IEST®

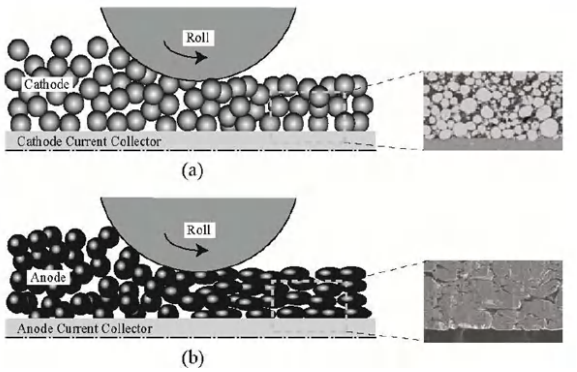
–Dedicated to lithium-ion battery testing and developmenT–

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

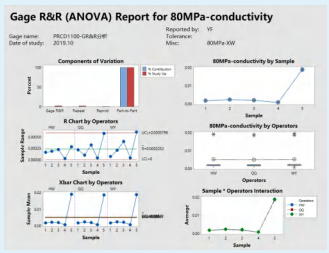
The rate performance of lithium-ion batteries is closely related to the battery resistance. The battery resistance includes ionic resistance and electronic resistance. The ionic resistance mainly refers to the resistance of lithium ions in the electrolyte in the electrode pores, the resistance of lithium ions through the SEI membrane, and the resistance of lithium ions and electrons. The charge transfer resistance of the active material/SEI film interface and the solid phase diffusion resistance of lithium ions inside 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, and the contact resistance between the active material and the current collector. And the welding resistance of tabs. In the actual battery development and producti on process, the ionic resistance part needs to be evaluated at the finished battery end, and the electronic resistance part can be quickly evaluated at the material and pole piece end. **Therefore, the accurate evaluation of the material and the electrode elect-ronic resistance is important for the battery. The resistance estimation is of great significance.**



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

MEASUREMENT SYSTEM ANALYZE

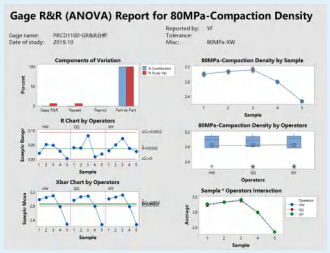
Test Condition: 5 samples, 3 operators, 3times/pcs/operator



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

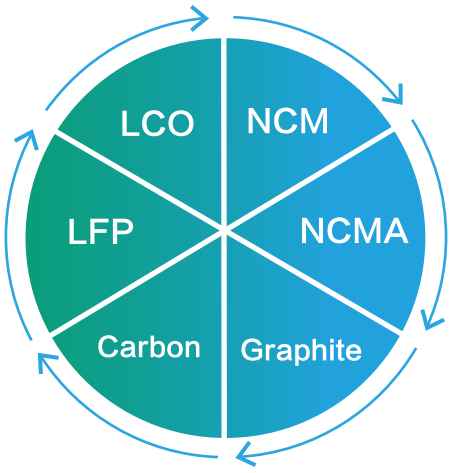
Source	StdDev (SD)	Study Var (6 × SD)	%Study Var (%SV)
Total Gage R&R	0.022141	0.13284	6.42
Repeatability	0.022141	0.13284	6.42
Reproducibility	0.000000	0.00000	0.00
Operators	0.000000	0.00000	0.00
Part-To-Part	0.344266	2.06560	99.79
Total Variation	0.344978	2.06987	100.00

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

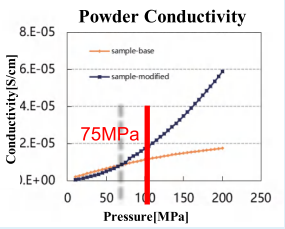
APPLICTIONS

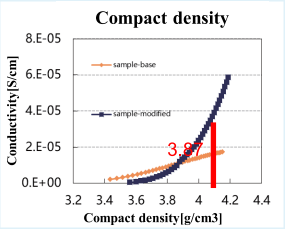


APPLICATION CASES

1) LCO MATERIAL ASSESSMENT

Evaluation of electrical properties of modified powder (LCO)





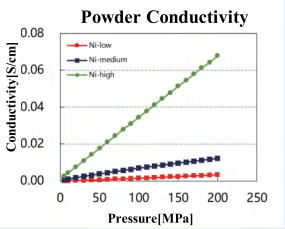
Parameter: 10~200MPa, 5MPa steps, keep 15s

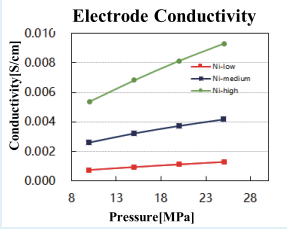
Results: When the Compact density of the modified powder is greater than 3.87g/cm3 (applied pressure > 75MPa), the conductivity of the modified powder is greatly improved.

The effectiveness of the modification can be evaluated.

2) NCM MATERIAL ASSESSMENT

Relation of powder resistivity and electrode: NCM Material





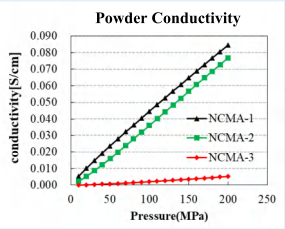
Results Analyze

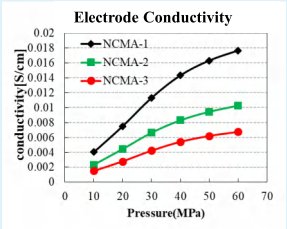
- By adjusting the Ni content in the ternary material, the powder conductivity increases with the increase of Ni content.
- Compared with three kinds of ternary electrodes with different Ni content, the conductivity of the electrode increases with the increasing of Ni content;

Powder resistivity and electrode have the same trend !

3) NCMA MATERIAL ASSESSMENT

Relation of powder resistivity and electrode: NCMA Material





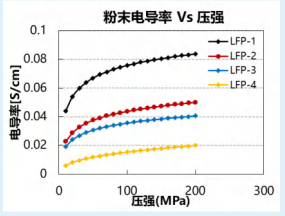
Results Analyze

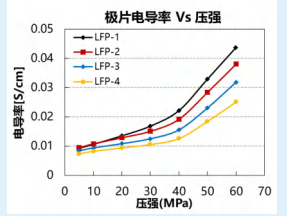
- The conductivity trend of the Quaternary powder and electrode under three different modification conditions is NCMA-1 > NCMA-2 > NCMA-3 ;
- The conductivity of NCMA-3 in powder state is much smaller than that of the former two samples, but there is a small difference in the electrode plate, which may be related to the addition of conductive in the electrode plate, which reduces the difference between the powder.

Powder resistivity and electrode have the same trend !

4) LFP MATERIAL ASSESSMENT

Relation of powder resistivity and electrode: LFP Material





Results Analyze

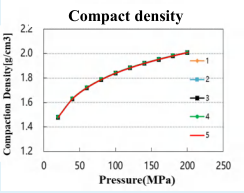
Compared with the LFP powder and electrode sheet under four different modification conditions, the conductivity trend of LFP powder and electrode sheet is as follows

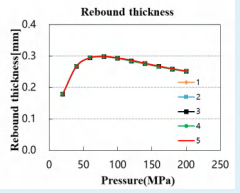
LFP-1>LFP-2>LFP-3>LFP-4

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

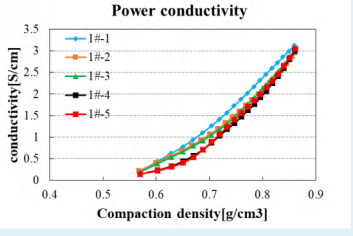
压力 (T)	压强 (Mpa)	1	2	3	4	5	COV
0.4107	20.01	1.4811	1.4791	1.479	1.4806	1.4783	0.08%
0.8211	40.02	1.6317	1.6299	1.6292	1.6308	1.6288	0.07%
1.2311	60	1.7226	1.7206	1.7199	1.7215	1.72	0.07%
1.6418	80.07	1.7887	1.7878	1.787	1.7884	1.7867	0.05%
2.0526	100.04	1.8416	1.8406	1.8399	1.8413	1.8398	0.04%
2.4616	119.98	1.8856	1.8842	1.8835	1.8849	1.8826	0.06%
2.8738	140.07	1.9221	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%
4.1012	200.04	2.0094	2.0096	2.0082	2.0094	2.0087	0.02%

Results Analyze

- The cov of five 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 material increases gradually and tends to be flat.
- The rebound of powder thickness under pressure and pressure relief reaches the maximum value at 80MPa, which indicates that this condition is the maximum pressure that the powder can bear, and if it is too large, the material structure is likely to 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 g / cm^3 .

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	0.6028	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	0.6873	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	0.8294	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 clamp 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 with high reliability, to 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.

PRCDMS 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 scan.
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 modes: interval time mode or automatic steady state condition determine mode.
5. Data statistical analysis functions.
6. Automatic generation of reports with the value of resistivity (or conductivity) and Compaction density.

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

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 accuracy/ resolution	0.5um/±5um
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)

CE EN PRCD 202207

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	

IEST®
INITIAL ENERGY SCIENCE & TECHNOLOGY (XIAMEN) CO.,LTD
Address: 4th Floor, No. 2, Xinfeng 2nd Road, Torch Development Zone, Huli District, Xiamen CityTechnology (Xiamen) Co., Ltd.
Tel：(86)592-5367060 Fax：(86)592-5367062
www.iesttech.com E-mail：info@iesttech.com
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