IEST®
元 能 科 技

MULTIFUNCTIONAL BATTERY ELECTRODE RESISTANCE ANALYZER – A CREATIVE SOLUTION

–Dedicated to lithium-ion battery testing and development–

THE IMPORTANCE OF ELECTRODE RESISTANCE

Electrode resistance (conductivity) influences the basic performance of batteries,not only on the power capability (internal resistance),but also on he reliability or safety performance. Through the measurement of electrode resistance,the property of electric conductive,micro-structural uniformity of electrodes can be evaluated during the electrode manufacture process in advance,thus help us to research and improve the formulation of composite electrodes but also to control parameters of mixing, coating and calendering processes.
In the composite electrodes,the electric conductivity is determined by several primary factors,such as the interfacial resistance between the coating layer and the conductive foil,the distributions of conductive agents,the intrinsic resistance of active material and the contact areas between particles.

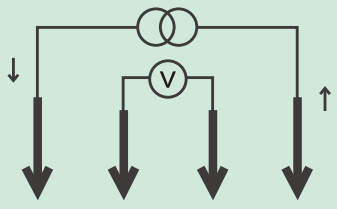
The functions of BER multi-function electrode resistance analysis method for electrode process monitoring are listed as follows: The functions of BER are listed as Follows:

1. Comprehensively assessment of tle mixing and coating stability of slurry, which helps to recognize the anomaly aggregation of conductive agents in advance;
2.Recognition of uneven mixing on mixture silicon-carbon anodes;
3. Assessment of electric conductivityof active materials with different formulas;
4. Assessment of electric conductivity of different conductive agents;
5. Assessment of electric conductivity of the fimctional pre-coating layers of current collector;
6.Failure analysis for the electric conductive network of electrodes;
7.Analysis of contact resistance of the positive or negative electrode after formation.

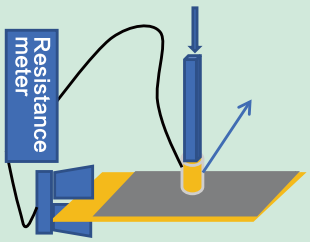
THE LIMITATIONS OF TRADITIONAL TEST METHODS

Currently, Several methods have been used to test the electrode resistance, such as four point probe method or multi point probe method and single point probe method. Though these traditionalmethods may have been maturely used in different types of film industry,for the evaluation of the composite electrode in lithium ion batteries, there are stillseveral deficiencies that can not be ignored.
The four point probe film resistance test method has been widely used in thin films industries, which use four or more probes to test the surface resistance of the film. Its test procedure is easy and simple, and it can reveal the anisotropic resistance components of thin film by a simple equivalent circuit model fitting. However,considering its test principle and model fitting process, this method can only be suitable for a uniform thin filn with smooth surface,and the test sample should be loaded on an insulating substrate for ideal resistance fitting. Unfortunately, the electrodes of lithium ion batteries are composite electrode with complex compositions, rough surface and loadingon a low resistance current collector, so the four point probe test data are often inconsistent and difficult to analyze the result by theoretical models. Although increasing the probe number and using more complicate models can a little bit improve the test reliability the result analysis is still difficult.
The single point test method was another wildley used method in the lithium ionbatteries industry, which use a fixed probe on the end of the current collector and a mobile probe on the surface of the electrode to directly measure the electrode resistance. This is a very simple way for electrode resistance test which is often carried out by a homebuilt system for different users, butit is still a rough and empirical test method without considering the influence of press pressure, conductive path length, contact area and so on. As a result, the single point probe method still can not provide a reliable and consistent electrode resistance data
.

Four Point probe method



Traditional singlepoint probe method



Methods	Four point probe test	Single point probe test
Electric Test Circuit	Kelvin four-wire test technonlogy+direct current stimulation	Kelvin four-wire test technonlogy+altemating-current
Probe Structure	four assembled equidistant probes (< Φ 1mm), which’ s tops are kept in the same plane during the test to get a physical contact with the sample surface	One prode(usually is an alligator clib)is fixed on the current collector,and the other prode(usually is a Cuterminals)is mobile to contact on the sample surface.
Applicable Samples	Single component thin layer material with smooth surface	Composite electrode with current collector
Advantages and Limitations	√ Simple and fast measurement √ To reveal the anisotropic resistance components of thin film × Not suitable for composite electrode with current collector	√ Simple and fast measurement √ Suitable for composite electrode with current collector × A rough empirical test method without considering the influence of press pressure, conductive path length, substrate material, etc.

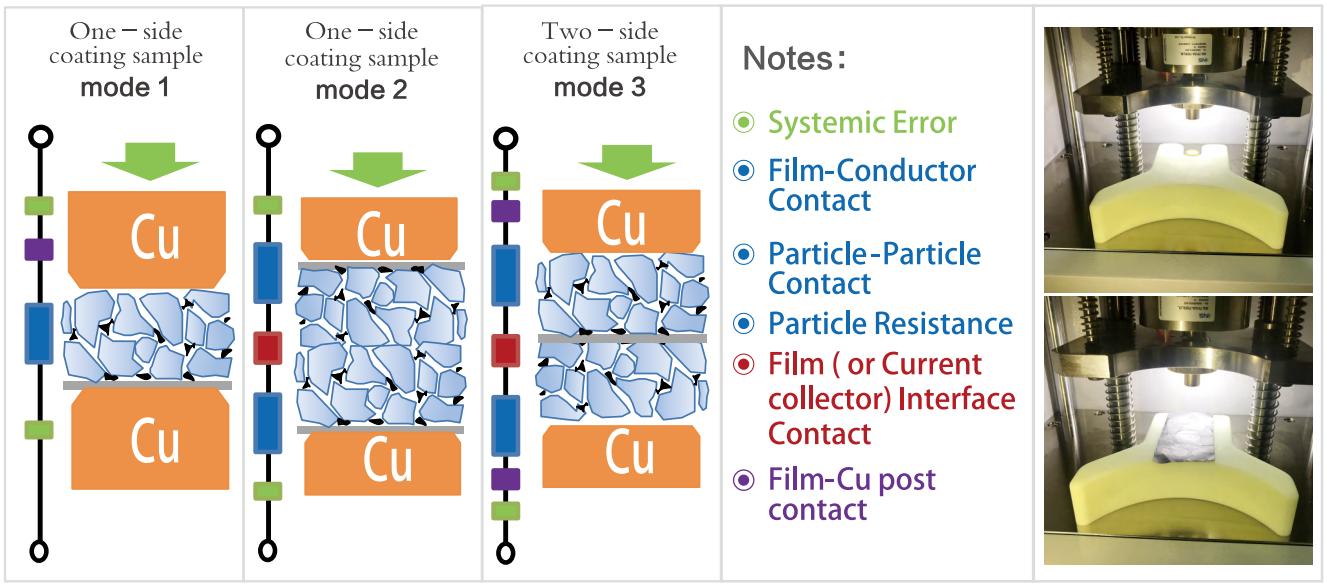
★ Developed with CATL the top power battery company and Authorized exclusively for the Patent.

THE IEST’S CREATIVE SOLUTION

The battery electrode resistance analyzer(BER series)uses two pressure-controllable plane probes to directly measure the electrode resistance,which can obtain the overall resistance and resistivity in the thickness direction of the electrode, including the contact the collector and the current.

The dual-plane,pressure-controllable,high-conductivity probe specially designed for composite electrode and micron-level flat surface treatment ensure the measurement accuracy; the high-precision resistance resolution and the attached calibration module ensure the stability and reliability of the results.

Introduction of principles



Calculation formula → Resistance(Ohm)： $R = \rho \frac{l}{S}$

Multifunction

One-stop data collection for key parameters including pressure,resistance,thickness,temperature, Humidity,etc.guarantee the reliability and tracebility of measurement result.

Automatic measurement

Automatic measurement of the resistance under different pressure, thickness, temperature and humidity, etc.; provide a real time data display.

Professional processing software

Provides various resistance measurement and analysis methods, including
- Single point test, continuous test,
- fixed pressure mode, variable pressure mode (For BER1300)
- Show data curve
- different presented modes of data analysis and statistics.

Integrated design

Complete integration of pressure control module, resistance and voltage measurement module, thickness measurement module and the chamber illuminating module.

Device	Four-probe and multi-probe methods
Principle	Device Fou-probe and multi-probe methods
Structure	Four taper equidistant probes in the same
Suitable	Single-component film with smooth surface (non-battery electrode)
Features	Measure sing-component film resistance and conductivity of smooth surface
Conclusion	1.The traditional test method does not consider the influence of parameters such as pressure and contact area during the electrode test: and the theoretical calculation model of the multi-prode is quite differnet from the actual sample,and the data results are uncontrollable; 2.The BER series electrode resistance meter can accurately control the test parameters such as test Pressure and area to ensure stable and reliable results,and can directly obtain the corresponding relationship between the electrode compaction and electrode resistance.

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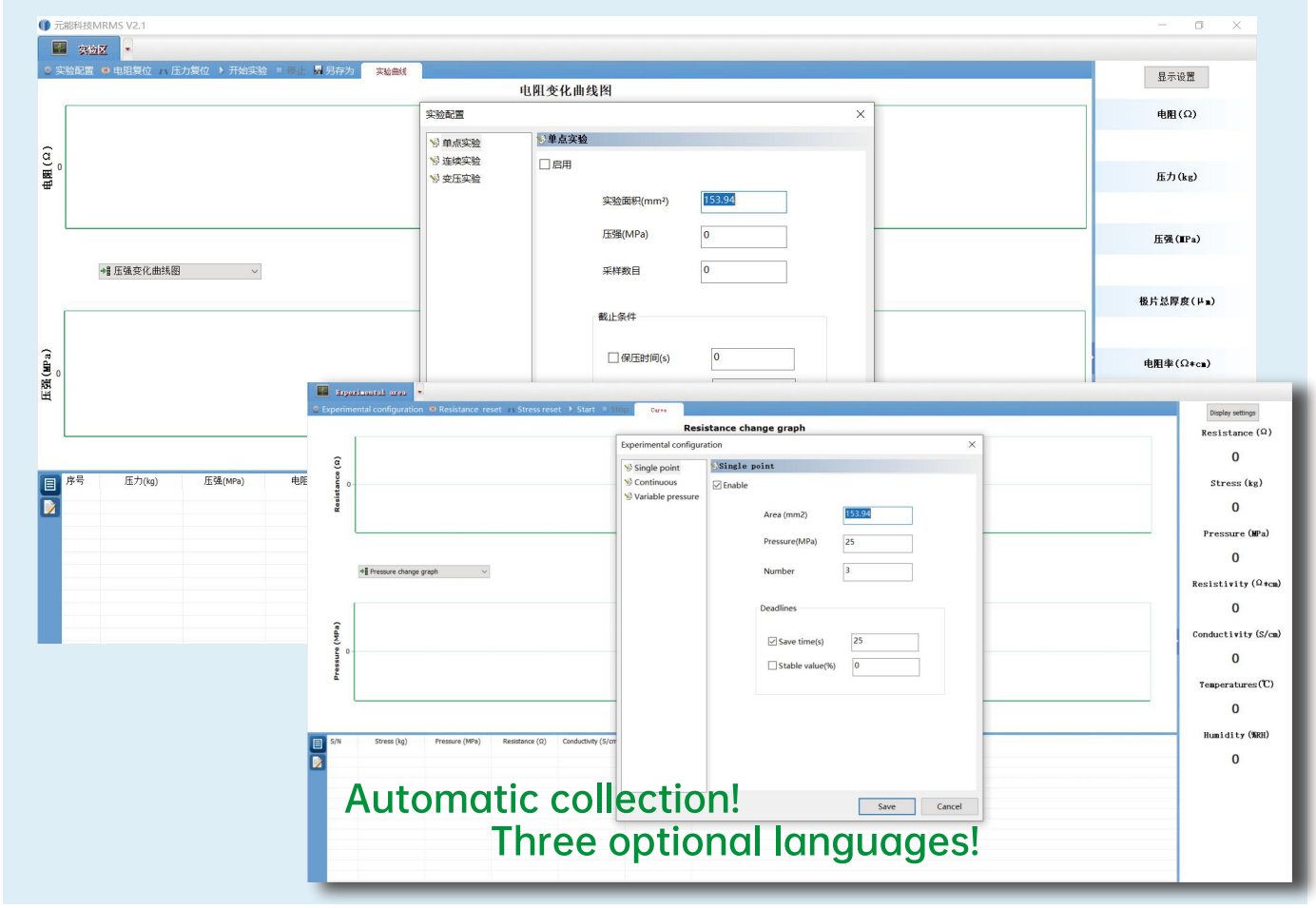
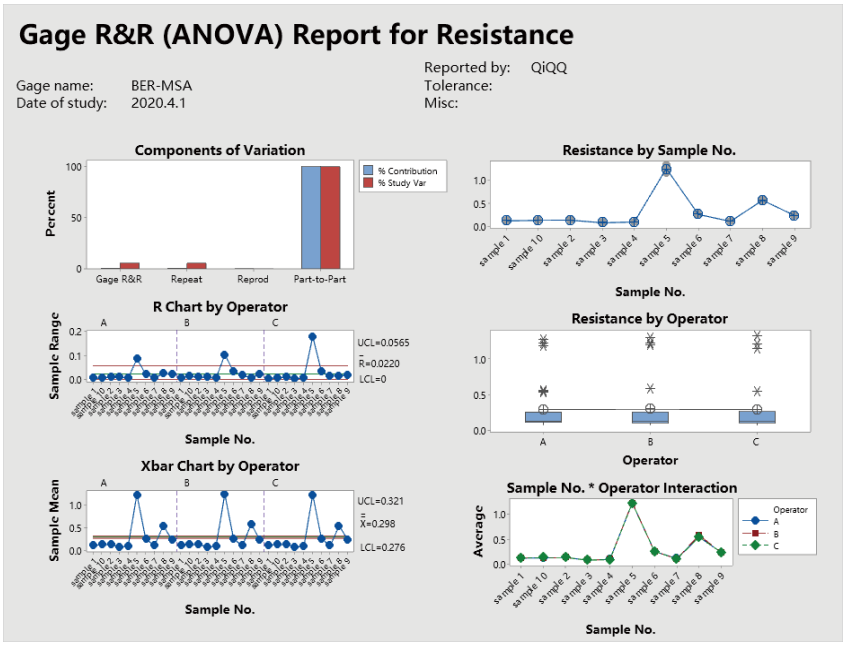
SOFTWARE



MEASUREMENT SYESTEM ANALYZE



Gage Evaluation

Source	StdDev (SD)	Study Var (6 × SD)	%Study Var (%SV)
Total Gage R&R	0.019726	0.11835	5.51
Repeatability	0.019726	0.11835	5.51
Reproducibility	0.000000	0.00000	0.00
Operator	0.000000	0.00000	0.00
Part-To-Part	0.357625	2.14575	99.85
Total Variation	0.358169	2.14901	100.00

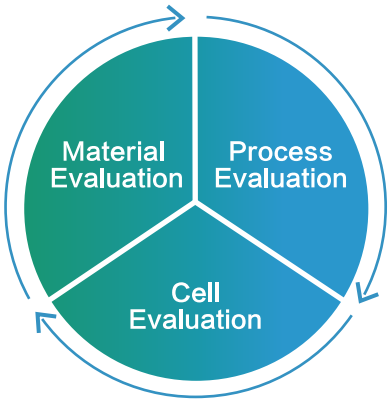
Number of Distinct Categories = 25

Excellent

%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

APPLICTIONS

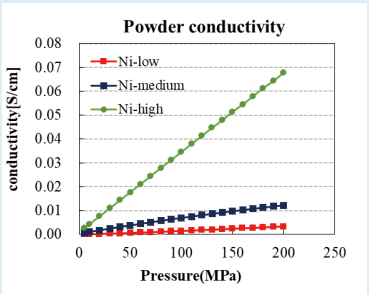
- Active material conductivity evaluation
- Conductivity evaluation of conductor types

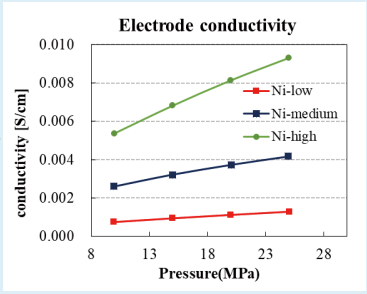


- Evaluation of electrode primer technology
- Conductive agent distribution uniformity evaluation
- Uniformity evaluation of silicon-carbon hybrid material

- Analysis of electrode resistance during high temperature cycle & storage

MATERIAL EVALUATION 1.1 Correlation between powder conductivity and electrode conductivity



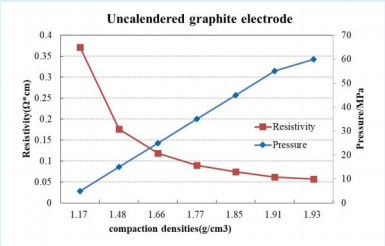


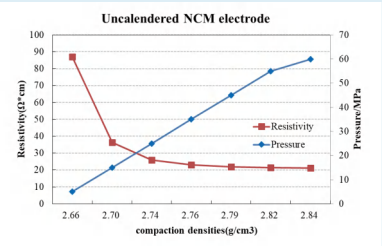
Results Analyze

- Adjust the Ni content in the NCM material, and test the powder conductivity. It can be found that as the Ni content increases, the powder conductivity increases;
- Comparing three NCM positve electrodes with different Ni content,it can also be obtained that as the Ni content increases,the conductivity of the electrode increases;

Powder resistivity and electrode resistivity have the same trend!

1.2 Evaluate the resistivity of uncalendered electrode under different compaction densities





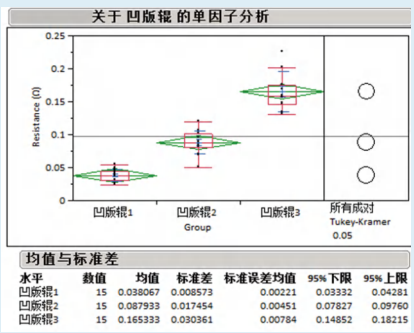
Conditions:5–60MPa, step10MPa, keep 25s

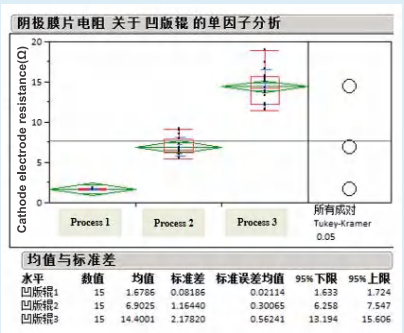
Results Analyze

- For graphite electrode,with the increase of compaction density, the resistivity continues to decrease.The reason is that the contact between active becomes better under higher pressure,so that the overall conductivity of the electrode becomes better;
- For NCM electrode, with the compaction density increases,the resistivity continues to decrease. The main reason is that as the pressure increases,the contact between teminals and the active material becomes better under higher perssure,so that.becomes better;

The variable pressure mode can simulate the change of resistivity of electrodes under different compaction conditions,and quickly evaluate the performance of the electrode!

PROCESS EVALUATION 2.1 Evaluation of electrode primer technology



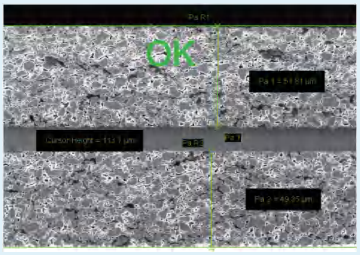


<a> The thicker the primer, the greater the resistance of the current collector;

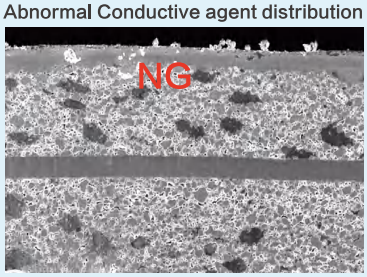
<b> The thicker the primer, the greater the cathode resistance;

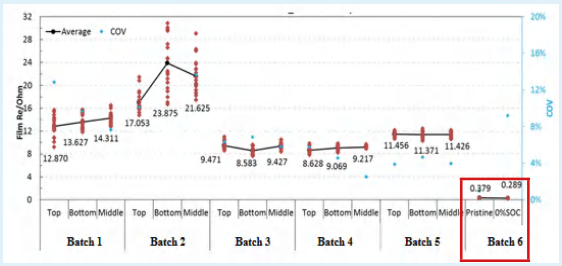
<c> After determing the best primer coating process the electrode resistance test can be used as a method for long-term monitoring of process stability.

2.2 Uniformity evaluation for the distribution of conductive agent



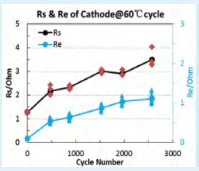
Abnormal Conductive agent distribution

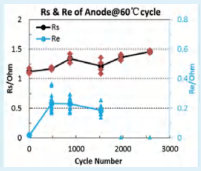


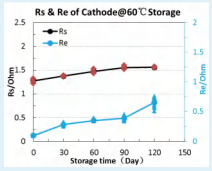


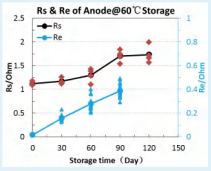
By using the resistance to monitor the coating quality of the electrode, an abnormal battery electrode can be quickly identified, It is useful to prevent the bad battery electrode from flowing into the process,and to save production costs.

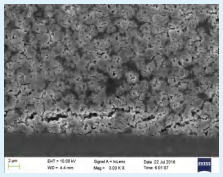
3.1 Analysis of electrode resistance during high temperature cycle & storage

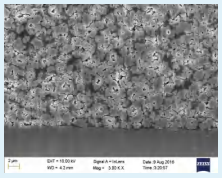












The resistance of the cathode continues to increase with the increase of the mumber cyceles,indicating that a large change has taken place on the cathode side after the high temperature cycle,which may be related to the byproducts on the surface of the cathode particles or the contact between the particles;

The resistance of the anode increases with the increase of the storage time,implying that the anode side has changed a lot during the storage process,which may be related to the increase of side rections on the anode material surface.

Parameter	
Resistance range	1μΩ~3.1kΩ
Resistance accuracy	±0.5%F.S
Pressure range	50~600kg/5~35MPa (BER2100) (BER2200)
	50~1000kg/5~60MPa (BER2300) (BER2500)
Pressure accuracy	±0.3% F.S
Thickness range	0~5mm (BER2500)
Thickness resolution/ accuracy	0.1μm/±1μm (BER2500)
Temperature and humidity range	
Temperature and humidity accuracy	

Installation Requirement	
Voltage	200-240V/50-60Hz
Voltage variation tolerance	±10%
Power dissipation	50W (BER2100) (BER2200) 450W (BER2300) (BER2500)
Air source	Pipeline gas or air compressor is required (BER2100、BER2200)
Environmental temperature	25±5℃
Environmental humidity	Humidity <80%RH at the temperature of 40℃
Environmental magnetic field	Keep away from intense electromagnetic
Net weight	76kg (BER2100) (BER2200) 83kg (BER2300) 85kg (BER2500)
Dimension (W*D*H)	355*320*550mm (BER2100、BER2200) 355*320*800 (BER2300、BER2500)

Model	BER2100	BER2200	BER2300	BER2500
Press mode	Cylinder(Pipeline gas required, range:5~35MPa)		Servo motor(No pipeline gas required,range:5~60MPa)	
Testable parameters	Resistance、Pressure Temperature and humidity	Resistance、Pressure Temperature and humidity conductivity、resistivity	Resistance、Pressure Temperature and humidity conductivity、resistivity	Resistance、Pressure Temperature and humidity conductivity、resistivity thickness、compaction density
Function	◆ One point test ◆ Constant pressure condition	◆ Included BER2100 function ◆ Automatic measurement software	◆ Included BER2200 function ◆ Variable pressure	◆ Included BER2300 function ◆ Thickness measurement ◆ Compaction density measurement

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