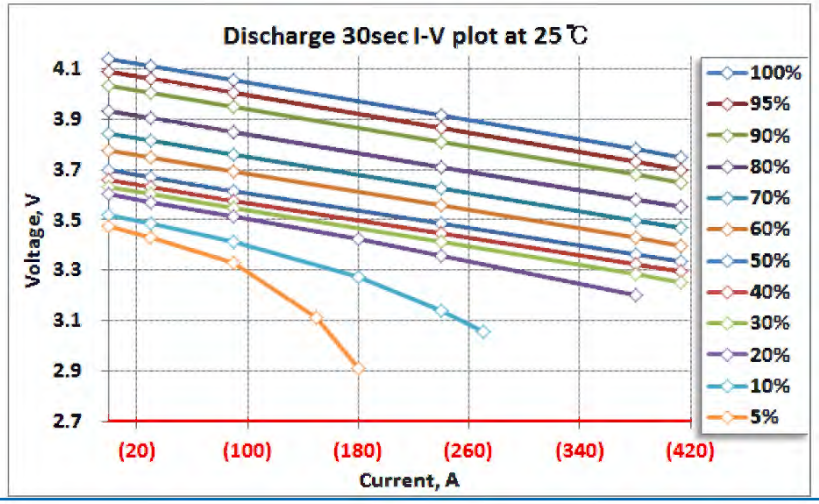
Pulse power characterization test

I-V plot at 5sec, 30sec at 25℃



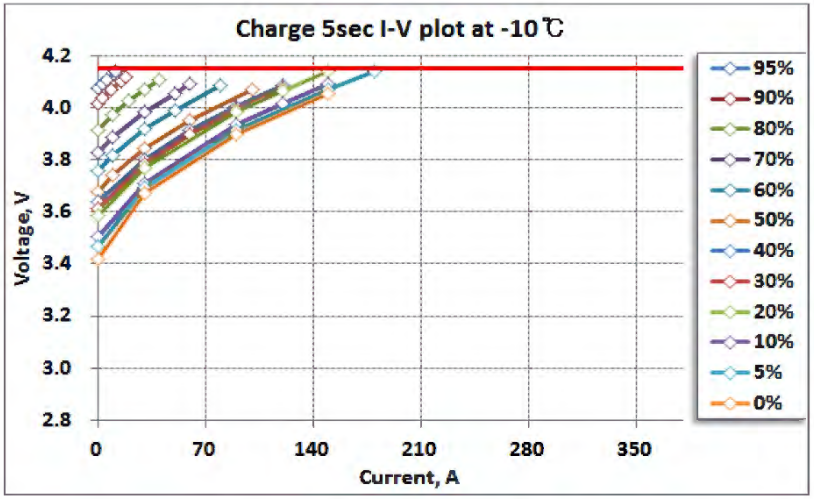


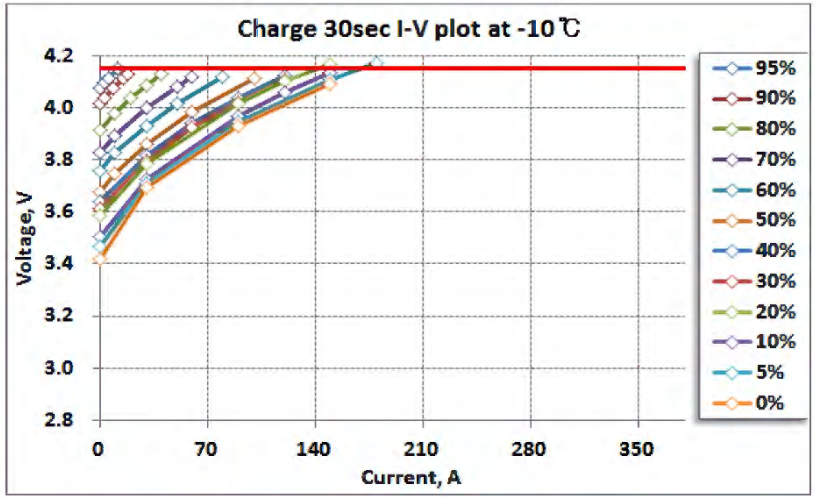


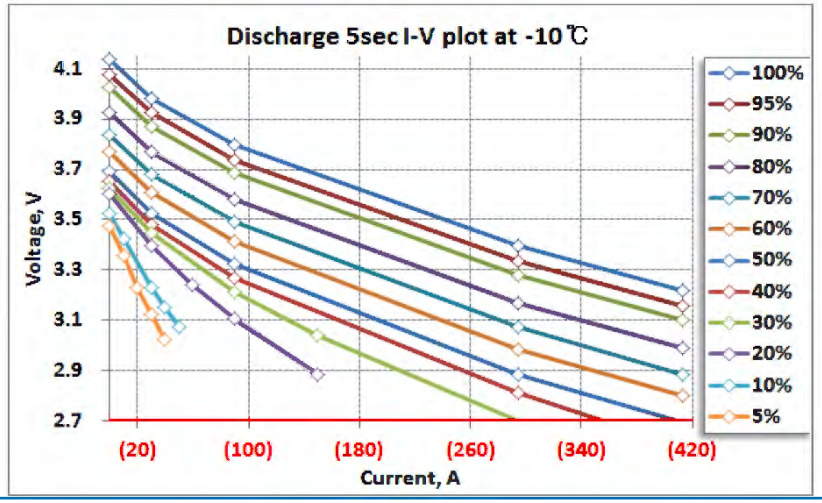


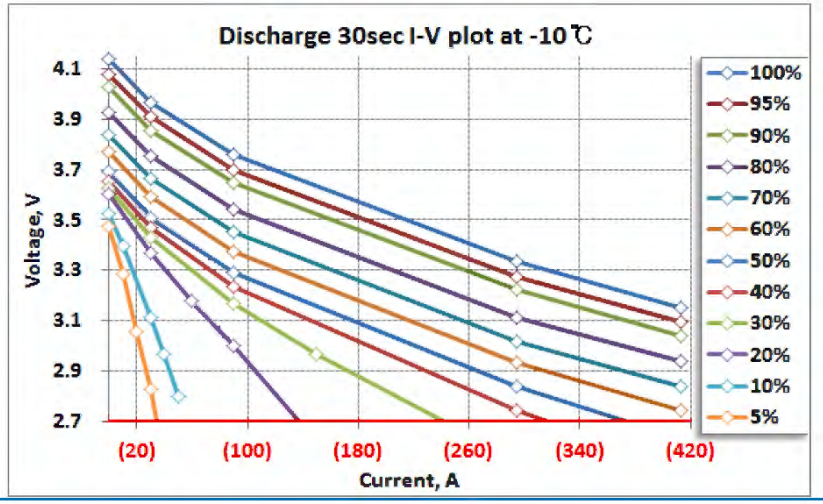
Pulse power characterization test

I-V plot at 5sec, 30sec at -10℃



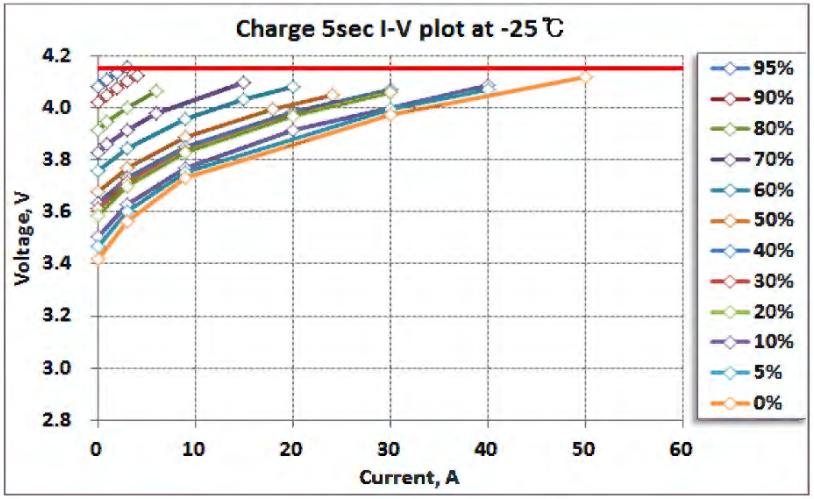


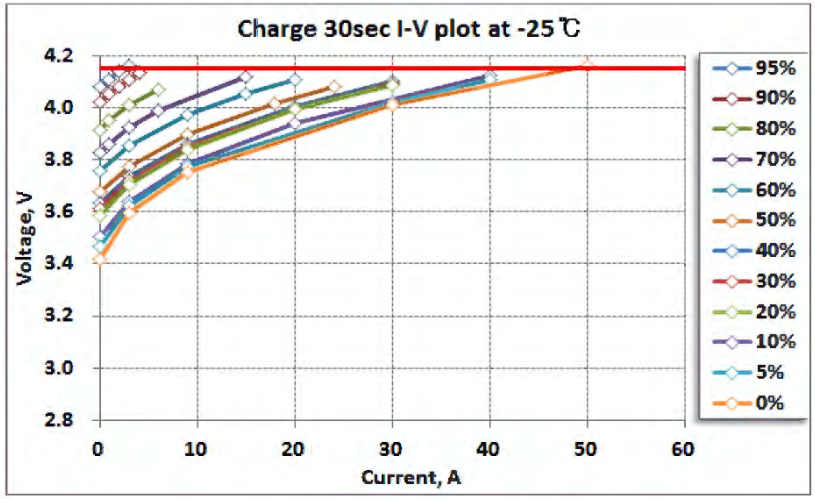


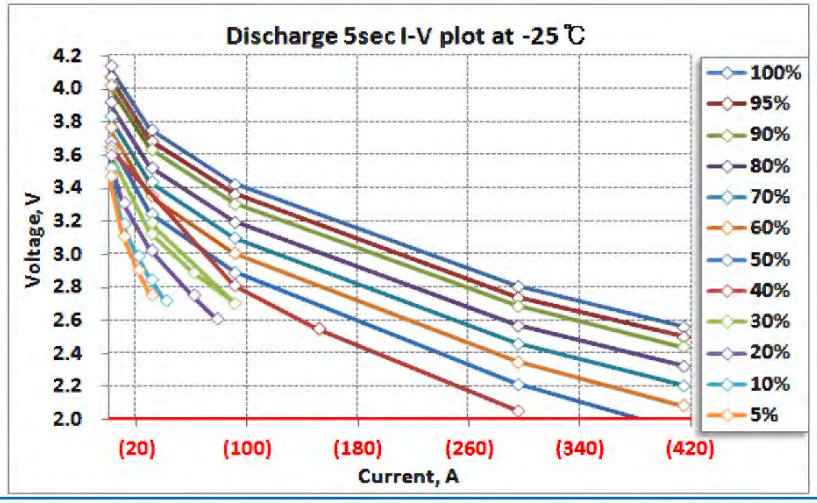


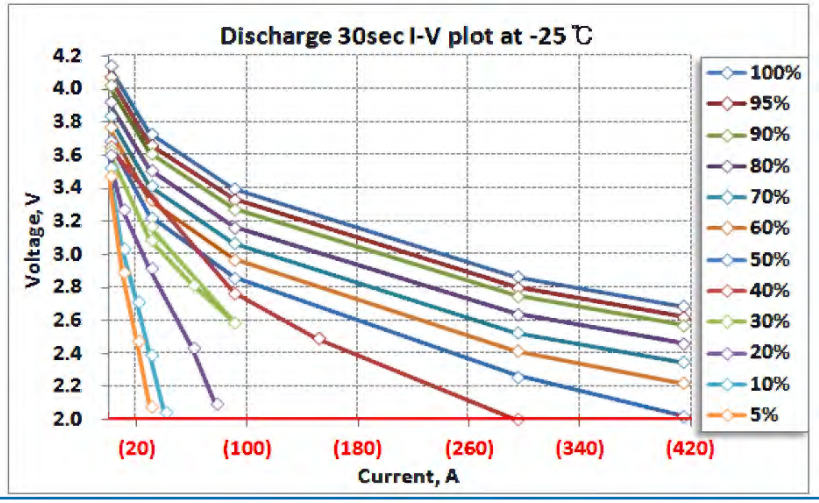
Pulse power characterization test

I-V plot at 5sec, 30sec at -25℃









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Cycle / Calendar life

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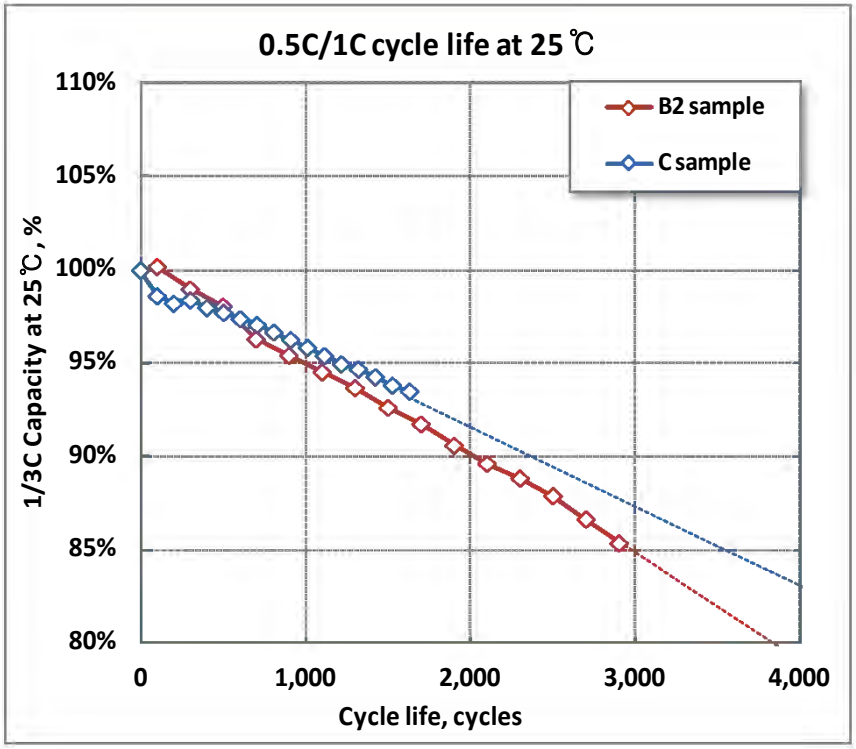
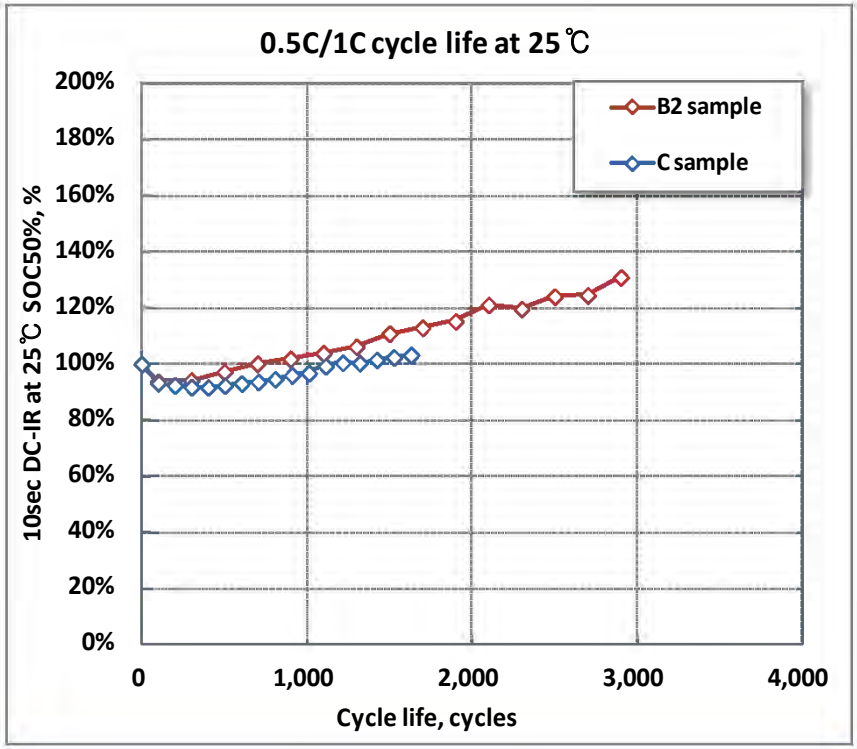
Life status

Cycle life_0.5C/1C at 25℃





※ RPT condition

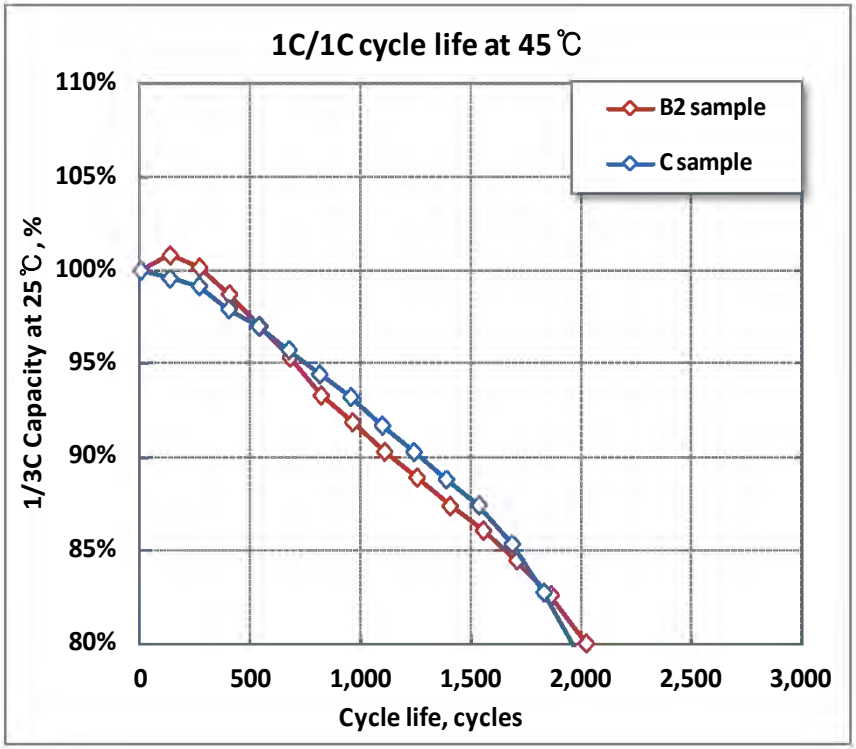
Charge : 1/3C Vmax CCCV charge, 1/50C cut off rest 30 min

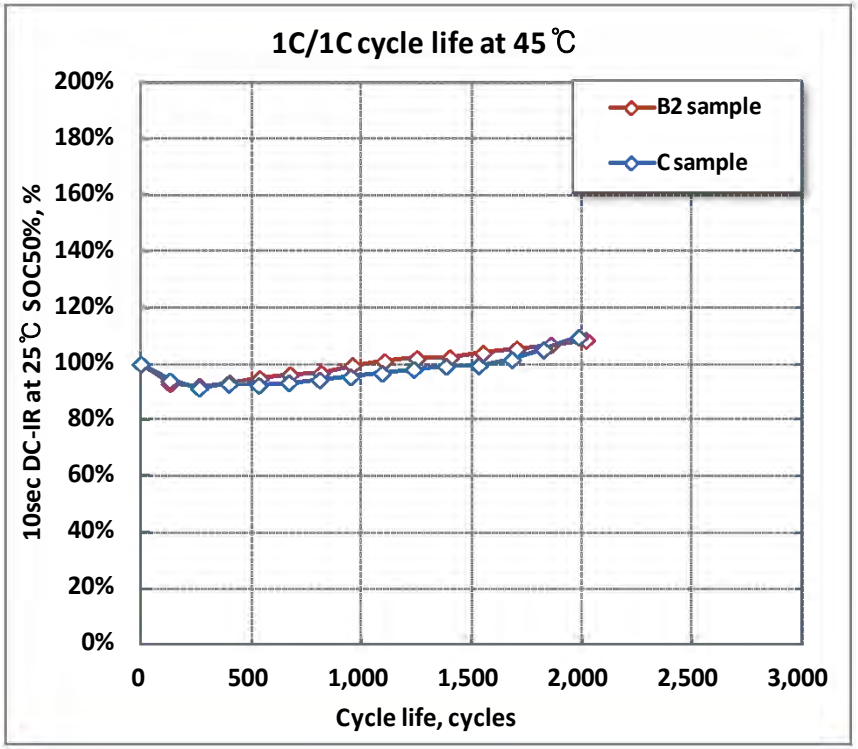
Discharge : 1/3C CC discharge Vmin cut off rest 60 min at 25℃

Sample	Vol. range	Estimated life at EOL
94Ah, B2 sample	4.15~2.7V	> 3,200 cycle
94Ah, C sample	4.15~2.7V	↑

Life status

Cycle life_1C/1C at 45℃





※ RPT condition

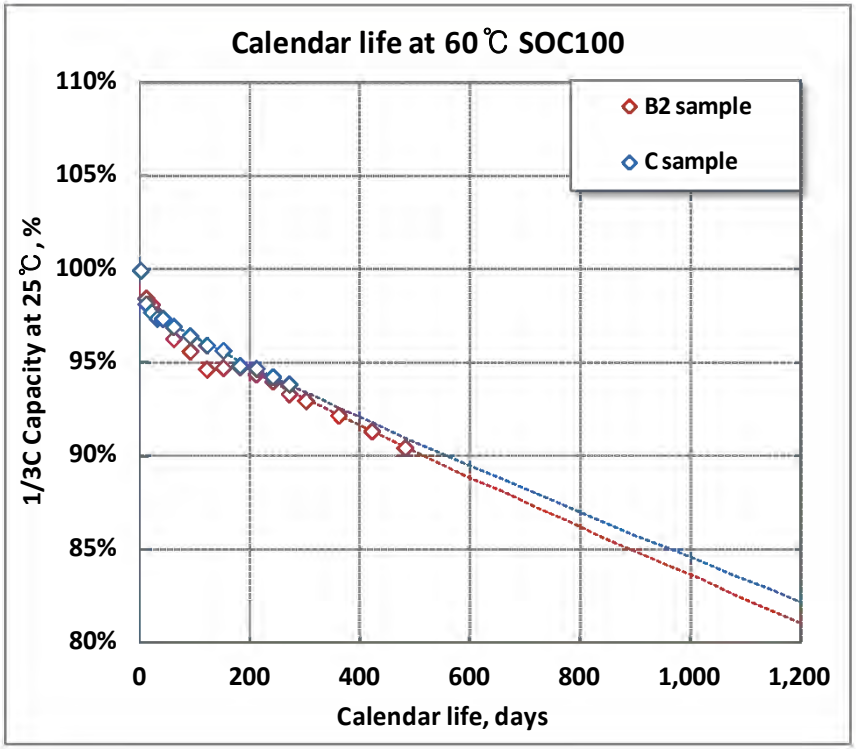
Charge : 1/3C Vmax CCCV charge, 1/50C cut off rest 30 min

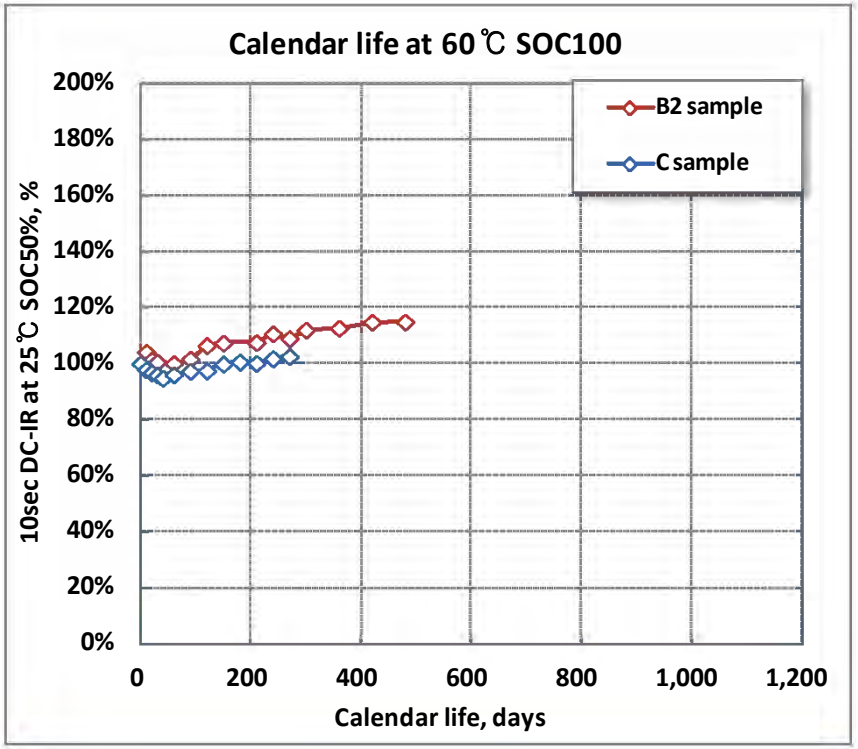
Discharge : 1/3C CC discharge Vmin cut off rest 60 min at 25℃

Sample	Vol. range	Estimated life at EOL
94Ah, B2 sample	4.15~2.7V	1,700 cycle
94Ah, C sample	4.15~2.7V	↑

Life status

Calendar life_SOC100% at 60℃





※ RPT condition

Charge : 1/3C Vmax CCCV charge, 1/50C cut off rest 30 min

Discharge : 1/3C CC discharge Vmin cut off rest 60 min at 25℃

Sample	Vol. range	Estimated life at EOL
94Ah, B2 sample	4.15~2.7V	> 2.50 year
94Ah, C sample	4.15~2.7V	↑

Evaluation of Fast Charging

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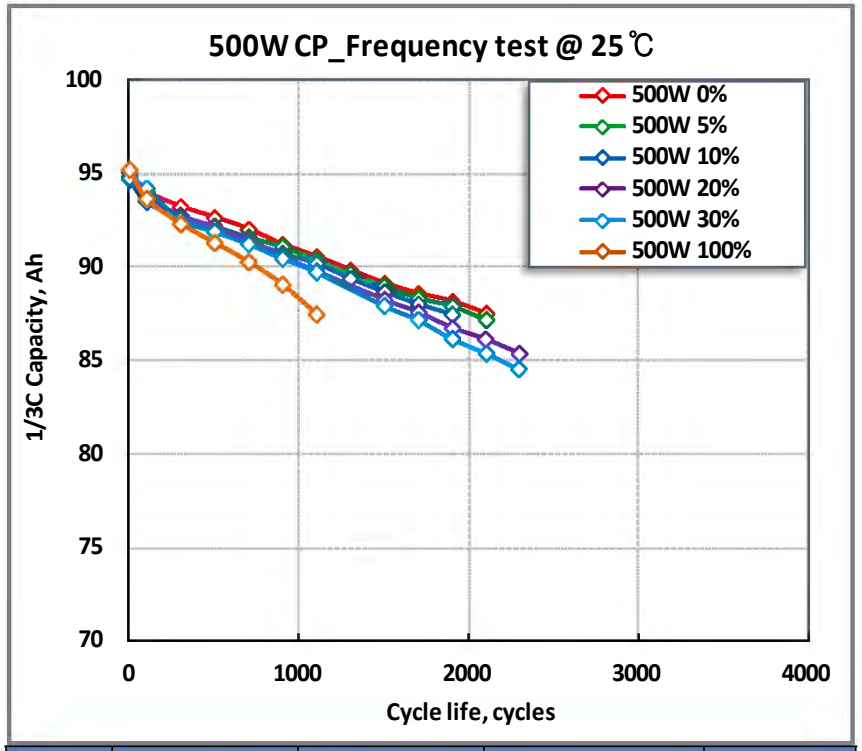
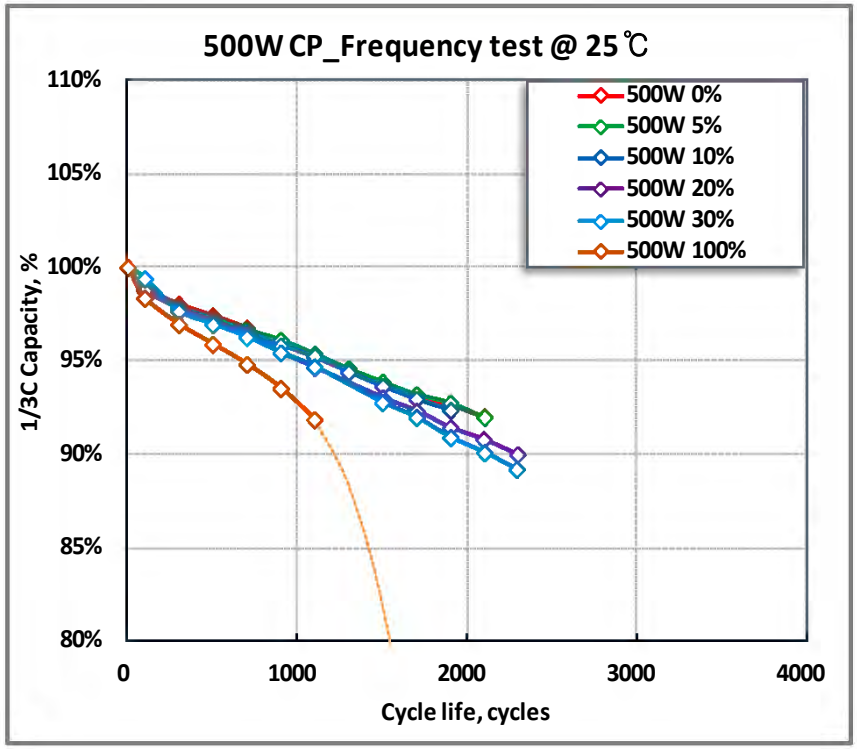
Evaluation of fast charging

500W CP / Frequency effect / RPT capacity





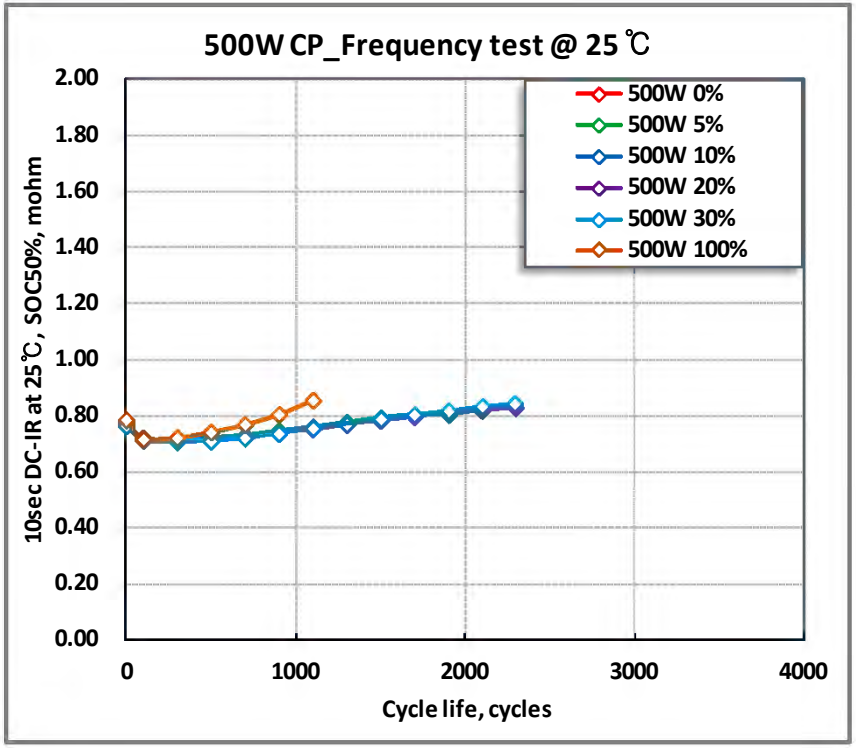
#	Ref. charging	Fast charging	Frequency of 500W	Discharge
Case1	0.5C	500W	0%	1.0C
Case2			5%	
Case3			10%	
Case4			20%	
Case5			30%	
Case6			100%	

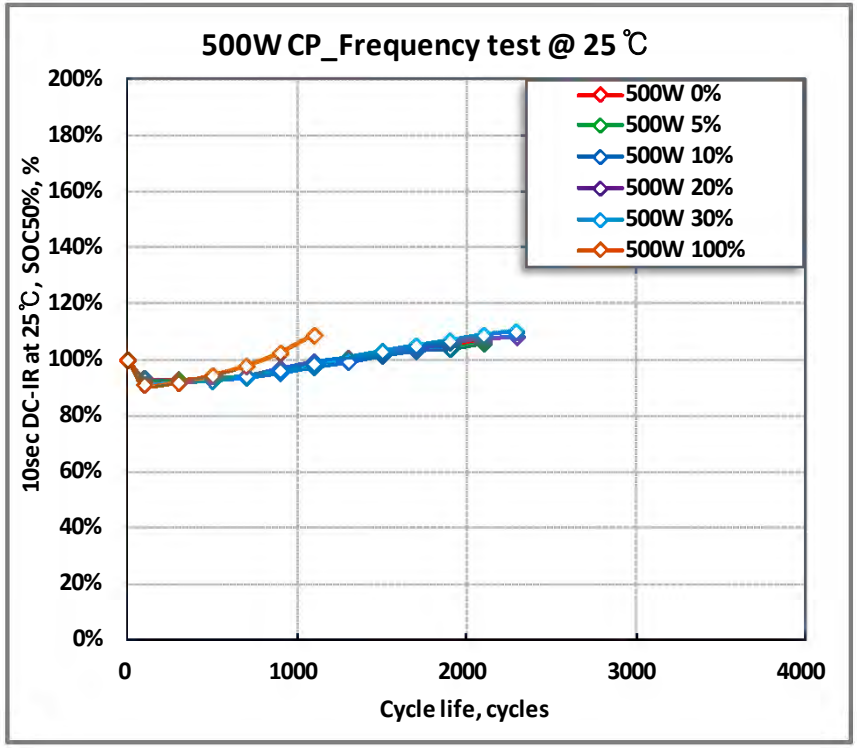
❖ **Detailed charging condition**

- 0% : 0.5C charge only
- 5% : 500W CP charge(1 cycles) + 0.5C charge(19 cycles)
- 10% : 500W CP charge(2 cycles) + 0.5C charge(18 cycles)
- 20% : 500W CP charge(4 cycles) + 0.5C charge(16 cycles)
- 30% : 500W CP charge(6 cycles) + 0.5C charge(14 cycles)
- 100% : 500W CP charge only

Evaluation of fast charging

500W CP / Frequency effect / 10sec DC-IR





※ RPT condition @ 25°C

Charge : 1/3C 4.15V CCCV charge, 1/50C cut off rest 30 min

Discharge : 1/3C CC discharge 2.7V cut off rest 60 min

❖ Summary of fast charging

- 100% usage of 500W CP can cause abnormal capacity degradation, so it can not be allowed.

- But by limiting the frequency of 500W CP, this fast charging can be applicable to 94Ah cell.

Compression force and Swelling force

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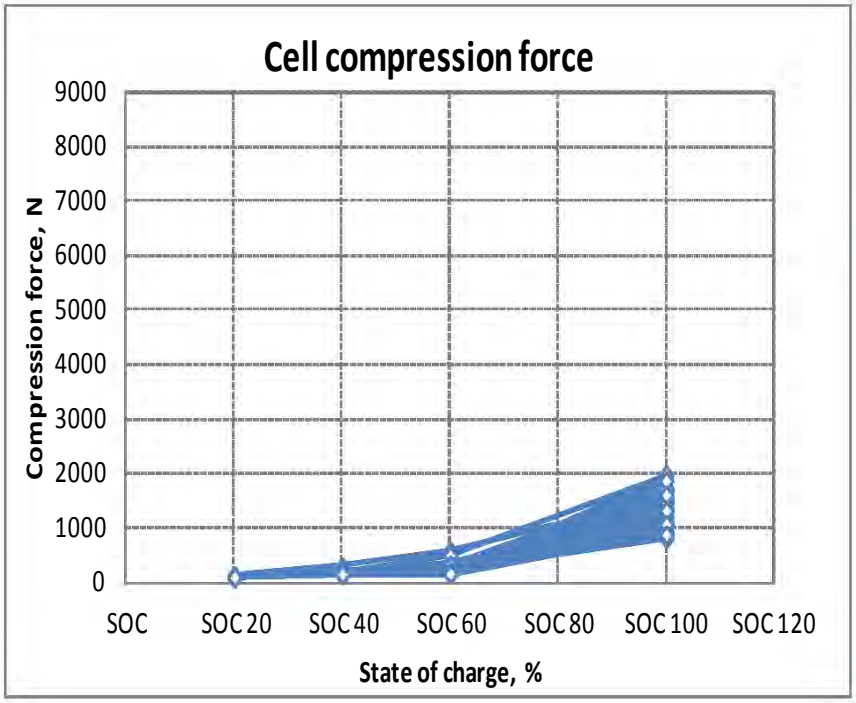
Compression force

SOC dependency, Single cell



✓ Avg. cell compression force: 1433N @SOC100%

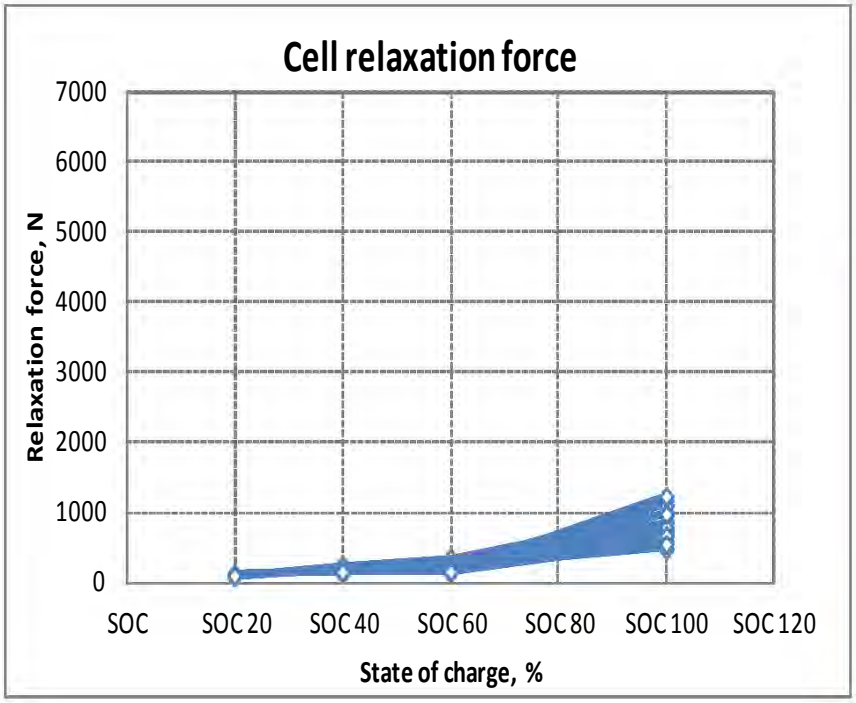
❖ Test conditions

- Target thickness : 45 mm without insulation tape.
- Compression velocity : 0.02 mm/s
- Duration : 5 min

Compression force, N				
Cell No.	SOC 20	SOC 40	SOC 60	SOC 100
#1	120	171	345	1350
#2	120	195	270	876
#3	135	195	306	1380
#4	129	198	210	939
#5	132	300	588	1560
#6	105	213	285	1203
#7	111	207	510	1980
#8	111	207	219	816
#9	120	195	201	1134
#10	102	186	327	1722
#11	105	192	183	1350
#12	120	201	213	1698
#13	90	171	174	1545
#14	114	189	210	1605
#15	129	222	210	1875
#16	114	180	174	1296
#17	96	183	195	1512
#18	123	204	219	1743
#19	117	147	198	1452
#20	105	141	189	1326
#21	106	171	201	1044
#22	120	144	162	1980
#23	111	156	153	1674
#24	111	141	183	1056
#25	105	144	153	1683
#26	114	168	177	1740
#27	120	156	180	1074
#28	135	168	195	1875
#29	102	153	162	885
#30	105	162	171	1617
Avg.	114	182	232	**1433**
STDEV.	11.22	32.34	99.76	342.37

Relaxation force

SOC dependency, Single cell



✓ Avg. cell relaxation force: 848N @SOC100%

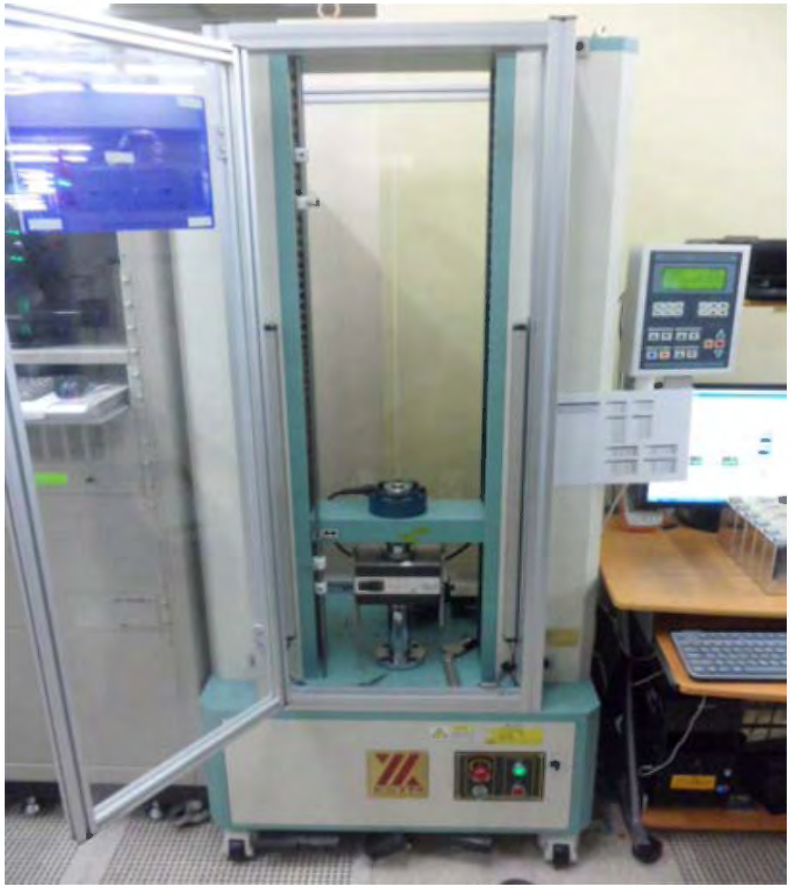
❖ Test conditions

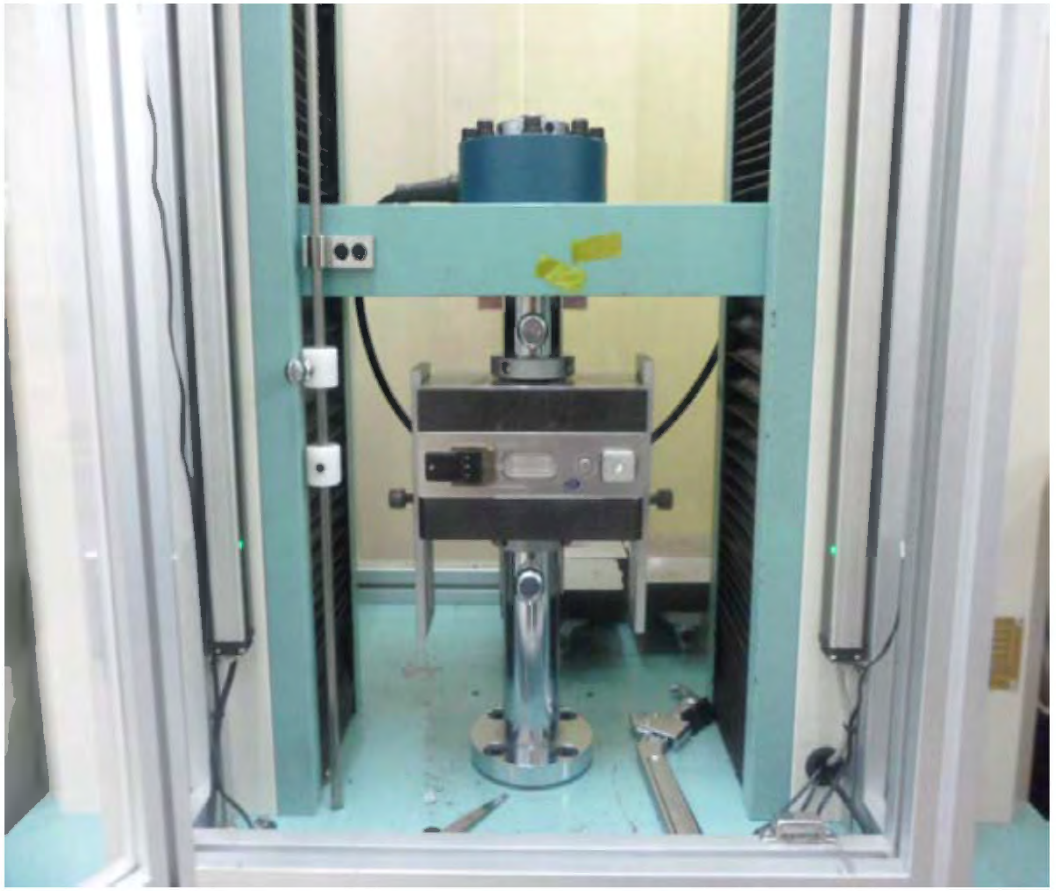
- Target thickness : 45 mm without insulation tape.
- Compression velocity : 0.02 mm/s
- Duration : 5 min

Relaxation force, N				
Cell No.	SOC 20	SOC 40	SOC 60	SOC 100
#1	117	168	249	867
#2	114	186	210	492
#3	132	189	216	873
#4	126	192	198	594
#5	126	252	357	987
#6	102	204	237	759
#7	108	198	276	1110
#8	108	201	210	477
#9	117	192	192	729
#10	99	180	225	972
#11	102	186	174	720
#12	117	195	201	1011
#13	90	165	165	807
#14	111	183	198	861
#15	123	213	198	984
#16	111	174	168	687
#17	93	174	183	798
#18	123	198	207	966
#19	117	141	192	777
#20	102	135	180	792
#21	105	162	189	669
#22	104	141	153	1176
#23	108	147	144	1116
#24	105	135	171	681
#25	102	138	151	1098
#26	111	159	168	996
#27	114	150	171	672
#28	132	159	180	1236
#29	99	147	153	552
#30	102	156	162	981
Avg.	111	174	196	**848**
STDEV.	10.80	27.35	42.83	201.69

Image of test equipment

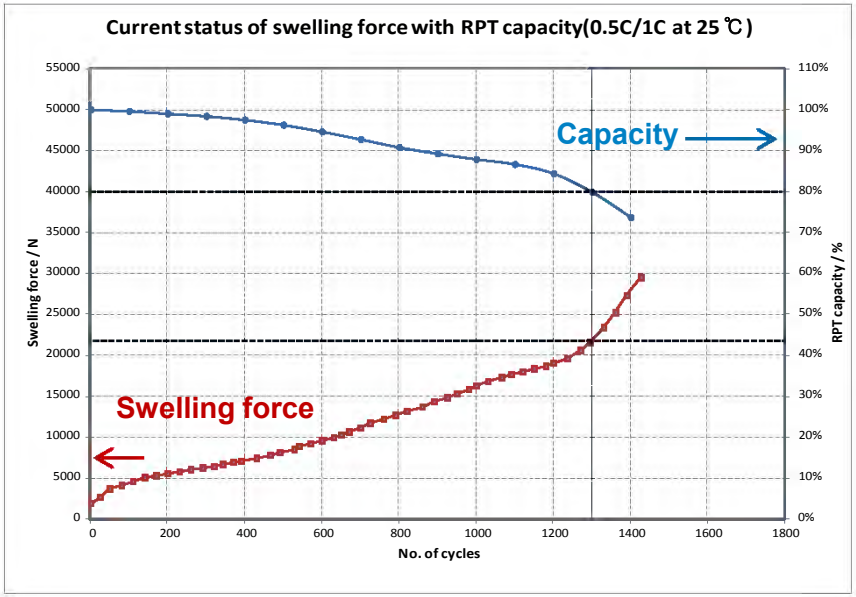
Compression force test

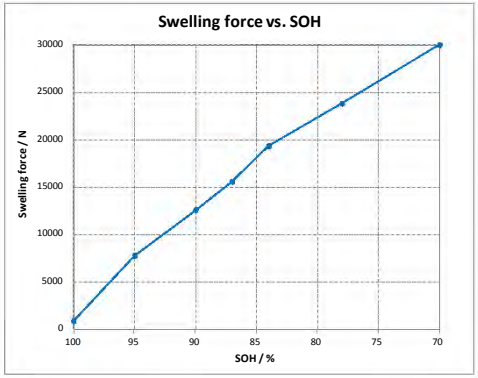




Swelling force

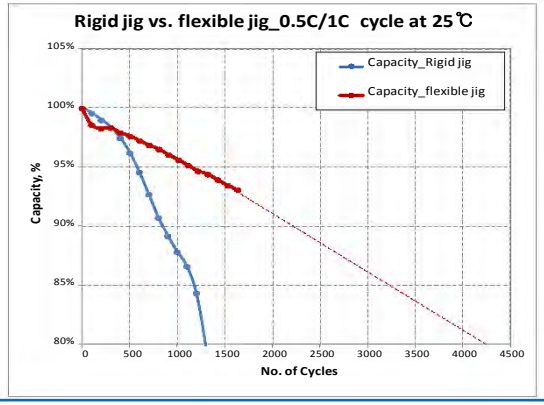
At 0.5C/1C cycle, 25℃ with rigid jig





✓ In this test condition(w/o elongation and bulging), the measured swelling force of 94Ah cell is **22,000N** at EOL80%.

✓ For current 94Ah sample, the estimated max. swelling force at EOL80% is **25,000N** (w/o elongation and bulging),



✓ Without elongation and bulging, the expected cycle life is <1,500cycles at EOL80%.

✓ To increase cycle life (and to decrease swelling force), SDI proposes to make a gap between cells in module.

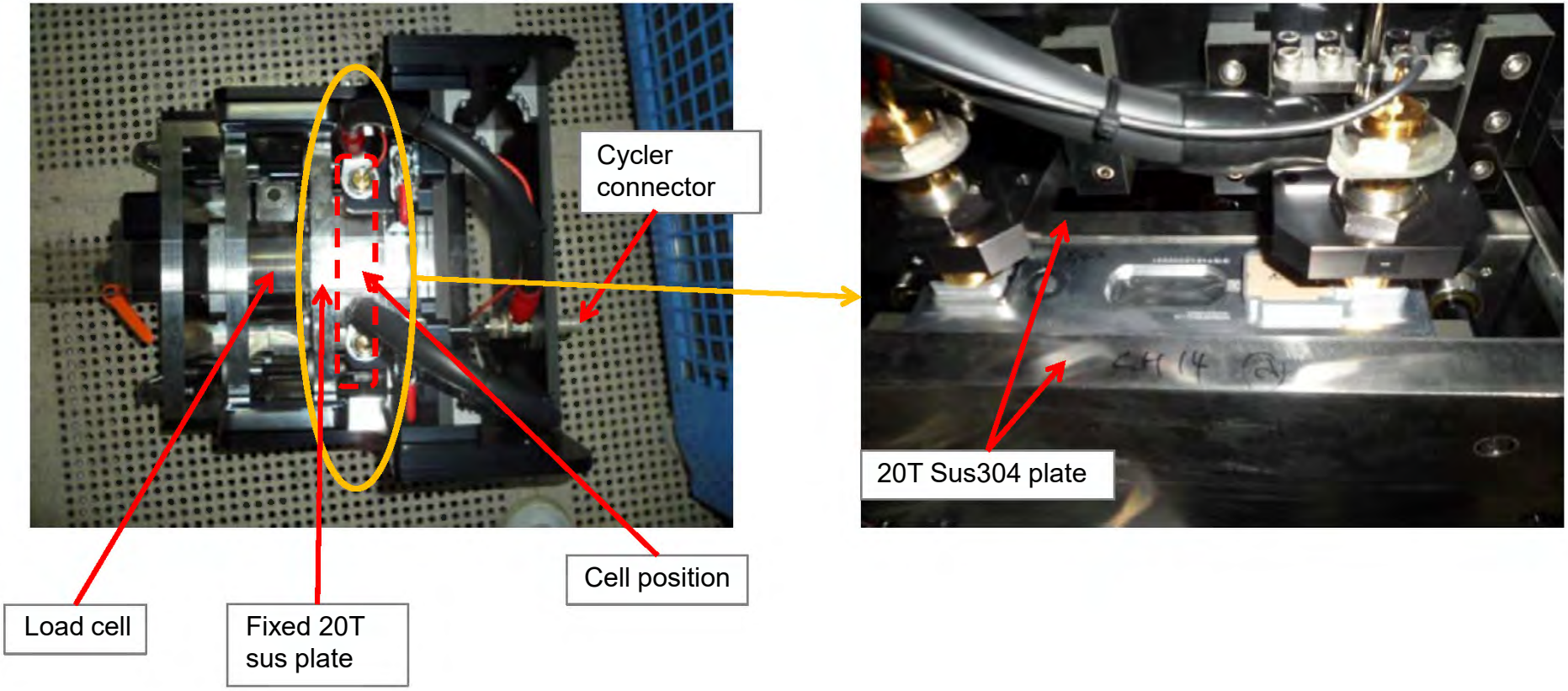
✓ If cell is compressed severely(too rigid housing), separator can be compressed together. In this condition, capacity degradation can be accelerated.

✓In opposite, too much gap can also make a problem. In this condition, cell thickness can increase and it can induce to increase gap between electrodes.

✓SDI' proposal is **0.5mm < gap+elogation@20kN max < 2.0mm**

Image of rigid jig

SUS, 20mm thickness



✓Above test jig(SUS 20T) dose not allow elongation and bulging of cell.

Self discharge

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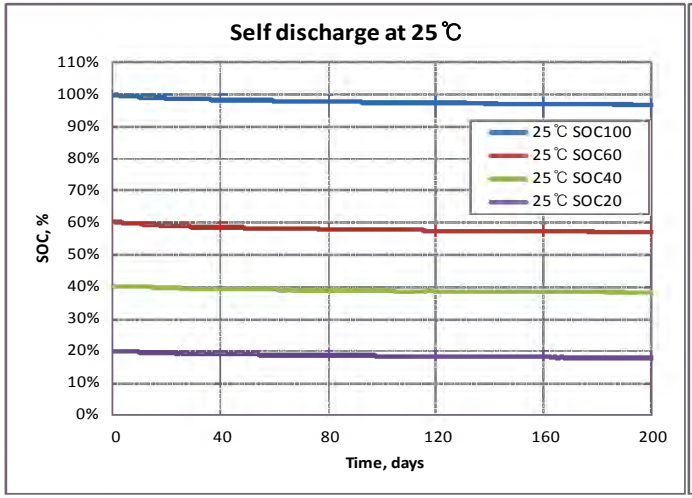
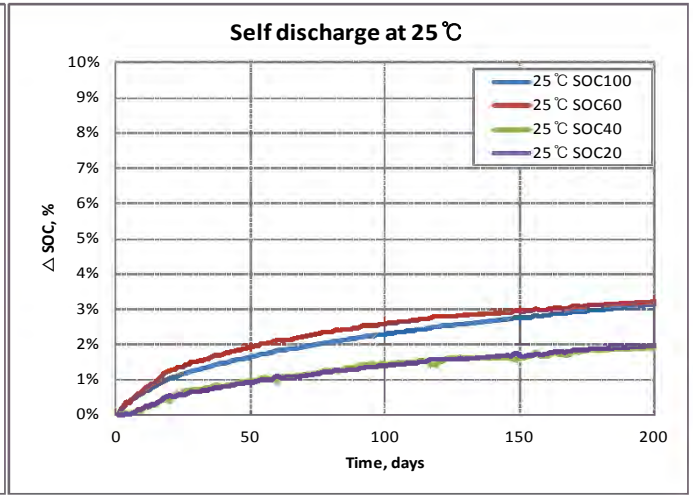
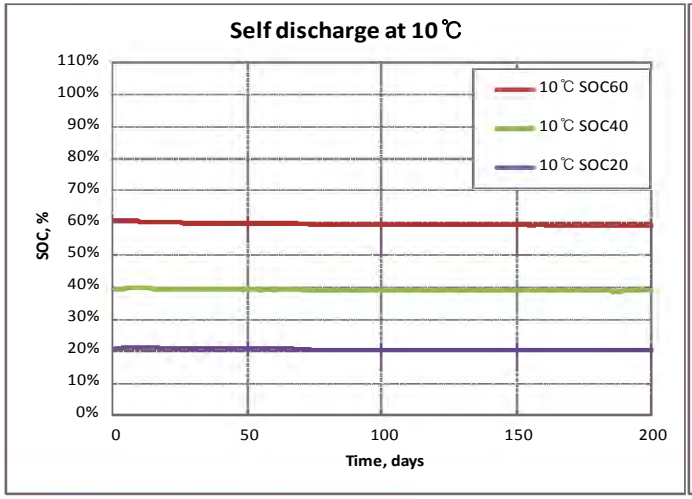
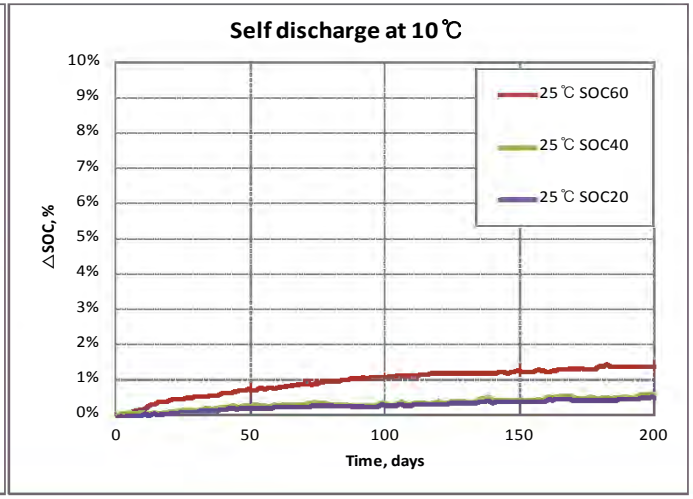
Self discharge

At 25℃ / 10℃









❖ OCV drop during storage at each SOC and temperature condition was measured without recharging

SOC, %	△SOC after 200D	
	at 25℃	at 10℃
SOC100	3.2%	-
SOC60	3.3%	1.4%
SOC40	1.9%	0.6%
SOC20	2.0%	0.5%

• At 25℃, 94Ah cell shows <5% of self discharge rate after 200D storage

• At 10℃, much lower SOC drop than 25℃ was observe. Below SOC60%, it is expected that <2% of self discharge at 200D storage

Operating and Safety limit

SAMSUNG SDI

Operating current limit

Charge and Discharge

Temperature (℃)	Charge Operating Current Limit			
	$I_{ch\_max\_peak}$ (A)	Continuous Current Limit		
		Duration (sec)	$I_{ch\_max\_continuous}$	
			I_{rms} (A)	Allowable usages over life
60	270	100	107	100%
50	270	100	107	100%
40	270	100	96	100%
35	270	100	84	100%
30	270	100	73	100%
25	270	100	61	100%
20	270	100	51	100%
15	270	100	41	100%
10	270	100	32	100%
5	270	100	24	100%
0	237	100	18	100%
-5	185	100	12	100%
-10	125	100	7.2	100%
-15	62	100	4.3	100%
-20	33	100	2.7	100%
-25	22	100	1.7	100%
-30	7	100	1.0	100%
-40	1	100	0.4	100%

Temperature (℃)	Discharge Operating Current Limit			
	$I_{dch\_max\_peak}$ (A)	Continuous Current Limit		
		Duration (sec)	$I_{dch\_max\_continuous}$	
			I_{rms} (A)	Allowable usages over life
60	409	150	223	100%
50	409	150	223	100%
40	409	150	223	100%
35	409	150	210	100%
30	409	150	196	100%
25	409	150	180	100%
20	409	150	166	100%
15	409	150	153	100%
10	409	150	136	100%
5	409	150	124	100%
0	409	150	108	100%
-5	409	150	93	100%
-10	409	150	77	100%
-15	409	150	74	100%
-20	409	150	62	100%
-25	409	150	57	100%
-30	409	150	46	100%
-40	409	150	33	100%

- ✓ **Continuous current limit($I_{max\_continuous}$)** : Maximum continuous-current which can be used until capacity reaches to 80% of initial capacity without abnormal capacity degradation.
- ✓ **Maximum current limit(I_{max_peak})** : Maximum allowable current in system, but allowable time is limited by algorithm of operating current limit(refer to page4)

Operating current limit

Algorithm

Operating Current Limit on Charge ➔

$$\int_{t-100}^{t} I^2 \cdot dt \le \int_{0}^{100} I_{ch\_max\_continuous}{}^2 \cdot dt$$

$$\begin{cases} I = 0, \text{ when } I \le 0 \text{ (discharge)} \\ I = I, \text{ when } I > 0 \text{ (charge)} \end{cases}$$

And, charging current $\le I_{ch\_max\_peak}$

Remark) $I_{ch\_max\_continuous}$ = max continuous charge current at each temperature

Operating Current Limit on Discharge ➔

$$\int_{t-150}^{t} I^2 \cdot dt \le \int_{0}^{150} I_{dch\_max\_continuous}{}^2 \cdot dt$$

$$\begin{cases} I = -I, \text{ when } I \le 0 \text{ (discharge)} \\ I = I, \text{ when } I > 0 \text{ (charge)} \end{cases}$$

And, discharging current $\le I_{dch\_max\_peak}$

Remark) $I_{dch\_max\_continuous}$ = max continuous discharge current at each temperature

Safety current limit

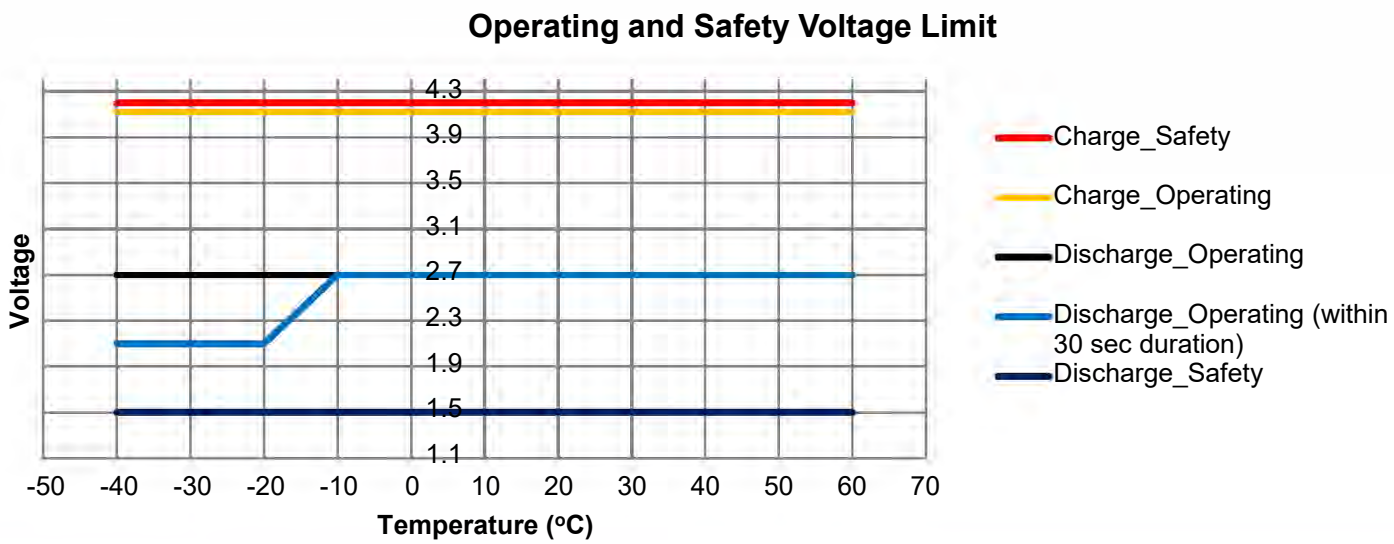
Charge and Discharge

Temperature (℃)	Safety Current Limit			
	Discharge		Charge	
	I_{max} (safety)	max. allowed duration (msec)	I_{max} (safety)	max. allowed duration (msec)
60	500	700	360	700
50	500	700	360	700
40	500	700	360	700
35	500	700	360	700
30	500	700	360	700
25	500	700	360	700
20	500	700	360	700
15	500	700	360	700
10	500	700	360	700
5	500	700	360	700
0	500	700	360	700
-5	500	700	245	700
-10	500	700	165	700
-15	500	700	83	700
-20	500	700	45	700
-25	500	700	30	700
-30	500	700	9.4	700
-40	500	700	1.8	700

Operating and safety voltage limit

Charge and Discharge

	Item	Value	Remark
Safety limit	Charge	4.25 V	
	Discharge	1.5 V	
Operating limit	Charge	4.15 V	
	Discharge	2.7 V	2.1 V at below -20°C within 30 sec duration



Operating and safety temperature limit

Operating and storage

	Item	Value	Remark
Safety limit	Maximum storage	80°C	This is to be ensured in an ambient temperature range (Electrolyte gas generation, OSD deformation vent opening, leakage, etc.)
	Minimum storage	-40°C	This is to be ensured in an ambient temperature range
	Maximum operation	80°C	This is to be ensured in a cell core temperature
	Minimum operation	-40°C	This is to be ensured in a cell core temperature
Operation limit	Maximum operation	60°C	This is to be ensured in a cell core temperature
	Minimum operation	-40°C	This is to be ensured in a cell core temperature