IEST®

–Dedicated to lithium-ion battery testing and developmenT–

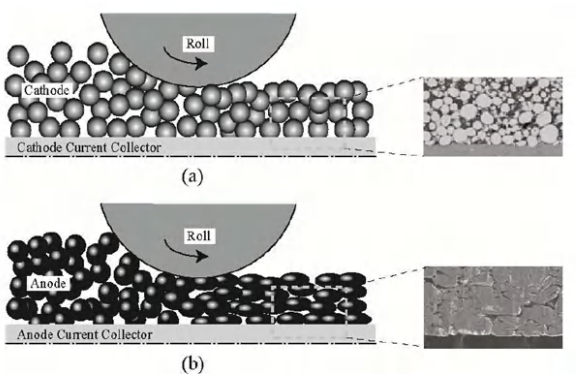
POWDER RESISTIVITY MEASUREMENT SYSTEM & COMPACTION DENSITY MEASUREMENT SYSTEM

Developed with CATL (the top power battery company) and
Authorized exclusively for the Patent

THE SIGNIFICANCE OF POWDER RESISTANCE

The rate performance of lithium-ion batteries(LIBs) is closely related to the battery resistance. The battery resistance includes ionic resistance and electronic resistance. The ionic resistance mainly refers to the resistance of lithium ions in the electrolyte in the electrode pores, the resistance of

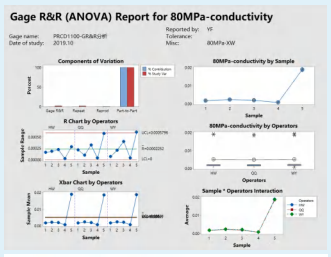
Lithium ions through the solid electrolyte interphase(SEI),the charge transfer resistance of the lithium ions and electrons at the interface of the active material/SEI , and the solid diffusion resistance of the lithium ions in the active material. The electronic resistance mainly refers to the resistance of the positive and negative active materials, the current collector resistance, the contact resistance between the active materials, the contact resistance between the active material and the collector, and the welding resistance of tabs. In the practical production process of LIBs, the ionic resistance part needs to be evaluated by using the finished product. However,the electronic resistance part can be quickly evaluated by using the materials and electrodes. Therefore, the accurate evaluation of the electronic resistance of the materials and electrodes is of great significance for predicting the resistance of the LIBs.



B.G. Westphal et al. Journal of Energy Storage 2017, 11, 76–85

MEASUREMENT SYSTEM ANALYZE

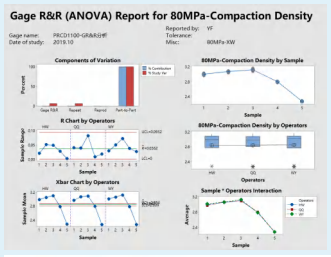
Test Condition: 5 samples, 3 operators, 3 times/pcs/operator.



Gage Evaluation

Source	StdDev (SD)	Study Var (6 × SD)	%Study Var (%SV)
Total Gage R&R	0.0001649	0.0009892	2.13
Repeatability	0.0001565	0.0009389	2.03
Reproducibility	0.0000519	0.0003116	0.67
Operators	0.0000519	0.0003116	0.67
Part-To-Part	0.0077254	0.0463524	99.98
Total Variation	0.0077272	0.0463630	100.00

Number of Distinct Categories = 66



Gage Evaluation

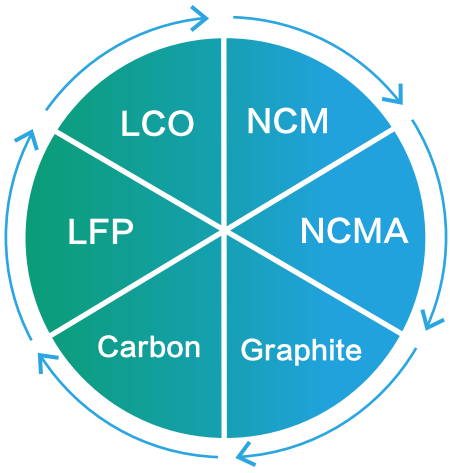
Source	StdDev (SD)	Study Var (6 × SD)	%Study Var (%SV)
Total Gage R&R	0.022141	0.13284	6.42
Repeatability	0.022141	0.13284	6.42
Reproducibility	0.000000	0.00000	0.00
Operators	0.000000	0.00000	0.00
Part-To-Part	0.344266	2.06560	99.79
Total Variation	0.344978	2.06987	100.00

Number of Distinct Categories = 21

%GRR accepted rule	%GRR≤10%	Excellent
	10% < %GRR≤30%	Acceptable
	%GRR > 30%	Unacceptable
ndc accepted rule	ndc≥10	Excellent
	5≤ndc < 10	Acceptable
	ndc < 5	Unacceptable

- Powder Resistance : GRR-Excellent
- Compact density : GRR-Excellent

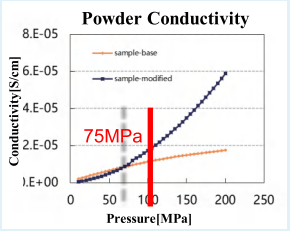
APPLICTIONS

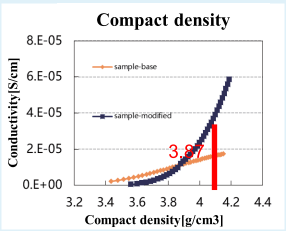


APPLICATION CASES

1) LCO MATERIAL ASSESSMENT

Evaluation of electrical properties of modified powder (LCO)





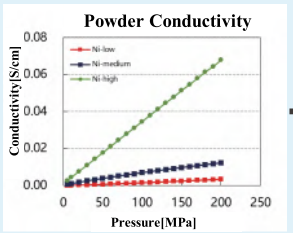
Parameter: 10~200MPa, 5MPa steps, keep 15s

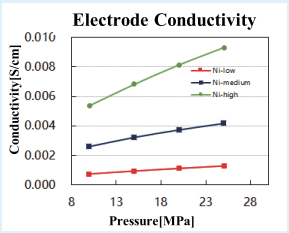
Results: When the compact density of the modified powder is greater than 3.87 g/cm³ (applied pressure > 75MPa) , the conductivity of the modified powder shows greatly improved.

The effectiveness of the modification can be evaluated.

2) NCM MATERIAL ASSESSMENT

Relation of powder resistivity and electrode: NCM Material





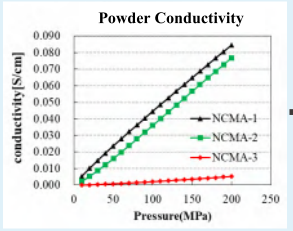
Results

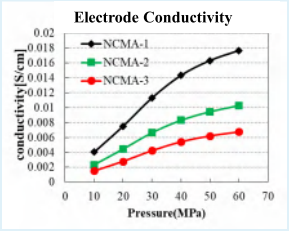
- By adjusting the Ni content in the NCM material, the powder conductivity increases with the increase of Ni content.
- Compared with three kinds of NCM electrodes with different Ni content, the conductivity of the Electrode also increases with the increasing of Ni content.

Powder resistivity and electrode have the same trend !

3) NCMA MATERIAL ASSESSMENT

Relation of powder resistivity and electrode: NCMA Material



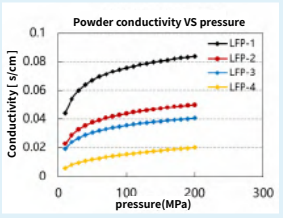


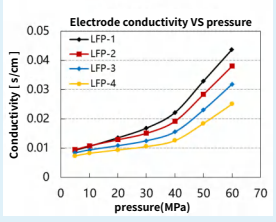
- The conductivity trend of the quintenary powder and electrode under three different modifications conditions is NCMA-1 > NCMA-2 > NCMA-3;
- The conductivity of NCMA-3 in powder state is much smaller than that of the former two samples, but there only has small difference among these three electrodes, which may be related to the addition of conductive in the electrode, which reduces the difference detected in the powder state.

Powder resistivity and electrode have the same trend !

4) LFP MATERIAL ASSESSMENT

Relation of powder resistivity and electrode: LFP Material





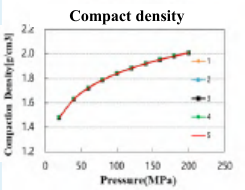
Results

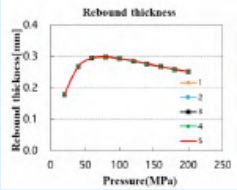
Compared the LFP powders with corresponding electrodes under four different modifications conditions, the conductivity trend of LFP powders and electrodes is as follows LFP-1 > LFP-2 > LFP-3 > LFP-4

Powder resistivity and electrode have the same trend !

5) GRAPHITE MATERIAL ASSESSMENT

Compact density: Parallel test 5 times





Parameter: 20~200MPa, 20MPa steps, keep 30s, relief 3MPa steps, keep 10s

Compaction Density

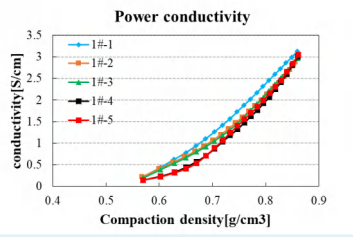
N 力 (T)	压 强(Mpa)	1	2	3	4	5	COV
0.4107	20.01	1.4811	1.4791	1.479	1.4806	1.4783	0.08%
0.8211	40.02	1.6317	1.6299	1.6292	1.6308	1.6288	0.07%
1.2311	60	1.7226	1.7206	1.7199	1.7215	1.72	0.07%
1.6428	80.07	1.7887	1.7878	1.787	1.7884	1.7867	0.05%
2.0526	100.04	1.8416	1.8406	1.8399	1.8413	1.8398	0.04%
2.4616	119.98	1.8856	1.8842	1.8835	1.8849	1.8826	0.06%
2.8738	140.07	1.9224	1.9209	1.9201	1.9217	1.9201	0.05%
3.2838	160.05	1.9546	1.9536	1.9525	1.9546	1.9525	0.05%
3.693	180	1.9831	1.9821	1.9818	1.9834	1.9819	0.04%
4.1042	200.04	2.0094	2.0096	2.0082	2.0094	2.0087	0.02%

Results

- The COV of live parallel samples is less than 0.1% in the whole pressure range, which indicates that the equipment has good repeatability.
- With the increase of pressure, the compact density of graphite increases gradually and tends to be flat.
- The rebound thickness of graphite powder under compression and decompression process reaches the maximum value at 80MPa, which indicates that this pressure is the maximum pressure that the powder can bear. If continue to increase the pressure, the structure of the material will be damaged.

6) CARBON MATERIAL ASSESSMENT

Compact density VS Resistivity: Parallel test 5 times



Parameter: relief mode: 10~200MPa, 10MPa steps, keep 10s

Results: The COV of five parallel samples is less than 0.3% in the whole pressure range, which indicates that the equipment has good repeatability.

With the increase of pressure , the compact density of carbon material increases gradually, and the compaction range is 0.5-0.9/cm³. .

Pressure(Mpa)	Compaction density[g/cm3]					
	1#-1	1#-2	1#-3	1#-4	1#-5	COV
9.99	0.5701	0.5676	0.57	0.5699	0.5699	0.19%
20	0.6025	0.6	0.6026	0.6025	0.6026	0.19%
30.02	0.6281	0.6257	0.6283	0.6283	0.6284	0.18%
40	0.65	0.6474	0.6504	0.6504	0.6505	0.20%
50.05	0.6695	0.6668	0.6698	0.6699	0.67	0.20%
60.07	0.6871	0.6844	0.6875	0.6877	0.6878	0.21%
70.04	0.7034	0.7006	0.7037	0.704	0.7042	0.21%
80.02	0.7184	0.7157	0.7189	0.7192	0.7194	0.21%
90.05	0.7327	0.7298	0.7331	0.7333	0.7336	0.21%
100.04	0.7462	0.7432	0.7466	0.747	0.7472	0.22%
110.12	0.759	0.7559	0.7594	0.7598	0.7601	0.22%
120.09	0.7714	0.7682	0.7718	0.7721	0.7726	0.23%
130.07	0.7832	0.7802	0.7838	0.7842	0.7846	0.22%
140	0.7947	0.7916	0.7953	0.7958	0.7962	0.23%
150.08	0.8059	0.8027	0.8065	0.807	0.8073	0.24%
160.1	0.8169	0.8137	0.8176	0.8182	0.8185	0.24%
170.01	0.8276	0.8244	0.8284	0.829	0.8293	0.24%
180.02	0.8382	0.835	0.839	0.8397	0.8402	0.25%
190.04	0.8488	0.8456	0.8497	0.8503	0.8507	0.24%
200.16	0.8592	0.8561	0.8602	0.8608	0.8612	0.24%

High Accuracy Pressure System: Driven by servo motor. **High Accuracy Displacement sensor:** Precisely measure the variation of thickness.

Specific mold for resistivity& compaction density test of powder samples: Simplify the process of the powder loading and cleaning.

Multi-functions: One-stop data collection of key parameters of pressure, resistance, thickness, temperature and humidity. It can ensure the high reliability of the data and provide a complete traceability for each result.

Automatic Measurement: Providing flexible measurement modes for different kinds of samples, and all the process parameter setting are integrated into a simple software control interface, with one-button to start a measurement.

RPCDMS Software:

1.Pressure can be set willfully within the extent of max pressure.

2.The resistivity under different pressure can be measured in succession with controllable rate and interval of pressure.

3.Different data analysis curves can be generated, including resistivity-pressure curve, resistivity-thickness curve, compaction density-pressure curve, and pressure-thickness curve.

4.Two resistance data collection mode: interval time mode and stable pressurization mode.

5.Data statistical analysis functions.

6.Automatically generate reports with the value of resistivity(or conductivity) and compaction density.

Integrated design: Integration of control and measurement systems for pressure, resistivity and thickness.

Parameter	
Resistance range	1uΩ~ 1200MΩ
Resistance accuracy	±0.05%
Resistivity range	10^{-6}Ω · cm~10^{9}Ω · cm
Conductivity range	10^{-9}^S/cm~10^{6} S/cm
Pressure range	0~200Mpa
Pressure accuracy	±0.30% F.S
Thickness range	0~8mm
Thickness resolution / accuracy	0.5μm/±10μm
Max filling capacity	Φ16mm x 8mm
Temperature and humidity range	20~90%RH、0~50℃
Temperature and humidity accuracy	±5%RH、±2℃

Installation Requirement	
Voltage	220V
Voltage change tolerance	±10%
Power consumption	2100W
Environment temperature	25±5℃
Environmental humidity	Humidity at 40℃ <80%RH
Environmental magnetic field	Away from intense electromagnetic fields
Net weight	165Kg
Dimenstion (W*D*H)	370*580*1100(mm)

Model	PRCD1000	PRCD2000	PRCD3000	PRCD1100	PRCD2100	PRCD3100
Test pressure	1T			5T		
Test principle	Two probes	Four probes	Two probe & Four probe dual function (software selection function + switch mold)	Two probes	Four probes	Two probe & Four probe dual function (software selection function + switch mold)
Applicable samples	High resistance samples (such as LFP,LCO, NCM, etc.)	Low resistance samples (such as LFP, graphite, conductive agent, etc.)	Positive and negative samples	High resistance samples (such as LFP，LCO, NCM, etc.)	Low resistance samples (such as graphite, conductive agent, etc.)	Positive and negative samples （Resistance Range 1μΩ~200MΩ）
Test Condition Range	1.Die diameter：13mm; 2.Pressure：70MPa; 3.Resistance range：1μΩ~20MΩ Remarks: National Standard for Graphite Negative Materials: GB／T 24533-2019，Stress Required 2200lb			1.Die diameter：16mm; 2.Pressure：200MPa; 3.Resistance range: 1μΩ~1200MΩ	1.Die diameter：16mm; 2.Pressure：200MPa; 3.Resistance Range：1μΩ~200MΩ	

EN PRCD 202207

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IEST public account

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